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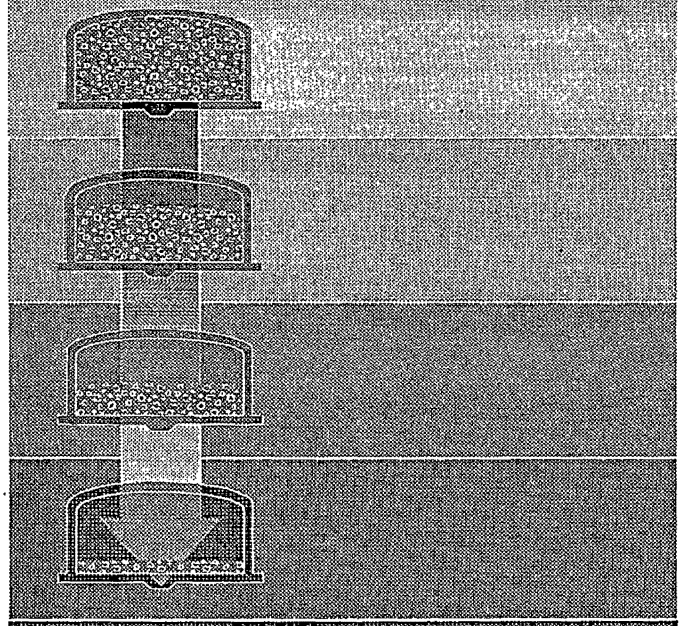
Tank Waste Remediation System, Hanford Site, Richland, Washington, Final Environmental Impact Statement

Volume Five



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ACRONYMS AND ABBREVIATIONS

CFR	Code of Federal Regulations
DST	double-shell tank
EPA	U.S. Environmental Protection Agency
HLW	high-level waste
ISC2	Industrial Source Complex Model
ISCLT2	long-term ISC2
ISCST2	short-term ISC2
LAW	low-activity waste
TWRS	Tank Waste Remediation System
WAC	Washington Administrative Code
WESF	Waste Encapsulation and Storage Facility

NAMES AND SYMBOLS FOR UNITS OF MEASURE, RADIOACTIVITY, AND ELECTRICITY/ENERGY

Length

cm	centimeter
ft	foot
in	inch
km	kilometer
m	meter
mi	mile

Area

ac	acre
ft^2	square foot
ha	hectare
km^2	square kilometer
mi^2	square mile

Volume

cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
ppb	parts per billion
ppm	parts per million
yd^3	cubic yard

Mass

g	gram
kg	kilogram
lb	pound
mg	milligram
mt	metric ton

Radioactivity

Ci	curie
MCi	megacurie (1.0E+06 Ci)
mCi	millicurie (1.0E-03 Ci)
μCi	microcurie (1.0E-06 Ci)
nCi	nanocurie (1.0E-09 Ci)
pCi	picocurie (1.0E-12 Ci)

Electricity/Energy

A	ampere
J	joule
kV	kilovolt
kW	kilowatt
MeV	million electron volts
MW	megawatt
V	volt
W	watt

Temperature

°C	degrees centigrade
°F	degrees Fahrenheit

APPENDIX G
AIR MODELING

G.1.0 INTRODUCTION

This appendix describes the air dispersion modeling that was performed to assess the impacts on air quality resulting from normal operations associated with the various Tank Waste Remediation System (TWRS) alternatives. The analyses were conducted to accomplish the following objectives:

- Compare the analyzed impacts of potential criteria pollutant releases against National Ambient Air Quality Standards and applicable Washington State regulations;
- Compare the analyzed impacts of emissions of toxic and hazardous air pollutants against applicable Washington State regulations; and
- Compare the analyzed impacts of emissions of radionuclides against applicable Washington State and Federal standards.

The following sections describe the proposed Hanford Site TWRS alternatives and discuss the dispersion models used in the analyses. The remaining sections describe the methodology of the modeling approach, the data used as input to the model (meteorology, source, and receptor parameters), and the results of the modeling effort.

G.2.0 DESCRIPTION OF ALTERNATIVES

The remedial alternatives are broadly separated into those activities related to remediating the tank waste, and those activities involving remediation of the cesium (Cs) and strontium (Sr) capsules. The following alternatives were studied:

- Tanks Waste Alternatives
  - No Action - The waste would be maintained in the existing tanks.
  - Long-Term Management - The double-shell tank (DST) waste would be transferred to newly constructed DSTs. The tanks would be replaced twice, at 50-year intervals.
  - In Situ Fill and Cap - Waste would be disposed of in situ by filling the tanks with gravel and placing a Hanford Barrier over them to inhibit infiltration of rain water or human intrusion.
  - In Situ Vitrification - The waste contained in the existing storage tanks would be vitrified in-place.
  - Ex Situ Intermediate Separations - The tank waste would be separated into high-level waste (HLW) and low-activity waste (LAW) and the waste vitrified. The LAW would be disposed of onsite in subsurface vaults, and the HLW would be shipped offsite for disposal at the potential geologic repository.
  - Ex Situ No Separations - Under the vitrification option, the waste would be immobilized as glass cullet. Under the calcination option, the waste would be treated at temperatures below those required for vitrification, with a resulting dry-powder waste form. All of the treated waste would be shipped offsite for disposal at the potential geologic repository.

- Ex Situ Extensive Separations - This is an extension of the Ex Situ Intermediate Separations alternative. The difference is that waste would undergo a more extensive series of processing steps that would result in a smaller volume of HLW and a larger volume of LAW. Vitrification and disposal activities would be similar to those in the Ex Situ Intermediate Separations alternative.
- Ex Situ/In Situ Combination 1 and 2 - These alternatives are a combination of the Ex Situ Intermediate Separations alternative and the In Situ Fill and Cap alternative. Waste would be retrieved from 70 tanks (Combination 1) or 25 tanks (Combination 2), separated into LAW and HLW, and vitrified. The LAW would be disposed of onsite in LAW vaults, and the HLW would be shipped offsite for disposal at the potential geologic repository. The remainder of the tanks (107 under Combination 1 and 152 under Combination 2) would undergo fill and cap, as described for the In Situ Fill and Cap alternative.
- Phased Implementation - For the first phase of this alternative, two demonstration vitrification facilities would be built and operated. One facility would treat LAW, while the other would separate and treat LAW and HLW streams. For the second phase of this alternative, the facilities from the first phase would continue to operate and large-scale facilities would be built to separate the tank waste into HLW and LAW. The LAW would be disposed of onsite in subsurface vaults, and the HLW would be shipped offsite for disposal at the potential geologic repository.

- Cesium and Strontium Capsules Alternatives
  - No Action - The capsules would be maintained in the Waste Encapsulation and Storage Facility (WESF).
  - Onsite Disposal - The capsules would be transferred from their existing location to a newly constructed drywell storage facility.
  - Overpack and Ship - The capsules would be retrieved from their existing location, transferred to a newly constructed repackaging facility, repackaged, and transferred to a storage location pending future disposal at the potential geologic repository.
  - Vitrify with Tank Waste - The capsules would be retrieved, and the contents would be vitrified along with the HLW.

G.2.1 SOURCE IDENTIFICATION AND CHARACTERIZATION

Reviewing available data resulted in identifying several locations and processes expected to emit air pollutants (WHC 1995c, j, n, and Jacobs 1996). The following discussion describes the location and nature of each of these sources. Section G.2.2 details the manner in which these sources were grouped to analyze each alternative. Section G.3.1.2 discusses the emission rates assigned to each source for each alternative.

Pollutant emitting activities were depicted as either area sources or point sources in the dispersion models. Area sources are used for simulating emissions that exist in a known area of activity, especially if the exact source locations are unknown or are expected to move from time to time. In other words, the emissions occurring within the area need not be uniform over space or time. Area sources are defined in the model as square areas and are assigned an areal emission rate (typically specified as grams per square meter per second [$g/m^2/s$]). In this study, the area sources were chosen to include the area in which most of the emissions from a particular operation or grouping of sources would be expected to occur.

Point sources are used for simulating the emissions from sources that are expected to remain in a fixed location and are vented through a stack. The models consider the effects of elevated release heights, building downwash, release temperature, and release velocity when calculating predicted concentrations from point sources. Figure G.2.1.1 shows the source locations used in the modeling scenarios.

Tank Farms

Area sources were used to represent logical groupings of tanks and tank farms. Locations of all sources for all alternatives are shown in Volume Two, Appendix B. Eleven such groupings (identified as TF1E through TF11E) were assigned to tanks in the 200 East Area, while six groupings (TF1W through TF6W) were assigned to the tanks in the 200 West Area. Air emissions that are assumed to occur in these areas include:

- Vehicular emissions associated with construction activities at these sites; and
- Emissions of radiological and nonradiological components from the tanks for all alternatives during continued operations, retrieval, and gravel filling operations.

Waste Retrieval Annex Areas

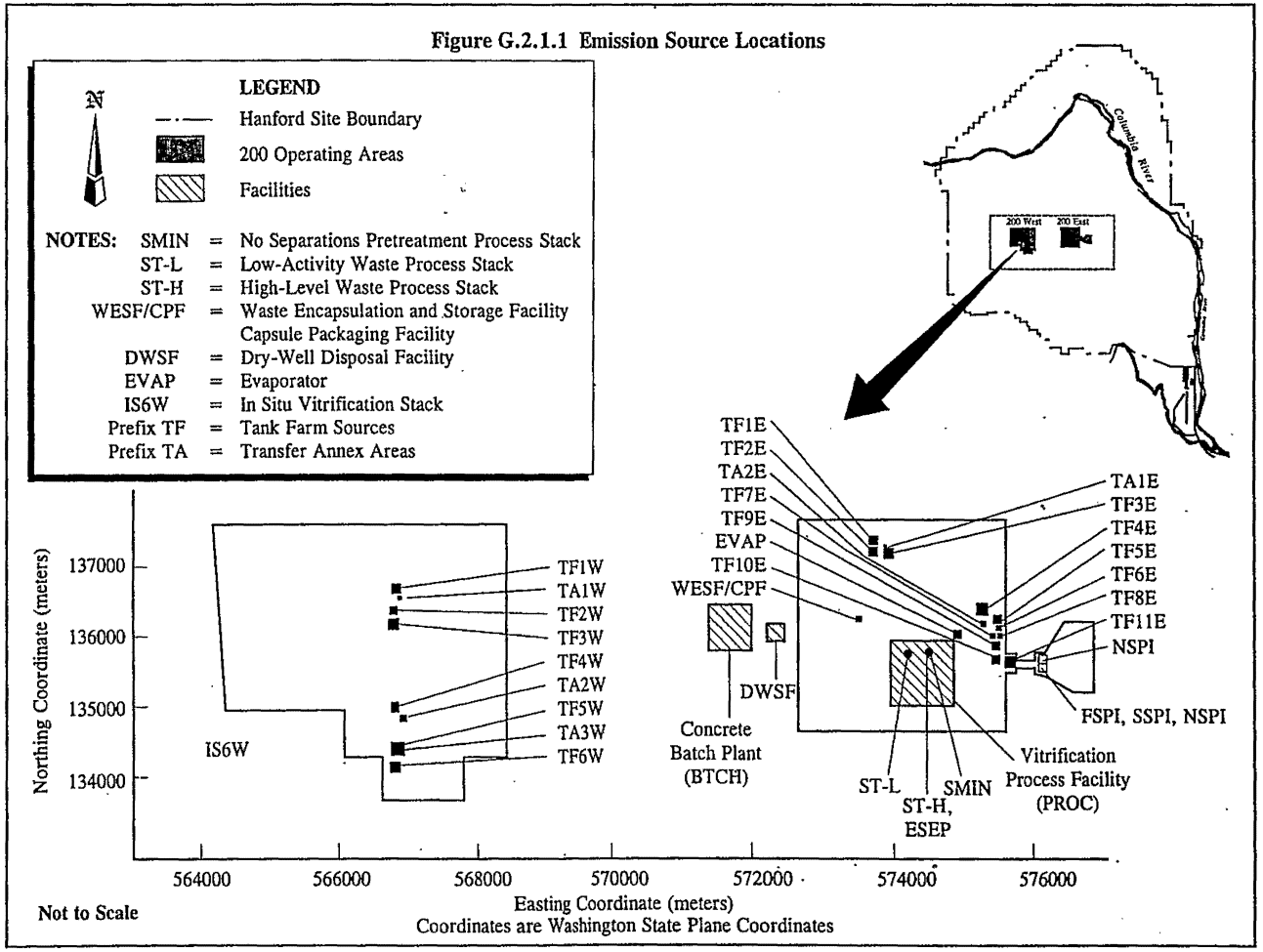
As part of the ex situ alternatives, the Ex Situ/In Situ Combination 1 and 2 alternatives, and the Phased Implementation alternative, waste transfer annexes would be constructed to collect and distribute the waste retrieved from the tanks. Two such facilities (identified as TA1E and TA2E) are expected to be constructed in the 200 East Area, while three facilities (TA1W, TA2W, and TA3W) would be constructed in the 200 West Area. All annexes would be the same size, except the facility identified as TA2W, which would be larger and also serve as a waste sampling facility.

Although no emissions would be expected to result from operating these facilities, vehicular emissions and fugitive dust would be produced during their construction. These sources were depicted as area sources in the dispersion models.

Concrete Batch Plant

A concrete batch plant would be constructed to support construction activities. For each model scenario, the batch plant was assumed to have sufficient capacity to support the remediation activities. For the purpose of impact assessment, this batch plant was assumed to be located between the 200 Areas. The emissions from this process were modeled as an area source (identified as BTCH).

Figure G.2.1.1 Emission Source Locations



Process Facilities and Tank Farm Construction

Emissions from constructing the processing facilities related to the ex situ and Ex Situ/In Situ Combination 1 and 2 alternatives would include vehicle exhaust emissions and fugitive dust released during earthmoving operations. A single area source (identified as PROC) centered on and equal in size to the disturbed area (80 hectares [ha] [200 acres (ac)]) expected for constructing the process facilities for the Ex Situ Intermediate Separations alternative was used to model these emissions. Bounding case construction emissions related to constructing retrieval equipment at the tank farm locations were modeled as an area source at the tank farm designated TF6W.

For the first phase of the Phased Implementation alternative, two processing facilities would be constructed. Emissions associated with this activity would include vehicle and heavy equipment exhaust emissions and fugitive dust releases. A single area source (FCPI), which encompasses the locations of both plants, was used to model these emissions. In addition, particulate matter emissions from the Pit 30 site (BTCH) would occur.

During the second phase of this alternative, large-scale facilities would be constructed to treat the remainder of the tank waste. Emissions would come from constructing the five waste transfer annexes, process facilities, and a concrete batch plant. Emissions from erecting retrieval equipment at the tank farms would occur simultaneously.

Borrow Site Excavation

For the In Situ Fill and Cap alternative, particulate matter emissions would result from the use of heavy equipment to excavate and transport borrow materials from Pit 30, which is located between the 200 East and 200 West Areas at the same location as the concrete batch plant (BTCH).

For all tank waste alternatives except the No Action alternative, excavation of borrow materials from the Vernita Quarry and McGee Ranch would result in similar particulate matter emissions. These emissions would be associated with installing post-closure barriers over the tank farms. Because of a lack of data concerning these operations, specific emissions estimates and modeling were not performed. However, any such operations would include appropriate control measures (such as using surfactants and water spray procedures) that would result in compliance with Federal and State air quality standards.

Process Facilities Operation

Essentially all the emissions during the processing operations for the ex situ alternatives and the Ex Situ/In Situ Combination 1 and 2 alternatives would occur through the main processing facility stacks. The LAW and HLW processing facilities stacks for the Ex Situ Intermediate Separations alternative were designated as ST-L and ST-H, respectively. The Ex Situ No Separations alternative would have one stack, identified as SMIN. Although two plants would operate in the Ex Situ Extensive Separations alternative scenario, emissions from both plants would be routed through a common stack, designated as ESEP. Processing facilities for the Ex Situ/In Situ Combination 1 and 2 alternatives would be similar to, but with less capacity than, facilities for the Ex Situ Intermediate Separations

alternative. Because stack locations and release parameters are expected to be similar, these stacks were modeled using sources ST-L and ST-H. All stacks were modeled as point sources.

Emissions from the vitrification processing facilities that would be constructed for the Phased Implementation alternative would be routed through stacks. The stack for the Phase 1 LAW processing facility was designated as SSPI, while the Phase 1 combined LAW/HLW processing facility stack was designated as NSPI. The stacks for the Phase 2 full-scale LAW processing facilities were designated as ST-L1 and ST-L2. The full-scale processing facility stack was designated as ST-H. All stacks were modeled as point sources.

In Situ Vitrification Process Stacks
During vitrification operations for the In Situ Vitrification alternative, off-gases would be treated and released through one process stack per tank farm. Although two tanks from a single tank farm would be vitrified simultaneously, it was assumed that emissions from both vitrified tanks would be discharged from a single stack. The facility location that would produce the highest impact (in association with the construction emissions) was identified to be at the tank farm location known as TF6W. A point source (identified as IS6W) was used to model emissions from the process stack.

Drywell Storage Facility
A Drywell storage facility would be constructed as part of the Onsite Disposal alternative for the Cs and Sr capsules. The emissions resulting from the construction of this facility are represented as an area source identified as DWSF. No emissions were assumed to result from the operations phase of this alternative.

Capsule Packaging Facility
The capsules Overpack and Ship alternative would involve emissions resulting from constructing and operating a Capsule Packaging Facility (CPF). These emissions are represented by an area source identified as CPF.

Waste Encapsulation and Storage Facility
Routine radiological emissions from the WESF were analyzed for all alternatives. These emissions would occur through a stack, and were modeled as a point source (WESF).

Evaporator
Operating an evaporator during continued operations and waste processing operations is expected to release radiological and nonradiological components. These emissions would occur through a stack, and were modeled as a point source (EVAP).

W-314 Project
This project potentially involves the replacement of various transfer lines located in the 200 East and 200 West Areas. The data available for this project indicate that construction activities would be spread out over various areas and would be of relatively low intensity compared to construction

activities associated with other TWRS alternatives. In addition, dust-control measures would be employed that would minimize emissions from these activities. Because substantial emissions are not anticipated, the emissions from the W-314 Project were not separately analyzed.

G.2.2 MODEL SCENARIOS

The various alternatives would involve emissions from one or several of the sources described previously. Implementing alternatives would involve an initial phase of facility construction followed by a phase during which the treatment, transfer, or repackaging processes would occur. Consequently, each alternative could have different phases in which the emissions and analyzed impacts were distinctly different. Therefore, the emissions and analyzed impacts resulting from each phase were calculated and are reported separately for each alternative. The following sections discuss each proposed TWRS alternative and describe the associated emissions sources.

G.2.2.1 Tank Waste Alternatives

No Action Alternative (Tank Waste)

The No Action alternative would involve routine radiological and nonradiological emissions from continued operation of the storage tanks, and continued operation of the evaporator as a waste management activity. In addition, routine radiological releases from WESF would occur and are considered. No construction activities would be associated with this alternative.

The emissions from the continued operations of tank farms would also occur during the construction and operation phases of the alternatives, and are included in the analysis of these alternatives.

Long-Term Management Alternative

The Long-Term Management alternative would involve two phases having air emissions, each of which was analyzed separately. The first phase would involve transferring waste from existing DSTs to newly constructed DSTs 50 years in the future. Waste from the SSTs would not be retanked. The new tanks would be constructed in the same area as the process facility that would be built for the Ex Situ Intermediate Separations, Ex Situ No Separations, and Ex Situ Extensive Separations alternatives; the construction emissions were modeled by assigning them to the location PROC. In addition, continued tank and evaporator emissions would occur simultaneously at the tank farms and the evaporator locations. Increased emissions would be expected from tanks undergoing retrieval. These increased emissions were modeled by assigning the highest increased emission rate for each pollutant to the TF6W Tank Farm, which was identified as the tank farm location producing the highest impacts. The actual emissions for every chemical would not necessarily be the highest at TF6W.

The emissions from the tank farms during retrieval operations would be the same as would be expected for retrieval activities associated with the operational phases of the Ex Situ (Intermediate Separations, No Separations, and Extensive Separations) alternatives. These impacts have been included with the analysis of these alternatives.

The second phase (replacement of the tanks 100 years in the future) is similar to the first phase, except that the routine and increased tank emissions would occur within the PROC area, as well as the construction emissions.

In Situ Fill and Cap Alternative

Implementing this alternative would involve construction and gravel-filling operations at the tank farm locations, as well as gravel removal from Pit 30.

For the purposes of the analysis, construction activities are assumed to occur simultaneously with the filling operations and routine emissions from the continued operation of the tank farms. The following text summarizes the pollutant emitting activities and sources for this alternative.

- Particulate matter emissions are expected as a result of gravel handling operations at Pit 30 (BTCH).
- Construction equipment emissions are expected at the tank farm location. To provide a conservative approach, emissions from construction activities were assigned to the bounding case location (TF6W).
- Gravel handling operations are assumed to occur at a location central to several tank farms; the corresponding emissions were assigned to location TF5W.
- Increased tank emissions during filling operations are expected. To ensure a conservative approach, the increased tank emissions were assigned to location TF6W in a similar manner as was done for retrieval operations.

The emissions from the tank farms during gravel filling operations would be the same as would be expected during the in situ portion of the Ex Situ/In Situ Combination 1 and 2 alternatives and have been included in the analysis of that alternative.

In Situ Vitrification Alternative

Implementing this alternative would involve constructing a tank farm confinement facility and an off-gas treatment facility at each tank farm. Construction of one confinement facility would occur while vitrification processes were occurring at an adjacent tank farm. For potential air quality impacts, the bounding case location for construction was identified as TF6W, and the impacts described are for this bounding case scenario.

Operations associated with this alternative would release pollutants that would be treated in an off-gas treatment facility. The emissions from the off-gas treatment facility would be from a vertical stack. The bounding case location for this operation was shown to be adjacent to TF6W. Although construction and operations activities would not occur at the same time and at the same tank farm location, the operational emissions were assigned to this location (IS6W) to provide a bounding case analysis.

Ex Situ Intermediate Separations Alternative

The construction phase would involve vehicular and fugitive dust emissions from constructing five waste transfer annexes and two waste processing facilities and constructing and operating a concrete batch plant to support these operations. Additionally, vehicular emissions associated with constructing tank waste retrieval equipment at the tank farms would occur during this time.

According to the estimated construction schedule, work would not be expected to occur at more than two tank farms at a time. An analysis was conducted to determine the two locations that would produce the highest impact when construction activities occurred simultaneously. It identified the TF5W and TF6W areas as having the highest combined impacts. Accordingly, the impacts of these activities were analyzed by assuming simultaneous construction operations at:

- The process facility locations;
- The concrete batch plant;
- The five transfer annex areas (TA1W, TA2W, TA3W, TA1E, TA2E); and
- Two tank farm locations (TF5W and TF6W).

The operational phase of the Ex Situ Intermediate Separations alternative would involve separating the waste into HLW and LAW streams and processing the waste at separate facilities. HLW vitrification processing would occur over a 12-year period while LAW processing would occur over a 19-year period. Additionally, retrieval equipment would operate at no more than two tank farm locations at a time during the course of the processing. Therefore, the impacts of the operations phase of the alternative were calculated by evaluating the simultaneous operation of both processing facilities (ST-L and ST-H) and the two tank farm locations (i.e., TF5W and TF6W) producing the highest impacts.

Ex Situ No Separations Alternative

The emission scenario for the Ex Situ No Separations alternative differs from the Ex Situ Intermediate Separations alternative because the tank waste would not be separated into LAW and HLW components and only one processing plant with one process stack (as opposed to two) would be operated. Two options (vitrification and calcination) were analyzed for this alternative. The sources and emission rates associated with the calcination option are identical to those of the vitrification alternative, with the exception of the emission rates of nitrogen oxides and carbon-14 (C-14) (Jacobs 1996).

The construction phase would involve vehicular and fugitive dust emissions from constructing the five waste transfer annexes and the process facilities, and from constructing and operating a concrete batch plant to support these operations. Additionally, vehicular emissions from erecting the retrieval equipment at the tank farms would occur during this time. These emissions were assigned in the same manner as described for the Ex Situ Intermediate Separations alternative construction phase, although emission rates would differ.

Operational processes for the Ex Situ No Separations alternative would occur over a 14-year period, beginning after completion of the construction phase. Emissions would occur through the main process stack at the vitrification facility. Additionally, installing and operating retrieval equipment would occur

at only two tank farm locations at a time during processing. Therefore, the impacts of the operations phase of the alternative were calculated by evaluating the simultaneous operation of the process facility and the two tank farm locations (i.e., TF5W and TF6W) producing the highest combined impacts.

Ex Situ Extensive Separations Alternative

The construction phase would involve vehicular and fugitive dust emissions from constructing the five waste transfer annexes and the process facilities, and from constructing and operating a concrete batch plant to support these operations. Additionally, vehicular emissions from erecting the retrieval equipment at the tank farms would occur during this time. These emissions were assigned in the same manner as described for the Ex Situ Intermediate Separations alternative construction phase, although emission rates would differ.

The operational phase of this alternative would involve separating the tank waste into HLW and LAW streams and processing the waste at separate facilities. HLW and LAW processing vitrification processing would occur over a 21-year period. The off-gas emissions from these two processes would be combined and routed through a common stack (ESEP). In addition, retrieval equipment would be operated at only two tank farm locations at a time during processing. Therefore, the impacts of the operations phase of the alternative were calculated by evaluating the simultaneous operation of the process facilities (ESEP) and the two tank farm locations (i.e., TF5W and TF6W) producing the highest combined impacts.

Ex Situ/In Situ Combination 1 and 2 Alternatives

Implementing the in situ portion of these alternatives would involve the same source locations and emissions scenarios as described for the In Situ Fill and Cap alternative, although lower emission rates would be expected. These emissions would occur simultaneously with those associated with the operational phase of the ex situ portion of the alternatives.

The construction phases would involve vehicular and fugitive dust emissions from constructing the waste transfer annexes and the process facilities, and from constructing and operating a concrete batch plant to support these operations. Additionally, vehicular emissions from erecting the retrieval equipment at the tank farms would occur during this time. These emissions were assigned in the same manner as described for the Ex Situ Intermediate Separations alternative construction phase, although emission rates would differ.

The operational phase of the ex situ vitrification portion of the alternatives would involve separating the HLW and LAW streams and processing the waste at separate facilities. Retrieval and ex situ vitrification operations would be expected to occur over a 21-year period for Combination 1, and over a 20-year period for Combination 2. Additionally, retrieval equipment would be expected to operate at no more than two tank farm locations at a time during processing. Therefore, the impacts of the operational phase of these alternatives were calculated by evaluating the simultaneous operation of both process facilities (ST-L and ST-H) and the two tank farm locations (i.e., TF5W and TF6W) producing the highest impacts.

Phased Implementation Alternative

Phase 1

Implementation of the first phase of this alternative would involve a construction period, during which two vitrification facilities would be constructed. Because construction on both facilities would occur simultaneously, the construction emissions were assigned to a single area source (FCPI) that would encompass the expected disturbed area.

Following completion of construction, operation of the two facilities would commence. Emissions from the vitrification processes would be released through two stacks – one located at the combined LAW/HLW facility (NSPI), and one located at the LAW facility (SSPI). LAW operations at both plants would occur over a 10-year period; HLW operations at the combined plant would occur for 6 years. The impacts from these activities were calculated by using the peak hourly emission rates from all processes simultaneously.

Phase 2

In the second phase of this alternative, large-scale facilities would be constructed to treat the remainder of the tank waste. Emissions would come from constructing the five waste transfer annexes (TA1W, TA2W, TA3W, TA1E, TA2E), process facilities, and a concrete batch plant (BTCH). Emissions from erecting retrieval equipment at the tank farms producing the highest impacts (TF5W, TF6W) would occur simultaneously. These emissions were assessed in the same manner as described for the Ex Situ Intermediate Separations alternative.

Total Alternative

Impacts from the operation of the total Phased Implementation alternative are analyzed in the same manner as for the Ex Situ Intermediate Separations alternative. This involves the simultaneous operation of the two facilities discussed under Phase 1 (NSPI and SSPI), the large-scale facilities (ST-L1, ST-L2 and ST-H), and the two tank farm locations producing the highest impacts (TF5W and TF6W).

G.2.2.2 Cesium and Strontium Capsule Alternatives

No Action Alternative (Capsules)

This alternative would involve maintaining the capsules at WESF. Routine radiological emissions from WESF were analyzed for this alternative and were included in the analysis of all other alternatives. These emissions were modeled as a point source (WESF). No other impacts are expected from this alternative.

Onsite Disposal Alternative

This alternative would involve transferring the existing capsules to a newly constructed Drywell storage facility. Constructing the Drywell storage facility would result in emissions from construction. These construction emissions were assigned to the source identified as DWSF. There would be no emissions during operations for this alternative. No airborne emissions are anticipated from the sealed Cs and Sr capsules while they are in storage. The only operational activities would be facility monitoring.

Overpack and Ship Alternative

This alternative would involve recovering the capsules from WESF, repackaging them, and shipping them to the potential geologic repository. A repackaging facility would be built as part of this alternative. Construction emissions and minor operational emissions would occur. These emissions were assigned to the area source identified as CPF.

Vitrify with Tank Waste Alternative

This alternative would involve recovering the Cs and Sr capsules from WESF, removing the contents, and vitrifying the capsule contents along with tank waste. Because the emissions occurring under this alternative are combined with emissions from remediating tank waste, no separate air quality impacts were analyzed.

G.3.0 MODEL SELECTION AND METHODOLOGY

Version two of the U.S. Environmental Protection Agency (EPA) Industrial Source Complex Model (ISC2) was selected to perform the air-dispersion modeling (EPA 1992a). The ISC2 model is a Gaussian dispersion model capable of simulating emissions from diverse source types. In a Gaussian dispersion model, pollutant concentrations are assumed to be distributed normally (i.e., bell-shaped curve) about the centerline of the plume, a relationship that has been observed to occur for releases of gases and small particles from many types of sources. ISC2 is a guideline air quality model (i.e., it is accepted by EPA for regulatory applications [40 CFR Part 51]). It is also routinely recommended for performing screening and refined analyses for remedial actions at Resource Conservation and Recovery Act and Superfund sites (EPA 1989a). This model was selected based on its widespread acceptability and versatility.

The ISC2 consists of two models: a short-term version (ISCST2) appropriate for predicting concentrations averages of 1 to 24 hours, and a long-term version (ISCLT2) for predicting seasonal and yearly concentrations. Both models were incorporated in this study. ISCLT2 was used to generate annual average predicted concentrations for comparison with annual average ambient air quality standards and target levels. ISCST2 was executed in a screening mode to predict short-term ambient air concentrations for comparisons to 1 to 24 hour average air quality standards and other target levels (EPA 1992b).

G.3.1 MODEL OPTIONS AND INPUTS

ISC2 requires the input of source and meteorological data as well as receptor coordinates (i.e., locations for which the model computes a concentration). The model must also be configured properly by the selection of various options. The following discussions document the inputs and model configuration.

G.3.1.1 Model Options

The models were run using the standard rural dispersion coefficients. These were selected based on the nature of the land use in the vicinity of the emission sources. Standard EPA procedures were followed in making this determination (40 CFR Part 51).

The regulatory default option was selected, which implemented the following model options:

- Final plume rise;
- Buoyancy-induced dispersion;
- Default wind profile exponents;
- Default vertical potential temperature gradients; and
- Upper bound values for supersquat buildings.

G.3.1.2 Source Data

The manner in which sources were grouped for each alternative is discussed in Section G.2.2. Source-related model input data are shown on Table G.3.1.1. Please note that all tables are located at the end of Appendix G. The chemical pollutant emission rates for each phase of the alternatives are shown in Tables G.3.1.2 through G.3.1.19. Tables G.3.1.20 through G.3.1.31 contain the radiological emission rates. When appropriate, construction and operational emissions from the alternatives were analyzed separately, and separate emissions data for construction and operational activities are reported. In other cases, construction and operational processes would occur simultaneously, and the emission rates reported represent the combined emissions from construction and operational activities.

The primary sources of data used for the emission rates were the engineering data packages for the various alternatives, which were prepared by the Hanford Site Management and Operations contractor (WHC 1995 a, b, c, d, e, f, g, h, i, n) and the TWRS EIS contractor (Jacobs 1996). The following discussion describes the protocol used for calculating model emission rates from the available data.

Routine Emissions from Tank Farms and the Waste Encapsulation and Storage Facility

Routine emissions of radiological and nonradiological components from continued operations of the tank farms and WESF are shown for the No Action alternative (Tank Waste) in Tables G.3.1.2 and G.3.1.20. Emissions are reported separately for each tank farm location (Jacobs 1996). Similar emissions are expected to occur and were analyzed for all alternatives. However, during retrieval operations (and during gravel filling operations associated with the In Situ Fill and Cap alternative), the routine emissions rates would be expected to increase at the affected tank farm location. In these situations, the increased emission rates were analyzed in the following manner: the highest routine emission rate for each pollutant was assigned to source TF6W to provide a bounding case scenario and increased by the appropriate factor to represent retrieval or gravel filling operations.

In Situ Vitrification Emission Data

Data contained in the engineering data packages for this alternative were analyzed to generate tables of radiological and nonradiological emissions for this alternative (Jacobs 1996). Separate emissions data for the construction and operational phases for the alternative were created. Annual construction emissions were converted to peak hourly emissions based on an assumed schedule of construction activities. The peak hourly emission rate of each pollutant for the vitrification process was used for the model input.

Process Facility Stack Emissions Data

Process flow diagrams and mass balance data contained in the engineering data packages were analyzed to generate tables of average annual emissions, maximum daily emissions, and peak hourly emissions from the vitrification facility process stacks for the Ex Situ Intermediate Separations, Ex Situ No Separations, and Ex Situ Extensive Separations alternatives, including the Ex Situ/In Situ Combination 1 and 2 and the Phased Implementation alternatives (Jacobs 1996). The peak hourly emissions for pollutants listed in these tables were used to generate emission rates for the process stacks.

Construction Activities Emission Data

The primary sources of construction activity emission data were the engineering data packages for the various alternatives. In some cases, data concerning the construction emissions were not given explicitly in the data package. Calculations were performed to estimate the emissions given the scope of the construction activity (Jacobs 1996). Annual emissions were converted to hourly emissions based on an assumed schedule for construction activities.

G.3.1.3 Meteorological Data

Long-Term Meteorological Data

The meteorological data used for the ISCLT2 model consisted of a joint frequency distribution, also referred to as a stability array (STAR) of wind speed, wind direction, and stability class compiled for each of 5 years (1989 to 1993). The stability arrays are shown in Tables G.3.1.33 through G.3.1.37. These data were based on measurements collected at the Hanford Meteorological Station located between the 200 East Area and 200 West Area (PNL 1994g). The general wind direction is to the southeast.

Additional meteorological data, such as the annual mean temperature and mixing heights, were obtained from the Hanford Climatological Data Summary (PNL 1994g) and a standard summary document of morning and afternoon mixing heights (Holzworth 1972). The protocol for assigning these values was taken from the ISC2 User's Manual (EPA 1992a). As outlined in the user's manual, the average annual maximum daily temperature (18 °C [65 °F]) was used for the A, B, and C stability classes; the average minimum daily temperature (5 °C [42 °F]) was used for the stability classes E and F; and the average annual temperature (12 °C [53 °F]) was used for the D stability class. Mixing height values were assigned as follows: 1.5 times the average afternoon mixing height of 1,500 m (4,900 ft) was used for stability class A and the average afternoon mixing height was used for stability classes B, C, and D. Because ISCLT2 in the rural mode assumes that there is no restriction in vertical mixing in the E and F stability classes, 1.5 times the average afternoon mixing height was considered to be appropriate for these stability classes.

Short-Term Meteorological Data

ISCST2 requires hourly meteorological data. Typically, for refined and regulatory modeling, a full year of sequential hourly records are input to the model. Because data in this format for the Hanford Site were unavailable and a refined level of modeling was not considered necessary given the preliminary nature of the design data, the ISCST2 model was executed in a screening mode. This

required inputting a range of possible meteorological conditions which might reasonably occur at this site. This screening meteorological file was prepared according to procedures outlined in EPA's SCREEN2 Model User's Guide (EPA 1992c).

For each of 36 wind directions, 54 possible combinations of stability class and wind speed were input (i.e., 1,944 hourly records). A matrix of windspeed and stability classes is shown in Table G.3.1.32.

Atmospheric mixing heights were assigned to stability classes A, B, C, and D using the mechanical mixing height (Z_m) and calculated using the following formula taken from Section 3.2 of the SCREEN2 Model User's Guide:

$$Z_m = 320 \cdot u_{10}$$

Where: Z_m = mechanical mixing height (m)
u_{10} = wind speed at 10 m elevation (m/s)

To allow for unlimited mixing, heights of 10,000 m (32,800 ft) were assigned to stability classes E and F, in keeping with the scheme outlined in the SCREEN2 User's Manual. Ambient temperatures for each stability class were assigned in the same manner as the ISCLT2 model inputs.

G.3.1.4 Receptor Locations

Three receptor sets were used for the study. The first set was used to predict concentrations for comparison with Washington State and Federal ambient air quality standards and target levels for nonradionuclide impacts, and for comparison with the Washington State ambient air quality standard for radionuclides. These receptor locations were placed to correspond to areas that might be considered to be ambient air (i.e., areas where the general public could be exposed). Because of the potential release of the Fitzner Eberhardt Arid Lands Ecology portion of the Hanford Site, the public would have access to land southwest of State Route 240, and it was selected to represent the southern boundary of the facility. For the same reason, the Columbia River was selected to define the northern and eastern facility boundaries. A total of 614 receptors were placed along the Columbia River, State Route 240, and the Hanford Site boundary line north of the Columbia River. Because of the size of the Hanford Site, most offsite receptors are quite distant from the sources and were placed with a 2-km (1.2-mi) spacing. To ensure that the areas of maximum impact were identified, receptors were placed at 500-m (1,650-ft) intervals along sections of State Route 240 to ensure adequate coverage.

The second set of receptors was used to assess compliance with the Federal standard for radionuclide release impacts contained in 40 Code of Regulations [CFR] Part 61. Compliance with this standard is calculated at the nearest residence, rather than at the nearest ambient air location. Although the distance from the source locations to the nearest residence in all directions is not known, available data indicate that no residence lies within 24 km (15 mi) of the 200 West area, or 16 km (10 mi) of the 200 East Area (DOE 1994d). Thus, a circular set of 72 receptors, centered on the 200 West Area and

with a radius of 24 km (15 mi), was established to assess compliance with this standard. This circular grid encompasses all locations within 16 km (10 mi) of the 200 East Area.

A rectangular grid of 834 receptors, which encompasses the entire Hanford Site, was used to generate isopleths of radionuclide impacts.

ISC2 is designed to model simple terrain (i.e., terrain less than or equal to stack height). Terrain elevation is relevant for modeling point sources. Concentration predictions from area source emissions are not affected by terrain. Elevations for all receptor locations were obtained from a Geographic Information System database of the Hanford Site and U.S. Geological Survey topographical maps of the surrounding area.

G.3.2 MODEL OUTPUT

The model output consisted of ground level average concentration values. ISCLT2 produced annual average concentrations for each of the 5 years (1989 to 1993) of meteorological input data. The predicted concentrations reported are from the year producing the highest impact. ISCST2 was executed to determine the maximum 1-hour average concentrations resulting from inputting a range of possible meteorological conditions. The 1-hour averages were multiplied by various correction factors for predictions of 3-, 8-, and 24-hour average concentrations. The following sections provide more details on the concentration calculations.

G.3.2.1 Normalized Concentrations

To provide efficiency in processing the results and flexibility for incorporating future changes, the sources were modeled with unit emission rates, resulting in predictions of normalized concentrations (also referred to as Chi/Q values).

The normalized concentrations, having dimensions of 1.0E-06 seconds/cubic meter (s/m^3), were produced by assigning each source a unit emission rate of 1.0 grams per second (g/s). The concentration at a receptor was calculated by multiplying the actual emission rate (referred to as the source term) by the appropriate Chi/Q value. For example, a source term expressed in units of g/s will produce a concentration given as micrograms per cubic meter ($\mu g/m^3$), and a source term expressed in units of curies per second (Ci/s) will produce a concentration given as $\mu Ci/m^3$.

The total concentration at any receptor consists of the sum of the concentrations contributed by each emitting source. Therefore, the total concentration at a receptor with n contributing sources is calculated as follows:

$$C_{total} = (X/Q)_1 \cdot T_1 + (X/Q)_2 \cdot T_2 + \ldots + (X/Q)_n \cdot T_n$$

Where:

C_{total}	= total concentration ($\mu g/m^3$ or $\mu Ci/m^3$)
$(Chi/Q)_n$	= predicted Chi/Q value (1.0E-06 s/m^3) for source *n*
T	= source term (g/s or Ci/s) for source *n*

Separate Chi/Q plot files were generated for each of the 30 identified sources. To calculate the total concentration values these plot files have been entered into spreadsheets. These spreadsheets allow the input of source terms of interest for each pollutant and the calculation of total concentration values at each receptor location.

G.3.2.2 Averaging Time Conversions

Values for 3-, 8-, and 24-hour averages were obtained by multiplying the calculated 1-hour average concentration by the following conversion factor: 0.9 for 3-hour averages, 0.7 for 8-hour averages, and 0.4 for 24-hour averages (EPA 1992b).

G.4.0 MODEL RESULTS

The results of the modeling were compared with Washington State air quality standard or acceptable source impact levels. Washington State standards are listed in the Washington Administrative Code (WAC) and include:

- Acceptable Source Impact Levels for toxic air pollutants (WAC 173-460);
- Ambient Air Quality Standards for particulate matter (WAC 173-470);
- The Ambient Air Quality Standards for sulfur oxides (WAC 173-474);
- The Ambient Air Quality Standards for carbon monoxide ozone and nitrogen dioxide (WAC 173-474);
- The Ambient Air Quality Standards for radionuclides (WAC 173-480); and
- The Ambient Air Quality Standards for fluorides (WAC 173-481).

The results were also compared with national primary and secondary Ambient Air Quality Standards listed in 40 CFR Part 50. The Washington Ambient Air Quality Standards are equal to or are more stringent than the National Ambient Air Quality Standards, and thus compliance with the Washington Ambient Air Quality Standards implies compliance with the National Ambient Air Quality Standards.

Predicted maximum emissions for hazardous air pollutants and pollutants for which a Washington Acceptable Source Impact Level exists are provided along with the applicable level. Modeling result for chemical pollutants are given in Tables G.4.0.1 through G.4.0.20. Modeled impacts for key radionuclides during operations are plotted in Figures G.4.0.1 through G.4.0.13 and presented for each alternative in Tables G.4.0.21 through G.4.0.32. The modeling results show radionuclide emissions converted to doses and compares them to Washington Air Quality Standards for radiation doses contained in WAC 173-480 and Federal standards for radioactive emissions from DOE facilities (40 CFR 61, Subpart H). The Ambient Air Quality Standard (WAC 173-480) for the maximum accumulated dose equivalent at any offsite receptor from a commercial nuclear facility is 25 mrem/yr. As a Federal facility, the Hanford Site could be expected to comply with the EPA regulation (40 CFR

61), which limits the maximum predicted dose at the nearest residence to 10 mrem/yr dose equivalent. Uranium-235 (U-235) was not included in the impacts for radionuclides. Uranium trioxide was, however, analyzed as a hazardous air pollutant. This approach is consistent with the risk analysis for routine operations for each alternative, because the chemical toxicity of uranium is much greater than its radiological hazard. Additionally, emissions of U-235 were determined to have a very small contribution to overall risk.

The modeling results for all alternatives show no exceedances of Federal or State air quality standards for criteria pollutants, hazardous air pollutants, or radionuclides. Substantial impacts from all sources (those that exceed 10 percent of the applicable standard) are listed in the following text:

Particulates	The impacts, as a percentage of the Federal and State 24-hour standard, that would occur during the construction phases of the In Situ Vitrification alternative (64 percent of the standard) and the construction phases of the Ex Situ Extensive Separations, Ex Situ Intermediate Separations, and Ex Situ No Separations) alternatives (63 percent, 62 percent, and 57 percent, respectively). In addition, substantial impacts occur during the construction phases of the Ex Situ/In Situ Combination 1 and 2 alternatives (34 percent of the 24-hour State and Federal standards), the Phased Implementation Phase 1 alternative (58 percent of the State and Federal 24-hour standard), Phased Implementation Phase 2 (65 percent of the State and Federal 24-hour standard) and the Capsules Onsite Disposal alternative (12 percent of the State and Federal 24-hour standard).
Carbon Monoxide	The impacts, as a percentage of the Federal and State 8-hour standard, that would occur during the construction phases of the Ex Situ Extensive Separations, Ex Situ Intermediate Separations, and Ex Situ No Separations alternatives are 25 percent, 21 percent, and 17 percent, respectively.
Sulfur Oxides	The impacts, as a percentage of the State 1-hour standard, that would occur during the In Situ Vitrification alternative are 10 percent of the standard.
Radionuclides	The impacts, as a percentage of the State annual standard, that would occur during the In Situ Vitrification alternative are 75 percent of standard, with primary contributors being C-14 and iodine-129 (I-129). The impacts, as a percentage of the Federal annual standard, that would occur during the In Situ Vitrification alternative are 24 percent of standard, with primary contributors being C-14 and I-129.

G.5.0 ACCURACY AND UNCERTAINTY

Various assumptions and other factors can introduce uncertainty in air dispersion modeling studies. With regard to the modeling performed to analyze air impacts from the various alternatives, these uncertainties can be broadly separated into the following categories:

- Uncertainty inherent in the air dispersion models;
- Uncertainty in data used as model inputs; and
- Uncertainty in interpretation of model output.

These categories are discussed in more detail in the following text.

G.5.1 AIR DISPERSION MODELING

Air dispersion models are mathematical tools designed to estimate pollutant concentration and/or deposition at specific locations. These predictions are based on various input parameters and physical assumptions, such as the following:

- Pollutant release characteristics (emission rate, temperature, flow rate);
- Meteorological conditions (ambient temperature, mixing height, stability, wind speed and direction, atmospheric temperature and wind speed profile); and
- Pollutant transport behavior (dispersion, plume rise, interaction with terrain).

In an ideal case, the values entered into the model for these known parameters will closely duplicate the range of actual conditions that exist for a particular scenario. However, the stocastic nature of the atmosphere results in other unknown factors (e.g., wind perturbations) that influence the actual dispersion at a particular time or place. It has been estimated that even when the known conditions are exactly duplicated in the model, the unknown factors can contribute to variations in concentration as much as ± 50 percent (EPA 1995).

Gaussian air dispersion models are accurate within a factor of two when properly executed with accurate data. In general, models are more reliable when estimating long-term average concentrations as opposed to short-term averages, and are reasonably reliable in estimating the magnitude of the highest concentration occurring, but are not capable of predicting the exact time or position of the occurrence. In other words, the highest concentration that can be expected in an area can be predicted with reasonable accuracy; the location and time that the maximum concentration will occur are less reliably predicted.

The air dispersion models used in this study are considered to be state-of the-art for regulatory modeling and are recommended by EPA for this type of analysis. To compensate for the uncertainties in model results, conservative input values were used that provide conservative (higher than might actually occur under average conditions) results.

G.5.2 MODEL INPUT DATA

Two types of input data are used for the air dispersion models: meteorological data and source data. Both types of input data are discussed in the following text.

G.5.2.1 Meteorological Data

Two types of meteorological data (i.e., long-term and short-term) were used in the dispersion modeling study. Long-term (i.e., annual) average concentrations were estimated using meteorological data collected at the Hanford Meteorological Station from 1989 to 1993. The assumption inherent in this choice is that this data represent future meteorological conditions. A 5-year record is generally accepted as an adequate sample set for modeling purposes. Although long-term climatic shifts may occur, many of the air pollutant emitting activities analyzed in this study are expected to occur within several decades of project initiation, which is a relatively short time frame on a climatic scale. Therefore, the use of this data is not expected to adversely affect the results.

Typically, short-term average (i.e., 1- 3- 8- and 24-hour) concentrations are predicted using hourly meteorological measurements from a station located at, or near, the site of interest. Because the data were not available for this study, a screening approach was taken, and a standard set of hourly meteorological conditions were incorporated in the modeling. These standard conditions are accepted by the EPA to encompass the range of atmospheric stabilities and wind speeds that could be expected to occur anywhere. Each combination of wind speed and atmospheric stability was assumed to occur in every possible wind direction. The predicted concentrations represent the highest value that could be reasonably expected to occur anywhere. This approach is conservative because the meteorological condition leading to the reported result may not occur at the site for all wind directions.

G.5.2.2 Source Data

Data describing the location, emission rate, and emission characteristics of the sources was input to the models. Information concerning pollutant emission rates was derived from data packages supplied by the Site Management and Operations contractor and analyzed by the Environmental Impact Statement contractor. In general, when emissions estimates were being developed, conservative values were used.

The location of the pollutant emitting sources is not known with complete certainty in all cases. Pollutant emitting activities associated with the existing tank farms will occur in the present locations. However, the exact location of future facilities is subject to some uncertainty. In general, the closer a source is to a receptor, the higher the predicted concentration at that receptor will be. As a consequence, if the eventual location of an emitting activity is closer to a plant boundary than depicted in the model, the impacts may be higher. Of course, if the activity is located farther from the boundary than depicted in the model, the impacts may be lower.

The temporal arrangement of the pollutant emitting activities affects the predicted concentrations as well. The predicted concentration at any receptor represents the contributions of each individual emitting source. To properly analyze a scenario, all the pollutant emitting activities that could occur at the same time must be considered. In general, most of the scenarios analyzed involved a period of facility construction followed by an operational period.

In some cases, the location of an emitting source is expected to move from place to place as the project progresses. An example of this would be emissions related to remedial activities at tank farm locations. In most cases, work would be occurring at one or two of the possible 17 locations at one time. Given these uncertainties, a conservative analysis was produced by assuming that activities that might or might not overlap in time would occur simultaneously. In addition, activities that would be expected to move from place to place were modeled as if occurring in the location producing the highest potential impact.

Sources were modeled as either point or area sources. Point sources are used to approximate pollutant releases from a stack or other fixed, functional opening or vent. The dispersion algorithms used for point sources modify the effective release height to take into account plume buoyancy (from a heated release) and momentum (from vertical release velocity). Typically, area sources are used to approximate pollutant releases that do not occur at a single well-defined point, but instead can be defined as occurring within a defined area. For instance, an area source could include many small fixed point sources that were too numerous to model individually, or could made up of several mobile sources that may move about within the fixed area. In this study, the construction activities were represented as area sources. The classification of the sources into these two categories involved some degree of uncertainty and some assumptions as well. The models use different algorithms to represent dispersion from point and area sources and the predicted concentration at a receptor could vary, depending on the algorithm chosen. In general, these effects are more noticeable at locations close to the source and tend to diminish as the distance between source and receptor increases.

G.5.3 INTERPRETATION OF MODEL OUTPUT

The short-term model was run using screening meteorology to produce maximum predicted 1-hour average concentrations. These 1-hour average values were converted to 3- ,8-, and 24-hour average concentrations, when appropriate, to compare to applicable standards. This was accomplished by applying conversion factors to the 1-hour average values. Consistent with modeling guidelines (EPA 1988), the factors of 0.9, 0.7, and 0.4 were applied to convert to 3-, 8-, and 24-hour averages, respectively. These factors involve an implied assumption regarding the persistence of the meteorological condition producing the highest 1-hour impact. In other words, conservative meteorological conditions that produced the highest 1-hour concentration can be expected to persist for most of a 3-hour period and to a lesser degree over an 8- or 24-hour period. The modeling guidelines indicate a range of values for each conversion factor: the 3-hour conversion factor can range from 0.8 to 1.0, the 8-hour factor from 0.5 to 0.9, and the 24-hour factor from 0.2 to 0.6. Use of the midpoint values was considered appropriate for this study.

Figure G.4.0.1 Radionuclide Dose (mrem/yr) for the No Action Alternative

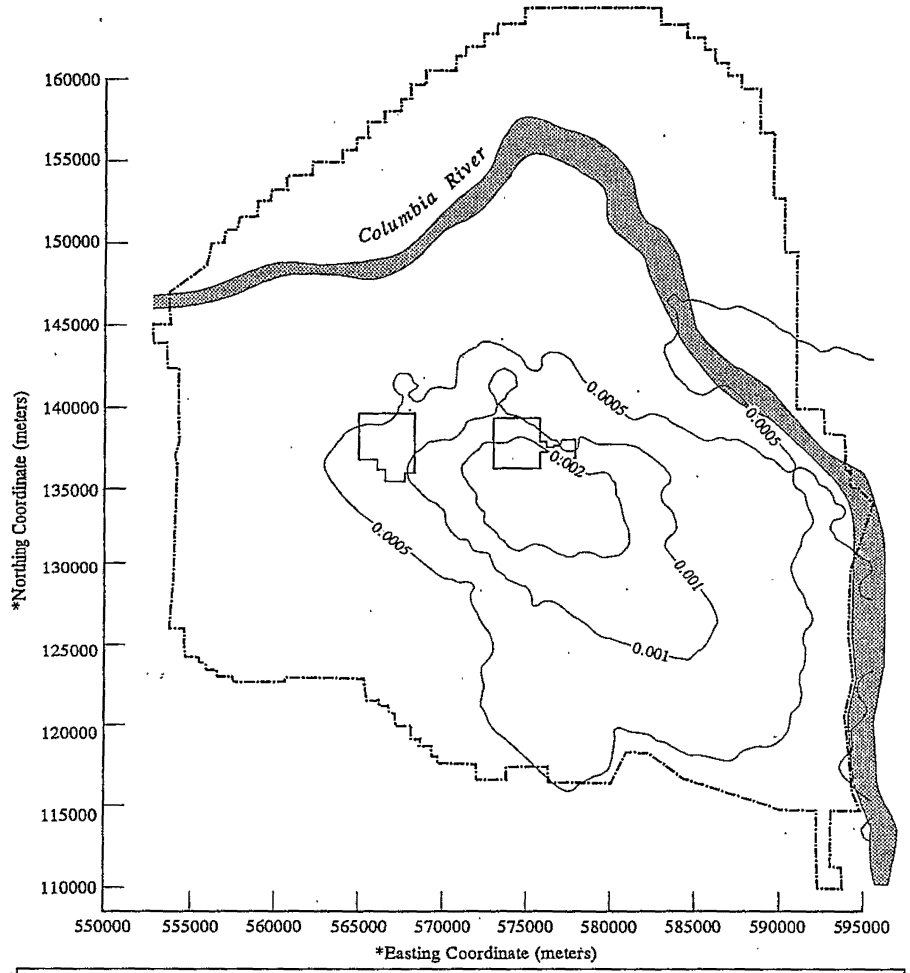


Figure G.4.0.2 Radionuclide Dose (mrem/yr) for the Long-Term Management Alternative (Phase 1)

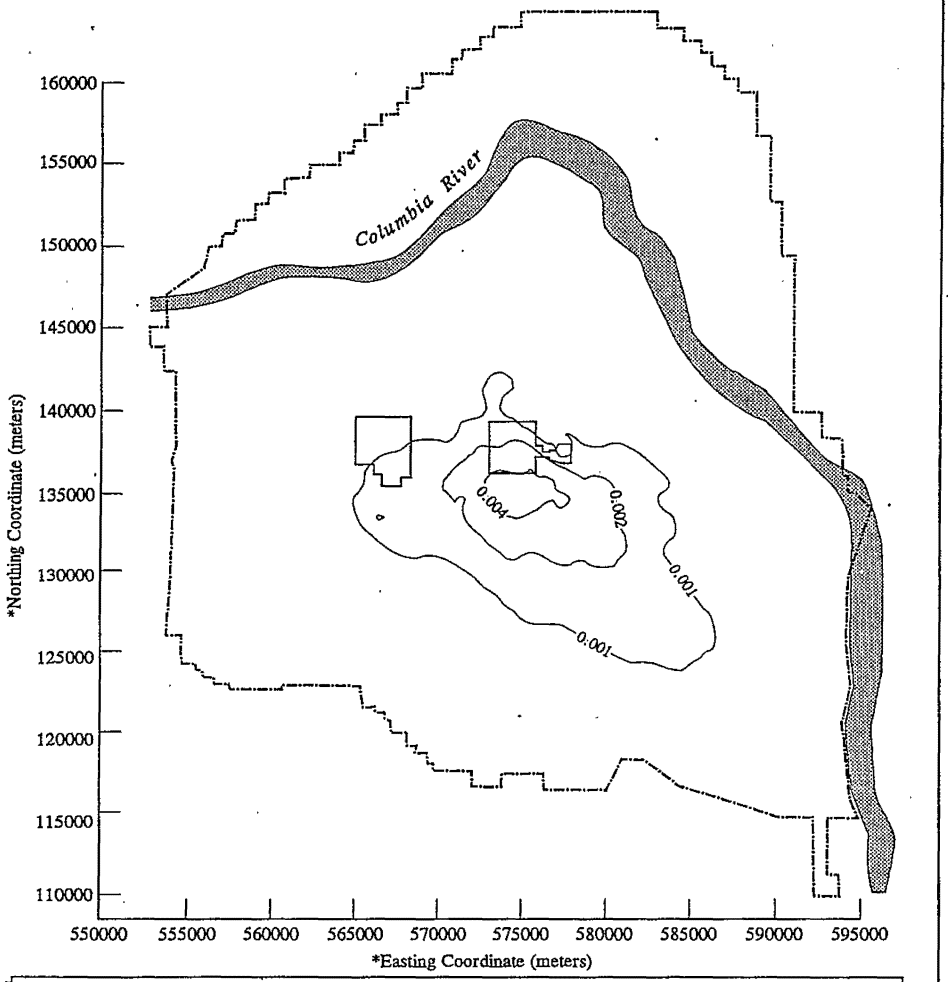


Figure G.4.0.3 Radionuclide Dose (mrem/yr) for the Long-Term Management Alternative (Phase 2)

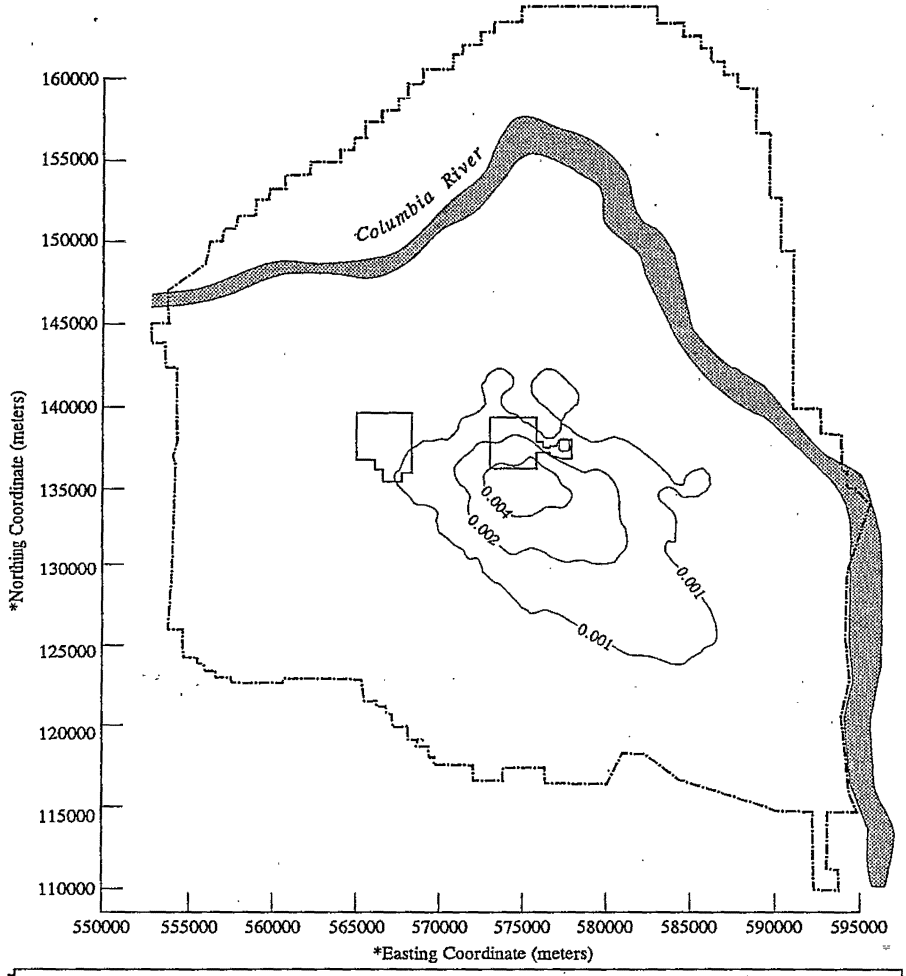


Figure G.4.0.4 Radionuclide Dose (mrem/yr) for the In Situ Fill and Cap Alternative

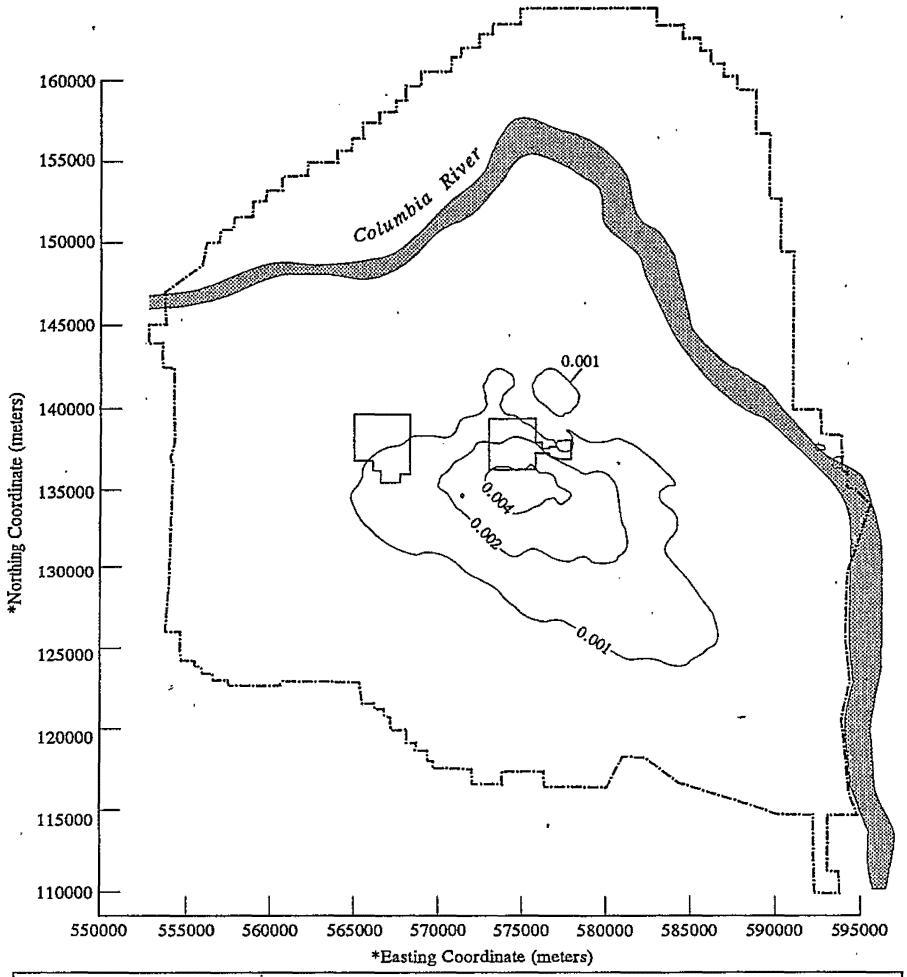


Figure G.4.0.5 Radionuclide Dose (mrem/yr) for the In Situ Vitrification Alternative

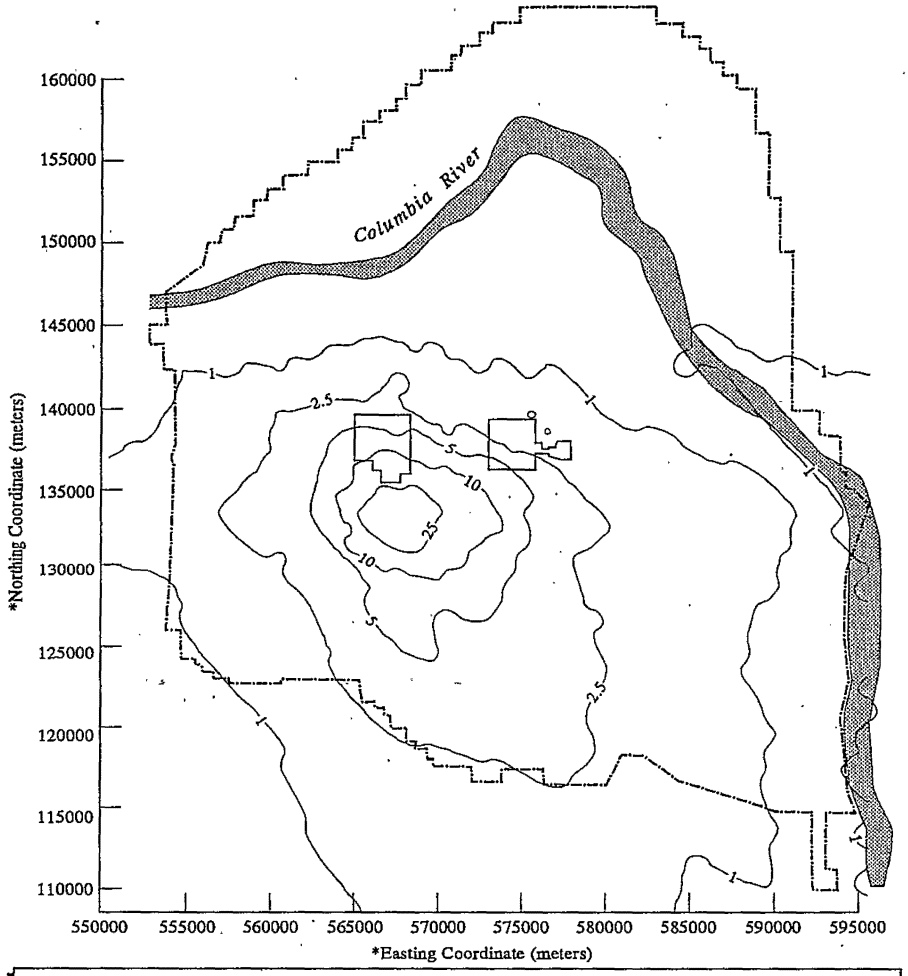


Figure G.4.0.6 Radionuclide Dose (mrem/yr) for the Ex Situ Intermediate Separations Alternative

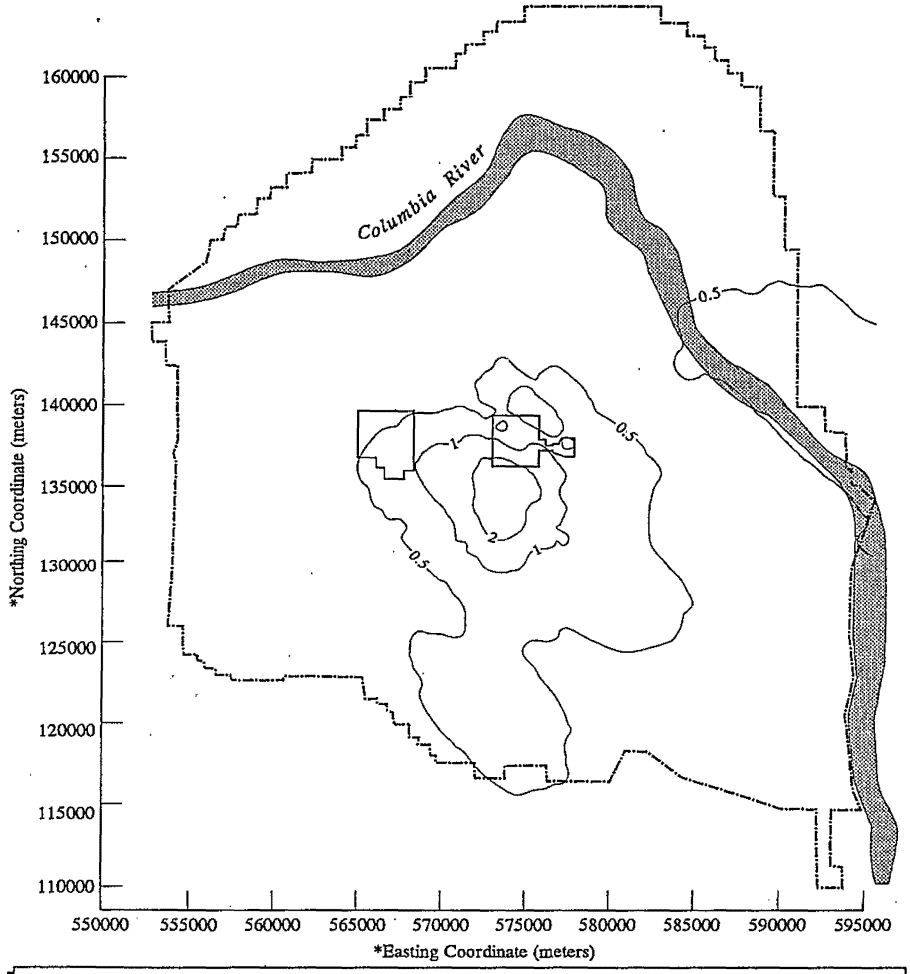


Figure G.4.0.7 Radionuclide Dose (mrem/yr) for the Ex Situ No Separations Alternative (Vitrification)

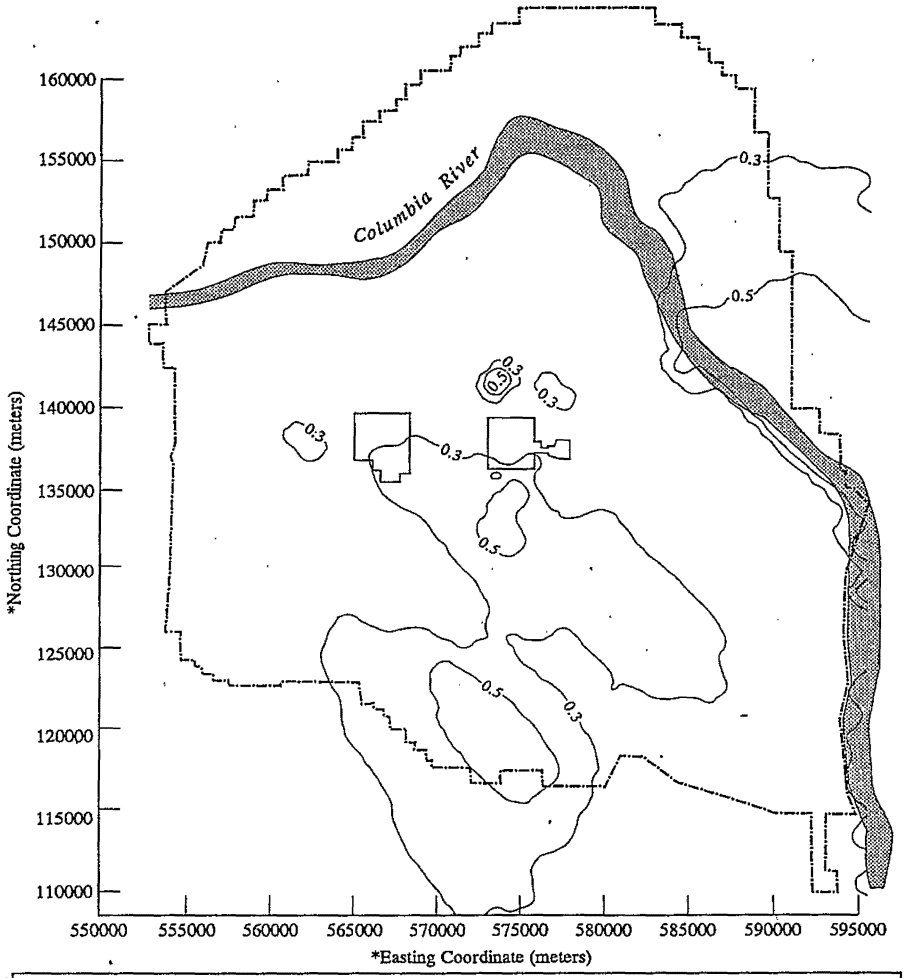


Figure G.4.0.8 Radionuclide Dose (mrem/yr) for the Ex Situ No Separations Alternative (Calcination)

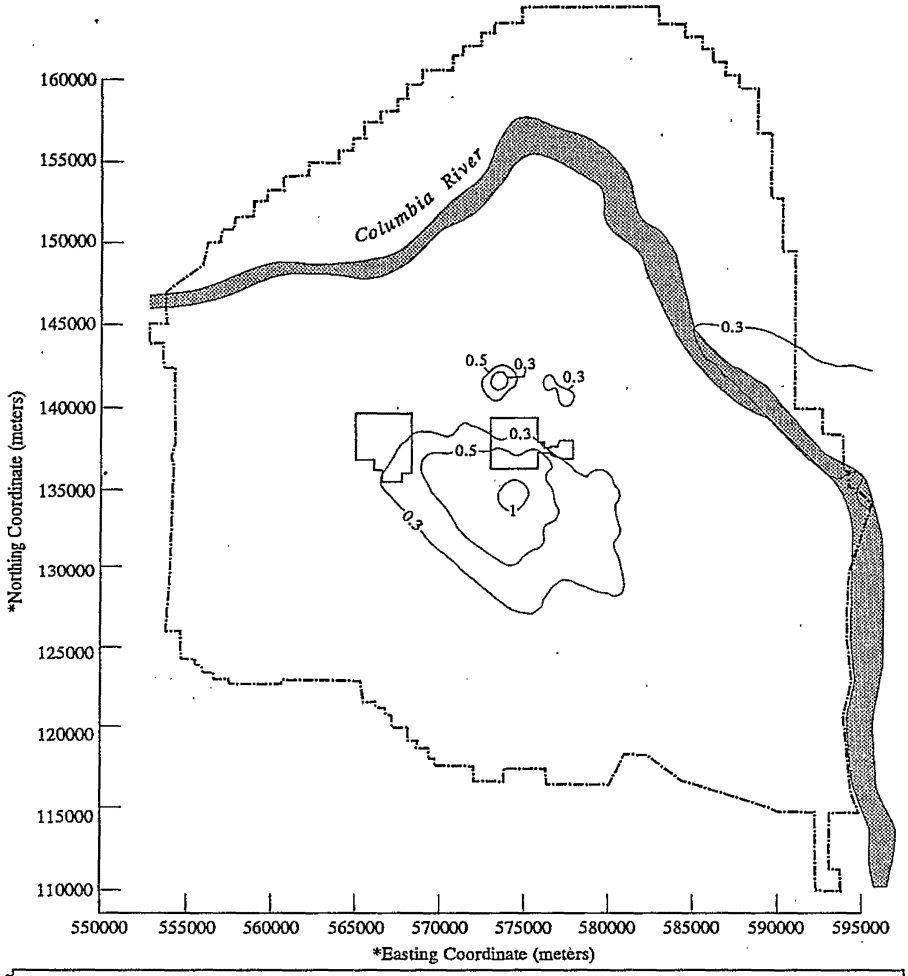


Figure G.4.0.9 Radionuclide Dose (mrem/yr) for the Ex Situ Extensive Separations Alternative

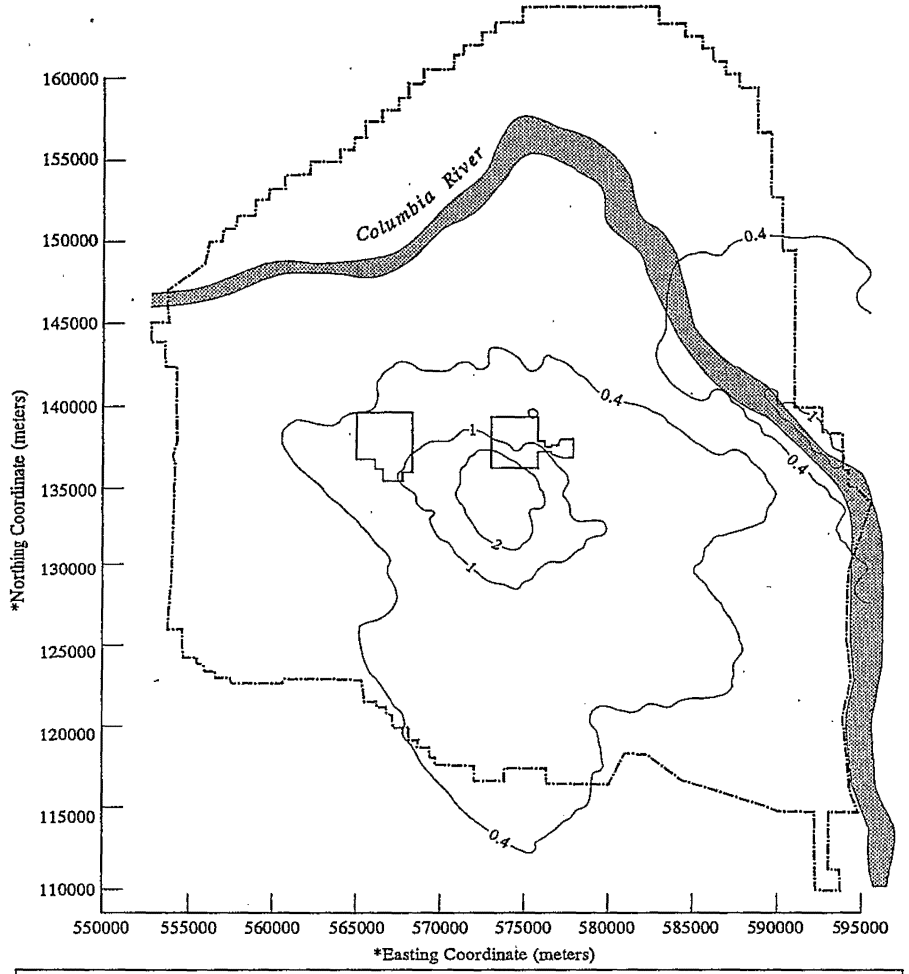


Figure G.4.0.10 Radionuclide Dose (mrem/yr) for the Ex Situ/In Situ Combination 1 Alternative

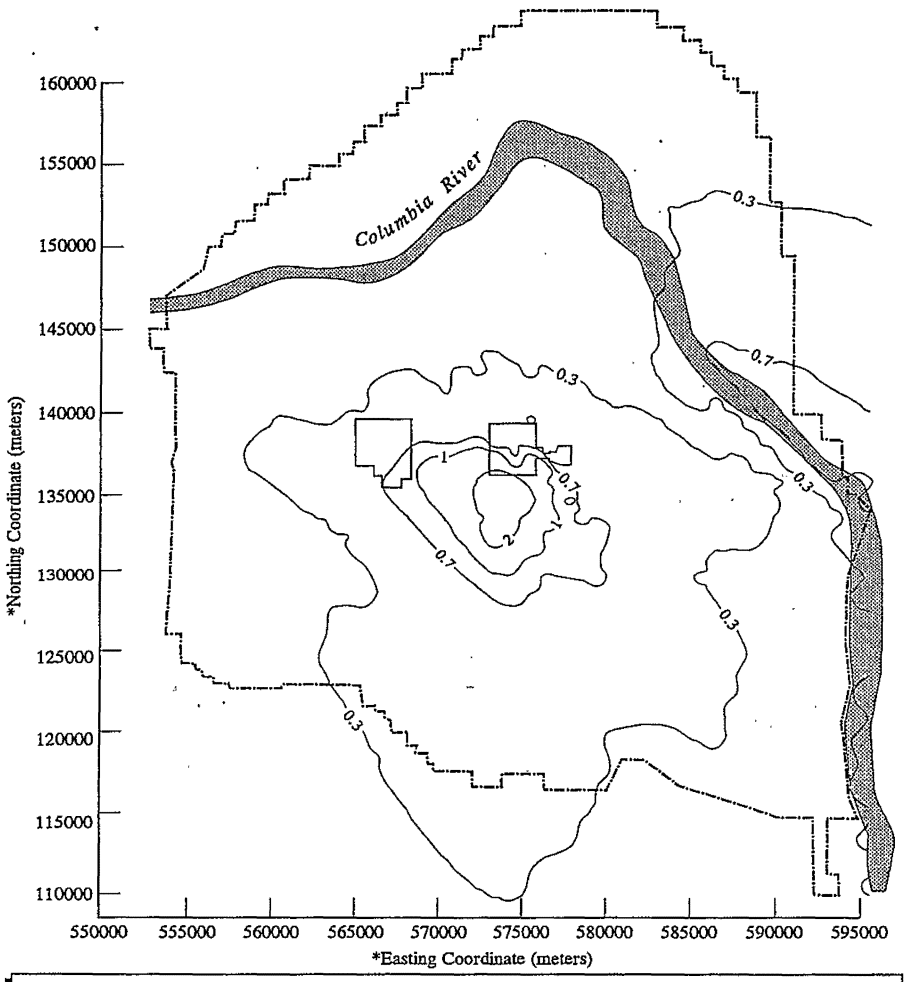


Figure G.4.0.11 Radionuclide Dose (mrem/yr) for the Ex Situ/In Situ Combination 2 Alternative

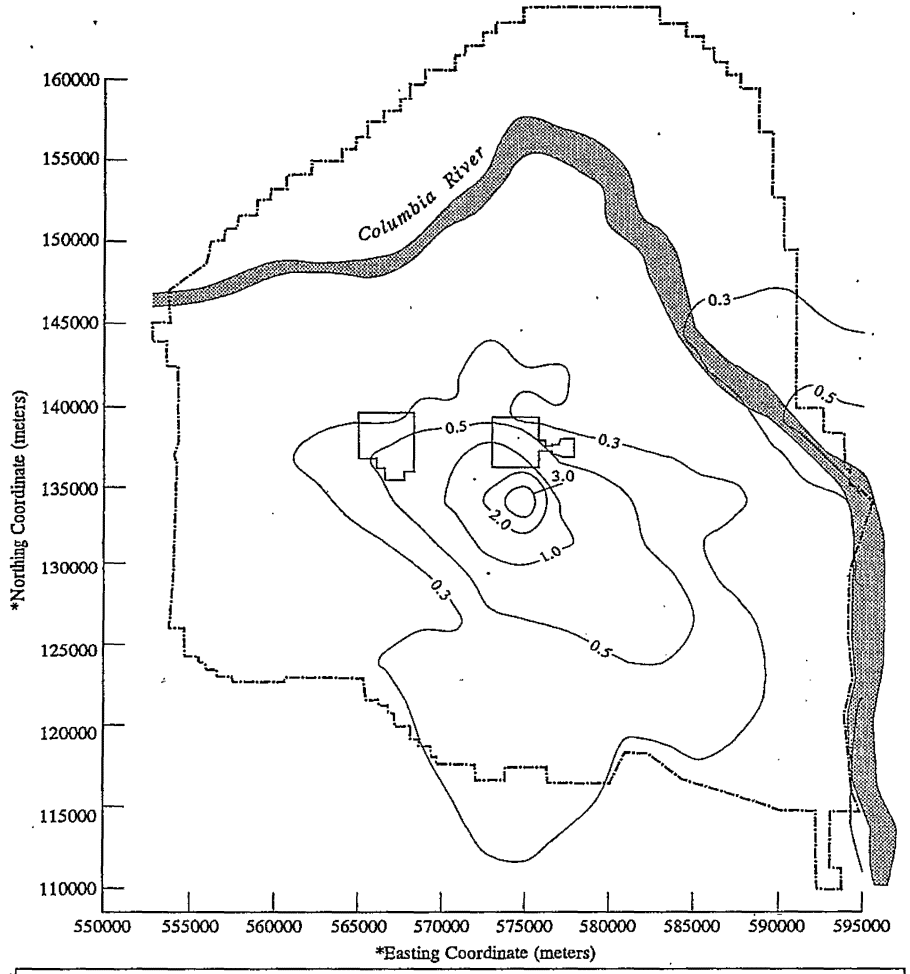


Figure G.4.0.12 Radionuclide Dose (mrem/yr) for the Phased Implementation Alternative - Phase 1

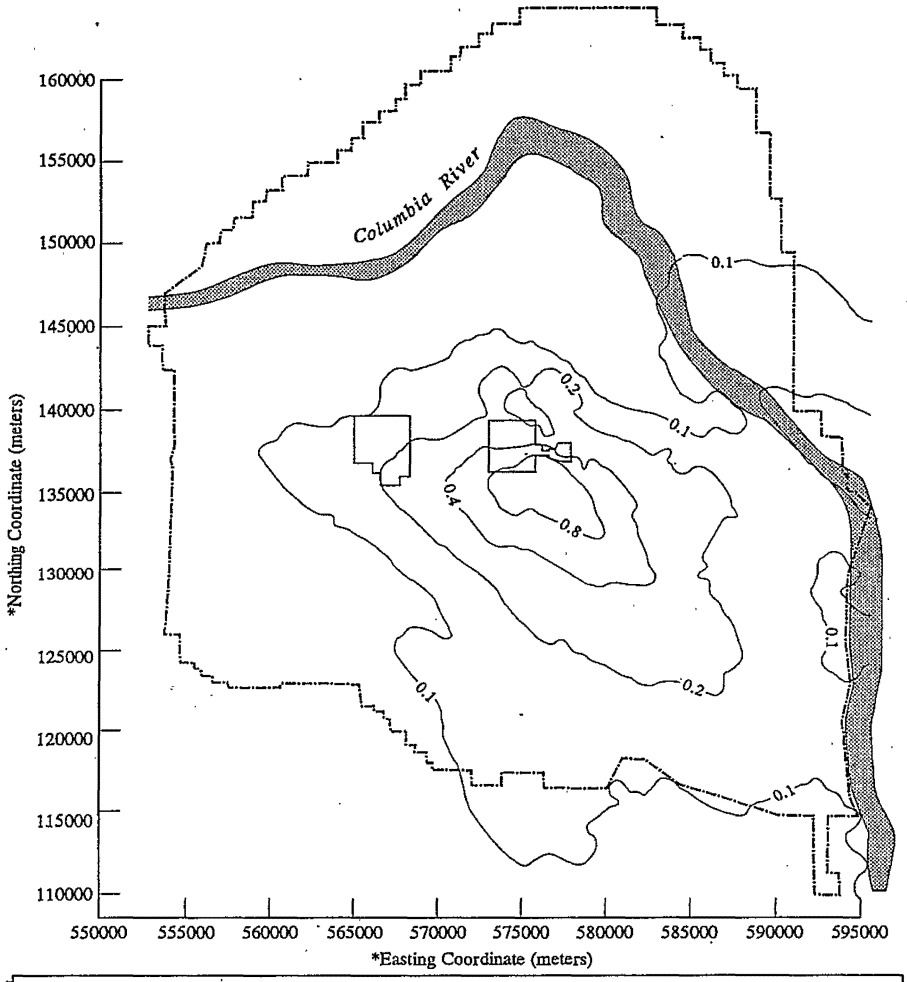


Figure G.4.0.13 Radionuclide Dose (mrem/yr) for the Phased Implementation Alternative - Phase 2

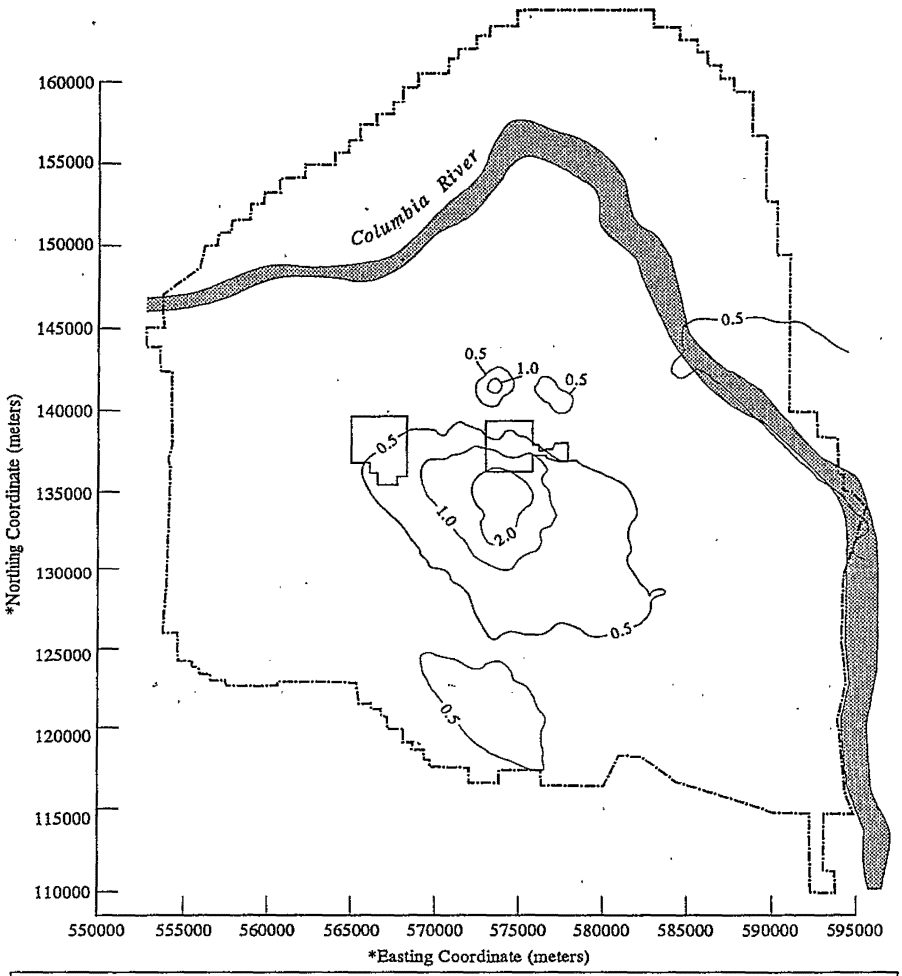


Table G.3.1.1 Source Locations and Parameters

Source Name **	Source Location*		Side Length (m)	Elevation of Center (m)	Source Type	Stack Height (m)
	x coord.	y coord.				
TF1E	573556	137442	114	200	AREA	-- --
TF2E	573556	137282	114	200	AREA	-- --
TF3E	573771	137252	114	200	AREA	-- --
TF4E	575075	136493	149	200	AREA	-- --
TF5E	575332	136378	91	205	AREA	-- --
TF6E	575365	136279	61	205	AREA	-- --
TF7E	575281	136157	61	205	AREA	-- --
TF8E	575380	136159	56	205	AREA	-- --
TF9E	575310	136015	86	210	AREA	-- --
TF10E	575304	135806	101	210	AREA	-- --
TF11E	575481	135747	152	210	AREA	-- --
TF1W	566738	136662	118	210	AREA	-- --
TF2W	566715	136373	87	210	AREA	-- --
TF3W	566689	136146	145	210	AREA	-- --
TF4W	566744	135000	118	205	AREA	-- --
TF5W	566750	134399	176	205	AREA	-- --
TF6W	566746	134162	145	205	AREA	-- --
TA1W	566833	136570	35	210	AREA	-- --
TA2W	566886	134878	80	205	AREA	-- --
TA3W	566930	134444	35	205	AREA	-- --
TA1E	573755	137383	35	200	AREA	-- --
TA2E	575163	136336	35	200	AREA	-- --
PROC	573879	135229	875	215	AREA	-- --
BTCH	571332	135953	578	225	AREA	-- --
SMIN	574425	135978	N/A	215	POINT	54.86
ST-L	574120	135901	N/A	215	POINT	54.86
ST-H	574410	135978	N/A	215	POINT	54.86
CPF	573370	136370	60	200	AREA	-- --
DWSF	572141	136082	195	200	AREA	-- --
IS6W	566318	133734	N/A	205	POINT	30.00
EVAP	575374	135996	N/A	205	POINT	6.70
ESEP	574400	136000	N/A	205	POINT	54.86
WESF	573361	136433	N/A	205	POINT	21.34
SSPI	576210	135680	N/A	215	POINT	45.73
NSPI	576220	136080	N/A	215	POINT	45.73
FCPI	576180	135600	3.887	215	AREA	-- --

Notes:
* Location of area sources represents southwest corner of area (coordinates in meters)
** Tank farm sources have the prefix TF, transfer annex areas have the prefix TA; source IDs ending in E are located in the 200 East Area, while those ending in W are located in the 200 West Area. Other sources are defined as follows:
BTCH = Concrete batch plant emissions
CPF = Capsule Packaging Facility
DWSF = Drywell storage facility
ESEP = Extensive Separations facility process stack
EVAP = Evaporator
IS6W = ISV Stack located adjacent to TF6W
PROC = Vitrification process facility construction emissions
SMIN = No Separations process stack
ST-H = Intermediate Separations, HLW facility process stack
ST-L = Intermediate Separations, LAW facility process stack
WESF = Waste Encapsulation and Storage Facility Stack
Coordinates are Washington State plane coordinates

Table G.3.1.2 Emission Rates for the No Action Alternative (Tank Waste)

Pollutant	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)
Carbon Monoxide	TF1E	1.29E-04	TF2E	2.40E-04	TF3E	3.06E-04	TF4E	1.8.E-04
	TF8E	7.86E-05	TF9E	1.07E-04	TF1W	3.86E-07	TF2W	1.48E-07
	TF3W	3.11E-07	TF4W	3.69E-07	TF5W	2.00E-06	TF6W	7.14E-06
Nitrogen Oxides	TF1E	7.97E-06	TF2E	1.44E-05	TF3E	1.84E-05	TF4E	1.25E-05
	TF5E	1.15E-05	TF6E	3.29E-06	TF7E	3.29E-06	TF8E	4.80E-06
	TF9E	6.44E-06	TF10E	9.86E-06	TF11E	1.32E-05	TF1W	2.31E-08
	TF2W	8.91E-09	TF3W	2.19E-08	TF4W	2.22E-08	TF5W	2.34E-08
	TF6W	1.68E-09	--	--	--	--	--	--
1,3 butadiene	TF1E	5.58E-07	TF2E	1.04E-06	TF3E	1.33E-06	TF4E	7.97E-07
	TF5E	8.31E-07	TF6E	2.38E-07	TF7E	2.38E-07	TF8E	3.28E-07
	TF9E	4.67E-07	TF10E	7.14E-07	TF11E	9.50E-07	TF1W	1.67E-09
	TF2W	6.44E-10	TF3W	1.45E-09	TF4W	1.60E-09	TF5W	2.10E-09
	TF6W	1.82E-09	--	--	--	--	--	--
2-hexanone	TF1E	1.03E-05	TF2E	1.89E-05	TF3E	2.41E-05	TF4E	1.45E-05
	TF5E	1.51E-05	TF6E	4.33E-06	TF7E	4.33E-06	7F8E	6.31E-06
	TF9E	8.47E-06	TF10E	1.30E-05	TF11E	1.73E-05	TF1W	3.03E-08
	TF2W	1.17E-08	TF3W	2.64E-08	TF4W	2.92E-08	TF5W	3.80E-08
	TF6W	3.33E-08	EVAP	8.3E-07	--	--	--	--
2-pentanone	TF1E	1.64E-05	TF2E	3.008E-05	TF3E	3.8.E-05	TF4E	2.29E-05
	TF5E	2.40E-05	TF6E	6.87E-06	TF7E	6.87E-06	TF8E	8.86E-06
	TF9E	1.34E-05	TF10E	2.06E-05	TF11E	2.74E-05	TF1W	4.83E-08
	TF2W	1.86E-08	TF3W	4.19E-08	TF4W	4.61E-08	TF5W	6.05E-08
	TF6W	5.27E-08	--	--	--	--	--	--
Acetone	TF1E	1.95E-04	TF2E	3.61E-04	TF3E	4.58E-04	TF4E	2.76E-04
	TF5E	2.89E-04	TF6E	8.22E-05	TF7E	8.22E-05	TF8E	1.20E-04
	TF9E	1.61E-04	TF10E	2.47E-04	TF11E	3.31E-04	TF1W	5.81E-07
	TF2W	2.23E-07	TF3W	5.03E-07	TF4W	5.56E-07	TF5W	7.25E-07
	TF6W	6.31E-07	EVAP	2.3E-04	--	--	--	--
Acetonitrile	TF1E	9.36E-05	TF2E	1.74E-04	TF3E	2.21E-04	TF4E	1.33E-04
	TF5E	1.39E-04	TF6E	3.97E-05	TF7E	3.97E-05	TF8E	5.81E-05
	TF9E	7.78E-05	TF10E	1.19E-04	TF11E	1.59E-04	FT1W	2.81E-07
	TF2W	1.08E-07	TFW3	2.43E-07	TF4W	2.68E-07	TF5W	3.49E-07
	TF6W	3.04E-07	--	--	--	--	--	--

Table G.3.1.2 Emission Rates for the No Action Alternative (Tank Waste) (cont'd)

Pollutant	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)
Ammonia	TF1E	9.94E-04	TF2E	1.66E-03	TF3E	2.11E-03	TF4E	1.44E-03
	TF8E	5.53E-04	TF9E	7.42E-04	TF1W	2.66E-06	TF2W	1.03E-06
	TF3W	4.17E-10	TF4W	2.55E-06	TF5W	3.33E-05	TF6W	1.32E-04
	EVAP	2.2E-04	--	--	--	--	--	--
Benzene	TF1E	4.50E-06	TF2E	8.28E-06	TF3E	1.05E-05	TF4E	6.31E-06
	TF5E	6.58E-06	TF6E	1.89E-06	TF7E	1.89E-06	TF8E	2.76E-06
	TF9E	3.69E-06	TF10E	5.67E-06	TF11E	7.53E-06	TF1W	1.33E-08
	TF2W	5.11E-06	TF3W	1.15E-08	TF4W	3.42E-08	TF5W	1.66E-08
	TF6W	1.45E-08	--	--	--	--	--	--
Heptane	TF1E	1.17E-05	TF2E	2.12E-05	TF3E	2.70E-05	TF4E	1.62E-05
	TF5E	1.69E-05	TF6E	4.83E-06	TF7E	4.83E-06	7F8E	7.08E-06
	TF9E	9.50E-06	TF10E	1.45E-05	TF11E	1.93E-05	TF1W	3.42E-08
	TF2W	1.31E-08	TF3W	2.94E-08	TF4W	3.25E-08	TF5W	4.27E-08
	TF6W	3.69E-08	--	--	--	--	--	--
Hexane	TF1E	1.26E-05	TF2E	2.21E-05	TF3E	2.81E-05	TF4E	1.69E-05
	TF5E	1.76E-05	TF6E	5.06E-06	TF7E	5.06E-06	TF8E	7.36E-06
	TF9E	9.89E-06	TF10E	1.51E-05	TF11E	2.02E-05	TF1W	3.56E-08
	TF2W	1.37E-08	TF3W	3.08E-08	TF4W	3.39E-08	TF5W	4.44E-08
	TF6W	3.87E-08	--	--	--	--	--	--
Methyl Amyl Ketone	TF1E	1.11E-05	TF2E	2.05E-05	TF3E	2.61E-05	TF4E	1.56E-05
	TF5E	1.64E-05	TF6E	4.68E-06	TF7E	4.68E-06	TF8E	6.83E-06
	TF9E	9.17E-06	TF10E	1.40E-05	TF11E	1.87E-05	TF1W	3.31E-08
	TF2W	1.27E-08	TF3W	2.86E-08	TF4W	3.17E-08	TF5W	4.14E-08
	TF6W	3.60E-08	--	--	--	--	--	--
Methyl Isobutyl Ketone	EVAP	1.6E-05	--	--	--	--	--	--
n-Butyl alcohol	EVAP	1.73E-03	--	--	--	--	--	--
Nonane	TF1E	6.25E-06	TF2E	1.15E-05	TF3E	1.47E-05	TF4E	8.81E-06
	TF5E	9.19E-06	TF6E	2.64E-06	TF7E	2.64E-06	TF8E	3.8.E-06
	TF9E	5.17E-06	TF10E	7.89E-06	TF11E	1.05E-05	TF1W	1.94E-08
	TF2W	7.47E-09	TF3W	1.68E-08	TF4W	1.86E-08	TF5W	2.43E-08
	TF6W	2.12E-08	--	--	--	--	--	--

Table G.3.1.2 Emission Rates for the No Action Alternative (Tank Waste) (cont'd)

Pollutant	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)
Octane	TF1E	6.64E-06	TF2E	1.21E-05	TF3E	1.54E-05	TF4E	9.22E-06
	TF5E	9.64E-06	TF6E	2.76E-06	TF7E	2.76E-06	TF8E	4.03E-06
	TF9E	5.42E-06	TF10E	8.25E-06	TF11E	1.10E-05	TF1W	1.94E-08
	TF2W	7.47E-09	TF3W	1.68E-08	TF4W	1.86E-08	TF5W	2.43E-08
	TF6W	2.12E-08	--	--	--	--	--	--
Phos Acid, Tributyl Ester	TF1E	2.33E-05	TF2E	4.33E-05	TF3E	1.47E-05	TF4E	8.81E-06
	TF5E	9.19E-06	TF6E	2.64E-06	TF7E	2.64E-06	TF8E	3.83E-06
	TF9E	5.17E-06	TF10E	7.89E-06	TF11E	1.05E-05	TF1W	1.85E-08
	TF2W	7.14E-09	TF3W	1.61E-08	TF4W	1.77E-08	TF5W	2.32E-08
	TF6W	2.02E-08	--	--	--	--	--	--
Toluene	TF1E	9.92E-07	TF2E	1.68E-06	TF3E	2.14E-06	TF4E	1.28E-06
	TF5E	1.34E-06	TF6E	3.85E-07	TF7E	3.85E-07	TF8E	5.61E-07
	TF9E	7.53E-07	TF10E	1.15E-06	TF11E	1.54E-06	TF1W	2.70E-09
	TF2W	1.04E-09	TF3W	1.24E-10	TF4W	2.38E-09	TF5W	3.38E-09
	TF6W	2.95E-09	--	--	--	--	--	--

Notes:
g/sec = Grams per second
-- Indicates no additional sources or emission rates.

Table G.3.1.3 Emission Rates for the Long-Term Management Alternative Phase 1 (First Retanking)

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	PROC	6.9E-03
Carbon Monoxide	PROC	1.38E-01
Nitrogen Oxides	PROC	2.05E-02
PM-10	PROC	1.86E-01
Hazardous/Toxic Air Pollutants		
Formaldehyde	PROC	6.73E-04
In addition, emissions from tank farms TF1E - TF11E and TF1W - TF5W, identical to those shown in Table G.3.1.2, would occur. Emissions from tank farm TF6W (during retrieval) were used to determine bounding emission rates and are shown below.		
Carbon Monoxide	TF6W	9.17E-04
Nitrogen Oxides	TF6W	5.51E-05
1,3-butadiene	TF6W	3.98E-06
2-hexanone	TF6W	7.23E-05
2-pentanone	TF6W	1.15E-04
Acetone	TF6W	1.38E-03
Acetonitrile	TF6W	6.64E-04
Ammonia	TF6W	6.33E-03
Benzene	TF6W	3.16E-05
Heptane	TF6W	8.10E-05
Hexane	TF6W	8.42E-05
Nonane	TF6W	4.41E-05
Octane	TF6W	4.61E-05
Phosphoric acid, Tributyl Ester	TF6W	1.30E-04
Toluene	TF6W	6.43E-06

Notes:
g/sec = Grams per second

Table G.3.1.4 Emission Rates for the Long-Term Management Alternative Phase 2 (Second Retanking)

Pollutant	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)
Carbon Monoxide	TF1E	1.29E-04	TF2E	2.40E-04	TF3E	3.06E-04	TF4E	1.8.E-04
	TF8E	7.86E-05	TF9E	1.07E-04	TF1W	3.86E-07	TF2W	1.48E-07
	TF3W	3.11E-07	TF4W	3.69E-07	TF5W	3.61E-07	TF6W	7.14E-06
	PROC	1.38E-01	--	--	--	--	--	--
Nitrogen Oxide	TF1E	7.97E-06	TF2E	1.44E-05	TF3E	1.84E-05	TF4E	1.25E-05
	TF8E	4.80E-06	TF9E	6.44E-06	TF1W	2.31E-08	TF2W	8.91E-09
	TF3W	2.19E-08	TF4W	2.22E-08	TF5W	2.34E-08	TF6W	2.52E-8
	PROC	2.05E-02	--	--	--	--	--	--
1,3 butadiene	TF1E	5.58E-07	TF2E	1.04E-06	TF3E	1.33E-06	TF4E	7.97E-07
	TF8E	3.28E-07	TF9E	4.67E-07	TF1W	1.67E-09	TF2W	6.44E-10
	TF3W	1.45E-09	TF4W	1.60E-09	TF5W	1.70E-09	TF6W	1.82E-09
	PROC	3.20E-06	--	--	--	--	--	--
2-hexanone	TF1E	1.03E-05	TF2E	1.89E-05	TF3E	2.41E-05	TF4E	1.45E-05
	TF8E	6.31E-06	TF9E	8.47E-06	TF1W	3.03E-08	TF2W	1.17E-08
	TF3W	2.64E-08	TF4W	2.92E-08	TF5W	3.80E-08	TF6W	3.33E-08
	EVAP	8.3E-07	PROC	5,82E-05	--	--	--	--
2-pentanone	TF1E	1.64E-05	TF2E	3.00E-05	TF3E	3.8.E-05	TF4E	2.29E-05
	TF8E	8.86E-06	TF9E	1.34E-05	TF1W	4.83E-08	TF2W	1.86E-08
	TF3W	4.19E-08	TF4W	4.61E-08	TF5W	4.92E-08	TF6W	5.27E-08
	PROC	9.24E-05	--	--	--	--	--	--
Acetone	TF1E	1.95E-04	TF2E	3.61E-04	TF3E	4.58E-04	TF4E	2.76E-04
	TF8E	1.20E-04	TF9E	1.61E-04	TF1W	5.81E-07	TF2W	2.23E-07
	TF3W	5.03E-07	TF4W	5.56E-07	TF5W	5.89E-07	TF6W	6.31E-07
	EVAP	2.3E-04	PROC	1.11E-03	--	--	--	--
Acetonitrile	TF1E	9.36E-05	TF2E	1.74E-04	TF3E	2.21E-04	TF4E	1.33E-04
	TF8E	5.81E-05	TF9E	7.78E-05	TF1W	2.81E-07	TF2W	1.08E-07
	TFW3	2.43E-07	TF4W	2.68E-07	TF5W	2.83E-07	TF6W	3.04E-07
	PROC	5.35E-04	--	--	--	--	--	--
Ammonia	TF1E	9.94E-04	TF2E	1.66E-03	TF3E	2.11E-03	TF4E	1.44E-03
	TF8E	5.53E-04	TF9E	7.42E-04	TF1W	2.66E-06	TF2W	1.03E-06
	TF3W	4.17E-10	TF4W	2.55E-06	TF5W	2.71E-06	TF6W	1.32E-04
	EVAP	2.2E-04	PROC	3.06E-05	--	--	--	--

Table G.3.1.4 Emission Rates for the Long-Term Management Alternative Phase 2 (Second Retanking) (cont'd)

Pollutant	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)
Benzene	TF1E	4.50E-06	TF2E	8.28E-06	TF3E	1.05E-05	TF4E	6.31E-06
	TF8E	2.76E-06	TF9E	3.69E-06	TF1W	1.33E-08	TF2W	5.11E-06
	TF3W	1.15E-08	TF4W	3.42E-08	TF5W	1.35E-08	TF6W	1.45E-08
	PROC	2.54E-05	--	--	--	--	--	--
Heptane	TF1E	1.17E-05	TF2E	2.12E-05	TF3E	2.70E-05	TF4E	1.62E-05
	TF8E	7.08E-06	TF9E	9.50E-06	TF1W	3.42E-08	TF2W	1.31E-08
	TF3W	2.94E-08	TF4W	3.25E-08	TF5W	3.74E-08	TF6W	3.69E-08
	PROC	6.51E-05	--	--	--	--	--	--
Hexane	TF1E	1.26E-05	TF2E	2.21E-05	TF3E	2.81E-05	TF4E	1.69E-05
	TF8E	7.36E-06	TF9E	9.89E-06	TF1W	3.56E-08	TF2W	1.37E-08
	TF3W	3.08E-08	TF4W	3.39E-08	TF5W	3.61E-08	TF6W	3.87E-08
	PROC	6.79E-05	--	--	--	--	--	--
Methyl Amyl Ketone	TF1E	1.11E-05	TF2E	2.05E-05	TF3E	2.61E-05	TF4E	1.56E-05
	TF8E	6.83E-06	TF9E	9.17E-06	TF1W	3.31E-08	TF2W	1.27E-08
	TF3W	2.86E-08	TF4W	3.17E-08	TF5W	3.36E-08	TF6W	3.60E-08
	PROC	6.29E-05	--	--	--	--	--	--
Methyl Isobutyl Ketone	EVAP	1.6E-05	--	--	--	--	--	--
n-Butyl alcohol	EVAP	1.73E-03	--	--	--	--	--	--
Nonane	TF1E	6.25E-06	TF2E	1.15E-05	TF3E	1.47E-05	TF4E	8.81E-06
	TF8E	3.8.E-06	TF9E	5.17E-06	TF1W	1.94E-08	TF2W	7.47E-09
	TF3W	1.68E-08	TF4W	1.86E-08	TF5W	1.88E-08	TF6W	2.12E-08
	PROC	3.54E-05	--	--	--	--	--	--
Octane	TF1E	6.64E-06	TF2E	1.21E-05	TF3E	1.54E-05	TF4E	9.22E-06
	TF8E	4.03E-06	TF9E	5.42E-06	TF1W	1.94E-08	TF2W	7.47E-09
	TF3W	1.68E-08	TF4W	1.86E-08	TF5W	1.98E-08	TF6W	2.12E-08
	PROC	3.71E-05	--	--	--	--	--	--
Phosphoric Acid, Tributyl Ester	TF1E	2.33E-05	TF2E	4.33E-05	TF3E	1.47E-05	TF4E	8.81E-06
	TF8E	3.83E-06	TF9E	5.17E-06	TF1W	1.85E-08	TF2W	7.14E-09
	TF3W	1.61E-08	TF4W	1.77E-08	TF5W	7.08E-08	TF6W	2.02E-08
	PROC	3.54E-05	--	--	--	--	--	--

Table G.3.1.4 Emission Rates for the Long-Term Management Alternative Phase 2 (Second Retanking) (cont'd)

Pollutant	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)	Source	Emission Rate (g/sec)
Toluene	TF1E	9.92E-07	TF2E	1.68E-06	TF3E	2.14E-06	TF4E	1.28E-06
	TF8E	5.61E-07	TF9E	7.53E-07	TF1W	2.70E-09	TF2W	1.04E-09
	TF3W	1.24E-10	TF4W	2.38E-09	TF5W	2.79E-09	TF6W	2.95E-09
	PROC	5.17E-06	--	--	--	--	--	--
Sulfur Oxides	PROC	6.90E-03	--	--	--	--	--	--
PM-10	PROC	1.86E-01	--	--	--	--	--	--
Formaldehyde	PROC	6.73E-04	--	--	--	--	--	--

Notes:
g/sec = Grams per second
-- Indicates no additional sources or emission rates.

Table G.3.1.5 Emission Rates for the In Situ Fill and Cap Alternative

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF6W	2.4E-01
Carbon Monoxide	TF6W	5.0E-01
Nitrogen Oxides	TF6W	1.12E+00
PM-10	TF6W	6.6E-01
	BTCH	3.3E-01
	TF5W	5.56E-02
Hazardous/Toxic Air Pollutants		
Formaldehyde	TF6W	1.90E-04
In addition, emissions from tank farms TF1E - TF11E and TF1W - TF4W, identical to those shown in Table G.3.1.2, would occur. Emissions from tank farms TF5W and TF6W (during filling) were used to determine bounding emission rates and are shown below.		
Carbon Monoxide	TF5W, TF6W	4.89E-04
Nitrogen Oxides	TF5W, TF6W	2.94E-05
1,3-butadiene	TF5W, TF6W	2.12E-06
2-hexanone	TF5W, TF6W	3.86E-05
2-pentanone	TF5W, TF6W	6.13E-05
Acetone	TF5W, TF6W	7.33E-04
Acetonitrile	TF5W, TF6W	3.54E-04
Ammonia	TF5W, TF6W	3.38E-03
Benzene	TF5W, TF6W	1.68E-05
Heptane	TF5W, TF6W	4.32E-05
Hexane	TF5W, TF6W	4.49E-05
Nonane	TF5W, TF6W	2.35E-05
Octane	TF5W, TF6W	2.46E-05
Phosphoric acid, Tributyl Ester	TF5W, TF6W	6.93E-05
Toluene	TF5W, TF6W	6.43E-06

Notes:
g/sec = Grams per second

Table G.3.1.6 Emission Rates for the In Situ Vitrification Alternative

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF6W (construction)	6.85E-01
Carbon Monoxide	TF6W (construction)	9.92E+00
Nitrogen Oxides	TF6W (construction)	3.3E+00
	IS6W (operations)	6.86E-01
PM-10	TF6W (construction)	2.41E+00
	IS6W (operations)	1.14E-01
Hazardous/Toxic Air Pollutants		
Formaldehyde	TF6W (construction)	7.74E-04
Ammonia	IS6W (operations)	1.07E-01

Notes:
g/sec = Grams per second
Routine emissions from tank farm sources TF1E - TF11E and TF1W - TF5W and from the evaporator (EVAP) would occur as shown in Table G.3.1.2.

Table G.3.1.7 Emission Rates for the Ex Situ Intermediate Separations Alternative - Construction Phase

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W	1.77E-03
	TF6W	1.77E-03
	TA1W	7.18E-03
	TA2W	3.77E-02
	TA3W	7.18E-03
	TA1E	7.18E-03
	TA2E	7.18E-03
	PROC	2.13E-01
Carbon Monoxide	TF5W	3.72E-02
	TF6W	3.72E-02
	TA1W	9.69E-02
	TA2W	0.510
	TA3W	9.69E-02
	TA1E	9.69E-02
	TA2E	9.69E-02
	PROC	1.60E+02
Nitrogen Dioxide	TF5W	1.46E-01
	TF6W	1.46E-01
	TA1W	3.15E-01
	TA2W	1.66
	TA3W	3.15E-01
	TA1E	3.15E-01
	TA2E	3.15E-01
	PROC	1.6E+01
PM-10	TF5W	1.03E-02
	TF6W	1.03E-02
	TA1W	7.40E-02
	TA2W	3.88E-01
	TA3W	7.40E-02
	TA1E	7.40E-02
	TA2E	7.40E-02
	PROC	6.67E+00
	BTCH	3.17E+00
Hazardous Air Pollutants		
Formaldehyde	TF5W	3.61e-05
	TF6W	3.61E-05
	TA1W	9.33E-05
	TA2W	4.89E-04
	TA3W	9.33E-05
	TA1E	9.33E-05
	TA2E	9.33E-05
	PROC	3.89E-03

Notes:
g/sec = Grams per second
Routine emissions from tank farms and evaporator would occur as shown in Table G.3.1.2

Table G.3.1.8 Emission Rates for the Ex Situ Intermediate Separations Alternative - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W, TF6W	1.77E-03
	ST-H	2.75E-02
	ST-L	7.56E-01
Carbon Monoxide	TF5W, TF6W	3.72E-02
	ST-H	1.21E+00
	ST-L	8.5E+00
Nitrogen Dioxide	TF5W, TF6W	1.46E-01
	ST-H	2.62E-02
	ST-L	5.14E-01
PM-10	TF5W, TF6W	1.03E-02
Hazardous Air Pollutants		
Formaldehyde	TF5W, TF6W	3.61E-05
Arsenic Compounds	ST-H	1.83E-09
	ST-L	8.8E-10
Beryllium Compounds	ST-H	4.67E-11
	ST-L	6.3E-12
Cadmium Compounds	ST-H	1.75E-08
	ST-L	7.6E-09
Cobalt Compounds	ST-H	1.96E-09
	ST-L	2.2E-10
Chromium Compounds	ST-H	9.86E-08
	ST-L	5.7E-07
Manganese Compounds	ST-H	3.50E-07
	ST-L	6.5E-08
Lead Compounds	ST-H	6.19E-08
	ST-L	9.4E-09
Antimony Compounds	ST-H	4.42E-09
	ST-L	2.3E-10
Selenium Compounds	ST-H	5.39E-09
	ST-L	2.7E-09
Nickle Compounds	ST-H	3.50E-04
	ST-L	3.2E-09
Hydrogen Chloride	ST-H	1.16E-02
	ST-L	9.6E-03
Iodine	ST-H	1.21E-05
	ST-L	1.39E-03
Ammonia	ST-H	0.000
	ST-L	1.12E-01
Silver Oxide	ST-H	8.03E-10
	ST-L	1.1E-10
Boric Oxide	ST-H	5.3E-06
	ST-L	3.0E-09

Table G.3.1.8 Emission Rates for the Ex Situ Intermediate Separations Alternative - Operation Phase (cont'd)

Pollutant	Source	Emission Rate (g/sec)
Calcium Oxide	ST-H	0
	ST-L	9.6E-06
Ferric Oxide	ST-H	2.12E-06
	ST-L	4.0E-08
Magnesium Oxide	ST-H	1.58E-08
	ST-L	9.5E-06
Tellurium Trioxide	ST-H	6.19E-10
	ST-L	2.1E-11
Uranium Trioxide	ST-H	2.81E-06
	ST-L	2.9E-07
Vanadium Pentoxide	ST-H	1.26E-10
	ST-L	5.2E-11
Zinc Oxide	ST-H	3.33E-09
	ST-L	3.3E-09
Zirconium Oxide	ST-H	1.36E-06
	ST-L	5.7E-08
Fluoride	ST-H	2.71E-02
	ST-L	2.24E-02
Nitric Acid	ST-H	5.06E-03
	ST-L	4.18E-03
Barium Oxide	ST-H	4.17E-09
	ST-L	1.0E-09

Notes:
g/sec = Grams per second
In addition, routine and retrieval emissions from tank farms and evaporator would occur as shown in Table G.3.1.3.

Table G.3.1.9 Emission Rates for the Ex Situ No Separations Alternative - Construction Phase

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W	1.75E-03
	TF6W	1.75E-03
	TA1W	7.2E-03
	TA2W	3.8E-02
	TA3W	7.2E-03
	TA1E	7.2E-03
	TA2E	7.2E-03
	PROC	1.78E-01
Carbon Monoxide	TF5W	3.7E-02
	TF6W	3.7E-02
	TA1W	9.7E-02
	TA2W	5.10E-01
	TA3W	9.7E-02
	TA1E	9.7E-02
	TA2E	9.7E-02
	PROC	1.33E+02
Nitrogen Dioxide	TF5W	1.46E-01
	TF6W	1.46E-01
	TA1W	3.15E-01
	TA2W	1.66E+00
	TA3W	3.15E-01
	TA1E	3.15E-01
	TA2E	3.15E-01
	PROC	1.33E+01
PM-10	TF5W	1.03E-02
	TF6W	1.03E-02
	TA1W	7.4E-02
	TA2W	3.89E-01
	TA3W	7.4E-02
	TA1E	7.4E-02
	TA2E	7.4E-02
	PROC	5.57E+00
	BTCH	3.14E+00
Hazardous Air Pollutants		
Formaldehyde	TF5W	3.61E-05
	TF6W	3.61E-05
	TA1W	9.33E-05
	TA2W	4.89E-04
	TA3W	9.33E-05
	TA1E	9.33E-05
	TA2E	9.33E-05
	PROC	3.30E-03

Notes:
g/sec = Grams per second
Construction emissions for the vitrification and calcination options are the same.
Additional emissions from routine operation of tank farms and evaporator would occur as shown in Table G.3.1.2.

Table G.3.1.10 Emission Rates for the Ex Situ No Separations Alternative - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W, TF6W,	1.75E-03
	SMIN	1.37E+00
Carbon Monoxide	TF5W, TF6W,	3.70E-02
	SMIN	1.36E+01
Nitrogen Dioxide	TF5W, TF6W	1.46E-01
	SMIN (Vitrification)	9.18E-01
	SMIN (Calcination)	4.59E+00
PM-10	TF5W, TF6W	1.03E-02
Hazardous Air Pollutants		
Formaldehyde	TF5W, TF6W	3.61E-05
Chlorine	SMIN	3.10E-01
Arsenic Compounds	SMIN	4.14E-11
Beryllium Compounds	SMIN	8.42E-11
Cadmium Compounds	SMIN	3.89E-10
Cobalt Compounds	SMIN	3.67E-11
Chromium Compounds	SMIN	8.39E-09
Manganese Compounds	SMIN	7.36E-09
Lead Compounds	SMIN	1.19E-09
Antimony Compounds	SMIN	7.94E-11
Selenium Compounds	SMIN	1.23E-10
Hydrogen Chloride	SMIN	4.50E-02
Iodine	SMIN	2.0E-03
Ammonia	SMIN	1.2E-01
Silver Oxide	SMIN	1.52E-11
Boric Oxide	SMIN	1.36E-06
Calcium Oxide	SMIN	1.05E-07
Ferric Oxide	SMIN	4.06E-08
Magnesium Oxide.	SMIN	9.69E-08
Tellurium Trioxide	SMIN	1.11E-11
Uranium Trioxide	SMIN	5.67E-08
Vanadium Pentoxide	SMIN	2.75E-12
Zinc Oxide	SMIN	9.36E-11
Zirconium Oxide	SMIN	2.65E-08
Fluoride (as Hydrofluoric Acid)	SMIN	1.08E-01
Nitric Acid	SMIN	8.97E-03

Notes:
g/sec = Grams per second
Calcination emissions differ from vitrification only for nitrogen oxides.
Additional emissions from routine operations and retrieval operations from tank farms and evaporator would occur as shown in Table G.3.1.3.

Table G.3.1.11 Emission Rates for the Ex Situ Extensive Separations Alternative - Construction Phase

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W	1.75E-03
	TF6W	1.75E-03
	TA1W	7.2E-03
	TA2W	3.8E-02
	TA3W	7.2E-03
	TA1E	7.2E-03
	TA2E	7.2E-03
	PROC	0.2558
Carbon Monoxide	TF5W	3.7E-02
	TF6W	3.7E-02
	TA1W	9.7E-02
	TA2W	5.10E-01
	TA3W	9.7E-02
	TA1E	9.7E-02
	TA2E	9.7E-02
	PROC	191.74
Nitrogen Dioxide	TF5W	1.46E-01
	TF6W	1.46E-01
	TA1W	3.15E-01
	TA2W	1.66E+00
	TA3W	3.15E-01
	TA1E	3.15E-01
	TA2E	3.15E-01
	PROC	19.176
PM-10	TF5W	1.03E-02
	TF6W	1.03E-02
	TA1W	5.46E-02
	TA2W	2.78E-01
	TA3W	5.46E-02
	TA1E	5.46E-02
	TA2E	5.46E-02
	PROC	6.901
	BTCH	1.82E+00
Hazardous Air Pollutants		
Formaldehyde	TF5W	7.2E-05
	TF6W	7.2E-05
	TA1W	1.86E-04
	TA2W	9.74E-04
	TA3W	1.86E-04
	TA1E	1.86E-04
	TA2E	1.86E-04
	PROC	4.781E-03

Notes:
g/sec = Grams per second

Table G.3.1.12 Emission Rates for the Ex Situ Extensive Separations Alternative - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W, TF6W	1.75E-03
	ESEP	2.216
Carbon Monoxide	TF5W, TF6W	3.70E-02
	ESEP	8.105
Nitrogen Dioxide	TF5W, TF6W	1.46E-01
	ESEP	1.038
PM-10	TF5W, TF6W	1.03E-02
	ESEP	1.54E-05
Hazardous Air Pollutants		
Formaldehyde	TF5W, TF6W	3.61E-05
Chromium Compounds	ESEP	7.48E-05
Manganese Compounds	ESEP	1.64E-05
Nickle Compounds	ESEP	2.3E-06
Fluoride (as HF)	ESEP	2.10E-03
Nitric Acid	ESEP	3.61E-02
Hydrogen Peroxide	ESEP	4.67E-05
Formic Acid	ESEP	2.57E-03
Ammonia	ESEP	1.20E-01

Notes:
g/sec = Grams per second
Additional emissions from routine operations and retrieval operations would occur as shown in Table G.3.1.3.
Emission rates of all inorganic compounds are not given; however, negligible impacts similar to those predicted for the Ex Situ Intermediate Separations and Ex Situ No Separations alternatives are expected.

Table G.3.1.13 Emission Rates for the Ex Situ/In Situ Combination 1 and 2 Alternatives - Construction Phase

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W	8.7E-04
	TF6W	0.24
	TA1W	3.6E-03
	TA2W	1.9E-02
	TA3W	3.6E-03
	TA1E	3.6E-03
	TA2E	3.6E-03
	PROC	8.0E-02
Carbon Monoxide	TF5W	1.9E-02
	TF6W	5.2E-01
	TA1W	4.8E-02
	TA2W	2.5E-01
	TA3W	4.8E-02
	TA1E	4.8E-02
	TA2E	4.8E-02
	PROC	6.17E+01
Nitrogen Dioxide	TF5W	7.3E-02
	TF6W	1.19E+00
	TA1W	1.6E-01
	TA2W	8.3E-01
	TA3W	1.6E-01
	TA1E	1.6E-01
	TA2E	1.6E-01
	PROC	5.86E+00
PM-10	TF5W	5.2E-03
	TF6W	6.7E-01
	TA1W	3.7E-02
	TA2W	1.94E-01
	TA3W	3.7E-02
	TA1E	3.7E-02
	TA2E	3.7E-02
	PROC	3.54E+00
	BTCH	1.20E+00
Hazardous Air Pollutants		
Formaldehyde	TF5W	1.81E-05
	TF6W	2.08E-04
	TA1W	4.67E-05
	TA2W	2.45E-04
	TA3W	4.67E-05
	TA1E	4.67E-05
	TA2E	4.67E-05
	PROC	1.51E-03

Notes:
g/sec = Grams per second
Additional emissions from tank farms and evaporator would occur as shown in Table G.3.1.2.

Table G.3.1.14 Emission Rates for the Ex Situ/In Situ Combination 1 Alternative - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W, TF6W	8.7E-04
	ST-H	1.38E-02
	ST-L	3.78E-01
Carbon Monoxide	TF5W, TF6W	1.9E-02
	ST-H	6.07E-01
	ST-L	4.25E+00
Nitrogen Dioxide	TF5W, TF6W	7.3E-02
	ST-H	1.31E-02
	ST-L	0.257
PM-10	TF6W	5.2E-03
	TF5W	3.3E-02
	BTCH	1.7E-01
Hazardous Air Pollutants		
Formaldehyde Chlorine	TF5W, TF6W	1.81E-05
	ST-H	1.81E-05
	ST-L	1.81E-05
Arsenic Compounds	ST-H	9.2E-10
	ST-L	4.4E-10
Beryllium Compounds	ST-H	2.4E-11
	ST-L	3.2E-12
Cadmium Compounds	ST-H	8.8E-09
	ST-L	3.8E-09
Cobalt Compounds	ST-H	9.8E-10
	ST-L	1.1E-10
Chromium Compounds	ST-H	4.9E-08
	ST-L	2.9E-07
Manganese Compounds	ST-H	1.8E-07
	ST-L	3.3E-08
Lead Compounds	ST-H	3.1E-08
	ST-L	4.7E-09
Antimony Compounds	ST-H	2.2E-09
	ST-L	1.7E-10
Selenium Compounds	ST-H	2.7E-09
	ST-L	1.4E-09
Nickle Compounds	ST-H	1.8E-04
	ST-L	1.6E-09
Hydrogen Chloride	ST-H	5.8E-03
	ST-L	4.8E-03
Iodine	ST-H	6.0E-06
	ST-L	6.5E-04
Ammonia	ST-H	0.0
	ST-L	5.6E-02
Silver Oxide	ST-H	4.0E-10
	ST-L	5.5E-11

Table G.3.1.14 Emission Rates for the Ex Situ/In Situ Combination 1 Alternative - Operation Phase (cont'd)

Pollutant	Source	Emission Rates (g/sec)
Boric Oxide	ST-H	2.79E-09
	ST-L	1.5E-09
Calcium Oxide	ST-H	0
	ST-L	4.8E-06
Ferric Oxide	ST-H	1.1E-06
	ST-L	2.0E-08
Magnesium Oxide	ST-H	8.0E-09
	ST-L	4.8E-06
Tellurium Trioxide	ST-H	3.1E-10
	ST-L	1.0E-11
Uranium Trioxide	ST-H	1.4E-06
	ST-L	1.4E-07
Vanadium Pentoxide	ST-H	6.3E-11
	ST-L	2.6E-11
Zinc Oxide	ST-H	1.6E-09
	ST-L	1.6E-09
Zirconium Oxide	ST-H	6.8E-07
	ST-L	2.8E-08
Fluoride	ST-H	1.3E-02
	ST-L	1.1E-02
Nitric Acid	ST-H	2.5E-03
	ST-L	2.1E-03
Barium Oxide	ST-H	2.1E-09
	ST-L	5.0E-10

Notes:
g/sec = Grams per second
In addition, routine and retrieval emissions from tank farms and evaporator would occur as shown in Table 3.1.3.

Table G.3.1.15 Emission Rates for the Ex Situ/In Situ Combination 2 Alternative - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W, TF6W	3.5E-04
	ST-H	2.0E-03
	ST-L	2.6E-01
Carbon Monoxide	TF5W, TF6W	7.6E-03
	ST-H	9.0E-02
	ST-L	3.0E+00
Nitrogen Dioxide	TF5W, TF6W	2.9E-02
	ST-H	2.0E-03
	ST-L	1.8E-01
PM-10	TF6W	5.2E-03
	TF5W	1.3E-02
	BTCH	2.4E-01
Hazardous Air Pollutants		
Formaldehyde	TF5W, TF6W	7.2E-06
	ST-H	1.4E-10
Arsenic Compounds	ST-L	3.1.E-10
	ST-H	3.6E-12
Beryllium Compounds	ST-L	2.2E-12
	ST-H	1.3E-09
Cadmium Compounds	ST-L	2.7E-09
	ST-H	1.5E-10
Cobalt Compounds	ST-L	7.7E-11
	ST-H	7.5E-09
Chromium Compounds	ST-L	2.0E-07
	ST-H	3.7E-08
Manganese Compounds	ST-L	2.3E-08
	ST-H	4.6E-09
Lead Compounds	ST-L	3.3E-09
	ST-H	3.3E-10
Antimony Compounds	ST-L	1.2E-10
	ST-H	4.0E-10
Selenium Compounds	ST-L	1.0E-09
	ST-H	2.7E-05
Nickle Compounds	ST-L	1.1E-09
	ST-H	8.5E-04
Hydrogen Chloride	ST-L	3.4E-03
	ST-H	9.0E-07
Iodine	ST-L	4.6E-04
	ST-H	0.0
Ammonia	ST-L	3.9E-02
	ST-H	6.0E-11
Silver Oxide	ST-L	3.8E-11
	ST-H	4.2E-10
Boric Oxide	ST-L	1.1E-09

Table G.3.1.15 Emission Rates for the Ex Situ/In Situ Combination 2 Alternative - Operation Phase (cont'd)

Pollutant	Source	Emission Rates (g/sec)
Calcium	ST-H	0.0
	ST-L	6.7E-06
Ferric Oxide	ST-H	3.2E-07
	ST-L	2.8E-08
Magnesium Oxide	ST-H	2.3E-09
	ST-L	6.6E-06
Tellurium Trioxide	ST-H	1.0E-10
	ST-L	1.5E-11
Uranium Trioxide	ST-H	4.2E-07
	ST-L	2.0E-07
Vanadium Pentroxide	ST-H	1.9E-11
	ST-L	3.6E-11
Zinc Oxide	ST-H	5.0E-10
	ST-L	2.3E-09
Zirconium Oxide	ST-H	2.0E-07
	ST-L	4.0E-08
Fluoride	ST-H	4.0E-03
	ST-L	1.6E-02
Nitric Acid	ST-H	7.5E-04
	ST-L	2.9E-03
Barium Oxide	ST-H	6.5E-10
	ST-L	7.0E-10

Notes:
g/sec = Grams per second
In addition, routine and retrieval emissions from tank farms and evaporator would occur as shown in Table G.3.1.3.

Table G.3.1.16 Emission Rates for the Phased Implementation Alternative Phase 1 - Construction Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	FCPI	1.93E-01
Carbon Monoxide	FCPI	46.2
Nitrogen Dioxide	FCPI	8.59E+00
PM-10	FCPI	6.8E+00
	BTCH	3.15E+00
Hazardous Air Pollutants		
Formaldehyde	FCPI	3.50E-05

Notes:
g/sec = Grams per second
Routine emissions from tank farms and evaporator would occur as shown in Table G.3.1.2.

Table G.3.1.17 Emission Rates for the Phased Implementation Alternative Phase 1 - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	SSPI	1.358E-01
	NSPI	2.338E-01
Carbon Monoxide	SSPI	2.27E+00
	NSPI	3.78E+00
Nitrogen Dioxide	SSPI	9.589E-02
	NSPI	1.613E-01
PM-10	SSPI	6.215E-03
	NSPI	1.287E-02
Hazardous Air Pollutants		
Chromium Compounds	SSPI	4.78E-08
	NSPI	8.88E-08
Manganese Compounds	SSPI	4.62E-09
	NSPI	3.70E-08
Nickle Compounds	SSPI	1.33E-09
	NSPI	3.70E-09
Fluoride (as HF)	SSPI	3.92E-02
	NSPI	6.69E-02
Nitric Acid	SSPI	8.88E-03
	NSPI	2.37E-02
Ammonia	SSPI	1.08E-02
	NSPI	2.62E-02
Hydrogen Chloride	SSPI	1.07E-03
	NSPI	1.79E-03

Notes:
g/sec = Grams per second
Additional emissions from routine operations and retrieval operations would occur as shown in Table G.3.1.2.
Emission rates of all inorganic compounds are not given; however, negligible impacts similar to those predicted for the Ex Situ Intermediate Separations and Ex Situ No Separations alternatives are expected.

Table G.3.1.18 Emission Rates for the Phased Implementation Alternative Phase 2 - Construction Phase

Pollutant	Source	Emission Rate (g/sec)
Criteria Pollutants		
Sulfur Oxides	TF5W	1.77E-03
	TF6W	1.77E-03
	TA1W	7.18E-03
	TA2W	3.77E-02
	TA3W	7.18E-03
	TA1E	7.18E-03
	TA2E	7.18E-03
	PROC	2.34E-01
Carbon Monoxide	TF5W	3.72E-02
	TF6W	3.72E-02
	TA1W	9.69E-02
	TA2W	0.510
	TA3W	9.69E-02
	TA1E	9.69E-02
	TA2E	9.69E-02
	PROC	1.76E+02
Nitrogen Dioxide	TF5W	1.46E-01
	TF6W	1.46E-01
	TA1W	3.15E-01
	TA2W	1.66
	TA3W	3.15E-01
	TA1E	3.15E-01
	TA2E	3.15E-01
	PROC	1.76E+02
PM-10	TF5W	1.03E-02
	TF6W	1.03E-02
	TA1W	7.40E-02
	TA2W	3.88E-01
	TA3W	7.40E-02
	TA1E	7.40E-02
	TA2E	7.40E-02
	PROC	7.34E+00
	BTCH	3.17E+00
Hazardous Air Pollutants		
Formaldehyde	TF5W	3.61e-05
	TF6W	3.61E-05
	TA1W	9.33E-05
	TA2W	4.89E-04
	TA3W	9.33E-05
	TA1E	9.33E-05
	TA2E	9.33E-05
	PROC	4.28E-03

Notes:
g/sec = Grams per second
Routine emissions from tank farms and evaporator would occur as shown in Table G.3.1.2.

Table G.3.1.19 Emission Rates for the Phased Implementation Alternative Phase 2 - Operation Phase

Pollutant	Source	Emission Rates (g/sec)
Criteria Pollutants		
Sulfur Oxides	SSPI	1.36E-01
	NSPI	2.34E-01
	TF5W, TF6W	1.77E-03
	ST-H	1.65E-02
	ST-L	6.99E-01
Carbon Monoxide	SSPI	2.27E+00
	NSPI	3.78E+00
	TF5W, TF6W	3.72E-02
	ST-H	7.28E-01
	ST-L	7.86E+00
Nitrogen Dioxide	SSPI	9.59E-02
	NSPI	1.61E-01
	TF5W, TF6W	1.46E-01
	ST-H	1.57E-02
	ST-L	4.75E-01
PM-10	SSPI	6.22E-03
	NSPI	1.29E-02
	TF5W, TF6W	1.03E-02
Hazardous Air Pollutants		
Formaldehyde	TF5W, TF6W	3.61E-05
Arsenic Compounds	ST-H	1.10E-09
	ST-L	8.14E-10
Beryllium Compounds	ST-H	2.80E-11
	ST-L	5.83E-12
Cadmium Compounds	ST-H	1.05E-08
	ST-L	7.03E-09
Cobalt Compounds	ST-H	1.18E-09
	ST-L	2.04E-10
Chromium Compounds	SSPI	4.79E-08
	NSPI	8.88E-08
	ST-H	5.92E-08
	ST-L	5.27E-07
Manganese Compounds	SSPI	4.62E-09
	NSPI	3.70E-08
	ST-H	2.10E-07
	ST-L	6.01E-08
Lead Compounds	ST-H	3.71E-08
	ST-L	8.70E-09
Antimony Compounds	ST-H	2.65E-09
	ST-L	2.13E-10
Selenium Compounds	ST-H	3.23E-09
	ST-L	2.50E-09
	NSPI	3.70E-09
	ST-H	2.1E-04
	ST-L	2.96E-09

Table G.3.1.19 Emission Rates for the Phased Implementation Alternative Phase 2 - Operation Phase (cont'd)

Pollutant	Source	Emission Rates (g/sec)
Hydrogen Chloride	SSPI	1.07E-03
	NSPI	1.79E-03
	ST-H	6.96E-03
	ST-L	8.88E-03
Iodine	ST-H	7.26E-06
	ST-L	1.29E-03
Ammonia	SSPI	1.08E-02
	NSPI	2.62E-02
	ST-H	0.000
	ST-L	1.04E-01
Silver Oxide	ST-H	4.82E-10
	ST-L	1.02E-10
Boric Oxide	ST-H	3.19E-06
	ST-L	1.23E-04
Calcium Oxide	ST-H	0
	ST-L	8.88E-06
Ferric Oxide	ST-H	1.27E-06
	ST-L	3.70E-08
Magnesium Oxide	ST-H	9.48E-09
	ST-L	8.79E-06
Tellurium Trioxide	ST-H	3.71E-10
	ST-L	1.94E-11
Uranium Trioxide	ST-H	1.69E-06
	ST-L	2.68E-07
Vanadium Pentoxide	ST-H	7.56E-11
	ST-L	4.81E-11
Zinc Oxide	ST-H	2.00E-09
	ST-L	3.05E-09
Zirconium Oxide	ST-H	8.16E-07
	ST-L	5.27E-08
Fluoride	SSPI	3.92E-02
	NSPI	6.69E-02
	ST-H	1.63E-02
	ST-L	2.07E-02
Nitric Acid	SSPI	8.88E-03
	NSPI	2.37E-02
	ST-H	3.04E-03
	ST-L	3.87E-03
Barium Oxide	ST-H	2.50E-09
	ST-L	9.25E-10

Notes:
g/sec = Grams per second
In addition, routine and retrieval emissions from tank farms and evaporator would occur as shown in Table G.3.1.3.

Table G.3.1.20 Radionuclide Emission Rates for the No Action Alternative (Tank Waste)

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	WESF	2.6E-06
I-129	TF6E	2.3E-05	TF7E	2.3E-05	--	--
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.85E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.1E-09	TF6W	0.00
	EVAP [1]	1.4E-04	WESF	2.4E-07	--	--
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.1E-06
	TF6W [2]	2.4E-07	EVAP [2]	8.0E-05	WESF	5.1E-06

Notes:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci/yr = Curie per year
-- Indicates no additional sources or emission rates.

Table G.3.1.21 Radionuclide Emission Rates for the Long-Term Management Alternative Phase 1

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	TF6W	8.0E-05
	WESF	2.6E-06	--	--	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF6W	6.9E-05
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.1E-09	TF6W [1]	4.5E-08
	EVAP [1]	1.4E-04	WESF	2.4E-07	--	--
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.1E-06
	TF6W	1.2E-05	EVAP [2]	8.0E-05	WESF	5.1E-06

Notes:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci/yr = Curie per year
-- Indicates no additional sources or emission rates.

Table G.3.1.22 Radionuclide Emission Rates for the Long-Term Management Alternative Phase 2

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Cs-137	TFIE	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF8E	2.60E-08	TF9E	3.20E-08	TF2W	8.00E-09
	TF4W	8.40E-08	PROC	5.71E-05	--	--
I-129	PROC	4.95E-05	--	--	--	--
Pu-239	PROC	2.23E-08	EVAP	2.10E-05	--	--
Sr-90	TFIE	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF8E	7.40E-07	TF9E	9.10E-07
	TF2W	1.10E-07	TF4W	2.44E-06	TF5W	2.41E-06
	TF6W	2.40E-07	PROC	9.96E-06	EVAP	8.00E-05

Notes:
Ci/yr = Curie per year
-- Indicates no additional sources or emission rates.

Table G.3.1.23 Radionuclide Emission Rates for the In Situ Fill and Cap Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF5W	0.00	TF6W	0.00	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.20E-08	TF6W	4.24E-05
	WESF	2.6E-06	--	--	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF5W	0.00
	TF6W	3.7E-05	--	--	--	--
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.10E-09	TF6W [1]	2.40E-08
	EVAP [1]	1.4E-04	WESF	2.4E-07	--	--
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.10E-06	TF8E	7.40E-07	TF9E [1]	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.11E-06
	TF6W [2]	5.00E-06	EVAP [2]	8.0E-05	WESF	5.1E-06

Notes:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci/yr = Curie per year
-- Indicates no additional sources or emission rates.

Table G.3.1.24 Radionuclide Emission Rates for the In Situ Vitrification Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF6W	0.00	IS6W	2.0E-07	--	--
C-14	IS6W	1.1E+03	--	--	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	IS6W	7.0E-05
	WESF	2.6E-06	--	--	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	IS6W	7.6E+00
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.1E-09	TF6W	0.00
	IS6W	6.6E-08	EVAP	1.4E-04	WESF	2.4E-07
Ru-106	IS6W	7.6E-14	--	--	--	--
Sm-151	IS6W	1.3E-06	--	--	--	--
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.1E-06
	TF6W [2]	9.1E-08	IS6W	1.4E-04	EVAP [2]	8.0E-05
	WESF	5.1E-06	--	--	--	--
Zr-93	IS6W	7.8E-09	--	--	--	--

Notes:
[1] Alpha assumed to be Pu-239.
[2] Beta assumed to be Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.

Table G.3.1.25 Radionuclide Emission Rates for the Ex Situ Intermediate Separations Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF6W	0.00	STH	2.1E-03	--	--
C-14	STL	3.1E+02	--	--	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	TF6W	8.1E-05
	STH	1.5E-00	WESF	2.6E-06	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF6W	6.9E-05
	STL	2.2E+00	--	--	--	--
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.1E-09	TF6W [1]	4.50E-08
	STH	2.3E-03	EVAP [1]	1.4E-04	WESF	2.4E-07
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.1E-06
	TF6W [2]	9.33E-06	STH	1.4E-04	EVAP [2]	8.0E-05
	WESF	5.1E-06	--	--	--	--
Tc-99	STH	1.3E-04	--	--	--	--

Note:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.
Emission rates shown are for the operational phase of the alternative. Emission rates for the construction phase are the same as those shown for the No Action alternative (tank waste) (Table G.3.1.19). No radionuclides will be emitted from the construction areas.

Table G.3.1.26 Radionuclide Emission Rates for the Ex Situ No Separations Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF6W	0.00	SMIN	3.8E-03	--	--
C-14	SMIN	3.8E+02	--	--	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	TF6W	8.10E-05
	SMIN	2.5E-00	WESF	2.6E-06	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF6W	6.9E-05
	SMIN	2.7E+00	--	--	--	--
Pu-239	TF6E	2.9E-09 [1]	TF7E	2.9E-09 [1]	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W	8.1E-09	TF6W	4.50E-08
	SMIN	3.9E-03	EVAP	1.4E-04	WESF	2.4E-07
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.1E-06
	TF6W [2]	9.33E-06	SMIN	3.9E-00	EVAP [2]	8.0E-05
	WESF	5.1E-06	--	--	--	--
Tc-99	SMIN	1.2E-03	--	--	--	--

Note:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.
Emission rates shown are for the operational phase of the alternative. Emission rates for the construction phase are the same as those shown for the No Action alternative (tank waste) (Table G.3.1.19). No radionuclides will be emitted from the construction areas.

Table G.3.1.27 Radionuclide Emission Rates for the Ex Situ Extensive Separations Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF6W	0.00	ESEP	2.7E-03	--	--
C-14	ESEP	3.14+02	--	--	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	TF6W	8.10E-05
	ESEP	8.9E-01	WESF	2.6E-06	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF6W	6.9E-05
	ESEP	2.2E+00	--	--	--	--
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.1E-09	TF6W [1]	4.50E-08
	EVAP [1]	1.4E-04	ESEP [1]	8.4E-04	WESF [1]	2.4E-07
Ru-106	ESEP	1.0E-09	--	--	--	--
Sm-151	ESEP	1.7E-02	--	--	--	--
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E+06	TF5W [2]	3.1E-06
	TF6W [2]	9.33E-06	EVAP [2]	8.0E-05	ESEP	1.4E-00
	WESF	5.1E-06	--	--	--	--
Tc-99	ESEP	8.4E-04	--	--	--	--
Zr-93	ESEP	1.1E-04	--	--	--	--

Note:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.
Emission rates shown are for the operational phase of the alternative. Emission rates for the construction phase are the same as those shown for the No Action alternative (tank waste) (Table G.3.1.19). No radionuclides will be emitted from the construction areas.

Table G.3.1.28 Radionuclide Emission Rates for the Ex Situ/In Situ Combination 1 Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF5W	0.00	TF6W	0.00	STH	1.9E-03
C-14	STL	2.8E+02	--	--	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	4.24E-05	TF6W	4.24E-05
	STH	1.3E-00	WESF	2.6E-06	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF5W	3.68E-05
	TF6W	3.68E-05	STL	19E+00	--	--
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	2.40E-08	TF6W [1]	2.40E-08
	STH	2.1E-03	EVAP [1]	1.4E-04	WESF	2.4E-07
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	4.98E-06
	TF6W [2]	4.98E-06	STH	1.3E-4	EVAP [2]	8.0E-05
	WESF	5.1E-06	--	--	--	--
Tc-99	STH	1.2E-04	--	--	--	--

Note:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.
Emission rates shown are for the operational phase of the alternative. Emission rates for the construction phase are the same as those shown for the No Action alternative (tank waste) (Table G.3.1.19). No radionuclides will be emitted from the construction areas.

Table G.3.1.29 Radionuclide Emission Rates for the Ex Situ/In Situ Combination 2 Alternative

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF5W	0.00	TF6W	0.00	STH	5.7E-04
C-14	STL	2.5E+02	--	--	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	4.24E-05	TF6W	4.24E-05
	STH	3.9E-01	WESF	2.6E-06	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF5W	3.68E-05
	TF6W	3.68E-05	STL	1.8	--	--
Pu-239	TF6E [1]	2.9E-09	TF7E [1]	2.9E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	2.40E-08	TF6W [1]	2.40E-08
	STH	6.3E-04	EVAP [1]	1.4E-04	WESF	2.4E-07
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	4.98E-06
	TF6W [2]	4.98E-06	STH	6.3E-01	EVAP [2]	8.0E-05
	WESF	5.1E-06	--	--	--	--
Tc-99	STH	3.6E-05	--	--	--	--

Note:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.
Emission rates shown are for the operational phase of the alternative. Emission rates for the construction phase are the same as those shown for the No Action alternative (tank waste) (Table G.3.1.19). No radionuclides will be emitted from the construction areas.

Table G.3.1.30 Radionuclide Emission Rates for the Phased Implementation Alternative Phase 1

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	TF1W	0.00	TF2W	0.00	TF4W	0.00
	TF6W	0.00	SSPI	3.26E-07	NSPI	2.40E-04
C-14	SSPI	4.0E+01	NSPI	7.0E+01	--	--
Cs-137	TF1E	2.60E-08	TF2E	2.33E-07	TF3E	1.00E-07
	TF6E	2.65E-05	TF7E	2.65E-05	TF8E	2.60E-08
	TF9E	3.20E-08	TF10E	2.8E-08	TF2W	8.00E-09
	TF4W	8.40E-08	TF5W	8.2E-08	WESF	2.60E-06
	SSPI	1.87E-03	NSPI	1.73E-01	--	--
I-129	TF6E	2.30E-05	TF7E	2.30E-05	SSP1	2.2E-01
	NSPI	2.2E-01	--	--	--	--
Pu-239	TF6E [1]	2.85E-09	TF7E [1]	2.85E-09	TF10E [1]	1.5E-08
	TF1W	0.00	TF2W	0.00	TF3W	0.00
	TF4W	0.00	TF5W [1]	8.1E-09	TF6W	0.00
	EVAP [1]	1.4E-04	WESF	2.4E-07	SSPI	7.90E-08
	NSPI	2.63E-04	--	--	--	--
Sr-90	TF1E	2.60E-08	TF2E	6.00E-09	TF3E	2.71E-06
	TF4E	2.80E-08	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	7.40E-07	TF9E	9.10E-07
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	1.10E-07
	TF3W	0.00	TF4W	2.44E-06	TF5W [2]	3.1E-06
	TF6W [2]	9.1E-08	EVAP [2]	8.0E-05	WESF	5.1E-06
	SSPI	7.20E-05	NSPI	2.67E-01	--	--
Tc-99	SSPI	9.83E-07	NSPI	1.65E-05	--	--

Notes:
[1] Alpha assumed as Pu-239.
[2] Beta assumed as Sr-90.
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.

Table G.3.1.31 Radionuclide Emission Rates for the Phased Implementation Alternative Phase 2

Radionuclide	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)	Source	Emission Rate (Ci/yr)
Am-241	SSPI	3.26E-07	NSPI	2.40E-04	--	--
	TF1W	7.6E-08	TF2W	4.0E-04	TF4W	1.1E-03
	TF6W	3.2E-03	STH	1.25E-03	--	--
C-14	STL	2.60E+02	SSPI	4.0E+01	NSPI	7.0E+01
Cs-137	SSPI	1.87E-03	NSPI	1.73E-01	--	--
	TF1E	2.4E-05	TF2E	2.1E-04	TF3E	9.1E-05
	TF6E	2.7E-05	TF7E	2.7E-05	TF8E	2.4E-05
	TF9E	2.9E-05	TF10E	2.8E-08	TF2W	4.3E-04
	TF4W	1.0E-03	TF5W	8.2E-08	TF6W	3.1E-03
	STH	8.88E-01	WESF	2.6E-06	--	--
I-129	TF6E	2.3E-05	TF7E	2.3E-05	TF6W	6.9E-05
	STL	7.79E-01	--	--	--	--
Pu-239	SSPI	7.90E-08	NSPI	2.63E-04	--	--
	TF6E	2.9E-09	TF7E	2.9E-09	TF10E	1.5E-08
	TF1W	2.3E-08	TF2W	2.3E-04	TF3W	7.1E-05
	TF4W	1.0E-03	TF5W	8.1E-09	TF6W	3.0E-03
	STH	1.38E-03	EVAP	1.4E-04	WESF	2.4E-07
Sr-90	SSPI	7.20E-05	NSPI	2.67E-01	--	--
	TF1E	2.4E-05	TF2E	5.4E-06	TF3E	2.5E-03
	TF4E	2.5E-05	TF5E	1.2E-07	TF6E	4.1E-06
	TF7E	4.1E-06	TF8E	6.7E-04	TF9E	8.3E-04
	TF10E	1.6E-07	TF11E	6.6E-08	TF2W	2.4E-04
	TF3W	7.0E-02	TF4W	1.1E-03	TF5W	3.1E-06
	TF6W	2.1E-01	IS6W	1.4E-04	EVAP	8.0E-05
	WESF	5.1E-06	STH	1.39E+00	--	--
Tc-99	STH	7.80E-05	SSPI	9.83E-07	--	--

Note:
Ci\yr = Curie per year
-- Indicates no additional sources or emission rates.
Emission rates shown are for the operational phase of the alternative. Emission rates for the construction phase are the same as those shown for the No Action alternative (tank waste) (Table G.3.1.19). No radionuclides will be emitted from the construction areas.

Table G.3.1.32 Matrix of Wind Speed and Stability Classes

Wind Speed and Stability Class Combinations Used for the ISCLT2 Model													
Stability Class	10-Meter Wind Speed (Meters Per Second)												
	1	1.5	2	2.5	3	3.5	4	4.5	5	8	10	15	20
A	*	*	*	*	*								
B	*	*	*	*	*	*	*	*	*				
C	*	*	*	*	*	*	*	*	*	*	*		
D	*	*	*	*	*	*	*	*	*	*	*	*	*
E	*	*	*	*	*	*	*	*	*				
F	*	*	*	*	*	*	*						

Table G.3.1.33 Stability Array for Year 1989

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
N	A	4.10E-03	2.30E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	A	3.20E-03	4.00E-04	6.00E-04	2.00E-04	0.00E+00	0.00E+00
NE	A	3.30E-03	6.00E-04	4.00E-04	2.00E-04	0.00E+00	0.00E+00
ENE	A	3.60E-03	4.00E-04	1.00E-04	2.00E-04	0.00E+00	0.00E+00
E	A	4.00E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	A	1.20E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	A	2.20E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	A	7.00E-04	0.00E+00	4.00E-04	0.00E+00	0.00E+00	0.00E+00
S	A	1.20E-03	1.00E-04	0.00E+00	1.00E-04	0.00E+00	0.00E+00
SSW	A	5.00E-04	4.00E-04	4.00E-04	5.00E-04	0.00E+00	0.00E+00
SW	A	4.00E-04	5.00E-04	5.00E-04	7.00E-04	0.00E+00	0.00E+00
WSW	A	2.00E-04	5.00E-04	7.00E-04	7.00E-04	1.00E-04	0.00E+00
W	A	1.20E-03	6.00E-04	6.00E-04	7.00E-04	0.00E+00	0.00E+00
WNW	A	1.50E-03	1.80E-03	1.00E-04	2.00E-04	0.00E+00	0.00E+00
NW	A	1.30E-03	5.00E-03	1.50E-03	1.10E-03	4.00E-04	0.00E+00
NNW	A	1.50E-03	2.80E-03	1.00E-04	4.00E-04	0.00E+00	0.00E+00
N	B	2.20E-03	1.10E-03	2.00E-04	0.00E+00	1.00E-04	0.00E+00
NNE	B	7.00E-04	6.00E-04	6.00E-04	4.00E-04	0.00E+00	0.00E+00
NE	B	9.00E-04	1.00E-04	4.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	B	7.00E-04	4.00E-04	1.00E-04	0.00E+00	1.00E-04	0.00E+00
E	B	7.00E-04	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	B	6.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	B	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	B	5.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S	B	2.00E-04	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSW	B	2.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04
SW	B	4.00E-04	4.00E-04	7.00E-04	2.00E-04	1.00E-04	0.00E+00
WSW	B	2.00E-04	2.00E-04	5.00E-04	1.40E-03	1.00E-04	0.00E+00
W	B	4.00E-04	4.00E-04	6.00E-04	2.00E-04	1.00E-04	0.00E+00
WNW	B	9.00E-04	1.10E-03	2.00E-04	2.00E-04	0.00E+00	0.00E+00
NW	B	6.00E-04	4.00E-03	1.50E-03	8.00E-04	1.00E-04	0.00E+00
NNW	B	1.20E-03	1.50E-03	1.30E-03	2.00E-04	0.00E+00	0.00E+00
N	C	9.00E-04	8.00E-04	5.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	C	1.10E-03	1.20E-03	7.00E-04	1.00E-04	1.00E-04	0.00E+00

Table G.3.1.33 Stability Array for Year 1989 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
NE	C	1.10E-03	9.00E-04	5.00E-04	1.00E-04	0.00E+00	0.00E+00
ENE	C	7.00E-04	1.00E-04	0.00E+00	1.00E-04	0.00E+00	0.00E+00
E	C	6.00E-04	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	C	1.20E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	C	1.50E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+0
SSE	C	1.20E-03	5.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
S	C	8.00E-04	1.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	C	6.00E-04	9.00E-04	4.00E-04	1.00E-04	1.00E-04	0.00E+00
SW	C	6.00E-04	6.00E-04	1.10E-03	1.00E-04	5.00E-04	0.00E+00
WSW	C	7.00E-04	5.00E-04	1.80E-03	1.10E-03	5.00E-04	0.00E+00
W	C	1.20E-03	5.00E-04	1.10E-03	2.00E-04	1.00E-04	0.00E+00
WNW	C	1.40E-03	9.00E-04	2.00E-04	1.00E-04	0.00E+00	0.00E+00
NW	C	1.10E-03	2.80E-03	1.80E-03	2.00E-04	1.00E-04	0.00E+00
NNW	C	1.80E-03	1.30E-03	5.00E-04	1.00E-04	0.00E+00	0.00E+00
N	D	1.55E-02	1.37E-02	4.00E-03	5.00E-04	0.00E+00	0.00E+00
NNE	D	1.08E-02	7.40E-03	2.00E-03	1.10E-03	2.00E-04	0.00E+00
NE	D	1.08E-02	3.50E-03	1.30E-03	1.00E-04	0.00E+00	0.00E+00
ENE	D	7.70E-03	2.20E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
E	D	1.22E-02	3.50E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	D	6.60E-03	2.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	D	7.90E-03	2.50E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	D	5.20E-03	2.70E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
S	D	7.50E-03	2.50E-03	1.20E-03	5.00E-04	0.00E+00	0.00E+00
SSW	D	4.20E-03	3.90E-03	2.20E-03	1.20E-03	9.00E-04	0.00E+00
SW	D	5.50E-03	2.80E-03	3.20E-03	4.10E-03	2.60E-03	4.00E-04
WSW	D	3.30E-03	5.20E-03	5.60E-03	5.00E-03	1.30E-03	1.00E-04
W	D	7.10E-03	8.10E-03	3.70E-03	1.90E-03	4.00E-04	0.00E+00
WNW	D	5.70E-03	7.40E-03	4.00E-03	1.20E-03	1.00E-04	0.00E+00
NW	D	8.60E-03	1.39E-02	9.60E-03	4.00E-03	1.10E-03	0.00E+00
NNW	D	9.10E-03	1.38E-02	3.70E-03	1.10E-03	0.00E+00	0.00E+00
N	E	8.10E-03	4.20E-03	1.20E-03	2.00E-04	0.00E+00	0.00E+00
NNE	E	4.20E-03	1.30E-03	1.40E-03	3.70E-03	1.10E-03	0.00E+00
NE	E	2.60E-03	6.00E-04	8.00E-04	1.10E-03	4.00E-04	0.00E+00
ENE	E	3.30E-03	9.00E-04	4.00E-04	1.00E-04	0.00E+00	0.00E+00

Table G.3.1.33 Stability Array for Year 1989 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
E	E	5.30E-03	2.60E-03	0.00E+00	1.00E-04	0.00E+00	0.00E+00
ESE	E	4.10E-03	1.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	E	5.00E-03	3.00E-03	7.00E-04	1.00E-04	0.00E+00	0.00E+00
SSE	E	5.70E-03	3.70E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00
S	E	6.70E-03	4.90E-03	1.60E-03	6.00E-04	2.00E-04	0.00E+00
SSW	E	3.20E-03	3.30E-03	1.50E-03	7.00E-04	5.00E-04	0.00E+00
SW	E	6.00E-03	4.20E-03	4.10E-03	5.90E-03	1.10E-03	0.00E+00
WSW	E	4.90E-03	7.30E-03	8.10E-03	2.90E-03	6.00E-04	0.00E+00
W	E	1.07E-02	2.01E-02	1.39E-02	2.30E-03	2.00E-04	0.00E+00
WNW	E	8.40E-03	1.97E-02	1.97E-02	7.50E-03	1.00E-04	0.00E+00
NW	E	7.00E-03	1.63E-02	1.76E-02	9.40E-03	9.00E-04	0.00E+00
NNW	E	8.10E-03	7.60E-03	1.60E-03	2.00E-04	0.00E+00	0.00E+00
N	F	5.70E-03	2.20E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NNE	F	3.00E-03	9.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
NE	F	2.10E-03	5.00E-04	5.00E-04	1.00E-04	0.00E+00	0.00E+00
ENE	F	2.10E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	F	4.10E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	F	4.10E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	F	3.60E-03	4.80E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	F	4.10E-03	6.10E-03	4.00E-04	2.00E-04	0.00E+00	0.00E+00
S	F	8.00E-03	6.30E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	F	5.50E-03	4.90E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	F	6.70E-03	7.30E-03	1.30E-03	0.00E+00	0.00E+00	0.00E+00
WSW	F	5.90E-03	1.86E-02	2.00E-03	1.00E-04	0.00E+00	0.00E+00
W	F	1.02E-02	3.51E-02	3.90E-03	0.00E+00	0.00E+00	0.00E+00
WNW	F	8.10E-03	2.57E-02	3.60E-03	0.00E+00	0.00E+00	0.00E+00
NW	F	5.90E-03	2.19E-02	4.70E-03	0.00E+00	0.00E+00	0.00E+00
NNW	F	6.00E-03	8.40E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00

Notes:
Dir = wind direction
Stab = stability class
ws1 = wind speed category 1 (1.50 m/sec)
ws2 = wind speed category 2 (2.50 m/sec)
ws3 = wind speed category 3 (4.30 m/sec)
ws4 = wind speed category 4 (6.80 m/sec)
ws5 = wind speed category 5 (9.50 m/sec)
ws6 = wind speed category 6 (12.50 m/sec)

Table G.3.1.34 Stability Array for Year 1990

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
N	A	1.40E-03	1.40E-03	8.00E-04	8.00E-04	0.00E+00	0.00E+00
NNE	A	8.00E-04	5.00E-04	1.00E-04	6.00E-04	0.00E+00	0.00E+00
NE	A	1.20E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	A	5.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	A	8.00E-04	1.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	A	1.40E-03	1.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	A	1.20E-03	1.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	A	4.00E-04	9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S	A	7.00E-04	2.00E-04	1.00E-04	6.00E-04	0.00E+00	0.00E+00
SSW	A	1.00E-04	4.00E-04	9.00E-04	5.00E-04	5.00E-04	0.00E+00
SW	A	4.00E-04	1.00E-04	6.00E-04	1.40E-03	2.20E-03	1.30E-03
WSW	A	1.00E-04	4.00E-04	4.00E-04	2.10E-03	9.00E-04	6.00E-04
W	A	7.00E-04	2.00E-04	1.50E-03	1.30E-03	6.00E-04	0.00E+00
WNW	A	0.00E+00	5.00E-04	1.30E-03	8.00E-04	2.00E-04	0.00E+00
NW	A	0.00E+00	2.20E-03	3.40E-03	2.50E-03	5.00E-04	0.00E+00
NNW	A	4.00E-04	1.80E-03	1.80E-03	7.00E-04	0.00E+00	0.00E+00
N	B	9.00E-04	1.30E-03	7.00E-04	2.00E-04	1.00E-04	0.00E+00
NNE	B	8.00E-04	6.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
NE	B	7.00E-04	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	B	5.00E-04	1.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
E	B	1.10E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	B	5.00E-04	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	B	7.00E-04	5.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	B	4.00E-04	1.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
S	B	1.00E-04	4.00E-04	1.00E-04	2.00E-04	1.00E-04	0.00E+00
SSW	B	1.00E-04	1.00E-04	4.00E-04	2.00E-04	1.00E-04	0.00E+00
SW	B	2.00E-04	4.00E-04	8.00E-04	1.10E-03	5.00E-04	5.00E-04
WSW	B	0.00E+00	0.00E+00	5.00E-04	9.00E-04	1.30E-03	1.00E-04
W	B	0.00E+00	1.00E-04	5.00E-04	2.00E-04	0.00E+00	2.00E-04
WNW	B	1.00E-04	4.00E-04	1.00E-04	8.00E-04	0.00E+00	0.00E+00
NW	B	5.00E-04	4.00E-04	1.90E-03	1.60E-03	2.00E-04	0.00E+00
NNW	B	2.00E-04	7.00E-04	5.00E-04	2.00E-04	0.00E+00	0.00E+00
N	C	2.20E-03	3.20E-03	7.00E-04	7.00E-04	1.00E-04	0.00E+00
NNE	C	1.80E-03	1.80E-03	4.00E-04	1.00E-04	0.00E+00	0.00E+00

Table G.3.1.34 Stability Array for Year 1990 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
NE	C	1.30E-03	7.00E-04	0.00E+00	5.00E-04	0.00E+00	0.00E+00
ENE	C	9.00E-04	1.10E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
E	C	1.40E-03	9.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	C	1.60E-03	1.10E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	C	1.10E-03	1.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	C	1.00E-04	5.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
S	C	5.00E-04	7.00E-04	5.00E-04	6.00E-04	1.00E-04	0.00E+00
SSW	C	4.00E-04	6.00E-04	5.00E-04	5.00E-04	4.00E-04	0.00E+00
SW	C	4.00E-04	0.00E+00	1.10E-03	1.20E-03	7.00E-04	7.00E-04
WSW	C	1.00E-04	4.00E-04	1.20E-03	1.40E-03	1.00E-04	1.00E-04
W	C	0.00E+00	1.00E-04	5.00E-04	5.00E-04	2.00E-04	4.00E-04
WNW	C	4.00E-04	4.00E-04	5.00E-04	5.00E-04	0.00E+00	0.00E+00
NW	C	4.00E-04	1.20E-03	1.90E-03	1.50E-03	2.00E-04	0.00E+00
NNW	C	8.00E-04	1.90E-03	4.00E-04	2.00E-04	0.00E+00	0.00E+00
N	D	1.08E-02	1.58E-02	3.00E-03	1.60E-03	2.00E-04	4.00E-04
NNE	D	8.10E-03	9.20E-03	1.30E-03	5.00E-04	4.00E-04	0.00E+00
NE	D	6.70E-03	6.10E-03	5.00E-04	4.00E-04	4.00E-04	0.00E+00
ENE	D	6.20E-03	3.90E-03	9.00E-04	2.00E-04	0.00E+00	0.00E+00
E	D	7.80E-03	6.20E-03	9.00E-04	1.00E-04	0.00E+00	0.00E+00
ESE	D	5.10E-03	4.70E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	D	6.40E-03	6.00E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	D	3.20E-03	4.30E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00
S	D	4.80E-03	3.00E-03	1.30E-03	8.00E-04	2.00E-04	1.00E-04
SSW	D	3.00E-03	3.40E-03	1.90E-03	2.60E-03	2.30E-03	2.30E-03
SW	D	3.20E-03	5.10E-03	3.70E-03	6.20E-03	4.20E-03	2.60E-03
WSW	D	2.90E-03	5.40E-03	8.60E-03	5.80E-03	2.50E-03	1.30E-03
W	D	4.60E-03	7.20E-03	7.80E-03	6.10E-03	6.00E-04	1.20E-03
WNW	D	3.30E-03	5.50E-03	4.00E-03	2.80E-03	5.00E-04	0.00E+00
NW	D	4.20E-03	1.27E-02	1.16E-02	6.80E-03	2.30E-03	1.00E-04
NNW	D	7.20E-03	1.46E-02	5.50E-03	1.30E-03	2.00E-04	0.00E+00
N	E	6.00E-03	6.40E-03	1.10E-03	0.00E+00	0.00E+00	0.00E+00
NNE	E	3.20E-03	4.10E-03	1.30E-03	4.00E-04	1.00E-04	0.00E+00
NE	E	3.30E-03	2.10E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	E	2.90E-03	1.20E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00

Table G.3.1.34 Stability Array for Year 1990 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
E	E	3.50E-03	4.30E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	E	2.80E-03	2.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	E	3.70E-03	2.50E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	E	3.00E-03	5.40E-03	1.10E-03	1.00E-04	0.00E+00	0.00E+00
S	E	3.40E-03	5.40E-03	1.20E-03	4.00E-04	5.00E-04	0.00E+00
SSW	E	3.40E-03	2.20E-03	2.30E-03	1.20E-03	1.10E-03	7.00E-04
SW	E	3.90E-03	4.90E-03	3.40E-03	2.00E-03	1.20E-03	6.00E-04
WSW	E	4.40E-03	9.20E-03	6.50E-03	3.20E-03	1.30E-03	6.00E-04
W	E	5.10E-03	2.31E-02	2.04E-02	4.30E-03	8.00E-04	1.00E-04
WNW	E	5.30E-03	1.87E-02	1.89E-02	9.30E-03	1.30E-03	0.00E+00
NW	E	6.10E-03	1.23E-02	1.80E-02	1.78E-02	5.40E-03	4.00E-04
NNW	E	4.70E-03	1.07E-02	3.00E-03	2.00E-04	0.00E+00	0.00E+00
N	F	4.60E-03	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NNE	F	2.00E-03	1.90E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
NE	F	1.80E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	F	2.50E-03	7.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
E	F	3.00E-03	1.80E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	F	2.00E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	F	3.40E-03	2.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	F	3.40E-03	5.00E-03	1.30E-03	2.00E-04	0.00E+00	0.00E+00
S	F	3.70E-03	6.90E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	F	3.50E-03	6.40E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	F	4.40E-03	8.50E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00
WSW	F	5.40E-03	2.07E-02	5.50E-03	0.00E+00	0.00E+00	0.00E+00
W	F	5.60E-03	3.85E-02	6.20E-03	1.00E-04	0.00E+00	0.00E+00
WNW	F	3.90E-03	2.11E-02	9.30E-03	1.00E-04	0.00E+00	0.00E+00
NW	F	3.70E-03	1.47E-02	1.51E-02	8.00E-04	0.00E+00	0.00E+00
NNW	F	4.00E-03	7.70E-03	1.20E-03	0.00E+00	0.00E+00	0.00E+00

Notes:
Dir = wind direction
Stab = stability class
ws1 = wind speed category 1 (1.50 m/sec)
ws2 = wind speed category 2 (2.50 m/sec)
ws3 = wind speed category 3 (4.30 m/sec)
ws4 = wind speed category 4 (6.80 m/sec)
ws5 = wind speed category 5 (9.50 m/sec)
ws6 = wind speed category 6 (12.50 m/sec)

Table G.3.1.35 Stability Array for Year 1991

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
N	A	1.20E-03	7.10E-03	2.60E-03	3.00E-04	0.00E+00	0.00E+00
NNE	A	1.70E-03	4.90E-03	2.90E-03	1.60E-03	1.00E-04	0.00E+00
NE	A	1.90E-03	3.50E-03	1.00E-03	2.00E-04	0.00E+00	0.00E+00
ENE	A	1.60E-03	3.10E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
E	A	2.70E-03	3.50E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	A	7.00E-04	1.40E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	A	7.00E-04	9.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	A	1.20E-03	1.20E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
S	A	1.00E-03	9.00E-04	3.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	A	5.00E-04	7.00E-04	6.00E-04	3.00E-04	0.00E+00	0.00E+00
SW	A	2.00E-04	8.00E-04	1.40E-03	1.00E-03	0.00E+00	0.00E+00
WSW	A	2.00E-04	1.00E-03	1.20E-03	2.10E-03	1.70E-03	5.00E-04
W	A	5.00E-04	1.00E-03	3.00E-03	2.00E-03	8.00E-04	0.00E+00
WNW	A	1.00E-04	8.00E-04	9.00E-04	9.00E-04	1.00E-04	0.00E+00
NW	A	2.00E-04	1.30E-03	6.00E-03	5.80E-03	1.70E-03	1.00E-04
NNW	A	5.00E-04	3.40E-03	3.90E-03	2.20E-03	5.00E-04	0.00E+00
N	B	2.80E-03	4.80E-03	1.00E-03	1.00E-04	0.00E+00	0.00E+00
NNE	B	2.10E-03	2.90E-03	8.00E-04	1.00E-04	0.00E+00	0.00E+00
NE	B	2.20E-03	1.70E-03	8.00E-04	2.00E-04	0.00E+00	0.00E+00
ENE	B	2.20E-03	1.30E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00
E	B	2.40E-03	3.40E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	B	1.20E-03	2.30E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	B	1.00E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	B	5.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S	B	5.00E-04	6.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	B	5.00E-04	3.00E-04	6.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	B	2.00E-04	9.00E-04	5.00E-04	1.00E-04	2.00E-04	0.00E+00
WSW	B	2.00E-04	1.20E-03	6.00E-04	5.00E-04	3.00E-04	0.00E+00
W	B	3.00E-04	6.00E-04	1.90E-03	2.00E-04	2.00E-04	0.00E+00
WNW	B	6.00E-04	1.30E-03	5.00E-04	2.00E-04	0.00E+00	0.00E+00
NW	B	9.00E-04	1.30E-03	2.00E-03	1.60E-03	8.00E-04	0.00E+00
NNW	B	1.50E-03	3.10E-03	2.40E-03	5.00E-04	1.00E-04	1.00E-04
N	C	2.30E-03	6.40E-03	1.00E-03	0.00E+00	0.00E+00	0.00E+00
NNE	C	2.40E-03	2.40E-03	2.00E-04	3.00E-04	1.00E-04	0.00E+00
NE	C	2.90E-03	2.40E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00

Table G.3.1.35 Stability Array for Year 1991 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
ENE	C	3.00E-03	1.60E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	C	2.80E-03	2.20E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	C	1.70E-03	1.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	C	7.00E-04	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	C	8.00E-04	6.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
S	C	7.00E-04	8.00E-04	7.00E-04	2.00E-04	0.00E+00	0.00E+00
SSW	C	8.00E-04	8.00E-04	3.00E-04	1.00E-04	2.00E-04	0.00E+00
SW	C	2.00E-04	1.20E-03	3.00E-04	1.00E-04	5.00E-04	0.00E+00
WSW	C	5.00E-04	3.00E-04	3.00E-04	5.00E-04	2.00E-04	0.00E+00
W	C	1.50E-03	1.50E-03	5.00E-04	5.00E-04	0.00E+00	0.00E+00
WNW	C	1.20E-03	7.00E-04	6.00E-04	1.00E-04	0.00E+00	0.00E+00
NW	C	1.50E-03	3.40E-03	2.20E-03	1.00E-03	3.00E-04	2.00E-04
NNW	C	1.50E-03	5.50E-03	1.60E-03	1.00E-04	0.00E+00	0.00E+00
N	D	1.28E-02	8.80E-03	2.80E-03	3.00E-04	0.00E+00	0.00E+00
NNE	D	7.10E-03	4.20E-03	2.00E-03	2.00E-04	1.00E-04	0.00E+00
NE	D	7.00E-03	1.90E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	D	5.90E-03	1.90E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
E	D	5.60E-03	4.30E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	D	4.60E-03	3.70E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	D	6.20E-03	2.40E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	D	4.30E-03	2.30E-03	3.00E-04	1.00E-04	0.00E+00	0.00E+00
S	D	3.50E-03	2.40E-03	1.30E-03	7.00E-04	0.00E+00	0.00E+00
SSW	D	2.10E-03	1.00E-03	2.00E-03	1.40E-03	9.00E-04	0.00E+00
SW	D	2.20E-03	1.40E-03	1.90E-03	1.70E-03	1.00E-03	5.00E-04
WSW	D	2.80E-03	2.90E-03	3.10E-03	2.80E-03	1.00E-03	3.00E-04
W	D	6.60E-03	6.20E-03	4.60E-03	2.30E-03	8.00E-04	9.00E-04
WNW	D	5.30E-03	6.40E-03	4.40E-03	2.20E-03	2.00E-04	0.00E+00
NW	D	6.90E-03	1.63E-02	1.43E-02	1.03E-02	4.60E-03	6.00E-04
NNW	D	5.70E-03	1.08E-02	5.30E-03	1.20E-03	5.00E-04	0.00E+00
N	E	4.10E-03	6.50E-03	1.60E-03	6.00E-04	0.00E+00	0.00E+00
NNE	E	3.00E-03	2.20E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
NE	E	1.50E-03	9.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	E	2.70E-03	7.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
E	E	2.60E-03	3.50E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00

Table G.3.1.35 Stability Array for Year 1991 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
ESE	E	2.20E-03	2.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	E	4.30E-03	1.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	E	3.00E-03	4.60E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
S	E	4.50E-03	3.10E-03	1.70E-03	8.00E-04	1.00E-04	0.00E+00
SSW	E	3.60E-03	3.00E-03	1.20E-03	1.00E-03	3.00E-04	0.00E+00
SW	E	2.40E-03	5.30E-03	2.80E-03	1.60E-03	8.00E-04	1.00E-04
WSW	E	4.00E-03	7.00E-03	6.00E-03	2.90E-03	7.00E-04	1.00E-04
W	E	6.90E-03	2.62E-02	1.51E-02	2.40E-03	2.00E-04	0.00E+00
WNW	E	7.60E-03	2.03E-02	2.17E-02	4.90E-03	6.00E-04	0.00E+00
NW	E	3.70E-03	1.86E-02	2.23E-02	1.64E-02	3.70E-03	2.00E-04
NNW	E	3.50E-03	1.09E-02	5.50E-03	9.00E-04	0.00E+00	0.00E+00
N	F	3.70E-03	2.60E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	F	2.30E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NE	F	1.90E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	F	2.10E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	F	3.40E-03	1.90E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	F	1.90E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	F	3.00E-03	1.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	F	3.30E-03	5.10E-03	1.40E-03	0.00E+00	0.00E+00	0.00E+00
S	F	3.70E-03	7.00E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	F	2.30E-03	4.50E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	F	2.90E-03	7.10E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00
WSW	F	3.10E-03	1.42E-02	3.60E-03	0.00E+00	0.00E+00	0.00E+00
W	F	6.40E-03	3.32E-02	6.70E-03	2.00E-04	0.00E+00	0.00E+00
WNW	F	3.00E-03	2.58E-02	4.10E-03	0.00E+00	0.00E+00	0.00E+00
NW	F	3.70E-03	2.03E-02	1.24E-02	1.00E-04	0.00E+00	0.00E+00
NNW	F	4.60E-03	1.09E-02	2.90E-03	0.00E+00	0.00E+00	0.00E+00

Notes:
dir = wind direction
stab = stability class
ws1 = wind speed category 1 (1.50 m/sec)
ws2 = wind speed category 2 (2.50 m/sec)
ws3 = wind speed category 3 (4.30 m/sec)
ws4 = wind speed category 4 (6.80 m/sec)
ws5 = wind speed category 5 (9.50 m/sec)
ws6 = wind speed category 6 (12.50 m/sec)

Table G.3.1.36 Stability Array for Year 1992

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
N	A	5.30E-03	1.24E-02	2.20E-03	2.00E-04	0.00E+00	0.00E+00
NNE	A	3.00E-03	6.70E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00
NE	A	4.70E-03	4.40E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	A	4.50E-03	5.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	A	4.60E-03	7.60E-03	5.00E-04	1.00E-04	0.00E+00	0.00E+00
ESE	A	1.60E-03	5.10E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	A	1.30E-03	3.10E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	A	7.00E-04	1.50E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00
S	A	1.70E-03	7.00E-04	2.00E-04	1.00E-04	0.00E+00	0.00E+00
SSW	A	7.00E-04	1.00E-03	8.00E-04	1.00E-04	0.00E+00	0.00E+00
SW	A	8.00E-04	1.90E-03	1.20E-03	8.00E-04	2.00E-04	0.00E+00
WSW	A	5.00E-04	1.60E-03	3.10E-03	3.40E-03	9.00E-04	1.00E-04
W	A	9.00E-04	1.20E-03	2.90E-03	1.90E-03	1.00E-03	0.00E+00
WNW	A	1.30E-03	1.20E-03	1.00E-03	1.20E-03	0.00E+00	0.00E+00
NW	A	1.00E-03	3.00E-03	4.20E-03	5.80E-03	1.90E-03	1.00E-04
NNW	A	1.40E-03	8.40E-03	6.60E-03	4.90E-03	8.00E-04	1.00E-04
N	B	1.90E-03	5.30E-03	3.00E-04	3.00E-04	0.00E+00	0.00E+00
NNE	B	2.20E-03	1.70E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NE	B	2.10E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	B	1.40E-03	1.00E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
E	B	3.80E-03	1.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	B	1.40E-03	1.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	B	7.00E-04	6.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	B	5.00E-04	8.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
S	B	9.00E-04	7.00E-04	0.00E+00	1.00E-04	0.00E+00	0.00E+00
SSW	B	6.00E-04	2.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	B	3.00E-04	6.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
WSW	B	5.00E-04	2.00E-04	6.00E-04	5.00E-04	2.00E-04	0.00E+00
W	B	6.00E-04	5.00E-04	1.30E-03	3.00E-04	0.00E+00	0.00E+00
WNW	B	1.00E-03	1.00E-04	5.00E-04	1.00E-04	0.00E+00	0.00E+00
NW	B	9.00E-04	1.70E-03	2.00E-03	1.30E-03	5.00E-04	0.00E+00
NNW	B	1.50E-03	4.60E-03	2.30E-03	7.00E-04	1.00E-04	0.00E+00
N	C	3.40E-03	4.90E-03	3.00E-04	1.00E-04	0.00E+00	0.00E+00
NNE	C	1.90E-03	1.20E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00

Table G.3.1.36 Stability Array for Year 1992 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
NE	C	2.10E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	C	1.20E-03	1.20E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
E	C	1.60E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	C	5.00E-04	9.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	C	5.00E-04	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	C	5.00E-04	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
S	C	3.00E-04	1.00E-04	1.00E-04	1.00E-04	0.00E+00	0.00E+00
SSW	C	2.00E-04	3.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	C	1.00E-04	5.00E-04	2.00E-04	2.00E-04	0.00E+00	0.00E+00
WSW	C	3.00E-04	6.00E-04	1.00E-04	1.30E-03	1.00E-04	1.00E-04
W	C	7.00E-04	2.00E-04	9.00E-04	8.00E-04	1.00E-04	0.00E+00
WNW	C	6.00E-04	1.20E-03	3.00E-04	3.00E-04	0.00E+00	0.00E+00
NW	C	3.00E-04	1.90E-03	1.90E-03	9.00E-04	1.00E-04	0.00E+00
NNW	C	1.00E-03	4.60E-03	1.70E-03	6.00E-04	1.00E-04	0.00E+00
N	D	8.30E-03	9.10E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	D	7.60E-03	3.60E-03	1.00E-04	1.00E-04	0.00E+00	0.00E+00
NE	D	4.70E-03	2.00E-03	2.00E-04	1.00E-04	0.00E+00	0.00E+00
ENE	D	5.70E-03	1.70E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
E	D	7.60E-03	5.70E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	D	6.90E-03	2.70E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	D	6.00E-03	2.70E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	D	4.90E-03	2.00E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
S	D	3.80E-03	1.90E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	D	2.30E-03	7.00E-04	2.00E-04	3.00E-04	0.00E+00	0.00E+00
SW	D	1.70E-03	7.00E-04	1.20E-03	5.00E-04	3.00E-04	3.00E-04
WSW	D	1.70E-03	1.20E-03	1.00E-03	2.30E-03	5.00E-04	5.00E-04
W	D	5.00E-03	2.80E-03	6.60E-03	2.30E-03	3.00E-04	0.00E+00
WNW	D	2.70E-03	4.70E-03	6.50E-03	2.70E-03	0.00E+00	0.00E+00
NW	D	3.50E-03	1.27E-02	2.07E-02	1.27E-02	2.30E-03	0.00E+00
NNW	D	6.10E-03	1.53E-02	6.00E-03	3.00E-03	6.00E-04	0.00E+00
N	E	7.20E-03	4.40E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	E	3.20E-03	1.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NE	E	3.10E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	E	4.20E-03	6.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00

Table G.3.1.36 Stability Array for Year 1992 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
E	E	5.20E-03	2.80E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	E	2.40E-03	2.30E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	E	4.40E-03	2.90E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	E	4.60E-03	5.60E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
S	E	4.60E-03	3.60E-03	1.30E-03	1.00E-04	0.00E+00	0.00E+00
SSW	E	3.20E-03	1.50E-03	1.40E-03	7.00E-04	0.00E+00	0.00E+00
SW	E	4.20E-03	2.40E-03	2.20E-03	1.00E-03	5.00E-04	1.00E-04
WSW	E	4.00E-03	4.40E-03	3.50E-03	1.50E-03	2.00E-04	0.00E+00
W	E	7.60E-03	2.27E-02	9.80E-03	1.70E-03	0.00E+00	0.00E+00
WNW	E	5.20E-03	2.05E-02	1.85E-02	2.70E-03	0.00E+00	0.00E+00
NW	E	6.90E-03	2.24E-02	2.72E-02	9.60E-03	1.00E-03	1.00E-04
NNW	E	6.70E-03	1.30E-02	5.30E-03	2.00E-03	1.00E-04	0.00E+00
N	F	4.70E-03	2.80E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	F	2.10E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NE	F	2.00E-03	3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ENE	F	1.40E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	F	2.30E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
ESE	F	2.10E-03	1.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	F	2.30E-03	2.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	F	3.10E-03	6.50E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00
S	F	3.70E-03	7.50E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	F	3.40E-03	5.10E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SW	F	4.70E-03	7.50E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
WSW	F	4.00E-03	1.25E-02	1.90E-03	1.00E-04	0.00E+00	0.00E+00
W	F	7.60E-03	3.71E-02	5.90E-03	2.00E-04	0.00E+00	0.00E+00
WNW	F	6.00E-03	2.29E-02	5.80E-03	0.00E+00	0.00E+00	0.00E+00
NW	F	4.60E-03	2.66E-02	1.41E-02	1.00E-04	0.00E+00	0.00E+00
NNW	F	5.90E-03	1.39E-02	3.50E-03	0.00E+00	0.00E+00	0.00E+00

Notes:
Dir = wind direction
Stab = stability class

Table G.3.1.37 Stability Array for Year 1993

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
N	A	5.00E-03	8.90E-03	3.50E-03	4.00E-04	0.00E+00	0.00E+00
NNE	A	6.00E-03	4.30E-03	2.80E-03	2.00E-04	0.00E+00	0.00E+00
NE	A	6.20E-03	2.90E-03	1.50E-03	1.20E-03	7.00E-04	0.00E+00
ENE	A	3.60E-03	2.90E-03	9.00E-04	0.00E+00	0.00E+00	0.00E+00
E	A	3.80E-03	4.50E-03	8.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	A	3.60E-03	3.40E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	A	1.60E-03	2.20E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	A	1.30E-03	1.40E-03	5.00E-04	0.00E+00	0.00E+00	0.00E+00
S	A	7.00E-04	9.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	A	8.00E-04	1.50E-03	7.00E-04	5.00E-04	0.00E+00	0.00E+00
SW	A	8.00E-04	2.60E-03	2.10E-03	1.80E-03	1.00E-04	0.00E+00
WSW	A	1.20E-03	1.20E-03	3.60E-03	3.90E-03	8.00E-04	0.00E+00
W	A	9.00E-04	1.80E-03	2.70E-03	2.60E-03	1.00E-04	0.00E+00
WNW	A	6.00E-04	6.00E-04	4.00E-04	2.00E-04	0.00E+00	0.00E+00
NW	A	1.50E-03	3.20E-03	3.60E-03	1.80E-03	1.40E-03	2.00E-04
NNW	A	2.10E-03	5.70E-03	6.00E-03	1.80E-03	4.00E-04	0.00E+00
N	B	3.30E-03	3.80E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	B	2.10E-03	9.00E-04	2.00E-04	1.00E-04	0.00E+00	0.00E+00
NE	B	1.80E-03	9.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	B	1.10E-03	1.80E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
E	B	1.60E-03	7.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	B	7.00E-04	5.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	B	1.60E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	B	9.00E-04	7.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
S	B	1.20E-03	6.00E-04	1.00E-04	1.00E-04	0.00E+00	0.00E+00
SSW	B	8.00E-04	1.10E-03	2.00E-04	1.00E-04	0.00E+00	0.00E+00
SW	B	9.00E-04	1.20E-03	5.00E-04	1.00E-04	0.00E+00	0.00E+00
WSW	B	9.00E-04	6.00E-04	9.00E-04	7.00E-04	2.00E-04	0.00E+00
W	B	9.00E-04	8.00E-04	1.10E-03	2.00E-04	4.00E-04	0.00E+00
WNW	B	6.00E-04	5.00E-04	6.00E-04	0.00E+00	0.00E+00	0.00E+00
NW	B	9.00E-04	2.60E-03	2.20E-03	8.00E-04	7.00E-04	0.00E+00
NNW	B	1.40E-03	3.60E-03	1.10E-03	2.00E-04	2.00E-04	0.00E+00
N	C	2.80E-03	4.50E-03	5.00E-04	1.00E-04	0.00E+00	0.00E+00
NNE	C	1.40E-03	1.10E-03	5.00E-04	1.00E-04	0.00E+00	0.00E+00

Table G.3.1.37 Stability Array for Year 1993 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
NE	C	1.10E-03	8.00E-04	2.00E-04	1.00E-04	0.00E+00	0.00E+00
ENE	C	1.10E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	C	1.50E-03	9.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	C	1.20E-03	1.30E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	C	7.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	C	9.00E-04	4.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
S	C	7.00E-04	6.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SSW	C	8.00E-04	4.00E-04	2.00E-04	4.00E-04	0.00E+00	0.00E+00
SW	C	9.00E-04	6.00E-04	2.00E-04	2.00E-04	0.00E+00	0.00E+00
WSW	C	5.00E-04	6.00E-04	2.00E-04	4.00E-04	0.00E+00	0.00E+00
W	C	9.00E-04	1.90E-03	8.00E-04	5.00E-04	4.00E-04	0.00E+00
WNW	C	1.40E-03	1.40E-03	6.00E-04	1.00E-04	0.00E+00	0.00E+00
NW	C	1.90E-03	3.90E-03	4.90E-03	5.00E-04	2.00E-04	0.00E+00
NNW	C	1.90E-03	4.80E-03	1.80E-03	6.00E-04	0.00E+00	0.00E+00
N	D	1.15E-02	9.50E-03	1.30E-03	5.00E-04	0.00E+00	0.00E+00
NNE	D	7.70E-03	3.50E-03	5.00E-04	6.00E-04	0.00E+00	0.00E+00
NE	D	6.20E-03	2.20E-03	1.00E-04	6.00E-04	0.00E+00	0.00E+00
ENE	D	6.90E-03	1.10E-03	5.00E-04	4.00E-04	0.00e+00	0.00e+00
E	D	9.00E-03	2.90E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	D	4.60E-03	1.60E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SE	D	4.60E-03	2.20E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	D	4.20E-03	2.60E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
S	D	3.50E-03	2.50E-03	7.00E-04	1.00E-04	0.00E+00	0.00E+00
SSW	D	2.80E-03	1.80E-03	7.00E-04	7.00E-04	0.00E+00	0.00E+00
SW	D	2.30E-03	1.60E-03	1.40E-03	1.30E-03	5.00E-04	0.00E+00
WSW	D	3.40E-03	1.80E-03	1.10E-03	9.00E-04	2.00E-04	1.00E-04
W	D	6.70E-03	5.60E-03	3.60E-03	2.60E-03	6.00E-04	0.00E+00
WNW	D	5.00E-03	6.20E-03	2.20E-03	2.70E-03	1.00E-04	0.00E+00
NW	D	6.80E-03	1.45E-02	1.88E-02	7.30E-03	2.20E-03	1.00E-04
NNW	D	8.60E-03	1.31E-02	8.60E-03	2.70E-03	1.00E-04	0.00E+00
N	E	6.00E-03	4.50E-03	6.00E-04	1.00E-04	0.00E+00	0.00E+00
NNE	E	3.00E-03	1.60E-03	9.00E-04	5.00E-04	0.00E+00	0.00E+00
NE	E	3.20E-03	1.40E-03	6.00E-04	1.00E-04	1.00E-04	0.00E+00
ENE	E	3.00E-03	1.10E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table G.3.1.37 Stability Array for Year 1993 (cont'd)

Dir	Stab	ws1	ws2	ws3	ws4	ws5	ws6
E	E	5.20E-03	2.30E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	E	4.20E-03	1.90E-03	0.00E+00	4.00E-04	1.00E-04	0.00E+00
SE	E	5.30E-03	2.00E-03	1.00E-04	0.00E+00	0.00E+00	0.00E+00
SSE	E	5.50E-03	4.10E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
S	E	4.10E-03	3.60E-03	7.00E-04	6.00E-04	0.00E+00	0.00E+00
SSW	E	3.80E-03	1.90E-03	1.10E-03	6.00E-04	1.00E-04	0.00E+00
SW	E	4.50E-03	3.30E-03	9.00E-04	1.40E-03	9.00E-04	1.00E-04
WSW	E	5.90E-03	4.80E-03	2.20E-03	1.30E-03	2.00E-04	1.00E-04
W	E	8.90E-03	1.71E-02	1.07E-02	3.60E-03	2.00E-04	0.00E+00
WNW	E	6.30E-03	2.09E-02	1.37E-02	2.30E-03	0.00E+00	1.00E-04
NW	E	7.00E-03	2.45E-02	2.40E-02	1.06E-02	1.20E-03	5.00E-04
NNW	E	4.30E-03	1.34E-02	5.70E-03	2.00E-03	4.00E-04	0.00E+00
N	F	6.20E-03	4.10E-03	2.00E-04	0.00E+00	0.00E+00	0.00E+00
NNE	F	2.30E-03	9.00E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00
NE	F	2.80E-03	7.00E-04	2.00E-04	0.00E+00	0.00E+00	0.00E+00
ENE	F	2.10E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
E	F	3.60E-03	2.20E-03	4.00E-04	0.00E+00	0.00E+00	0.00E+00
ESE	F	2.30E-03	7.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SE	F	3.60E-03	2.50E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SSE	F	3.60E-03	4.60E-03	6.00E-04	0.00E+00	0.00E+00	0.00E+00
S	F	5.40E-03	7.50E-03	2.00E-04	2.00E-04	0.00E+00	0.00E+00
SSW	F	4.60E-03	5.50E-03	4.00E-04	0.00E+00	1.00E-04	0.00E+00
SW	F	4.00E-03	7.70E-03	9.00E-04	1.00E-04	0.00E+00	1.00E-04
WSW	F	3.50E-03	1.36E-02	3.60E-03	2.00E-04	0.00E+00	0.00E+00
W	F	7.00E-03	2.65E-02	5.20E-03	4.00E-04	0.00E+00	0.00E+00
WNW	F	5.40E-03	2.08E-02	3.00E-03	0.00E+00	0.00E+00	0.00E+00
NW	F	5.60E-03	2.50E-02	1.37E-02	1.00E-04	0.00E+00	0.00E+00
NNW	F	5.60E-03	1.11E-02	2.30E-03	0.00E+00	0.00E+00	0.00E+00

Notes:
Dir = wind direction
Stab = stability class

Table G.4.0.1 Modeling Results for the No Action Alternative (Tank Waste)

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	2.4 E-02	571700, 127700	40,000	40,000
	8 hour	1.6 E-02	571700, 127700	10,000	10,000
Nitrogen Oxides	Annual (1993)	1.1E-05	583500, 128500	100	100
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7 E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.1 E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8 E-03	573400, 126700	N/A	24
Ammonia	24 hour	6.9 E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Heptane	24 hour	1.2 E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3 E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0 E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	1.0 E-05	585500, 144500	N/A	500
Nonane	24 hour	6.5 E-03	573400, 126700	N/A	3500
Octane	24 hour	6.8 E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3 E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5 E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents the data year producing the highest impact.
Impact from the No Action alternative (capsules) are also analyzed in this table.

Table G.4.0.2. Modeling Results for the Long-Term Management Alternative Phase 1

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x,y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	2.5	567900, 130300	40,000	40,000
	8 hour	1.8	567900, 130300	10,000	10,000
Nitrogen Oxides	Annual (1992)	2.2E-03	583500, 128500	100	100
Sulfur Oxides	1 hour	0.13	583500, 128500	N/A	655
	3 hour	0.11	583500, 128500	1300	1300
	24 hour	5.0E-02	583500, 128500	365	260
	Annual (1992)	7.2E-04	583500, 128500	80	60
PM-10	24 hour	1.4	583500, 128500	150	150
	Annual (1992)	2.0E-02	583500, 128500	50	50
Formaldehyde	Annual (1992)	7.1E-05	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	1.9E-06	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	3.1E-03	563700, 132200	N/A	67
2 -Pentanone	24 hour	5.0E-03	563700, 132200	N/A	2300
Acetone	24 hour	6.0E-02	563700, 132200	N/A	5900
Acetonitrile	24 hour	3.0E-02	563700, 132200	N/A	24
Ammonia	24 hour	0.30	563700, 132200	N/A	100
Benzene	Annual (1993)	1.5E-05	569500, 130500	N/A	0.12
Heptane	24 hour	3.5E-02	563700, 132200	N/A	5500
Hexane	24 hour	3.7E-03	563700, 132200	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10.E-03	585500, 144500	N/A	500
Nonane	24 hour	1.9E-03	563700, 132200	N/A	3500
Octane	24 hour	2E-03	563700, 132200	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	5.4E-03	563700, 132200	N/A	3.3
Toluene	24 hour	2.8E-04	563700, 132200	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents the data year producing the highest impact.

Table G.4.0.3 Modeling Results for the Long-Term Management Alternative Phase 2

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	2.5	571500, 128500	40,000	40,000
	8 hour	1.8	571500, 128500	10,000	10,000
Nitrogen Oxides	Annual (1992)	2.2E-03	583500, 128500	100	100
Sulfur Oxides	1 hour	1.3E -01	571500, 128500	N/A	655
	3 hour	1.1E-01	571500, 128500	1300	N/A
	24 hour	5.0E-02	571500, 128500	365	260
	Annual (1992)	7.2E-04	583500, 126500	80	60
PM-10	24 hour	1.4	571500, 128500	150	150
	Annual (1992)	2.0E-02	583500, 128500	50	50
Formaldehyde	Annual (1992)	7.1E-05	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.7E-06	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	567900, 130300	N/A	67
2 -Pentanone	24 hour	1.8E-03	567900, 130300	N/A	2300
Acetone	24 hour	2.2E-02	567900, 130300	N/A	5900
Acetonitrile	24 hour	1.0E-02	567900, 130300	N/A	24
Ammonia	24 hour	6.9E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.1E-06	583500,128500	N/A	0.12
Heptane	24 hour	1.3E-03	567900, 130300	N/A	5500
Hexane	24 hour	1.3E-03	567900, 130300	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	1.0E-02	585500, 144500	N/A	500
Nonane	24 hour	6.8E-04	567900, 130300	N/A	3500
Octane	24 hour	7.1E-04	567900, 130300	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.4E-03	569500, 130500	N/A	3.3
Toluene	24 hour	1.0E-04	567900, 130300	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.4 Modeling Results for the In Situ Fill and Cap Alternative

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	49	563700, 132200	40,000	40,000
	8 hour	35	563700, 132200	10,000	10,000
Nitrogen Oxides	Annual (1992)	4.5E-03	569500, 130500	100	100
Sulfur Oxides	1 hour	24	563700, 132200	N/A	655
	3 hour	21	563700, 132200	1300	N/A
	24 hour	9.5	563700, 132200	365	260
	Annual (1992)	9.6E-02	569500, 130500	80	60
PM-10	24 hour	4.0	563700, 132200	150	150
	Annual (1992)	0.29	571500, 128500	50	50
Formaldehyde	Annual (1992)	7.7E-05	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	1.9E-06	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	3.0E-03	564800, 131200	N/A	67
2 -Pentanone	24 hour	4.7E-03	564800, 131200	N/A	2300
Acetone	24 hour	6.0E-02	564800, 131200	N/A	5900
Acetonitrile	24 hour	3.0E-02	564800, 131200	N/A	24
Ammonia	24 hour	0.30	564800, 131200	N/A	100
Benzene	Annual (1993)	1.5E-05	569500, 130500	N/A	0.12
Heptane	24 hour	3.3E-03	564800, 131200	N/A	5500
Hexane	24 hour	3.5E-03	564800, 131200	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nonane	24 hour	1.8E-03	564800, 131200	N/A	3500
Octane	24 hour	1.9E-03	564800, 131200	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	5.2E-03	564800, 131200	N/A	3.3
Toluene	24 hour	2.6E-04	564800, 131200	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using the data meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.5 Modeling Results for the In Situ Vitrification Alternative

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	980	563700, 132200	40,000	40,000
	8 hour	690	563700, 132200	10,000	10,000
Nitrogen Oxides	Annual (1993)	1.5	569500, 130500	100	100
Sulfur Oxides	1 hour	68	563700, 132200	N/A	655
	3 hour	6.1	563700, 132200	1300	N/A
	24 hour	27	563700, 132200	365	260
	Annual (1992)	2.8E-01	569500, 130500	80	60
PM-10	24 hour	96	563700, 132200	150	150
	Annual (1992)	1.0	569500, 130500	50	50
Formaldehyde	Annual (1992)	3.1E-04	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	0.85	559500, 132500	N/A	100
Benzene	Annual (1993)	6.0E-06	569500, 130500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.6 Modeling Results for the Ex Situ Intermediate Separations Alternative - Construction Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	2900	567900, 130300	40,000	40,000
	8 hour	2050	567900, 130300	10,000	10,000
Nitrogen Oxides	Annual (1992)	1.9	583500, 128500	100	100
Sulfur Oxides	1 hour	7.3	567900, 130300	N/A	655
	3 hour	6.5	567900, 130300	1300	N/A
	24 hour	2.9	567900, 130300	365	260
	Annual (1992)	2.7E-02	583500, 128500	80	60
PM-10	24 hour	93	567900, 130300	150	150
	Annual (1992)	1.0	583500, 128500	50	50
Formaldehyde	Annual (1992)	4.8E-04	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	7.0E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.7 Modeling Results for the Ex Situ Intermediate Separations Alternative - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	60	585500, 142500	40,000	40,000
	8 hour	42	585500, 142500	10,000	10,000
Nitrogen Oxides	Annual (1992)	0.12	569500, 130500	100	100
Sulfur Oxides	1 hour	4.9	585500, 142500	N/A	655
	3 hour	4.4	585500,142500	1300	N/A
	24 hour	2.0	585500, 142500	365	260
	Annual (1990)	2.1E-02	587500, 140500	80	60
PM-10	24 hour	0.75	564800, 142500	150	150
	Annual (1993)	7.8E-03	569500, 130500	50	50
Formaldehyde	Annual (1992)	2.8E-05	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	1.9E-06	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	3.1E-03	563700, 132200	N/A	67
2 -Pentanone	24 hour	5.0E-03	563700, 132200	N/A	2300
Acetone	24 hour	6.0E-02	563700, 132200	N/A	5900
Acetonitrile	24 hour	3.0E-02	563700, 132200	N/A	24
Ammonia	24 hour	0.40	563700, 132200	N/A	100
Antimony Compounds	24 hour	1.1E-08	585500, 142500	N/A	1.7
Arsenic Compounds	Annual (1990)	7.4E-11	587500, 140500	N/A	0.00023
Barium Oxide	24 hour	1.2E-08	585500, 142500	N/A	1.7
Benzene	Annual (1993)	1.5E-05	169500, 130500	N/A	0.12
Beryllium Compounds	Annual (1990)	1.4E-12	587500, 140500	N/A	0.00042
Boric Oxide	24 hour	1.2E-05	585500, 142500	N/A	33
Cadmium Compounds	Annual (1990)	6.8E-10	587500, 140500	N/A	0.00056
Calcium Oxide	24 hour	2.4E-05	585500, 142500	N/A	6.7
	Annual	1.1E-05	585500, 142500	N/A	0
Chromium Compounds	24 hour	1.7E-06	585500, 142500	N/A	1.7
	Annual (1990)	1.8E-08	587500, 140500	N/A	0.00083
Cobalt Compounds	24 hour	5.0E-09	585500, 142500	N/A	0.17
Ferric Oxide	24 hour	5.0E-06	585500, 142500	N/A	17
Fluoride (as HF)	24 hour	0.12	585500, 142500	N/A	2.9
HCl	24 hour	5.0E-02	585500, 142500	N/A	7
Heptane	24 hour	4.0E-03	563700, 132200	N/A	5500
Hexane	24 hour	4.0E-03	563700, 132200	N/A	200
Iodine	24 hour	4.0E-03	585500, 142500	N/A	3.3
Lead Compounds	24 hour	1.7E-07	585500, 142500	N/A	0.5

Table G.4.0.7 Modeling Results for the Ex Situ Intermediate Separations Alternative - Operation Phase (cont'd)

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Magnesium Oxide	24 hour	2.4E-05	585500, 142500	N/A	33
Manganese Compounds	24 hour	9.7E-07	585500, 142500	N/A	0.4
Methyl Isobutyl Ketone	24 hour	9.0E-05	563700, 132200	N/A	680
N-Butyl Alcohol	24 hour	1.0E-02	585500, 144500	N/A	500
Nickel Compounds	Annual (1990)	9.6E-06	587500, 140500	N/A	0.0021
Nitric Acid	24 hour	2.0E-02	585500, 142500	N/A	17
Nonane	24 hour	1.9E-03	563700, 132200	N/A	3500
Octane	24 hour	2E-03	563700, 132200	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.0E-02	563700, 132200	N/A	3.3
Selenium Compounds	24 hour	1.9E-08	585500, 142500	N/A	0.67
Silver Oxide	24 hour	2.1E-09	585500, 142500	N/A	0.033
Tellurium Trioxide	24 hour	1.5E-09	585500, 142500	N/A	0.33
Toluene	24 hour	2.8E-04	563700, 132200	N/A	400
Uranium Trioxide	24 hour	7.2E-06	585500, 142500	N/A	0.67
Vanadium Pentoxide	24 hour	4.2E-10	585500, 142500	N/A	0.17
Zinc Oxide	24 hour	1.6E-08	585500, 142500	N/A	17
Zirconium Oxide	24 hour	3.3E-06	585500, 142500	N/A	17

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.8 Modeling Results for the Ex Situ No Separations Alternative - Construction Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	2500	567900, 130300	40,000	40,000
	8 hour	1700	567900, 130300	10,000	10,000
Nitrogen Oxides	Annual (1992)	1.6	583500, 128500	100	100
Sulfur Oxides	1 hour	6.6	567900, 130300	N/A	655
	3 hour	6.0	567900, 130300	1300	N/A
	24 hour	2.7	567900, 130300	365	260
	Annual (1993)	3.0E-02	569500, 130500	80	60
PM-10	24 hour	85	567900, 130300	150	150
	Annual (1992)	0.88	583500, 128500	50	50
Formaldehyde	Annual (1992)	1.7E-03	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	7.0E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E 03	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E 04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.
Modeling results from vitrification and calcination are the same.

Table G.4.0.9 Modeling Results for the Ex Situ No Separations Alternative - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	85	585500, 142500	40,000	40,000
	8 hour	60	585500, 142500	10,000	10,000
Nitrogen Oxides	Annual (1992)	0.12 (vitrification)	569500, 130500	100	100
	Annual (1992)	0.13 (calcination)	569500, 130500	100	100
Sulfur Oxides	1 hour	8.6	585500, 142500	N/A	655
	3 hour	7.7	585500, 142500	1300	N/A
	24 hour	3.41	585500, 142500	365	260
	Annual (1990)	3.0E-02	587500, 140500	80	60
PM-10	24 hour	0.75	564800, 131200	150	150
	Annual (1992)	7.9E-03	569500, 130500	50	50
Formaldehyde	Annual (1992)	2.8E-05	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	1.9E-06	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	3.1E-03	563700, 132200	N/A	67
2 -Pentanone	24 hour	5.0E-03	563700, 132200	N/A	2300
Acetone	24 hour	6.0E-02	563700, 132200	N/A	5900
Acetonitrile	24 hour	3.0E-02	563700, 132200	N/A	24
Ammonia	24 hour	0.38	563700, 132200	N/A	100
Antimony Compounds	24 hour	2.0E-10	585500, 142500	N/A	1.7
Arsenic Compounds	Annual (1990)	9.2E-13	587500, 140500	N/A	0.00023
Benzene	Annual (1993)	1.5E-05	569500, 130500	N/A	0.12
Beryllium Compounds	Annual (1990)	1.9E-12	587500, 140500	N/A	0.00042
Boric Oxide	24 hour	3.4E-06	585500, 142500	N/A	33
Cadmium Compounds	Annual (1990)	8.6E-12	587500, 140500	N/A	0.00056
Calcium Oxide	24 hour	2.6E-07	585500, 142500	N/A	6.7
Chromium Compounds	24 hour	2.1E-08	585500, 142500	N/A	1.7
	Annual (1990)	1.9E-10	587500, 140500		0.00083
Cobalt Compounds	24 hour	9.2E-11	585500, 142500	N/A	0.17
Ferric Oxide	24 hour	1.0E-07	585500, 142500	N/A	17
Fluoride (as HF)	24 hour	0.27	585500, 142500	N/A	2.9
HCl	24 hour	0.11	585500, 142500	N/A	7
Heptane	24 hour	4.0E-03	563700, 132200	N/A	5500
Hexane	24 hour	4.0E-03	563700, 132200	N/A	200
Iodine	24 hour	5.0E-03	585500, 142500	N/A	3.3
Lead Compounds	24 hour	3.0E-09	585500, 142500	N/A	0.5
Magnesium Oxide	24 hour	2.4E-07	585500, 142500	N/A	33

Table G.4.0.9 Modeling Results for the Ex Situ No Separations Alternative - Operation Phase (cont'd)

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Manganese Compounds	24 hour	1.9E-05	585500, 142500	N/A	0.4
Methyl Isobutyl Ketone	24 hour	9.0E-05	563700, 132200	N/A	680
Nitric Acid	24 hour	2.0E-02	585500, 142500	N/A	17
Nonane	24 hour	1.9E-03	563700, 132200	N/A	3500
Octane	24 hour	2.0E-03	563700, 132200	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.0E-02	563700, 132200	N/A	3.3
Selenium Compounds	24 hour	3.1E-10	585500, 142500	N/A	0.67
Silver Oxide	24 hour	3.8E-11	585500, 142500	N/A	0.033
Tellurium Trioxide	24 hour	2.8E-11	585500, 142500	N/A	0.33
Toluene	24 hour	2.8E-04	563700, 132200	N/A	400
Uranium Trioxide	24 hour	1.4E-07	585500, 142500	N/A	0.67
Vanadium Pentoxide	24 hour	7.0E-12	585500, 142500	N/A	0.17
Zinc Oxide	24 hour	2.4E-10	585500, 142500	N/A	17
Zirconium Oxide	24 hour	6.7E-08	585500, 142500	N/A	17

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.
Additional emissions from routine operations of tank farm and evaporator are as shown in Table G.3.1.3.

Table G.4.0.10 Modeling Results for the Ex Situ Extensive Separations Alternative - Construction Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	3500	571500, 128500	40,000	40,000
	8 hour	2500	571500, 128500	10,000	10,000
Nitrogen Oxides	Annual (1992)	2.2	583500, 128500	100	100
Sulfur Oxides	1 hour	8.0	567900, 130300	N/A	655
	3 hour	7.2	567900, 130300	1300	N/A
	24 hour	3.2	567900, 130300	365	260
	Annual (1992)	3.1E-02	583500, 128500	80	60
PM-10	24 hour	95	567900, 130300	150	150
	Annual (1992)	1.0	583500, 128500	50	50
Formaldehyde	Annual (1992)	5.6E-04	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	7.0E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.11 Modeling Results for the Ex Situ Extensive Separations - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	27	585500, 142500	40,000	40,000
	8 hour	19	585500, 142500	10,000	10,000
Nitrogen Oxides	Annual (1990)	1.7	587500, 140500	100	100
Sulfur Oxides	1 hour	14	585500, 142500	N/A	655
	3 hour	13	585500, 142500	1300	N/A
	24 hour	5.6	585500, 142500	365	260
	Annual (1990)	6.0E-02	587500, 140500	80	60
PM-10	24 hour	1.4	571500, 128500	150	150
	Annual (1992)	2.0E-02	583500, 128500	50	50
Formaldehyde	Annual (1992)	7.1E-05	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	1.9E-06	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	3.0E-03	563700, 132200	N/A	67
2 -Pentanone	24 hour	5.0E -03	563700, 132200	N/A	2300
Acetone	24 hour	6.0E-02	563700, 132200	N/A	5900
Acetonitrile	24 hour	3.0E-02	563700, 132200	N/A	24
Ammonia	24 hour	0.38	563700, 132200	N/A	100
Benzene	Annual (1993)	1.5E-05	569500, 130500	N/A	0.12
Chromium Compounds	24 hour	1.9E-04	585500, 142500	N/A	1.7
	Annual (1990)	2.1E-06	587500, 140500	N/A	0.00083
Fluoride (as HF)	24 hour	1.0E-02	585500, 142500	N/A	2.9
Heptane	24 hour	4.0E-03	563700, 132200	N/A	5500
Hexane	24 hour	4.0E-03	563700, 132200	N/A	200
Manganese Compounds	24 hour	4.1E-05	585500, 142500	N/A	0.4
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nickel Compounds	Annual (1990)	6.7E-08	587500, 140500	N/A	.0021
Nitric Acid	24 hour	9.0E-02	585500, 142500	N/A	17
Nonane	24 hour	2.0E-03	563700, 132200	N/A	3500
Octane	24 hour	3.0E-03	563700, 132200	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	5.0E-03	563700, 132200	N/A	3.3
Toluene	24 hour	2.8E-04	563700, 132200	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.12 Modeling Results for the Ex Situ/In Situ Combination 1 and 2 Alternatives - Construction Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	1100	567900, 130300	40,000	40,000
	8 hour	800	567900, 130300	10,000	10,000
Nitrogen Oxide	Annual (1993)	1.1	569500, 130500	100	100
Sulfur Oxides	1 hour	27	563700, 132200	N/A	655
	3 hour	24	563700, 132200	1300	N/A
	24 hour	11	563700, 132200	365	260
	Annual (1992)	0.11	569500, 130500	80	60
PM-10	24 hour	51	563700, 132200	150	150
	Annual (1992)	0.60	569500, 130500	50	50
Formaldehyde	Annual (1992)	1.9E-04	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	7.0E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	58.500, 128500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10.E-03	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.13 Modeling Results for the Ex Situ/In Situ Combination 1 Alternative - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	32	567500, 124500	40,000	40,000
	8 hour	22	567500, 124500	10,000	10,000
Nitrogen Oxides	Annual (1992)	5.9E-02	569500, 130500	100	100
Sulfur Oxides	1 hour	2.5	585500, 142500	N/A	655
	3 hour	2.2	585500, 142500	1,300	N/A
	24 hour	0.98	585500, 142500	365	260
	Annual (1990)	1.0E-02	587500, 140500	80	60
PM-10	24 hour	1.4	564800, 131200	150	150
	Annual (1992)	1.4E-02	569500, 130500	50	50
Formaldehyde	Annual (1992)	1.4E-05	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	3.1E-03	563700, 132200	N/A	67
2 -Pentanone	24 hour	5.0E-03	563700, 132200	N/A	2,300
Acetone	24 hour	6.0E-02	563700, 132200	N/A	5,900
Acetonitrile	24 hour	2.9E-02	563700, 132200	N/A	24
Ammonia	24 hour	2.7E-01	563700, 132200	N/A	100
Antimony Compounds	24 hour	5.6E-09	563700, 132200	N/A	1.7
Arsenic Compounds	Annual (1990)	3.7E-11	587500, 140500	N/A	0.00023
Barium Oxide	24 hour	6.0E-09	585500, 142500	N/A	1.7
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Beryllium Compounds	Annual (1990)	7.2E-13	587500, 140500	N/A	0.00042
Boric Oxide	24 hour	1.7E-04	585500, 142500	N/A	33
Cadmium Compounds	Annual 91990)	3.4E-10	587500, 140500	N/A	0.00056
Calcium Oxide	24 hour	1.2E-05	585500, 142500	N/A	6.7
Chromium Compounds	24 hour	8.3E-07	585500, 142500	N/A	1.7
	Annual (19900	8.9E-09	587500, 140500		0.00083
Cobalt Compounds	24 hour	2.5E-09	587500, 140500	N/A	0.17
Ferric Oxide	24 hour	2.5E-06	587500, 140500	N/A	17
Fluoride (as HF)	24 hour	5.9E-02	587500, 140500	N/A	2.9
HCl	24 hour	2.5E-02	587500, 140500	N/A	7
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5,500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200

Table G.4.0.13 Modeling Results for the Ex Situ/In Situ Combination 1 Alternative - Operation Phase (cont'd)

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Iodine	24 hour	1.2E-03	585500, 142500	N/A	3.3
Lead Compounds	24 hour	1.9E-08	585500, 142500	N/A	0.5
Manganese Compounds	24 hour	1.4E-07	585500, 142500	N/A	0.4
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	9.9E-03	585500, 144500	N/A	500
Nickel Compounds	Annual (1990)	7.4E-06	587500, 140500	N/A	0.0021
Nitric Acid	24 hour	9.0E-03	585500, 142500	N/A	17
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3,500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4,700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Selenium Compounds	24 hour	3.4E-09	585500, 142500	N/A	0.67
Silver Oxide	24 hour	2.3E-10	585500, 142500	N/A	0.033
Tellurium Trioxide	24 hour	2.7E-10	585500, 142500	N/A	0.33
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400
Uranium Trioxide	24 hour	1.5E-06	585500, 142500	N/A	0.67
Vanadium Pentoxide	24 hour	1.3E-10	585500, 142500	N/A	0.17
Zinc Oxide	24 hour	7.0E-09	585500, 142500	N/A	17
Zirconium Oxide	24 hour	6.0E-07	585500, 142500	N/A	17

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.14 Modeling Results for the Ex Situ/In Situ Combination 2 Alternative - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	19	585500, 142500	40,000	40,000
	8 hour	14	567500, 124500	10,000	10,000
Nitrogen Oxides	Annual (1992)	2.4E-02	569500, 130500	100	100
Sulfur Oxides	1 hour	1.6	585500, 142500	N/A	655
	3 hour	1.5	585500, 142500	1,300	N/A
	24 hour	0.66	585500, 142500	365	260
	Annual (1990)	7.0E-03	587500, 140500	80	60
PM-10	24 hour	0.67	564800, 131200	150	150
	Annual (1992)	6.8E-03	569500, 130500	50	50
Formaldehyde	Annual (1992)	5.5E-06	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2,300
Acetone	24 hour	2.1E-02	573400, 126700	N/A	5,900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	1.3E-01	569500, 130500	N/A	100
Antimony Compounds	24 hour	1.1E-09	585500, 142500	N/A	1.7
Arsenic Compounds	Annual (1990)	1.2E-11	587500, 140500	N/A	0.00023
Barium Oxide	24 hour	3.3E-09	585500, 142500	N/A	1.7
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Beryllium Compounds	Annual (1990)	1.6E-13	587500, 140500	N/A	0.00042
Boric Oxide	24 hour	37E-04	585500, 142500	N/A	33
Cadmium Compounds	Annual (1990)	1.1E-10	587500, 140500	N/A	0.00056
Calcium Oxide	24 hour	1.7E-05	585500, 142500	N/A	6.7
Chromium Compounds	24 hour	52E-07	585500, 142500	N/A	1.7
	Annual (1990)	5.5E-09	587500, 140500	N/A	0.00083
Cobalt Compounds	24 hour	5.4E-10	585500, 142500	N/A	0.17
Ferric Oxide	24 hour	8.0E-07	585500, 142500	N/A	17
Fluoride (as HF)	24 hour	4.9E-02	585500, 142500	N/A	2.9
HCl	24 hour	1.0-02	585500, 142500	N/A	7
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5,500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Iodine	24 hour	1.2E-03	585500, 142500	N/A	3.3
Lead Compounds	24 hour	1.9E-08	585500, 142500	N/A	0.5
Manganese Compounds	24 hour	1.4E-07	585500, 142500	N/A	0.4
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	9.9E-03	585500, 144500	N/A	500
Nickel Compounds	Annual (1990)	7.4E-07	587500, 140500	N/A	0.0021
Nitric Acid	24 hour	9.0E-03	585500, 142500	N/A	17
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3,500

Table G.4.0.14 Modeling Results for the Ex Situ/In Situ Combination 2 Alternative - Operation Phase (cont'd)

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Octane	24 hour	6.8E-04	573400, 126700	N/A	4,700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Selenium Compounds	24 hour	3.4E-09	585500, 142500	N/A	0.67
Silver Oxide	24 hour	2.3E-10	585500, 142500	N/A	0.033
Tellurium Trioxide	24 hour	2.7E-10	585500, 142500	N/A	0.33
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400
Uranium Trioxide	24 hour	1.5E-06	585500, 142500	N/A	0.67
Vanadium Pentoxide	24 hour	1.3E-10	585500, 142500	N/A	0.17
Zinc Oxide	24 hour	7.0E-09	585500, 142500	N/A	17
Zirconium Oxide	24 hour	6.0E-07	585500, 142500	N/A	17

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.15 Modeling Results for the Phased Implementation Alternative Phase 1 - Construction Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	1100	571700, 127700	40,000	40,000
	8 hour	800	571700, 127700	10,000	10,000
Nitrogen Oxides	Annual (1993)	1.3	583500, 128500	100	100
Sulfur Oxides	1 hour	4.8	571700, 127700	N/A	655
	3 hour	4.3	571700, 127700	1300	N/A
	24 hour	3.2	571700, 127700	365	260
	Annual (1993)	2.9E-02	583500, 128500	80	60
PM-10	24 hour	87	571700, 127700	150	150
	Annual (1993)	1.2	583500, 128500	50	50
Formaldehyde	Annual (1993)	5.2E-06	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.6E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	7.0E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	583500, 128500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.16 Modeling Results for the Phased Implementation Alternative Phase 1 - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	39	569500, 124500	40,000	40,000
	8 hour	27	569500, 124500	10,000	10,000
Nitrogen Oxides	Annual (1993)	9.6E-03	583500, 128500	100	100
Sulfur Oxides	1 hour	2.4	569500, 124500	N/A	655
	3 hour	2.1	569500, 124500	1300	N/A
	24 hour	0.9	569500, 124500	365	260
	Annual (1993)	1.4E-02	583500, 128500	80	60
PM-10	24 hour	5.0E-02	587500, 142500	150	150
	Annual (1993)	7.1E-04	583500, 128500	50	50
1,3 -Butadiene	Annual (1993)	1.9E-06	569500, 130500	N/A	0.0036
2 -Hexanone	24 hour	3.0E-03	563700, 132200	N/A	67
2 -Pentanone	24 hour	5.0E -03	563700, 132200	N/A	2300
Acetone	24 hour	6.0E-02	563700, 132200	N/A	5900
Acetonitrile	24 hour	3.0E-02	563700, 132200	N/A	24
Ammonia	24 hour	0.38	563700, 132200	N/A	100
Benzene	Annual (1993)	1.5E-05	569500, 130500	N/A	0.12
Chromium Compounds	24 hour Annual (1993)	3.5E-07 5.1E-09	569500, 124500 583500, 128500	N/A N/A	1.7 0.00083
Fluoride (as HF)	24 hour	1.0E-02	585500, 142500	N/A	2.9
Heptane	24 hour	4.0E-03	563700, 132200	N/A	5500
Hexane	24 hour	4.0E-03	563700, 132200	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	10E-03	585500, 144500	N/A	500
Nickel Compounds	Annual (1993)	1.9E-10	583500, 128500	N/A	.0021
Nitric Acid	24 hour	9.0E-02	585500, 142500	N/A	17
Nonane	24 hour	2.0E-03	563700, 132200	N/A	3500
Octane	24 hour	3.0E-03	563700, 132200	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	5.0E-03	563700, 132200	N/A	3.3
Toluene	24 hour	2.8E-04	563700, 132200	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.17 Modeling Results for the Phased Implementation Alternative Phase 2 - Construction Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	3,200	567900, 130300	40,000	40,000
	8 hour	2,300	567900, 130300	10,000	10,000
Nitrogen Oxide	Annual (1992)	2.1	583500, 128500	100	100
Sulfur Oxides	1 hour	7.6	567900, 130300	N/A	655
	3 hour	6.9	567900, 130300	1300	N/A
	24 hour	3.1	567900, 130300	365	260
	Annual (1992)	2.9E-02	583500, 128500	80	60
PM-10	24 hour	98	567900, 130300	150	150
	Annual (1992)	1.1	583500, 128500	50	50
Formaldehyde	Annual (1992)	5.1E-04	583500, 128500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.5E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.1E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.7E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.0E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.8E-03	573400, 126700	N/A	24
Ammonia	24 hour	7.0E-02	571700, 127700	N/A	100
Benzene	Annual (1993)	6.0E-06	58.500, 128500	N/A	0.12
Heptane	24 hour	1.2E-03	573400, 126700	N/A	5500
Hexane	24 hour	1.3E-03	573400, 126700	N/A	200
Methyl Isobutyl Ketone	24 hour	9.0E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	1.0E-02	585500, 144500	N/A	500
Nonane	24 hour	6.5E-04	573400, 126700	N/A	3500
Octane	24 hour	6.8E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.3E-03	569500, 130500	N/A	3.3
Toluene	24 hour	9.5E-05	573400, 126700	N/A	400

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993. The number in parenthesis represents data year producing the highest impact.

Table G.4.0.18 Modeling Results for the Phased Implementation Alternative Phase 2 - Operation Phase

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	48	569500, 122500	40,000	40,000
	8 hour	34	569500, 122500	10,000	10,000
Nitrogen Oxides	Annual (1992)	1.20E-01	569500, 130500	100	100
Sulfur Oxides	1 hour	4.0	569500, 130500	N/A	655
	3 hour	3.6	569500, 130500	1300	N/A
	24 hour	1.6	569500, 130500	365	260
	Annual (1990)	1.97E-02	587500, 140500	80	60
PM-10	24 hour	0.75	564800, 131200	150	150
	Annual (1992)	7.91E-03	569500, 130500	50	50
Formaldehyde	Annual (1992)	2.77E-05	569500, 130500	N/A	0.077
1,3 -Butadiene	Annual (1993)	7.52E-07	583500, 128500	N/A	0.0036
2 -Hexanone	24 hour	1.07E-03	573400, 126700	N/A	67
2 -Pentanone	24 hour	1.69E-03	573400, 126700	N/A	2300
Acetone	24 hour	2.07E-02	573400, 126700	N/A	5900
Acetonitrile	24 hour	9.80E-03	573400, 126700	N/A	24
Ammonia	24 hour	2.5E-01	569500, 122500	N/A	100
Antimony Compounds	24 hour	5.41E-09	585500, 142500	N/A	1.7
Arsenic Compounds	Annual (1990)	4.75E-11	587500, 140500	N/A	0.00023
Barium Oxide	24 hour	6.56E-09	569500, 122500	N/A	1.7
Benzene	Annual (1993)	5.98E-06	583500, 128500	N/A	0.12
Beryllium Compounds	Annual (1990)	8.01E-13	587500, 140500	N/A	0.00042
Boric Oxide	24 hour	6.07E-06	585500, 142500	N/A	33
Cadmium Compounds	Annual (1990)	4.34E-10	587500, 140500	N/A	0.00056
Calcium Oxide	24 hour	2.01E-05	569500, 122500	N/A	6.7
Chromium Compounds	24 hour	1.30E-06	569500, 122500	N/A	1.7
	Annual (1990)	1.58E-08	569500, 122500	N/A	0.00083
Cobalt Compounds	24 hour	2.585-09	585500, 142500	N/A	0.17
Ferric Oxide	24 hour	2.35E-06	585500, 142500	N/A	17
Fluoride (as HF)	24 hour	7.37E-02	569500, 122500	N/A	2.9
HCl	24 hour	3.24E-02	569500, 122500	N/A	7
Heptane	24 hour	1.20E-03	573400, 126700	N/A	5500

Table G.4.0.18 Modeling Results for the Phased Implementation Alternative Phase 2 - Operation Phase (cont'd)

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Hexane	24 hour	1.25E-03	573400, 126700	N/A	200
Iodine	24 hour	2.95E-03	569500, 122500	N/A	3.3
Lead Compounds	24 hour	8.56E-08	569500, 122500	N/A	0.5
Manganese Compounds	24 hour	5.08E-07	569500, 122500	N/A	0.4
Methyl Isobutyl Ketone	24 hour	9.03E-05	585500, 144500	N/A	680
N-Butyl Alcohol	24 hour	9.96E-03	585500, 144500	N/A	500
Nickel Compounds	Annual (1990)	4.79E-06	587500, 140500	N/A	0.0021
Nitric Acid	24 hour	1.41E-02	569520, 122500	N/A	17
Nonane	24 hour	6.50E-04	573400, 126700	N/A	3500
Octane	24 hour	6.81E-04	573400, 126700	N/A	4700
Phosphoric Acid, Tributyl Ester	24 hour	1.32E-03	569500, 130500	N/A	3.3
Selenium Compounds	24 hour	1.14E-08	569500, 122500	N/A	0.67
Silver Oxide	24 hour	1.11E-09	585500, 142500	N/A	0.033
Tellurium Trioxide	24 hour	7.41E-10	585500, 142500	N/A	0.33
Toluene	24 hour	9.54E-05	573400, 126700	N/A	400
Uranium Trioxide	24 hour	3.64E-06	585500, 142500	N/A	0.67
Vanadium Pentoxide	24 hour	3.43E-10	569500, 122500	N/A	0.17
Zinc Oxide	24 hour	1.01E-08	569500, 122500	N/A	17
Zirconium Oxide	24 hour	1.67E-06	585500, 142500	N/A	17

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents data year producing the highest impact.

Table G.4.0.19 Modeling Results for the Onsite Disposal Alternative

Pollutant	Averaging period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	83	567500, 130500	40,000	40,000
	8 hour	58	567500, 130500	10,000	10,000
Nitrogen Oxides	Annual (1992)	0.40	583500, 128500	100	100
Sulfur Oxides	1 hour	5.0	567500, 130500	N/A	655
	3 hour	4.5	567500, 130500	1300	N/A
	24 hour	2.0	567500. 130500	365	260
	Annual (1992)	1.0E-02	583500, 128500	80	60
PM-10	24 hour	18	567500, 130500	150	150
	Annual (1992)	0.11	571500, 128500	50	50
Formaldehyde	Annual (19920	1.1E-04	583500, 128500	N/A	0.077

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents the data year producing the highest impact.

Table G.4.0.20 Modeling Results for the Overpack and Ship Alternative

Pollutant	Averaging Period	Concentration ($\mu g/m^3$)	Location (x, y) m	Standard or Level	
				Federal ($\mu g/m^3$)	State ($\mu g/m^3$)
Carbon Monoxide	1 hour	39	566600, 130800	40,000	40,000
	8 hour	27	566600, 130800	10,000	10,000
Nitrogen Oxides	Annual (1993)	0.15	583500, 128500	100	100
PM-10	24 hour	1.8	566600, 130800	150	150
	Annual (1993)	2.0E-02	583500, 128500	50	50

Note:
$\mu g/m^3$ = Micrograms per cubic meter
Annual average concentrations shown are the maximum value predicted using data from meteorological years 1989-1993.
The number in parenthesis represents the data year producing the highest impact.

Table G.4.0.21 Radionuclide Modeling Results for the No Action Alternative (Tank Waste)

Radionuclide	Maximum Dose (mrem/yr)	Location	Year [3]	Standard	
				State	Federal
Cs-137	1.32E-07	591500, 136000	1989	N/A	N/A
	2.20E-07	*569500, 130500*	*1993*	*N/A*	*N/A*
Pu-239, -240	1.11E-03	591409, 138092	1993	N/A	N/A
	1.61E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Sr-90	4.81E-07	591409, 138092	1989	N/A	N/A
	7.05E-07	*583500, 128500*	*1993*	*N/A*	*N/A*
I-129	3.78E-06	591500, 136000	1989	N/A	N/A
	6.20E-06	*583500, 128500*	*1993*	*N/A*	*N/A*
Total	1.11E-03	591409, 138092	1993	N/A	10
	1.62E-03	*583500, 128500*	*1993*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.
[3] Annual average doses are the maximum value predicted using data from meteorological years 1989-1993. The number in this column represents data the year producing the highest impact.
The results for the No Action alternative (capsules) are included in this table.

Table G.4.0.22 Radionuclide Modeling Results for the Long-Term Management Alternative Phase 1

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Cs-137	1.11E-06	591409, 133908	1989	N/A	N/A
	9.18E-06	*569500, 130500*	*1992*	*N/A*	*N/A*
Pu-239, -240	1.11E-03	591409, 138092	1989/1993	N/A	N/A
	1.61E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Sr-90	5.24E-07	591409, 138092	1989	N/A	N/A
	1.04E-06	*569500, 130500*	*1993*	*N/A*	*N/A*
I-129	3.72E-05	591409, 133908	1989	N/A	N/A
	3.07E-04	*569500, 130500*	*1992*	*N/A*	*N/A*
Total	1.14E-03	591409, 138092	1989	N/A	10
	1.66E-03	*583500, 128500*	*1993*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Table G.4.0.23 Radionuclide Modeling Results for the Long-Term Management Alternative Phase 2

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Cs-137	1.14E-06	591500, 136000	1989	N/A	N/A
	1.71E-06	583500, 128500	1992	*N/A*	*N/A*
Pu-239, -240	1.11E-03	591409, 138092	1993	N/A	N/A
	1.61E-03	583500, 128500	1993	*N/A*	*N/A*
Sr-90	5.28E-07	591409, 138092	1989	N/A	N/A
	7.92E-07	583500, 128500	1993	*N/A*	*N/A*
I-129	3.81E-05	591500, 136000	1989	N/A	N/A
	5.72E-05	583500, 128500	1993	*N/A*	*N/A*
Total	1.14E-03	591409, 138092	1989	N/A	10
	1.67E-03	*583500, 128500*	*1993*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Table G.4.0.24 Radionuclide Modeling Results for the In Situ Fill and Cap Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Cs-137	1.18E-06	591409, 133908	1989	N/A	N/A
	9.31E-06	*569500, 130500*	*1992*	*N/A*	*N/A*
Pu-239, -240	1.11E-03	591409, 138092	1993	N/A	N/A
	1.61E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Sr-90	5.16E-07	591409, 138092	1989	N/A	N/A
	9.29E-07	*569500, 130500*	*1993*	*N/A*	*N/A*
I-129	3.94E-05	591409, 133908	1989	N/A	N/A
	3.12E-04	*569500, 130500*	*1992*	*N/A*	*N/A*
Total	1.14E-03	591409, 138092	1989	N/A	10
	1.66E-03	*583500, 128500*	*1993*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Table G.4.0.25 Radionuclide Modeling Results for the In Situ Vitrification Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	7.60E-07	579500, 115215	1993	N/A	N/A
	6.05E-06	*569500, 130500*	*1993*	*N/A*	*N/A*
Cs-137	5.58E-07	579500, 115215	1993	N/A	N/A
	4.17E-06	*569500, 130500*	*1993*	*N/A*	*N/A*
Pu-239, -240	1.11E-03	591409, 138092	1989/1993	N/A	N/A
	1.61E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Sr-90	6.68E-07	591135, 140168	1990	N/A	N/A
	2.73E-06	*569500, 130500*	*1993*	*N/A*	*N/A*
I-129	8.91E-01	579500, 115215	1993	N/A	N/A
	7.10E+0	*569500, 130500*	*1993*	*N/A*	*N/A*
Ru-106	3.3E-16 [1]	579500, 115215	1992	N/A	N/A
	2.6E-15 [2]	*569500, 130500*	*1993*	*N/A*	*N/A*
Sm-151	2.9E-10 [1]	579500, 115215	1992	N/A	N/A
	2.3E-09 [2]	*569500, 130500*	*1993*	*N/A*	*N/A*
Tc-99	7.13E-11	579500, 115215	1993	N/A	N/A
	5.68E-10	*569500, 130500*	*1993*	*N/A*	*N/A*
Zr-93	2.0E-11 [1]	579500, 115215	1992	N/A	N/A
	1.6E-19 [2]	*569500, 130500*	*1993*	*N/A*	*N/A*
C-14	1.45E+0	579500, 115215	1993	N/A	N/A
	1.15E+01	*569500, 130500*	*1993*	*N/A*	*N/A*
Total	2.34E+0	579500, 115215	1993	N/A	10
	1.86E+01	*569500, 130500*	*1993*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Table G.4.0.26 Radionuclide Modeling Results for the Ex Situ Intermediate Separations Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	6.97E-03	591135, 140168	1990	N/A	N/A
	8.59E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Cs-137	9.21E-03	591135, 140168	1990	N/A	N/A
	1.14E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Pu-239, -240	8.73E-03	591135, 140168	1990	N/A	N/A
	1.07E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Sr-90	5.16E-03	591135, 140168	1990	N/A	N/A
	6.35E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
I-129	5.17E-01	591135, 140168	1990	N/A	N/A
	6.44E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Tc-99	1.27E-07	591135, 140168	1990	N/A	N/A
	1.57E-07	*587500, 140500*	*1990*	*N/A*	*N/A*
C-14	3.58E-01	591135, 140168	1990	N/A	N/A
	4.45E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Total	9.05E-01	591135, 140168	1990	N/A	10
	1.13E+00	*587500, 140500*	*1990*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas.

Table G.4.0.27 Radionuclide Modeling Results for the Ex Situ No Separations Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	9.81E-03	591135, 140168	1990	N/A	N/A
	1.25E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Cs-137	1.20E-02	591135, 140168	1990	N/A	N/A
	1.52E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Pu-239, -240	1.13E-02	591135, 140168	1990	N/A	N/A
	1.42E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Sr-90	6.77E-03	591135, 140168	1990	N/A	N/A
	8.59E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
I-129	5.18E-01	591135, 140168	1990	N/A	N/A
	6.58E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Tc-99	8.83E-07	591135, 140168	1990	N/A	N/A
	1.12E-06	*587500, 140500*	*1990*	*N/A*	*N/A*
C-14	3.59E-01	591135, 140168	1990	N/A	N/A
	4.56E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Total	9.17E-01	591135, 140168	1990	N/A	10
	1.16E+0	*587500, 140500*	*1990*	*25*	*N/A*
Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas. Radionuclide impacts from the calcination option are identical to those shown on this table, except that the maximum C-14 and total radionuclide impacts are as shown below:					
C-14	5.46E-02	591135, 140168	1990	N/A	N/A
	6.94E-02	587500, 140500	1990	N/A	N/A
Total	6.13E-01	591135, 140168	1990	N/A	10
	7.78E-01	587500, 140500	1990	25	N/A
C-14 emissions from the calcination option are 5.8E+01 Ci/yr. All other radionuclide emission rates for the calcination option are as shown above.					

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Table G.4.0.28 Radionuclide Modeling Results for the Ex Situ Extensive Separations Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	9.82E-03	591135, 140168	1990	N/A	N/A
	1.18E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Cs-137	5.99E-03	591135, 140168	1990	N/A	N/A
	7.21E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Pu-239, -240	4.12E-03	591135, 140168	1990	N/A	N/A
	4.93E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Sr-90	3.40E-03	591135, 140168	1990	N/A	N/A
	4.09E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
I-129	5.79E-01	591135, 140168	1990	N/A	N/A
	6.96E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Ru-106	4.1E-12 [1]	591135, 140168	1990	N/A	N/A
	4.9E-12 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Sm-151	3.6E-06 [1]	591135, 140168	1990	N/A	N/A
	4.4E-06 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Tc-99	8.86E-07	591135, 140168	1990	N/A	N/A
	1.07E-06	*587500, 140500*	*1990*	*N/A*	*N/A*
Zr-93	2.5E-07 [1]	591135, 140168	1990	N/A	N/A
	3.0E-07 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
C-14	4.06E-01	591135, 140168	1990	N/A	N/A
	4.88E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Total	1.01E+0	591135, 140168	1990	N/A	10
	1.21E+0	*587500, 140500*	*1990*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas.

Table G.4.0.29 Radionuclide Modeling Results for the Ex Situ/In Situ Combination 1 Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	6.27E-03	591135, 140168	1990	N/A	N/A
	7.73E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Cs-137	8.29E-03	591135, 140168	1990	N/A	N/A
	1.02E-02	*587500, 140500*	*1990*	*N/A*	*N/A*
Pu-239, -240	7.97E-03	591135, 140168	1990	N/A	N/A
	9.77E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Sr-90	4.64E-03	591135, 140168	1990	N/A	N/A
	5.72E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
I-129	4.65E-01	591135, 140168	1990	N/A	N/A
	5.79E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Tc-99	1.14E-07	591135, 140168	1990	N/A	N/A
	1.41E-07	*587500, 140500*	*1990*	*N/A*	*N/A*
C-14	3.40E-01	591135, 140168	1990	N/A	N/A
	4.23E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Total	8.32E-01	591135, 140168	1990	N/A	10
	1.04E+0	*587500, 140500*	*1990*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas.

Table G.4.0.30 Radionuclide Modeling Results for the Ex Situ/In Situ Combination 2 Alternative

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	3.23E-03 [1]	581135, 140168	1990	N/A	N/A
	3.98E-03 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Cs-137	4.13E-03 [1]	591135, 140168	1990	N/A	N/A
	5.09E-03 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Pu-239, -240	4.67E-03 [1]	591135, 140168	1990	N/A	N/A
	5.70E-03 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Sr-90	2.38E-03 [1]	591135, 140168	1990	N/A	N/A
	2.93E-03 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
I-129	7.2E-01 [1]	591135, 140168	1990	N/A	N/A
	8.95E-01 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Tc-99	6.0E-08 [1]	591135, 140168	1990	N/A	N/A
	7.38E-08	*587500, 140500*	*1990*	*N/A*	*N/A*
C-14	4.9E-01 [1]	591135, 140168	1990	N/A	N/A
	6.1E-01 [2]	*587500, 140500*	*1990*	*N/A*	*N/A*
Total	1.22 [1]	591135, 140168	1990	N/A	10
	1.52 [2]	*587500, 140500*	*1990*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas.

Table G.4.0.31 Radionuclide Modeling Results for the Phased Implementation Alternative Phase 1

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	1.0E-03	591135, 140168	1990	N/A	N/A
	1.3E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Cs-137	1.4E-03	591135, 140168	1990	N/A	N/A
	1.8E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Pu-239, -240	2.2E-03	591135, 140168	1990	N/A	N/A
	3.1E-03	*583500, 128500*	*1993*	*N/A*	*N/A*
Sr-90	7.6E-04	591135, 140168	1990	N/A	N/A
	9.9E-04	*583500, 128500*	*1993*	*N/A*	*N/A*
Tc-99	2.2E-08	591135, 140168	1990	N/A	N/A
	2.9E-08	*583500, 128500*	*1993*	*N/A*	*N/A*
C-14	1.7E-01	591135, 140168	1990	N/A	N/A
	2.2E-01	*583500, 128500*	*1993*	*N/A*	*N/A*
I-129	1.4E-01	591135, 140168	1990	N/A	N/A
	1.8E-01	583500, 128500	1993	N/A	N/A
Total	3.06E-01	591135, 140168	1990	N/A	10
	4.11E-01	*583500, 128500*	*1993*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas.

Table G.4.0.32 Radionuclide Modeling Results for the Phased Implementation Alternative Phase 2

Radionuclide	Maximum Dose (mrem/yr)	Location	Year	Standard	
				State	Federal
Am-241	4.17E-03	591135, 140168	1990	N/A	N/A
	5.14E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Cs-137	4.67E-03	591135, 140168	1990	N/A	N/A
	5.75E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Pu-239, -240	4.93E-03	591135, 140168	1990	N/A	N/A
	6.02E-03	*587500, 140500*	*1990*	*N/A*	*N/A*
Sr-90	6.26E-07	591135, 140168	1990	N/A	N/A
	8.54E-07	*583500, 128500*	*1993*	*N/A*	*N/A*
I-129	4.70E-01	591135, 140168	1990	N/A	N/A
	5.58E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Tc-99	6.36E-08	591135, 140168	1990	N/A	N/A
	7.83E-08	*587500, 140500*	*1990*	*N/A*	*N/A*
C-14	2.88E-01	591135, 140168	1990	N/A	N/A
	3.43E-01	*587500, 140500*	*1990*	*N/A*	*N/A*
Total	3.93E-01	591135, 140168	1990	N/A	10
	4.89E-01	*587500, 140500*	*1990*	*25*	*N/A*

Notes:
[1] Results in standard type compare the maximum predicted dose at the nearest residence to the 10 mrem/yr effective dose equivalent standard of 40 CFR Part 61.
[2] Results in italic type compare the maximum accumulated dose equivalent at any offsite receptor to the 25 mrem/yr standard contained in WAC 173-480.

Results shown are for the operational phase of the alternative. Radionuclide impacts for the construction phase are the same as those shown for the No Action alternative (tank waste). No radionuclides will be emitted from the construction areas.

APPENDIX G
REFERENCES

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Appendix H
Socioeconomic Impact Modeling

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ACRONYMS AND ABBREVIATIONS

D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
HLW	high-level waste
LAW	low-activity waste
M&M	monitoring and maintenance
MSA	Metropolitan Statistical Area
NEPA	National Environmental Policy Act
TAR	Tri-Cities Association of Realtors
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TWRS	Tank Waste Remediation System
WSDES	Washington State Department of Employment Security
WSDFM	Washington State Department of Financial Management
WSDR	Washington State Department of Revenue

NAMES AND SYMBOLS FOR UNITS OF MEASURE, RADIOACTIVITY, AND ELECTRICITY/ENERGY

Length

cm	centimeter
ft	foot
in	inch
km	kilometer
m	meter
mi	mile

Area

ac	acre
ft^2	square foot
ha	hectare
km^2	square kilometer
mi^2	square mile

Volume

cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
ppb	parts per billion
ppm	parts per million
yd^3	cubic yard

Mass

g	gram
kg	kilogram
lb	pound
mg	milligram
mt	metric ton

Radioactivity

Ci	curie
MCi	megacurie (1.0E+06)
mCi	millicurie (1.0E-03 Ci)
μCi	microcurie (1.0E-06 Ci)
nCi	nanocurie (1.0E-09 Ci)
pCi	picocurie (1.0E-12 Ci)

Electricity/Energy

A	ampere
J	joule
kV	kilovolt
kW	kilowatt
MeV	million electron volts
MW	megawatt
V	volt
W	watt

Temperature

°C	degrees centigrade
°F	degrees Fahrenheit

APPENDIX H
SOCIOECONOMIC IMPACT MODELING

H.1.0 INTRODUCTION

This appendix describes the socioeconomic impact modeling for the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS) alternatives. It describes the methodology and assumptions used in the modeling effort and provides additional technical information about the analysis. This appendix discusses:

- The development of the baseline Hanford Site employment estimates used to assess the socioeconomic impacts of the EIS alternatives;
- The econometric forecasting model used to project economic variables; and
- Details of the employment projections for the EIS alternatives.

The appendix also includes tables showing socioeconomic impacts for each alternative during each year of the remediation period, analyzed up to the year 2040.

The socioeconomic impact analysis addresses the Tri-Cities Metropolitan Statistical Area (MSA), which encompasses all of Benton and Franklin counties. The analysis does not address impacts on other areas of the region because there are too few Hanford Site employees in the surrounding counties for changes in Hanford Site employment to cause substantial economic impacts there. Historically, only about 7 percent of the total Site work force has lived outside Benton and Franklin counties (Cushing 1995). Most of these employees live in Yakima County, which has a total nonfarm employment of over 65,000 (WSDES 1993b). With Hanford Site employees representing approximately 1 percent of total Yakima County nonfarm employment, the EIS alternatives would have too small an employment impact to warrant detailed analysis. The analysis does not address potential economic impacts of accidents that potentially could occur during implementation of the alternatives. Because there is a very low probability that an accident would have major economic impact, this issue does not warrant detailed analysis. However, Appendix E does provide a discussion of potential impacts associated with remediation accidents and mitigation measures that would be taken to address those impacts.

It was assumed that the schedule for implementing each alternative would meet the applicable Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) milestones (Ecology et al. 1994). There are uncertainties related to waste characterization (Appendix A, Section A.3.0) and waste loading (Appendix B, Section B.3.10 and B.8.0) that could affect the schedules for completing all of the ex situ alternatives. Under conservative case conditions, because of these uncertainties completing the ex situ alternative could require from one to four years beyond the applicable Tri-Party Agreement milestones for low-activity waste. However, there are factors that could compensate for these uncertainties and allow the Tri-Party Agreement schedule to be maintained. For example, it may be possible to achieve a higher percentage of waste loading than projected under the conservative case. Also, larger processing facilities could be constructed or construction schedules could be accelerated, both of which could shorten alternatives' schedules for completion.

Section H.1.1 provides a discussion of the assumptions, data, methodology, and uncertainties directly associated with the development of the baseline scenario used to calculate and compare the impacts of the EIS alternatives. The major uncertainties are associated with the projection of future levels of non-TWRS Hanford Site employment and future overall employment in the Tri-Cities MSA. In both cases, substantial changes in future overall employment would change each alternative's impact on future Hanford Site employment, Tri-Cities MSA nonfarm employment, population, taxable retail sales, and average home prices. In turn, changes to the population projection would result in comparable changes to each alternative's impact on public services and facilities such as schools, police, and fire (Volume One, Section 5.6). Also, changes to the projection of future Hanford Site employment would result in changes to the analysis of transportation impacts (Volume One, Section 5.10). In each case, however, the changes in future employment would impact all of the alternatives equally. Therefore, while the level of each impact would change, the comparison of the relative impacts among the alternatives would not be affected.

In the time between publication of the Draft EIS and preparation of the Final EIS, revisions have occurred in the schedules of a number of EIS alternatives. In all cases except for Phase 2 of the Phased Implementation alternative, these schedule changes would have a very small effect (less than 5 percent) on the level or timing of employment under the various alternatives. Because this is well within the accuracy of the socioeconomic modeling, the modeling was not revised.

The Final EIS includes a new alternative that was not analyzed in detail in the Draft EIS. This alternative, the Ex Situ/In Situ Combination 2 alternative, would have lower overall employment levels than the Ex Situ/In Situ Combination 1 alternative that was analyzed in detail in the Draft EIS. However, the timing of the employment peaks under the Ex Situ/In Situ Contamination 2 alternative, as well as the duration of its construction and operations phases, would be similar to the Ex Situ/In Situ Combination 1 alternative. Data are provided in this appendix for peak and average employment levels for the Ex Situ/In Situ Combination 2 alternative. However, no socioeconomic modeling has been performed because of its similarity to the Ex Situ/In Situ Combination 1 alternative.

H.1.1 DEVELOPMENT OF THE BASELINE ECONOMIC ESTIMATE

This section describes the assumptions, data, and methodology used to develop the baseline estimate of future economic activity in the Richland, Kennewick, and Pasco (also called the Tri-Cities) MSA. This estimate was used to analyze the socioeconomic impacts of the EIS alternatives.

The socioeconomic impact analysis compares the impacts of the EIS alternatives to an estimate of future economic conditions in the Tri-Cities area, based on Hanford Site employment in the absence of any TWRS activities (except for a phased shutdown of routine tank farm operations). The scenario for future Hanford Site employment that provided the baseline for the impact analysis was calculated using the following method:

1) The latest available estimate of total Hanford Site employment was obtained from Hanford Site facility planning personnel (Daly 1995). This estimate assumed implementing the TWRS program as defined by the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology et al. 1994).
2) Labor requirements were estimated over time to implement the TWRS programs as defined in the Tri-Party Agreement, based on engineering data provided by the Hanford Site Management and Operations contractor (WHC 1995a). The engineering data were provided for total labor hours by phase of the activity. The EIS contractor then adjusted the labor hours to reflect the final alternatives selected for analysis in the EIS and to ensure consistency in the methodology used to develop labor estimates among the alternatives (Jacobs 1996). These data were then provided for inclusion as inputs into the socioeconomic modeling.
3) The labor requirements for the TWRS program were then subtracted from the overall estimate of Hanford Site employment to derive a calculational baseline for Hanford Site employment that excludes remediation of the tank waste.

This calculational baseline for Hanford Site employment (total employment without TWRS employment) then was used in an econometric forecasting model to analyze the socioeconomic impacts of the various EIS alternatives. Figure H.1.1.1 shows both the estimate of total Site employment and the calculational baseline of total Site employment without TWRS employment. All figures and tables in this appendix are provided after page H-15.

Assumptions incorporated into the impact analysis included the following:

- The latest available estimated total Hanford Site employment (including potential TWRS activities as defined in the Tri-Party Agreement) was derived from data for selected years between 1994 and 2025. The intervening years were estimated using straight-line interpolation. For the years subsequent to 2025, a straight-line extrapolation was used, with 2040 as the end year.
- The latest available estimated total Hanford Site employment incorporated planned restructuring of the Hanford Site labor force, including early retirements and reductions in force, as well as new hires expected in 1995 for the Hanford Site environmental restoration contractor, and for the U.S. Department of Energy (DOE), Richland Operations Office. Because plans for labor force restructuring and new hires are under constant review, these estimates are imprecise but are the best currently available.
- The latest available total Hanford Site labor employment estimate includes other (non-TWRS) environmental cleanup and restoration activities, operations and maintenance, research and development (including the Environmental and Molecular Sciences Laboratory and the Laser Interferometer Gravitational Wave Observatory), and facilities management personnel required to operate and maintain the Hanford Site.
- The data on the proposed TWRS program, as defined in the Tri-Party Agreement, provided by the Hanford Site Management and Operations contractor and the TWRS EIS contractor were used in the following manner. Annual employment data were developed based on engineering projections that allocated estimated labor requirements

over the different phases of the project. The annual labor requirements data were then interpolated (or assigned intermediate values) to provide quarterly data, as required by the regression model, to be used to estimate impacts. Because the total Hanford Site employment data were estimated using smoothed interpolations, the TWRS Tri-Party Agreement labor requirements estimates also were smoothed using a 30-quarter moving average before subtracting them from the total Hanford Site employment estimates to obtain the calculational baseline employment estimates. This smoothing was done to maintain consistency between the two data series. Without smoothing the data, the annual fluctuations in the TWRS Tri-Party Agreement data would have been transferred to the calculational baseline estimate, creating a misleading result. However, the smoothed TWRS Tri-Party Agreement data were used only to estimate calculational baseline employment. The socioeconomic impact analysis of the EIS alternatives used unsmoothed data added to the calculational baseline. The calculational baseline estimate used to construct estimates of total Hanford Site employment for each of the proposed EIS alternatives is described in Section H.3.1.

- Routine operations at the tank farms were included in the latest available total Hanford Site employment estimate and in the estimated labor requirements for the TWRS Tri-Party Agreement labor estimate. As envisioned in the Tri-Party Agreement, tank farm routine operations would be phased out over time as remediation occurs. Estimates for employment in routine operations (including phaseouts over time) were incorporated into the labor requirements for the other TWRS EIS alternatives as described in Section H.3.1. The inclusion of the routine operations labor estimate in the calculational baseline was factored into the labor estimates for each of the alternatives. Routine operations were estimated to require 1,016 full-time equivalent employees. In the calculational baseline, it was assumed that the routine operation activities would phaseout beginning in 2005, with an end to routine operations in 2029. For alternatives with routine operations extending at current levels beyond 2005, the labor required to maintain the 1,016 employment level was added to the alternative labor estimates. This was the case for the No Action, Long-Term Management, and In Situ Fill and Cap alternatives. For other alternatives that ended routine operations prior to 2029, the appropriate level of employment was subtracted for the labor estimate. This was the case for the In Situ Vitrification, Ex Situ/In Situ Combination 1, Ex Situ/In Situ Contamination 2, and Phased Implementation alternatives.

The calculational baseline estimate of Hanford Site employment is used only to provide a basis for analyzing the impacts of the proposed EIS alternatives. These impacts are measured in terms of percentage changes from the calculational baseline. Neither the calculational baseline nor the impact analysis itself is intended to be a precise forecast of future economic conditions in the Tri-Cities MSA. Any forecast that extends over 40 years can only project current trends and is subject to unpredictable changes in future economic conditions. The Tri-Cities is in the early stages of an economic transition as Site employment decreases. There are currently little definitive data to indicate how successful attempts to diversify the local economy will be in reducing dependence on the Hanford Site, the area's

largest single employer. Likewise, any estimates of future Hanford Site employment under any scenario must be considered as estimates rather than definitive data. The calculational baseline estimate, however, provides a consistent projection of one possible path for Hanford Site employment that can be used as the basis for analyzing and comparing the impacts of the EIS alternatives. Changes in future Hanford Site employment or future Tri-City MSA employment would affect the amount of population growth, taxable sales growth, housing price changes, and other socioeconomic factors analyzed in the EIS. However, such future employment changes would affect all EIS alternatives equally and thus would not affect the comparison of the relative impacts of the alternatives.

H.2.0 ECONOMETRIC FORECASTING MODEL METHODOLOGY

Quantitative projections of the impacts of the TWRS EIS alternatives on nonfarm employment, population, housing prices, and taxable retail trade were obtained by regression analysis, using Hanford Site employment as the key independent variable. The regression analysis used data from historical experience to determine the statistical relationship between Hanford Site employment and total Tri-Cities MSA nonfarm employment (1987 to 1993), and the statistical relationship between nonfarm employment and taxable retail sales (1987 to 1993), population (1980 to 1993), and housing market conditions (1980 to 1993). These statistical relationships provide information on the potential impacts of future changes in Hanford Site employment on retail sales, population, and housing market conditions.

Analyzing the impacts of the EIS alternatives required specific estimates of labor hours for implementing each alternative. In each case, these labor hours were estimated based on cost and labor input data supplied by the Hanford Site Management and Operations contractor (WHC 1995a, c, e, f, g, h, i, j, n) and by the TWRS EIS contractor (Jacobs 1996). The data first were estimated as annual average full-time equivalent employees, then interpolated to obtain quarterly full-time equivalent employees (at annual rates). The labor estimates for the EIS alternatives then were added to the calculational baseline estimate of total Hanford Site employment to obtain total Hanford Site employment estimates under each alternative. The estimates of total Hanford Site employment associated with the EIS alternatives then were used to estimate impacts on nonfarm employment in the Tri-Cities MSA. Because Hanford Site activities do not impact farm employment, the analysis addresses nonfarm employment only. Nonfarm employment then was used to estimate impacts on taxable retail sales and population. Population was used to estimate impacts on housing prices.

1. The econometric model used to estimate impacts accounts for the "multiplier effect" of Hanford Site jobs on the Tri-Cities economy. For each new job at the Hanford Site, it was estimated that approximately 2.4 jobs would be created in the nonfarm employment sector. These jobs, as well as the new Hanford Site jobs, then were used in estimating other impacts, including taxable retail sales, population, and housing market conditions. This 2.4 multiplier is in reasonably close agreement with employment multipliers used in other recent Hanford Site National Environmental Policy Act (NEPA) documents. For example, the Safe Interim Storage of Hanford's Tank Waste Final EIS (DOE 1995i) used a 2.2 multiplier based on input/output analysis by the Pacific Northwest National Laboratory. However, the model used for the

TWRS is based on historical data for the Tri-Cities through the end of 1993, whereas the Pacific Northwest National Laboratory multiplier was developed in the late 1980's and is considered to be less representative of current economic conditions. These two models are the only known comprehensive economic models that were developed by analyzing the local economy.

All equations are linear and were estimated using ordinary least squares. The following sections of this appendix (H.2.1 through H.2.4) document the regression equations used in the quantitative assessments.

H.2.1 EMPLOYMENT

The regression equation for total Tri-Cities MSA nonfarm employment uses quarterly data from the third quarter of 1987 to the fourth quarter of 1993 and has the following explanatory variables:

X1 = Hanford Site employment (full-time equivalent employees);
X2 = Time trend;
X3 = First quarter dummy variable;
X4 = Lagged Hanford Site employment (one year or four quarters); and
Y1 = Nonfarm employment.

The time trend starts at one for the third quarter of 1987. Data on Hanford Site employment were obtained from the DOE Richland Operations Office. Data on Tri-Cities MSA employment were obtained from the Washington State Department of Employment Security (WSDES 1993b).
Table H.2.1.1 shows the data used to estimate the regression equation. The T-value for each estimated parameter (a measure of the statistical significance of the estimated parameter, where a T-value greater than two means that there is a high degree of confidence that the true value of the parameter is different than zero) is shown in parentheses. The adjusted R-squared value (a measure of the goodness-of-fit of the estimated equation) is shown immediately after the equation. An adjusted R-squared value of 1.0 indicates a perfect fit.

The estimated equation for employment is:

$$Y1 = 36998.466489 + 2.438843 \cdot X1 + 209.789246 \cdot X2 - 1500.74503 \cdot X3 - 0.822646 \cdot X4$$
$$\quad (4.574603) \quad (3.103108) \quad (1.039399) \quad (-4.539982) \quad (-4.440990)$$

Adjusted R-squared: 0.986

Note:
· = Multiplied by

H.2.2 TAXABLE RETAIL SALES

The regression equation for taxable retail sales uses quarterly data from the third quarter of 1987 to the third quarter of 1993 (the latest data available). The equation has the following explanatory variables:

X5 = Time trend;
X6 = Quarterly nonfarm employment at annual rates;
X7 = First quarter dummy variable;
X8 = Fourth quarter dummy variable; and
Y2 = Taxable retail sales.

The data on taxable retail sales were obtained from the Washington State Department of Revenue (WSDR 1993). Table H.2.2.1 shows the data used to estimate the regression equation.

The equation for taxable retail sales is:

$$Y2 = -68.899165 + 5.089547 \cdot X5 + 0.005126 \cdot X6 - 37.779538 \cdot X7 + 0.687021 \cdot X8$$
$$(-0.613913) \quad (3.652568) \quad (2.471805) \quad (-4.976665) \quad (0.108059)$$

Adjusted R-squared: 0.964
Note:
· = Multiplied by

H.2.3 POPULATION

The regression equation for population in the Tri-Cities MSA used annual data on population for 1980 to 1993. The explanatory variables are:

X14 = Time trend;
X15 = Annual average nonfarm employment, with a lag of 1 year; and
Y3 = Population.

The time trend starts at one for 1980, although 1980 is not used in the regression because lagged employment is used. The data on population comes from the 1980 and 1990 U.S. Census (DOC 1991) and the Washington State Department of Financial Management (WSDFM 1987-95) for years other than 1980 and 1990. Table H.2.3.1 shows the data used in the regression analysis.

The equation for population is:

$$Y3 = 58107.265102 + 358.944822 \cdot X14 + 1.465489 \cdot X15$$
$$(3.805755) \quad (1.160945) \quad (5.370630)$$

Adjusted R-squared: 0.764
Note:
· = Multiplied by

H.2.4 AVERAGE HOME PRICES

The regression equation for the average home price in the Tri-Cities MSA used annual data for 1980 to 1993 (HBA 1994). The explanatory variables are:

X9 = Time trend;
X10 = Population; and
Y4 = Average home price.

Data on home prices were obtained from the Tri-Cities Association of Realtors (TAR 1995). Table H.2.4.1 shows the data used to estimate the equation.

The equation for the average home price is:

$$Y4 = -176.372436 + 0.508830 \cdot X9 + 0.001653 \cdot X10$$
$$(-7.901429) \quad (1.755588) \quad (10.435336)$$

Adjusted R-squared: 0.926

Note:
· = Multiplied by

H.3.0 TWRS EIS ALTERNATIVES IMPACT PROJECTIONS

For each EIS alternative, the economic impact estimates were made using the following four steps.

1) Estimates of total Hanford Site employment under the alternative were used to estimate quarterly nonfarm employment.
2) Estimated quarterly nonfarm employment was used to estimate quarterly taxable retail sales. Quarterly sales were summed for each year to yield estimated annual taxable retail sales.
3) Quarterly sales estimates of nonfarm employment for each year were averaged to estimate the average annual employment for that year. Average annual employment was lagged 1 year and then used to estimate population.
4) Annual population estimates were used to estimate average annual home prices.

H.3.1 HANFORD SITE EMPLOYMENT PROJECTIONS

This section provides detail on the development of the employment estimates for the EIS alternatives. For each alternative, the annual average employment was estimated for each phase of activity based on engineering data and cost estimates provided by the Hanford Site Management and Operations contractor (WHCa, c, e, f, g, h, i, j, n) and the TWRS EIS contractor (Jacobs 1996).

Employment for each phase of each EIS alternative was divided into three phases for purposes of this analysis. These phases are 1) construction of facilities; 2) facilities operations; and 3) post remediation, including decontamination and decommissioning (D&D) of remediation facilities and monitoring and maintenance (M&M) activities as applicable. Activities for each phase then were divided into waste retrieval, waste transfer, and waste processing activities. For analytical purposes, the estimates of waste retrieval and processing activities were aggregated into the construction, operations, and post-remediation phases. Each alternative would also involve routine operations of the tank farms that,

for all alternatives except No Action and Long-Term Management, would be phased out over time as remediation occurs.

Once total annual average employment for each alternative was derived by combining the annual data for the various phases, the data were converted to quarterly employment by straight line interpolation. Interpolation was used to build ramp-up and ramp-down periods into the quarterly Hanford Site employment data, which more accurately reflect the process of increasing or decreasing staffing levels for large-scale projects. However, because of the interpolations, annual average Hanford Site employment data as used in the forecasts and reported in Tables H.3.2.1 through H.3.2.3 will differ slightly from the annual employment data reported in Tables H.3.1.1 through H.3.1.10. Then, the quarterly data for the alternatives were added to the calculational baseline of quarterly average total Hanford Site employment. The resulting estimate of total Hanford Site employment under each alternative then was input to the forecasting model to produce the socioeconomic impact analysis for the Tri-Cities MSA.

No Action Alternative (Tank Waste)

The No Action alternative would have one phase: routine tank farm operations. Figure H.3.1.1 and Table H.3.1.1 show the number of potential full-time equivalent employees by phase under this alternative. The routine tank farm operations phase assumes that routine operations would be maintained at the TWRS program Tri-Party Agreement level through 2005. After 2005, the TWRS program Tri-Party Agreement would involve a steady phaseout of routine operations, while the No Action alternative would maintain routine operations staffing at the 2005 level of just over 1,000 full-time equivalent employees. The difference between routine operations employment under the No Action alternative and under the TWRS program Tri-Party Agreement was used to calculate total employment for the No Action alternative. Use of the TWRS program Tri-Party Agreement routine operations estimates in the baseline estimate resulted in the need to add employment to the No Action alternative estimates from 2005 through 2029. The jobs were added to maintain employment levels at 1,016 for routine operations.

Long-Term Management Alternative

The Long-Term Management alternative would have two phases: 1) routine tank farm operations; and 2) tank replacement (which would include waste retrieval and transfer activities as well as new tank construction).

The routine operations phase of the Long-Term Management alternative is identical to the routine operations phase for the No Action alternative. The Long-Term Management alternative assumes that the double-shell waste tanks would be replaced every 50 years. The data in Table H.3.1.2 and Figure H.3.1.2 show one such replacement cycle in the 2030's. Future tank replacements would occur beyond the 2040 time frame for the analysis in this EIS.

In Situ Fill and Cap Alternative

This alternative would involve neither a waste retrieval and transfer or a D&D phase. The phases for the In Situ Fill and Cap alternative would include:

- Construction (install fill equipment);
- Fill and cap operations;
- Post remediation - M&M and tank closure; and
- Routine tank farms operations.

Employment under this alternative would be low; a maximum change from the calculational baseline of less than 150 in the peak year, which is approximately 1 percent of the calculational baseline total Hanford Site employment. Figure H.3.1.3 and Table H.3.1.3 show the number of full-time equivalent employees by phase for the In Situ Fill and Cap alternative. Under this alternative, routine tank farm operations would differ greatly from the TWRS program Tri-Party Agreement estimate. The In Situ Fill and Cap alternative would result in a faster completion of tank waste remediation, which would result in routine operations being phased out sooner. The calculation of Hanford Site employment under the In Situ Fill and Cap alternative includes the difference between routine tank farm operations under the TWRS program defined in the Tri-Party Agreement and routine operations under the In Situ Fill and Cap alternative. This difference would represent a reduction in Hanford Site employment, as compared to the baseline. Because of this difference, the estimate of employment impacts presented in Figure H.3.1.3 and Table H.3.1.3 show a negative estimate of total employment under the alternative from 2023 through 2030. This comparison only represents a negative number of jobs compared to the baseline estimate.

In Situ Vitrification Alternative

The In Situ Vitrification alternative would not involve waste retrieval and transfer but would involve a relatively minor D&D phase. The operations phases for this alternative would include:

- Vitrification facilities construction;
- Vitrification operations;
- Post-remediation activities - M&M, D&D, and tank closure; and
- Routine tank farm operations.

Figure H.3.1.4 and Table H.3.1.4 show the number of full-time equivalent employees by phase for the In Situ Vitrification alternative.

Ex Situ Intermediate Separations Alternative

The Ex Situ Intermediate Separations alternative would involve the following phases:

- Waste retrieval and transfer - construction;
- Waste retrieval and transfer - operations;
- Waste retrieval and transfer - D&D;
- Waste processing - construction;
- Waste processing - operations;

- Post remediation - M&M, D&D, and tank closure; and
- Routine tank farm operations.

Figure H.3.1.5 and Table H.3.1.5 show projected employment for each phase of the alternative. The routine operations phase is identical to the routine operations estimate for the TWRS program as defined in the Tri-Party Agreement, and it is therefore currently built into the baseline projection as part of the current forecast of Hanford Site employment. Because of this, routine operations were not separately incorporated into the calculated Hanford Site employment for this alternative. Construction employment for both waste retrieval and transfer and for the vitrification facilities would peak in the year 2000 and decline sharply through 2010. Operations employment would begin in 1997, climb steadily from 2001 through 2003, level off for several years, and then climb sharply in 2009 when full-scale waste processing operations would begin. Operations employment would drop off sharply in 2019, at which point post-remediation activities would be conducted.

Ex Situ No Separations Alternative

This alternative's breakdown by phase is the same as for the Ex Situ Intermediate Separations alternative. Figure H.3.1.6 and Table H.3.1.6 show employment for the Ex Situ No Separations alternative by construction, operations, and post-remediation phases. The data show a large spike in construction activity in the period 1997 to 2003. Not only would the level of employment for construction reach almost 4,500 jobs in 2000, but the period of construction activity would be very short, with construction jobs falling to 3,000 in 2001 and below 1,000 by 2003.

Ex Situ Extensive Separations Alternative

Employment would involve the same phases for this alternative as for the Ex Situ Intermediate Separations alternative. As shown in Figure H.3.1.7 and Table H.3.1.7, employment under the alternative would result in two spikes in construction activity. Both spikes would occur during construction of the waste processing facilities. The boom-bust cycle reflected by the two spikes would result in substantial economic impacts because of the transient nature of crews working on large construction projects. The Tri-Cities MSA experienced similar conditions in the early 1980's with the Washington Public Supply System nuclear project (as noted in Section 4.6).

Ex Situ/In Situ Combination 1 Alternative

This alternative is a combination of the In Situ Fill and Cap alternative and the Ex Situ Extensive Separations alternative. The waste from approximately 70 tanks would be retrieved, transferred, and processed as described for the Ex Situ Intermediate Separations alternative, with the remaining tanks undergoing fill and cap construction and operations activities as described for the In Situ Fill and Cap alternative. The breakdown by phases for Ex Situ/In Situ Combination 1 alternative would be as follows:

In Situ Fill and Cap Component

- Construction (install fill equipment);
- Fill and cap operations;

Ex Situ Intermediate Separations Component

- Waste retrieval and transfer - construction;
- Waste retrieval and transfer - operations;

- Post remediation M&M, D&D; and tank closure; and
- Routine tank farm operations.
- Waste retrieval and transfer - D&D;
- Waste processing - construction;
- Waste processing - operations;
- Post remediation M&M, D&D, and tank closure; and
- Routine tank farm operations.

Figure H.3.1.8 and Table H.3.1.8 show estimated employment under the Ex Situ/In Situ Combination 1 alternative by project phase. Construction activity, including both waste retrieval and transfer and waste processing facilities, would peak in 2000, and then begin a steady decrease through 2010. After several years of level employment, construction activity then would fall steadily until it ends in 2018. Operations, including both transfer and retrieval and waste processing, would begin to increase in the late 1990's with a fairly level period between 2003 and 2009. This would be followed by a large increase to a peak level in 2010, when waste processing would reach its full operational status. After 2018, operations would decline sharply when the post-remediation activity (including tank closure and D&D of facilities) would occur. Except for minimal M&M activities, total Hanford Site employment for the Ex Situ/In Situ Combination 1 alternative and the calculational baseline would converge by 2030.

Ex Situ/In Situ Combination 2 Alternative

This alternative is very similar to the Ex Situ/In Situ Combination 1 alternative except that wastes would be retrieved from 25 tanks rather than from approximately 70 tanks under the Ex Situ/In Situ Combination 1 alternative. The remainder of the 177 tanks would undergo fill and cap construction and operations activities as described for the Ex Situ/In Situ Combination 1 alternative. The primary difference between the two Ex Situ/In Situ Combination alternatives is that the Ex Situ/In Situ Combination 2 alternative would involve scaled-down waste retrieval, waste transfer, and waste processing activities, which include pretreatment, LAW processing, high-level waste (HLW) processing, LAW vaults, and HLW temporary storage. This smaller scale of operations is because there would be fewer tanks from which the waste would be retrieved and a smaller volume of waste to be processed. The smaller scale of operations generally would result in lower levels of employment to implement the Ex Situ/In Situ Combination 2 alternative than would be required for the Ex Situ/In Situ Combination 1 alternative, particularly during the operations phase. However, the timing of the employment peaks and the nature and duration of the various phases of activity would be similar between these two alternatives.

Peak construction phase employment under the Ex Situ/In Situ Combination 2 alternative would occur in the year 2001 at about 2,200 workers. Over the 14-year construction period, employment would average about 1,400 workers. Over the 35-year operating period under this alternative, there would be a broad peak employment period from the year 2008 to 2019. During this peak period, employment would average approximately 750 workers. Over the entire 35-year operations period, employment would average about 430 workers.

As mentioned in Section H.1.0, no detailed year-by-year employment data were generated for the Ex Situ/In Situ Combination 2 alternative, nor was any socioeconomic modeling performed to assess its impacts. Thus, this appendix contains no detailed data tables or graphics for this alternative, either describing employment under the alternative or evaluating its impacts on overall Tri-Cities nonfarm employment, population, taxable retail sales, or housing prices. The lower levels of employment under this alternative compared to the Ex Situ/In Situ Combination 1 alternative would result in smaller socioeconomic impacts on the Tri-Cities area.

Phased Implementation Alternative

The Phased Implementation alternative differs from the other alternatives, and this difference is reflected in the economic impact analysis. Phased Implementation would involve a demonstration phase (Phase 1) and a full-scale treatment phase (Phase 2). The demonstration phase would involve two combined separations and LAW facilities and one separations and HLW vitrification facility. After completing the demonstration phase, the demonstration plants would be shut down and two LAW vitrification facilities and one HLW vitrification facility would be built, together with waste retrieval and transfer facilities. The full-scale facilities would operate through 2025. The economic impact analysis is divided into two parts; Phase 1 covers the demonstration phase only, and the total alternative covers the entire Phased Implementation alternative.

Labor force requirements for the Phased Implementation alternative were based on the Ex Situ Intermediate Separations alternative, scaled for the reduced size of the facilities, and include construction, operation, and post-remediation labor force for the two plants. In addition, there was a further 15 percent reduction in labor force requirements based on an improved overall efficiency in operating personnel operations during the first phase.

Phase 1

Phase 1 of the Phased Implementation alternative would consist of construction, operations, and post remediation (including D&D).

Because this alternative would involve a reduced-scale demonstration and terminate in 2012 after processing only a portion of the tank waste, routine operations are assumed to be the same as under the calculational baseline and are not separately identified. Also, M&M activities are not included because of the limited duration of the alternative. A small number of workers would be involved in transferring waste from the tanks to the treatment facility and are included in the operations phase labor force projections. Figure H.3.1.9 and Table H.3.1.9 show the labor force projections for each element of the alternative. Since publication of the Draft EIS, changes in Phase 1 of this alternative resulted in estimated employment levels that are within 2 percent of the levels presented in the Draft EIS. Thus, socioeconomic impacts for Phase 1 would be very similar to those presented in the Draft EIS.

Total Alternative

The total Phased Implementation alternative would consist of construction, operations, post remediation (including D&D and M&M), and routine operations.

Labor requirements for the total Phased Implementation alternative track the Phase 1 labor requirements through 2003. Construction of waste retrieval and transfer facilities for Phase 2 would begin in 2004. Construction of the waste treatment facility would begin in 2005. Operation of the Phase 2 waste retrieval and treatment facilities would extend through 2025. D&D of the waste retrieval and transfer facilities would begin in 2015 and extend through 2027, while D&D of the waste treatment facilities would begin in 2022 and extend through 2030. Tank closure would begin in 2016 and conclude in 2039. Routine operations virtually would be the same as in the calculational baseline, except for some accelerated reduction in the labor force after 2020. Figure H.3.1.10 and Table H.3.1.10 show the labor force projections for each phase.

Capsule Alternatives

The maximum number of employees that would be involved in implementing any of the capsule alternatives would be 47 employees in the peak year. This low level of employment will not have a measurable impact on current and future socioeconomic conditions. For this reason, the socioeconomic impacts of capsule alternatives were not modeled. However, where appropriate, data regarding employment under the alternatives are presented in Section 5.6.

H.3.2 DATA TABLES FOR IMPACTS OF TWRS EIS ALTERNATIVES

The annual impacts of the EIS alternatives are presented in the following data tables.

Data regarding Hanford Site employment are presented in Tables H.3.2.1, H.3.2.2, and H.3.2.3. Tri-Cities nonfarm employment data are presented in Tables H.3.2.4, H.3.2.5, and H.3.2.6. Data regarding Tri-Cities population are presented in Tables H.3.2.7, H.3.2.8, and H.3.2.9. Tri-Cities taxable retail sales data are presented in Tables H.3.2.10, H.3.2.11, and H.3.2.12 and data regarding Tri-Cities housing prices are presented in Tables H.3.2.13, H.3.2.14, and H.3.2.15.

For all tables presented in this Appendix, routine operations are those in addition to routine operations labor requirements under the TWRS program Tri-Party Agreement estimate, which includes approximately 1,000 employees for routine operations through 2005 and a phaseout of employment through 2029. The employment estimate assumes employment for routine operations would continue at 1995 levels through 2040. Negative numbers in Tables H.3.1.3 to H.3.1.10 and H.3.2.1 to H.3.2.15 result from the phaseout of routine operations on an earlier schedule than included in the TWRS program Tri-Party Agreement estimates.

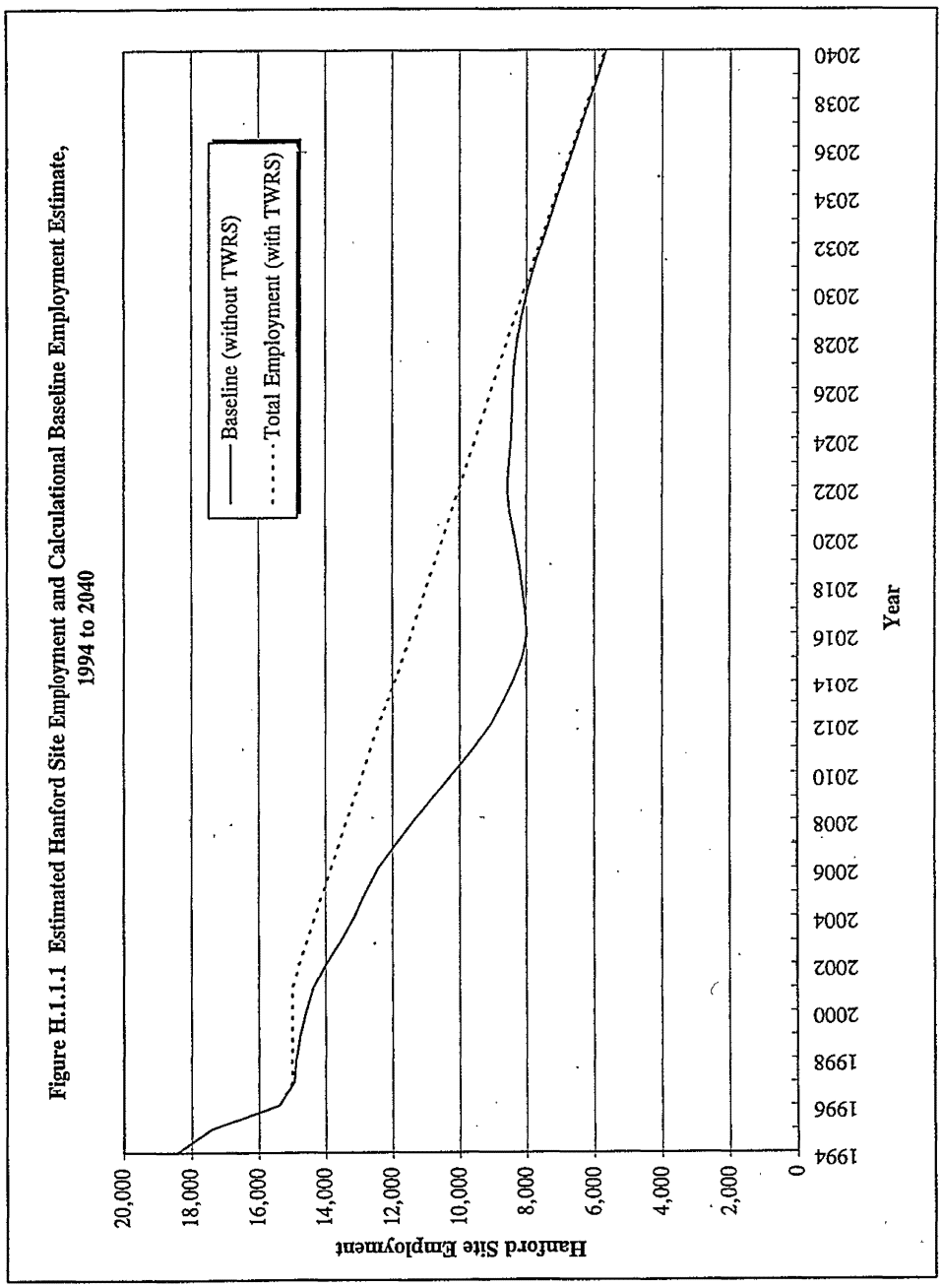


Figure H.1.1.1 Estimated Hanford Site Employment and Calculational Baseline Employment Estimate, 1994 to 2040

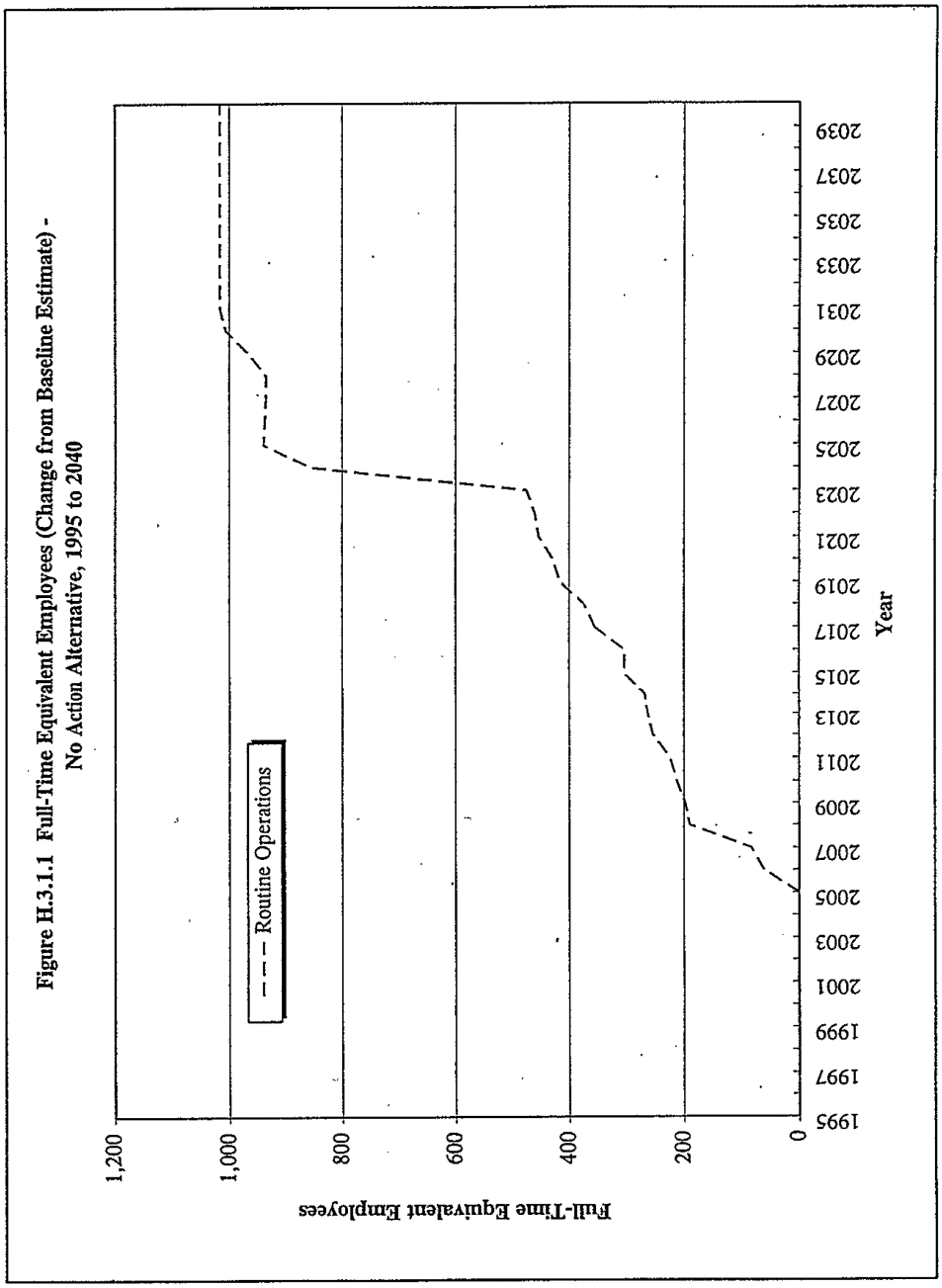
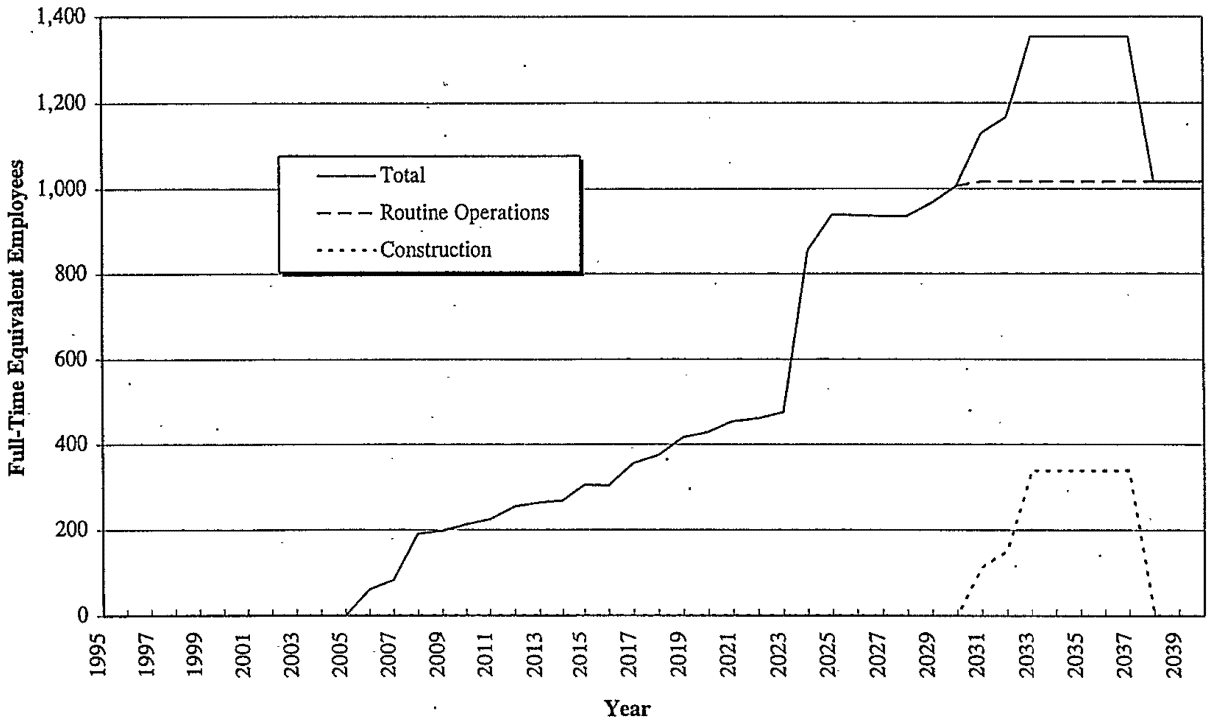


Figure H.3.1.1 Full-Time Equivalent Employees (Change from Baseline Estimate) - No Action Alternative, 1995 to 2040

Figure H.3.1.2 Full-Time Equivalent Employees (Change from Baseline Estimate) - Long-Term Management Alternative, 1995 to 2040



Routine operations are those in addition to routine operations labor requirements under the TWRS program Tri-Party Agreement estimate, which includes approximately 1,000 employees for routine operations through 2005 and a phaseout of employment through 2029. The employment estimate assumes employment for routine operations would continue at 1995 levels through 2040.

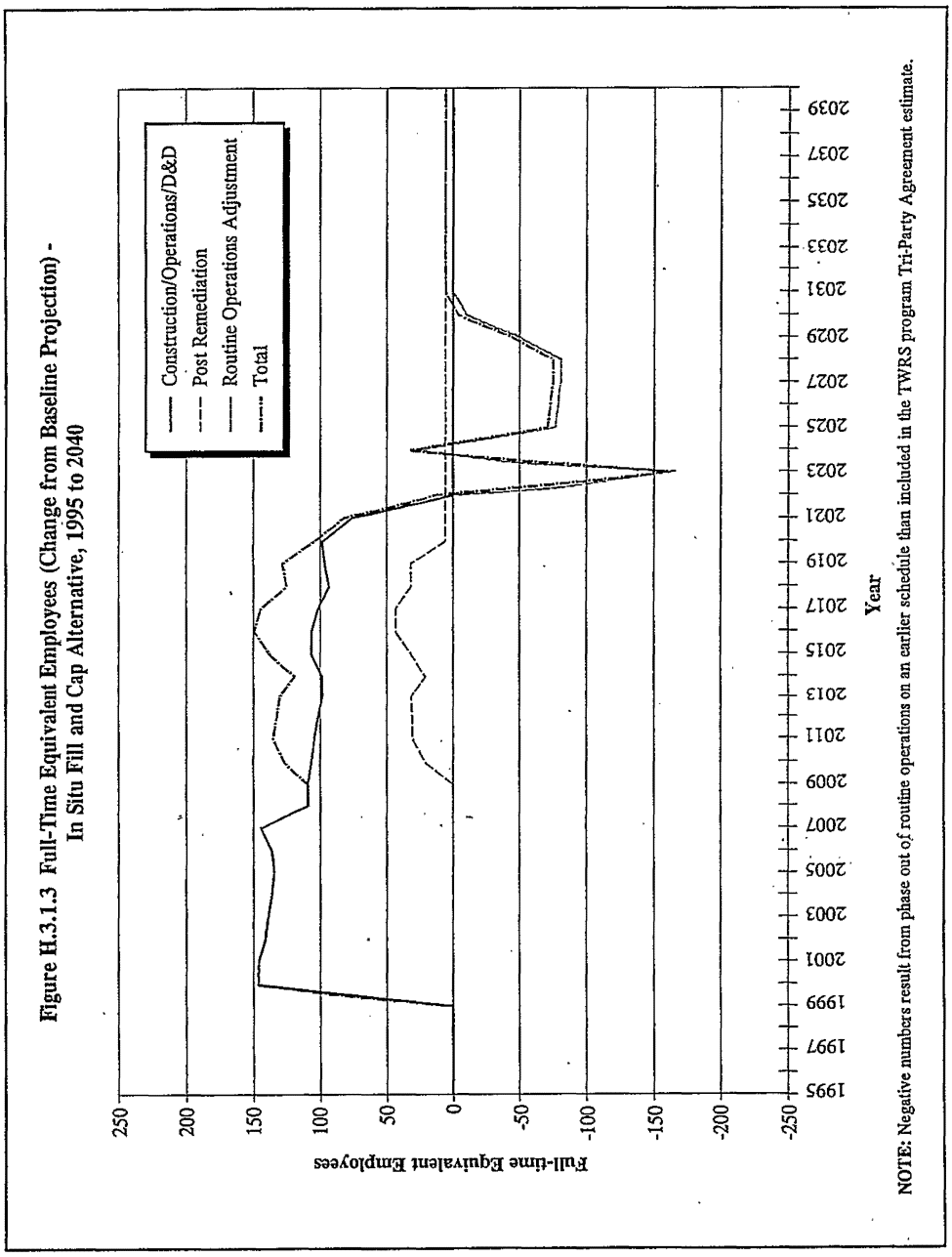
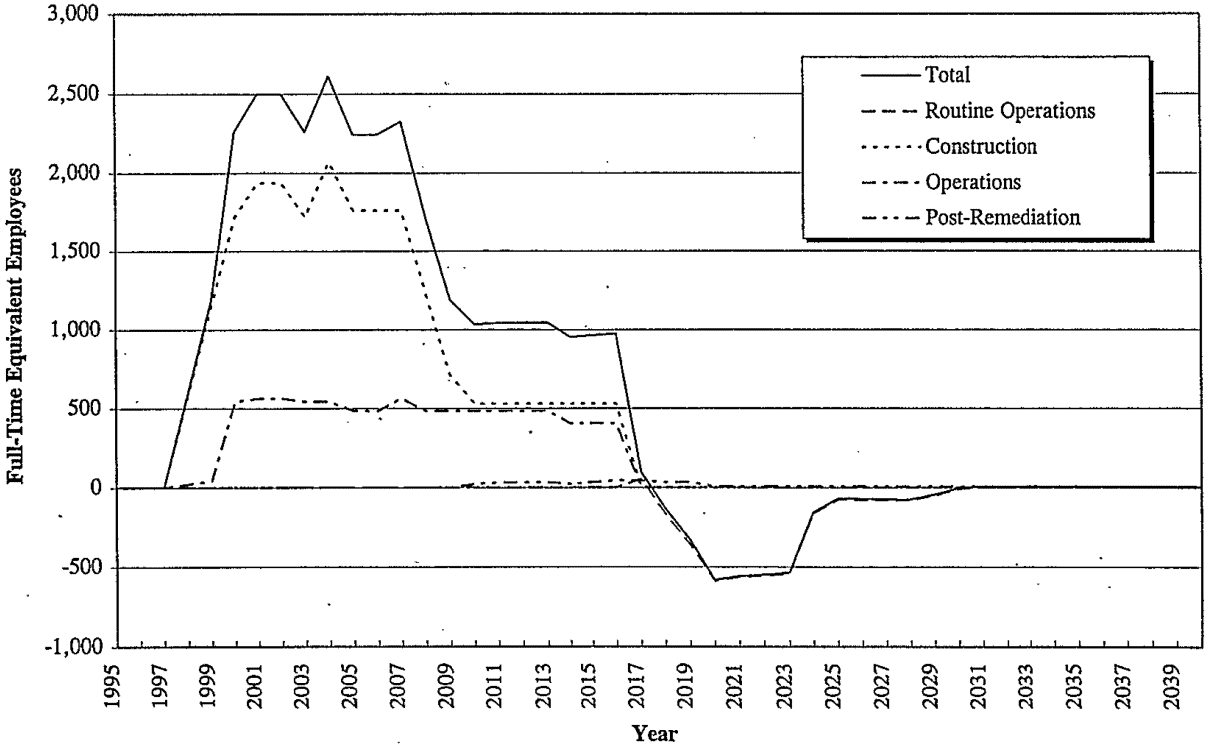


Figure H.3.1.3 Full-Time Equivalent Employees (Change from Baseline Projection) - In Situ Fill and Cap Alternative, 1995 to 2040

Figure H.3.1.4 Full-Time Equivalent Employees (Change from Baseline Estimate) - In Situ Vitrification Alternative, 1995 to 2040



Routine Operations - Less than zero in some years when compared to the total employment, which includes routine tank farm operations in the TWRS program Tri-Party Agreement estimate.

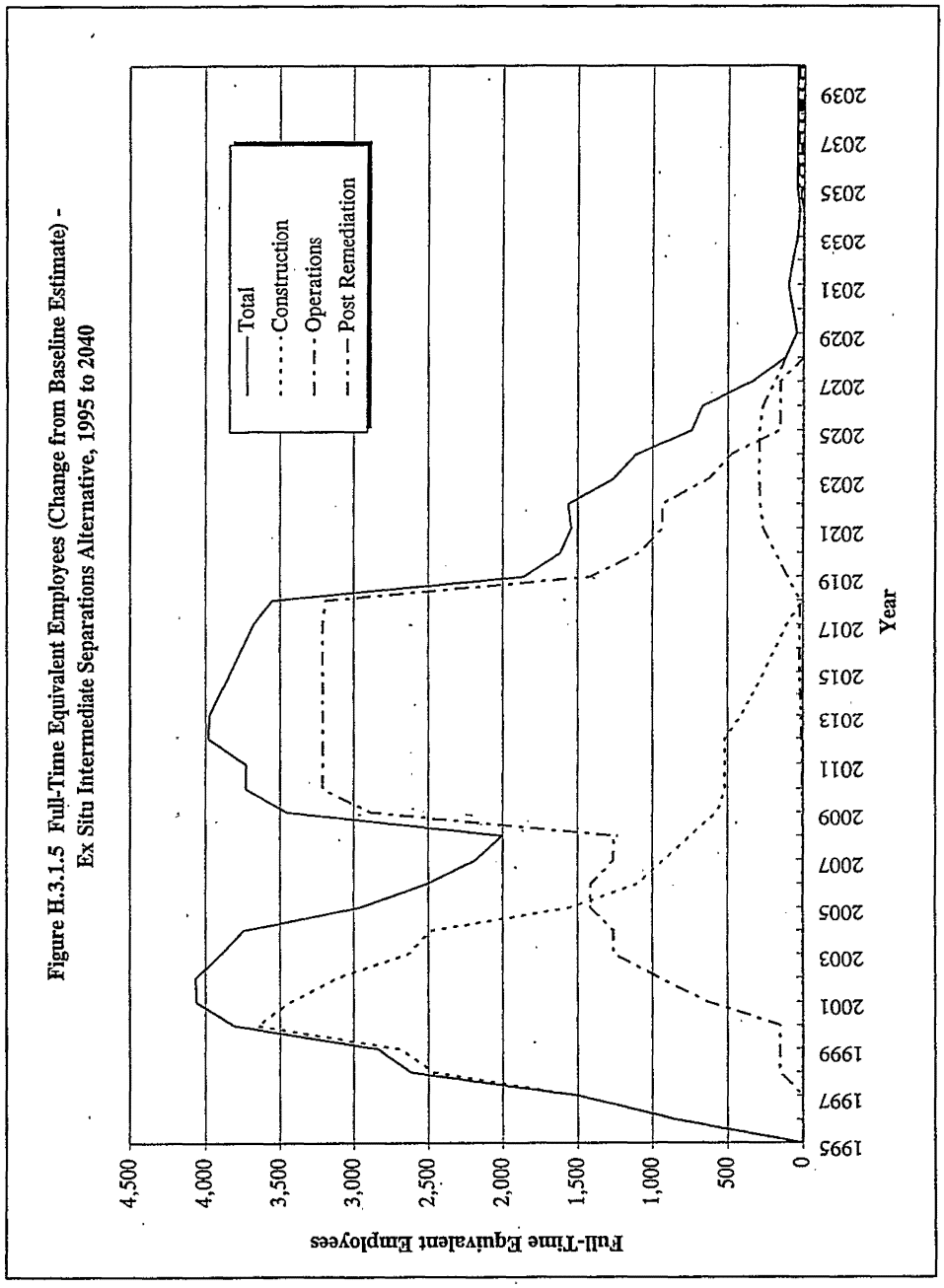


Figure H.3.1.5 Full-Time Equivalent Employees (Change from Baseline Estimate) - Ex Situ Intermediate Separations Alternative, 1995 to 2040

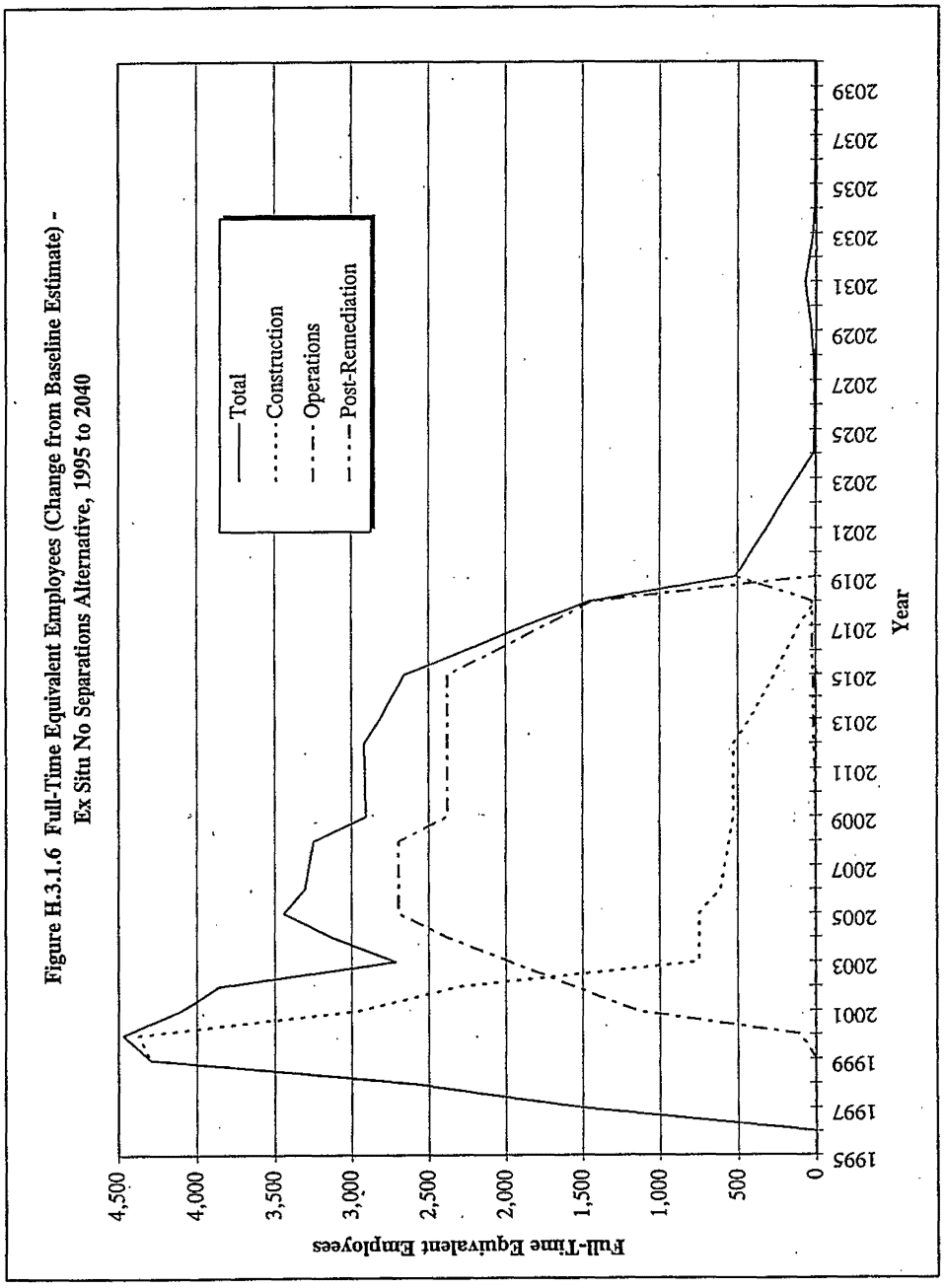


Figure H.3.1.6 Full-Time Equivalent Employees (Change from Baseline Estimate) - Ex Situ No Separations Alternative, 1995 to 2040

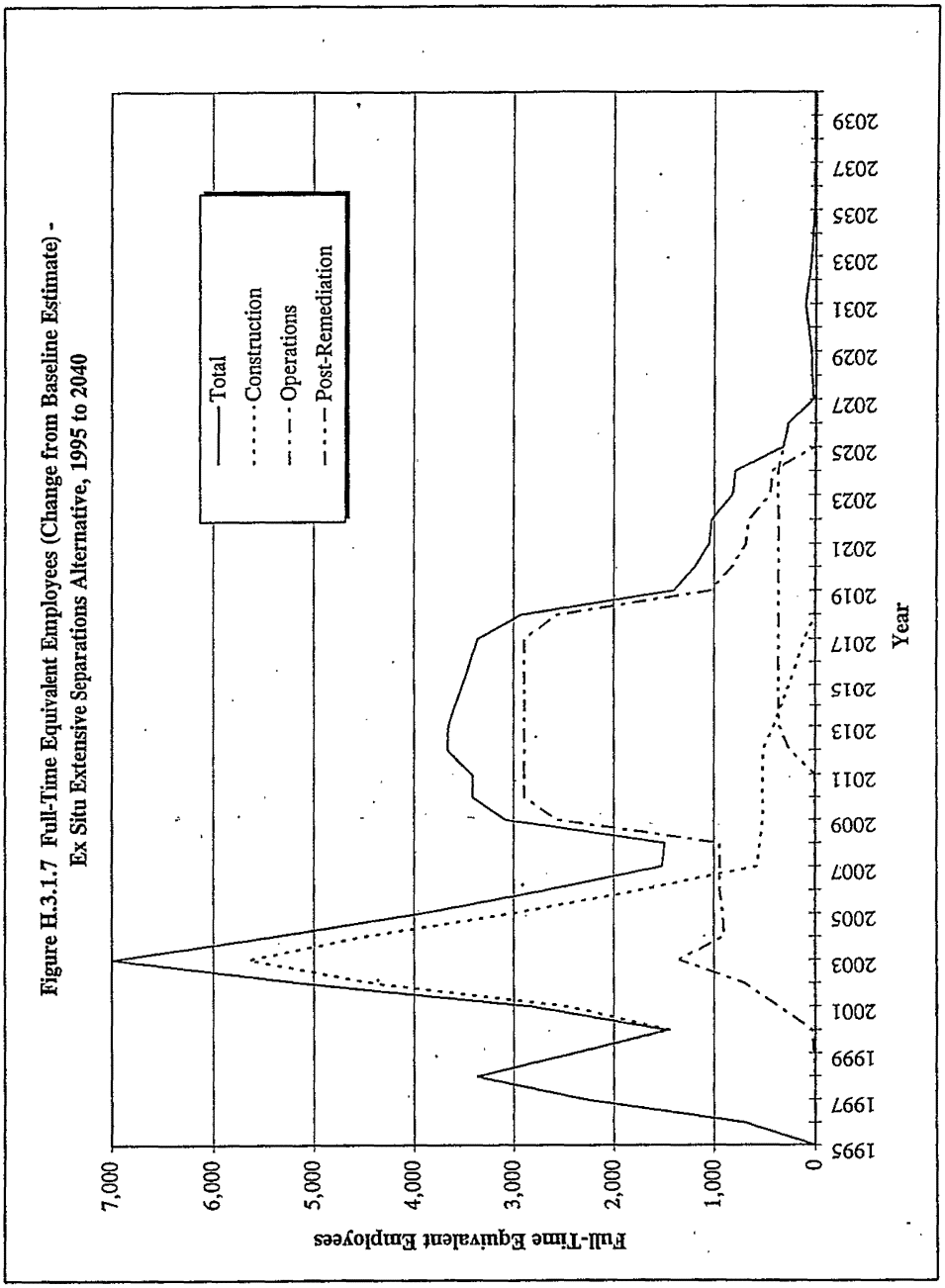


Figure H.3.1.7 Full-Time Equivalent Employees (Change from Baseline Estimate) - Ex Situ Extensive Separations Alternative, 1995 to 2040

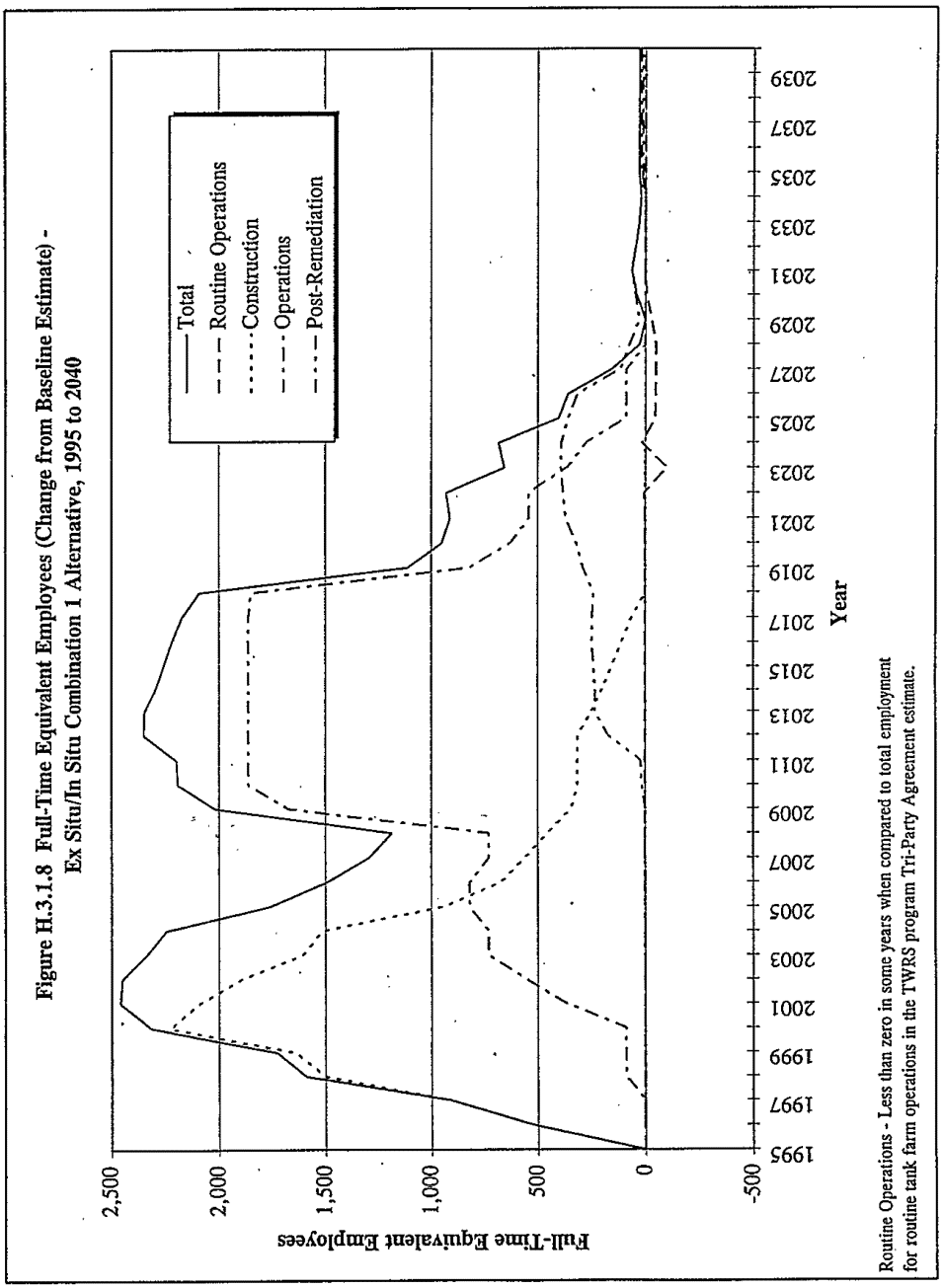


Figure H.3.1.8 Full-Time Equivalent Employees (Change from Baseline Estimate) - Ex Situ/In Situ Combination 1 Alternative, 1995 to 2040

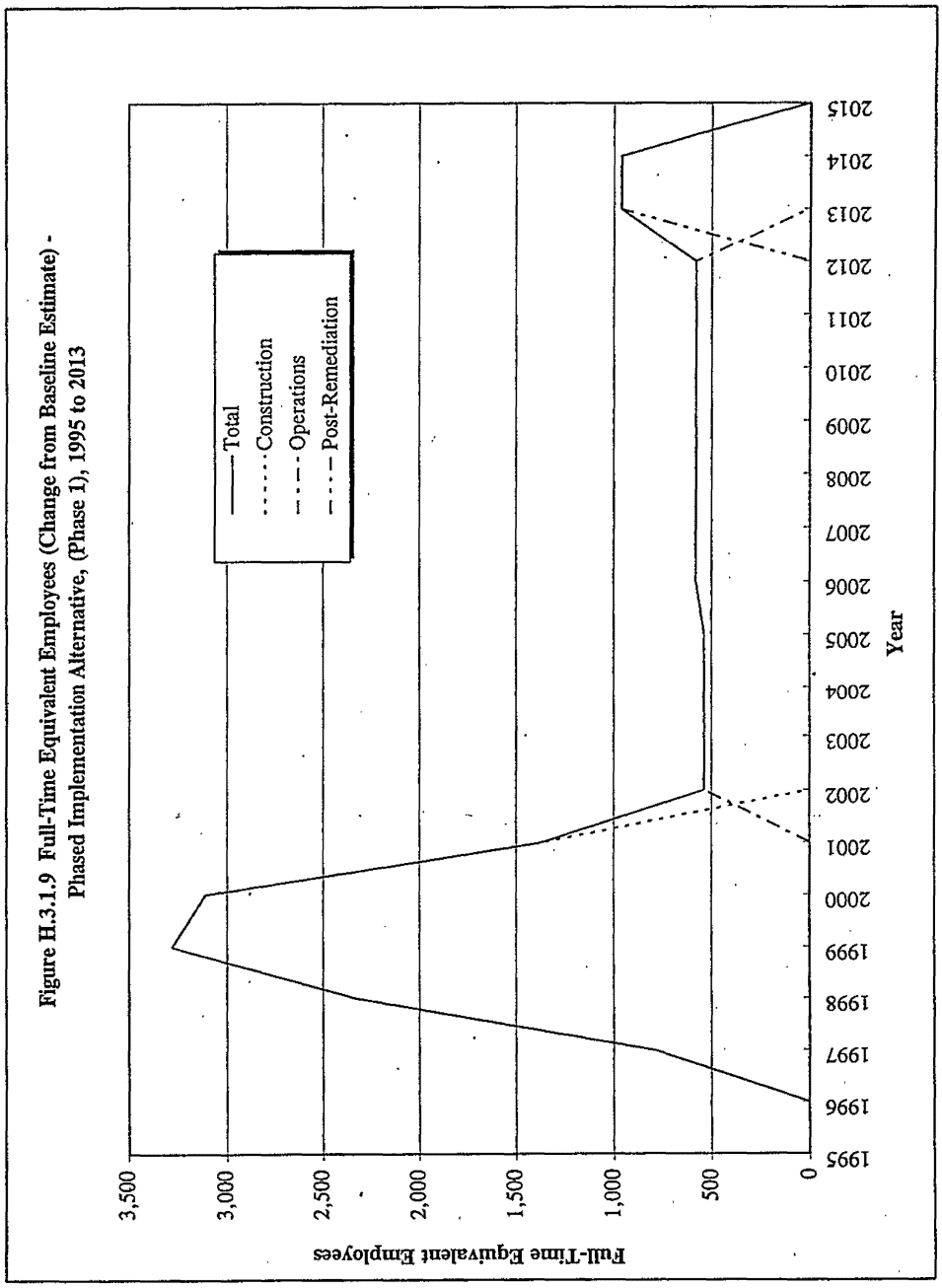
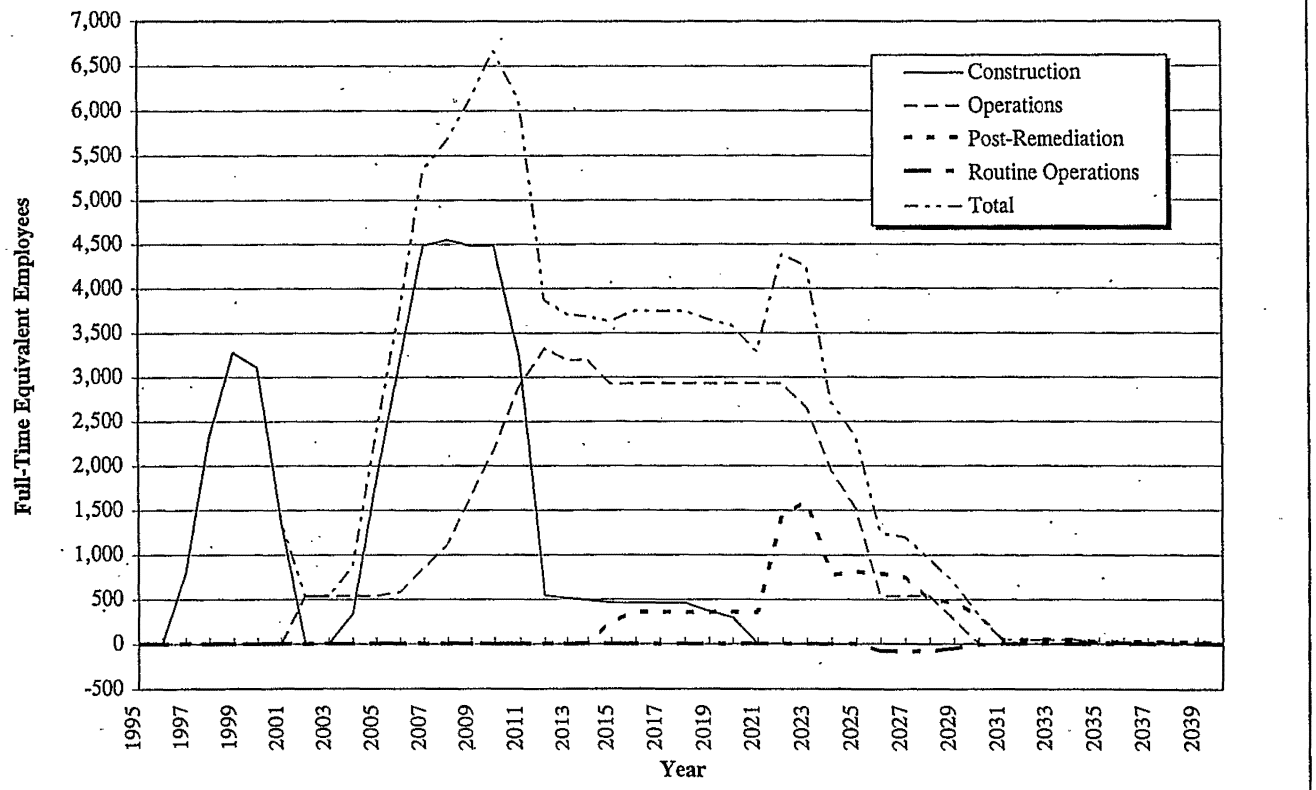


Figure H.3.1.9 Full-Time Equivalent Employees (Change from Baseline Estimate) - Phased Implementation Alternative, (Phase 1), 1995 to 2013

Figure H.3.1.10 Full-Time Equivalent Employees (Change from Baseline Estimate) - Phased Implementation (Total Alternative), 1995 to 2040



Routine Operations - Less than zero in some years when compared to the total employment, which precludes routine tank farm operations in the TWRS program Tri-Party Agreement estimate.

Table H.2.1.1 Regression Data for Nonfarm Employment in the Tri-Cities MSA

Y1	X1	X2	X3	X4
55,537	12,400	1	0	14,500
55,237	12,200	2	0	14,100
55,033	12,100	3	1	13,500
57,433	12,300	4	0	12,900
58,233	12,700	5	0	12,400
58,600	13,000	6	0	12,200
59,233	13,300	7	1	12,100
63,033	13,800	8	0	12,300
62,767	14,000	9	0	12,700
62,933	14,200	10	0	13,000
61,533	14,400	11	1	13,300
64,967	14,800	12	0	13,800
64,967	15,000	13	0	14,000
65,800	15,100	14	0	14,200
64,967	15,500	15	1	14,400
68,067	16,000	16	0	14,800
67,433	16,100	17	0	15,000
67,567	16,200	18	0	15,100
66,770	16,500	19	1	15,500
69,830	17,200	20	0	16,000
70,300	17,300	21	0	16,100
70,900	17,800	22	0	16,200

Notes:
Y1 = Nonfarm employment
X1 = Hanford Site employment (full-time equivalent employees)
X2 = Time trend
X3 = First quarter dummy variable
X4 = Lagged Hanford Site employment (one year or four quarters)

Table H.2.2.1 Regression Data for Taxable Retail Sales in the Tri-Cities MSA

Y2	X5	X6	X7	X8
239	1	57,390	0	0
234	2	57,413	0	1
203	3	54,837	1	0
238	4	56,343	0	0
238	5	55,537	0	0
250	6	55,237	0	1
220	7	55,033	1	0
270	8	57,433	0	0
268	9	58,233	0	0
282	10	58,600	0	1
252	11	59,233	1	0
309	12	63,033	0	0
326	13	62,767	0	0
321	14	62,933	0	1
286	15	61,533	1	0
325	16	64,967	0	0
335	17	64,967	0	0
347	18	65,800	0	1
316	19	64,967	1	0
384	20	68,067	0	0
373	21	67,433	0	0
407	22	67,567	0	1
338	23	66,770	1	0
428	24	69,830	0	0
447	25	70,300	0	0

Notes:
Y2 = Taxable retail sales ($ Millions)
X5 = Time trend
X6 = Nonfarm employment
X7 = First quarter dummy variable
X8 = Fourth quarter dummy variable

Table H.2.3.1 Regression Data for Population in the Tri-Cities MSA

Y3	X14	X15
144,469	1	not applicable
150,100	2	58,710
147,900	3	63,940
144,700	4	58,860
144,000	5	55,360
140,900	6	52,870
139,300	7	54,020
139,600	8	55,230
139,600	9	56,970
138,300	10	55,400
150,030	11	57,325
153,400	12	61,992
157,700	13	64,317
163,900	14	67,008

Notes:
Y3 = Population
X14 = Time trend
X15 = Lagged nonfarm employment

Table H.2.4.1 Regression Data for Average Home Prices in the Tri-Cities MSA

Y4	X9	X10
65.1	1	144,469
73.1	2	150,100
66.8	3	147,900
64.8	4	144,700
62.6	5	144,000
60.9	6	140,900
60.0	7	139,300
59.6	8	139,600
58.8	9	139,600
59.7	10	138,300
68.3	11	150,030
78.7	12	153,400
93.8	13	157,700
106.6	14	163,900

Notes:
Y4 = Average home price ($ Thousands)
X9 = Time trend
X10 = Population

Table H.3.1.1 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - No Action Alternative, 1995 to 2040

Year	Routine Operations (Difference from Baseline) [1,2]
1995	0
1996	0
1997	0
1998	0
1999	0
2000	0
2001	0
2002	0
2003	0
2004	0
2005	0
2006	61
2007	83
2008	190
2009	197
2010	212
2011	224
2012	254
2013	263
2014	268
2015	304
2016	303
2017	355
2018	374
2019	416
2020	428
2021	453
2022	460
2023	475
2024	854
2025	939
2026	937
2027	935
2028	935
2029	966
2030	1,006
2031	1,016
2032	1,016
2033	1,016
2034	1,016
2035	1,016
2036	1,016
2037	1,016
2038	1,016
2039	1,016
2040	1,016

Notes:
[1] Hanford Site baseline employment is shown on Table H.3.2.1.
[2] Routine operations are those in addition to routine operations labor requirements under the TWRS program Tri-Party Agreement estimate, which includes approximately 1,000 employees for routine operations through 2005 and a phaseout of employment through 2029. The employment estimate assumes employment for routine operations would continue at 1995 levels through 2040.

Table H.3.1.2 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - Long-Term Management Alternative, 1995 to 2040

Year	Routine Operations (Difference from Baseline) [1,2]	New Tank Construction	Total
1995	0	0	0
1996	0	0	0
1997	0	0	0
1998	0	0	0
1999	0	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	0	0	0
2005	0	0	0
2006	61	0	61
2007	83	0	83
2008	190	0	190
2009	197	0	197
2010	212	0	212
2011	224	0	224
2012	254	0	254
2013	263	0	263
2014	268	0	268
2015	304	0	304
2016	303	0	303
2017	355	0	355
2018	374	0	374
2019	416	0	416
2020	428	0	428
2021	453	0	453
2022	460	0	460
2023	475	0	475
2024	854	0	854
2025	939	0	939
2026	937	0	937
2027	935	0	935
2028	935	0	935
2029	966	0	966
2030	1,006	0	1,006
2031	1,016	113	1,129
2032	1,016	150	1,166
2033	1,016	338	1,354
2034	1,016	338	1,354
2035	1,016	338	1,354
2036	1,016	338	1,354
2037	1,016	338	1,354
2038	1,016	0	1,016
2039	1,016	0	1,016
2040	1,016	0	1,016

Notes:
[1] Hanford Site Baseline employment is shown on Table H.3.2.1.
[2] Routine operations are those in addition to routine operations labor requirements under the TWRS program Tri-Party Agreement estimate, which includes approximately 1,000 employees for routine operations through 2005 and a phaseout of employment through 2029. The employment estimate assumes employment for routine operations would continue at 1995 levels through 2040.

Table H.3.1.3 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - In Situ Fill and Cap Alternative, 1995 to 2040 [1]

Year	Construction/Operations/ D&D	Post Remediation	Routine Operations Adjustment [2]	Total
1995	0	0	0	0
1996	0	0	0	0
1997	0	0	0	0
1998	0	0	0	0
1999	0	0	0	0
2000	146	0	0	146
2001	146	0	0	146
2002	141	0	0	141
2003	139	0	0	139
2004	136	0	0	136
2005	134	0	0	134
2006	136	0	0	136
2007	144	0	0	144
2008	109	0	0	109
2009	109	0	0	109
2010	106	21	0	127
2011	104	31	0	135
2012	101	31	0	132
2013	98	32	0	130
2014	98	21	0	119
2015	106	32	0	138
2016	106	43	0	149
2017	101	43	0	144
2018	93	32	0	125
2019	96	32	0	128
2020	98	6	0	104
2021	76	6	0	82
2022	0	6	0	13
2023	0	6	-166	-160
2024	0	6	26	32
2025	0	6	-77	-71
2026	0	6	-79	-73
2027	0	6	-81	-75
2028	0	6	-81	-75
2029	0	6	-50	-44
2030	0	6	-10	-4
2031	0	6	0	6
2032	0	6	0	6
2033	0	6	0	6
2034	0	6	0	6
2035	0	6	0	6
2036	0	6	0	6
2037	0	6	0	6
2038	0	6	0	6
2039	0	6	0	6
2040	0	6	0	6

Notes:

[1] Hanford Site Baseline employment is shown on Table H.3.2.1.

[2] Routine operations are those in addition to routine operations labor requirements under the TWRS program Tri-Party Agreement estimate, which includes approximately 1,000 employees for routine operations through 2005 and a phaseout of employment through 2029. The employment estimate assumes employment for routine operations would continue at 1995 levels through 2040. Negative numbers in Tables H.3.1.3 to H.3.1.10 and H.3.2.1 to H.3.2.15 result from the phaseout of routine operations on an earlier schedule than included in the TWRS program Tri-Party Agreement estimates.

Table H.3.1.4 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - In Situ Vitrification Alternative, 1995 to 2040

Year	Construction	Operations	Monitoring and Maintenance	Closure	Routine Operations (Difference from Baseline)	Total
1995	0	0	0	0	0	0
1996	0	0	0	0	0	0
1997	0	0	0	0	0	0
1998	572	20	0	0	0	592
1999	1,144	39	0	0	0	1,183
2000	1,716	542	0	0	0	2,258
2001	1,936	562	0	0	0	2,498
2002	1,936	562	0	0	0	2,498
2003	1,716	542	0	0	0	2,258
2004	2,068	542	0	0	0	2,610
2005	1,760	483	0	0	0	2,243
2006	1,760	483	0	0	0	2,243
2007	1,760	564	0	0	0	2,324
2008	1,232	483	0	0	0	1,715
2009	704	483	0	0	0	1,187
2010	528	483	0	21	0	1,032
2011	528	483	0	31	0	1,042
2012	528	483	0	31	0	1,042
2013	528	483	0	32	0	1,043
2014	528	403	0	21	0	952
2015	528	403	0	32	0	963
2016	528	403	0	43	0	974
2017	0	0	0	43	52	95
2018	0	0	0	32	-167	-135
2019	0	0	0	32	-362	-330
2020	0	0	6	0	-588	-582
2021	0	0	6	0	-563	-557
2022	0	0	6	0	-556	-550
2023	0	0	6	0	-541	-535
2024	0	0	6	0	-162	-156
2025	0	0	6	0	-77	-71
2026	0	0	6	0	-79	-73
2027	0	0	6	0	-81	-75
2028	0	0	6	0	-81	-75
2029	0	0	6	0	-50	-44
2030	0	0	6	0	-10	-4
2031	0	0	6	0	0	6
2032	0	0	6	0	0	6
2033	0	0	6	0	0	6
2034	0	0	6	0	0	6
2035	0	0	6	0	0	6
2036	0	0	6	0	0	6
2037	0	0	6	0	0	6
2038	0	0	6	0	0	6
2039	0	0	6	0	0	6
2040	0	0	6	0	0	6

Table H.3.1.5 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - Ex Situ Intermediate Separations Alternative, 1995 to 2040

Year	Waste Retrieval and Transfer Phase		Decontamination and Decommissioning	Operations Phase		Decontamination and Decommissioning	Monitoring and Maintenance	Closure	Total
	Construction	Operations		Construction	Operations				
1995	0	0	0	0	0	0	0	0	0
1996	0	0	0	844	0	0	0	0	844
1997	0	0	0	1,488	0	0	0	0	1,488
1998	378	0	0	2,082	153	0	0	0	2,613
1999	604	0	0	2,082	153	0	0	0	2,839
2000	680	0	0	2,970	153	0	0	0	3,803
2001	756	325	0	2,674	305	0	0	0	4,060
2002	832	650	0	2,276	305	0	0	0	4,063
2003	756	650	0	1,878	610	0	0	0	3,894
2004	756	650	0	1,728	610	0	0	0	3,744
2005	756	650	0	790	763	0	0	0	2,959
2006	606	650	0	494	763	0	0	0	2,513
2007	576	650	0	346	610	0	0	0	2,182
2008	546	650	0	198	610	0	0	0	2,004
2009	516	2,275	0	50	610	0	0	0	3,451
2010	516	2,600	0	0	610	0	0	3	3,729
2011	516	2,600	0	0	610	0	0	4	3,730
2012	516	2,600	245	0	610	0	0	10	3,981
2013	410	2,600	343	0	610	0	0	11	3,974
2014	334	2,600	343	0	610	0	0	17	3,904
2015	258	2,600	343	0	610	0	0	20	3,831
2016	182	2,600	343	0	610	0	0	20	3,755
2017	106	2,600	343	0	610	0	0	20	3,679
2018	0	2,275	343	0	915	0	0	20	3,553
2019	0	650	343	0	763	82	0	20	1,858
2020	0	325	343	0	763	163	0	20	1,614
2021	0	325	343	0	610	245	0	19	1,542
2022	0	325	343	0	610	266	0	19	1,563
2023	0	325	343	0	305	266	9	18	1,266
2024	0	325	343	0	153	266	9	16	1,112
2025	0	0	294	0	153	266	9	16	738

Table H.3.1.5 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - Ex Situ Intermediate Separations Alternative, 1995 to 2040 (cont'd)

Year	Waste Retrieval and Transfer Phase		Decontamination and Decommissioning	Operations Phase		Decontamination and Decommissioning	Monitoring and Maintenance	Closure	Total
	Construction	Operations		Construction	Operations				
2026	0	0	245	0	153	245	9	16	668
2027	0	0	0	0	153	163	9	15	340
2028	0	0	0	0	0	82	9	27	118
2029	0	0	0	0	0	0	9	34	43
2030	0	0	0	0	0	0	9	63	72
2031	0	0	0	0	0	0	9	92	101
2032	0	0	0	0	0	0	8	63	71
2033	0	0	0	0	0	0	8	34	42
2034	0	0	0	0	0	0	8	20	28
2035	0	0	0	0	31	0	8	6	45
2036	0	0	0	0	31	0	8	6	45
2037	0	0	0	0	31	0	8	6	45
2038	0	0	0	0	31	0	8	6	45
2039	0	0	0	0	31	0	8	6	45
2040	0	0	0	0	31	0	8	6	45

Table H.3.1.6 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - Ex Situ No Separations Alternative, 1995 to 2040

Year	Construction	Operation	Post Remediation	Total
1995	0	0	0	0
1996	0	0	0	0
1997	1,481	0	0	1,481
1998	2,595	0	0	2,595
1999	4,292	0	0	4,292
2000	4,371	98	0	4,469
2001	2,968	1,141	0	4,109
2002	2,306	1,553	0	3,859
2003	746	1,966	0	2,712
2004	746	2,379	0	3,125
2005	746	2,694	0	3,440
2006	609	2,694	0	3,303
2007	581	2,694	0	3,275
2008	554	2,694	0	3,248
2009	526	2,379	0	2,905
2010	526	2,379	6	2,911
2011	526	2,379	7	2,912
2012	526	2,379	14	2,919
2013	420	2,379	15	2,814
2014	342	2,379	15	2,736
2015	263	2,379	15	2,657
2016	185	2,064	21	2,270
2017	106	1,749	21	1,876
2018	0	1,434	23	1,457
2019	0	0	512	512
2020	0	0	414	414
2021	0	0	315	315
2022	0	0	217	217
2023	0	0	118	118
2024	0	0	16	16
2025	0	0	10	10
2026	0	0	10	10
2027	0	0	10	10
2028	0	0	18	18
2029	0	0	29	29
2030	0	0	49	49
2031	0	0	70	70
2032	0	0	43	43
2033	0	0	21	21
2034	0	0	11	11
2035	0	0	9	9
2036	0	0	9	9
2037	0	0	9	9
2038	0	0	9	9
2039	0	0	9	9
2040	0	0	9	9

Table H.3.1.7 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - Ex Situ Extensive Separations Alternative, 1995 to 2040

Year	Construction	Operations	Post Remediation	Total
1995	0	0	0	0
1996	700	0	0	700
1997	2,288	0	0	2,288
1998	3,366	0	0	3,366
1999	2,380	14	0	2,394
2000	1,432	28	0	1,460
2001	2,448	367	0	2,815
2002	4,404	706	0	5,110
2003	5,644	1,345	0	6,989
2004	4,516	900	0	5,416
2005	3,012	914	0	3,926
2006	1,734	942	0	2,676
2007	576	942	0	1,518
2008	546	942	0	1,488
2009	516	2,567	0	3,083
2010	516	2,892	3	3,411
2011	516	2,892	4	3,412
2012	516	2,892	255	3,663
2013	410	2,892	354	3,656
2014	334	2,892	360	3,586
2015	258	2,892	363	3,513
2016	182	2,892	363	3,437
2017	106	2,892	363	3,361
2018	0	2,567	363	2,930
2019	0	1,039	363	1,402
2020	0	825	363	1,188
2021	0	686	362	1,048
2022	0	659	362	1,021
2023	0	450	370	820
2024	0	422	368	790
2025	0	0	319	319
2026	0	0	270	270
2027	0	0	24	24
2028	0	0	36	36
2029	0	0	43	43
2030	0	0	72	72
2031	0	0	101	101
2032	0	0	71	71
2033	0	0	42	42
2034	0	0	28	28
2035	0	0	14	14
2036	0	0	14	14
2037	0	0	14	14
2038	0	0	14	14
2039	0	0	14	14
2040	0	0	14	14

Table H.3.1.8 Full-Time Equivalent Employees by Phase (Change from Baseline Estimate) - Ex Situ/In Situ Combination 1 Alternative, 1995 to 2040

Year	Construction	Operation	Post Remediation	Routine Operations (Difference from Baseline) [1]	Total
1995	0	0	0	0	0
1996	515	0	0	0	515
1997	908	0	0	0	908
1998	1,501	89	0	0	1,589
1999	1,638	89	0	0	1,727
2000	2,227	89	0	0	2,315
2001	2,092	365	0	0	2,458
2002	1,896	554	0	0	2,450
2003	1,607	731	0	0	2,338
2004	1,515	731	0	0	2,246
2005	943	820	0	0	1,763
2006	671	820	0	0	1,491
2007	562	731	0	0	1,293
2008	454	731	0	0	1,185
2009	345	1,673	0	0	2,019
2010	315	1,862	15	0	2,191
2011	315	1,862	21	0	2,198
2012	315	1,862	174	0	2,351
2013	250	1,862	235	0	2,347
2014	204	1,862	232	0	2,298
2015	157	1,862	241	0	2,260
2016	111	1,862	247	0	2,220
2017	65	1,862	247	0	2,174
2018	0	1,850	241	0	2,091
2019	0	820	291	0	1,110
2020	0	631	320	0	952
2021	0	542	370	0	912
2022	0	542	383	4	929
2023	0	365	391	-100	657
2024	0	277	390	16	683
2025	0	89	360	-46	403
2026	0	89	317	-47	359
2027	0	89	117	-49	157
2028	0	0	75	-49	26
2029	0	0	29	-30	-1
2030	0	0	46	-6	40
2031	0	0	63	0	63
2032	0	0	45	0	45
2033	0	0	28	0	28
2034	0	0	20	0	20
2035	0	18	12	0	30
2036	0	18	12	0	30
2037	0	18	12	0	30
2038	0	18	12	0	30
2039	0	18	12	0	30
2040	0	18	12	0	30

Table H.3.1.9 Full-Time Equivalent Employees by Element (Change from Baseline Estimate) - Phased Implementation Alternative (Phase 1), 1995 to 2014

Year	Construction	Operations	Post Remediation	Total
1995	0	0	0	0
1996	0	0	0	0
1997	789	0	0	789
1998	2,322	0	0	2,322
1999	3,281	0	0	3,281
2000	3,111	0	0	3,111
2001	1,371	0	0	1,371
2002	0	536	0	536
2003	0	536	0	536
2004	0	536	0	536
2005	0	536	0	536
2006	0	578	0	578
2007	0	578	0	578
2008	0	578	0	578
2009	0	578	0	578
2010	0	578	0	578
2011	0	578	0	578
2012	0	578	0	578
2013	0	0	961	961
2014	0	0	961	961

Note:
Phase 1 of the Phased Implementation alternative would conclude in 2012 with closure of the Phase 1 facilities occurring in 2013 and 2014.

Table H.3.1.10 Full-Time Equivalent Employees by Element (Change from Baseline Estimate) - Phased Implementation Alternative (Total Alternative), 1995 to 2040

Year	Construction	Operations	Post Remediation	Routine Operations (Difference from Baseline) [1]	Total
1995	0	0	0	0	0
1996	0	0	0	0	0
1997	789	0	0	0	789
1998	2,322	0	0	0	2,322
1999	3,281	0	0	0	3,281
2000	3,111	0	0	0	3,111
2001	1,371	0	0	0	1,371
2002	0	536	0	0	536
2003	0	536	0	0	536
2004	337	536	0	0	873
2005	1,817	536	0	0	2,353
2006	3,164	578	0	0	3,742
2007	4,483	850	0	0	5,333
2008	4,551	1,122	0	0	5,673
2009	4,483	1,649	0	0	6,132
2010	4,483	2,185	0	0	6,667
2011	3,232	2,896	0	0	6,127
2012	541	3,325	0	0	3,866
2013	514	3,196	0	0	3,710
2014	487	3,196	0	0	3,683
2015	461	2,928	247	0	3,635
2016	461	2,928	356	0	3,744
2017	461	2,928	356	0	3,744
2018	461	2,928	356	0	3,744
2019	366	2,928	356	0	3,650
2020	298	2,928	356	0	3,582
2021	0	2,928	356	0	3,284
2022	0	2,928	1,456	0	4,384
2023	0	2,661	1,594	0	4,254
2024	0	1,944	772	0	2,716
2025	0	1,510	808	0	2,318
2026	0	536	786	-79	1,243
2027	0	536	745	-81	1,199
2028	0	536	498	-81	953
2029	0	272	463	-50	685
2030	0	0	323	-10	313
2031	0	0	44	0	44
2032	0	0	44	0	44
2033	0	0	44	0	44
2034	0	0	44	0	44
2035	0	0	24	0	24
2036	0	0	24	0	24
2037	0	0	24	0	24
2038	0	0	24	0	24
2039	0	0	24	0	24
2040	0	0	5	0	5

Table H.3.2.1 Hanford Site Employment with the No Action, Long-Term Management, and In Situ Fill and Cap Alternatives (Change from Baseline Estimate), 1994 to 2040 (Full-Time Equivalent Employees)

Year	Baseline	No Action	Long-Term Management	In Situ Fill and Cap	Percentage Change from Baseline		
					No Action	Long-Term Management	In Situ Fill and Cap
1994	18,436	18,436	18,436	18,436	0.00	0.00	0.00
1995	17,406	17,406	17,406	17,406	0.00	0.00	0.00
1996	15,401	15,401	15,401	15,401	0.00	0.00	0.00
1997	14,939	14,939	14,939	14,939	0.00	0.00	0.00
1998	14,883	14,883	14,883	14,883	0.00	0.00	0.00
1999	14,758	14,758	14,758	14,770	0.00	0.00	0.08
2000	14,580	14,580	14,580	14,713	0.00	0.00	0.92
2001	14,366	14,366	14,366	14,511	0.00	0.00	1.01
2002	13,976	13,976	13,976	14,117	0.00	0.00	1.01
2003	13,527	13,527	13,527	13,666	0.00	0.00	1.03
2004	13,120	13,120	13,120	13,256	0.00	0.00	1.04
2005	12,795	12,800	12,800	12,929	0.04	0.04	1.05
2006	12,416	12,474	12,474	12,553	0.46	0.46	1.10
2007	11,889	11,979	11,979	12,029	0.76	0.76	1.18
2008	11,335	11,517	11,517	11,447	1.60	1.60	0.99
2009	10,779	10,976	10,976	10,889	1.83	1.83	1.03
2010	10,182	10,393	10,393	10,308	2.08	2.08	1.24
2011	9,559	9,784	9,784	9,693	2.36	2.36	1.40
2012	9,042	9,294	9,294	9,174	2.79	2.79	1.46
2013	8,704	8,966	8,966	8,833	3.02	3.02	1.48
2014	8,403	8,674	8,674	8,525	3.22	3.22	1.45
2015	8,122	8,423	8,423	8,259	3.70	3.70	1.69
2016	7,985	8,293	8,293	8,133	3.85	3.85	1.85
2017	8,041	8,393	8,393	8,184	4.38	4.38	1.78
2018	8,131	8,507	8,507	8,258	4.62	4.62	1.56
2019	8,229	8,642	8,642	8,355	5.02	5.02	1.53
2020	8,344	8,773	8,773	8,449	5.14	5.14	1.25
2021	8,497	8,949	8,949	8,575	5.31	5.31	0.92
2022	8,577	9,038	9,038	8,582	5.37	5.37	0.05
2023	8,518	9,023	9,023	8,388	5.93	5.93	-1.52
2024	8,454	9,283	9,283	8,461	9.81	9.81	0.09
2025	8,430	9,361	9,361	8,367	11.05	11.05	-0.74
2026	8,416	9,353	9,353	8,343	11.13	11.13	-0.87
2027	8,369	9,304	9,304	8,294	11.17	11.17	-0.89
2028	8,277	9,215	9,215	8,205	11.33	11.33	-0.88
2029	8,143	9,109	9,109	8,099	11.87	11.87	-0.53
2030	7,983	8,987	8,996	7,977	12.57	12.69	-0.08
2031	7,781	8,796	8,903	7,786	13.05	14.42	0.07
2032	7,551	8,567	8,730	7,557	13.45	15.61	0.08
2033	7,314	8,330	8,652	7,320	13.89	18.29	0.08
2034	7,081	8,097	8,435	7,087	14.35	19.12	0.08
2035	6,849	7,865	8,203	6,855	14.83	19.76	0.09
2036	6,612	7,628	7,966	6,618	15.37	20.48	0.09
2037	6,371	7,387	7,697	6,377	15.95	20.81	0.09
2038	6,130	7,146	7,174	6,136	16.57	17.03	0.10
2039	5,891	6,907	6,907	5,897	17.25	17.25	0.10
2040	5,652	6,668	6,668	5,658	17.98	17.98	0.11

Table H.3.2.2 Hanford Site Employment with the In Situ Vitrification, Ex Situ Intermediate Separations, and Ex Situ No Separations Alternatives (Change from Baseline Estimate), 1994 to 2040 (Full-Time Equivalent Employees)

Year	Baseline	In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations	Percentage Change from Baseline		
					In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations
1994	18,436	18,436	18,436	18,436	0.00	0.00	0.00
1995	17,406	17,406	17,476	17,406	0.00	0.40	0.00
1996	15,401	15,401	16,228	15,524	0.00	5.37	0.80
1997	14,939	14,989	16,468	16,390	0.33	10.23	9.71
1998	14,883	15,474	17,421	17,526	3.98	17.05	17.76
1999	14,758	15,981	17,658	18,923	8.29	19.65	28.22
2000	14,580	16,768	18,324	19,004	15.01	25.68	30.35
2001	14,366	16,844	18,405	18,484	17.25	28.11	28.67
2002	13,976	16,454	18,025	17,760	17.73	28.97	27.08
2003	13,527	15,835	17,423	16,369	17.06	28.80	21.01
2004	13,120	15,670	16,811	16,236	19.44	28.13	23.76
2005	12,795	15,068	15,782	16,197	17.77	23.35	26.59
2006	12,416	14,666	14,939	15,728	18.12	20.32	26.68
2007	11,889	14,156	14,084	15,164	19.06	18.46	27.55
2008	11,335	13,057	13,475	14,557	15.19	18.87	28.42
2009	10,779	11,997	14,132	13,713	11.30	31.11	27.22
2010	10,182	11,227	13,888	13,092	10.27	36.40	28.59
2011	9,559	10,600	13,310	12,471	10.89	39.24	30.47
2012	9,042	10,084	13,001	11,951	11.53	43.79	32.18
2013	8,704	9,739	12,672	11,520	11.90	45.60	32.36
2014	8,403	9,364	12,307	11,139	11.43	46.46	32.56
2015	8,122	9,085	11,953	10,753	11.86	47.17	32.40
2016	7,985	8,885	11,740	10,255	11.27	47.02	28.42
2017	8,041	8,190	11,716	9,915	1.85	45.70	23.31
2018	8,131	7,999	11,554	9,545	-1.62	42.09	17.38
2019	8,229	7,894	10,208	8,812	-4.07	24.05	7.08
2020	8,344	7,785	9,973	8,758	-6.70	19.51	4.96
2021	8,497	7,939	10,047	8,812	-6.57	18.24	3.71
2022	8,577	8,028	10,114	8,794	-6.40	17.91	2.53
2023	8,518	8,013	9,796	8,635	-5.92	15.00	1.38
2024	8,454	8,273	9,547	8,478	-2.14	12.94	0.28
2025	8,430	8,351	9,193	8,434	-0.93	9.06	0.05
2026	8,416	8,343	9,062	8,353	-0.87	7.68	-0.74
2027	8,369	8,294	8,718	8,299	0.89	4.17	-0.84
2028	8,277	8,205	8,407	8,217	-0.88	1.57	-0.73
2029	8,143	8,099	8,194	8,123	-0.53	0.63	-0.24
2030	7,983	7,977	8,055	8,020	-0.08	0.90	0.46
2031	7,781	7,786	7,877	7,846	0.07	1.24	0.84
2032	7,551	7,557	7,622	7,595	0.08	0.94	0.57
2033	7,314	7,320	7,357	7,336	0.08	0.59	0.30
2034	7,081	7,087	7,111	7,092	0.08	0.43	0.17
2035	6,849	6,855	6,892	6,858	0.09	0.64	0.13
2036	6,612	6,618	6,657	6,621	0.09	0.68	0.14
2037	6,371	6,377	6,416	6,380	0.09	0.71	0.14
2038	6,130	6,136	6,175	6,139	0.10	0.73	0.15
2039	5,891	5,897	5,936	5,900	0.10	0.76	0.15
2040	5,652	5,658	5,697	5,661	0.11	0.80	0.16

Table H.3.2.3 Hanford Site Employment with the Ex Situ Extensive Separations, Ex Situ/In Situ Combination 1, and Phased Implementation Alternatives (Change from Baseline Estimate), 1994 to 2040
(Full-Time Equivalent Employees)

						Percentage Change from Baseline			
		Ex Situ Extensive	Ex Situ/ In Situ	Phased Implementation		Ex Situ Extensive	Ex Situ/ In Situ	Phased Implementation	
Year	Baseline	Separations	Combination	Phase 1	Total	Separations	Combination 1	Phase 1	Total
1994	18,436	18,436	18,436	18,436	18,436	0.00	0.00	0.00	0.0
1995	17,406	17,464	17,449	17,413	17,413	0.33	0.25	0.04	0.0
1996	15,401	16,175	15,906	15,539	15,539	5.03	3.28	0.90	0.4
1997	14,939	17,185	15,871	15,781	15,781	15.03	6.24	5.63	5.7
1998	14,883	18,078	16,427	17,139	17,139	21.47	10.37	15.16	15.3
1999	14,758	17,155	16,522	17,927	17,927	16.24	11.96	21.47	21.6
2000	14,580	16,230	16,858	17,542	17,542	11.32	15.63	20.32	20.4
2001	14,366	17,259	16,811	15,796	15,796	20.14	17.02	9.96	10.1
2002	13,976	19,052	16,417	14,588	14,580	36.31	17.47	4.37	4.3
2003	13,527	20,229	15,867	14,071	14,091	49.54	17.29	4.02	4.2
2004	13,120	18,543	15,333	13,664	14,028	41.33	16.87	4.15	7.4
2005	12,795	16,741	14,575	13,342	14,423	30.84	13.91	4.28	18.3
2006	12,416	15,100	13,913	12,999	14,758	21.61	12.06	4.69	30.3
2007	11,889	13,501	13,190	12,475	15,222	13.56	10.94	4.93	44.0
2008	11,335	12,959	12,599	11,921	15,080	14.32	11.14	5.17	50.1
2009	10,779	13,756	12,742	11,365	14,979	27.62	18.22	5.44	56.9
2010	10,182	13,566	12,359	10,768	14,842	33.23	21.38	5.76	64.6
2011	9,559	12,992	11,769	10,176	13,920	35.90	23.12	6.46	62.6
2012	9,042	12,683	11,379	9,971	12,496	40.30	25.85	10.28	44.7
2013	8,704	12,354	11,047	9,585	12,239	41.90	26.92	10.12	42.8
2014	8,403	11,989	10,702	8,483	11,930	42.70	27.35	0.95	43.8
2015	8,122	11,635	10,382	8,122	11,617	43.30	27.82	0.00	44.9
2016	7,985	11,422	10,205	7,985	11,567	43.00	27.79	0.00	46.8
2017	8,041	11,372	10,211	8,041	11,632	41.40	27.00	0.00	46.6
2018	8,131	10,970	10,147	8,131	11,715	34.90	24.79	0.00	46.0
2019	8,229	9,740	9,408	8,229	11,727	18.40	14.32	0.00	44.4
2020	8,344	9,539	9,306	8,344	11,753	14.30	11.52	0.00	42.7
2021	8,497	9,555	9,414	8,497	11,690	12.40	10.79	0.00	40.0
2022	8,577	9,584	9,482	8,577	12,106	11.70	10.55	0.00	49.9
2023	8,518	9,352	9,199	8,518	11,802	9.80	8.00	0.00	48.6
2024	8,454	9,207	9,111	8,454	10,523	8.90	7.78	0.00	33.3
2025	8,430	8,784	8,852	8,430	9,936	4.20	5.01	0.00	26.8
2026	8,416	8,669	8,761	8,416	8,973	3.00	4.11	0.00	15.8
2027	8,369	8,414	8,532	8,369	8,779	0.50	1.95	0.00	14.1
2028	8,277	8,313	8,312	8,277	8,479	0.40	0.42	0.00	11.5
2029	8,143	8,187	8,147	8,143	8,332	0.60	0.06	0.00	8.3
2030	7,983	8,055	8,022	7,983	8,139	0.90	0.48	0.00	4.0
2031	7,781	7,877	7,841	7,781	7,826	1.24	0.77	0.00	0.9
2032	7,551	7,622	7,596	7,551	7,585	0.94	0.60	0.00	0.6
2033	7,314	7,357	7,343	7,314	7,348	0.59	0.39	0.00	0.6
2034	7,081	7,109	7,102	7,081	7,114	0.40	0.30	0.00	0.6
2035	6,849	6,864	6,877	6,849	6,874	0.22	0.42	0.00	0.4
2036	6,612	6,626	6,641	6,612	6,636	0.21	0.45	0.00	0.4
2037	6,371	6,385	6,400	6,371	6,395	0.22	0.46	0.00	0.4
2038	6,130	6,144	6,160	6,130	6,154	0.23	0.48	0.00	0.4
2039	5,891	5,905	5,920	5,891	5,913	0.24	0.50	0.00	0.4
2040	5,652	5,666	5,681	5,652	5,657	0.25	0.52	0.00	0.1

Table H.3.2.4 Tri-Cities MSA Nonfarm Employment with the No Action, Long-Term Management, and In Situ Fill and Cap Alternatives (Change from Baseline Estimate), 1994 to 2040

Year	Baseline	No Action	Long-Term Management	In Situ Fill and Cap	Percentage Change from Baseline		
					No Action	Long-Term Management	In Situ Fill and Cap
1994	73,604	73,604	73,604	73,604	0.00	0.00	0.00
1995	69,885	69,885	69,885	69,885	0.00	0.00	0.00
1996	66,683	66,683	66,683	66,683	0.00	0.00	0.00
1997	68,046	68,046	68,046	68,046	0.00	0.00	0.00
1998	69,126	69,126	69,126	69,126	0.00	0.00	0.00
1999	69,707	69,707	69,707	69,737	0.00	0.00	0.04
2000	70,215	70,215	70,215	70,531	0.00	0.00	0.45
2001	70,679	70,679	70,679	70,924	0.00	0.00	0.35
2002	70,744	70,744	70,744	70,969	0.00	0.00	0.32
2003	70,809	70,809	70,809	71,032	0.00	0.00	0.31
2004	71,023	71,023	71,023	71,240	0.00	0.00	0.31
2005	71,405	71,417	71,417	71,620	0.02	0.02	0.30
2006	71,589	71,725	71,725	71,811	0.19	0.19	0.31
2007	71,453	71,625	71,625	71,683	0.24	0.24	0.32
2008	71,376	71,745	71,745	71,533	0.52	0.52	0.22
2009	71,313	71,646	71,646	71,490	0.47	0.47	0.25
2010	71,154	71,508	71,508	71,371	0.50	0.50	0.31
2011	70,965	71,341	71,341	71,188	0.53	0.53	0.31
2012	71,055	71,485	71,485	71,267	0.60	0.60	0.30
2013	71,496	71,929	71,929	71,702	0.61	0.61	0.29
2014	71,880	72,324	72,324	72,070	0.62	0.62	0.26
2015	72,281	72,792	72,792	72,515	0.71	0.71	0.32
2016	73,018	73,520	73,520	73,265	0.69	0.69	0.34
2017	74,104	74,711	74,711	74,331	0.82	0.82	0.31
2018	75,119	75,746	75,746	75,311	0.83	0.83	0.26
2019	76,122	76,821	76,821	76,324	0.92	0.92	0.27
2020	77,162	77,868	77,868	77,313	0.92	0.92	0.20
2021	78,279	79,028	79,028	78,384	0.96	0.96	0.13
2022	79,188	79,940	79,940	79,134	0.95	0.95	-0.07
2023	79,816	80,669	80,669	79,496	1.07	1.07	-0.40
2024	80,547	82,155	82,155	80,672	2.00	2.00	0.15
2025	81,381	82,971	82,971	81,222	1.95	1.95	-0.20
2026	82,206	83,725	83,725	82,079	1.85	1.85	-0.15
2027	82,942	84,452	84,452	82,820	1.82	1.82	-0.15
2028	83,596	85,113	85,113	83,481	1.82	1.82	-0.14
2029	84,183	85,769	85,769	84,137	1.88	1.88	-0.05
2030	84,744	86,396	86,419	84,764	1.95	1.98	0.02
2031	85,221	86,871	87,123	85,239	1.94	2.23	0.02
2032	85,666	87,309	87,618	85,677	1.92	2.28	0.01
2033	86,115	87,757	88,410	86,125	1.91	2.66	0.01
2034	86,582	88,224	88,783	86,591	1.90	2.54	0.01
2035	87,046	88,688	89,235	87,056	1.89	2.51	0.01
2036	87,499	89,141	89,687	87,509	1.88	2.50	0.01
2037	87,945	89,587	90,064	87,954	1.87	2.41	0.01
2038	88,396	90,038	89,852	88,405	1.86	1.65	0.01
2039	88,849	90,491	90,468	88,859	1.85	1.82	0.01
2040	89,301	90,944	90,944	89,311	1.84	1.84	0.01

Table H.3.2.5 Tri-Cities MSA Nonfarm Employment with the In Situ Vitrification, Ex Situ Intermediate Separations, and Ex Situ No Separations Alternatives (Change from Baseline Estimate), 1994 to 2040

Year	Baseline	In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations	Percentage Change from Baseline		
					In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations
1994	73,604	73,604	73,604	73,604	0.00	0.00	0.00
1995	69,885	69,885	70,057	69,885	0.00	0.25	0.00
1996	66,683	66,683	68,643	66,984	0.00	2.94	0.45
1997	68,046	68,166	71,092	71,482	0.18	4.48	5.05
1998	69,126	70,529	74,059	74,380	2.03	7.14	7.60
1999	69,707	72,204	74,693	77,691	3.58	7.15	11.45
2000	70,215	74,545	76,960	77,578	6.17	9.61	10.49
2001	70,679	74,922	77,449	77,083	6.00	9.58	9.06
2002	70,744	74,749	77,295	76,585	5.66	9.26	8.26
2003	70,809	74,398	76,979	74,627	5.07	8.71	5.39
2004	71,023	75,344	76,820	76,286	6.08	8.16	7.41
2005	71,405	74,852	75,654	77,138	4.83	5.95	8.03
2006	71,589	75,205	75,283	76,867	5.05	5.16	7.37
2007	71,453	75,130	74,731	76,716	5.15	4.59	7.37
2008	71,376	73,710	74,788	76,539	3.27	4.78	7.23
2009	71,313	72,867	77,732	75,818	2.18	9.00	6.32
2010	71,154	72,702	77,433	75,839	2.18	8.82	6.58
2011	70,965	72,644	77,064	75,674	2.37	8.59	6.64
2012	71,055	72,740	77,626	75,755	2.37	9.25	6.61
2013	71,496	73,163	77,917	75,970	2.33	8.98	6.26
2014	71,880	73,371	78,136	76,236	2.07	8.70	6.06
2015	72,281	73,839	78,412	76,447	2.16	8.48	5.76
2016	73,018	74,420	79,024	76,388	1.92	8.23	4.62
2017	74,104	73,728	79,978	76,808	-0.51	7.93	3.65
2018	75,119	74,675	80,443	77,024	-0.59	7.09	2.54
2019	76,122	75,414	78,133	76,380	-0.93	2.64	0.34
2020	77,162	76,074	79,505	77,692	-1.41	3.04	0.69
2021	78,279	77,377	80,719	78,707	-1.15	3.12	0.55
2022	79,188	78,307	81,660	79,457	-1.11	3.12	0.34
2023	79,816	79,037	81,668	79,924	-0.98	2.32	0.14
2024	80,547	80,522	82,163	80,509	-0.03	2.01	-0.05
2025	81,381	81,339	82,343	81,371	-0.05	1.18	-0.01
2026	82,206	82,092	83,155	82,050	-0.14	1.15	-0.19
2027	82,942	82,820	83,261	82,823	-0.15	0.38	-0.14
2028	83,596	83,481	83,627	83,507	-0.14	0.04	-0.11
2029	84,183	84,137	84,202	84,185	-0.05	0.02	0.00
2030	84,744	84,764	84,877	84,849	0.02	0.16	0.12
2031	85,221	85,239	85,396	85,350	0.02	0.21	0.15
2032	85,666	85,677	85,761	85,718	0.01	0.11	0.06
2033	86,115	86,125	86,162	86,133	0.01	0.05	0.02
2034	86,582	86,591	86,621	86,592	0.01	0.05	0.01
2035	87,046	87,056	87,128	87,059	0.01	0.09	0.01
2036	87,499	87,509	87,573	87,513	0.01	0.08	0.02
2037	87,945	87,954	88,017	87,959	0.01	0.08	0.02
2038	99,396	88,405	88,468	88,410	0.01	0.08	0.02
2039	88,849	88,859	88,922	88,864	0.01	0.08	0.02
2040	89,301	89,311	89,374	89,316	0.01	0.08	0.02

Table H.3.2.6 Tri-Cities MSA Nonfarm Employment with the Ex Situ Extensive Separations, Ex Situ/In Situ Combination 1, and Phased Implementation Alternatives (Change from Baseline Estimate), 1994 to 2040

						Percentage Change from Baseline			
		Ex Situ Extensive	Ex Situ/ In Situ	Phased Implementation		Ex Situ Extensive	Ex Situ/ In Situ	Phased Implementation	
Year	Baseline	Separations	Combination	Phase 1	Total	Separations	Combination 1	Phase 1	Total
1994	73,604	73,604	73,604	73,604	73,604.00	0.00	0.00	0.00	0.0
1995	69,885	70,027	69,990	69,903	69,903	0.20	0.15	0.03	0.0
1996	66,683	68,523	67,879	67,014	67,014	2.76	1.79	0.50	0.2
1997	68,046	72,885	69,903	69,983	69,983	7.11	2.73	2.85	3.0
1998	69,126	75,071	72,125	73,936	73,936	8.60	4.34	6.96	7.0
1999	69,707	72,925	72,741	75,579	75,580	4.62	4.35	8.42	8.5
2000	70,215	72,268	74,319	74,832	74,832	2.92	5.85	6.58	6.6
2001	70,679	76,377	74,768	71,731	71,729	8.06	5.79	1.49	1.5
2002	70,744	80,742	74,686	71,058	71,041	14.13	5.57	0.44	0.4
2003	70,809	82,977	74,506	71,633	71,688	17.18	5.22	1.16	1.2
2004	71,023	78,736	74,497	71,902	72,775	10.86	4.89	1.24	2.7
2005	71,405	76,567	73,926	72,292	74,629	7.23	3.53	1.24	6.9
2006	71,589	74,887	73,774	72,559	75,960	4.61	3.05	1.36	10.1
2007	71,453	73,177	73,394	72,403	77,655	2.41	2.72	1.33	13.5
2008	71,376	74,009	73,387	72,323	77,767	3.69	2.82	1.33	13.4
2009	71,313	77,239	75,062	72,260	78,476	8.31	5.26	1.33	14.4
2010	71,154	76,957	74,849	72,101	79,063	8.16	5.19	1.33	15.4
2011	70,965	76,554	74,564	71,989	77,768	7.90	5.07	1.44	12.9
2012	71,055	77,112	74,939	72,815	75,892	8.50	5.47	2.48	6.9
2013	71,496	77,404	75,287	72,879	77,276	8.30	5.30	1.94	8.0
2014	71,880	77,622	75,558	71,351	77,572	8.00	5.12	-0.74	8.2
2015	72,281	77,898	75,900	72,215	77,903	7.80	5.01	-0.09	8.1
2016	73,018	78,511	76,572	73,018	78,879	7.50	4.87	0.00	8.4
2017	74,104	79,402	77,572	74,104	79,916	7.10	4.68	0.00	8.2
2018	75,119	79,302	78,250	75,119	80,904	5.60	4.17	0.00	8.0
2019	76,122	77,473	77,338	76,122	81,706	1.80	1.60	0.00	7.7
2020	77,162	78,831	78,537	77,162	82,598	2.20	1.78	0.00	7.4
2021	78,279	79,876	79,725	78,279	83,261	2.00	1.85	0.00	6.8
2022	79,188	80,772	80,641	79,188	85,167	2.00	1.84	0.00	9.7
2023	79,816	81,022	80,734	79,816	84,923	1.50	1.15	0.00	8.2
2024	80,547	81,698	81,590	80,547	82,893	1.40	1.29	0.00	4.3
2025	81,381	81,625	81,870	81,381	83,353	0.30	0.60	0.00	3.9
2026	82,206	82,533	82,701	82,206	82,326	0.40	0.60	0.00	1.7
2027	82,942	82,845	83,056	82,942	83,484	-0.10	0.14	0.00	2.2
2028	83,596	83,645	83,547	83,596	83,750	0.10	-0.06	0.00	1.6
2029	84,183	84,263	84,166	84,183	84,479	0.10	-0.02	0.00	1.0
2030	84,744	84,883	84,834	84,744	84,967	0.10	0.11	0.00	0.3
2031	85,221	85,396	85,335	85,221	85,202	0.21	0.13	0.00	-0.1
2032	85,666	85,761	85,727	85,666	85,712	0.11	0.07	0.00	0.1
2033	86,115	86,162	86,148	86,115	86,170	0.05	0.04	0.00	0.1
2034	86,582	86,614	86,610	86,582	86,634	0.04	0.03	0.00	0.1
2035	87,046	87,060	87,099	87,046	87,080	0.02	0.06	0.00	0.0
2036	87,499	87,521	87,547	87,499	87,537	0.03	0.06	0.00	0.0
2037	87,945	87,967	87,992	87,945	87,984	0.03	0.05	0.00	0.0
2038	88,396	88,418	88,443	88,396	88,435	0.03	0.05	0.00	0.0
2039	88,849	88,872	88,897	88,849	88,884	0.03	0.05	0.00	0.0
2040	89,301	89,324	89,349	89,301	89,295	0.03	0.05	0.00	0.0

Table H.3.2.7 Tri-Cities MSA Population with the No Action, Long-Term Management, and In Situ Fill and Cap Alternatives (Change from Baseline Estimate), 1994 to 2040

Year	Baseline	No Action	Long-Term Management	In Situ Fill and Cap	Percentage Change from Baseline		
					No Action	Long-Term Management	In Situ Fill and Cap
1994	164,911	164,911	164,911	164,911	0.00	0.00	0.00
1995	171,358	171,358	171,358	171,358	0.00	0.00	0.00
1996	166,266	166,266	166,266	166,266	0.00	0.00	0.00
1997	161,933	161,933	161,933	161,932	0.00	0.00	0.00
1998	164,289	164,289	164,289	164,289	0.00	0.00	0.00
1999	166,230	166,230	166,230	166,230	0.00	0.00	0.00
2000	167,442	167,442	167,442	167,485	0.00	0.00	0.03
2001	168,544	168,544	168,544	169,008	0.00	0.00	0.28
2002	169,583	169,583	169,583	169,942	0.00	0.00	0.21
2003	170,037	170,037	170,037	170,367	0.00	0.00	0.19
2004	170,492	170,492	170,492	170,818	0.00	0.00	0.19
2005	171,164	171,164	171,164	171,483	0.00	00.2	0.19
2006	172,083	172,101	172,101	172,399	0.01	0.19	0.18
2007	172,711	172,911	172,911	173,037	0.12	0.24	0.19
2008	172,872	173,124	173,124	173,209	0.15	0.52	0.20
2009	173,117	173,658	173,658	173,348	0.31	0.47	0.13
2010	173,384	173,872	173,872	173,644	0.28	0.50	0.15
2011	173,510	174,028	174,028	173,828	0.30	0.53	0.18
2012	173,592	174,143	174,143	173,919	0.32	0.60	0.19
2013	174,083	174,713	174,713	174,393	0.36	0.61	0.18
2014	175,088	175,722	175,722	175,390	0.36	0.62	0.17
2015	176,010	176,660	176,660	176,288	0.37	0.71	0.16
2016	176,956	177,705	177,705	177,300	0.42	0.69	0.19
2017	178,395	179,131	179,131	178,758	0.41	0.82	0.20
2018	180,346	181,235	181,235	180,679	0.49	0.83	0.18
2019	182,193	183,112	183,112	182,474	0.50	0.92	0.15
2020	184,021	185,045	185,045	184,317	0.56	0.92	0.16
2021	185,904	186,939	186,939	186,125	0.56	0.96	0.12
2022	187,901	188,997	188,997	188,054	0.58	0.95	0.08
2023	189,590	190,693	190,693	189,512	0.58	1.07	-0.04
2024	190,870	192,121	192,121	190,402	0.66	2.00	-0.25
2025	192,301	194,657	194,657	192,484	1.22	1.95	0.10
2026	193,882	196,212	196,212	193,649	1.20	1.85	-0.12
2027	195,450	197,675	197,675	195,264	1.14	1.82	-0.09
2028	196,888	199,101	199,101	196,708	1.12	1.82	-0.09
2029	198,204	200,428	200,428	198,036	1.12	1.88	-0.08
2030	199,424	201,749	201,749	199,356	1.17	1.98	-0.03
2031	200,605	203,026	203,059	200,634	1.21	2.23	0.01
2032	201,662	204,081	204,451	201,689	1.20	2.28	0.01
2033	202,674	205,082	205,534	202,689	1.19	2.66	0.01
2034	203,691	206,098	207,959	203,705	1.18	2.54	0.01
2035	204,733	207,140	208,981	204,748	1.18	2.51	0.01
2036	205,774	208,180	208,981	205,788	1.17	2.50	0.01
2037	206,796	209,202	210,003	206,810	1.16	2.41	0.01
2038	207,808	210,215	210,914	207,822	1.16	1.65	0.01
2039	208,828	211,234	210,962	208,842	1.15	1.82	0.01
2040	209,851	212,258	212,224	209,865	1.15	1.84	0.01

Table H.3.2.8 Tri-Cities MSA Population with the In Situ Vitrification, Ex Situ Intermediate Separations, and Ex Situ No Separations Alternatives (Change from Baseline Estimate), 1994 to 2040

Year	Baseline	In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations	Percentage Change from Baseline		
					In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations
1994	164,911	164,911	164,911	164,911	0.00	0.00	0.00
1995	171,358	171,358	171,358	171,358	0.00	0.00	0.00
1996	166,266	166,266	166,518	166,266	0.00	0.15	0.00
1997	161,933	161,933	164,805	162,374	0.00	1.77	0.27
1998	164,289	164,465	168,753	169,324	0.11	2.72	3.06
1999	166,230	168,286	173,459	173,930	1.24	4.35	4.63
2000	167,442	171,100	174,748	179,142	2.19	4.36	6.99
2001	168,544	174,891	178,429	179,335	3.77	5.86	6.40
2002	169,583	175,802	179,505	178,968	3.67	5.85	5.53
2003	170,037	175,907	179,638	178,598	3.45	5.65	5.03
2004	170,492	175,751	179,534	176,087	3.08	5.30	3.28
2005	171,164	177,497	179,660	178,878	3.70	4.96	4.51
2006	172,083	177,134	178,309	180,485	2.94	3.62	4.88
2007	172,711	178,011	178,126	180,447	3.07	3.14	4.48
2008	172,872	178,260	177,675	180,584	3.12	2.78	4.46
2009	173,117	176,538	178,188	180,683	1.98	2.89	4.37
2010	173,384	175,662	182,791	179,987	1.31	5.43	3.81
2011	173,510	175,779	182,712	180,375	1.31	5.30	3.96
2012	173,592	176,053	182,530	180,493	1.42	5.15	3.98
2013	174,083	176,552	183,713	180,971	1.42	5.53	3.96
2014	175,088	177,532	184,499	181,645	1.40	5.38	3.75
2015	176,010	178,195	185,178	182,393	1.24	5.21	3.63
2016	176,956	179,240	185,941	183,062	1.29	5.08	3.45
2017	178,395	180,450	187,198	183,334	1.15	4.93	2.77
2018	180,346	179,794	188,953	184,308	-0.31	4.77	2.20
2019	182,193	181,541	189,994	184,984	-0.36	4.28	1.53
2020	184,021	182,983	186,968	184,399	-0.56	1.60	0.21
2021	185,904	184,310	189,338	186,681	-0.86	1.85	0.42
2022	187,901	186,578	191,476	188,528	-0.70	1.90	0.33
2023	189,590	188,300	193,214	189,986	-0.68	1.91	0.21
2024	190,870	189,729	193,585	191,029	-0.60	1.42	0.08
2025	192,301	192,264	194,669	192,245	-0.02	1.23	-0.03
2026	193,882	193,820	195,292	193,867	-0.03	0.73	-0.01
2027	195,450	195,283	196,840	195,221	-0.09	0.71	-0.12
2028	196,888	196,708	197,355	196,713	-0.09	0.24	-0.09
2029	198,204	198,036	198,249	198,074	-0.09	0.02	-0.07
2030	199,424	199,356	199,451	199,426	-0.03	0.01	0.00
2031	200,605	200,634	200,800	200,759	0.01	0.10	0.08
2032	201,662	201,689	201,919	201,851	0.01	0.13	0.09
2033	202,674	202,689	202,812	202,751	0.01	0.07	0.04
2034	203,691	203,706	203,760	203,718	0.01	0.03	0.01
2035	204,733	204,748	204,791	204,749	0.01	0.03	0.01
2036	205,774	205,788	205,893	205,792	0.01	0.06	0.01
2037	206,796	206,810	206,904	206,817	0.01	0.05	0.01
2038	207,808	207,822	207,915	207,829	0.01	0.05	0.01
2039	208,828	208,842	208,935	208,849	0.01	0.05	0.01
2040	209,851	209,866	209,958	209,873	0.01	0.05	0.01

Table H.3.2.9 Tri-Cities MSA Population with the Ex Situ Extensive Separations, Ex Situ/In Situ Combination 1, and Phased Implementation Alternatives (Change from Baseline Estimate), 1994 to 2040

						Percentage Change from Baseline			
				Phased Implementation				Phased Implementation	
Year	Baseline	Ex Situ Extensive Separations	Ex Situ/ In Situ Combination	Phase 1	Total	Ex Situ Extensive Separations	Ex Situ/ In Situ Combination 1	Phase 1	Total
1994	164,911	164,911	164,911	164,911	164,9111	0.00	0.00	0.00	0.0
1995	171,358	171,358	171,358	171,358	171,358	0.00	0.00	0.00	0.0
1996	166,266	166,475	166,420	166,293	166,293	0.13	0.09	0.02	0.0
1997	161,933	164,628	163,685	162,418	162,418	1.66	1.08	0.30	0.1
1998	164,289	171,381	167,010	167,128	167,128	4.32	1.66	1.73	1.8
1999	166,230	174,943	170,625	173,280	173,280	5.24	2.64	4.24	4.3
2000	167,442	172,157	171,887	176,048	176,048	2.82	2.66	5.14	5.2
2001	168,544	171,554	174,559	175,311	175,311	1.79	3.57	4.01	4.0
2002	169,583	177,934	175,576	171,125	171,123	4.92	3.53	0.91	0.9
2003	170,037	184,689	175,814	170,498	170,473	8.62	3.40	0.27	0.2
2004	170,492	188,324	175,910	171,699	171,780	10.46	3.18	0.71	0.8
2005	171,164	182,467	176,255	172,453	173,731	6.60	2.97	0.75	1.6
2006	172,083	179,648	175,777	173,384	176,807	4.40	2.15	0.76	4.2
2007	172,711	177,545	175,914	174,133	179,118	2.80	1.85	0.82	6.1
2008	172,872	175,398	175,716	174,264	181,960	1.46	1.65	0.81	8.2
2009	173,117	176,976	176,064	174,505	182,484	2.23	1.70	0.80	8.1
2010	173,384	182,069	178,879	174,772	183,882	5.00	3.17	0.80	8.7
2011	173,510	182,014	178,925	174,898	185,101	4.90	3.12	0.80	9.3
2012	173,592	181,782	178,866	175,092	183,562	4.70	3.04	0.86	7.8
2013	174,083	182,960	179,774	176,662	181,171	5.10	3.27	1.48	4.2
2014	175,088	183,745	180,644	177,115	183,559	4.90	3.17	1.16	4.8
2015	176,010	184,425	181,400	175,234	184,352	4.80	3.06	-0.44	4.9
2016	176,956	185,188	182,260	176,859	185,195	4.70	3.00	-0.05	4.9
2017	178,395	186,445	183,604	178,395	186,984	4.50	2.92	0.00	5.0
2018	180,346	188,109	185,429	180,346	188,863	4.30	2.82	0.00	4.9
2019	182,193	188,322	186,781	182,193	190,670	3.40	2.52	0.00	4.9
2020	184,021	186,001	185,803	184,021	192,204	1.10	0.97	0.00	4.6
2021	185,904	188,350	187,919	185,904	193,870	1.30	1.08	0.00	4.5
2022	187,901	190,240	190,018	187,901	195,201	1.20	1.13	0.00	4.2
2023	189,590	191,913	191,720	189,590	198,353	1.20	1.12	0.00	5.9
2024	190,870	192,638	192,215	190,870	198,354	0.90	0.70	0.00	5.0
2025	192,301	193,988	193,828	192,301	195,739	0.90	0.79	0.00	2.6
2026	193,882	194,240	194,599	193,882	196,772	0.20	0.37	0.00	2.4
2027	195,450	195,929	196,176	195,450	195,625	0.20	0.37	0.00	1.0
2028	196,888	196,745	197,055	196,888	197,681	-0.10	0.08	0.00	1.3
2029	198,204	198,277	198,133	198,204	198,431	0.04	-0.04	0.00	1.0
2030	199,424	199,541	199,399	199,424	199,858	0.10	-0.01	0.00	0.6
2031	200,605	200,808	200,737	200,605	200,932	0.10	0.07	0.00	0.2
2032	201,662	201,919	201,830	201,662	201,635	0.13	0.08	0.00	-0.1
2033	202,674	202,812	202,764	202,674	202,742	0.07	0.04	0.00	0.0
2034	203,691	203,760	203,740	203,691	203,772	0.03	0.02	0.00	0.1
2035	204,733	204,781	204,775	204,733	204,811	0.02	0.02	0.00	0.0
2036	205,774	205,794	205,851	205,774	205,822	0.01	0.04	0.00	0.0
2037	206,796	206,828	206,867	206,796	206,852	0.02	0.03	0.00	0.0
2038	207,808	207,841	207,878	207,808	207,865	0.02	0.03	0.00	0.0
2039	208,828	208,861	208,898	208,828	208,885	0.02	0.03	0.00	0.0
2040	209,851	209,884	209,921	209,851	209,903	0.02	0.03	0.00	0.0

Table H.3.2.10 Tri-Cities MSA Taxable Retail Sales with the No Action, Long-Term Management, and In Situ Fill and Cap Alternatives (Change from Baseline Estimate), 1994 to 2040 ($ Millions)

Year	Baseline	No Action	Long-Term Management	In Situ Fill and Cap	Percentage Change from Baseline		
					No Action	Long-Term Management	In Situ Fill and Cap
1994	513	513	513	513	0.00	0.00	-0.04
1995	646	646	646	646	0.00	0.00	0.06
1996	706	706	706	706	0.00	0.00	0.01
1997	746	746	746	746	0.00	0.00	-0.03
1998	818	818	818	818	0.00	0.00	-0.02
1999	898	898	898	898	0.00	0.00	-0.04
2000	977	977	977	978	0.00	0.00	0.07
2001	1,055	1,055	1,055	1,058	0.00	0.00	0.27
2002	1,132	1,132	1,132	1,135	0.00	0.00	0.26
2003	1,206	1,206	1,206	1,208	0.00	0.00	0.20
2004	1,278	1,278	1,278	1,281	0.00	0.00	0.25
2005	1,351	1,351	1,351	1,354	0.00	0.02	0.23
2006	1,426	1,426	1,426	1,428	0.01	0.19	0.17
2007	1,499	1,501	1,501	1,502	0.08	0.24	0.18
2008	1,570	1,572	1,572	1,573	0.12	0.52	0.20
2009	1,640	1,644	1,644	1,642	0.23	0.47	0.12
2010	1,710	1,714	1,714	1,712	0.24	0.50	0.12
2011	1,779	1,784	1,784	1,782	0.25	0.53	0.16
2012	1,848	1,853	1,853	1,851	0.25	0.60	0.17
2013	1,919	1,924	1,924	1,921	0.27	0.61	0.12
2014	1,993	1,999	1,999	1,996	0.27	0.62	0.14
2015	2,069	2,074	2,074	2,071	0.27	0.71	0.12
2016	2,144	2,150	2,150	2,147	0.28	0.69	0.13
2017	2,223	2,229	2,229	2,226	0.28	0.82	0.14
2018	2,305	2,313	2,313	2,308	0.31	0.83	0.11
2019	2,389	2,396	2,396	2,391	0.33	0.92	0.10
2020	2,472	2,481	2,481	2,475	0.34	0.92	0.12
2021	2,556	2,565	2,565	2,558	0.34	0.96	0.08
2022	2,640	2,650	2,650	2,642	0.35	0.95	0.06
2023	2,724	2,733	2,733	2,724	0.35	1.07	0.02
2024	2,804	2,814	2,814	2,801	0.37	2.00	-0.10
2025	2,884	2,901	2,901	2,884	0.59	1.95	0.01
2026	2,965	2,984	2,984	2,964	0.64	1.85	-0.03
2027	3,046	3,065	3,065	3,044	0.63	1.82	-0.06
2028	3,126	3,146	3,146	3,125	0.61	1.82	-0.04
2029	3,206	3,225	3,225	3,204	0.60	1.88	-0.06
2030	3,285	3,305	3,305	3,284	0.61	1.98	-0.02
2031	3,363	3,383	3,384	3,363	0.61	2.23	0.01
2032	3,440	3,461	3,463	3,440	0.60	2.28	0.00
2033	3,517	3,538	3,541	3,517	0.59	2.66	0.01
2034	3,593	3,614	3,621	3,593	0.58	2.54	-0.01
2035	3,670	3,691	3,698	3,670	0.57	2.51	0.00
2036	3,747	3,768	3,775	3,747	0.56	2.50	0.01
2037	3,823	3,844	3,851	3,823	0.54	2.41	-0.01
2038	3,900	3,921	3,927	3,900	0.53	1.65	0.01
2039	3,976	3,997	3,998	3,976	0.52	1.82	-0.01
2040	4,053	4,074	4,074	4,053	0.51	1.84	0.00

Table H.3.2.11 Tri-Cities MSA Taxable Retail Sales with the In Situ Vitrification, Ex Situ Intermediate Separations, and Ex Situ No Separations Alternatives (Change from Baseline Estimate), 1994 to 2040 ($ Millions)

Year	Baseline	In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations	Percentage Change from Baseline		
					In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations
1994	513	513	513	513	0.00	0.00	-0.04
1995	646	646	646	646	0.00	0.00	0.06
1996	706	706	707	706	0.00	0.20	0.01
1997	746	746	763	749	0.00	2.28	0.38
1998	818	819	850	848	0.12	3.83	3.64
1999	898	911	951	953	1.36	5.80	6.08
2000	977	1,002	1,037	1,063	2.57	6.09	8.77
2001	1,055	1,100	1,132	1,146	4.26	7.28	8.62
2002	1,132	1,183	1,215	1,217	4.49	7.31	7.50
2003	1,206	1,256	1,289	1,283	4.21	6.88	6.42
2004	1,278	1,325	1,358	1,336	3.70	6.25	4.55
2005	1,351	1,403	1,427	1,415	3.87	5.60	4.74
2006	1,426	1,472	1,487	1,495	3.28	4.30	4.87
2007	1,499	1,545	1,551	1,567	3.07	3.45	4.52
2008	1,570	1,616	1,615	1,637	2.96	2.87	4.27
2009	1,640	1,675	1,684	1,706	2.15	2.68	4.02
2010	1,710	1,735	1,779	1,770	1.46	4.02	3.51
2011	1,779	1,801	1,855	1,839	1.21	4.27	3.36
2012	1,848	1,869	1,925	1,908	1.15	4.16	3.25
2013	1,919	1,940	2,000	1,978	1.12	4.23	3.09
2014	1,993	2,014	2,075	2,051	1.06	4.08	2.90
2015	2,069	2,088	2,149	2,125	0.95	3.87	2.73
2016	2,144	2,164	2,223	2,198	0.92	3.66	2.51
2017	2,223	2,241	2,300	2,269	0.83	3.46	2.08
2018	2,305	2,308	2,381	2,344	0.13	3.27	1.67
2019	2,389	2,386	2,459	2,418	-0.11	2.94	1.23
2020	2,472	2,465	2,513	2,484	-0.28	1.64	0.48
2021	2,556	2,544	2,589	2,564	-0.45	1.31	0.32
2022	2,640	2,629	2,672	2,647	-0.43	1.20	0.25
2023	2,724	2,712	2,755	2,728	-0.41	1.16	0.17
2024	2,804	2,793	2,830	2,806	-0.37	0.93	0.08
2025	2,884	2,880	2,906	2,884	-0.13	0.78	0.01
2026	2,965	2,963	2,980	2,965	-0.05	0.53	0.01
2027	3,046	3,044	3,059	3,045	-0.05	0.44	-0.03
2028	3,126	3,125	3,134	3,125	-0.05	0.23	-0.04
2029	3,206	3,205	3,209	3,205	-0.05	0.08	-0.03
2030	3,285	3,284	3,286	3,284	-0.03	0.03	-0.02
2031	3,363	3,363	3,364	3,364	0.00	0.04	0.04
2032	3,440	3,440	3,442	3,441	0.00	0.06	0.03
2033	3,517	3,517	3,518	3,518	0.00	0.04	0.03
2034	3,593	3,594	3,594	3,594	0.00	0.03	0.02
2035	3,670	3,670	3,671	3,670	0.00	0.02	0.00
2036	3,747	3,747	3,748	3,747	0.00	0.02	0.01
2037	3,823	3,823	3,824	3,823	0.00	0.02	-0.01
2038	3,900	3,900	3,901	3,900	0.00	0.02	0.01
2039	3,976	3,976	3,977	3,976	0.00	0.02	-0.01
2040	4,053	4,053	4,054	4,053	0.00	0.02	0.00

Table H.3.2.12 Tri-Cities MSA Taxable Retail Sales with the Ex Situ Extensive Separations, Ex Situ/In Situ Combination 1, and Phased Implementation Alternatives (Change from Baseline Estimate), 1994 to 2040 ($ Millions)

						Percentage Change from Baseline			
				Phased Implementation		Ex Situ Extensive Separations	Ex Situ/ In Situ Combination 1	Phased Implementation	
Year	Baseline	Ex Situ Extensive Separations	Ex Situ/ In Situ Combination	Phase 1	Total			Phase 1	Total
1994	513	513	513	513	513	-0.04	0.00	0.00	0.0
1995	646	646	646	646	646	0.06	0.00	0.00	0.0
1996	706	707	707	706	706	0.16	0.11	0.01	0.0
1997	746	762	757	749	749	2.12	1.38	1.38	0.2
1998	818	864	837	835	835	5.60	2.33	2.10	2.1
1999	898	964	930	945	945	7.30	3.53	5.15	5.2
2000	977	1,026	1,014	1,042	1,042	4.98	3.70	6.65	6.7
2001	1,055	1,089	1,102	1,116	1,116	3.21	4.43	5.75	5.8
2002	1,132	1,191	1,182	1,162	1,162	5.20	4.43	2.60	2.6
2003	1,206	1,310	1,256	1,218	1,218	8.66	4.15	1.04	1.0
2004	1,278	1,415	1,326	1,289	1,289	10.74	3.76	0.88	0.9
2005	1,351	1,462	1,396	1,362	1,370	8.22	3.36	0.82	1.5
2006	1,426	1,507	1,462	1,437	1,459	5.71	2.56	0.79	3.4
2007	1,499	1,554	1,530	1,511	1,547	3.65	2.05	0.80	5.1
2008	1,570	1,603	1,597	1,582	1,638	2.11	1.70	0.77	6.8
2009	1,640	1,673	1,666	1,652	1,717	2.01	1.58	0.73	7.1
2010	1,710	1,771	1,750	1,722	1,796	3.57	2.36	0.71	7.4
2011	1,779	1,849	1,824	1,791	1,875	3.92	2.51	0.67	7.6
2012	1,848	1,918	1,893	1,861	1,937	3.79	2.45	0.68	6.6
2013	1,919	1,993	1,967	1,938	1,990	3.90	2.50	1.00	4.3
2014	1,993	2,068	2,041	2,011	2,066	3.80	2.41	0.91	3.8
2015	2,069	2,142	2,116	2,070	2,141	3.60	2.28	0.08	3.6
2016	2,144	2,216	2,191	2,144	2,216	3.40	2.16	0.00	3.5
2017	2,223	2,293	2,268	2,223	2,296	3.20	2.05	0.00	3.4
2018	2,305	2,374	2,350	2,305	2,379	3.00	1.93	0.00	3.3
2019	2,389	2,447	2,430	2,389	2,462	2.40	1.73	0.00	3.2
2020	2,472	2,503	2,496	2,472	2,544	1.30	0.97	0.00	3.0
2021	2,556	2,580	2,576	2,556	2,626	1.00	0.77	0.00	2.9
2022	2,640	2,662	2,659	2,640	2,706	0.80	0.71	0.00	2.6
2023	2,724	2,744	2,742	2,724	2,796	0.80	0.68	0.00	3.2
2024	2,804	2,821	2,818	2,804	2,871	0.60	0.50	0.00	3.0
2025	2,884	2,899	2,897	2,884	2,926	0.50	0.47	0.00	2.0
2026	2,965	2,972	2,973	2,965	2,996	0.20	0.29	0.00	1.6
2027	3,046	3,051	3,053	3,046	3,057	0.20	0.23	0.00	0.9
2028	3,126	3,127	3,130	3,126	3,135	0.03	0.11	0.00	0.8
2029	3,206	3,207	3,207	3,206	3,210	0.03	0.02	0.00	0.6
2030	3,285	3,286	3,285	3,285	3,289	0.04	0.00	0.00	0.4
2031	3,363	3,364	3,364	3,363	3,366	0.04	0.02	0.00	0.2
2032	3,440	3,442	3,441	3,440	3,441	0.06	0.03	0.00	0.0
2033	3,517	3,518	3,518	3,517	3,518	0.03	0.03	0.00	0.0
2034	3,593	3,594	3,594	3,593	3,594	0.02	0.02	0.00	0.0
2035	3,670	3,671	3,671	3,670	3,671	0.03	0.01	0.00	0.0
2036	3,747	3,747	3,747	3,747	3,747	0.01	0.02	0.00	0.0
2037	3,823	3,824	3,824	3,823	3,824	0.02	0.02	0.00	0.0
2038	3,900	3,900	3,900	3,900	3,900	0.01	0.02	0.00	0.0
2039	3,976	3,977	3,977	3,976	3,977	0.02	0.02	0.00	0.0
2040	4,053	4,053	4,053	4,052	4,053	0.00	0.01	0.00	0.0

Table H.3.2.13 Tri-Cities MSA Home Prices with the No Action, Long-Term Management, and In Situ Fill and Cap Alternatives (Change from Baseline Estimate), 1994 to 2040 ($ Thousands)

Year	Baseline	No Action	Long-Term Management	In Situ Fill and Cap	Percentage Change from Baseline		
					No Action	Long-Term Management	In Situ Fill and Cap
1994	103	103	103	103	0.00	0.00	-0.29
1995	115	115	115	114	0.00	0.00	-0.44
1996	107	107	107	107	0.00	0.00	0.38
1997	100	100	100	100	0.00	0.00	0.10
1998	104	104	104	104	0.00	0.00	-0.29
1999	108	108	108	108	0.00	0.00	0.00
2000	111	111	111	111	0.00	0.00	0.45
2001	113	113	113	114	0.00	0.00	0.97
2002	115	115	115	116	0.00	0.00	0.78
2003	116	116	116	117	0.00	0.00	0.52
2004	118	118	118	118	0.00	0.00	0.34
2005	119	119	119	120	0.00	0.02	0.67
2006	121	121	121	122	0.00	0.19	0.58
2007	123	123	123	123	0.24	0.24	0.16
2008	124	124	124	124	0.32	0.52	0.32
2009	125	125	125	125	0.72	0.47	0.40
2010	126	126	126	126	0.64	0.50	0.40
2011	126	127	127	127	0.63	0.53	0.63
2012	127	128	128	127	0.71	0.60	0.16
2013	128	129	129	129	0.86	0.61	0.70
2014	130	131	131	131	0.84	0.62	0.54
2015	132	133	133	133	0.83	0.71	0.53
2016	134	136	136	135	0.89	0.69	0.45
2017	137	139	139	138	.087	0.82	0.51
2018	141	143	143	142	1.06	0.83	0.71
2019	145	146	146	145	1.04	0.92	0.28
2020	148	150	150	149	1.15	0.92	0.61
2021	152	154	154	152	1.19	0.96	0.20
2022	156	157	157	156	1.16	0.95	0.26
2023	159	161	161	159	1.13	1.07	0.06
2024	162	164	164	161	1.24	2.00	-0.31
2025	164	168	168	165	2.31	1.95	0.36
2026	168	171	171	167	2.27	1.85	-0.30
2027	171	174	174	170	2.17	1.82	-0.35
2028	174	177	177	173	2.07	1.82	-0.29
2029	176	180	180	176	2.10	1.88	-0.06
2030	179	183	183	179	2.13	1.98	0.17
2031	181	185	185	181	2.21	2.23	-0.06
2032	183	187	188	183	2.18	2.28	-0.22
2033	186	190	190	186	2.10	2.66	0.22
2034	188	192	193	188	2.08	2.54	0.11
2035	190	194	195	190	2.11	2.51	0.00
2036	192	196	198	192	2.08	2.50	-0.10
2037	194	198	200	194	2.06	2.41	-0.21
2038	197	201	202	197	2.03	1.65	0.20
2039	199	203	202	199	2.01	1.82	0.10
2040	201	205	205	201	1.99	1.84	0.00

Table H.3.2.14 Tri-Cities MSA Home Prices with the In Situ Vitrification, Ex Situ Intermediate Separations, and Ex Situ No Separations Alternatives (Change from Baseline Estimate), 1994 to 2040 ($ Thousands)

Year	Baseline	In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations	Percentage Change from Baseline		
					In Situ Vitrification	Ex Situ Intermediate Separations	Ex Situ No Separations
1994	103	103	103	103	0.00	0.00	-0.29
1995	115	115	115	114	0.00	0.00	-0.44
1996	107	107	107	107	0.00	0.38	0.38
1997	100	100	105	101	0.00	4.80	1.10
1998	104	105	112	113	0.29	7.09	8.34
1999	108	111	120	121	3.15	11.11	12.04
2000	111	117	123	130	5.52	10.95	17.65
2001	113	123	129	131	9.30	14.44	16.03
2002	115	125	132	131	8.95	14.25	13.81
2003	116	126	132	131	8.33	13.57	12.54
2004	118	126	133	127	7.40	12.76	7.99
2005	119	130	133	132	8.81	11.83	10.74
2006	121	130	132	135	6.84	8.49	11.29
2007	123	132	132	136	7.17	7.33	10.75
2008	124	133	132	136	7.20	6.39	10.03
2009	125	130	133	137	4.58	6.67	10.04
2010	126	129	141	136	2.95	12.35	8.37
2011	126	130	141	138	2.93	12.04	9.35
2012	127	131	142	138	3.23	11.67	8.83
2013	128	132	144	140	3.20	12.49	9.29
2014	130	134	146	141	3.07	11.97	8.21
2015	132	136	148	143	2.72	11.49	8.09
2016	134	138	149	145	2.83	11.09	7.89
2017	137	141	152	145	2.48	10.56	5.61
2018	141	140	155	148	-0.64	10.14	4.96
2019	145	144	158	149	-0.76	8.92	3.04
2020	148	146	153	149	-1.15	3.31	0.61
2021	152	149	157	153	-1.71	3.76	0.86
2022	156	153	162	157	-1.41	3.79	0.90
2023	159	157	165	160	-1.38	3.71	0.69
2024	162	160	166	162	-1.18	2.79	0.31
2025	164	164	168	164	-0.06	2.37	-0.24
2026	168	167	170	167	-0.06	1.37	-0.30
2027	171	170	173	170	-0.18	1.35	-0.35
2028	174	173	174	173	-0.17	0.40	-0.29
2029	176	176	176	176	-0.11	0.06	-0.06
2030	179	179	179	179	-0.06	0.00	0.17
2031	181	181	182	181	0.06	0.22	-0.06
2032	183	183	184	184	0.00	0.22	0.33
2033	186	186	186	186	0.00	0.11	0.22
2034	188	188	188	188	0.00	0.05	0.11
2035	190	190	190	190	0.00	0.05	0.00
2036	192	192	192	192	0.00	0.10	-0.10
2037	194	194	195	194	0.00	0.10	-0.21
2038	197	197	197	197	0.00	0.10	0.20
2039	199	199	199	199	0.00	0.10	0.10
2040	201	201	201	201	0.00	0.10	0.00

Table H.3.2.15 Tri-Cities MSA Home Prices with the Ex Situ Extensive Separations, Ex Situ/In Situ Combination 1, and Phased Implementation Alternatives (Change from Baseline Estimate), 1994 to 2040 ($ Thousands)

						Percentage Change from Baseline			
				Phased Implementation				Phased Implementation	
Year	Baseline	Ex Situ Extensive Separations	Ex Situ/ In Situ Combination	Phase 1	Total	Ex Situ Extensive Separations	Ex Situ/ In Situ Combination 1	Phase 1	Total
1994	103	103	103	103	103	-0.29	0.00	0.00	0.0
1995	115	114	115	115	115	-0.44	0.00	0.00	0.0
1996	107	107	107	107	107	0.38	0.19	0.00	0.0
1997	100	104	103	101	101	4.10	2.90	0.80	0.4
1998	104	116	109	109	109	11.22	4.31	4.51	4.7
1999	108	122	115	120	120	12.96	6.76	10.83	10.9
2000	111	118	118	125	125	6.79	6.70	12.94	12.9
2001	113	118	123	124	124	4.52	8.77	9.92	10.0
2002	115	129	125	118	118	12.08	8.60	2.17	2.3
2003	116	141	126	117	117	21.13	8.16	0.60	0.6
2004	118	147	127	120	120	25.00	7.65	1.70	1.8
2005	119	138	128	121	124	15.77	7.13	1.85	3.9
2006	121	134	127	123	129	10.47	5.03	1.73	9.8
2007	123	131	128	125	133	6.68	4.32	1.95	14.3
2008	124	128	128	126	139	3.56	3.80	1.86	18.9
2009	125	131	129	127	140	5.22	3.94	1.85	18.6
2010	126	140	135	128	143	11.55	7.17	1.75	19.9
2011	126	140	135	129	145	10.94	7.05	1.82	21.1
2012	127	140	136	129	143	10.41	6.86	1.97	17.5
2013	128	143	138	132	140	11.40	7.34	3.36	9.3
2014	130	145	140	134	144	11.00	7.06	2.61	10.7
2015	132	146	141	131	146	10.50	6.73	-0.91	10.8
2016	134	148	143	134	148	10.10	6.55	-0.15	10.6
2017	137	151	146	137	152	9.70	6.26	0.00	10.8
2018	141	154	149	141	155	9.10	5.96	0.00	10.4
2019	145	155	152	145	159	7.00	5.26	0.00	10.1
2020	148	151	151	148	162	2.20	2.03	0.00	9.5
2021	152	156	155	152	165	2.70	2.24	0.00	9.1
2022	156	160	159	156	168	2.40	2.25	0.00	8.3
2023	159	163	162	159	173	2.40	2.20	0.00	11.7
2024	162	164	164	162	174	1.80	1.36	0.00	9.8
2025	164	167	167	164	170	1.70	1.52	0.00	5.1
2026	168	168	169	168	172	0.40	0.72	0.00	4.6
2027	171	171	172	171	171	0.23	0.70	0.00	2.0
2028	174	173	174	174	175	-0.10	0.12	0.00	2.5
2029	176	176	176	176	177	0.10	-0.06	0.00	1.9
2030	179	179	179	179	179	0.17	-0.06	0.00	1.2
2031	181	181	181	181	182	-0.06	0.11	0.00	0.3
2032	183	184	184	183	183	0.33	0.16	0.00	-0.1
2033	186	186	186	186	186	0.22	0.05	0.00	0.1
2034	188	188	188	188	188	0.11	0.05	0.00	0.1
2035	190	190	190	190	190	0.00	0.05	0.00	0.1
2036	192	192	192	192	192	-0.10	0.05	0.00	0.0
2037	194	194	195	194	195	0.00	0.05	0.00	0.0
2038	197	197	197	197	197	0.20	0.05	0.00	0.0
2039	199	199	199	199	199	0.10	0.05	0.00	0.0
2040	201	201	201	201	201	0.00	0.05	0.00	0.0

APPENDIX H
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Affected Environment

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ACRONYMS AND ABBREVIATIONS

ADT	average daily traffic
BLM	Bureau of Land Management
CFR	Code of Federal Regulations
CLUP	Comprehensive Land Use Plan
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
dBA	decibels on the A scale
DOE	U.S. Department of Energy
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FEALE	Fitzner Eberhardt Arid Lands Ecology
HMS	Hanford Meteorological Station
HSDP	Hanford Site Development Plan
L_{eq}	Level equivalent sound
LOS	Level of Service
MMI	Modified Mercalli Intensities
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NESHA	National Emission Standards for Hazardous Air Pollutants
NRC	Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NWR	National Wildlife Refuge
PCB	polychlorinated biphenhyl
PM-10	particulate matter nominally greater than 10μm
ppm	parts per million
PSD	prevention of significant deterioration
PUREX	Plutonium-Uranium Extraction
SCS	Soil Conservation Service
SST	single-shell tank
TRAC	Track Radioactive Component
TWRS	Tank Waste Remediation System
USFWS	U.S. Fish and Wildlife Service

NAMES AND SYMBOLS FOR UNITS OF MEASURE, RADIOACTIVITY AND ELECTRICITY/ENERGY

Length		Area		Volume	
cm	centimeter	ha	hectare	cm^3	cubic centimeter
ft	foot	ac	acre	ft^3	cubic foot
in	inch	km^2	square kilometer	gal	gallon
km	kilometer	mi^2	square mile	L	liter
m	meter	ft^2	square foot	m^3	cubic meter
mi	mile			ppb	parts per billion
				ppm	parts per million
				yd^3	cubic yard

Mass		Radioactivity		Electricity/Energy	
g	gram	Ci	curie	A	ampere
kg	kilogram	mCi	millicurie (1.0E-03 Ci)	kV	kilovolt
mg	milligram	μCi	microcurie (1.0E-06 Ci)	kW	kilowatt
lb	pound	nCi	nanocurie (1.0E-09 Ci)	MeV	million electron volts
mt	metric ton	pCi	picocurie (1.0E-12 Ci)	MW	megawatt
				V	volt
				W	watt

°C	degrees centigrade
°F	degrees Fahrenheit

APPENDIX I
AFFECTED ENVIRONMENT

I.1.0 INTRODUCTION

This appendix describes the environmental setting for the proposed Tank Waste Remediation System (TWRS) activities at the Hanford Site. By describing the environmental conditions that could be potentially impacted by TWRS activities, this appendix provides the context and basis for analyzing the impacts of the Environmental Impact Statement (EIS) alternatives. Data to support comparisons between the potential impacts of the various EIS alternatives are also provided within this appendix. Existing conditions are discussed for all aspects of the environment (soil, groundwater, air, plant and animal species habitats, socioeconomic conditions, biological and ecological resources, cultural resources, land use, visual resources, noise, and transportation). Additional details on existing environmental conditions can be found in the Hanford Site National Environmental Policy Act (NEPA) Characterization Report (Cushing 1994 and 1995, Neitzel 1996), the Hanford Environmental Report for Calendar Years 1994 and 1995 (PNL 1995 and 1996), and in other references cited within the text. Information on the potential TWRS borrow sites was obtained largely from the Site Evaluation Report for Candidate Basalt Quarry Sites (Duranceau 1995).

The Hanford Site is in the semi-arid region of the Columbia Plateau in southeastern Washington State (Figure I.1.0.1). The Hanford Site occupies about 1,450 square kilometers (km^2) (560 square miles [mi^2]) of shrub and grasslands just north of Richland, Washington. The majority of this large land area, with restricted public access, provides a buffer to the smaller areas within the Hanford Site historically used for producing nuclear materials, waste storage, and waste disposal. About 6 percent of the land has been disturbed and is actively used. The Hanford Site extends approximately 77 kilometers (km) (48 miles [mi]) north to south and 61 km (38 mi) east to west.

The Columbia River flows through the northern part of the Hanford Site, turning south to form part of its eastern boundary. The Yakima River runs along part of the southern boundary and joins the Columbia River at the city of Richland. Adjoining lands to the west, north, and east are principally range and agricultural land. The cities of Richland, Kennewick, and Pasco (also known as the Tri-Cities) comprise the nearest population centers and are located southeast of the Site.

I.1.1 GEOLOGY AND SOIL

Geologic information on the Hanford Site (Figure I.1.1.1) has been collected in connection with a variety of Site activities. Reports by Delaney (Delaney et al. 1991), Reidel (Reidel et al. 1992), and Cushing (Cushing 1994), summarizing the information collected during many of these activities, are the primary basis for the following overview of the Hanford Site's subsurface environment.

The geology of the Hanford Site forms the framework for the Site's groundwater and surface water resources. Of particular relevance are 1) the topography, which impacts surface water flows and infiltration; 2) the vadose zone, because of potential impacts associated with releases during proposed TWRS activities; and 3) the saturated sediments beneath the vadose zone that form the unconfined

Figure I.1.0.1 Hanford Site Map and Vicinity

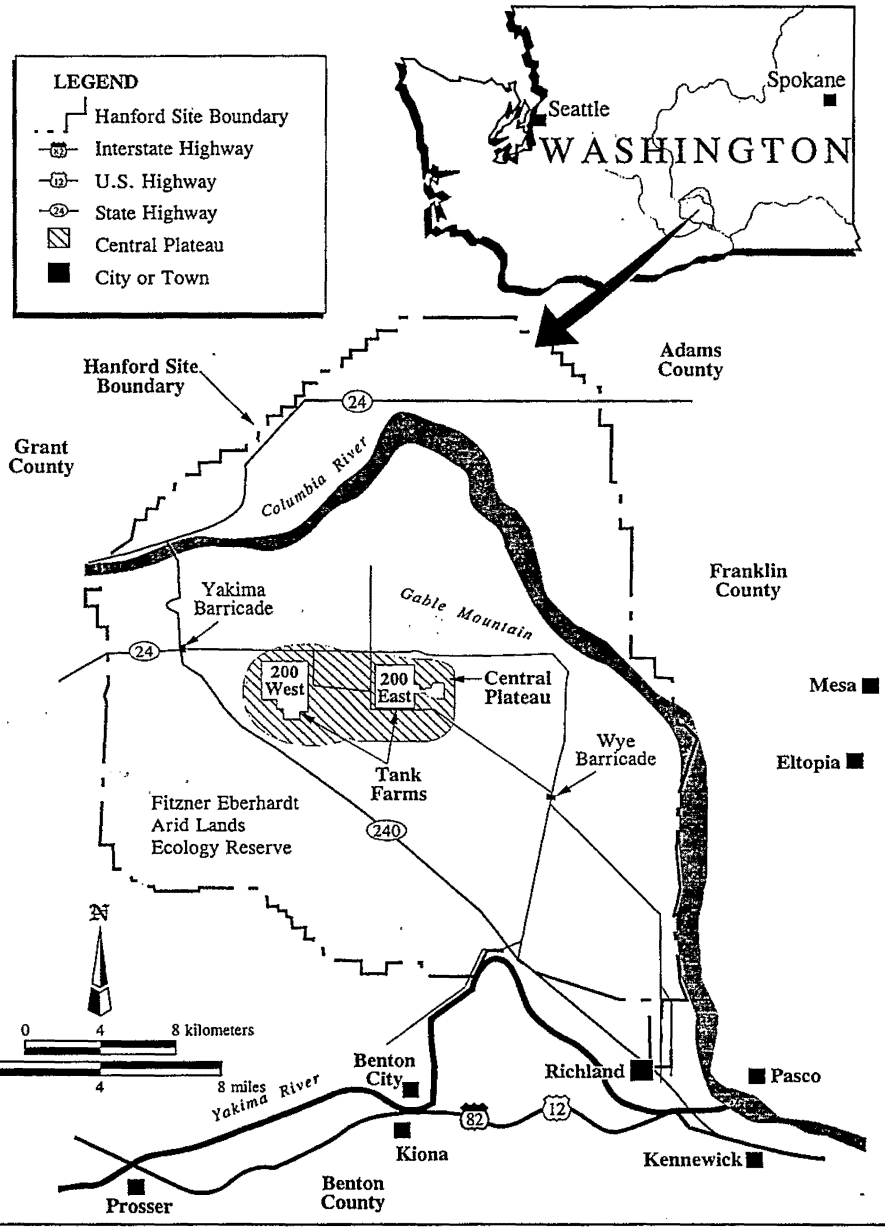
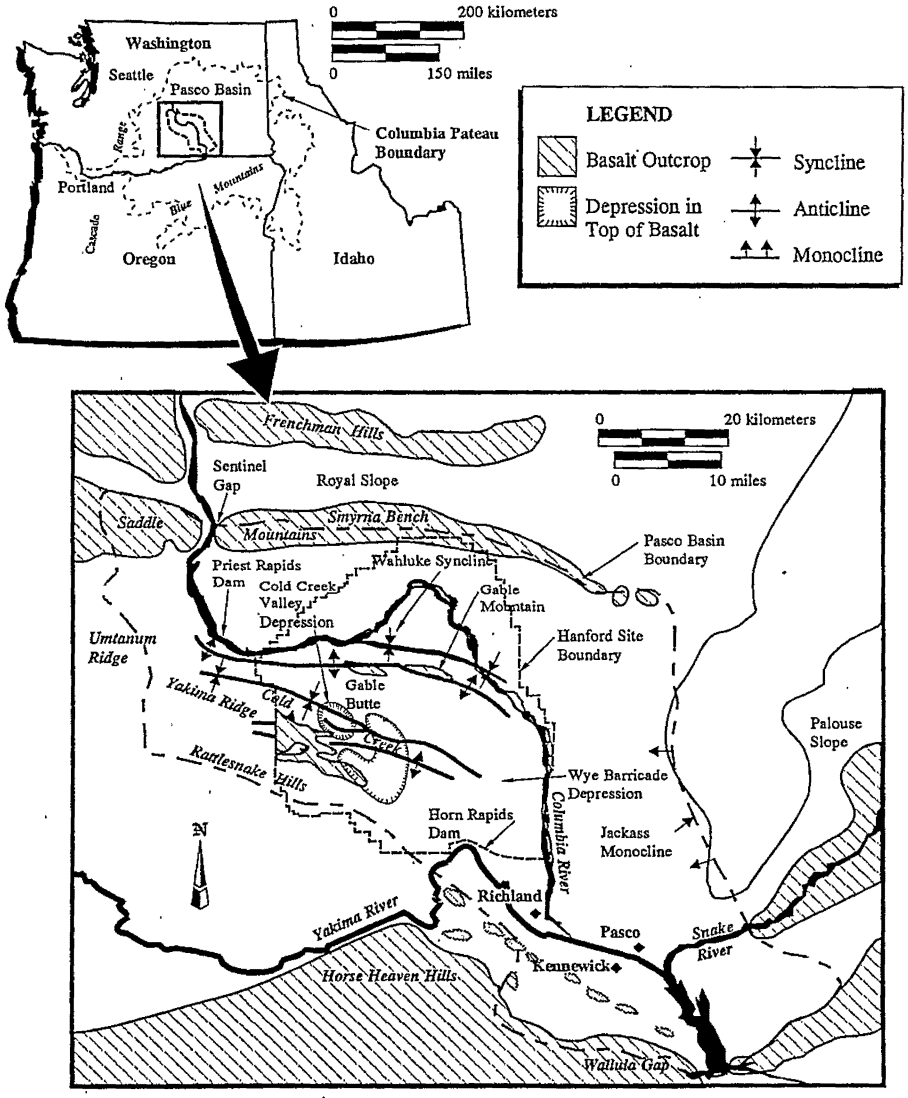


Figure I.1.1.1 Geographic Setting and General Structural Geology of the Pasco Basin and Hanford Site



SOURCE: Adapted from Lindsay 1992

aquifer, because of potential impacts from releases that pass through the vadose zone from proposed TWRS activities.

The geology and water resources sections focus primarily on conditions in the 200 Areas, where the tank waste and strontium (Sr) and cesium (Cs) capsules are located and where virtually all TWRS facilities, except for three potential borrow sites, would be located under any of the EIS alternatives. The potential Pit 30 borrow site, a possible source of sand and gravel, is located between the 200 East and 200 West Areas. The geologic setting of the Pit 30 area is the same as is described for the 200 Areas. The potential McGee Ranch and Vernita Quarry borrow sites, possible sources of silt (McGee) and basalt (Vernita), are located approximately 6 km (4 mi) north and west of the 200 West Area. Geologic conditions for the McGee Ranch and Vernita Quarry areas are briefly described in the following sections.

I.1.1.1 Topography and Geomorphology

The existing tank farms are on a broad flat area called the Central Plateau, which overlies an alluvial terrace (Figure I.1.1.1). The Central Plateau is in a portion of the Pasco Basin, a topographic, structural depression in the southwest corner of the Columbia Basin physiographic subprovince. This subprovince is characterized by generally low-relief hills with deeply incised river drainage. The Central Plateau's elevation is approximately 200 meters (m) (650 feet [ft]) to 230 m (750 ft) above sea level. The Plateau decreases in elevation to the north, northwest, and east toward the Columbia River. Plateau escarpments have elevation changes of 15 m (50 ft) to 30 m (100 ft). The proposed Vernita Quarry and McGee Ranch borrow sites are located to the west of the northern portions of the Central Plateau.

The Pasco Basin is an area of generally low relief ranging from 120 m (390 ft) above mean sea level at the Columbia River level, to 230 m (750 ft) above mean sea level in the vicinity of the TWRS sites in the 200 East Area. The Pasco Basin is bounded on the north by the Saddle Mountains; on the west by Umtanum Ridge, Yakima Ridge, and the Rattlesnake Hills; on the south by Rattlesnake Mountain and the Rattlesnake Hills; and on the east by the Palouse Slope (Figure I.1.1.1).

Surface topography at the Hanford Site is the result of the uplift of anticlinal ridges, Pleistocene cataclysmic flooding, Holocene eolian activity, and landslides (Delaney et al. 1991). Uplift of the ridges began in the Miocene Epoch, concurrent with the eruption of the flood basalts and continues to present. Cataclysmic flooding occurred when glacial ice dams in western Montana and northern Idaho were breached, allowing large volumes of water to spill across eastern and central Washington State. Much of the landscape in the path of the floodwater was stripped of sediments and basalt bedrock was scoured, forming scabland topography (elevated areas underlain by flat-lying basalt flows that generally exhibit deep, dry channels scoured into the surface). The last major flood occurred approximately 13,000 years ago during the late Pleistocene Epoch.

Braided flood channels with giant water current ripples, bergmounds (hummocky areas where grounded icebergs melted), and giant flood bars are among the landforms created by flooding that are apparent

on the Hanford Site. Since the end of the Pleistocene Epoch, winds have reworked the flood sediments locally, depositing sand dunes in the lower elevations and loess (wind-blown silt) around the margins of the Pasco Basin. Sand dunes generally have been stabilized by anchoring vegetation, except in localized areas where they have been reactivated around disturbed vegetation and within the barchan dune complex in the west-central portion of the Site.

Observed landslide activity in the area is generally limited to the White Bluffs area east of the Hanford Site and the Rattlesnake Hills south of the Hanford Site. No landslide activity has been observed in the vicinity of the tank farms or the TWRS sites in the 200 East Area.

I.1.2 GEOLOGIC STRUCTURE

The Hanford Site lies in the Pasco Basin near the eastern limit of the Yakima Fold Belt. The Pasco Basin is a structural depression bounded by anticlinal ridges on the north, west, and south and a monocline on the east (Figure I.1.1.1). The Pasco Basin is divided by the Gable Mountain anticline in the Wahluke syncline to the north and the Cold Creek syncline to the south. Geologic materials that include basalts and sediments thicken into the Pasco Basin and generally reach maximum thickness in the Cold Creek syncline (Delaney et al.1991).

The 200 Areas are situated between the Gable Mountain anticline and the Cold Creek syncline (Figure I.1.1.1). The Gable Mountain anticline is of particular importance to groundwater flow in the unconfined aquifer. This anticline consists of a series of southeast to northwest trending folds (Trent 1992b). Portions of the Gable Mountain anticline have been uplifted high enough that basalt is above the current water table. These basalts have a low hydraulic conductivity and act as a barrier to horizontal groundwater flow in the unconfined aquifer.

The uppermost basalt underlying the 200 Areas is the Elephant Mountain Member of the Saddle Mountain Basalt Formation (Trent 1992a and b). Two adjacent boreholes north of the 200 East Area (6-53-55 and 6-55-55) encountered the Rattlesnake Ridge interbed of the Ellensburg Formation (Trent 1992b), but the Elephant Mountain Member basalt flow was absent. The absence of the Elephant Mountain Member basalt flow is referred to as a "window" (Trent 1992a and b) and is probably erosional, formed during the Pleistocene cataclysmic flooding. There is no evidence for other substantial erosion into the top of the Elephant Mountain Member and no indication of erosional windows through the basalt into the underlying Rattlesnake Ridge interbed in the 200 West Area (Trent 1992a).

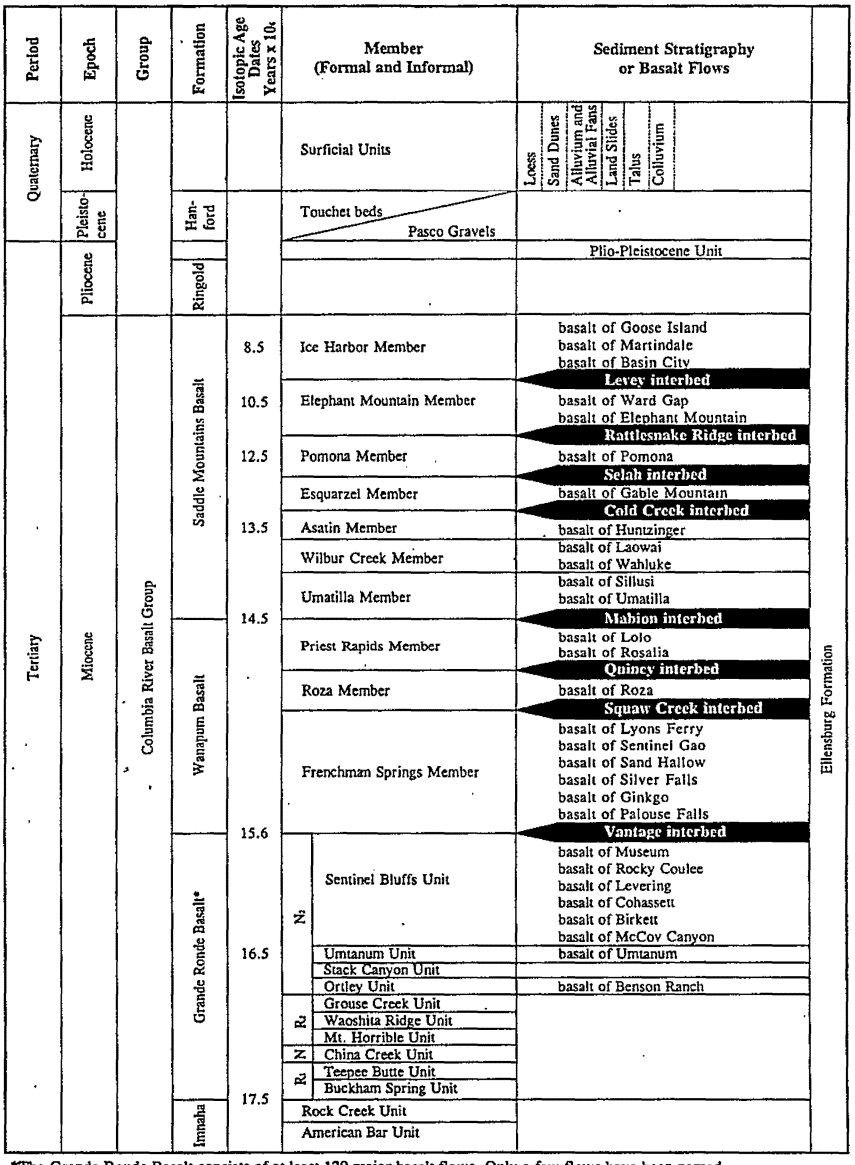
I.1.3 STRATIGRAPHY AND LITHOLOGY

A generalized stratigraphic column illustrating the nomenclature for the formations that underlie the Hanford Site is provided in Figures I.1.3.1 and I.1.3.2.

I.1.3.1 Columbia River Basalt Group

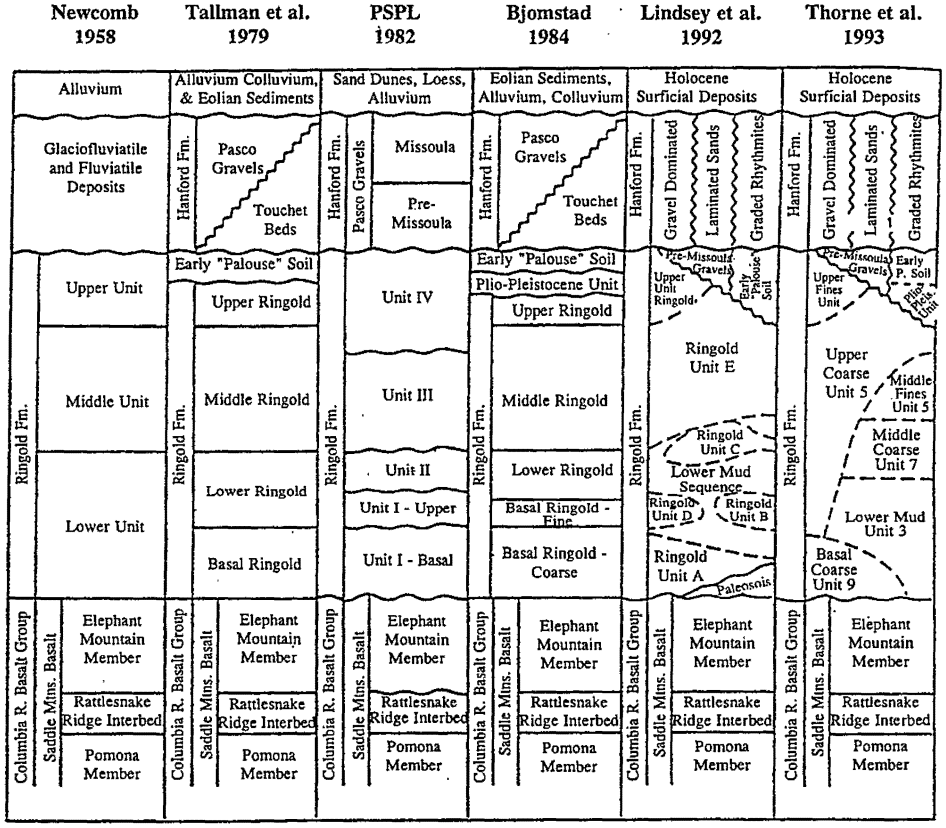
The Columbia River Basalt Group, which is a sequence of basaltic rock found typically on the ocean floor, erupted as basalt flows between 6 and 17 million years ago. These flows cover an area of more

Figure I.1.3.1 Generalized Stratigraphy of the Hanford Site



*The Grande Ronde Basalt consists of at least 120 major basalt flows. Only a few flows have been named.
N_2, R_2 are magneiostratigraphic units.
SOURCE: DOE 1993b

Figure I.1.3.2 Stratigraphic Column for the Hanford Site Showing Nomenclature From Previous Investigations by Various Authors



SOURCE: Schramke et al. 1994

than 163,000 km^2 (63,000 mi^2) and have an estimated area of 174,000 km^2 (40,800 mi^2). The thickness of basalt accumulations in the Pasco Basin is in excess of 3,000 m (10,000 ft) (Delaney et al. 1991). The Columbia River Basalt Group is divided into five formations (from oldest to youngest): Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt. Only the Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt are exposed on the Hanford Site. The Elephant Mountain member of the Saddle Mountains Basalt forms the uppermost basalt unit beneath most of the Hanford Site, except near the 300 Area where the Ice Harbor member is present, and north of the Central Plateau near Gable Gap where the Saddle Mountains Basalt has been eroded down to the Umatilla member.

I.1.3.2 Ellensburg Formation

The Ellensburg Formation consists of a series of sedimentary units that are interbedded between many of the basalt flows of the Columbia River Basalt Group. The Ellensburg Formation generally displays volcanic characteristics produced by volcanic events in the Cascade Range, and silicic characteristics derived from erosion of the Rocky Mountains. At the Hanford Site, the Ellensburg Formation consists of a mix of sediments deposited by the ancestral Clearwater and Columbia Rivers (Delaney et al. 1991). The three uppermost units of the Ellensburg Formation at the Site are the Levey Interbed, confined to the vicinity of the 300 Area, and the Rattlesnake Ridge and Selah interbeds, found beneath most of the Hanford Site (Delaney et al. 1991).

I.1.3.3 Suprabasalt Sediments

The suprabasalt sediments are a sedimentary sequence overlying the basalts at the Site and include the Ringold and Hanford formations. These sediments are up to approximately 230 m (750 ft) thick in the west-central Cold Creek syncline and pinch-out against the Saddle Mountains, Gable Mountain and Umtanum Ridge, Yakima Ridge, and Rattlesnake Hills anticlines. The suprabasalt sediments are dominated by laterally extensive deposits assigned to the late Miocene to Pliocene Ringold Formation and the Pleistocene Hanford formation. The informally defined Plio-Pleistocene unit, early Palouse soil, and pre-Missoula gravels separate the Ringold Formation and Hanford formation locally.

I.1.3.4 Ringold Formation

The Ringold Formation consists of semi-indurated clay, silt, pedogenically altered sediment, fine to coarse grained sand, and gravel. The Ringold Formation at the Site is up to 180 m (600 ft) thick in the deepest part of the Cold Creek syncline south of the 200 West Area, but is largely absent in the northern and northeastern parts of the 200 East Area and adjacent areas to the north (Delaney et al. 1991, Reidel et al. 1992, and Cushing 1994).

Five sediment facies (or differentiation) associations, defined on the basis of lithology, stratification, and pedogenic (formation and development of soil) alteration, are recognized in the Ringold Formation (Delaney et al. 1991). These sediment facies include:

- Fluvial (produced by action of a stream) gravel deposited in wide-shifting river channels;
- Fluvial sand deposited in shallow channels incised into a muddy floodplain,

- Overbank-paleosol deposits that record deposition on a floodplain;
- Lacustrine (in-lake) deposits that record deposition in a lake; and
- Alluvial fan deposits that record deposition of basaltic detritus around the periphery of the Pasco Basin.

The distribution of facies associations within the Ringold Formation forms the basis for stratigraphic subdivision of the formation (Lindsey 1991). The lower half of the Ringold Formation contains five separate stratigraphic intervals dominated by fluvial gravels. These gravels, designated Units A, B, C, D, and E, are separated by intervals containing deposits typical of the overbank-paleosol and lacustrine facies associations (Delaney et al. 1991). The lowermost of the fine-grained sequences overlying Unit A is designated the lower mud sequence. The uppermost gravel unit, Unit E, grades upward into interbedded fluvial sand and overbank deposits that are in turn overlain by lacustrine-dominated strata.

The lower mud sequence (Figure I.1.3.3) consists of overbank and lacustrine deposits. The lower mud sequence is hydrologically substantive in that it is a potential confining layer that may offer some hydraulic separation between the saturated Ringold Formation above and the underlying Unit A gravels. The lower mud sequence is generally absent in the northern part of the 200 East Area and at the main lobe of B Pond (Trent 1992b). In the 200 West Area, the lower mud sequence is generally present throughout, except in the northeast corner (Trent 1992a). In the 200 West Area, the thickness of the lower mud sequence ranges from over 30 m (100 ft) in the south-central portion of the area to nonexistent in the northeast corner.

I.1.3.5 Post-Ringold and Pre-Hanford Units

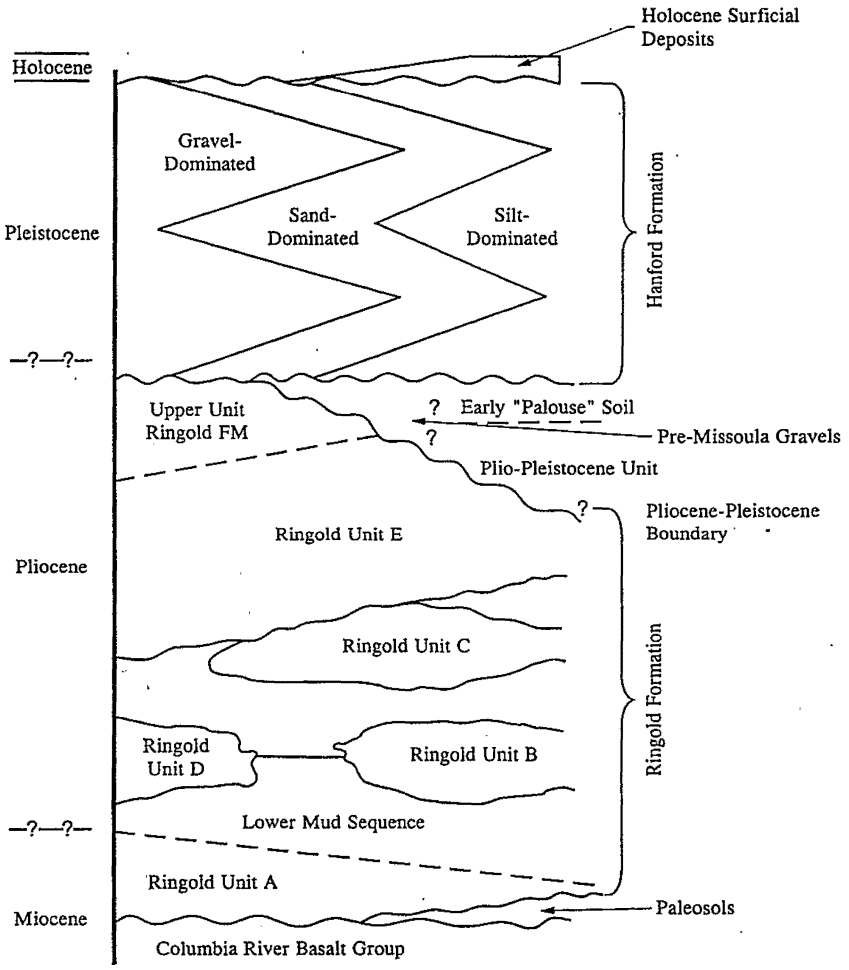
Thin, laterally discontinuous alluvial deposits separate the Ringold Formation from the Hanford formation in various parts of the Hanford Site. These deposits are referred to informally as the Plio-Pleistocene unit, pre-Missoula gravels, and early Palouse soil (Figure I.1.3.3). The Plio-Pleistocene unit unconformably overlies the Ringold Formation in the western Cold Creek syncline in the vicinity of the 200 West Area. Depending on location, two types of materials may be present within the Plio-Pleistocene unit: 1) interfingering carbonate-cemented silt, locally referred to as the "caliche layer" (Trent 1992a), sand and gravel, carbonate-poor silt, and sand; and/or 2) basaltic detritus consisting of weathered and unweathered basaltic gravels deposited as locally derived slope wash, colluvium, and sidestream alluvium.

Pre-Missoula gravels are composed of quartzose to gneissic pebble-to-cobble gravel with a sand matrix. These gravels are up to 25 m (82 ft) thick, contain less basalt than underlying Ringold gravels and overlying Hanford deposits, have a distinctive white or bleached color, and sharply truncate underlying strata. The early Palouse soil consists of up to 20 m (66 ft) of silt and fine-grained sand. Deposits composing the early Palouse soil are massive, brownish-yellow, and compact.

I.1.3.6 Hanford Formation

The Hanford formation consists of pebble-to-boulder gravel, fine- to coarse-grained sand, and silt. These deposits are divided into three facies; gravel-dominated, sand-dominated, and silt-dominated

Figure I.1.3.3 General Stratigraphy of the Suprabasalt Sediments of the Hanford Site



SOURCE: Lindsey 1992

(Figure I.1.3.3). These facies are referred to as coarse-grained deposits, plane laminated sand facies, and rhythmite facies, respectively (Reidel et al. 1992). The rhythmites also are referred to as the Touchet Beds or slack water deposits. The Hanford formation is thickest in the vicinity of the Central Plateau where it is up to 65 m (210 ft) thick. The Hanford formation was deposited by cataclysmic flood waters that drained out of a glacial lake named Missoula. Hanford Site deposits are absent on ridges more than approximately 385 m (1,260 ft) above sea level, the highest level of cataclysmic flooding in the Pasco Basin (Reidel et al. 1992).

The sand-dominated facies was deposited adjacent to the main flood channelways and is found most commonly in the central Cold Creek syncline in the central to southern parts of the Central Plateau and in the vicinity of the Washington Public Power Supply System facilities. The silt-dominated facies was deposited under slack water conditions in back-flooded areas and is found throughout the central, southern, and western Cold Creek syncline within and south of the Central Plateau.

I.1.3.7 Holocene Surficial Deposits

Holocene surficial deposits consist of silt, sand, and gravel that form a thin (less than 10 m [30 ft]) veneer across much of the Hanford Site. These sediments were deposited by a mix of eolian (wind) and alluvial processes.

I.1.4 MINERAL RESOURCES

The geology of the potential Vernita Quarry and McGee Ranch borrow sites contains successions of basalts flows and suprabasalt sediments similar to those found on the Central Plateau and the areas near these sites along the Columbia River. The Vernita Quarry site is located in the Umatilla flow of the Saddle Mountain basalt. The Umatilla Flow at this location is composed of a single collonade characterized by columns 0.9 to 1.2 m (3.0 to 4.0 ft) wide. A bench approximately 12 to 15 m (40 to 50 ft) thick exists at the current quarry site and extends eastward as part of a series of benches that correspond to erode basalt flows along the valley of the Columbia River. The Pomona flow overlies the Umatilla flow and crops out approximately 300 m (1,000 ft) east of the existing quarry. The Pomona flow locally comprises a single colonnade with columns generally less than 0.6 m (2.0 ft) wide (Duranceau 1995).

At the potential McGee Ranch borrow site, a geological evaluation revealed a layer of fine-grained sediments immediately below the surface that range in thickness from 0.5 m to 10.0 m (1.5 ft to 33 ft). A layer of silty, sandy gravel was identified directly beneath the surficial layer of fine-grained sediments. Hanford formation sediments overlay the Plio-Pleistocene unit and range in thickness from 0.15 to 12 m (0.5 to 40 ft). The ground surface at McGee Ranch is covered with pebbles, some cobble gravels and occasional boulders (DOE 1994h).

Currently no mineral resources other than crushed rock, sand, and gravel are produced from the Pasco Basin. Deep, natural gas production from anticlines in the basalt has been tested by oil exploration companies without commercial success. There are no current indications of any commercial mineral resource potential at any of the TWRS sites.

I.1.5 GEOLOGIC HAZARDS

Geologic processes that alter topography are landslides, floods, and volcanic activity. Each of these processes are briefly discussed in the following text as they relate to proposed TWRS activities.

I.1.5.1 Landslides

Landslides in the Ringold Formation sediments are common in areas where these sediments have been oversteepened by erosion, such as the White Bluffs area along the Columbia River. The likelihood of such oversteepening in the TWRS site areas is extremely low because of flat topography, a deep water table, and the absence of any actively eroding streams.

I.1.5.2 Floods

The nearest potential flooding source to the TWRS sites is Cold Creek. Studies of the probable maximum flood show that its effect is limited to the southwestern corner of the 200 West Area only (Cushing 1994). Because of the distance from the river, the probable maximum flood on the Columbia River would not impact the 200 Areas or any of the potential borrow sites. Failure of the upstream dams, either because of natural causes or sabotage, would not likely impact the 200 Areas or the potential borrow sites (Cushing 1994).

I.1.5.3 Volcanic Activity

Two types of volcanic activity have impacted the Pasco Basin in the past: basaltic flood volcanism and cascade-style diacitic volcanism to the west. The basaltic volcanism has been latent for the past eight million years and appears unlikely to resume because of changes in the plate tectonic regime of the region. The only source of volcanic activity that could impact the TWRS sites would be volcanism in the Cascade Mountain Range, more than 100 km (60 mi) west of the Hanford Site. The eruption of Mount St. Helens in 1980 is an example of such a volcanic event. This eruption caused considerable ashfall at the Hanford Site.

I.1.6 SEISMICITY

Seismicity at the Hanford Site is dominated by the position of the Site within the back-arc terrain of the Cascadia Subduction Zone formed where the Juan de Fuca Plate slides underneath the North American Plate (DOE 1995i). The back arc terrain of Washington occurs east of the Cascade Mountains and is underlain primarily by Jurassic to early Miocene metamorphic and volcanic rocks, which represent the accreted terrains of past collisions and continental deposits eroded from them (Reidel et al. 1989). Overlying a portion of this terrain is the Columbia Basalt Plateau, a region of thick tholeiitic basalt lava flows. The Hanford Site and proposed TWRS project sites lie within a subprovince of this basalt province known as the Yakima Fold Belt (RHO 1979).

The Yakima Fold Belt is characterized by narrow, linear anticlinal ridges of basalt and broad synclinal basins with an east to east southeast orientation. The folds have wavelengths of between 5 and 32 km (3 and 20 mi), amplitudes of less than 1 km (0.6 mi), and are commonly steeper on the northern limb. The faults in the subprovince appear to be associated with the folding and are found on the flanks of the folds. The folds extend eastward up to 113 km (70 mi) from the Cascade Range Province and were

growing during the eruption and emplacement of the basalt and probably continue to grow at the present time (DOE 1988). In general, the structures do not impact the sediments that overlie the basalt.

Sources of seismic activity (earthquakes) at the Hanford Site include shallow structures in the Yakima Fold Belt or Columbia River Basalts. The orientation of the structural fabric of the Yakima Fold Belt suggests an origin by north-south compressional forces that operated from the middle Miocene age to the present. Compression during the extrusion of the lavas resulted in the folds propagating upwards through succeeding flows, folding the latest flow, and faulting the underlying flows (Reidel et al. 1989). The Hooper and Convey Model (Reidel et al. 1989) suggests that the compressive stress is horizontal and transmits deformation in a brittle manner only in the Columbia River Basalt Group (WHC 1993). It is believed that the underlying pre-basalt rocks deform in a ductile fashion and thus do not generate seismic activity. One of the most active areas of shallow earthquake activity is along the Saddle Mountain anticline, north of the Hanford Site (RHO 1979). Seismic activity within deep basement structures does not adequately explain the pattern of seismicity recorded in the region. The most recent seismic hazard analysis of the Hanford Site assumes that seismic activity occurs more or less randomly in the crust (WHC 1993). The source of seismic activity in the region that could potentially impact the Hanford Site is the Cascadia Subduction Zone, which lies off the coast of the Pacific Northwest. Two separate sources of seismic activity exist within this zone: an intraplate source where seismic events occur within the subducted Juan de Fuca oceanic plate, and an interplate source where seismic events occur at the interface of the Juan de Fuca and the North American plates. Of the two, the interplate source has the highest probability of generating earthquakes of a magnitude capable of causing ground motion at the TWRS sites that could impact the proposed facilities (WHC 1993).

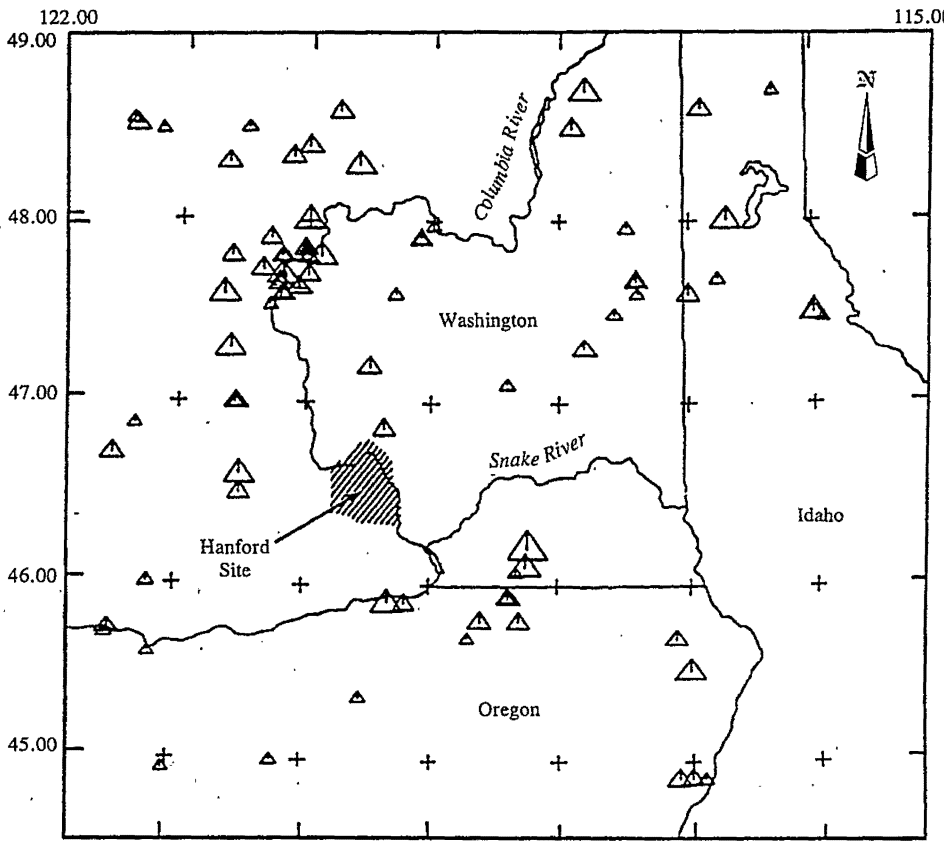
I.1.6.1 Earthquake History

The Hanford Site lies in an area of relatively low seismic activity (Figures I.1.6.1. and I.1.6.2). Between 1870 and 1980 only five earthquakes occurred in the Columbia Plateau region that had Modified Mercalli Intensities (MMI) of VI or greater. All these events occurred prior to 1937. The largest event was the July 16, 1936 Milton-Freewater, Oregon earthquake (MMI=VII; surface wave magnitude = 5.8) (DOE 1988). The location of this earthquake and its association with known geologic structures are uncertain (DOE 1988).

Other earthquakes with a Richter magnitude of 5.0 or larger have occurred near Lake Chelan, Washington to the northwest, along the boundary of the Columbia Plateau and the Cascade Mountain range, west and north of the Hanford Site, and east of the Hanford Site in Washington State and northern Idaho. In addition, earthquake swarms of small magnitudes occur on and around the Hanford Site. An earthquake swarm is a series of earthquakes closely related in terms of time and space.

Seismicity with the Columbia Plateau can be segregated into three depth zones: 0 to 4 km (0 to 2.5 mi); 4 to 8 km (2.5 to 5 mi); and deeper than 8 km (5 mi). Approximately 70 to 80 percent of the seismic activity occurs in the 0 to 4 km (0 to 2.5 mi) zone, and 90 percent of the activity occurs in the first two zones (0 to 8 km [0 to 5 mi]) (DOE 1988). Most of the earthquakes in the central Columbia plateau are

Figure I.1.6.1 Historical Seismicity of the Columbia Plateau and Surrounding Areas



All earthquakes between 1850 and 1969 with a Modified Mercalli Intensity of IV or larger with a magnitude of 3 or greater are shown.

LEGEND

MMI	Equivalent Richter Magnitude (Calculated)
IV	3.3 - 4.0
V	4.0 - 4.7
VI	4.7 - 5.3
VII	5.3 - 6.3

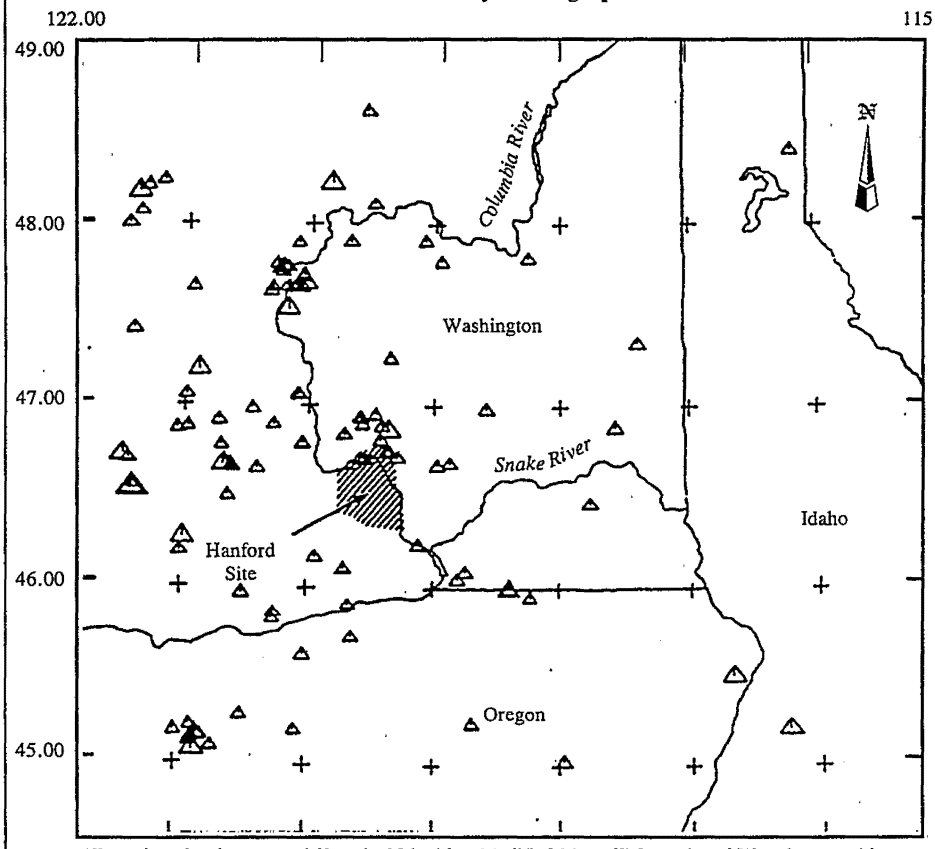
0 50 100 kilometers

0 25 50 miles

\+ Latitude/Longitude Intersection

SOURCE: Cushing 1994

Figure I.1.6.2 Recent Seismicity of the Columbia Plateau and Surrounding Areas as Measured by Seismographs



All earthquakes between 1969 and 1986 with a Modified Mercalli Intensity of IV or larger with a magnitude of 3 or greater are shown.

LEGEND

Richter Magnitude (Measured)

- 3.0 - 3.9
- 4.0 - 4.9
- 5.0

0 50 100 kilometers

0 25 50 miles

+ Latitude/Longitude Intersection

SOURCE: Cushing 1994

north or northeast of the Columbia River. Most of the earthquakes in the shallowest zone occur as swarms, which are not associated with mapped faults.

I.1.6.2 Seismic Hazards

Three major structures of the Yakima Fold Belt are found within the Hanford Site: the Umtanum Ridge-Gable Mountain Structure, the Yakima Ridge Structure, and the Rattlesnake Hills Structure. Each is composed of an asymmetrical anticline over-steepened to the north and with associated faults along their flanks. Two types of faults associated with the folds have been identified. Thrust faults occur on the northern, over-steepened limbs of the folds. These folds are sympathetic to the folds with more or less the same strike as the fold axes. Cross faults with a north-northwest trend cut the linear folds into separate segments and show a right lateral strike-slip movement (Reidel et al. 1989). Existing known faults within the Hanford area include wrench (strike-slip) faults, as long as 3 km (2 mi) on Gable Mountain and the Rattlesnake-Wallula Alignment, which has been interpreted as a right-lateral strike-slip fault. The faults in Central Gable Mountain are considered capable faults by Nuclear Regulatory Commission (NRC) criteria in that they have slightly displaced the Hanford formation gravels, but their relatively short lengths give them low seismic potential. No seismicity associated with the Gable Mountain Fault has been observed. The Rattlesnake-Wallula Alignment is interpreted to be capable faults by the NRC (Supply System 1981).

Earthquake sources considered relevant for the purpose of seismic design of TWRS facilities are the Rattlesnake-Wallula Alignment, Gable Mountain, an earthquake anywhere in the tectonic province, and the swarm area. For the Rattlesnake-Wallula Alignment, which passes along the southwest boundary of the Hanford Site, a maximum Richter magnitude of 6.5 has been estimated. For Gable Mountain, an east-west structure that passes through the northern portion of the Hanford Site, a maximum Richter magnitude of 5.0 has been estimated. An earthquake for the tectonic province was developed from the Milton-Freewater earthquake of Richter magnitude 5.75. A Richter magnitude 4.0 event is considered a maximum swarm earthquake for analyzing TWRS alternatives, based on the maximum swarm earthquake in 1973 (Cushing 1994). The Hanford Site current design basis for new facilities is for facilities to withstand a 0.2 gravity earthquake (Richter Magnitude of approximately 6.4) with a recurrence frequency of 2.0E-04.

I.1.7 SOIL

The surface and near-surface soils in the 200 Areas are not generally well developed and consist of a number of soil types: Rupert sand, Burbank loamy sand, and Ephrata sandy loam. Hezel sand is also present on the western boundary of the 200 West Area. Rupert sand consists of coarse sand and is also known as Quincy sand. Rupert sand covers the majority of the 200 West Area and approximately one-half of the 200 East Area. Burbank sand is coarse-textured sand that covers approximately the northeastern one-third of the 200 West Area, a relatively small portion of the 200 East Area, and the majority of the area between the 200 West and 200 East Areas, where the potential Pit 30 borrow site (sand and gravel source) is located. Ephrata soil is medium-textured soil and covers the northern portion of the 200 East Area. Hezel sand is similar to Rupert sand and covers a portion of the area on, and immediately west of, the boundary of the 200 West Area. The predominant soil types in the

general vicinity of the potential Vernita Quarry and McGee Ranch borrow sites are the Rupert sand and Burbank loamy sand.

I.1.7.1 Soil Contamination

Soil monitoring is conducted to detect the potential migration and deposition of radionuclides because of resuspension from other radioactive contaminated areas (wind-blown or water-borne) and waste intrusion by animals (PNL 1993a). The following contaminants have been consistently detectable in soil on the Hanford Site: cobalt-60 (Co-60), Sr-90, Cs-137, plutonium-239 (Pu-239), Pu-240, and uranium (U). Soil concentrations for these radionuclides were higher near and within Hanford Site facilities compared to offsite concentrations. In general, radionuclide concentrations near waste disposal sites are higher than concentrations further away.

Radiological surveys are conducted on Site areas that are known or suspected to contain surface or subsurface contamination. Areas that exceed specified levels are posted as radiologically controlled areas. A total of over 2,500 hectares (ha) (6,200 acres [ac]) of surface area and 1,030 ha (2,530 ac) of subsurface area were posted at the end of 1994. Ninety percent of the posted surface contamination area and 81 percent of the posted subsurface contamination area are in and near the 200 Areas. The net change in Sitewide surface contaminated areas reduced 44 ha (110 ac) from 1994 to 1995, which includes surface contamination areas, which includes a reduction of 33 ha (82 ac) in the 200 Areas. There was a corresponding net increase in Sitewide posted subsurface contamination areas of 44 ha (110 ac) from 1994 to 1995, which includes an increase of 33 ha (82 ac) in the 200 Areas (PNL 1995).

I.2.0 WATER RESOURCES

Baseline conditions for water resources and hydrology encompass surface water, vadose zone, and groundwater, each of which may be impacted by implementing proposed TWRS activities.

I.2.1 SURFACE HYDROLOGY, INCLUDING FLOODPLAINS

The following subsections describe surface water resources, including the occurrence and characteristics of surface water, floodplains, and runoff.

I.2.1.1 Occurrence and Characteristics of Surface Water

West Lake and two small spring-fed streams in the Fitzner Eberhardt Arid Lands Ecology (FEALE) Reserve are the only naturally occurring water bodies on the Hanford Site. West Lake is several hectares in size and is located approximately 8 km (5 mi) northeast of the 200 West Area and about 3 km (2 mi) north of the 200 East Area. It is situated in a topographically low-lying area and is sustained by groundwater inflow resulting from an intersection with the groundwater table. West Lake was considered to be an ephemeral lake before operations began at the Hanford Site, with water level fluctuations dependent on groundwater level fluctuations. However, because of recharge (primarily from B Ponds) that contains low-level waste processing and cooling water from B Plant, water levels in the lake have become more stable.

Rattlesnake Springs, located 10 km (6 mi) west of the 200 West Area, forms a small surface stream that flows for approximately 2.5 km (1.6 mi) before it disappears into the ground as a result of seepage and evapotranspiration. The stream's base flow is approximately 0.01 cubic meters per second (m^3/sec) (0.4 cubic feet per second [ft^3/sec]). Snively Springs is located to the west and at a higher elevation than Rattlesnake Springs. It flows to the west and off of the Hanford Site (Cushing 1994).

Two ephemeral creeks, Cold Creek and its tributary, Dry Creek, traverse the uplands of the Hanford Site south and southwest of the 200 Areas. These creeks drain southeasterly toward the horn of the Yakima River, located south of the Hanford Site. Surface runoff from the uplands in and west of the Site is minor. These ephemeral creeks are not sustained by groundwater baseflow during any part of the year because depth to groundwater is over 46 m (150 ft) near the intersection of these creeks. The Columbia River is 16 to 24 km (10 to 15 mi) downgradient from the nearest TWRS site toward the east and approximately 11 km (7 mi) toward the north. The river forms the eastern boundary of the Hanford Site and comprises the base-level and receiving water for groundwater and surface water in the region.

I.2.1.2 Floodplains and Runoff

There are no floodplains in the 200 Areas. The potential Vernita Quarry and McGee Ranch borrow sites are also not within areas of high flood risk. Although floods in Cold Creek and Dry Creek have occurred historically, there have not been any observed flood events or evidence of flooding in these creeks that has reached the 200 Areas before infiltrating into permeable sediments.

Natural runoff generated onsite or from offsite upgradient sources is not known to occur in the 200 Areas. Measurable runoff occurs during brief periods in two locations, Cold Creek Valley and Dry Creek Valley, which are west and southwest of the 200 West Area (Newcomb et al. 1972). This surface runoff either infiltrates into the valley floor or evaporates. During periods of unusually rapid snowmelt or heavy rainfall, surface runoff extends beyond Rattlesnake Springs in the upper part of Dry Creek. However, this runoff quickly infiltrates into the alluvial sediments of Cold Creek Valley. The total amount of annual recharge to the unconfined aquifer from these areas is estimated to be 555,000 square meters (m^2) (5,970,000 square feet [ft^2]). This generally occurs east of the Hanford Site (Newcomb et al. 1972).

I.2.2 GROUNDWATER

Groundwater conditions in the 200 Areas are described in the following subsections in terms of the general hydrogeologic setting, vadose zone characteristics, aquifer characteristics, and groundwater flow. Groundwater conditions in the areas of the potential Vernita Quarry and McGee Ranch borrow sites are similar to those of the 200 Areas, although limited specific information is available. Groundwater quality and supply are discussed in Section I.2.3.

I.2.2.1 Hydrogeologic Setting

A thick vadose zone (approximately 70 m [200 ft] to over 90 m [300 ft] thick) as well as both confined and unconfined aquifers are present beneath the 200 Areas (DOE 1993a and b). The vadose zone is

over 90 m (300 ft) thick in the vicinity of the TWRS site in the 200 East Area (DOE 1993a). The unconfined aquifer has not formally been named. This aquifer consists variably of the Ringold Formation (where present) and the lower portion of the Hanford formation. The confined aquifers are found primarily within the Columbia River Basalts. The confined aquifers are not a major focus of this EIS because they are separated from the TWRS facilities by the vadose zone, unconfined aquifer (the focus of the groundwater modeling effort), and confining layer(s) and thus are not likely to be impacted. The conceptual hydrogeologic column for the Hanford Site is illustrated in Figure I.2.2.1. Figure I.2.2.2 is a generalized cross section through the 200 Areas showing the major geologic units and the relative position of the water table. The water table is generally at or near the interface between the Hanford and Ringold formations, as illustrated in both Figures I.2.2.1 and I.2.2.2.

The occurrence and flow of groundwater in the unconfined aquifer must be described on a conceptual basis due to the difficulty of direct measurement. Five important concepts that describe flow in this aquifer are listed below:

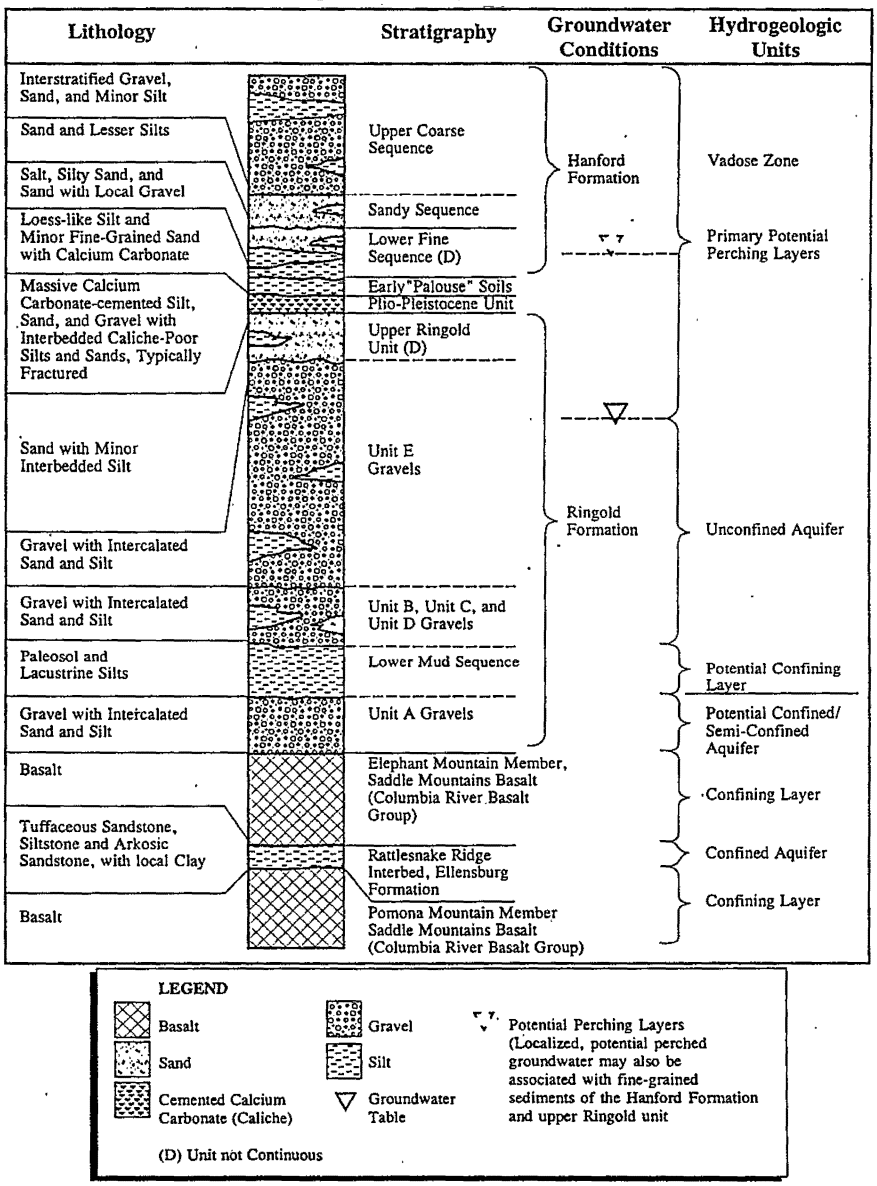
1) The numerous strata within the Ringold Formation, described in the previous section on stratigraphy, result in a much lower vertical hydraulic conductivity compared to the horizontal hydraulic conductivity. This results in a strong preference for groundwater to move horizontally.
2) Groundwater movement occurs mostly in the upper portion of the Ringold Formation. That is, most groundwater movement occurs in the sands and gravel that predominate in the upper portion of the Ringold Formation (Unit E Gravels).
3) The overbank deposits and the lower mud sequence near the base of the Ringold Formation act as confining layers, hydraulically separating the overlying unconfined aquifer from the confined aquifer.
4) Recharge to the unconfined aquifer is primarily from artificial sources (e.g., B Pond), groundwater inflow from the Dry Creek and Cold Creek synclines, and recharge from the Columbia River along the western reach of the horn of the Colombia River near N Reactor.
5) Discharge from the unconfined aquifer is primarily to the Columbia River from the top of the horn south of the Columbia River to the 300 Areas, and in the vicinity of the B and C Reactors. Groundwater discharge also occurs to West Lake.

Natural recharge to the unconfined aquifer on the Hanford Site is extremely low and occurs primarily in the upland areas west of the Hanford Site. Artificial recharge from retention ponds and trenches contribute approximately 10 times more recharge than natural recharge. Seasonal water table fluctuations are not large because of the low natural recharge.

I.2.2.2 Vadose Zone Characteristics

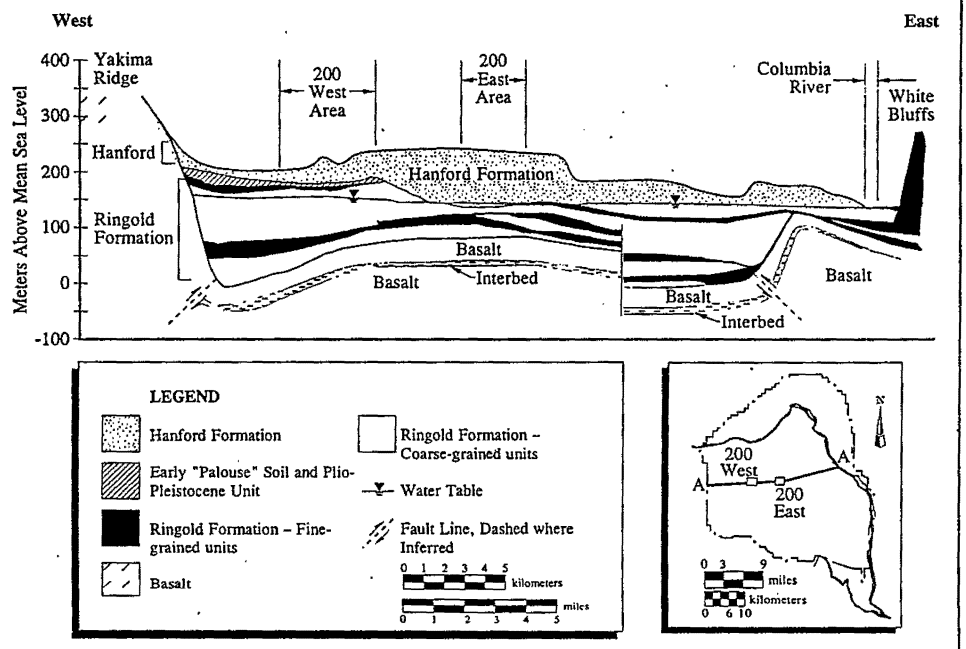
The vadose zone extends from the ground surface to the top of the saturated sediments of the unconfined aquifer. Vadose zone characteristics determine the rate, extent, and direction of liquid flow downward from the surface. This zone variably includes the Hanford formation and locally includes the Ringold Formation Unit E Gravel. In the 200 West Area, the vadose zone is approximately

Figure I.2.2.1 Conceptual Hydrologic Column for the Hanford Site



SOURCE: Lithology, stratigraphy, and groundwater condition based on data from Lindsey 1992 and Delany et al. 1991.

Figure I.2.2.2 Geologic Cross Section of the Hanford Site



SOURCE: Adapted from PNL 1995

72 m (240 ft) thick (DOE 1993b). In the 200 East Area, the vadose zone is over 90 m (300 ft) thick, based on the 1991 depth to water level of the unconfined aquifer (DOE 1993a).

The following sections describe vadose zone characteristics (infiltration, perched water, and soil moisture) and vadose zone contamination.

I.2.2.2.1 Infiltration

The thick vadose zone, combined with the general aridity of the climate in the area, result in natural infiltration ranging from near zero (below detection) to approximately 11 centimeters per year (cm/yr) (4.3 inches [in.]/yr) (Gee et al. 1992). Some episodic recharge of groundwater may occur following periods of high precipitation, especially if combined with topographic depressions, highly permeable surface deposits such as gravel, and where the land is denuded of vegetation. Also, present conditions (bare ground and coarse sand and gravel surfaces) within the tank farms are conducive to higher infiltration than would be expected on undisturbed ground within the 200 Areas. For such conditions,

infiltration near the upper range of 10 cm/yr (4.0 in./yr) would not be unreasonable. However, there are relatively recent changes that occurred after 1940 and would not necessarily have altered the flow within the full thickness of the vadose zone.

The total natural recharge in the 200 West Area is estimated to be approximately 1.3E+8 liters per year (L/yr) (3.4E+07 gallons [gal]/yr)(DOE 1993b). This is based on an average recharge rate of 0.1 cm/yr (0.04 in./yr) through fine-textured soil with deep-rooted vegetation. This value is approximately 10 times lower than recharge volumes from artificial sources.

The current principal sources of artificial recharge in the 200 West Area are four cribs and one ditch associated with the U Plant area, located in the eastern portion of the 200 West Area (DOE 1993b). There are also four septic tanks and drain fields that actively discharge water to the soil. The combined volume discharge from these drain fields is estimated to be 12,000 L/day (3,200 gal/day). The total wastewater discharged from these facilities from 1944 to 1992, including the U Plant cribs and ditches, is estimated to have been 1.7E+11 L (4.4E+09 gal). T Plant and S Plant operations also resulted in large volumes of wastewater discharged to the soil. Liquid is no longer discharged to the soil column from U, T, or S Plants.

Natural recharge in the 200 East Area is estimated to be approximately 2E+7 L (5E+06 gal) (DOE 1993a). This is based on a similar average natural recharge rate through fine-textured soil with deep-rooted vegetation, as noted previously for the 200 West Area. Artificial recharge in the 200 East Area is associated with approximately 140 ponds, trenches, cribs, and drains that were used to dispose of approximately 1E+12 L (3E+11 gal) of wastewater. The wastewater, except for limited discharges to the B Pond, is not directly discharged to the ground. The wastewater is treated to meet the State groundwater standards and piped to a common discharge location in the 200 Areas for discharge to the soil column. The remaining discharges to the ground at B Pond will be rerouted to the common discharge location in 1997. Currently, there are 11 active waste management units and 20 active drain fields. These waste management units are associated with B Plant and the Plutonium-Uranium Extraction (PUREX) Plant and are located east and northeast of the TWRS site (DOE 1993a). The primary recipients of the wastewater from three waste management units were the ponds and trenches associated with B Plant and PUREX Plant; the 216-A-25 and B-3 Ponds received approximately 7.0E+11 L (2.1E+11 gal). Liquid is no longer discharged to the soil column from B Plant or the PUREX Plant.

Wastewater, such as the condensate removed from tank waste by the 242-A Evaporator, which is located in the eastern portion of the 200 East Area, is transferred by pipeline to the Effluent Treatment Facility, also located in the 200 East Area. The treated effluent from the Effluent Treatment Facility is then transferred by pipeline and discharged to the ground at the State-approved land disposal site located north of the 200 West Area. The treated wastewater meets all State groundwater discharge requirements except for tritium. The water is disposed of at this location further to the west so that the tritium contamination will decay to below drinking water standards in the groundwater before it reaches the Columbia River.

I.2.2.2.2 Perched Water

Perched water may occur within the vadose zone in the 200 West Area upon the caliche layer, approximately 55 m (180 ft) beneath the ground surface (DOE 1993b). Measured hydraulic conductivities of this unit range from 0.0009 to 0.09 m/day (0.003 to 0.3 ft/day). Caliche layers have not been encountered in the 200 East Area, and perched groundwater is not as likely to occur except in localized areas (Hoffman et al. 1992). Perched water has been reported in the vicinity of B Pond within the lower part of the Hanford formation.

I.2.2.2.3 Soil Moisture

In areas where artificial recharge is occurring from ponds and trenches, soil is expected to be close to saturation and would not likely be capable of holding substantial amounts of additional liquid. In addition, groundwater mounds have developed beneath these recharge areas. Where there is no artificial recharge, soil in the 200 Areas has a large moisture-holding capacity (DOE 1992a). The potential effect of recharge from Site waste water disposal activities is discussed in Volume Five, Appendix K, Section K.4.1.

I.2.2.2.4 Vadose Zone Contamination

Contaminants in the vadose zone in the 200 Areas are believed to be associated primarily with waste disposal practices that use engineered structures such as cribs, drains, septic tanks and associated drain fields, and reverse wells (wells that do not penetrate to the groundwater); percolation from ponds, ditches, and trenches such as B Pond and U Pond; and unplanned releases such as leaks from single-shell tanks (SSTs). The vadose zone is expected to be impacted by these past (and in some cases ongoing) waste management practices in the area immediately beneath the discharging facility and in an undetermined adjacent area (due to spreading as liquid percolates downward). Emerging data regarding vadose zone contamination from past SST leaks are provided in Volume Four, Appendix F, and Volume Five, Appendix K. Most Hanford Site environmental investigations have focused on the potential impacts of contaminants to the groundwater, not the vadose zone. Vadose zone investigations have often relied on geophysical gamma logs that are semi-quantitative. The types of contaminants potentially present in the vadose zone near planned and unplanned release sites can be inferred by contaminants detected in the underlying groundwater, contaminants that are reported in waste disposal inventories, or from the Track Radioactive Component (TRAC) inventory system used for SSTs that may be leaking. Table I.2.2.1 lists these contaminants, which include both radioactive materials (transuranic isotopes, U, and fission products) and nonradioactive materials (metals, volatile organics, semivolatile organics, and inorganics).

1.2.2.3 Aquifer Characteristics

Groundwater of the unconfined aquifer is found throughout the Hanford Site in the suprabasalt sediments and locally includes the Rattlesnake Ridge Interbed in the area north of the 200 East area, where erosion has removed a portion of the basalt sequence (Trent 1992b). The relationship between the various stratigraphic units and the hydrogeologic units is shown in Figure I.2.2.1.

Table I.2.2.1 Isotopes, Metals, and Organic Chemicals of Potential Concern at the 200 Areas

Transuranic Isotopes		Radium-223
Americium-241		Radium-225
Americium-242		Radium-226
Americium-243		Radium-228
Barium-244		Radon-22
Barium-245		Rhodium-106
Neptunium-237		Ruthenium-106
Neptunium-239		Samarium-151
Plutonium-238		Selenium-79
Plutonium-239		Strontium-90
Plutonium-240		Technetium-99
Plutonium-241		Thallium-207
		Thorium-227
Uranium Isotopes		Thorium-229
Uranium-233		Thorium-230
Uranium-234		Thorium-231
Uranium-235	*	Thorium-232
Uranium-236		Thorium-234
Uranium-238		Tritium
		Yttrium-90
Fission Products and Other Radioisotopes		Zirconium-93
Actinium-225	**Metals**	
Actinium-227	**	Antimony
Antimony-125		Barium
Antimony-126		Beryllium
Antimony-126m		Cadmium
* Barium-133		Chromium
Barium-137m		Copper
Bismuth-210		Lead
Bismuth-211		Manganese
Bismuth-213		Mercury
Bismuth-214		Nickel
Carbon-14		Silver
Cesium-134	**	Thallium
Cesium-135	**	Titanium
Cesium-137		Uranium
Cobalt-60		Vanadium
Europium-154		Zinc
Europium-155		
Francium-221	**Volatile Organic Compounds**	
Iodine-129		Acetone
* Krypton-85	*	Carbon disulfide
Lead-209		Carbon tetrachloride
Lead-210		Chloroform
Lead-211	**	Cyclohexanone
Lead-214		1,1-Dichloroethane
* Nickel-59		1,2-Dichloroethane
Nickel-63	**	cis-1,2-Dichloroethane
Niobium-93	**	trans-1,2-Dichloroethane
Polonium-210		Methylene chloride
Polonium-214	**	Methyl ethyl ketone
Polonium-218		(Hexone)
Potassium-40	**	Methyl isobutyl ketone
** Promethium-147	**	Styrene
Protactinium-231		Tetrachloroethylene
		Toluene
		1,1,1-Trichloroethane
	**	1,1,2-Trichloroethane
		Trichloroethylene
	**	Trichloromonofluoromethane Hexone (MIBK)
	*	Tributyl phosphate
	*	Xylenes
	Semivolatile Organic Compounds	
		Aldrin gamma-BHC
	*	Bisphenol A
		Bis(2-ethylhexyl) phthalate
		Butyl phosphate
	**	p-Chloro-m-cresol
	*	Cresols
		2-Chlorophenol
		2.2-Bis (para-chlorphenol)-1,1-dichloroethane (DDD)
		Dichlorodiphenyl trichloroethane (DDT)
		Dibutyl phosphate
		2,4-Dichlorophenol
		Dieldrin
		Dimethoate
		2,4-Dimethylphenol
	**	2,4-Dinitrophenol
	**	2,4-Dinitrotoluene
		Endrin
		Heptachlor
	**	Hydrazine
	*	n-Nitrodimethylamine
		Pentachlorophenol
		Phenol
		Pyrene
	**	1,2-Propanedial
	**	2,3,4,5-Tetrachlorophenol
	**	2,4,5-Trichlorophenol
	**	Tributyl phosphate
	Other Organic Compounds	
		Ammonia
	**	Ammonium carbonate
		Ammonium nitrate
		Arsenic
		Boron
		Cyanide
		Ferrocyanide
		Fluoride
	**	Hydrofluoric acid
		Nitrate
		Nitrite
	**	Nitric acid
	**	Selenium
	**	Sodium dichromate
	*	Sulfuric acid

Notes:
Modified from DOE 1993a and b
* 200 West Area Only
** 200 East Area Only

I.2.2.3.1 200 West Area

In the 200 West Area, the water table begins approximately 70 m (230 ft) beneath the surface. The saturated section, considered to be the unconfined aquifer, is composed of Ringold Formation Units A, B, C, D, and E gravels and is approximately 110 m (350 ft) thick above the Elephant Mountain member of the basalt. Hydraulic conductivities measured in the 200 West Area in the Ringold Unit E aquifer range from approximately 0.02 to 60 m/day (0.06 to 200 ft/day). Hydraulic conductivities range from 0.5 to 1.2 m/day (1.6 to 4.0 ft/day) in the semiconfined to confined Ringold Unit A Gravels (DOE 1993b). A discontinuous layer of silt and sand cemented by calcium-carbonate (caliche Plio-Pleistocene Unit), with a thickness up to 9 m (30 ft), occurs locally nearly 55 m (180 ft) in depth in the 200 West Area. This unit is believed to be responsible for perched water conditions in the vicinity of the TWRS sites in the 200 West Area.

I.2.2.3.2 200 East Area

Depth to groundwater in the 200 East Area ranges from 97 m (320 ft) in the southeast to 36 m (120 ft) in the vicinity of the 216-B-3C Pond (B Pond mound) located approximately 5 km (3 mi) east of the TWRS sites (DOE 1993a). The unconfined aquifer occurs within the Hanford and Ringold Formations. Groundwater near the TWRS sites occurs under unconfined conditions within the Ringold formation, approximately 96 m (315 ft) deep. The saturated (groundwater) section is approximately 34 m (110 ft) thick. Erosional windows occur in the basalt several kilometers north of the 200 East Area that allow some interconnection between the regionally confined Rattlesnake Ridge Interbed of the Ellensburg Formation in the basalt and the unconfined aquifer of the Hanford and Ringold Formations. Hydraulic conductivities of the unconfined aquifer near the TWRS sites in the 200 East Area range from 150 to 300 m/day (500 to 1,000 ft/day) (DOE 1993a).

I.2.2.4 Groundwater Flow

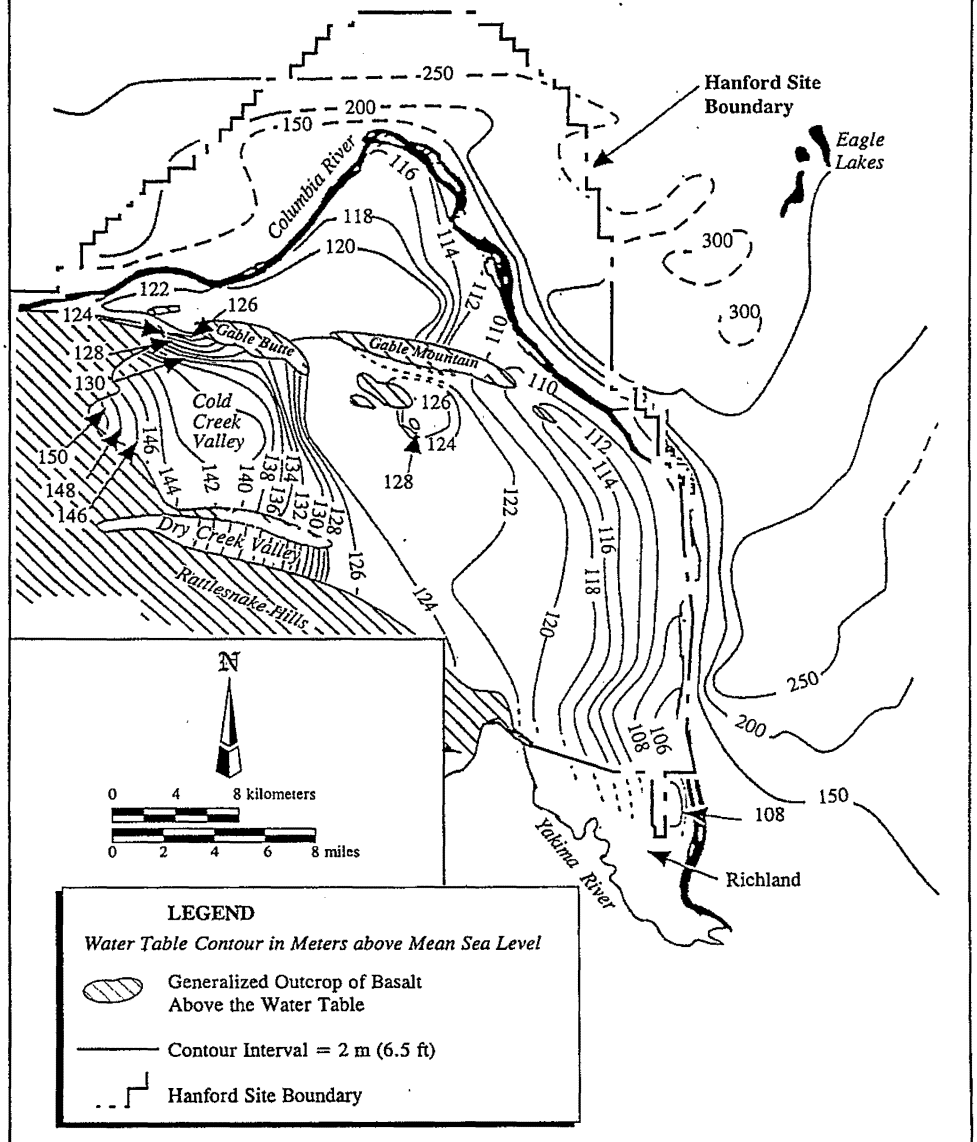
This section describes the physical characteristics of groundwater flow in the 200 Areas.

I.2.2.4.1 200 West Area

Figure I.2.2.3 is a contour map that shows the groundwater elevations for the Hanford Site. Groundwater generally flows from west to east, with some localized exceptions. In the northwest corner of the 200 West Area, groundwater flow is to the north. Also, it appears that flow from the 200 West Area may bifurcate east of the Gable Butte subcrop, with a lesser flow component north toward the gap between Gable Butte and Gable Mountain and the remaining flow east toward the Columbia River (Kasza 1994).

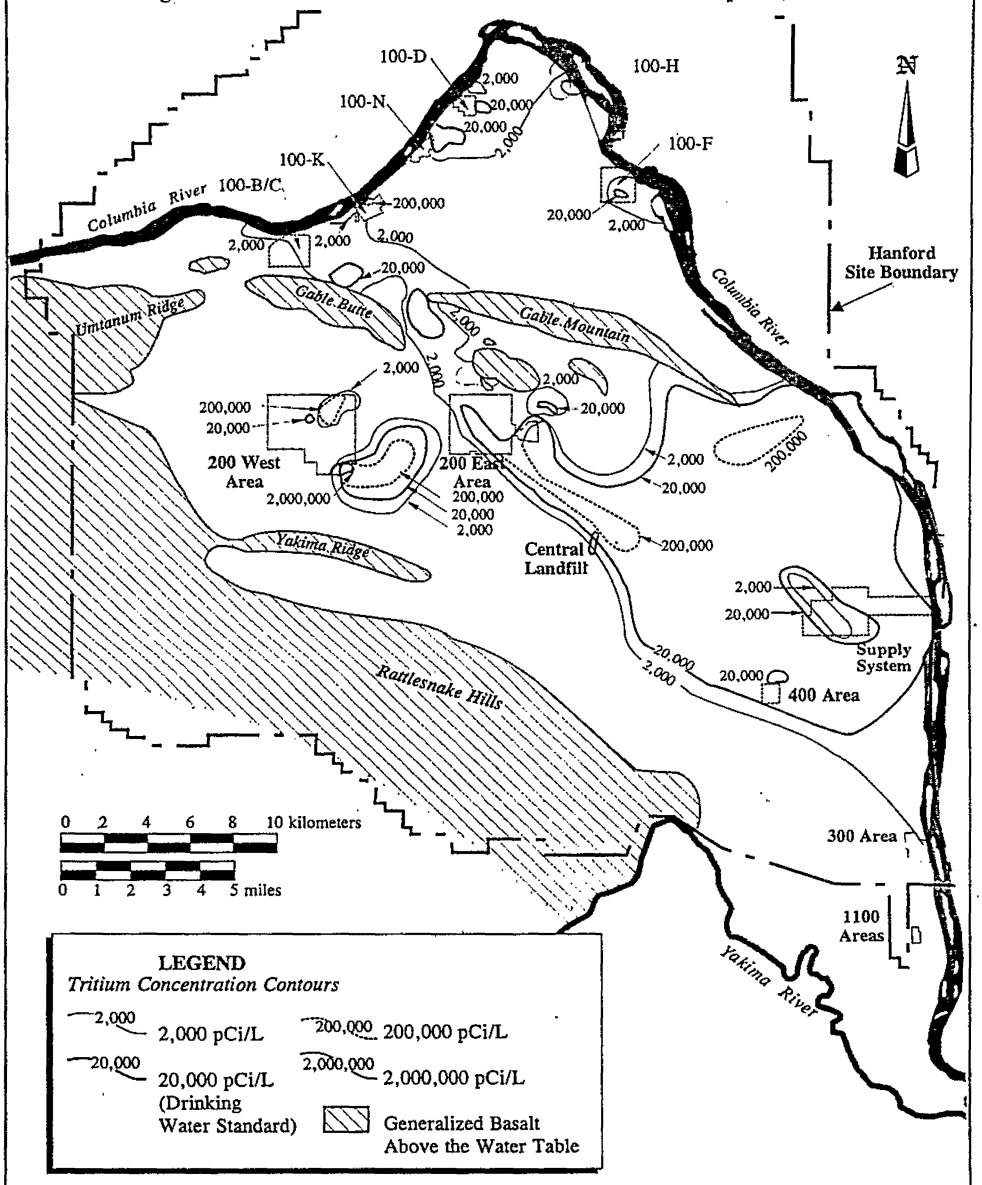
These groundwater movement patterns are also indicated by the 1994 distribution of tritium and nitrate in the unconfined aquifer, as shown on Figures I.2.2.4 and I.2.2.5, respectively. A north or northwest groundwater flow direction may also be indicated by the nitrate distribution in the area north and west of the 200 West Area. Because of the contrast in hydraulic conductivity, most basalt subcrops and outcrops appear as impermeable compared to groundwater flow in the transmissive Hanford and Ringold Formations.

Figure I.2.2.3 Groundwater Elevation Map of the Hanford Site



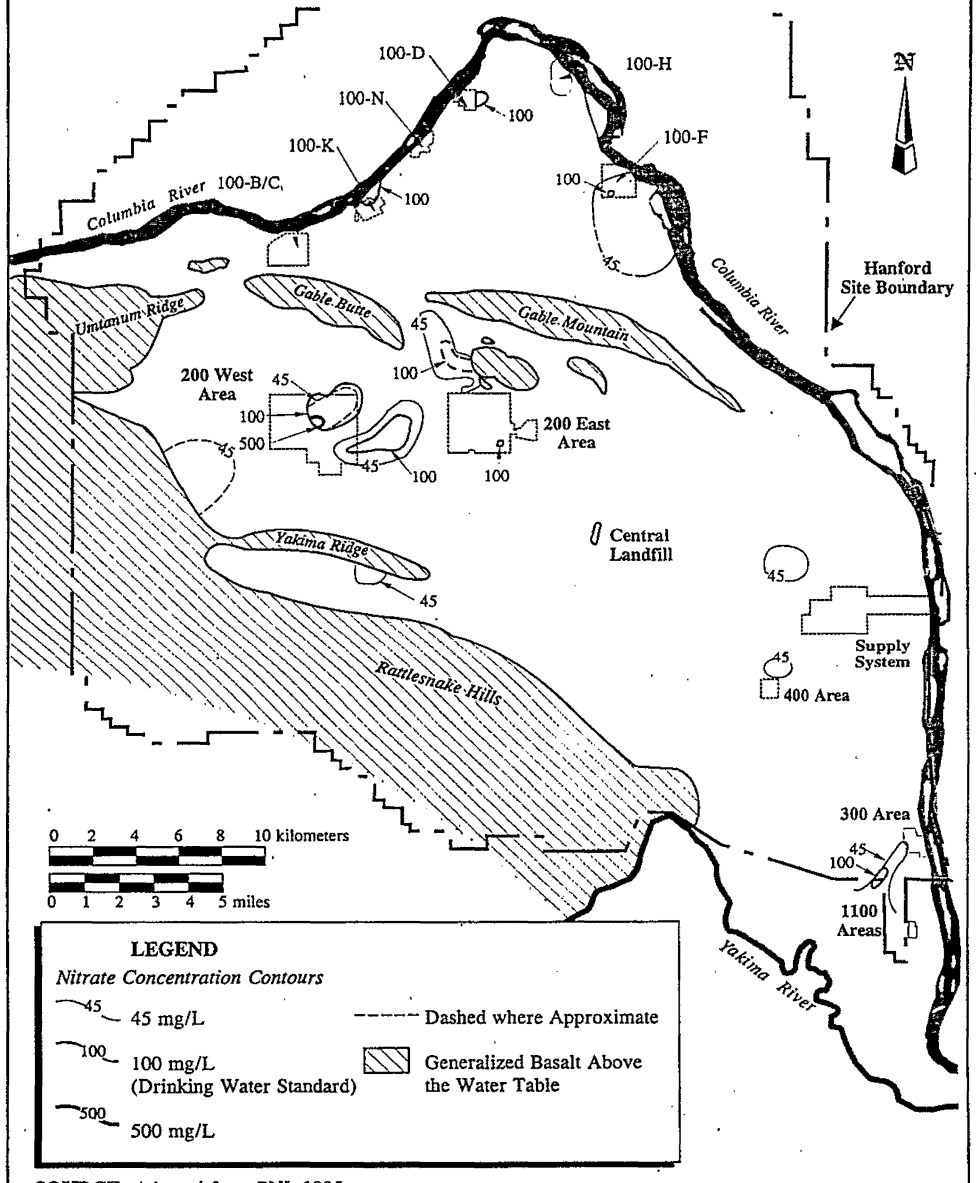
SOURCE: Adapted from PNL 1993a

Figure I.2.2.4 Distribution of Tritium in the Unconfined Aquifer, 1994



SOURCE: Adapted from PNL 1995

Figure I.2.2.5 Distribution of Nitrate in the Unconfined Aquifer, 1994



SOURCE: Adapted from PNL 1995

The tank farms in the 200 West Area are located above a groundwater mound caused by artificial recharge from the U Plant area, especially the 216-U-10 Pond. Groundwater elevations have declined greatly since the 216-U-10 Pond was decommissioned in the fall of 1984. Large declines in groundwater elevations have been recorded in seven wells in the U Plant area since 1984. Hydrographs of two wells (299-W19-1 and 299-W19-10) west of the tank farms indicate that groundwater elevations have declined approximately 5 m (15 ft) since the 216-U-10 Pond was decommissioned. The mound seems to have shifted slightly as it continues to dissipate beneath 216-U-10 Pond toward the northeast beneath the 216-U-14 Ditch and 216-Z-20 Crib (DOE 1993b).

I.2.2.4.2 200 East Area

Groundwater flow in much of the 200 East Area is characterized by relatively low hydraulic gradients, ranging from 0.01 to 0.02 m/day (0.3 to 0.6 ft/day) (Kasza 1994). As shown in Figure I.2.2.3, water table elevations in the uppermost aquifer generally decrease from the margins of the Yakima Ridge in the west to the Columbia River in the east. There is a strong relationship between the water table as shown in Figure I.2.2.3 and the distribution of tritium in the uppermost aquifer as shown in Figure I.2.2.4. Both figures indicate that groundwater flow in the vicinity of the TWRS sites in the 200 East Area is toward the southeast.

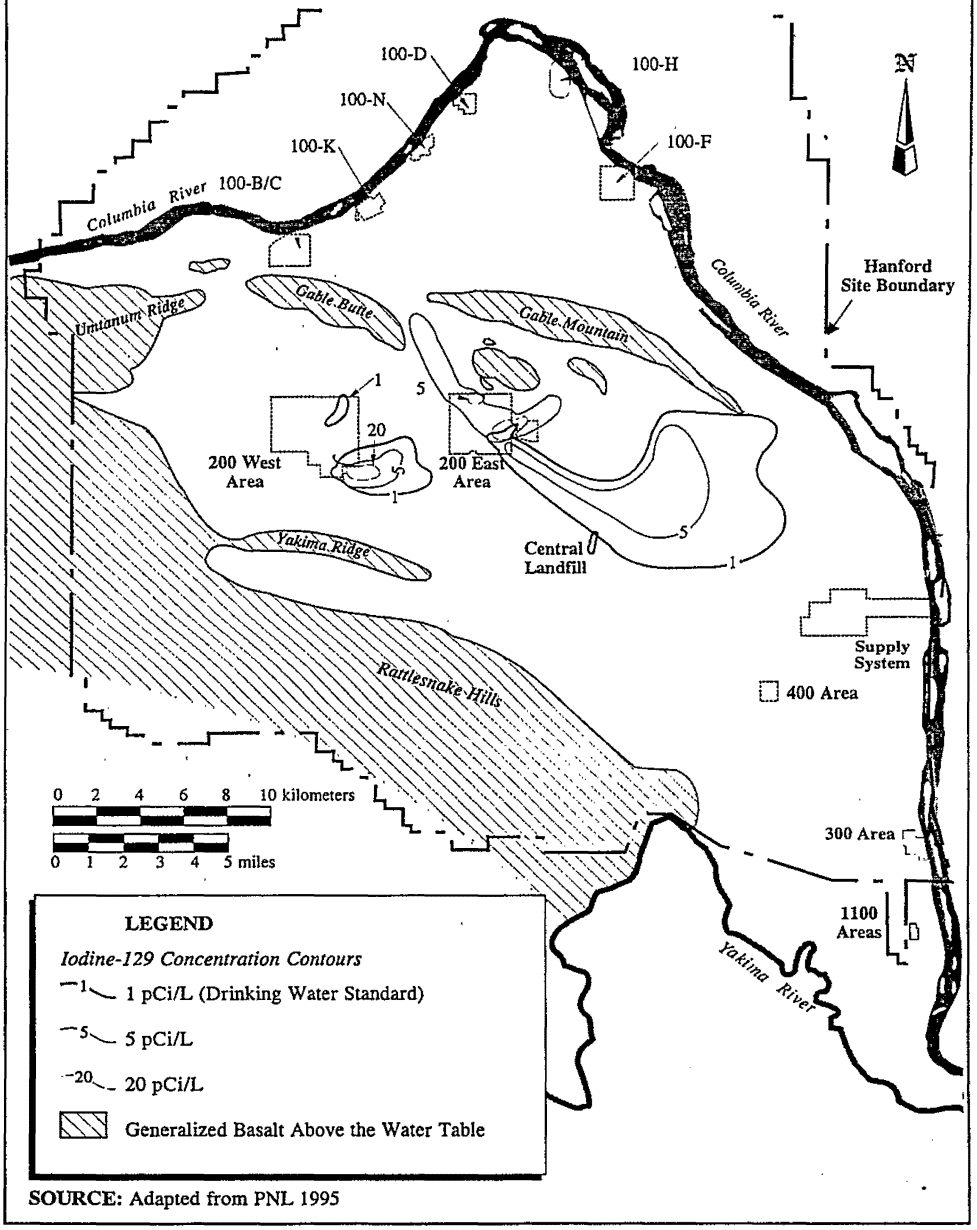
I-129 is an unretarded contaminant (i.e., it moves with groundwater at the average groundwater velocity), as are nitrate and tritium. The distribution of i-129 in the unconfined aquifer (Figure I.2.2.6) also shows a southeasterly groundwater flow direction. The i-129 plume is much smaller than the plumes associated with nitrate and tritium, probably because i-129 sources are not as ubiquitous in the unconfined aquifer.

The mound resulting from discharge from the 216-B-3 Pond is a notable perturbation to the easterly flow direction. B Pond is approximately 5 km (3 mi) east of the TWRS sites. Near the western portion of the mound, the groundwater gradient has been reversed in a west direction. The magnitude of this gradient direction reversal is currently diminishing as the mound decays. The groundwater gradient in the southeastern portion of the 200 East Area is expected to resume a more easterly trend as the decay continues (Kasza 1994).

I.2.2.4.3 Vertical Gradients

Vertical hydraulic gradients in the unconfined aquifer are estimated from water measurements in wells that are near to each other (sometimes referred to as well pairs) and have their sensing zones (screened intervals) completed at different elevations within the unconfined aquifer. In both the 200 East and 200 West Areas, downward hydraulic gradients have been observed (Trent 1992, and b). In general, these downward hydraulic gradients are associated with the moundings that have been created from infiltration of water discharged to the U Pond and B Pond. Away from these mounds, the vertical gradients are smaller. For instance, near the Grout Treatment Facility in the 200 East Area, which is located along the central portion of the eastern part of the 200 East Area, the vertical head differences between nearby well pairs are so slight that they are indistinguishable from measurement errors

Figure I.2.2.6 Distribution of Iodine-129 in the Unconfined Aquifer, 1994



SOURCE: Adapted from PNL 1995

(Trent 1992b). For information on the impact of the mounds on future groundwater flow see Appendix F, Section F.2.4.1.2.

I.2.2.4.4 Aquifer Communication

Aquifer communication is a process in which groundwater from distinct hydrogeological systems intermingle and mix. Of importance to the EIS is the degree of aquifer communication that exists between the unconfined aquifer and the underlying confined aquifer (Rattlesnake Ridge aquifer [Trent 1992b]). Several methods have been used to estimate the degree of aquifer communication at the Hanford Site including: analysis of joint and fracture systems in the basalt and presence of erosional windows, hydraulic head comparisons between aquifers, analysis and comparison of contaminant concentrations in adjacent aquifers, stable isotope analysis, and analysis of contaminant concentrations in adjacent aquifers. Interconnection between the unconfined and lower confined aquifer is possible across the Central Plateau; however, except for the area near the erosional windows, which occur in the basalt several kilometers north of the 200 East Area and B Pond vicinity, there is no indication of aquifer interconnection. In the vicinity of B Pond, groundwater mounding from B Pond discharges has resulted in a downward hydraulic gradient. Several kilometers north of the 200 East Area there is an absence of confining layer(s) associated with an erosional window that has resulted in enhanced interconnection of the aquifers in this area.

I.2.3 WATER QUALITY AND SUPPLY

Water for the Hanford Site is supplied by the Columbia River via distribution systems located at the 100-B, 100-D, 200, and 300 Areas, and at the Washington Public Power Supply System reactor. Wells supply water to the 400 Area and facilities at several remote locations. The city of Richland supplies water to the 700, 1100, and 3000 Areas.

Richland, Pasco, and Kennewick draw water from the Columbia River and operate their own water supply and treatment systems. Richland derives approximately 67 percent of its water from the Columbia River, 15 to 20 percent from a well field in North Richland, and the remaining 13 to 18 percent from groundwater wells (Cushing 1995). Richland's total water use in 1994 was 2.6E+10 L (6.9E+09 gal)..

Pasco also obtains its water from the Columbia River and in 1994 consumed an estimated 8.6E+9 L (2.3E+09 gal) of water (Cushing 1995). The city of Kennewick's water supply is derived from the Columbia River and two wells. The wells serve as the sole source of water between November and March. The total maximum water supply for Kennewick is approximately 2.8E+10 L (7.3E+09 gal); the wells can supply approximately 62 percent of that total. Kennewick's total water use in 1994 was 1.5E+10 L (3.9E+09gal) (Cushing 1995).

I.2.3.1 Surface Water

Surface waters considered for this EIS are onsite ponds, riverbank springs and seeps at the Columbia River, and the waters of the Columbia River. Water quality in ephemeral creeks is not known to be impacted by Hanford Site activities.

I.2.3.1.1 Columbia River

River water samples are routinely collected at the sample locations shown on Figure I.2.3.1. Additionally, river water samples have been collected at cross sections established at the Vernita Bridge upstream of the Hanford Site, and at the Richland City Pumphouse, downstream of the Hanford Site.

Radionuclides consistently detected in Columbia River water levels in 1995 were tritium, Sr-90, I-129, U-234, U-238, Pu-239, and Pu-240 (PNL 1996). Strontium-90 and tritium may come from worldwide fallout, as well as from releases of Hanford Site effluent. Tritium and U also occur naturally in the environment. Radionuclide concentrations at Priest Rapids Dam (upstream of the Site) generally were lower than those at the Richland Pumphouse (downstream from the Site), and were similar to levels observed in recent years.

All radiological contaminant concentrations measured in 1995 were less than the U.S. Department of Energy (DOE) Derived Concentration Guides and Washington State surface water quality standards (PNL 1996). Washington State classifies the Hanford Reach of the Columbia River as a Class A (Excellent) area. Class A waters are to be suitable for essentially all uses (e.g., raw drinking water, recreation, and wildlife habitat). Both State and Federal drinking water standards apply to the Columbia River and currently are being met (Neitzel 1996).

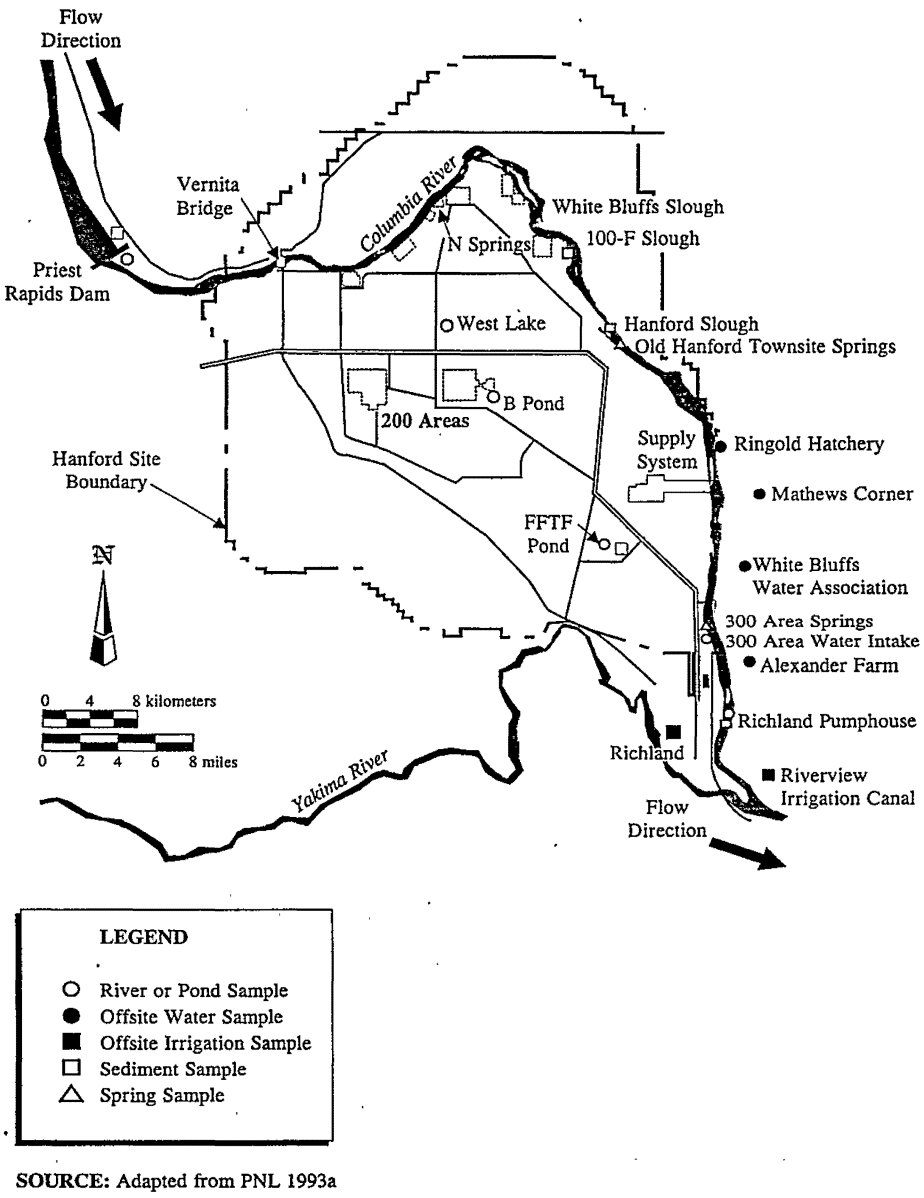
I.2.3.1.2 Ponds

Three ponds on the Hanford Site are routinely sampled: West Lake (located north of the 200 East Area), B Pond (located east of the 200 East Area), and the Fast Flux Test Facility Pond (located southeast of the 200 Areas) (PNL 1993a). Sampling data indicated that the ponds are impacted by Hanford Site activities, although the ponds are not used for human consumption. With the exception of U-234 and U-235 in the October 1995 sample of West Lake, all radionuclide concentrations were less than the DOE Derived Concentration Guides (PNL 1996). Average annual total beta concentrations exceeded the ambient surface water quality criteria in West Lake. The U.S. Environmental Protection Agency (EPA) proposed Hanford Site-specific drinking water standards for U also was exceeded in West Lake. All other radionuclide concentrations were less than the applicable surface water quality criteria (PNL 1996). West Lake surface water quality reflects the quality of the groundwater that feeds the lake (PNL 1993a).

Riverbank Springs and Seeps

Riverbank spring discharges have been documented along the Hanford Reach of the Columbia River since before the startup of Hanford Site operations. They have been observed to be of relatively small volume and to occur intermittently (PNL 1993a). Several springs in the 100 Areas, as well as the Old Hanford Townsite Springs and the 300 Area Springs, are routinely sampled. Water flows from these springs are a mechanism by which groundwater contaminated by past Site activities enter the river. All radiological contaminants measured in 1995 were less than the applicable DOE Derived Concentration Guides. However, Sr-90 in the 100-H Area and tritium in the 100-B Area and along the Old Hanford Townsite exceeded Federal and Washington State drinking water standards (PNL 1996). Total U exceeded the proposed EPA Hanford Site-specific drinking water standards (PNL 1996). The

Figure I.2.3.1 Water and Sediment Sampling Locations, 1992



SOURCE: Adapted from PNL 1993a

1995 nonradiological contaminant concentrations were below Washington State ambient surface water toxicity standards with the exception of copper and zinc in the 100-K Area spring. The chronic toxicity level of cadmium and the EPA standard for trichlorethylene also were exceeded in the 100-K Area Spring (PNL 1996).

I.2.3.2 Groundwater

I.2.3.2.1 Supply

Groundwater is not used in the 200 Areas except for emergency purposes. Three wells for emergency cooling water are located near B Plant in the 200 East Area. Water for drinking, most emergency uses, and facilities processes is obtained from the Columbia River. There are no water supply wells downgradient of the 200 Areas. Water supply wells on the Hanford Site are located at the Yakima Barricade, 6 km (4 mi) west of the 200 West Area; in the 400 Area, 16 km (10 mi) southeast of the 200 Areas; and at the Hanford Safety Patrol Training Academy, 25 km (16 mi) southeast of the 200 Areas.

I.2.3.2.2 Water Quality

Contamination by both radionuclide and nonradionuclide contaminants has been identified in the groundwater beneath the Hanford Site. Liquid effluents have been discharged to various ponds, cribs, and other Hanford Site waste management structures. Adsorption into soil particles, chemical precipitation, and ion exchange attenuate or delay the movement of some radionuclides and nonradionuclide contaminants in the effluent as they percolate downward through the vadose zone (PNL 1993a).

Constituents such as Sr-90, Cs-137, Pu-239, and Pu-240 are attenuated to varying degrees but eventually enter the groundwater. Compounds such as nitrate and radionuclides such as tritium, technetium-99 (Tc-99), and I-129 are not readily attenuated in the soil and reach the groundwater sooner than those that are. These ions then travel downgradient at the same rate as the natural groundwater (PNL 1993a). Figure I.2.2.4 shows the distribution of tritium in the unconfined groundwater. Two other major contaminant plumes include nitrates (Figure I.2.2.5) and I-129 (Figure I.2.2.6).

Groundwater beneath the 200 Areas and in plumes leading from the 200 Areas toward the Columbia River is contaminated with hazardous chemicals and radionuclides at levels that exceed Federal drinking water standards and State groundwater criteria. Hazardous chemical contaminants present at levels exceeding drinking water standards and State groundwater criteria include nitrates, cyanide, fluoride, chromium, chloroform, carbon tetrachloride, trichloroethylene, and techrachloroethylene. Radiological contaminants include I-129, tritium, Cs-137, Pu-239, Pu- 240, and Sr-90. Generally, the groundwater contamination beneath the 200 Areas substantially exceeds drinking water standards and State groundwater criteria. For example, I-129 is present at levels that exceed standards by up to 20 times. While other groundwater plumes from the 200 Areas tend to have lower levels of contaminants than the I-129 levels, many contaminants still exceed drinking water standards and State

groundwater criteria. Groundwater use is controlled at the Hanford Site to prevent use of contaminated groundwater.

I.2.3.2.3 200 East Area

Unconfined groundwater beneath the 200 East Area contains 13 different contaminants that have been mapped as plumes: arsenic, chromium, cyanide, nitrate, gross alpha, gross beta, tritium, Co-60, Sr-90, Tc-99, I-129, Cs-137, Pu-239, and Pu-240 (DOE 1993a).

I.2.3.2.4 200 West Area

Beneath the 200 West Area, 13 overlapping contaminant plumes are located within the unconfined gravels of Ringold Unit E: Tc-99, U, nitrate, carbon tetrachloride, chloroform, trichloroethylene, I-129, gross alpha, gross beta, tritium, arsenic, chromium, and fluoride (DOE 1993b). The tank farms are within the boundaries of most of these plumes. Plumes of Tc-99, U, I-129, gross alpha, and gross beta are associated with the U Plant area.

I.3.0 METEOROLOGY AND AIR QUALITY

The following subsections discuss Hanford Site climatology and air quality. The meteorological section summarizes measurements of wind, temperature and humidity, precipitation, fog and visibility, severe weather, and atmospheric dispersion. The air quality section includes information on air quality standards, emissions sources, and air quality monitoring.

I.3.1 METEOROLOGY

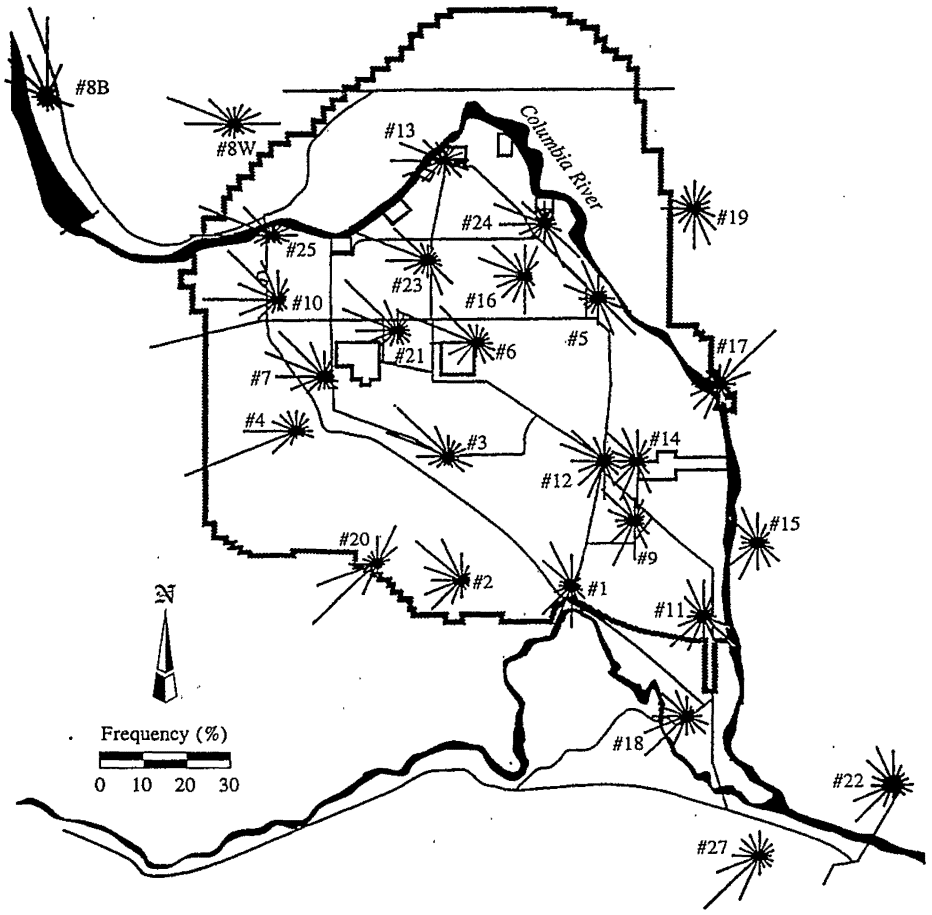
The Cascade Mountains greatly influence the climate of the Hanford Site by their rain shadow effect. This range also serves as a source of cold air drainage, which has a considerable effect on the wind regime over the Site.

Climatological data has been collected at Hanford Meteorological Monitoring Network sites. The Hanford Meteorological Station (HMS), located between the 200 East and 200 West Areas, is the most completely instrumented station. The HMS data are considered representative for assessing proposed TWRS activities. The following meteorological discussion is largely based on the Hanford Climatological Summaries (Stone et al. 1972), as well as information compiled by Cushing (Cushing 1994).

I.3.1.1 Wind

Figure I.3.1.1 shows winds measured at the Meteorological Monitoring Network sites. Prevailing winds at the HMS are from the west-northwest and northwest in all months of the year. Monthly average wind speeds are lowest during December, averaging 10 km/hr (6 mi/hr), and highest during June, averaging approximately 15 km/hr (9 mi/hr). The most prevalent wind speed class, 6 to 11 km/hr (4 to 7 mi/hr), occurs 36 percent of the time. Wind speeds are less than 21 km/hr (13 mi/hr) 84 percent of the time, and greater than 29 km/hr (18 mi/hr) less than 5 percent of the time. Peak gusts occur from the south-southwest, southwest, and west-southwest during all months.

Figure I.3.1.1 Hanford Meteorological Monitoring Network Wind Roses for the Period from 1982 through 1993



SOURCE: PNL 1993a

I.3.1.2 Temperature and Humidity

From 1961 through 1990, the average monthly temperatures varied from -1 °centigrade (C) (30.3 °Fahrenheit [F]) in January to 24.6 °C (76.2 °F) in July with a yearly average of 11.8 °C (53.2 °F). On the average, 51 days during the year (April through September) had maximum temperatures greater than or equal to 32 °C (90 °F), and 12 days (May through September) had a maximum temperature greater than or equal to 37.8 °C (100 °F). Also, an average of 25 days during the year (October through February) experienced maximum temperatures less than 0 °C (32 °F). An average of 106 days per year (October through April) experienced minimum temperatures less than 0 °C (32 °F). An average of 4 days per winter season (November through February) experienced daily minimum temperatures less than -18 °C (0 °F) but approximately half of all winters were free of such days. The record maximum and minimum temperatures recorded during the period 1945 to 1991 were 45 °C (113 °F) in 1961 and -45 °C (-23 °F) in 1950.

The annual average relative humidity, based on data from the years 1950 through 1993, was 54.5 percent. Relative humidity was highest during the winter months, averaging 80.2 percent in December, and lowest during the summer, averaging 33.3 percent in July.

I.3.1.3 Precipitation

The average annual precipitation measured at the HMS is 17 cm (6.6 in.). The bulk of the precipitation (54 percent) occurs during November through February. As the wettest month, December receives an average of 2.5 cm (1 in.) of precipitation while July averages 0.5 cm (0.2 in.) and is the driest month. On the average, only 1 day per year experiences precipitation greater than 1.3 cm (0.5 in.), and 68 days per year have precipitation greater than 0.02 cm (0.01 in.) per year. An average of 125 days per year receive a trace amount or more of precipitation. The monthly total time during which precipitation occurs ranges from 12.4 percent in December to 1.5 percent in July. Winter monthly average snowfall ranges from 0.8 cm (0.3 in.) in March to 13.5 cm (5.3 in.) in January. Yearly snowfall has ranged from 0.8 cm (0.3 in.) to 140 cm (56 in.). Annual average snowfall is 38 cm (15 in.).

I.3.1.4 Fog and Visibility

Although fog (visibility less than or equal to 10 km [6 mi]), has been recorded during every month of the year at the HMS, nearly 90 percent of the occurrences are during the late fall and winter months. The months of April through September account for only about 1 percent of the occurrences. On average, 46 days per year experience fog and 24 days per year experience dense fog (visibility less than or equal to 0.4 km [0.25 mi]).

Other phenomena restricting visibility to 10 km (6 mi) or less include dust, blowing dust, and smoke (typically from wildfires, orchard smudging, and agricultural field burning). An average of 5 days per year have dust or blowing dust and only about 2 days per year have reduced visibility resulting from smoke. On an annual basis, 3.8 percent of the hourly observations recorded for the years 1960 through 1980 indicate restricted visibility because of all phenomena.

I.3.1.5 Severe Weather

Severe high winds are associated with thunderstorms. On average the Hanford Site may experience 10 thunderstorms per year, most frequently (80 percent) occurring May through August. However, thunderstorms have been observed to occur in every month of the year. Estimates of the extreme wind velocities, based on peak gusts observed from 1945 through 1980, are shown in Table I.3.1.1 (Stone et al. 1983).

Tornadoes are smaller and less frequent in the northwest portion of the United States than elsewhere in the country. There were no reports of violent tornadoes for the region surrounding the Hanford Site. The HMS climatological summary (Stone et al. 1983) and the National Severe Storms Forecast Center database list 22 separate tornado occurrences within 160 km (100 mi) of the Hanford Site from 1916 through August 1982. Two additional tornadoes have been reported since August 1982. The probability of a tornado striking at the Hanford Site has been estimated to be approximately one in 10,000 (NRC 1977).

Table I.3.1.1 Estimates of Extreme Winds at the Hanford Site

Peak Gusts, km/hr (mi/hr)		
Return Period, year	15 m (50 ft) Aboveground	60 m (200 ft) Aboveground
2	97 (61)	109 (68)
10	114 (71)	129 (81)
100	137 (86)	151 (94)
1000	159 (99)	175 (109)

Notes:
km/hr = kilometers per hour
mi/hr = miles per hour

I.3.1.6 Atmospheric Dispersion

Atmospheric dispersion is a function of wind speed, duration and direction of wind, atmospheric stability, and mixing depth. Dispersion conditions are generally good if winds are moderate to strong, the atmosphere is of neutral or unstable stratification, and there is a deep mixing layer. Good dispersion conditions associated with neutral and unstable stratification exist about 57 percent of the time during the summer at the Hanford Site. Less favorable dispersion conditions may occur when the wind speed is light and the mixing layer is shallow. These conditions are most common during the winter when moderately to extremely stable stratification exists about 66 percent of the time. Less favorable conditions also occur periodically for surface and low-level releases in all seasons from sunset to 1 hour after sunrise as a result of ground-based temperature inversions and shallow mixing layers. Mixing layer thicknesses have been estimated at the HMS using remote sensors. The variations in the mixing layer are summarized in Table I.3.1.2.

The Hanford Site may experience occasional extended periods of poor dispersion conditions associated with stagnant air in stationary high-pressure systems that occur primarily during the winter months.

Table I.3.1.2 Percent Frequency of Mixing-Layer Thickness by Season and Time of Day

Mixing Layer, m (ft)	Winter		Summer	
	Night	Day	Night	Day
Less than 250 m (830 ft)	65.7	35.0	48.5	1.2
250 to 500 m (830 to 1,700 ft)	24.7	39.8	37.1	9.0
Greater than 500 m (1,700 ft)	9.6	25.2	14.4	89.9

The probability of an inversion period (e.g., poor dispersion conditions) extending more than 12 hours varies from a low of about 10 percent in May and June to a high of about 64 percent in September and October (Stone et al. 1972).

I.3.2 AIR QUALITY

Federal and State ambient air quality standards have been set for a limited number of pollutants. Monitoring is conducted to measure levels of selected pollutants that can then be compared to the standards.

I.3.2.1 Air Quality Standards

National Ambient Air Quality Standards (NAAQS) have been established by EPA, as mandated in the 1970 Clean Air Act. Ambient air is the portion of the atmosphere, external to buildings, that is accessible to the general public. The NAAQS define levels of air quality that, with an adequate margin of safety, are protective of public health (primary standards) and welfare (secondary standards). NAAQS exist for the following six criteria pollutants; sulfur oxides (measured as sulfur dioxide), nitrogen dioxide, carbon monoxide, particulate matter (PM-10, measured as particles less than 10 micrometers [μm] aerodynamic diameter), lead, and ozone. The standards specify the maximum pollutant concentrations and frequencies of occurrence that are allowed for various averaging periods ranging from 1 hour to 1 year depending on the pollutant.

Washington State has largely adopted the current NAAQS. However, Washington State has established more stringent standards for sulfur dioxide and ozone and maintains an air quality standard for total suspended particulates and gaseous fluorides. Table I.3.2.1 summarizes the NAAQS and supplemental Washington State standards.

The Hanford Site also evaluates concentrations of selected pollutants for which national and State ambient air quality standards do not exist. For toxic organic compounds (e.g., toluene, benzene), comparisons are made to the Occupational Safety and Health Administration's maximum allowable concentrations (29 Code of Federal Regulations [CFR] 1910). Concentrations of polychlorinated biphyenyls are compared against the National Institute of Occupational Safety and Health limit of 1,000 micrograms per m^3 ($\mu g/m^3$) as a 10-hour time-weighted average.

Table I.3.2.1 Federal and Washington State Ambient Air Quality Standards

Pollutant	Federal		Washington State
	Primary	Secondary	
Total suspended particulates			
Annual (geometric mean)	NS	NS	60 $\mu g/m^3$
24-hr	NS	NS	150 $\mu g/m^3$
PM-10			
Annual (arithmetic mean)	50 $\mu g/m^3$	50 $\mu g/m^3$	50 $\mu g/m^3$
24-hr	150 $\mu g/m^3$	150 $\mu g/m^3$	150 $\mu g/m^3$
Sulfur Dioxide			
Annual	0.03 ppm	NS	0.02 ppm
24-hr	0.14 ppm	NS	0.1 ppm
3-hr	NS	0.50 ppm	NS
1-hr	NS	NS	0.4 ppm[1]
Carbon Monoxide			
8-hr	9 ppm	9 ppm	9 ppm
1-hr [1]	35 ppm	35 ppm	35 ppm
Ozone			
1-hr [2]	0.12 ppm	0.12 ppm	0.12 ppm
Nitrogen Dioxide			
Annual	0.05 ppm	0.05 ppm	0.05 ppm
Lead			
Quarterly average	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$	1.5 $\mu g/m^3$
Gaseous Fluorides [3]			
12-hr [4]	-	-	3.7 $\mu g/m^3$
24-hr [5]	-	-	2.9 $\mu g/m^3$
7-day [6]	-	-	1.7 $\mu g/m^3$
30-day [7]	-	-	0.84 $\mu g/m^3$
March 1 through October 31	-	-	0.5 $\mu g/m^3$

Notes:
[1] 0.25 ppm not to be exceeded more than two times in any 7 consecutive days.
[2] Not to be exceeded more than 1 day per calendar year.
[3] Measured as hydrogen fluoride.
[4] Average over any 12 consecutive hours.
[5] Average over any 24 consecutive hours.
[6] Average over any 7 consecutive days.
[7] Average over any 30 consecutive days.
$\mu g/m^3$ = micrograms per cubic meter
NS = no standard
ppm = parts per million

I.3.2.2 Emission Sources

Sources of airborne emissions at the Hanford Site include combustion equipment (e.g., steam boilers, electric generation plants), coal handling operations, chemical separation processes, storage tanks, waste handling, and waste disposal. These activities result in routine emissions of air pollutants, including radionuclides.

The Clean Air Act amendments of 1990 established a new national permitting system for major sources of air pollution, and other categories of sources, such as facilities with equipment subject to a National Emission Standard for Hazardous Air Pollutants (NESHAP). The Hanford Site is classified as a major source for one or more criteria pollutants, as well as for hazardous air pollutants. The Hanford Site is currently subject to the radionuclide NESHAP of 10 millirems (10 mrem) per year. DOE has applied for a Sitewide Air Operating Permit for the Hanford Site, which will cover all substantial emission sources for which the Site is considered a major source.

For areas in attainment of the NAAQS, the EPA has established the Prevention of Significant Deterioration (PSD) program to protect existing ambient air quality while at the same time allowing a margin for future growth. Under the PSD program, new stationary sources of air pollution may only impact air quality by set increments and they must install best available control technology emission controls. The Hanford Site obtained a PSD permit in 1980 requiring specific limits for oxides of nitrogen emitted from the PUREX Plant.

I.3.2.3 Air Quality Monitoring

Air quality data have been collected at onsite and offsite locations. The following discussion concentrates on recent monitoring activities conducted largely for the purpose of assessing air quality impacts from the Hanford Site. The information was taken from the Hanford Site Environmental Report (PNL 1995 and 1996) and from the Site NEPA Characterization Report (Cushing 1995 and Neitzel 1996).

I.3.2.3.1 Onsite Monitoring

Onsite air quality monitoring was conducted during 1990 for nitrogen oxides at three locations. The monitoring was discontinued after 1990 because the primary source ceased operation. The highest annual average concentration was less than 0.006 parts per million (ppm), well below the applicable Federal and Washington State annual ambient standard of 0.05 ppm.

Based on a review of chemicals of concern for surveillance at PCBs, the Site, three types of semi-volatile organic compounds were identified for monitoring: polycyclic aromatic hydrocarbons, and a phthalate ester plasticizer. Organochlorine pesticides also were analyzed. Four polycyclic aromatic hydrocarbons, 19 polychlorinated biphenyl congeners, and 16 organochlorine pesticides were found above detection limits. The measured concentrations of pesticides were orders of magnitude below the occupational maximum allowable concentration values. No phthalate esters were found above detection limits (PNL 1996).

Nine of a total 17 PCB samples collected during 1993 were below the detection limit of 29 $\mu g/m^3$. Eight PCB samples were above the detection limit, with values ranging from 0.25 to 3.9 $\mu g/m^3$, all well below the National Institute of Occupational Safety and Health occupational limit of 1,000 $\mu g/m^3$. Fourteen volatile organic compound samples were obtained in 1993. All samples analyzed for benzene, alkylbenzenes, halogenated alkanes, and alkenes were within allowable limits. Volatile organic compound data from 1994 were within a similar range of values and also were within allowable limits.

I.3.2.3.2 Offsite Monitoring

The only offsite monitoring in the vicinity of the Site in 1993 was conducted by Washington State Department of Ecology. PM-10 was monitored at Columbia Center in Kennewick. The State's 24-hour PM-10 standard was exceeded twice in 1993. The maximum reading was 1,166 μ/m^3, with the suspected cause being windblown dust. There was no exceedance of the annual primary standard of 50 $\mu g/m^3$ (Cushing 1995).

Particulate concentrations can reach relatively high levels in eastern Washington State because of exceptional natural events (i.e., dust storms, volcanic eruptions, and large brush fires) that occur in the region. State ambient air quality standards have not distinguished rural fugitive dust from exceptional natural events when estimating the maximum background concentrations of particulates in the area east of the Cascade Mountain crest. No decision has been made to designate Benton County a nonattainment area pending studies to determine the source of high local PM-10 concentrations. It is suspected that the high readings are due to natural conditions (e.g., dust storms, brush fires) rather than man-made pollution.

I.3.2.3.3 Radiological Monitoring

Data were collected in 1995 through a system of 47 radiological monitoring stations located onsite, at the Site perimeter, in nearby communities (e.g., Richland, Kennewick, and Pasco), and in distant communities (Sunnyside and Yakima). Cesium-137, Pu-239, Pu-240, Sr-90, and U were consistently detected in air samples collected in the 200 Areas. Concentrations of these radionuclides were higher than concentrations measured offsite and were in the same range as measured in recent years. The levels measured at both onsite and offsite locations were much lower than the applicable standards (PNL 1996).

I.4.0 BIOLOGICAL AND ECOLOGICAL RESOURCES

This section describes the ecological resources potentially impacted by the proposed action and alternatives. A brief description of the regional environment is followed by a discussion of the ecological resources of the Central Plateau and nearby areas, which are the location of all facilities under all alternatives addressed in this EIS. The material presented is based largely on reports by Cushing (Cushing 1994 and 1995), which summarize many other site studies, on the 1994 biological survey of the TWRS site in the 200 East Area (PNL 1994e), and on the Site Evaluation Report for Candidate Basalt Quarry Sites (Duranceau 1995).

The Hanford Site and adjacent region have been characterized as shrub-steppe (Daubenmire 1970). Shrub-steppe vegetation zones are dominated by a shrub overstory with an understory of grasses. The Hanford Site has not been farmed or grazed by livestock for more than 50 years, allowing it to serve as a refuge for a variety of plant and animal species (Gray-Rickard 1989). Approximately 665 km^2 (257 mi^2) of undeveloped land within the Hanford Site have been designated as ecological study areas or refuges. Washington State considers shrub-steppe a priority habitat because of its importance to wildlife species of concern. The National Biological Service has identified native shrub and grassland steppe in Washington State and Oregon as an endangered ecosystem.

I.4.1 BIODIVERSITY

Biodiversity has been defined as the diversity of ecosystems, species, and genes, and the variety and variability of life (CEQ 1993). Major components of biodiversity are plant and animal species, microorganisms, ecosystems, and ecological processes, and the interrelationships between and among these components. Biodiversity also is a qualitative measure of the richness and abundance of ecosystems and species in a given area (NPS 1994). Biodiversity also provides a moderating effect on wide fluctuations in environmental conditions.

Two major factors that contribute to biodiversity on the Hanford Site are 1) the Site is one of the largest relatively undisturbed tracts of native shrub-steppe left in Washington State; and 2) the Hanford Reach is the last free-flowing nontidal stretch of the Columbia River in the United States (Sackschewsky et al. 1992 and Cushing 1994). Other factors include topographic features such as Rattlesnake Mountain, Gable Butte, and Gable Mountain, a variety of soil textures ranging from sand to silty and sandy loam, and the lack of human use and development over much of the Hanford Site. Specialized terrestrial habitats contributing to the biodiversity of the Hanford Site include areas of shrub-steppe, basalt outcrops, scarps (cliffs), scree slopes (accumulations of material at the base of a hole or cliff), and sand dunes. Aquatic components of biodiversity are mainly associated with the Columbia River and include aquatic habitat, wetland and riparian areas, and riverain habitat along the Hanford Reach shoreline and islands in the Columbia River.

The biological diversity of the Hanford Site has been emphasized by the recent discovery of 21 new species (two plant and 19 insects) in a study by the Nature Conservancy of Washington (Nature Conservancy 1996). These species may be dependent on the shrub-steppe environment and destruction, fragmentation, or other disturbance of this habitat could lead to the loss of these and other as yet unidentified species. None of these newly recorded species were found in potential TWRS areas (Brandt 1996).

Ecologically important plant and animal species on the Hanford Site include species of concern (Section I.4.6); commercial and recreational wildlife species such as salmon and steelhead, mule deer, and upland game birds; and plant species used as a source of food, medicine, fiber, and dye in the traditional lifestyles of Native People of the Columbia Basin (Section I.4.7) (Sackschewsky et al. 1992).

As stated previously, the Hanford Site has not been farmed or grazed for over 50 years and thus has served as a refuge for various plant and animal species. However, the invasion and spread of nonnative plant species into previously disturbed areas, such as abandoned farmland, represent a potential threat to biodiversity by displacing native species, simplifying plant communities, and fragmenting habitat. Introduced plant species account for approximately 21 percent of the vascular plants found on the Hanford Site and include species such as cheatgrass, Russian-thistle, and most of the tree species found onsite (Sackschewsky et al. 1992). Most of the Site's disturbed areas include abandoned farmland and areas burned by wildfire. These areas are dominated by pure stands of cheatgrass where the native shrub component has been modified severely or replaced altogether (Cushing 1994).

I.4.2 VEGETATION

The Hanford Site is a relatively undisturbed area of shrub-steppe, which is considered priority habitat by Washington State (WSDW 1993). Also, the National Biological Service has listed native shrub and grassland steppe in Washington and Oregon as an endangered ecosystem. Historically, the predominant plant in the area was big sagebrush (*Artemisia tridentata*) with an understory of perennial bunch grasses such as Sandbergs bluegrass (*Poa sandbergii*) and bluebunch wheatgrass (*Agropyron spicatum*). Following human settlement in the early 1800's, grazing and agriculture disrupted the native vegetation and opened the way for invader species such as tumbleweed or Russian-thistle (*Salosa kali*) and cheatgrass (*Bromus tectorum*). Establishing the Hanford Site as a nuclear facility in 1943 created a protected area of mostly undeveloped land with scattered, small industrial complexes. Consequently, the Hanford Site is one of a small number of remaining shrub-steppe tracts in Washington State that is relatively undisturbed.

The Central Plateau and the nearby areas of the potential McGee Ranch and Vernita Quarry borrow sites have been identified as predominantly shrub-steppe (Cushing 1994 and Duranceau 1995). This designation includes communities dominated by big sagebrush and bitterbrush (*Purshia tridentata*) with an understory of cheatgrass or Sandbergs bluegrass (Figure I.4.2.1). Over 100 plant species occur on the Central Plateau and vicinity. Common plant species include big sagebrush, rabbitbrush (*Chrysothamnus nauseous*), cheatgrass, and Sandbergs bluegrass (Table I.4.2.1). Much of the 200 Areas (e.g., the tank farms, the sites of several large processing facilities), have been disturbed by human activities. In these disturbed areas, introduced species, such as Russian-thistle and cheatgrass are common (Cushing 1994).

The TWRS sites in the 200 East Area and the immediate surrounding area are approximately 40 percent big sagebrush and rabbitbrush. Another 20 percent is dominated by Russian-thistle, with the remainder disturbed vegetation or bare gravel (PNL 1994e). The proposed Phased Implementation alternative site in the easternmost portion of the 200 East Area is comprised of approximately 65 percent shrub-steppe, with the remaining area disturbed by the construction in the 1980's of the unused Grout Treatment Facility (ASI 1995).

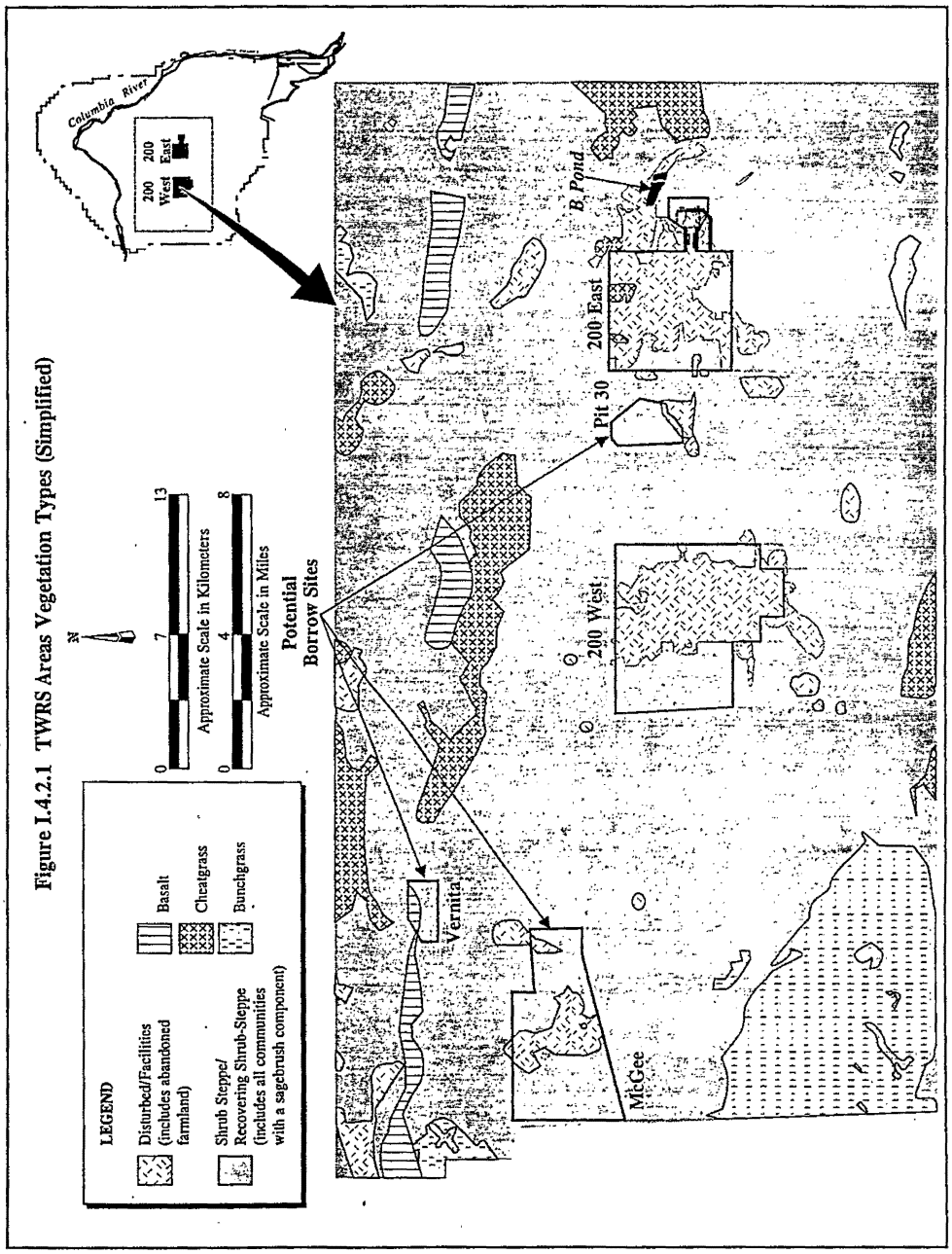


Figure I.4.2.1 TWRS Areas Vegetation Types (Simplified)

Table I.4.2.1 Common Vascular Plants Found on the Hanford Site

Scientific Name	Common Name
Shrub-Steppe Species Shrubs	
Artemisia tridentata	big sagebrush
Chrysothamnus nauseous	grey rabbitbrush
Chrysothamnus viscidiflorus	green rabbitbrush
Eriogonum niveum	snowy buckwheat
Grayia (Atriplex) spinosa	spiny hopsage
Purshia tridentata	bitterbrush
Perennial Grasses	
Agropyron dasystachyum	thick-spike wheatgrass
Agropyron desertorum (cristatum)	crested wheatgrass
Agropyron sibericum	Siberian-wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Oryzopsis hymenoides	Indian-ricegrass
Poa sandbergii (secunda)	Sandbergs bluegrass
Sitanion hystrix	bottlebrush squirreltail
Sporobolus cryptandrus	sand dropseed
Stipa comata	needle-and-thread grass
Perennial Forbs	
Achillea millefolium	yarrow
Arenaria franklinii	sandwort
Astragalus caricinus	buckwheat milkvetch
Astragalus sclerocarpus	stalked-pod milkvetch
Balsamorhiza careyana	balsamroot
Brodiaea douglasii	cluster lily
Comandra umbellata	comandra
Cymopterus terebinthinus	turpentine cymopterus
Erigeron filifolius	threadleaf milkbane
Frittillaria pudica	yellow bell
Helianthus cusickii	Cusick sandflower
Lomatium grayi	Gray desert-parsley
Machaeranthera canescens	hoary aster
Oenothera pallida	pale evening primrose
Penstemon acuminatus	Beard tongue
Phlox longifolia	long-leaved phlox
Psoralea lanceolata	scurf pea
Rumex venosus	sand dock
Sphaeralcea munroana	desert mallow
Thelypodium lanciniatum	thelypody

Table I.4.2.1 Common Vascular Plants Found on the Hanford Site (cont'd)

Scientific Name	Common Name
Annual Forbs	
Ambrosia acanthicarpa	ragweed
Amsinckia lycopsoides	fiddleneck tarweed
Chaenactis douglasii	false yarrow
Chorispora tenella	purple mustard
Crepis atrabarba	hawk beard
Cryptantha circumscissa	matted cryptantha
Cryptantha pterocarya	cryptantha
Descurainia pinnata	tansy mustard
Draba verna	spring draba
Epilobium paniculatum	willow-herb
Erodium cicutarium	filaree (cranes bill)
Erysimum asperum	western wall flower
Holosteum umbellatum	jagged chickweed
Lastuca serriola	prickly lettuce
Lepidium perfoliatum	pepperweed
Annual Grasses	
Bromus tectorum	cheatgrass
Festuca microstachys	small fescue
Festuca octoflora	six-weeks fescue
Riparian Plants Trees and Shrubs	
Apocynum cannabinum	dogbane
Morus alba	white mulberry
Populus trichocarpa	black cottonwood
Prunus spp.	peach, apricot, cherry
Robinia pseudo-acacia	black locust
Salix amygdaloides	peachleaf willow
Salix exigua	sand bar willow
Salix spp.	willow
Perennial Grasses and Forbs	
Allium spp.	wild onion
Artemisia campestris	pacific sage
Artemisia ludoviciana	prairie sage
Carex spp.	sedge
Centurea repens	Russian-knapweed
Coreopsis atkinsonia	tickseed
Eleocharis spp.	wiregrass
Equisetum spp.	horsetail
Gaillardia aristata	gaillardia
Grindelia columbiana	gumweed
Heterotheca villosa	golden aster

Table I.4.2.1 Common Vascular Plants Found on the Hanford Site (cont'd)

Scientific Name	Common Name
Juncus spp.	rushes
Lupinus spp.	lupine
Phalaris arundinacea	reed canary grass
Polygonum persicaria	smartweed
Scirpus spp.	bulrushes
Solidago occidentalis	goldenrod
Typha latifolia	cattail
Veronica anagallis-aquatica	speedwell
Aquatic Vascular	
Elodea canadensis	waterweed
Lemna minor	duckweed
Myriophyllum spicatum	water milfoil
Potamogeton spp.	pondweed
Rorippa nasturtium-aquaticum	watercress
Rorippa columbiae	Columbia yellow cress

Source: Cushing 1992

Other vegetation in the 200 Areas includes wetland species associated with man-made ditches and ponds and introduced perennial grass planted to revegetate disturbed areas. Wetland species such as cattail, reeds, and various trees, such as willow, cottonwood, and Russian-olive, are established around some of these ponds (Cushing 1992). However, several of the ponds have been decommissioned, which eliminated the supply of industrial water feeding the ponds. Without the water supply, the artificial wetland habitat was eliminated. None of the wetlands or ponds are near the TWRS sites.

Introduced perennial grass, such as Siberian-wheatgrass (*Agropyron sibericum*), has been used extensively in the 200 Areas to revegetate and stabilize waste burial grounds against wind and water erosion. Siberian-wheatgrass has proven to be drought tolerant and better adapted to sandy soil than other species used in the 200 Area's revegetation (Stegen 1993).

At the potential Vernita Quarry borrow site, the areas at the top of the basalt cliffs have very low shrub densities, primarily big sagebrush and rigid sagebrush. Grasses such as bluebunch wheatgrass and Sandbergs bluegrass are common. Areas between and below the basalt cliffs have shrub coverage of 30 to 40 percent, primarily big sagebrush with some spiny hopsage and prickly phlox (Duranceau 1995).

The potential McGee Ranch borrow site contains a wide variety of shrubs and flowering plants. Large portions of the site are covered with a dense stand of big sagebrush and spiny hopsage. This area has a Sandbergs bluegrass understory with very little cheatgrass or other alien weed species (Duranceau 1995). Approximately 25 percent of the site is abandoned farmland and is dominated by cheatgrass and Russian-thistle. The McGee Ranch area also is an important vegetation and wildlife corridor linking the Hanford Site and the Yakima Training Center, which are two largest shrub-steppe

areas remaining in Washington State (Fitzner 1992). In 1996, the Washington State Department of Fish and Wildlife asked DOE to preserve the McGee Ranch area as a wildlife corridor (Baker 1996).

The Nature Conservancy of Washington recently discovered a new species of buckwheat in the Umtanum Ridge area, which is in the same general area of the Hanford Site as McGee Ranch and Vernita Quarry (Nature Conservancy 1996).

I.4.3 WILDLIFE

Approximately 290 species of terrestrial vertebrates have been observed at the Hanford Site, including 41 species of mammals, 238 species of birds, three species of amphibians, and nine species of reptiles (Weiss-Mitchell 1992). Major terrestrial habitat types occurring on the Site include basalt outcrops, scarps and screes, riparian and riverain areas, shrub-steppe, sand dunes and blowouts, and abandoned fields (Downs et al. 1993).

I.4.3.1 Mammals

Common large mammal species include the mule deer and Rocky Mountain elk; predators such as coyotes, bobcats, and badger; and a variety of small mammals (Table I.4.3.1). Elk were not present when the Hanford Site was established in 1943 and did not appear onsite until 1972. The elk occur primarily on the FEALE Reserve, although they also may be found elsewhere on the Site, such as on the islands and along the Columbia River (PNL 1993a). Mule deer may occur almost anywhere on the Hanford Site, although concentrations are highest along the Columbia River between the Hanford townsite and the B Reactor area (Rickard et al. 1989). White-tailed deer are occasionally sighted along the Columbia River and at the Yakima River Delta near Richland (Fitzner-Gray 1991). Six species of bats also occur on the Hanford Site, primarily as fall or winter migrants, with some using abandoned buildings as roosting sites (Cushing 1992).

I.4.3.2 Birds

Bird species on the Site include a variety of raptors, songbirds, and species associated with riparian, riverain, and upland habitats. Approximately 240 species of birds, including migrants and accidental species, have been observed at the Hanford Site (Landeen et al. 1992). Of these, 36 are common species (Table I.4.3.2) and 40 occur as accidental species (Cushing 1994).

Common raptors that may occur onsite year-round are the northern harrier, red-tailed hawk, golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), American kestrel (*Falco sparverius*), barn owl (*Tyle albu*), great horned owl (*Bubo virginianus*), and long-eared owl (*Anio olus*) (Fitzner-Gray 1991). Raptors use a variety of habitats for nesting and foraging at the Hanford Site. Nest habitat include outcrops and cliffs, trees, marsh lands and fields, and utility towers. Depending on raptor size and species, prey may include small mammals, birds, reptiles such as snakes, and insects.

A variety of passerine (songbird) species is known to occur in the shrub-steppe vegetation type on the Hanford Site. These include the western meadowlark (*Sturnella neglecta*), grasshopper sparrow

Table I.4.3.1 List of Mammals Occurring on the Hanford Site

Scientific Name	Common Name
Antrozous pallidus	pallid bat
Brachylagus idahoensis	pygmy rabbit
Canis latrans	coyote
Castor canadensis	beaver
Cervus elaphus	elk
Erethizon dorsatum	porcupine
Eutamias minimus	least chipmunk
Lagurus curtatus	sagebrush vole
Lasionycteris noctivagans	silver-haired bat
Lasiurus cinereus	hoary bat
Lepus californicus	black-tailed jackrabbit
Lepus townsendi	white-tailed jackrabbit
Lutra canadensis	river otter
Lynx rufus	bobcat
Marmota flaviventris	yellow-bellied marmot
Mephitis mephitis	striped skunk
Microtus montanus	montane meadow mouse
Mus musculus	house mouse
Mustela erminea	short-tailed weasel
Mustela frenata	long-tailed weasel
Mustela vison	mink
Myotis californicus	California brown bat
Myotis lucifugus	little brown bat
Myotis yumanensis	Yuma brown bat
Neotoma cinerea	bushy-tailed woodrat
Odocoileus hemionus	mule deer
Odocoileus virginianus	white-tailed deer
Ondatra zibethicus	muskrat
Onychomys leucogaster	northern grasshopper mouse
Perognathus parvus	Great Basin pocket mouse
Peromyscus maniculatus	deer mouse
Plecotus townsendii townsendii	Pacific western big-eared bat
Procyon lotor	raccoon
Rattus norvegicus	Norway rat
Reithrodontomys megalotis	western harvest mouse
Sorex merriami	Merriam shrew
Sorex vagrans	vagrant shrew
Spermophilus townsendii	Townsend ground squirrel
Sylvilagus nuttallii	Nuttall cottontail rabbit
Taxidea taxus	badger
Thomomys talpoides	northern pocket gopher

Source: Cushing 1992

Table I.4.3.2 Common Birds Occurring on the Hanford Site

Scientific Name	Common Name
Ageless phonics	red-winged blackbird
Alas aceta	northern pintail
Alas americana	American wigeon
Anas clypeata	northern shoveler
Anas platyrhynchos	mallard
Ardea herodias	great blue heron
Aythya americana	redhead
Branta canadensis	Canada goose
Bucephala albeola	bufflehead
Calidris mauri	western sandpiper
Calidris minutilla	least sandpiper
Carpodacus mexicanus	house finch
Charadrius vociferus	killdeer
Chordeiles minor	common nighthawk
Columba livia	rock dove
Corvus corax	common raven
Dendroica coronata	yellow-rumped warbler
Eremophila alpestris	horned lark
Fulica americana	American coot
Hirundo pyrrhonota	cliff swallow
Hirundo rustica	barn swallow
Junco hyemalis	dark-eyed junco
Larus californicus	California gull
Larus delawarensis	ring-billed gull
Limnodromus scolopaceus	long-billed dowitcher
Mergus merganser	common merganser
Numenius americanus	long-billed curlew
Passer domesticus	house sparrow
Pica pica	black-billed magpie
Podilymbus podiceps	pied-billed grebe
Sturnella neglecta	western meadowlark
Sturnus vulgaris	european starling
Turdus migratorius	American robin
Tyrannus verticalis	western kingbird
Zenaida macroura	mourning dove
Zonotrichia leucophrys	white-crowned sparrow

Source: Cushing 1992

(*Ammodramus savannarum*), horned lark (*Eremophila alpestris*), and sage thrasher (*Oreoscoptes montanus*) (Downs et al. 1993). The western meadowlark and horned lark are the most abundant shrub-steppe passerine bird species that breed on the Hanford Site (Rickard-Poole 1989). The western

meadowlark and horned lark nest on the ground in the open, while shrub-steppe species like the sage sparrow, sage thrasher, and loggerhead shrike require sagebrush or bitterbrush for nesting habitat.

Common upland game bird species include the chukar partridge (*Alectoris chukar*), california quail (*Callipepla californicus*), and chinese ring-necked pheasant (*Phasianus colchicus*). Sage grouse (*Centrocercus urophasianus*) and gray partridge (*Perdix perdix*) are less common and rarely seen. Although once more common, sage grouse are now essentially absent from the Site, displaced after a major wildfire in 1984 (Brandt 1995). None of the upland birds are native to the area except the sage grouse.

I.4.3.3 Reptiles and Amphibians

Nine species of reptiles and three species of amphibians occur on the Hanford Site (Table I.4.3.3) (Fitzner-Gray 1991). The most abundant reptile is the side-blotched lizard (*Uta stansburiana*) (Cushing 1992). The short-horned lizard (*Phrynosoma douglassii*) and northern sagebrush lizard (*Sceloporous graciosus*) are also common in mature sagebrush habitats with sandy soil. Common snakes include the gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and pacific rattlesnake (*Crotalus viridis*). Less common are striped whipsnakes (*Masticophis taeniatus*) and desert night snakes (*Hyspiglena torquata*). Amphibians on the Hanford Site are associated with riparian habitats located along permanent water bodies or the Columbia River (Fitzner-Gray 1991). Included are the Great Basin spadefoot (*Spea intermontana*), Woodhouses toad (*Bufo woodhouseii*), and the Pacific tree frog (*Hyla regilla*).

Table I.4.3.3 Amphibians and Reptiles Occurring on the Hanford Site

Scientific Name	Common Name
Amphibians	
Bufo woodhouseii	Woodhouse toad
Hyla regilla	Pacific treefrog
Spea intermontana	Great Basin spadefoot
Reptiles	
Chrysemys picta	painted turtle
Coluber constrictor	western yellow-bellied racer
Crotalus viridis	western rattlesnake
Hyspiglena torquata	desert night snake
Masticophis taeniatus	striped whipsnake
Phrynosoma douglassii	short-horned lizard
Pituophis melanoleucus	gopher snake
Sceloporus graciosus	sagebrush lizard
Uta stansburiana	side-blotched lizard

Source: Cushing 1992

I.4.3.4 Insects

The Nature Conservancy of Washington, in an ongoing multi-year inventory project, has identified approximately 1,200 species of insects on the Hanford Site. This includes the discovery of six new

species of bees, six new species of flies, five new species of leafhopper and planthopper insects, one new species of wasp and one new species of beetle (Nature Conservancy 1996). None of the new species were found in potential TWRS areas. However, The Nature Conservancy project focused on the FEALE Reserve, the North Slope, and along the Columbia River rather than in areas of the Site where TWRS activities may occur under the various EIS alternatives.

Table I.4.3.4 lists the relative abundance (percentage) of insect taxa collected from three shrub species on the Site. Grasshoppers and darkling beetles represent some of the more conspicuous insect groups. The populations of both of these species of insects are subject to seasonal changes and weather variations (Rogers-Rickard 1977). Fifty percent of the known insect species are of the order Coleoptera (beetles) (ERDA 1975). Many of the insect species are important in the food web of birds and mammals found onsite. Species like the darkling beetle play an important role in the decomposition process by feeding on decaying plant material, animal excrement, fungi, and live plant tissue (Weiss-Mitchell 1992).

Table I.4.3.4 Relative Abundance of Insect Taxa Collected from Sagebrush, Rabbitbrush, and Hopsage

Taxa	Sagebrush (%)	Rabbitbrush (%)	Hopsage (%)
Araneida	6.5	20.7	21.3
Coleoptera	1.7	1.9	27.4
Diptera	1.1	1.2	5.3
Hemiptera	44.6	11.7	6.4
Homoptera	33.0	31.2	6.1
Hymenoptera	4.2	2.9	5.8
Lepidoptera	1.2	6.1	5.3
Neuroptera	0.3	0.3	0.3
Orthoptera	7.3	24.0	21.8
Other	0.1	0.1	0.3

Source: Cushing 1992

I.4.4 AQUATIC ECOLOGY

Aquatic habitats on the Hanford Site are primarily associated with the Columbia River, two small spring-fed streams on the FEALE Reserve, and artificial ponds and ditches occurring in or near the 200 Areas. Past studies (Cushing-Watson 1974, Emery-McShane 1978, and Cushing 1994) describe the ecology of some of these ponds. The Columbia River supports a large and diverse community of plankton, benthic invertebrates, fish, and other communities. The springs are also diverse and productive (e.g., dense watercress blooms and fairly high aquatic insect populations). The artificial ponds and ditches, many of which are now abandoned and dried out, often provide lush riparian habitat and support populations of migratory and breeding birds, particularly waterfowl. No extensive discussions are provided of Site aquatic habitats because none of them are in close proximity to any TWRS sites.

I.4.5 SENSITIVE HABITATS

Sensitive habitats on the Hanford Site include wetlands and riparian habitats. Wetlands include those transitional lands occurring between terrestrial and aquatic ecosystems where the water table is usually close to the surface or where shallow water covers the surface (Cowardin et al. 1979). The primary wetlands found on the Site occur along the Hanford Reach of the Columbia River and include the riparian habitats located along the river shoreline. Other wetland habitats found on the Hanford Site are associated with man-made ponds and ditches. These include B Pond and its associated ditches located near the 200 East Area. The B Pond Complex was constructed in 1945 to receive cooling water from facilities in that area. Wetland plants occurring along the shoreline of B Pond include herbaceous and woody species such as showy milkweed (*Asclepias speciosa*), western goldenrod (*Solidago occidentalis*), three square bulrush (*Scirpus americanus*), horsetail (*Equisetum* sp.), rush (*Juncus* sp.), common cattail (*Typha latifolia*), mulberry (*Morus alba*), silver poplar (*Populus alba*), black cottonwood (*Populus trichocarpa*), and willow (*Salix* sp.) (Sackschewsky et al. 1992). Wildlife species observed at B Pond include a variety of mammals and waterfowl species (Meinhardt-Frostenson 1979).

I.4.6 SPECIES OF CONCERN

Species of concern on the Hanford Site include Federally-listed threatened and endangered species, Federal candidate species, Washington State threatened or endangered species, State candidate species, State monitor species, State sensitive plant species, and species of ethnobiological concern to Native Americans.

Species of concern occurring on the Hanford Site are listed in Tables I.4.6.1 and I.4.6.2, along with definitions of each category. No Federally-listed threatened or endangered plant or animal species occur in the 200 Areas, at the potential Pit 30 borrow site located between the 200 East and 200 West Areas, or at the potential Vernita Quarry and McGee Ranch borrow sites. (Sackschewsky et al. 1992). Pipers daisy (*Erigeron piperianus*), a State sensitive species, has been found at B Pond near the 200 East Area and at Pit 30. The crouching milkvetch, stalked-pool milkvetch, and scilla onion, all State Class 3 monitor species, are also found in the 200 East Area.

Wildlife species of concern observed or considered likely to be found on or near the Central Plateau include the sage sparrow (*Amphispiza belli*), loggerhead shrike (*Lanius Ludovicianus*), and Swainsons hawk (*Buteo swainsoni*). The loggerhead shrike and sage sparrow commonly nest in undisturbed shrub-steppe habitat. The sage sparrow is one of the most common nesting birds on the Hanford Site (Downs et al. 1993). Other bird species of concern that may be found include the burrowing owl, ferruginous hawk, Swainsons hawk, golden eagle, sage thrasher, and prairie falcon (Cushing 1994).

Nonavian wildlife species of concern using the Central Plateau and vicinity include the striped whipsnake (*Mastocophis taeniatus*), which is a State candidate species; the desert night snake (*Hypsiglena torquata*), which is a State monitor species; the northern sagebrush lizard, a Federal Category 2 candidate species, and the pygmy rabbit, a Federal Category 2 candidate and State threatened species (Rogers-Rickard 1977).

Table I.4.6.1 Plant Species of Concern on the Hanford Site

Scientific Name	Common Name	Status*
Allium robinsonii	Robinsons onion	M3
Allium scillioides	squill onion	M3
Arenaria franklinii v.thompsonii	Tompsons sandwort	FC3b, M2
Artemisia campestris var. wormskioldii	northern wormwood	FC1, SE
Artemisia lindleyana	Columbia River mugwort	M3
Astragalus columbianus	Columbia milkvetch	FC2, ST
Astragalus sclerocarpus	stalked-pod milkvetch	M3
Astragalus speirocarpus	medick milkvetch	M3
Astragalus succumbens	crouching milkvetch	M3
Balsamorhiza rosea	rosy balsamroot	M3
Carex densa	dense sedge	S
Cirsium brevifolium	palouse thistle	M3
Cryptantha interrupta	bristly cyptantha	S
Cryptantha leucophaea	gray cryptantha	S
Cuscuta denticulata	desert dodder	M1
Cyperus rivularis	shining flatsedge	S
Erigeron piperianus	Pipers daisy	S
Limosella acaulis	southern mudwort	S
Lindernia anagallidea	false-pimpernel	S
Lomatium tuberosum	Hoovers desert-parsley	FC2, ST
Oenothera pygmaea	dwarf evening-primrose	S
Pellaea glabella	smooth cliffbrake	M3
Penstemon eriantherus	fuzzy beardtongue	M3
Rorippa columbiae	Columbia yellowcress	FC2, SE

* Plant species of concern status definitions:

State Definitions (WSDNR 1990)

SE - State endangered:
Plant taxa that are in danger of becoming extinct or extirpated within the near future if factors contributing to their decline continue.

ST- State threatened:
Plant taxa that are likely to become endangered within the near future if factors contributing to their population decline or habitat degradation continue.

S- Sensitive:
Plant taxa that are vulnerable or declining, and that could become endangered or threatened without active management or removal of threats.

M1 - Monitor group 1: Plant taxa in need of further field work before a status can be assigned.

M2 - Monitor group 2: Plant taxa with unresolved taxonomic questions.

M3 - Monitor group 3: Plant taxa that are more abundant and less threatened than previously assumed.

Federal Definitions (50 CFR 17)

FC1 - Candidate plant taxa for which enough substantial information on biological vulnerability and threat is available to support listing as threatened or endangered by the federal government.

FC2 - Candidate plant taxa for which there is some evidence of vulnerability, but not enough data to support listing proposals at this time.

FC3 - Candidate plant taxa that were once considered for listing as threatened or endangered but are no longer candidates for listing. Subcategory (FC3b) includes names that, on the basis of current taxonomic understanding, do not represent distinct taxa meeting the Endangered Species Act of 1973 definition of species.

Source: Sackschewsky et al. 1992

Table I.4.6.2 Wildlife Species of Concern on the Hanford Site

Scientific Name	Common Name	Status*
Mammals		
Antrozous pallidus	pallid bat	SM
Brachylagus idahoensis	pygmy rabbit	FC2, ST
Lagurus curtatus	sagebrush vole	SM
Onychomys leucogaster	northern grasshopper mouse	SM
Plecotus townsendii	pacific western big-eared bat	FC2, SC
Sorex merriami	merriams shrew	SC
Birds		
Accipter gentilis	northern goshawk	FC2, SC
Aechmophorus clarkii	clarks grebe	SM
Aechmophorus occidentalis	western grebe	SM
Ammodramus savannarum	grasshopper sparrow	SM
Amphispiza belli	sage sparrow	SC
Aquila chrysaetos	golden eagle	SC
Ardea herodias	great blue heron	SM
Athene cunicularia	burrowing owl	SC
*Branta canadensis leucopareia***	aleutian canadian goose	FE, SE
Buteo regalis	ferruginous hawk	FC2, ST
Buteo swainsoni	swainsons hawk	SC
Caserodius albus	great egret	SM
Cathartes aura	turkey vulture	SM
Centrocercus urophasianus	western sage grouse	FC2, SC
Chlidonias niger	black tern	FC2, SM
Falco columbarius	merlin	SM
Falco mexicanus	prairie falcon	SM
Falco peregrinus	peregrine falcon	FE, SE
Falco rusticolus	gyrfalcon	SM
Gavia immer	common loon	SC
Grus canadensis	sandhill crane	SE
Haliaeetus leucocephalus	bald eagle	FT, ST
Himantopus mexicanus	black-necked stilt	SM
Lanius ludovicianus	loggerhead shrike	FC2, SC
Melanerpes lewis	lewis woodpecker	SC
Myiarchus cinerascens	ash-throated flycatcher	SM
Numenius americanus	long-billed curlew	SM
Nyctea scandiaca	snowy owl	SM
Nycticorax nycticorax	black-crowned night heron	SM
Oreoscoptes montanus	sage thrasher	SC
Otus flammeolus	flammulated owl	SC
Pandion haliaetus	osprey	SM
Pelecanus erythrorhychos	white pelican	SE
Podiceps grisegena	horned grebe	SM
Podiceps grisegena	red-necked grebe	SM

Table I.4.6.2 Wildlife Species of Concern on the Hanford Site (cont'd)

Scientific Name	Common Name	Status*
Sialia mexicana	western bluebird	SC
Sterna caspia	caspian tern	SM
Sterna forsteri	forsters tern	SM
Sterna paradisaea	arctic tern	SM
Strix varia	barred owl	SM
Reptiles		
Hypsiglena torquata	desert night snake	SM
Masticophis taeniatus	striped whipsnake	SC
Amphibians		
Bufo woodhousei	Woodhouses toad	SM
Fish		
Catostomus platyrhynchus	mountain sucker	SM
Cottus beldingi	Piute sculpin	SM
Cottus perplexus	reticulate sculpin	SM
Percopsis transmontana	sand roller	SM
Mollusks		
Fisherola nuttalli	short-faced lanx	FC2, SC
Fluminicola columbiana	Columbia pebble snail	FC2, SC
Insects		
Cicindela columbica	Columbia River tiger beetle	SC

* Species of concern status definitions:

Federal Definitions (from Endangered Species Act, as amended by PL 100-707, November 23, 1988; Federal Register, Vol. 54, No. 4, January 6, 1989, Notice of Review-Animals, U.S. Fish and Wildlife Service)

FE - Federal endangered:
A species in danger of extinction or extirpation throughout all or a substantial portion of its range.

FT - Federal threatened:
A species that is likely to become endangered within the near future because of threats to its population.

FC2 - Federal candidate for listing, Category 2:
A species for which there is some evidence of vulnerability, but for which there are not enough data to support listing proposals at this time.

State Definitions (WSDW 1991)

SE - State endangered:
A species native to Washington State that is seriously threatened with extinction throughout all or a substantial portion of its range within the state. Endangered species are designated in WAC 232-12-014.

ST - State threatened:
A species native to Washington State likely to become endangered within the foreseeable future throughout substantial portions of its range within the state without cooperative management or the removal of threats. Threatened species are designated in WAC 232-12-011.

SC - State candidate:
A wildlife species native to Washington State that the Department of Wildlife will review for possible listing as endangered, threatened, or sensitive.

SM - State monitor:
A wildlife species native to Washington State of special interest because at one time it was classified as endangered, threatened, or sensitive; it requires habitat that has limited availability during some portion of its life cycle; it is an indicator of environmental quality; further field investigations are required to determine its population status; there are unresolved taxonomic problems that may bear upon its status classification; it may be competing with and impacting other species of concern; and it has substantial popular appeal.

** Rare migrant or accidental occurrence on the Hanford Site (Downs et al. 1993).

Source: Downs et al. 1993, Stengen 1993, Landeen et al. 1992

To understand the role of the Central Plateau in terms of ethnobiology, the role of the natural environment in a culture, it is necessary to briefly describe the subsistence life-style of the Native Americans that have long resided in the general area (Hunn 1990). The Native American people that resided along the reach of the Columbia River flowing through what is now the Hanford Site followed a seasonal, migratory life-style, as did the majority of Native American people along the Columbia River. They concentrated on salmon fishing at Priest Rapids in the summer and early fall (June through October) when weather and water conditions combined with salmon migration provided a productive fishery. In the spring, they moved towards the areas now known as Moses Lake and Ephrata to gather roots, at one time a substantial component of their diet. In the late fall, the Native Americans moved to the surrounding mountains to gather berries and hunt. In the winter they returned to lower, warmer, elevations along the river where they over-wintered in semi-permanent long-houses. Although Native Americans followed a well-defined pattern of movement throughout the year, they fished for other species when salmon were not present, hunted whenever the opportunity was available, and gathered available, edible food plants.

Affected Tribes have indicated that big game including elk and antelope were abundant on the Columbia Plateau (CTUIR 1996). Other researchers have indicated that the Columbia Plateau historically did not support large populations of big game and that it is more likely that big game hunting was associated with fall berry-gathering expeditions to areas where larger animals were more abundant (Devóto 1953 and Irving 1976). Smaller mammals such as the yellow-bellied marmot, Beldings ground squirrel, Townsends ground squirrel, jackrabbits, and cottontails probably made up a large portion of the diet of Columbia Basin Native Americans. This has been substantiated by archeological finds along the Columbia River (Aikens 1993).

Bird species were an additional source of food for Native Americans (CTUIR 1996). Historically, the Hanford Reach of the Columbia River has been an important waterfowl wintering and breeding area. Waterfowl were netted or shot. Egg collecting probably contributed to the Native American's diet. Birds and bird parts were used for medicinal purposes or as a part of religious practices. Bird parts were also used as decorations and to fletch arrows. Waterfowl and sage grouse probably made up the bulk of birds used for food (Hunn 1990).

Fish have been and remain an important part of the diet of the Native Americans residing along the Columbia River. Salmon played an important role in their diet, but suckers and other bottom fish are thought to have contributed as much to the diet as did salmon (Hunn 1990 and Aikens 1993).

For the Native Americans that live along the Columbia River, salmon and other fish continue to be an important part of their diet.

Plants have been and remain important to Native Americans along the Hanford Reach. Plants or plant parts provide food, medicine, cordage, building materials, and materials of religious significance. Several dozen plant species at the Hanford Site are considered to have uses in traditional Native

American cultures and lifestyles. A number of these plants species were identified in 1994 biological surveys of the TWRS sites in the 200 East Area (Fortner 1994).

I.5.0 CULTURAL RESOURCES

The Hanford Site is abundant in cultural sites, including such items as archaeological sites, districts, and objects; standing historical structures, locations of important historic events; and places, objects, and living or nonliving sites that are important to the practice and continuity of traditional cultures. In most cases, cultural sites are finite, unique, fragile, and nonrenewable (PNL 1989).

Archaeological sites are considered to be substantial if they are eligible for inclusion in the National Register of Historic Places (NRHP). Properties are deemed to be eligible for the NRHP if they are important in American history, architecture, archaeology, engineering, or culture.

Three categories of cultural sites are commonly delineated: prehistoric resources, historic era sites, and ethnographic or traditional cultural sites. Prehistoric sites date from before the time of written records. In the interior Pacific Northwest, prehistory refers to the period of time predating Euro-American contact with the Native American cultures and societies of the region. Historic resources are defined as those sites or properties that were occupied or used after written records became available. Structures must usually be at least 50 years old to be deemed historic. However, those items and structures that were built in support of the Manhattan Project during World War II, as well as those that are representations of the Hanford Site's defense mission during the Cold War must also be considered for historic significance (Harvey 1994). Ethnographic sites (traditional cultural sites with historic or socio-religious affiliations) are locations that are important to the heritage of contemporary communities.

The Hanford Site contains a rich diversity of known cultural sites in all three categories. The Site contains seven NRHP Districts as well as 964 sites and isolated finds representative of prehistoric, historic, and modern eras (Neitzel 1996). The overall condition (i.e., integrity) and thus potential significance of Hanford Site cultural sites is high because the area has had limited public access for over 50 years. This restricted access has saved most archaeological sites from looting and other adverse impacts. Another contributing factor to the importance of the Site's cultural sites is that similar areas along the Columbia River have been inundated by hydroelectric development. The Hanford Site has not experienced this type of development nor the resultant depletion of cultural sites, because the reach of the Columbia River adjacent to the Hanford Site has not been dammed.

The Hanford Site is of particular importance to Native Americans. The Hanford Site is part of the original homeland of a number of Tribal Nations. Although no specific religious sites have been identified at the TWRS sites, Gable Mountain is a traditional cultural property located approximately 3 km (2 mi) north of the 200 Areas that would potentially experience impacts from implementation of TWRS alternatives. Further, it is the view of the affected Tribes that all natural resources, including the Site's groundwater and the Columbia River, are also cultural resources to indigenous people (CTUIR 1996).

Archaeological sites or artifacts in the 200 Areas are scarce. A review of existing data for the TWRS sites in the 200 East Area indicates that 28 cultural resource surveys have been previously conducted (ASI 1994). These surveys included 18 block-tract surveys, 7 linear surveys, and 3 historic well surveys. In all, these surveys covered approximately 1,350 ha (3,400 ac). The number of archaeological sites or artifacts recorded as the result of these surveys is limited. Findings recorded in the areas surrounding and including the TWRS sites in the 200 East Area consist of individual isolated artifacts and four archaeological sites. Cultural resource surveys of the TWRS sites and vicinity conducted in 1994 confirmed the overall scarcity of archeological sites and artifacts in the 200 East Area. These surveys indicate no archeological resources in the 200 East Area that are likely to meet the eligibility criteria for inclusion in the NRHP (PNL 1994a, b, c).

The portion of the 200 East Area where TWRS facilities are proposed includes potentially historic buildings and structures associated with the Hanford Site's defense mission. Some of these may meet NRHP eligibility criteria although they have not yet been evaluated for their historical significance. Evaluations of the buildings and structures in the 200 Areas are expected to be completed by the end of 1996 (Cushing 1995). TWRS implementation is not expected to impact these structures.

The 200 West Area has not been as completely surveyed as the 200 East Area. However, a 1988 project by the Hanford Cultural Resources Laboratory surveyed 50 percent of the undisturbed, previously unsurveyed land in the 200 West Area. This survey recorded a small number of isolated historical and prehistoric artifacts, and one extensive cultural feature that has historical significance, the White Bluffs Road (Chatters-Cadoret 1990). None of these sites or artifacts are near TWRS sites, except the White Bluffs Road.

I.5.1 PREHISTORIC RESOURCES

Current cultural resources survey data for the potential TWRS sites in the 200 East Area indicates an overall low probability for prehistoric materials in these locations. Much of the land surface in the 200 East Area has been extensively disturbed by construction and other development activity.

A previous archaeological survey of all the undeveloped portions of the 200 East Area had indicated no findings of archaeological sites or known areas of Native American interest (Chatters-Cadoret 1990). The 1994 cultural resources surveys of the TWRS site and surrounding areas found only individual isolated artifacts and sites (lithics and historic trashcan scatters) (PNL 1994a, b, c). Surveys of the proposed Phased Implementation alternative site in the easternmost portion of the 200 East Area have identified no archaeological sites or artifacts (Cadoret 1995).

As stated previously, a 50 percent survey of all undeveloped and unsurveyed portions of the 200 West Area recorded no prehistoric sites and one prehistoric artifact (Chatters-Cadoret 1990).

Cultural resources surveys of the potential Vernita Quarry borrow site recorded several prehistoric isolates and prehistoric sites. A number of prehistoric isolates and prehistoric sites were also recorded at the potential McGee Ranch borrow site. No prehistoric materials have been recorded at the potential

Pit 30 borrow site. The Vernita Quarry and McGee Ranch sites are considered likely to contain more prehistoric materials (Duranceau 1995). Based on the scarcity of prehistoric resources in and around the 200 Areas, there is little likelihood of finding prehistoric resources at Pit 30.

I.5.2 HISTORICAL RESOURCES

The first Euro-Americans to enter this region were Lewis and Clark, who traveled along the Columbia and Snake rivers during their exploration of the Louisiana Territory from 1803 to 1806. Lewis and Clark were followed by fur trappers who also traversed the area on their way to more productive lands up and down the river and across the Columbia Basin. It was not until the 1860's that merchants set up stores, a freight depot, and the White Bluffs Ferry on the Hanford Reach. Chinese miners began to work the gravel bars for gold. Cattle ranches opened in the 1880's and farmers soon followed. Several small, thriving towns including Hanford, White Bluffs, and Ringold, grew up along the riverbanks in the early 20th century. Other ferries were established at Wahluke and Richmond. The towns, settlements, and nearly all other structures were razed after the U.S. Government acquired the land for the Hanford Site in the early 1940's (PNL 1989 and Cushing 1994).

The historic White Bluffs Road extends northeast-southwest across the northwest corner of the 200 West Area. It was an important transportation route during the mining, cattle ranching, and settlement eras of the 19th century, before Washington became a state. In the early 20th century, the road apparently was the primary northeast-southwest route across what is now the Hanford Site. The route was also used in prehistoric and historic times by Native Americans as a trail that connected Rattlesnake Springs with a Columbia River crossing at White Bluffs (Chatters-Cadoret 1990).

The White Bluffs Road has been nominated for the NRHP, although the segment in the 200 West Area is not considered to be a critical element in its historic value (Cushing 1994). The nomination to the NRHP is still pending. A 100-m (330-ft) easement has been created on either side of the road to protect it from uncontrolled disturbance (Cushing 1994). The CTUIR have indicated that the White Bluffs Road is an important cultural site to Native Americans. The road has been fragmented by recent activities associated with the Hanford Site (CTUIR 1996).

Historic materials from Euro-American settlement activities of the 19th and early 20th centuries have been found at both the potential Vernita Quarry and McGee Ranch borrow sites (Duranceau 1995). The McGee Ranch area has been deemed eligible for nomination to the NRHP as the McGee Ranch and Cold Creek District, in large part because of its historic sites (Cadoret 1995). No historic materials have been recorded at the potential Pit 30 borrow site.

Additional historic materials are likely to exist at both McGee Ranch and Vernita Quarry (Duranceau 1995). There is a low likelihood of important historic sites at Pit 30, although one homestead era structure is located in the area (Cadoret 1995).

Of a more recent historical nature (World War II and the Cold War period) are the nuclear reactors and associated materials processing facilities that now dominate the Hanford Site. The construction of three

reactor facilities (100-B, 100-D, and 100-F) began in March 1943 as part of the Manhattan Project. In late 1944, the first reactor (100-B) became operational. Plutonium production began in early 1945 and continued into the post-war period. Plutonium for the world's first nuclear explosion test at the Trinity Site in New Mexico and for the bomb that destroyed Nagasaki was produced at the 100-B Reactor (PNL 1989 and Cushing 1994).

Additional reactors and processing facilities were constructed after World War II during the Cold War. All the reactor buildings constructed during these periods still stand, although many of the ancillary support structures have been removed. Because of its significance in contributing to international and national historical events, the 100-B Reactor has been listed individually on the NRHP and is a National Mechanical Engineering Monument; approximately 110 other buildings have been evaluated for National Register eligibility. Other Manhattan Project facilities have yet to be evaluated. Until a full evaluation addressing each individual structure is conducted, no statement can be made about NRHP eligibility status. As mentioned in Section I.5.0, evaluation of the historic value of structure and buildings in the 200 Areas is scheduled for completion in 2000 (DOE 1996e). The Washington State Historic Preservation Officer and DOE have determined that the Hanford Site is a Manhattan Project/Cold War era historical district (Neitzel 1996). The waste storage tanks in the 200 Areas may be considered historically substantial, and documentation of the history and use of examples of the various kinds of tanks (e.g., SSTs, DSTs) will be required (DOE 1996e).

The Advisory Council on Historic Preservation recognizes the need to balance the historic preservation of facilities with operational or health and safety issues. The DOE Richland Operations Office, the Advisory Council on Historic Preservation, and the Washington State Historic Preservation Office have signed a Programmatic Agreement that addresses cultural resources management of the built environment at the Hanford Site (DOE 1996e).

I.5.3 NATIVE AMERICAN RESOURCES

The Hanford Site is situated on lands ceded to the U.S. Government by the Confederated Tribes and Bands of the Yakama Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation. The Yakama Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation occupy reservations within 130 km (80 mi) of the Hanford Site. Until 1942, the Wanapum People resided on land that is now part of the Hanford Site. In 1942, the Wanapum People agreed to move from their residence near White Bluffs to the Priest Rapids Area. The Nez Perce Tribe also has retained rights to the Columbia River under a treaty with the U.S. Government.

The Hanford Site has been occupied by humans since the end of the last glacial period. Over 10,000 years of continuous prehistoric human activity in this largely desert environment is reflected by the extensive archaeological deposits along the river shores. Inland areas with water resources point to evidence of concentrated human activity. Recent surveys also indicate the extensive, although dispersed, use of arid lowlands for hunting. Graves are common in various settings and spirit quest monuments are still to be found on high, rocky summits of the mountains and buttes (Cushing 1994).

As mentioned previously, recent biological and cultural resource surveys of the TWRS sites and nearby areas in the 200 East Area found plant species that are of ethnobotanical significance to Native Americans (e.g., plants used for food or medicinal purposes).

Native Americans have retained traditional secular and religious ties to the Hanford Site. Certain landmarks such as Rattlesnake Mountain, Gable Mountain, Gable Butte, and various sites along the Columbia River are sacred to tribes. Native American people also consider numerous burial sites to be sacred (PNL 1989 and Cushing 1994). No specific sacred sites are known at any of the TWRS sites. However, affected Tribes indicate that other culturally important sites are found within areas that may be impacted by TWRS alternatives (i.e., downgradient in the groundwater, the Columbia River, and areas downwind of possible air releases) (CTUIR 1996).

Tribal Nation Cultural Values Perspective

The Native American view of cultural resources is much broader than the view of some non-Native Americans. The affected Tribal Nations believe that "all natural resources are cultural resources to indigenous people" (CTUIR 1996). "The soils themselves and the groundwater contained within them are critical components of the structure and functions of the ecosystem as a whole and cannot be separated in piecemeal fashion. Any such attempts at separating interdependent components of a holistic system are contrary to tribal cultural and natural resources values" (CTUIR 1994). Cultural values "not directly related to public health and safety or the ecological aspects of the environment should be protected. These other cultural values stem from what could be termed religious beliefs and are associated with the sanctity of the land forms and other natural resources at Hanford" (YIN 1996).

I.6.0 SOCIOECONOMICS

The socioeconomic analysis focuses on Benton and Franklin counties in Washington State. These counties make up the Richland-Kennewick-Pasco Metropolitan Statistical Area (MSA), also known as the Tri-Cities MSA. Other jurisdictions in Benton County include Benton City, Prosser, and West Richland. Connell is the largest city in Franklin County after Pasco. A number of neighboring counties: Yakima, Walla Walla, Adams, and Grant counties in Washington; and Umatilla and Morrow counties in Oregon are impacted by activities at the Hanford Site. However, because nearly 90 percent of Hanford Site employees live in Benton and Franklin counties, the Site's impacts on these other counties are very small (Serot 1995). Thus, no discussion of baseline conditions in the neighboring counties is provided.

In accordance with Federal environmental justice policy, a discussion is provided in Sections I.6.1.4 and I.6.1.5 concerning the distribution and size of minority and Native American and low-income populations within an 80-km (50-mi) radius of the Hanford Site (Executive Order [EO] 12898). This discussion provides the basis for the required identification of potential disproportionate and adverse environmental impacts of EIS alternatives on minority and Native American populations and low-income populations. The 80-km (50-mi) radius includes counties not otherwise covered in this socioeconomic section because overall Site socioeconomic impacts on these counties are very small.

However, this section does identify the minority and Native American population and employment within the Hanford Site's primary zone of socioeconomic influence, the Tri-Cities MSA (Benton and Franklin counties).

Before World War II, the economy in the Tri-Cities MSA was based primarily on agriculture. Since World War II, the Hanford Site has been the largest factor in the local economy. Plutonium production and processing was the primary mission of the Site until 1988 when the Site's mission became waste management and environmental restoration. Basic and applied research became an important secondary mission continuing to present.

Changes in the Hanford Site's mission and the cancellation of a Washington Public Power Supply System project at Hanford in the early 1980's (after only one of three planned nuclear power plants was completed) have had a large impact on the economy of the Tri-Cities MSA, creating boom-bust cycles that have had ramifications for employment, population, housing, and infrastructure. Table I.6.0.1 details Hanford Site employment, Washington Public Power Supply System employment, and total nonfarm employment for the Tri-Cities MSA, together with population in the MSA for 1980 to 1994. The Tri-Cities is currently in the early stages of an economic transition as employment at the Hanford Site declines from its recent peak levels.

I.6.1 DEMOGRAPHICS

This section examines population characteristics in the Tri-Cities MSA and the effects of the Hanford Site on the demographics of the area.

I.6.1.1 Population Trends

Population tended to follow changes in nonfarm employment in the Tri-Cities area during the 1980's and early 1990's (Table I.6.0.1). Between 1981 and 1984, nonfarm employment fell by approximately 11,000 jobs, while population fell by about 6,000. Employment began to increase after 1984 but population continued to fall, hitting a low of 138,300 in 1989. Employment increased until 1987 and then fell in 1988 after the decision to close the last plutonium production reactor (N Reactor). Between 1988 and 1989, however, employment in the Tri-Cities jumped by almost 2,000 (despite a continued decline in Hanford Site employment). When employment began to increase again at the Hanford Site in 1990, population increased by almost 12,000, effectively returning to the 1981 level.

The population trends reflected actual employment in the Tri-Cities MSA and expectations of employment. Once the economy began to grow in the late 1980's, people moved into the area, some because they had jobs but many others because they were searching for work. The population of the Tri-Cities area continued to grow as the Site and total nonfarm employment increased through 1994. Data for 1995 showed total Tri-Cities population continuing to grow, while Hanford Site employment declined and total area nonfarm employment remained virtually unchanged from 1994 (Table I.6.0.1) (Neitzel 1996).

Table I.6.0.1 Population and Employment in the Richland-Kennewick-Pasco MSA, 1980 to 1994

Year	Hanford Site Employment	Washington Public Power Supply System Employment	Total Nonfarm Employment	Population
1980	12,100	7,935	58,710	144,469
1981	11,880	11,728	63,940	150,100
1982	11,357	8,841	58,860	147,900
1983	11,740	5,498	55,360	144,700
1984	12,891	2,015	52,870	144,000
1985	13,570	1,800	54,020	140,900
1986	14,015	1,745	55,230	139,300
1987	14,298	1,677	56,970	139,600
1988	13,433	1,633	55,400	139,600
1989	12,871	1,680	57,300	138,300
1990	14,152	1,762	62,200	150,030
1991	15,101	1,842	64,100	153,400
1992	16,209	1,904	66,400	157,700
1993	17,075	1,950	70,000	163,900
1994	18,388	1,750	73,800	169,900
1995	15,767	1,320	72,200	175,000

Notes:
Data for 1990 through 1992 reflect revised estimates made in April 1994. Hanford Site employment includes DOE and major contractors. Washington Public Power Supply System employment includes contractors. 1993 and 1994 Washington Public Power Supply System employment levels are estimates.
MSA = Metropolitan Statistical Area
Source: WSDES 1994, WSDFM 1987-95, Meeker 1994, Pitcher 1994, Cushing 1995, and Neitzel 1996.

I.6.1.2 Population by Race and Minority Status

Table I.6.1.1 details the 1990 population for Benton and Franklin counties and for comparison provides Washington State population by race and minority status. The data show that minorities are a smaller percentage of Benton County population than in Franklin County or Washington State. The largest minority group in the Tri-Cities MSA is the Hispanic origin group, which makes up 30.2 percent of the population of Franklin County and 7.7 percent of Benton County. African Americans make up 1 percent of population in Benton County and 3.5 percent of Franklin County's population.

The American Indian, Eskimo, and Aleut category (Native Americans) accounts for less than 1 percent of the population in each county.

I.6.1.3 Urban, Rural, and Farm Populations

Benton County has a higher percentage of its population classified as urban (87.2 percent) than Washington State (76.4 percent) as a whole, while Franklin County has a lower percentage of urban

Table I.6.1.1 Population by Race and Minority Status, 1990

	Benton County Population	Percent	Franklin County Population	Percent	Washington State Population	Percent
Total Population	112,560	100.0	37,473	100.0	4,866,692	100.0
White	102,832	91.4	26,917	71.8	4,308,937	88.5
African American	1,085	1.0	1,310	3.5	149,801	3.1
American Indian, Eskimo, Aleut	861	0.8	263	0.7	81,483	1.7
Asian and Pacific Islanders	2,246	2.0	869	2.3	210,958	4.3
Other	5,536	4.9	8,114	21.7	115,513	2.4

Notes:
Other is primarily a count of persons who marked Other Race on the Census form.
Source: WSDES 1993a

residence (72.7 percent) than Washington State. At the same time, Benton County's farm population is more than twice as large as a percentage of total population than for Washington State as a whole (12.6 percent to 5.5 percent). Franklin County's farm population is almost five times as large on a percentage basis (24.9 percent) as Washington State's farm population. Franklin County's nonfarm rural population makes up 30 percent of the county's total population, which is virtually the same as the State's (29.3 percent), while more than twice the percentage in Benton County (13.0 percent). These data suggest the relative importance of farming in Franklin County and to a lesser extent in Benton County, compared to Washington State as a whole.

I.6.1.4 Minority and Native American Populations

This section and the following section on low-income populations (I.6.1.5) provide data on the distribution of minority, Native American, and low-income populations within an 80 km (50 mi) radius of the Hanford Site, in accordance with the Federal environmental justice policy (EO 12898).

The data provided are based on the following definitions:

- Minority and Native American population: Individuals identified in U.S. Bureau of the Census data for 1990 as Negro, Black or African American, Hispanic, Asian, and Pacific Islander, Native American, Eskimo, Aleut, and other non-White persons (DOC 1991). The minority population consists of the number of individuals residing in the 80-km (50-mi) radius of the Hanford Site who are members of a minority group.
- Low-Income population: Individuals identified in the U.S. Bureau of the Census data for 1990 as having incomes at or below 100 percent of the poverty level (DOC 1991). The low-income population consist of the number of individuals residing in the 80-km (50-mi) radius of the Hanford Site who have incomes below the poverty level.
- Minority and CTUIR, Yakama Indian Nation, and Nez Perce Tribes and low-income communities: For the purposes of this EIS, minority and Native American and low-

income populations were analyzed at the census tract level. All tracts within a 80-km (50-mi) radius of the Hanford Site were included in the analysis. Tracts with a substantial minority or low income population were identified as a community for purposes of environmental justice analysis. The 80-km (50-mi) area of interest was selected based on guidance from DOE regarding the analysis of environmental justice in NEPA documents and is the same area used for the analysis of environmental and human health impacts in other sections of the EIS.

The first step in identifying minority and Native American and low-income communities was to identify the total population of each group within the 80-km (50-mi) radius area of interest. Native American populations of primary concern include members of the three affected Tribes: the Yakama Indian Nation, the CTUIR, and the Nez Perce Tribe. The second step was to identify the combination of census tracts for each type of community that had a total minority and Native American or low-income population that would total one-half of the total population for the entire area of interest.

For minority populations, census tracts with populations that when combined, totaled one-half of the minority and Native American population for the area of interest, had an average percentage of minority and Native American individuals of 33 percent of the tract's total population. These census tracts were then considered minority and CTUIR, Yakama Indian Nation, and Nez Perce Tribes for the purpose of environmental justice analysis in the EIS (Figure I.6.1.1). For low-income populations, census tracts with populations that when combined totaled one-half of the low-income population for the area of interest had an average percentage of low-income individuals of 22 percent of the census tract's total population. These census tracts were then considered low-income communities for the purpose of the environment justice analysis in the EIS (Figure I.6.1.2).

The 80-km (50-mi) radius surrounding the Hanford Site's Central Plateau had a total minority and Native American population of 86,415 individuals as of the 1990 Census (Table I.6.1.2). The area's minority and Native American population of 19.3 percent greatly exceeds the Washington State average of 13.1 percent. The Hanford Site region's principal minority groups consist of Hispanics. In 1990, Hispanics comprised approximately 14.3 percent (64,300 individuals) of the area's population. The Hispanic population is relatively dispersed throughout the area, although Adams, Franklin, and Yakima counties in Washington State have relatively higher populations of Hispanic residents than do the other counties in the region. The Native American population of the surrounding area was approximately 2.4 percent (10,800 individuals). The Native American population is disproportionately located on the Yakama Indian Reservation in south-central Washington, with smaller concentrations in Benton and Grant counties in Washington. African American (5,200 or 1.2 percent) and Asian (6,100 or 1.4 percent) populations in 1990 within the surrounding area were very small and located predominantly in Yakima, Benton, and Franklin counties in Washington State.

As of the 1990 census, 17 of the 97 census tracts that are contained completely or partially within the 80-km (50-mi) radius of the Hanford Site had minority or Native American populations that exceeded 33 percent of their total tract populations (Table I.6.1.3).

Figure I.6.1.1 Census Tracts within an 80-km (50-mi) Radius of the Hanford Site with Minority Populations Greater than 33 Percent of the Tract Populations

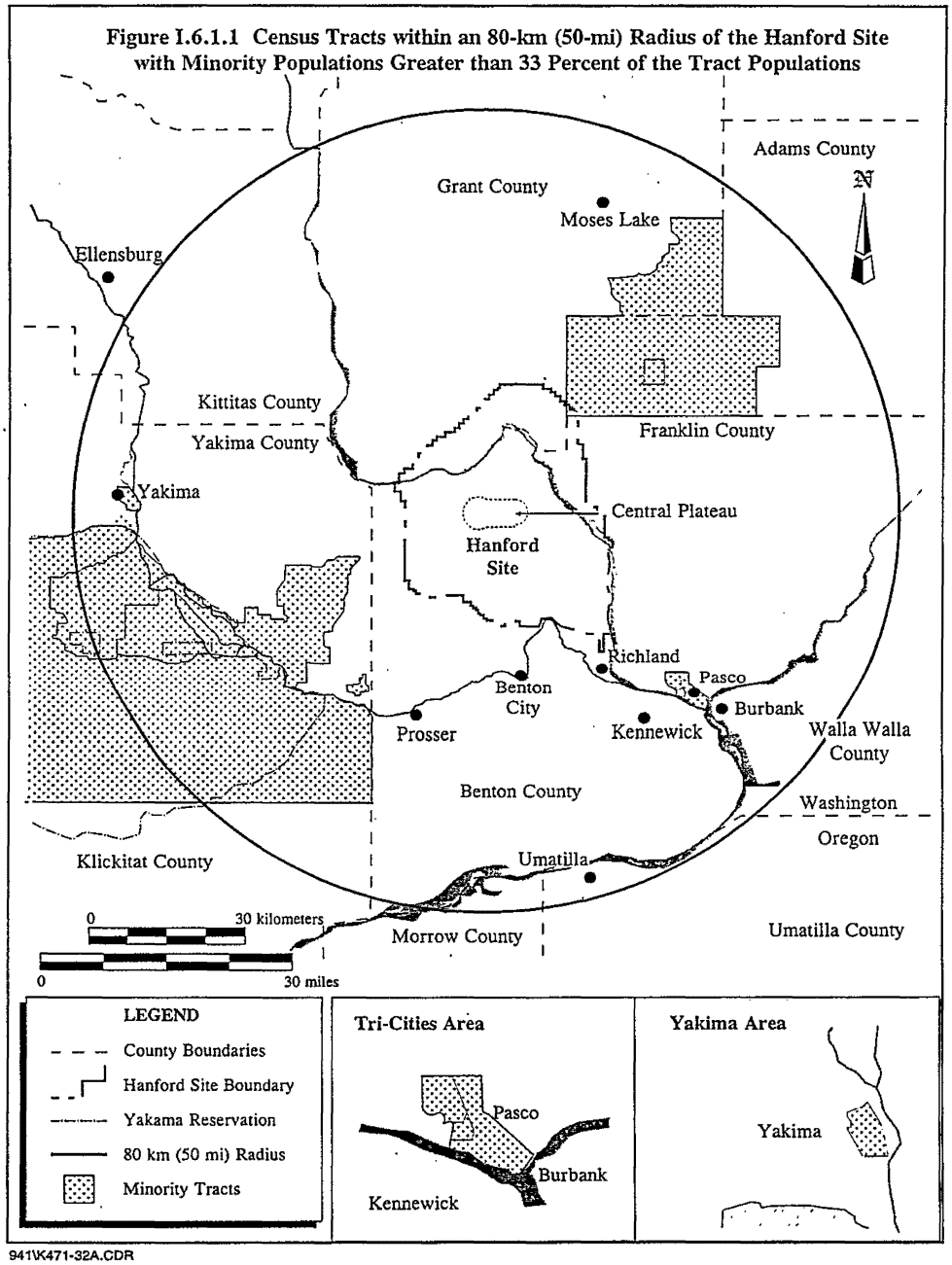


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Figure I.6.1.2 Census Tracts within an 80-km (50-mi) Radius of the Hanford Site with Low-Income Populations Greater than 22 Percent of the Tract Populations

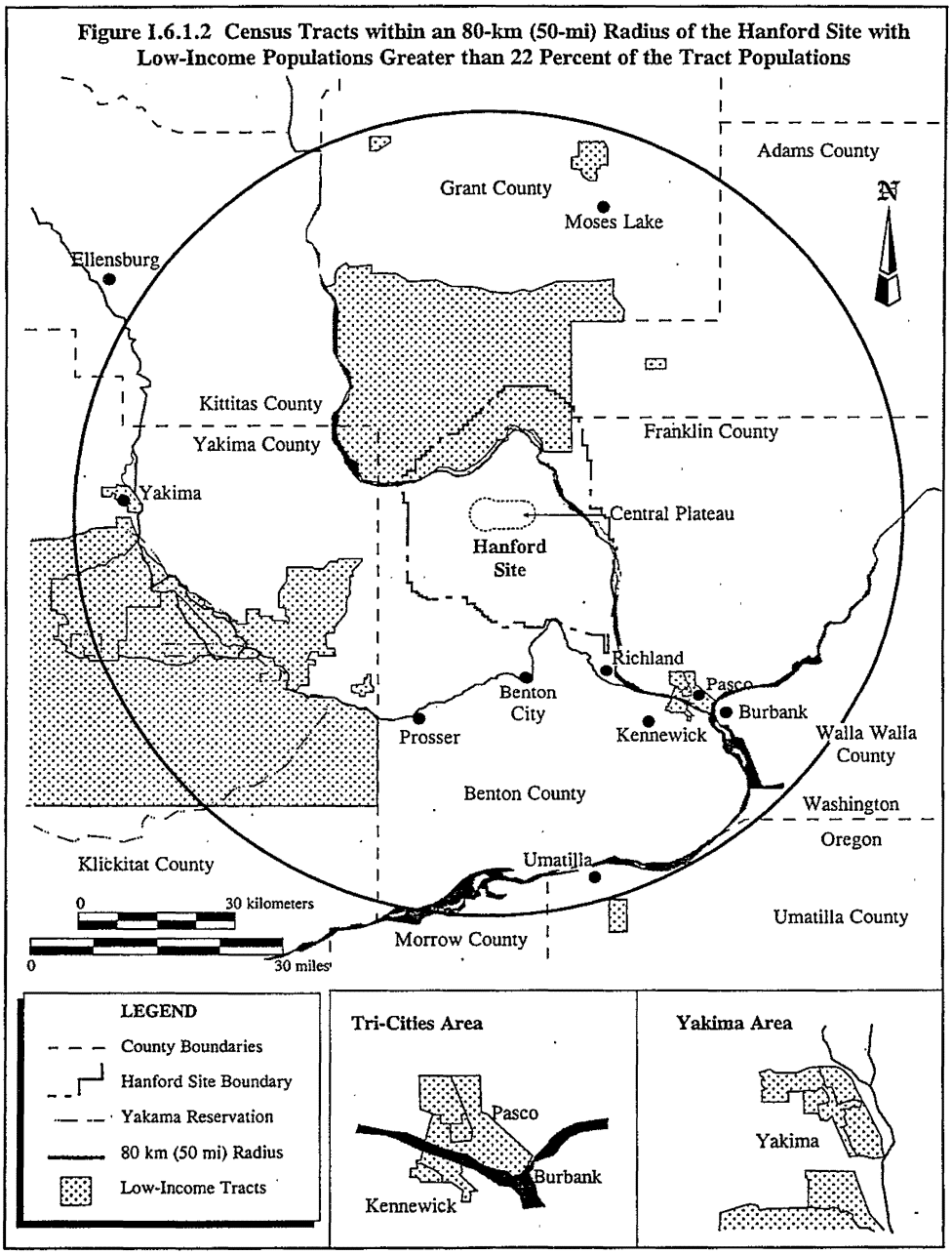


Table I.6.1.2 Minority Populations Within an 80-km (50-mi) Radius of the Hanford Site by County (1990 Census)

County	Total Population	White	African American	Native American, Eskimo, Aleut	Asian and Pacific Islander	Other (Hispanic)	Percent Minority
Adams, WA	11,076	6,630	24	42	84	4,296	40.14%
Benton, WA	112,560	102,832	1,085	861	2,246	5,536	8.64%
Franklin, WA	37,473	26,917	1,310	263	869	8,114	28.17%
Grant, WA	45,549	38,261	544	351	573	5,820	16.00%
Kittitas, WA	7,965	7,695	5	58	49	158	3.39%
Klickitat, WA	6,802	6,243	15	295	51	198	8.22%
Morrow, OR	4,444	3,703	5	58	17	661	16.67%
Umatilla, OR	25,920	22,894	282	380	303	2,061	11.67%
Walla Walla, WA	7,748	7,256	23	41	30	398	6.35%
Yakima, WA	188,823	139,514	1,938	8,405	1,922	37,044	26.11%
Area Total	448,360	361,945	5,231	10,754	6,144	64,286	---
Percent of 80-km (50-mi) Area	100%	80.73%	1.17%	2.39%	1.37%	14.34%	19.27%

Source: DOC 1991

These 17 census tracts contained less than one in five of the area's total residents, yet approximately 52 percent of the region's total minority or Native American population reside in these tracts. Moreover, in 1990 these 17 census tracts were home to over 6 in 10 of the area's Native American residents and at least 57 percent of the region's Hispanic population. Only 4 of the 10 counties in the area (Yakima, Franklin, Grant, and Adams) have census tracts with high levels of minority or Native American residents compared to the region as a whole. In 1990, Yakima County had 10 of the 17 tracts with a 33 percent or greater minority or Native American population. The highest percentage population of minority or Native American residents was found in census tract 0025, located in Yakima County (71.4 percent).

Geographically, the tracts with disproportionately high minority populations or Native American are located northeast of the Hanford Site in Adams and Grant counties, southeast of the Site in Franklin County, southwest and west of the Site along the Yakima River Valley in Yakima County, and on the Yakama Indian Reservation (Figure I.6.1.1). Of the remaining census tracts, 49 tracts had 1990 minority and Native American populations of less than 10 percent, 23 tracts had minority or Native American populations under 20 percent, and 9 tracts had minority and Native American populations of between 21 and 33 percent.

Table I.6.1.3 Census Tracts Within an 80-km (50-mi) Radius of the Hanford Site With Minority Populations Greater Than 33 Percent of the Tract Population

County and Census Tract	Total Population	White	African American	Native American, Eskimo, Aleut	Asian/ Pacific Islander	Other (Hispanic)	Total Minority	Percent Minority
Adams 9503	4,603	2,527	7	7	6	2,086	2,106	45.46%
Adams 9504	1,932	1,000	5	15	9	903	932	48.24%
Adams 9505	2,750	1,463	11	13	57	1,206	1,287	46.80%
Franklin 0201	3,917	1,404	455	30	20	2,008	2,513	64.16%
Franklin 0202	4,679	2,678	148	46	72	1,735	2,001	42.77%
Franklin 0203	4,172	2,520	188	37	215	1,212	1,652	39.60%
Grant 9813	2,678	1,547	13	12	38	1,068	1,131	42.23%
Yakima 0015	8,032	3,974	656	263	54	3,085	4,058	50.52%
Yakima 0019	7,134	3,943	38	29	58	3,066	3,191	44.73%
Yakima 0020.1	6,679	2,581	17	58	39	3,984	4,098	61.36%
Yakima 0020.2	5,825	3,621	17	43	49	2,095	2,204	37.84%
Yakima 0021	7,085	4,350	9	121	25	2,580	2,735	38.60%
Yakima 0023	7,615	2,745	50	659	26	4,135	4,870	63.95%
Yakima 0024	4,027	1,625	10	1,327	82	983	2,402	59.65%
Yakima 0025	5,360	1,531	20	1,061	169	2,579	3,829	71.44%
Yakima 0026	5,826	2,866	8	1,431	243	1,278	2,960	50.81%
Yakima 0027	6,585	2,372	20	1,647	39	2,507	4,213	63.98%
Total	88,924	42,747	1,672	6,799	1,201	36,510	46,182	51.93%
Percent of 80-km (50-mi) Area	19.83%	11.81%	31.96%	63.22%	19.55%	56.79%	53.44%	

Source: DOC 1991

Five census tracts (Table I.6.1.4), all located within the Yakama Indian Reservation in Yakima County, Washington have large Native American populations. In 1990, the population of these tracts contained nearly 57 percent of the 80-km (50-mi) radius area's Native American population. As of 1990, these tracts were the only census tracts in the area where the Native American population exceeded 8 percent of the tract population.

Census data are an imprecise tool for determining the exact representation of the Hispanic population. Individuals of Hispanic origin derive from diverse cultures and ethnicities. Racial identification is complicated by the lack of a Hispanic category. Hence, Hispanics select from among the available

Table I.6.1.4 Census Tracts Within an 80-km (50-mi) Radius of the Hanford with Native American Populations Greater Than 500 Individuals (1990 Census)

County and Census Tract	Total Population	Total Minority Population	Percent Minority	Total Native American, Eskimo, Aleut Population	Percent American Indian, Eskimo, Aleut
Yakima 0023	7,615	4,870	63.95%	659	8.65%
Yakima 0024	4,027	2,402	59.65%	1,327	32.95%
Yakima 0025	5,360	3,829	71.44%	1,061	19.80%
Yakima 0026	5,826	2,960	50.81%	1,431	24.56%
Yakima 0027	6,585	4,213	63.98%	1,647	25.01%
Total	29,413	18,274	63.13%	6,125	20.82%
Percent of 80-Km (50-mi) Area	6.56%	21.15%	N/A	56.96%	N/A

Notes:
N/A = Not applicable
Source: DOC 1991

choices of White, African American, American Indian, or Other. Many select Other, although up to 4 in 10 select a different designation, with the bulk selecting White. For the purposes of this report, the census data for the Other category is used to provide an indication of those census tracts that are disproportionately populated by residents of Hispanic origin. Although the Other category does tend to under report the Hispanic population, it provides a tool of sufficient accuracy to approximate Hispanic population concentrations.

All of the 17 census tracts with a minority and Native American population greater than 33 percent had substantial numbers of individuals listed in the Other category (Table I.6.1.5.). In all but three of the tracts, the Other category alone accounted for more than 33 percent of the population of the census tracts. Two of these three tracts are located on the Yakama Indian Reservation and have substantial Native American populations. The third tract is located in Franklin County.

I.6.1.5 Low-Income Populations

Figure I.6.1.2 shows the census tracts within an 80-km (50-mi) radius of the Hanford Site with low-income populations greater than 22 percent of the tract population. The 80-km (50-mi) radius surrounding the Hanford Site had a total low-income population in 1990 of 77,700 (Table I.6.1.6).

The area's low-income population of 17.3 percent greatly exceeded the Washington State average of 10.9 percent. In counties examined within Washington, only Walla Walla, Kittitas, and Benton counties had low-income populations below or slightly above the State-wide average.

All of the remaining counties had low-income populations exceeding the 17.3 percent region average. Franklin County, Washington had a low-income population more than double the State-wide average.

Table I.6.1.5 Census Tracts Within an 80-km (50-mi) Radius of the Hanford With Substantial Other Populations Within a Tract With Greater Than 33 Percent Minority and Native American Population (1990 Census)

County and Census Tract	Total Population	Total Minority and Native American	Percent Minority and Native American	Other (Hispanic)	Percent Other
Adams 9503	4,603	2,106	45.56%	2,086	0.453
Adams 9504	1,932	932	48.24%	903	0.467
Adams 9505	2,750	1,287	46.80%	1,206	0.439
Franklin 0201	3,917	2,513	64.16%	2,008	0.513
Franklin 0202	4,679	2,001	42.77%	1,735	0.371
Franklin 0203	4,172	1,652	39.60%	1,212	0.291
Grant 9813	2,678	1,131	42.23%	1,068	0.399
Yakima 0015	8,032	4,058	50.52%	3,085	0.384
Yakima 0019	7,134	3,191	44.73%	3,066	0.43
Yakima 0020.1	6,679	4,098	61.36%	3,984	0.597
Yakima 0020.2	5,825	2,204	37.84%	2,095	0.36
Yakima 0021	7,085	2,735	38.60%	2,580	0.364
Yakima 0023	7,615	4,870	63.95%	4,135	0.543
Yakima 0024	4,027	2,402	59.65%	983	0.244
Yakima 0025	5,360	3,829	71.44%	2,579	0.481
Yakima 0026	5,826	2,960	50.81%	1,278	0.219
Yakima 0027	6,585	4,213	0.64	2,507	0.381
Total	88,899	46,182	51.93%	36,510	0.411
Percent of 80-Km (50-mi) Area	0.198	53.43%	N/A	56.79%	N/A

Notes:
N/A = Not applicable
Source: DOC 1991

In all, 25 of the 97 census tracts that are contained all or in part within the 80-km (50-mi) radius of the Hanford Site had low-income populations in 1990 greater than 22 percent of their total populations (Table I.6.1.7). These 25 census tracts contained less than 3 in 10 of the area's total residents (27.9 percent), yet, more than half of the region's total low-income population lived in these tracts (50.8 percent). All but 4 of the counties, Walla Walla, Kittitas, and Klickitat in Washington, and Morrow County, Oregon, had at least 1 census tract containing at least 22 percent of the low-income population. Adams and Benton Counties in Washington, and Umatilla County, Oregon, had 2 or fewer census tracts with low-income populations greater than 22 percent.

Table I.6.1.6 Low-Income Population Within an 80-km (50-mi) Radius of the Hanford Site by County (1990 Census)

County	Total Population	Total Poverty Population	Percent Poverty Population
Adams, WA	11,076	1,967	17.76%
Benton, WA	112,560	12,402	11.02%
Franklin, WA	37,473	8,491	22.66%
Grant, WA	45,549	9,403	20.64%
Kittitas, WA	7,965	823	10.33%
Klickitat, WA	6,802	1,197	17.60%
Morrow, OR	4,444	848	19.08%
Umatilla, OR	25,920	4,253	16.41%
Walla Walla, WA	7,748	787	10.16%
Yakima, WA	188,823	37,486	19.85%
Area Total	448,360	77,657	17.32%

Source: DOC 1991

Yakima County had 4 of the 5 tracts with 22 percent or greater low-income population in 1990. The highest percentage population of low-income residents was found in census tract 0001, located in Yakima County (45.4 percent). The 25 tracts had a total average low-income population of more than 31.5 percent. Geographically, the tracts with large, low-income populations (22 percent or greater) are located north and northeast of the Hanford Site in Grant County, southeast of the Site in Franklin County, and southwest and west of the Site along the Yakima River Valley and on the Yakama Indian Reservation in Yakima County (Figure I.6.1.2).

Of the remaining census tracts, 30 tracts had 1990 low-income populations that are less than the Washington State average (10.9 percent), 27 tracts had low-income populations between 11 percent and the average low-income population level of 17.3 percent of the 80-km (50-mi) area, and 15 tracts had low-income populations between 17.3 and 22 percent. Fourteen of the 30 census tracts with low-income populations under the Washington State average are located in Benton County (12 tracts) or in the two Franklin County tracts located closest to Hanford Site transportation access.

I.6.1.6 Household Income

The largest fraction of Franklin County households is in the $15,000 to $24,999 income range (Table I.6.1.8). Benton County has its highest concentration of households in the $35,000 to $49,999 range, as does Washington State as a whole. Benton County incomes are slightly skewed to the higher household income ranges as compared to incomes in Washington State as a whole, while Franklin County incomes are skewed to the lower income ranges. Median household income in Benton County was $41,800 in 1993, while per capita income was $21,030. Median household income in

Table I.6.1.7 Census Tracts Within an 80-km (50-mi) Radius of the Hanford Site With Low-Income Populations Greater Than 22 Percent of the Population (1990 Census)

County and Census Tract	Total Population	Poverty Population	Percent Poverty Population
Adams 9504	1,932	630	32.61
Benton 112	5,479	1,589	29.00
Benton 113	4,118	912	22.15
Franklin 0201	3,917	1,685	43.02
Franklin 0202	4,679	1,748	37.36
Franklin 0203	4,172	1,150	27.56
Franklin 0204	6,351	1,911	30.09
Grant 9806	3,870	1,161	30.00
Grant 9808	3,806	1,384	36.36
Grant 9814	6,101	1,579	25.88
Umatilla 9512	5,757	1,301	22.60
Yakima 0001	2,430	1,102	45.35
Yakima 0002	4,217	1,677	39.77
Yakima 0003	2,903	650	22.39
Yakima 0006	4,598	1,743	37.91
Yakima 0013	2,269	527	23.23
Yakima 0015	8,032	3,524	43.87
Yakima 0019	7,134	1,983	27.80
Yakima 0020.1	6,679	2,079	31.13
Yakima 0021	7,085	1,692	23.88
Yakima 0023	7,615	2,139	28.09
Yakima 0024	4,027	1,594	39.58
Yakima 0025	5,360	1,692	31.57
Yakima 0026	5,826	1,562	26.81
Yakima 0027	6,585	2,497	37.92
Area Total	124,942	39,411	31.54
Percent of 80-km (50-mi) Area	27.87%	50.75%	17.32

Source: DOC 1991

Table I.6.1.8 Household Income, 1990

Income Category	Number of Households		
	Benton County	Franklin County	Washington State
Total Households	42,384	12,248	1,875,508
Less than $5,000	1,695	1,017	85,161
$5,000 to $9,999	3,662	1,420	157,317
$10,000 to $14,999	3,586	1,301	158,603
$15,000 to $24,999	7,177	2,485	335,204
$25,000 to $34,999	6,568	2,066	315,994
$35,000 to $49,999	8,833	1,824	367,466
$50,000 to $74,999	7,527	1,474	296,969
$75,000 to $99,999	2,290	372	90,290
$100,000 to $149,999	891	180	44,692
$150,000 or more	155	109	23,812
Income Category	Percent of Households		
	Benton County	Franklin County	Washington State
Less than $5,000	4.00	8.30	4.54
$5,000 to $9,999	8.64	11.59	8.39
$10,000 to $14,999	8.46	10.62	8.46
$15,000 to $24,999	16.93	20.29	17.87
$25,000 to $34,999	15.50	16.87	16.85
$35,000 to $49,999	20.84	14.89	19.59
$50,000 to $74,999	17.76	12.03	15.83
$75,000 to $99,999	5.40	3.04	4.81
$100,000 to $149,999	2.10	1.47	2.38
$150,000 or more	0.37	0.89	1.27

Source: DOC 1991

Franklin County was $30,525 in 1993, while per capita income was $17,230. In 1993, Washington State median household income was $37,316, while per capita income was $21,770.

Data on persons and families below the poverty level show that for most categories Benton County has the same or slightly higher poverty rates as Washington State (11.1 percent compared to 10.9 percent). In contrast, Franklin County's 23 percent poverty rate is substantially higher than the poverty rates for Washington State and Benton County (Table I.6.1.9). The data on income reflect overall the greater urbanization of Benton County and the effects of the Hanford Site as a large source of specialized technical and professional employment in Benton County.

Table I.6.1.9 Persons and Families Below Poverty Level, 1990

Category	Percent Below Poverty Level		
	Benton County	Franklin County	Washington State
All Persons	**11.1**	**23.0**	**10.9**
Persons 18 Years and Over	9.5	18.8	9.7
Persons 65 Years and Over	9.1	11.4	9.1
Related Children Under 18 Years	14.4	30.4	14.0
Related Children Under 5 Years	17.8	37.2	17.0
Related Children 5 to 17 Years	13.1	27.8	12.8
Unrelated Individuals	21.9	35.7	21.9
All Families	**8.9**	**18.4**	**7.8**
With Related Children Under 18 Years	13.5	26.0	12.3
With Related Children Under 5 Years	17.7	34.0	15.8
Female Householder Families	**38.1**	**51.4**	**30.1**
With Related Children Under 18 Years	46.1	66.1	39.5
With Related Children Under 5 Years	59.0	79.2	57.5

Source: DOC 1991

I.6.1.7 Educational Attainment

Benton County residents have approximately the same level of education as residents State-wide while Franklin County residents tend to have a lower level of educational attainment (Table I.6.1.10).

I.6.2 PUBLIC FACILITIES AND SERVICES

The following sections describe public facilities and service systems in the Tri-Cities that potentially could be impacted by implementation of the EIS alternatives. Discussions are provided for public safety, hospitals, electricity and natural gas, sewer, and solid waste. Water supply systems are discussed in Section I.2.3.

I.6.2.1 Public Safety

Public safety services, including police and fire, are provided by a number of jurisdictions in the region. Police protection is provided by the county sheriff departments of Benton and Franklin counties, local municipal police departments (Pasco, Richland, Kennewick, and West Richland), and the Washington State Patrol Division in Kennewick. In terms of total staffing, the local municipal police departments (179 commissioned officers and 76 reserve officers) are considerably larger than the two county sheriff departments, which had 62 commissioned officers and 45 reserve officers in 1995 (Neitzel 1996).

Fire protection in the Tri-Cities area is provided by fire departments in the cities of Kennewick, Pasco, and Richland, a volunteer fire department in West Richland, and three rural fire departments in Benton County.

Table I.6.1.10 Educational Attainment, 1990

Category	Benton County	Franklin County	Washington State
Persons 25 Years and Older	69,511	20,795	3,126,390
Educational Attainment	Persons 25 Years or Older		
Less than 9th Grade	4,263	3,760	171,311
9th to 12th Grade, No Diploma	6,942	2,871	334,472
High School Graduate	19,221	5,904	873,150
Some College, No Degree	16,877	3,845	782,010
Associate's Degree	6,015	1,628	248,478
Bachelor's Degree	10,770	2,073	496,866
Graduate or Professional Degree 9	5,423	714	220,103
Educational Attainment	Percent of Persons 25 Years or Older		
Less than 9th Grade	6.1	18.1	5.5
9th to 12th Grade, No Diploma	10.0	13.8	10.7
High School Graduate	27.7	28.4	27.9
Some College, No Degree	24.3	18.5	25.0
Associate's Degree	8.7	7.8	7.9
Bachelor's Degree	15.5	10.0	15.9
Graduate or Professional Degree	7.8	3.4	7.0
Percent High School Graduate or Higher	83.9	68.1	83.8
Percent Bachelor's or Higher Degree	23.3	13.4	22.9

Source: DOC 1991

Public safety services are also provided at the Hanford Site. In the past the Hanford Patrol has provided security and law enforcement services for the Site. Currently, the Benton County Sheriff's Department is providing law enforcement support. The Sheriff's Department maintains an office in the 300 Area. The Hanford Fire Department has approximately 155 firefighters who are trained to dispose of hazardous waste and fight chemical fires. The Hanford Fire Department has fire stations in the 100, 200, 300, 400, and 1100 Areas of the Hanford Site.

I.6.2.2 Hospitals

There are three large hospitals and four small emergency centers in the Tri-Cities area. Kadlec Medical Center in Richland has 133 beds, approximately 6,000 annual admissions, and operates at 50 percent capacity. Kennewick General Hospital has 70 beds, 4,800 annual admissions, and operates at approximately 44 percent capacity. Our Lady of Lourdes Hospital in Pasco had over 4,400 admissions in 1994 (Neitzel 1996).

The Hanford Environmental Health Foundation primarily provides risk-management services for the Site; they also provide health screening for workers and respond to emergencies at the Site.

The Hanford Environmental Health Foundation currently operates five onsite health service centers including facilities in the 100, 200 East, 200 West, and 300 Areas.

I.6.2.3 Schools

Educational services at the primary and secondary level are provided by four school districts. Kennewick is the largest district, serving approximately 13,000 students in 1994, with nearly 8,700 students in the Richland district, 7,800 students in the Pasco district, and 1,500 students in the Kiona-Benton district (Cushing 1995).

School enrollment has increased over the last few years, with all four school districts operating at or near their capacity during the 1994 school year (Cushing 1995). Despite declining Hanford Site employment, school enrollment in the 1995 school year increased by the following approximate amounts: Richland 0.9 percent; Pasco 1.1 percent; Kennewick 2.6 percent; and Kiona-Benton 5.1 percent (Brown 1995, Foley 1995, Haun 1995, Marsh 1995, Meilour 1995, O'Neil 1995). Portable classrooms are used in the Richland (20 portables) and Pasco (60 portables) school districts. In 1995, the Richland, Kennewick, and Kiona-Benton districts were operating at capacity, while the Pasco district was at capacity for the primary grades but had room for more students at the secondary level (Neitzel 1996).

Post-secondary education in the area is provided by the Columbia Basin Community College and the Tri-Cities branch campus of Washington State University. The fall 1995 enrollments for these schools were approximately 6,700 and 1,200, respectively (Neitzel 1996).

I.6.2.4 Electricity and Natural Gas

Electricity in the Tri-Cities is provided by the Benton County Public Utility District, Benton Rural Electrical Association, Franklin County Utility District, and the City of Richland Energy Services Department. The Bonneville Power Administration, a Federal power marketing agency, supplies all the power that these utilities provide in the local area.

Electrical power for the Hanford Site is purchased wholesale from the Bonneville Power Administration. The Hanford Site electrical distribution system is used to distribute power to the majority of the Site. The city of Richland distributes power to the 700, 1100, and 3000 Areas. This is approximately 2 percent of the total Hanford Site usage. Energy requirements for the Hanford Site exceeded 550 megawatts (MW) during fiscal year 1988 (Cushing 1994). The Site's electrical requirement in 1993 was substantially lower at approximately 57 MW (Cushing 1994).

Natural gas, provided by the Cascade Natural Gas Corporation, serves a small portion of the region's residents. In December 1993, Cascade Natural Gas Corporation had approximately 5,800 residential customers (Cushing 1994).

Hydroelectric, coal, nuclear power, oil, and natural gas fuel the Pacific Northwest's electrical generation system. Hydroelectricity is the primary power source in the region, accounting for

approximately 74 percent of the region's installed generating capacity of 40,270 MW, and supplying approximately 56 percent of the electricity used by the region. Coal provides 16 percent of the region's electrical generating capacity (Cushing 1994). The one operating commercial nuclear power plant in the Pacific Northwest (located on the Hanford Site) provides approximately 6 percent of the region's generating capacity.

Throughout the 1980's, the Pacific Northwest had more electric power than it required. However, this surplus has been exhausted and the regional system generates only enough power to meet regional electrical needs. It is estimated that the Pacific Northwest will need an additional 2,000 MW over 1991 consumption by the turn of the century (Neitzel 1996).

I.6.2.5 Sewer

Sanitary waste in the 200 Areas is currently disposed of through septic tanks and drain fields. There are concerns about the ability of the current system to handle projected sanitary waste disposal needs resulting from new facilities, increased personnel, and changing environmental regulations. The planned construction of a central collection and treatment facility in the 200 Areas was canceled due to funding constraints. Future upgrades to 200 Areas septic systems may be needed to meet capacity and regulatory requirements (Harvey 1995).

The major incorporated areas of Benton and Franklin counties are served by municipal wastewater treatment systems and the unincorporated areas are served by onsite septic systems. The city of Richland's wastewater treatment system is designed to treat a total capacity of 1.1E+08 L (30E+07 gal/day). The Richland system processed an average of 7.6E+07 L/day (2.0E+07 gal/day) in 1994 (Nietzel 1996). The wastewater treatment system for the city of Kennewick is also operating well below capacity. The Kennewick system has a treatment capacity of 8.3E+07 L/day (2.2E+07 gal/day). In 1994 the Kennewick system processed an average of 3.8E+07 L/day (1.0E+07 gal/day). The Pasco wastewater treatment system has the capacity to treat 9.5E+07 L/day (2.5E+07 gal/day), and currently processes an average of 2.9E+07 L/day (7.8E+06 gal/day) (Neitzel 1996).

I.6.2.6 Solid Waste

The existing Hanford Site nonradioactive solid waste landfill is expected to reach its capacity in 1996. In October 1995 it was announced that DOE and the city of Richland reached an agreement to send the Site's nonregulated and nonradioactive solid waste to the Richland Sanitary Landfill (DOE 1995k).

The city-operated Richland Sanitary Landfill serves Benton County. The landfill, which receives about 200 tons of solid waste per day, has a current life expectancy of 50 years (Penour 1994). This could be extended to approximately 100 years with design modifications.

The city of Kennewick has a contract with Waste Management of Kennewick for solid waste disposal. Waste Management disposes of the solid waste at the Columbia Ridge Landfill in Arlington, Oregon, a facility with a life expectancy of approximately 50 years (Denley 1994).

The cities of Pasco and West Richland have contracts with Basin Disposal, Inc. for solid waste disposal. Basin Disposal, Inc. disposes of the solid waste at the Roosevelt Regional Landfill in Roosevelt, Washington, a facility with a life expectancy of approximately 40 years (Thiele 1995).

I.6.3 ECONOMY

The Hanford Site is the largest employer in the Tri-Cities area. This is a key factor in the local economy. In 1995, total nonfarm employment in the area averaged about 72,200. During the same period, Hanford Site employment was about 15,800 or nearly 22 percent of total nonfarm employment. In addition, other workers who are not included in the data as Hanford Site employees provide goods and services to the Hanford Site or its contractors. Agriculture, food processing, retail trade, and other industries provide substantial economic diversity to the Tri-Cities MSA.

Farm employment averaged about 3,500 jobs in Franklin County in 1992 and 4,200 jobs in Benton County. However, Franklin County farm employment ranged from a high of about 9,000 in June 1992 to a low of 1,100 in January. The range in Benton County was 10,700 in June to 1,900 in December. This range reflects the seasonal nature of farm labor. In addition, many farm workers are migratory workers who come to the area during harvest seasons then move on to other regions. Also, year-to-year changes in farm employment are subject to random variations in weather and agricultural market conditions. Changes in Hanford Site employment do not impact the area's farm employment, and for this reason the following discussion focuses on nonfarm employment only.

I.6.3.1 Industries and Employment

Besides DOE and the Hanford Site contractors, major employers in the Tri-Cities MSA include Siemens Nuclear Power Corporation, Sandvik Special Metals, Burlington Northern Railroad, and the Washington Public Power Supply System. Two other major employers, Iowa Beef Processors and Boise-Cascade, have facilities in Walla Walla County adjacent to Franklin County with many of their employees living and shopping in the Tri-Cities (Cushing 1994).

Table I.6.3.1 shows average annual employment by sector in 1993 and 1995. Total nonfarm employment was approximately 72,200 in 1995, compared to 72,300 in 1994. The largest sector is services, which includes business services, research services (including most Hanford Site employees), and other services. Other Hanford Site employees are classified in the construction, health services, and business services sectors.

After services, the next largest sector is wholesale and retail trade. The Tri-Cities MSA is the main retailing sector for southeastern Washington State and northeastern Oregon. A number of national retail chains have opened outlets in the MSA in the last few years. Columbia Center in Kennewick is the primary regional shopping mall (Serot 1993).

Government is the third largest sector, including Federal, State, and local governments and public schools. Construction has been a key sector in the past few years because of new housing construction, commercial construction, and construction at the Hanford Site. Food processing is the largest

Table I.6.3.1 Average Annual Employment by Sector Tri-Cities Area, 1993 and 1995

	Annual Average Employment		Percent of Total Employment	
Industry	1993	1995	1993	1995
Manufacturing	5,600	5,600	8.0	7.8
Construction	3,900	4,400	5.6	6.1
Transport and Public Utilities	2,200	2,300	3.1	3.2
Wholesale and Retail Trade	14,000	15,600	20.0	21.6
Finance, Insurance, Real Estate	2,100	2,300	3.0	3.2
Services	28,900	28,400	41.3	39.3
Government	12,900	13,600	18.4	18.8
Total	70,000	72,200	100.0	100.0

Note:
Totals may not equal sum of components because of rounding.
Source: WSDES 1990-1995, Neitzel 1996

manufacturing industry, followed by chemicals. The services sector in Benton County, which includes most Hanford Site and Hanford-related employment, dominates the economy in the Tri-Cities MSA. The services sector in Benton County accounted for $769 million in wages, or about 43 percent of wages paid in the two counties (Table I.6.3.2). State-wide, services accounted for only 21 percent of wages paid. The average wage in the services sector in Benton County was more than $34,000, compared to $17,000 in Franklin County and $23,000 statewide. The higher wage in the services sector in Benton County reflects the specialized technical and professional work force at the Hanford Site.

Average wages were higher in Benton County than in Franklin County except in the wholesale and retail trade sector. In that sector, Franklin County has more wholesale trade, which typically pays higher wages than retail trade. Also, agriculture is a larger share of Franklin County's economy than Benton County's, although Benton County had a somewhat higher level of wages paid.

I.6.3.2 Labor Force

Data on occupations for 1990 show that the Benton County labor force is concentrated in the managerial and professional and the technical, sales, and administrative occupations, each of which accounts for about 30 percent of the work force (Table I.6.3.3). Franklin County has much lower percentages in these categories. Technical occupations and farming, forestry, and fishing (agricultural) occupations each accounts for about 21 percent of the Franklin County labor force. Franklin County also has a higher percentage of workers in the operators, fabricators, and laborers occupational category (17.3 percent) than Benton County (12.0 percent).

Table I.6.3.2 Average Wage by Industry in Benton and Franklin Counties and Washington State, 1992

Industry	Average Annual Employment	Total Wages Paid	Average Wage	Percent of Total Wages
Benton County				
Agriculture, Forestry, and Fisheries	4,810	$48,117,451	$10,004	3.3
Construction	3,164	$95,867,883	$30,300	6.5
Manufacturing	4,047	$126,619,073	$31,287	8.6
Transportation and Public Utilities	972	$26,037,160	$26,787	1.8
Wholesale and Retail Trade	8,370	$98,943,546	$11,821	6.7
Finance, Insurance, and Real Estate	1,418	$27,715,085	$19,545	1.9
Services	22,458	$768,781,080	$34,232	52.2
Government - Federal	731	$32,325,298	$44,221	2.2
State	664	$16,387,481	$24,680	1.1
Local	7,304	$230,961,237	$31,621	15.7
Totals	53,938	$1,471,755,294	$27,286	100
Franklin County				
Agriculture, Forestry, and Fisheries	4,251	$41,702,173	$9,810	13.0
Construction	702	$17,668,957	$25,169	5.5
Manufacturing	1,379	$29,379,341	$21,305	9.2
Transportation and Public Utilities	670	$16,028,222	$23,923	5
Wholesale and Retail Trade	4,087	$70,577,741	$17,269	22.1
Finance, Insurance, and Real Estate	362	$6,959,507	$19,225	2.2
Services	2,960	$51,110,754	$17,267	16
Government - Federal	452	$15,712,451	$34,762	4.9
State	845	$21,854,511	$25,863	6.8
Local	2,179	$49,062,133	$22,516	15.3
Totals	17,887	$320,055,790	$17,893	100
Washington State				
Agriculture, Forestry, and Fisheries	83,765	$1,125,052,045	$13,431	2
Construction	112,788	$3,134,818,800	$27,794	5.6
Manufacturing	342,768	$12,049,035,758	$35,152	21.4
Transportation and Public Utilities	106,851	$3,398,023,528	$31,802	6
Wholesale and Retail Trade	527,051	$9,607,280,153	$18,228	17.1
Finance, Insurance, and Real Estate	116,815	$3,506,125,264	$30,014	6.2
Services	511,417	$11,887,196,603	$23,244	21.2
Government - Federal	73,320	$2,445,421,381	$33,353	4.4
State	102,901	$3,055,252,305	$29,691	5.4
Local	224,660	$5,970,628,731	$26,576	10.6
Totals	2,202,336	$56,178,834,568	$25,509	100

Source: WSDES 1993b

Table I.6.3.3 Civilian Labor Force by Occupation Group, Sex, Race, and Hispanic Origin, 1990

Category	Total	Female Percent	Non-Hispanic				Hispanic Percent
			African American Percent	Native American Percent	Asian Percent	Other Percent	
Benton County							
Civilian Labor Force 16 Years and Older	55,842	42.7	0.9	0.7	2.0	0.0	6.9
Managerial and Professional Specialty Occupations	16,581	39.4	1.4	0.4	2.7	0.1	2.2
Technical, Sales, and Administrative Support Occupations	16,709	63.0	0.6	0.6	1.3	0.0	3.5
Service Occupations	7,089	56.5	0.7	1.3	3.5	0.0	7.6
Farming, Forestry, and Fishing Occupations	2,536	20.5	0.2	0.0	0.2	0.0	46.3
Precision Production, Craft, and Repair Occupations	6,006	7.7	0.8	1.1	1.2	0.0	5.9
Operators, Fabricators, and Laborers Occupations	6,680	24.4	1.0	1.2	1.9	0.0	11.9
Experienced Unemployed Not Classified by Occupation	241	77.2	0.0	0.0	5.8	0.0	12.0
Franklin County							
Civilian Labor Force 16 Years and Older	17,090	40.4	2.1	0.8	2.0	0.1	28.3
Managerial and Professional Specialty Occupations	2,975	51.5	2.0	1.1	1.2	0.1	7.2
Technical, Sales, and Administrative Support Occupations	3,627	65.3	3.4	1.0	0.5	0.1	9.8
Service Occupations	2,114	56.5	3.0	0.7	5.4	0.0	18.4
Farming, Forestry, and Fishing Occupations	3,510	20.0	0.4	0.4	0.4	0.0	63.2
Precision Production, Craft, and Repair Occupations	1,799	10.6	2.1	1.5	2.0	0.0	27.6
Operators, Fabricators, and Laborers Occupations	2,954	28.5	1.9	0.4	4.1	0.5	37.3
Experienced Unemployed Not Classified by Occupation	111	61.3	9.9	0.0	0.0	0.0	57.7

Source: WSDES 1993a

Hispanics account for 6.9 percent of the Benton County labor force and 46.3 percent of the workers in the agricultural occupational category (Table I.6.3.3). In Franklin County, Hispanics are 28.3 percent of the labor force and 63.2 percent of the workers in the agricultural occupations. At the same time,

Hispanics in Franklin County account for over 37 percent of the operators category and almost 28 percent of the precision production, craft, and repair occupations. In Benton County, Hispanics represent about 6 percent of the production occupations and 12 percent of the operators occupations. Among other non-Hispanic minority groups, the agriculture occupations have the smallest representation.

African Americans, who make up 0.9 percent of the labor force in Benton County, account for 1.4 percent of the managerial occupations, while in Franklin County African Americans account for 2.1 percent of the labor force and 2 percent of the managerial occupations. In Benton County, Native Americans account for a larger percentage of the production and operators than their percentage of the total labor force. In Franklin County, Native Americans account for a larger percentage of the managerial and production occupations than of the total labor force.

Asians and Pacific Islanders account for 2 percent of the labor force in Benton County and 2.7 percent of the managerial occupations. The same group accounts for 2 percent of the labor force in Franklin County but only 1.2 percent of the managerial occupations. Service occupations show the highest rate of Asian and Pacific Islander representation in both counties. Women account for 40.4 percent of the labor force in Benton County and 42.7 percent in Franklin county. Women account for 51.5 percent of the managerial and professional occupations in Benton County and 39.4 percent in Franklin County. In the other occupational categories the representation of women is similar or virtually the same in the two counties.

In terms of the Hanford Site (Table I.6.3.4), the Hanford Site's maintenance and operators contractor's work force is approximately 29 percent female, 4 percent Hispanic, 3 percent African American, 2 percent Asian, and 1 percent Native American (Pitcher 1994).

Table I.6.3.4 Hanford Site Management and Operations contractor Workforce Representation by Gender and Ethnic Group, 1994

Occupational Category	Total Percent	Female Percent	African American Percent	Hispanic Percent	Asian Percent	Native American Percent
Managers	13	10	2	2	2	0
Exempt, Nonmanagement	49	25	3	3	3	1
Technicians	3	23	2	5	2	1
Clerks and Secretaries	10	96	3	5	1	1
Crafts (skilled)	15	18	3	6	0	1
Operations (semi-skilled)	8	24	1	7	0	2
Service (fire protection)	3	5	3	8	0	2
Percent of Total Labor Force:	100	29	3	4	2	1

Source: Pitcher 1994

I.6.3.3 Tax Base

Local government revenues in Benton and Franklin counties come primarily from property taxes and the local share of sales taxes. Other revenues come from fees, fines, forfeitures, and transfers from the State or the Federal government. In 1993, assessed property values were about $3.8 billion in Benton County and $1.3 billion in Franklin County. These assessed values were $500 million more than 1992 assessments in Benton County (15 percent increase) and $86 million more in Franklin County (7 percent increase). These increases reflect both new residential and commercial construction and increasing property values caused by the increased demand for residential and commercial property (Serot 1993).

In 1992, the last year for which complete data are available, taxable retail sales were $1,054 million for Benton County and $400 million for Franklin County. This represents a 14 percent increase for Benton County from 1991 levels and a 16 percent increase for Franklin County. Between 1988 and 1992, combined taxable retail sales for the two counties increased from $992 million to $1,481 million (WSDR 1987-1995). This represents almost a 50 percent increase or about 10.5 percent per year. The increase in taxable retail sales shows the effects of rising employment (leading to more consumer spending), population growth, and a general increase in economic activity (Serot 1993).

I.6.3.4 Housing

The growth in employment and population in the Tri-Cities MSA in the late 1980's and early 1990's created a tight housing market. Between 1988 and 1993, the average price of a single-family home increased from approximately $59,000 to $107,000. This increase occurred despite record levels of housing construction. Housing starts increased from 42 in 1988 to 1,200 in 1993 (Table I.6.3.5). However, recent declines in Hanford Site employment, as well as continued construction, resulted in a softening of the housing market and a decline in housing prices and housing starts in 1995 (TAR 1980-1995). The average home sale price in August 1995 was approximately $101,000, down from $126,000 in August 1994. However, most of the drop in home prices occurred in the upper prices ranges, with sales remaining strong in the $70,000 to $120,000 range. In September 1995, the Tri-City Association of Realtors described the local housing market as healthy (Schafer 1995).

Housing prices and housing starts in the Tri-Cities MSA have responded to changes in economic conditions during the past 15 years. Home prices declined after the termination of the Washington Public Power Supply System construction project in 1982 and then again after the shut-down of the Hanford Site's last production reactor in 1987. However, the Hanford Site cleanup and environmental restoration mission and increasing staffing levels, as well as growth in other sectors of the economy caused housing prices to increase dramatically. Until recently, despite new construction and new residences, first-time home buyers faced both rising prices and the lack of available housing, especially at the lower end of the price spectrum.

Table I.6.3.5 Tri-Cities MSA Home Prices and Housing Starts, 1980 to 1993

Year	Average Selling Price ($1,000)	New Home Starts
1980	65.1	429
1981	73.1	459
1982	66.8	141
1983	64.8	129
1984	62.6	100
1985	60.9	95
1986	60.0	155
1987	59.6	110
1988	58.8	42
1989	59.7	164
1990	68.3	414
1991	78.7	460
1992	93.8	911
1993	106.6	1,200

Source: TAR 1980-1995, HBA 1980-1994.

The housing problem was compounded by very low vacancy rates and increasing rents in rental housing. A December 1993 survey of apartment complexes in Richland, Kennewick, Pasco, and West Richland showed vacancy rates between 1.0 and 2.3 percent. Overall Tri-Cities housing occupancy rates (both single-family and multiple-unit housing) were approximately 95 percent in 1994 and 1995 (Cushing 1995 and Neitzel 1996).

I.7.0 LAND USE

While the focus in the following land-use section is on the 200 Areas, a brief summary is provided on land uses for the remainder of the Hanford Site as well as surrounding offsite land-use patterns. Also addressed are the future planning efforts of other Federal and State agencies, Tribes, and local governments. Prime and unique farmlands and recreational opportunities also are identified.

I.7.1 PRIME AND UNIQUE FARMLAND

The Farmland Protection Policy Act requires Federal agencies to consider prime or unique farmlands when planning major projects and programs on Federal lands. Federal agencies are required to use prime and unique farmland criteria developed by the U.S. Department of Agriculture's Soil Conservation Service (SCS). Under Farmland Protection Policy Act, the SCS is authorized to maintain an inventory of prime and unique farmlands in the United States to identify the location and extent of rural lands important in the production of food, fiber, forage, and oilseed crops (7 CFR Part 657). The SCS has determined that because of low annual precipitation in southeast Washington State, none of the soil occurring on the Hanford Site would meet prime and unique farmland criteria unless

irrigated (Brincken 1994). The specific location of potential irrigable prime or unique farmlands at the Hanford Site has not been determined by the SCS because of the absence of detailed slope information.

I.7.2 EXISTING LAND-USE TYPES AND LAND-USE PLANS

This section discusses 1) existing Site land uses and associated issues based on the Hanford Site Development Plan (HSDP); 2) the Comprehensive Land Use Plan (CLUP) for the Site that was prepared by DOE and released for public comment in August 1996 (DOE 1996c), and other relevant land-use plans by Federal, State, and local agencies and Tribal Nations; and 3) recreational uses.

I.7.2.1 Hanford Site Development Plan

The HSDP provides an overview of land use, infrastructure, and facility requirements to support DOE at the Hanford Site (DOE 1993e). Although the HSDP is not a formal land use plan, it is the most current available planning document until the Site's CLUP is finalized. DOE has invited Tribal Nations, county and city governments, and other stakeholders to participate in the planning process. A draft of the CLUP was released for public comment in August 1996. Because the CLUP is not yet final, the following discussion focuses on the HSDP.

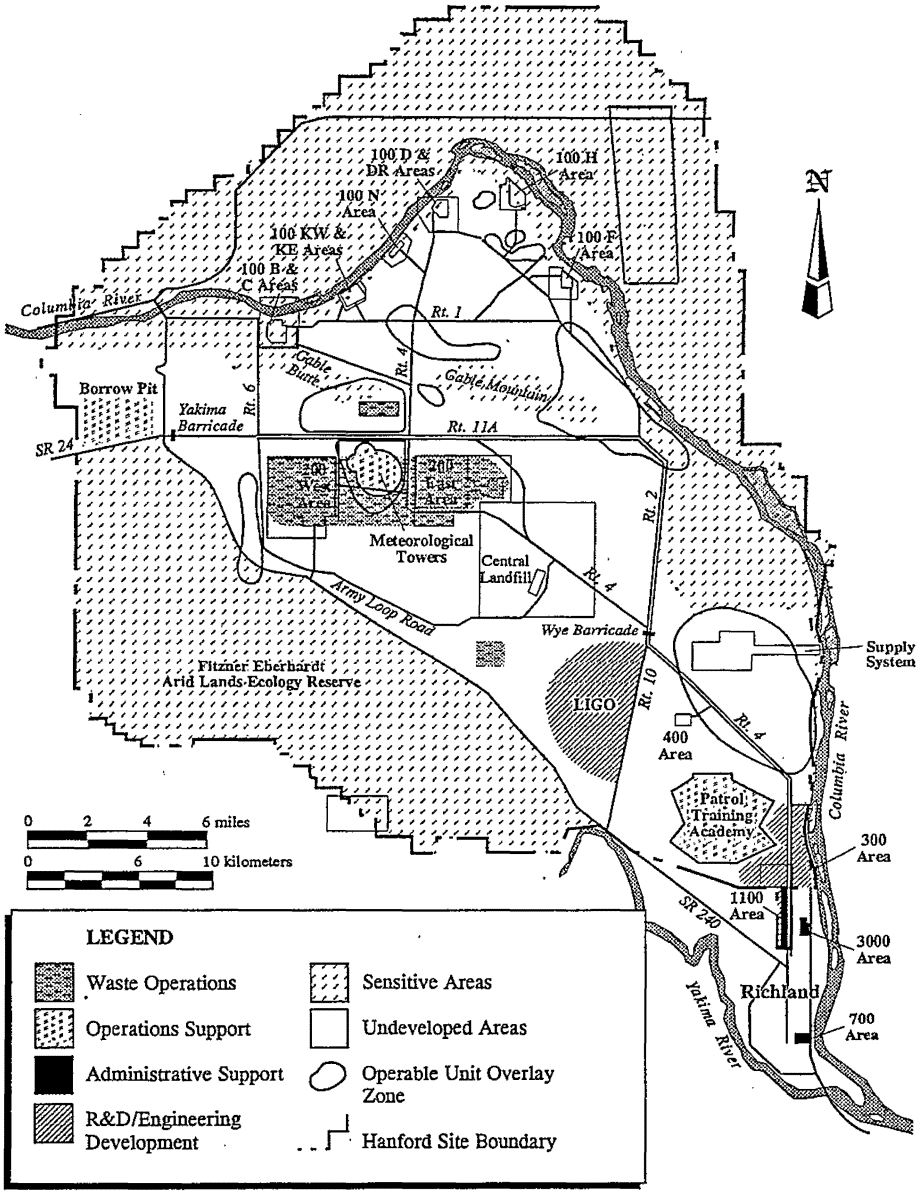
The HSDP has a Master Plan section that outlines the future land and the infrastructure needed by Hanford Site missions. The primary objective of the Master Plan has been to develop and maintain the Hanford Site infrastructure to meet ongoing and future program requirements (DOE 1993e). A goal of the HSDP has been to maximize the amount of land available for other beneficial uses, including protecting cultural and biological resources.

The HSDP provides for a compatible land-use transition from offsite agricultural uses in Adams, Grant, Franklin, and Benton counties to passive uses onsite in the FEALE Reserve and the proposed National Wildlife Refuge north of and along the Columbia River. The areas of the Hanford Site nearest to the river are proposed to remain undeveloped, providing an additional buffer area between sensitive natural areas and more intensely developed areas such as the Central Plateau. The HSDP accommodates future intensive uses, such as industrial development and research in the southeast area of the Hanford Site near the urban development of Richland. These more intensive uses are adequately separated from less intensive agricultural uses in Franklin County by the Columbia River. The future land uses are designed to facilitate cleanup, maintain a stable employment and economic foundation, provide energy research and development, continue waste management and disposal activities, and provide environmental protection.

Figure I.7.2.1 identifies the existing land uses on the Hanford Site. The Hanford Site has seven major land-use types:

- Reactor Operations, which involves the development and irradiation of nuclear fuels, fuel fabrication, fuel storage, and reactor plant operations (all operations except storage are currently inactive);

Figure I.7.2.1 Existing Land Use Map



SOURCE: Adapted from DOE 1993e

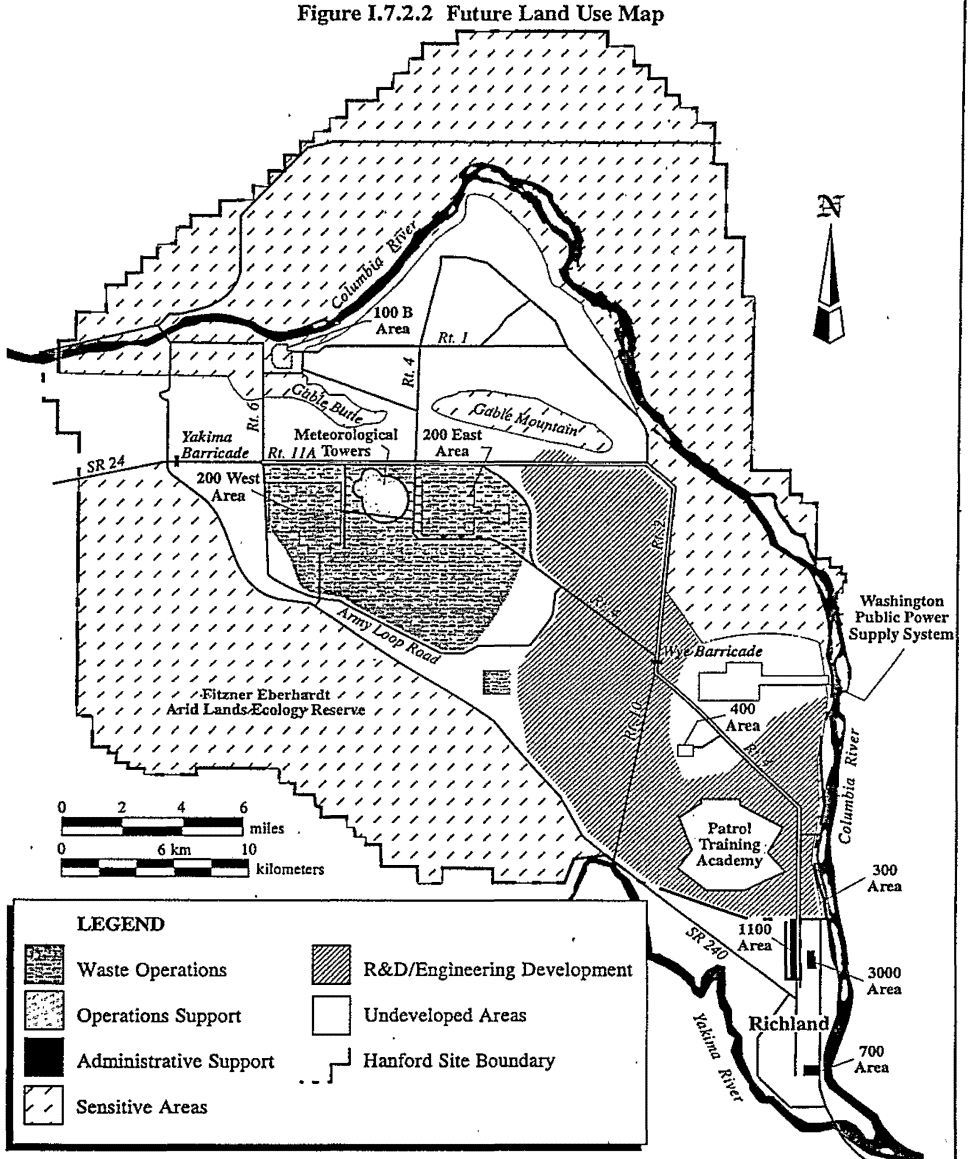
- Waste Operations, which include the treatment, storage, and disposal of radioactive and nonradioactive waste, including waste treatment facility operations, active and inactive tank farms, burial grounds, vaults, and cribs;
- Operations Support, which involves services provided specifically for operations that are primarily industrial;
- Administrative Support, which provides administrative services for overall Hanford Site activities;
- Research and Development and Engineering Development, which includes basic and applied research conducted to advance fundamental scientific knowledge related to Hanford Site activities as well as other major national needs;
- Sensitive Areas, which include environmentally (ecological) or culturally (historical, archaeological, and religious) important areas; and
- Undeveloped Areas, which include areas that have not been developed or have been restored to an undeveloped state. The undeveloped areas also contain sensitive biological and cultural resources.

Sensitive Areas are the largest portion of the existing land use on the Hanford Site. These include the FEALE Reserve, an area that occupies the entire southwest portion of the Hanford Site. Also included are all the Hanford Site lands north of the Columbia River, lands along the river, Gable Butte, Gable Mountain, and an area along the eastern boundary of the Hanford Site south of the river. The area north of the river, the North Slope, is administered by two separate agencies. The U.S. Fish and Wildlife Service (USFWS) administers the area in Grant County west of the northern point of the Hanford Reach known as the Saddle Mountain National Wildlife Refuge. The Washington State Department of Fish and Wildlife Services administers the area in Grant, Adams, and Franklin counties to the north and east of the Hanford Reach, which is known as the Wahluke Wildlife Recreation Area. These areas are undeveloped, natural wildlife areas.

The FEALE Reserve and the North Slope are being considered by DOE for release. The release of the FEALE Reserve could involve land exchange agreements between DOE and the Bureau of Land Management (BLM). The Yakama Indian Nation also has proposed that they take ownership of the Reserve, as has Benton County. Current considerations for the North Slope involve the proposed National Park Service designation of the area as a National Wildlife Refuge (NWR) to be administered by the USFWS. Benton, Franklin, and Grant county commissioners oppose the proposed designation of the North Slope (Campbell 1995). No final resolution of either of these issues has occurred.

The HSDP contains a Future Land Use Map that presents DOE's 1993 vision of future Site land-use needs (Figure I.7.2.2). The Future Land Use Map was intended for annual updates to reflect mission changes, regulatory decision documents, NEPA documents such as the Hanford Remedial Action EIS and the TWRS EIS, and other appropriate sources (DOE 1993e). However, the Site CLUP, was released in draft form in August 1996 with final decisions expected in early 1997, will provide an official DOE vision of future Site land uses (DOE 1996c).

Figure I.7.2.2 Future Land Use Map



NOTE: The land uses identified in this map represent DOE's 1993 vision of future land uses based on existing and potential Hanford missions. This map will be superseded by the Hanford Site Comprehensive Land Use Plan, which was released for public comment in August 1996 (DOE 1996c).

SOURCE: Adapted from DOE 1993e

As previously mentioned, a goal of the HSDP has been to maximize the amount of land available for other beneficial uses. Future land-use designations were also based on existing and potential Hanford Site missions and assumptions, and the recommendations of the Hanford Future Site Uses Working Group (HFSUWG 1992). The Reactor Operations, Sensitive Areas, and Administrative Support areas remain unchanged from the existing land-use plan (Figure I.7.2.2).

The Hanford Site consists of 1,450 km^2 (560 mi^2) or 145,000 ha (358,000 ac) of land. Of the total Hanford Site area, the Central Plateau, which has been identified for waste management operations, constitutes 117 km^2 (45 mi^2) or 11,700 ha (29,000 ac) of land. This represents approximately 8 percent of the total Hanford Site area. The Central Plateau would consist of 1) a buffer zone of 49 km^2 (19 mi^2) or 4,900 ha (12,000 ac); and 2) a waste management area of 26 km^2 (10 mi^2) or 2,600 ha (6,400 ac). The buffer zone would separate the waste management activities from other areas of the Hanford Site. The 200 Areas would be contained entirely within the waste management area. The 200 Areas consists of 26 km^2 (10 mi^2) or 2,600 ha (6,400 ac) of land. This represents approximately 22 percent of the total Central Plateau waste management area and 2 percent of the total Hanford Site.

The Waste Operations area is primarily limited to the 200 Areas. Virtually all proposed TWRS activities except two potential borrow sites would occur in or between the 200 Areas. The 200 Areas have been used to process irradiated nuclear fuel and store the resulting waste. Existing facilities in this area include the PUREX Plant, the Plutonium Finishing Plant, the U Plant, the tank farms, the Central Waste Complex, and the Waste Sampling and Characterization Facility. The PUREX, Plutonium Finishing Plant, and U Plants are being deactivated (DOE 1993e). The 200 Areas are also used for Research and Development and Engineering Development; they also contain meteorological towers.

The future locations of the Waste Operations area remain the same although the overall Waste Operation area has been expanded. This expansion reflects land dedicated to a potential cleanup scenario where Sitewide waste is collected and placed in a central location dedicated to exclusive use as a waste disposal area. This includes relocating waste sites, contaminants, and associated structures such as the 100 Area facilities.

According to the HSDP, the future Operations Support areas will remain unchanged except for closing and reclaiming the borrow pit in the western portion of the Hanford Site. The Research and Development and Engineering Development area has increased substantially to include the majority of the southeastern portion of the Hanford Site. The Undeveloped Areas, which include areas of sensitive ecological and cultural resources, have been reduced in size to reflect the future release and reuse of portions of the Site. DOE is working with a variety of governmental and nongovernmental organizations to ensure protection, preservation, and proper management of Hanford Site ecological and cultural resources.

The National Park Service released a Final EIS in June 1994 that recommended designating the Hanford Reach portion of the Columbia River as a Recreational River under the Wild and Scenic Rivers Act and also proposed designating the North Slope, an upland area north and east of the river, a National Wildlife Refuge (NPS 1994). This proposal would transfer management of the river and a 0.40 km (0.25 mi) strip of land along both shores of the river to the USFWS along with approximately 41,300 ha (102,000 ac) of adjacent lands. Development restrictions are included for protecting cultural resources, threatened and endangered species, water quality, unique scenic geologic features, and Native American access and use. The Secretary of the U.S. Department of Interior has issued a Record of Decision indicating a preference for this proposal. This recommendation has been sent to Congress with the final EIS for consideration (NPS 1994).

Benton, Franklin, and Grant county commissioners oppose the proposed U.S. Department of Interior recommendation and have offered an alternative approach that would leave the Reach under local government control (Stang 1996b). Various local groups (e.g., the Lower Columbia Basin Audubon Society) and many area residents support the Wild and Scenic Rivers designation. No final decisions have been made.

BLM owned many scattered tracts of land on the Hanford Site prior to transferring those lands to the Atomic Energy Commission for national security reasons in 1943. BLM currently does not own any lands on the Site's Central Plateau. However, BLM owns land that includes the potential Vernita Quarry borrow site.

I.7.2.2 Washington State

Washington State has several land interests onsite. The Washington State Department of Fish and Wildlife currently administers the area of the Hanford Site north and east of the Hanford Reach known as the Wahluke State Wildlife Recreation Area. This area is considered sensitive ecological upland habitat and is part of the Wahluke Slope. Washington State also leases a square parcel in the south-central portion of the Hanford Site between State Route 240 and the Route 2/Route 4 junction. This property is located within the undeveloped area of the Hanford Site.

I.7.2.3 Tribal Nations

The Hanford Site is located on land ceded from the Confederated Tribes and Bands of the Yakama Indian Nation and the Confederated Tribes of the Umatilla Indian Reservation (the Umatilla, Cayuse, and Walla Walla Tribes), based on treaties signed in 1855 (DOE 1992b). The Nez Perce Tribe has treaty rights on the Columbia River under a separate treaty.

I.7.2.4 Local Governments

The Hanford Site is located within portions of Benton, Franklin, Grant, and Adams counties. Other surrounding local jurisdictions include the cities of Richland, West Richland, Pasco, and Kennewick.

Because many of the local jurisdictions' existing comprehensive plans are incomplete or outdated, they have been updated recently or are in the process of being updated as mandated by the 1990 Washington

State Growth Management Act. Because of its limited recent growth, Adams County is not updating its plan.

The majority of the Hanford Site is located within Benton County and comprises up to 25 percent of the county land. The cities of Richland, West Richland, Kennewick, Prosser, and Benton City are located in Benton County. The unincorporated areas of the county adjacent to the Hanford Site currently have generalized land-use designations for rangeland and undeveloped and dry agriculture. Rangeland activities consist largely of cattle grazing. Undeveloped or vacant land is primarily open space. Dry agriculture, the largest single land use in the county, consists almost exclusively of dryland wheat and summer fallow (BCBCC 1985).

Benton County officials are concerned with the remediation and potential reuse of the Hanford Site because most of the land-use effects resulting from reuse would occur within Benton County. Benton County is in the process of updating its comprehensive plan. The county plan update will include a separate Hanford Comprehensive Plan that will be consistent with the overall county plan (Walker 1995). The County Planning Department has defined three categories of land use for the Site: 1) critical areas (e.g., wetlands, areas prone to landslides, fish and wildlife areas); 2) areas where development could occur only if damaged habitat was replaced or restored; and 3) areas where development could occur with minimal restrictions. Of the potential TWRS areas, the potential Vernita Quarry borrow site is within a defined critical area, and the potential McGee Ranch borrow site is within the land use category that would require replacement or restoration of affected land. The Washington State Department of Fish and Wildlife asked Benton County to designate the McGee Ranch as a critical area (preservation area) (McConnaughey 1996a). All other potential TWRS sites are within areas where only minimal development restrictions would be imposed (Fyall 1996).

Benton County's proposed Hanford Comprehensive Plan is in the process of review and public hearings before the County Planning Commission and then before the county commissioners. The Hanford Comprehensive Plan is expected to be formally adopted by the end of 1996 (Fyall 1996).

Franklin County is located east of the Hanford Site and includes the city of Pasco. The unincorporated area of the county adjacent to the Hanford Site is rural and sparsely developed (Franklin County 1982). The land-use designation surrounding the Hanford Site, as with most of the county, is agricultural. Franklin County adopted an updated comprehensive plan in April 1995. The updated plan does not directly impact any land uses at the Hanford Site (German 1995).

Grant County is located north of the Hanford Reach and includes the Area of the Hanford Site north of the river. The land uses adjacent to the Hanford Site are designated as agricultural (Grant County 1994). This use type is restricted to crop agriculture, agricultural related industries, livestock, and public utility functions (Grant County 1988). Grant County is in the process of updating its comprehensive plan with an expected completion date in 1998. However, no changes in the county plan would impact areas of the Hanford Site south and west of the Columbia River, which include all potential TWRS areas, because those areas are not within Grant County (Lambro 1996).

Adams County is located northeast of the Hanford Site although a small portion of the Site is located within Adams County. The land use adjacent to the Hanford Site within Adams County is designated as agricultural (Caputo 1994). These lands are either being used for rangeland or are lying fallow.

The city of Richland is located immediately adjacent to the Hanford Site. Richland is currently in the process of annexing the Site's 1100 Area (Milspa 1995). The existing land uses within Richland near the Hanford Site include industrial, agricultural, and public lands. The planned land use designation within the Richland area adjacent to the Site is identified as industrial (City of Richland 1988). Industrial use is compatible with the adjacent Site use. The city developed a set of alternatives for its updated comprehensive plan; these alternatives were released for public review in March 1996. The comprehensive plan itself is scheduled for adoption in early 1997 (Milspa 1996). With respect to the Hanford Site, the Richland plan focuses only on the southern portions of the Site, which are within the city's 20-year growth boundaries. The various alternatives being considered for the updated plan would be expected to call for maintaining and expanding industrial and research and development activities in the areas of the city adjacent to the site (Milspa 1996).

West Richland is located to the south of the Hanford Site and is one of the closest developing residential communities. The West Richland land use near the Hanford Site is designated low-density residential (West Richland 1994). This use is consistent with the nearby existing uses (FEALE Reserve and Undeveloped Area) at the Hanford Site. The West Richland Comprehensive Plan update was released in June 1996 and is expected to be adopted in September 1996. There is little in the update that would impact Hanford Site land-use issues (Corcoran 1996).

Pasco is located southeast of the Hanford Site and includes the Tri-Cities Airport, which is the area's primary airport. Pasco has been planning major commercial, industrial, office, and residential improvements along the Interstate 182 corridor to attract future Hanford Site-related and other businesses (McDonald 1994). Pasco adopted its updated comprehensive plan in August 1995. However, very little in the update is related to Hanford Site land-use issues (McDonald 1995).

Kennewick is located south of the Hanford Site and is separated from the Site by the Yakima River and the city of Richland. Like Pasco, Kennewick has been planning additional industrial and office areas to attract new businesses. Kennewick adopted its updated comprehensive plan in April 1995. Very little in the updated plan is related to Hanford Site land uses (White 1995).

Another local agency that could be impacted by remediation and reuse of the Hanford Site is the Port of Mattawa. The Port of Mattawa is located in Grant County, northwest of the Hanford Site. The Port of Mattawa is a local government agency obligated to enhance the economic development within District No. 3 of Grant County (Connelly 1994). The Port of Mattawa supports the Wahluke 2000 Plan, which proposes, with U.S. Bureau of Reclamation assistance, to expand irrigated farming acreage and increase recreation uses while protecting wildlife habitat (Wahluke 1994). The Wahluke 2000 Plan represents a different approach than the one outlined by the Park Service (in the Hanford Reach EIS),

which has proposed a Recreational River status under the Wild and Scenic Rivers Act for the Hanford Reach of the Columbia River.

I.7.2.5 Natural Resources Trustees Council

The Hanford Site Natural Resources Trustees Council is composed of representatives from the States of Washington and Oregon, Federal agencies (DOE and Interior), and three affected Tribal Nations (Yakama Indian Nation, CTUIR, and Nez Perce Tribe). The primary purpose of the Council is to facilitate the coordination and cooperation of the trustees in their efforts to restore and minimize impacts to natural resources injured as a result of or during cleanup of releases associated with DOE's activities at the Hanford Site. The Council's primary role with respect to the TWRS project will be to consult with DOE during development of the Mitigation Action Plan for impacts identified in the TWRS EIS.

I.7.3 RECREATIONAL RESOURCES AND THE NATIONAL ENVIRONMENTAL RESEARCH PARK

For the purposes of wildlife management and outdoor recreation, some portions of the Hanford Site are administered by agencies other than DOE. The entire Hanford Site was designated by DOE as a National Environmental Research Park in 1976 (NPS 1994). National Environmental Research Parks are aimed at original research into the ecology and natural sciences of an area. Nearly one-half of the Site is designated for use as wildlife management (Figure I.7.3.1). These wildlife management areas buffer developed areas of the Site. They are the FEALE Reserve, Saddle Mountain NWR, Wahluke Wildlife Recreation Area, Rattlesnake Slope Wildlife Area, and McNary NWR. Ecological data have been collected on these sites for more than 40 years.

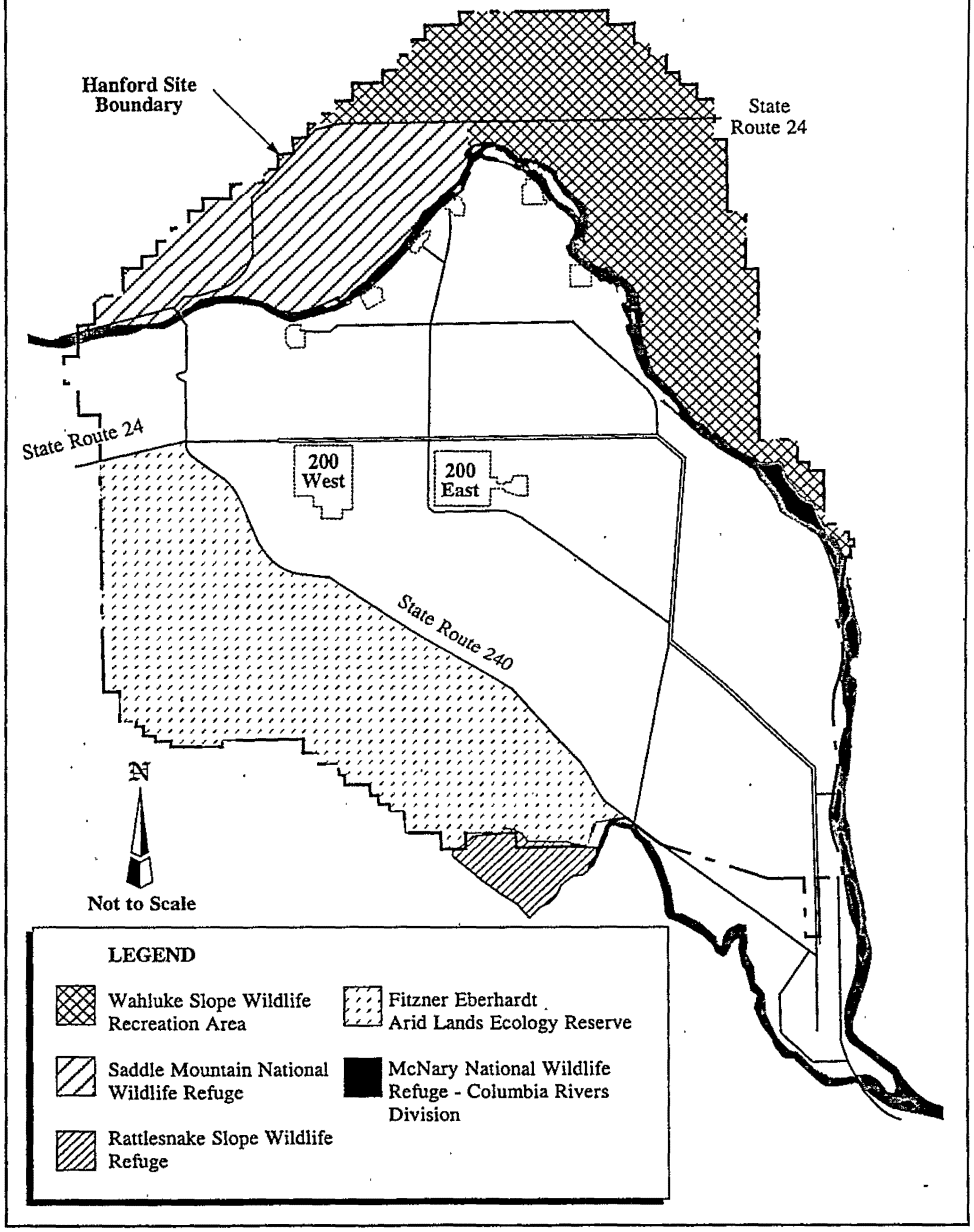
I.7.3.1 Fitzner Eberhardt Arid Lands Ecology Reserve

The FEALE Reserve is located in the southwest corner of the Hanford Site. Currently, all research activities on the FEALE Reserve are funded by DOE. Consisting of 310 km^2 (120 mi^2) including Rattlesnake Mountain, the FEALE Reserve is managed for DOE by the Pacific Northwest National Laboratory.

BLM is also involved in the FEALE Reserve. In July 1993, BLM proposed exchanging sections of the Hanford Site with DOE for the FEALE Reserve. BLM proposed to continue management of the FEALE Reserve for its wildlife benefits and to designate it a National Conservation Area. The Yakama Indian Nation also proposed assuming control of the Reserve, with an emphasis on wildlife management, as well as use for Native American cultural purposes. In addition, Benton County has proposed taking over the FEALE Reserve (Stang 1996a).

In July 1996, DOE notified the Yakama Indian Nation, other Federal agencies, and Benton County of its decision to keep control of the Reserve (O'Leary 1996). The Reserve will continue to function as a buffer zone for ongoing waste management in the 200 Areas. DOE also announced its intention to negotiate an agreement with the U.S. Fish and Wildlife Service to manage the Reserve while protecting the ecologically sensitive area and allowing greater public access (Stang 1996c).

Figure I.7.3.1 Recreation and Wildlife Areas and the Hanford Reach



I.7.3.2 McNary National Wildlife Refuge

The McNary NWR, located near the confluence of the Columbia and Snake Rivers, includes three divisions: Burbank Slough, Strawberry Island, and Hanford Islands (Figure I.7.3.1). Only the Hanford Islands Division is within the boundaries of the Hanford Site. The Hanford Islands Division contains six islands in the Columbia River and is located upstream from the city of Richland. The Hanford Islands extend a distance of 14.5 river km (9 river mi) and contain 140 ha (350 ac). The islands are closed to the public during waterfowl nesting season to protect breeding waterfowl, particularly aleutain canada geese, a Federal and State endangered species.

The McNary NWR was established in 1955 by a cooperative agreement with the U.S. Army Corp of Engineers, which transferred administrative control of nearly 1,200 ha (3,000 ac) of land to the USFWS. Additional acquisitions have enlarged the refuge to the present area of 1,300 ha (3,300 ac). Recreation activities include fishing, picnicking, swimming, and water skiing.

I.7.3.3 Saddle Mountain National Wildlife Refuge

The USFWS manages Saddle Mountain NWR, located on the Hanford Site north and west of the Columbia River (Figure I.7.3.1). Currently, the area is closed to all public use and is dedicated to wildlife management. The USFWS monitors the area for waterfowl populations, kestrel nesting activity, and raptor activity.

The Saddle Mountain NWR was established in 1971 by DOE through a joint agreement with the USFWS. The NWR is located north of the Columbia River from the center of the Hanford Reach to the western boundary of the Hanford Site. The area is currently controlled by DOE but will be transferred to the USFWS upon cleanup of its contaminated sites.

I.7.3.4 Wahluke Wildlife Recreation Area

The Washington State Department of Fish and Wildlife manages the Wahluke Wildlife Recreation Area, located on the Hanford Site north and east of the Columbia River (Figure I.7.2.1). The Wahluke Wildlife Recreation Area is open for public recreation. More than 41,000 people used the area and nearby facilities between July 1988 and July 1989, the most recent year for which statistics are available. More than half of this use took place at the Vernita boat launch, an unimproved launch area immediately upstream of the Vernita Bridge. The Washington State Department of Fish and Wildlife leases approximately 34 ha (85 ac) of Wahluke Wildlife Recreation Area to various private operations for agricultural sharecropping.

I.7.3.5 The Hanford Reach (Proposed Wild and Scenic River Designation)

As the last free-flowing segment of the Columbia River, the Hanford Reach has been proposed for Wild and Scenic River status. The Hanford Reach extends from river mile 396 downstream to river mile 345 and includes those portions of the Columbia River within the boundaries of the Hanford Site. The Hanford Reach boundaries include a 0.4-km (0.25-mi) strip of land on each side of the river, the Saddle Mountain NWR, and the Wahluke Wildlife Recreation Area (Figure I.7.3.1). Designation as a Recreational River (the least restrictive designation under the Wild and Scenic Rivers Act) would

provide permanent protection for salmon and cultural resources, enhance wildlife habitats and populations, and improve access and natural resource interpretation for visitors. The USFWS would be designated as the administrating agency. All lands within the proposed boundary would be transferred to USFWS (NPS 1994).

Benton, Franklin, and Grant county commissioners oppose designating the Hanford Reach as a Wild and Scenic River and have offered an alternative proposal that would provide for local government rather than federal control of the Reach (Stang 1996a). Other local residents support the Federal Wild and Scenic River designation. No final decisions have yet been made.

I.7.3.5.1 Recreational Use

The Hanford Reach and adjacent wildlife refuge and recreation areas provide a variety of recreational activities year-round for local residents and visitors. The most popular activities are sport fishing, boating, and waterfowl hunting, which are considered substantial in terms of impact on the local economy. Other popular activities include waterskiing, upland hunting, and nature observation. The heaviest use period occurs during September and October, coincident with runs of fall chinook salmon. Hunting occurs in areas downstream of the Hanford Townsite from mid-October until late January each year. Nature observation is most popular during autumn and winter months when the greatest number and diversity of migratory and wintering waterfowl species are present.

Because of restricted use of the Hanford Site and Saddle Mountain NWR lands, virtually all land-based recreation occurs on the Wahluke Wildlife Recreation Area. Water-based recreation is supplemented with boating that originates from areas downstream of the Hanford Site. However, the distance from Richland boat launches to key fishing and sightseeing locations suggests that boating accounts for less than 20 percent of water-based use within the Hanford Reach. Total current recreational use of the Hanford Reach comprises approximately 10,000 land-based visits by hunters, trappers, and nonconsumptive users and approximately 40,000 visits by water-based users (predominantly anglers) per year (NPS 1994).

I.7.3.5.2 Sport Fishing

The Hanford Reach is enjoyed by sport fisherman throughout the Pacific Northwest. Steelhead, sturgeon, and smallmouth bass are the primary sport fish. Of these species, the fall chinook salmon and steelhead are regionally important recreational resources, and the Hanford Reach is one of the leading sport salmon fishing areas along the Columbia River.

I.7.3.5.3 Waterfowl Hunting

Waterfowl hunting is the primary hunting activity in the Hanford Reach. The abundance of waterfowl and availability of favorable hunting conditions make the Hanford Reach a regionally important resource.

I.7.3.5.4 Boating

Although much of the boating along the Hanford Reach is related to fishing or waterfowl hunting, scenery, wildlife, and opportunities for solitude make the area increasingly attractive for recreational boaters. An analysis of flat-water boating rivers throughout Washington State, conducted as part of the Pacific Northwest River Study, identified the Hanford Reach as a regionally important boating resource (NPS 1994).

I.7.3.5.5 Nature Observation

The Hanford Reach and surrounding lands provide some of the best opportunities for viewing wildlife in eastern Washington State. Bald eagles, loons, pelicans, terns, gulls, great blue herons, mule and white-tailed deer, coyotes, and beavers are some of the larger species that may be observed. Bird-watching opportunities are optimal during winter months when the Hanford Reach is visited by many species of wintering birds and migratory waterfowl (NPS 1994).

I.7.3.5.6 Swimming

Swimming occurs locally from approximately Memorial Day to Labor Day. Visitors either swim from boats or from the shoreline. There are, however, no developed beaches or designated public swimming areas within the boundaries of the Hanford Site.

I.7.3.5.7 Waterskiing

Waterskiing typically occurs south of the Hanford Site in the vicinity of the city of Richland from mid-May to mid-September. Occasionally, water-skiers travel into the Hanford Reach north of Wooded Island in the vicinity of the Hanford Dunes.

I.7.3.5.8 Other Activities

A relatively small number of people pursue recreational activities within or adjacent to the Hanford Reach. Some activities such as off-road vehicle use, collecting artifacts, and camping are illegal and can be detrimental to the landscape and resources. Off-road vehicle use in the vicinity of White Bluffs has caused considerable damage in some areas and collecting artifacts is an ongoing problem throughout the Site. Camping is permitted at the Ringold boat launch, but occurs illegally at times along other parts of the Hanford Reach shoreline and on some of the islands. The sand dunes are sometimes used by shoreline swimmers, although this is a no-access area (NPS 1994).

I.7.3.6 Rattlesnake Slope Wildlife Refuge

The Rattlesnake Slope Wildlife Refuge is located adjoining the FEALE Reserve's southern boundary. The Refuge, which is managed by Washington State, is outside the boundary of the Hanford Site.

I.8.0 VISUAL RESOURCES

Visual resources reflect the importance of a landscape for its natural or man-made aesthetic qualities and for its sensitivity to change. Landscape character and potential viewing areas are primary factors to be considered in describing the Hanford Site's visual resource values.

I.8.1 LANDSCAPE CHARACTER

The landscape setting within the Hanford Site region is characterized by broad basins and plateaus interspersed with ridges, providing wide, open vistas throughout much of the area. Only about 6 percent of the Site has been disturbed. The remainder of the Site is undeveloped, including natural areas and abandoned agricultural lands that remain undisturbed because of restricted public access.

The major landscape feature of the Hanford Site is the Columbia River, which flows through the northern part of the Hanford Site and turns south, forming the eastern Hanford Site boundary. North of the Columbia River, the Saddle Mountains border the Hanford Site. The Yakima River is located along a small portion of the southern boundary and joins the Columbia River in the city of Richland on the southeastern border of the Hanford Site. Yakima Ridge and Umtanum Ridge form the western boundary of the Hanford Site. Two small east-west ridges, Gable Butte and Gable Mountain, rise above the Central Plateau of the Hanford Site. Adjoining lands to the north, east, and west are principally used for range and agriculture.

The primary focus of the proposed TWRS activities under all EIS alternatives would be in the interior of the Site on the large, flat, open, and semi-arid Central Plateau. Two potential borrow sites, Vernita Quarry and McGee Ranch, are located northwest of the Central Plateau. A third potential borrow site, Pit 30, is located on the Central Plateau between the 200 East and 200 West Areas. The dominant visual features of the Central Plateau vicinity include Gable Butte and Gable Mountain to the north, Rattlesnake Mountain to the south, and Umtanum Ridge to the west.

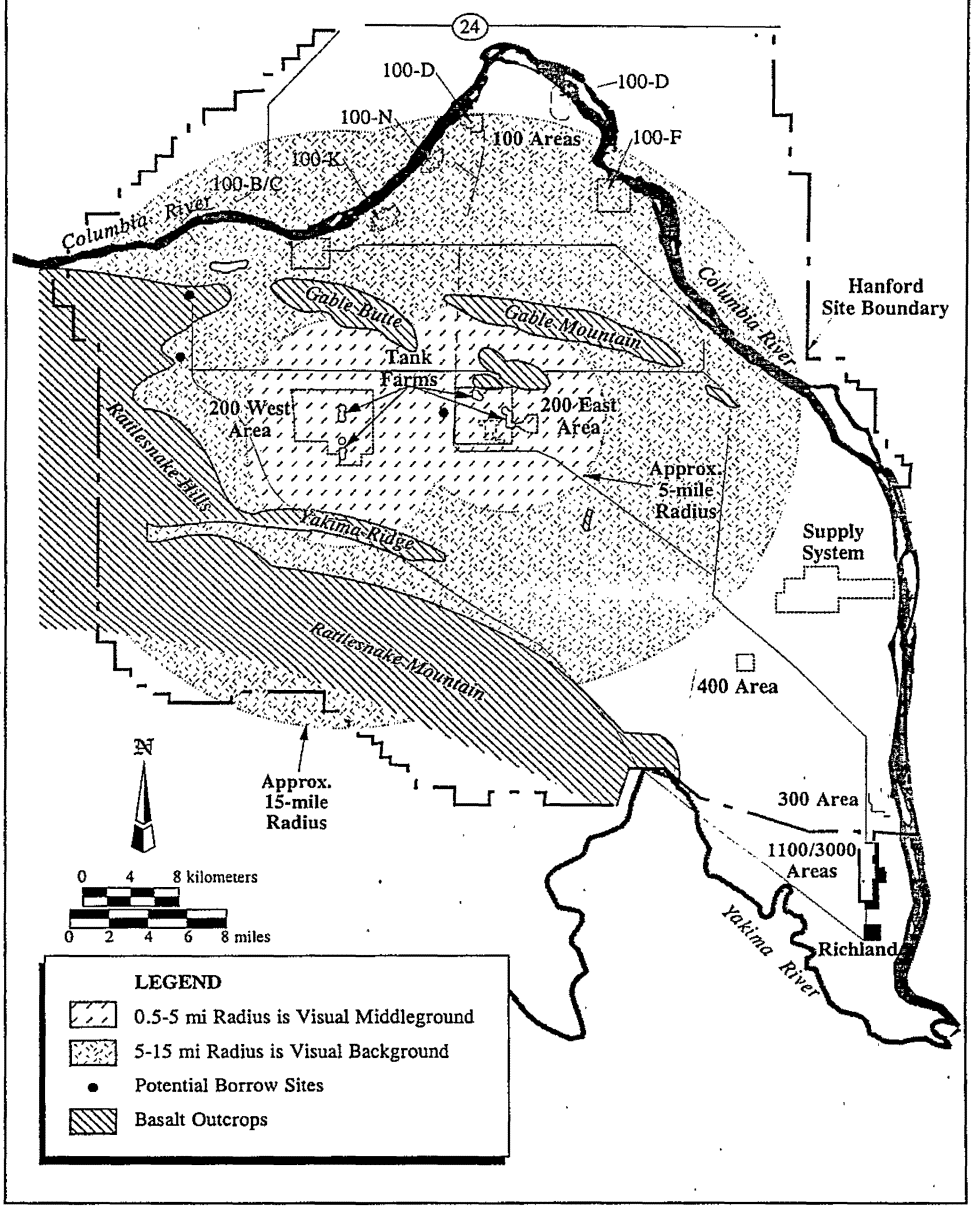
I.8.2 POTENTIAL VIEWING AREAS

For purposes of study and mapping, viewing areas are generally divided into four distance zones; the foreground, within 0.8 km (0.5 m); the middleground, from 0.8 km to 8 km (0.5 to 5 mi); the background, from greater than 8 to 24 km (5 to 15 mi); and seldom seen areas that are either beyond 24 km (15 mi) or are unseen because of topography (Figure I.8.2.1).

Hanford Site facilities can be seen from elevated locations such as Gable Mountain, Gable Butte, and Rattlesnake Mountain, which are used by Native Americans for religious purposes, and from offsite locations including State Routes 240 and 24 and the Columbia River. Because of terrain features, distances involved, the size of the Hanford Site, and the size of the individual facilities, not all facilities are visible from the highways or the Columbia River.

Facilities in the 200 East Area are in the interior of the site and cannot be seen from the Columbia River or State Route 24. Large facilities in the 200 East Area may be visible from State Route 240 only as distant background more then 8 km (5 mi) away. Facilities in the 200 West Area can be seen by travelers on an approximately 11 km (7 mi) segment of State Route 240 south of the Yakima Barricade. For these viewers the facilities are in the visual middleground (0.8 to 8 km [0.5 to 5 mi] away). Facilities in the 200 West Area cannot be seen from the Columbia River. Facilities throughout the 200 Areas are visible from elevated locations such as Gable Mountain, Gable Butte, and Rattlesnake Mountain.

Figure I.8.2.1 Potential Viewing Areas of 200 East and 200 West Areas



The potential Vernita Quarry borrow site is situated on a basalt outcrop immediately adjacent to State Route 24. The basalt resource is exposed in basalt cliffs adjacent to the highway and past quarry operations are highly visible. Quarry activities at the site would be visible from the Vernita Bridge, the Hanford Reach, and the Wahluke Slope north of the Columbia River. The quarry would also be readily observed from State Route 24 leading south from the Vernita Bridge. The potential McGee Ranch borrow site would be located west and north of State Route 24 in slightly rolling terrain. The borrow site would be readily visible from State Route 24 south and east of the borrow site. The potential Pit 30 borrow site is located between the 200 East and 200 West Areas and is only visible offsite from elevated locations.

I.9.0 NOISE

Noise as defined by Washington State constitutes the intensity, duration, and character of sounds from any and all sources (WAC 173-60). Sound is produced when a noise source induces vibrations into the surrounding air causing fluctuations in atmospheric pressure. Decibels (dB) are units of sound pressure used to measure changes in atmospheric pressure caused by the vibrations. Primary factors that influence the measurement of noise in ambient air are frequency and duration. The normal human auditory system cannot clearly discern sounds below 100 Hz (hertz or Hz is a measure of frequency or pitch) or substantially above 10,000 Hz. Sound occurring outside this range is not generally perceived as noise. Researchers have developed an A-weighted noise scale (dBA) to describe sounds emanating in those frequencies that are most readily detected by normal human hearing. Table I.9.0.1 lists some common levels of sound and their corresponding dBA levels. Sound duration is another important factor in determining cumulative noise impacts. Noise levels often are reported as the equivalent sound level (L_{eq}) and expressed as a weighted average (dBA) over a specified period of time; the L_{eq} integrates noise levels over time and expresses them as steady-state continuous sound levels.

I.9.1 REGULATORY CONTEXT AND PREVIOUS NOISE STUDIES

The Hanford Site (including its unoccupied areas) is classified as a Class C Environmental Designation for Noise Abatement by Washington State on the basis of industrial activities (Table I.9.1.1). Because they are neither Class A (residential) nor Class B (commercial), unoccupied Hanford Site areas are also classified as Class C areas.

Because of the remoteness of the Hanford Site, only a limited number of studies have been conducted that document environmental noise levels. Two sources of measured environmental noise at Hanford Site are 1) measurements made in 1981 during Hanford Site characterization of the Skagit/Hanford Nuclear Power Plant Site; and 2) noise measurements at five Hanford Site locations performed in 1987 as part of the Basalt Waste Isolation Project.

I.9.1.1 Skagit/Hanford Studies

During preconstruction measurements of environmental noise associated with the Skagit/Hanford Nuclear Power Plant Site, 15 sites were monitored and noise levels ranged from 30 to 65 dBA (L_{eq}). The values for isolated areas ranged from 30 to 38.8 dBA (L_{eq}). Measurements taken at the proposed reactor sites ranged from 50.6 to 64 dBA. Measurements taken along the Columbia River near the

Table I.9.0.1 Common Sounds and Corresponding Noise Levels

Common Sounds	Sound Level (dBA)	Loudness
Air Raid Siren	140	Uncomfortable
Subway	100	Very Loud
Gas Lawn Mower at 0.9 m (3 ft)	94	
Food Blender at 0.9 m (3 ft)	88	Loud
Garbage Disposal	80	
Inside an Automobile at 64.4 km/hr (40 mi/hr)	75	Moderate
Normal Speech	60	
Outside an Automobile at 61 m (200 ft)	55	
Private Office	50	Quiet
Library	35	
Quiet Rural Nighttime	25	Very Quiet
Whisper	20	
Threshold of Hearing	5	Barely Audible

Notes:
dBA = decibels on the A scale
km/hr = kilometers per hour
mi/hr = mile per hour
Source: Bell 1973

Table I.9.1.1 Applicable State Noise Limitations for the Hanford Site [1]

Environmental Designation for Noise Abatement		Maximum Allowable Noise Level in L_{eq} (dBA)
Source Area	Receptor Area	
Class C (industrial)	Class A (residential)	60 (day) 50 (night)
	Class B (commercial)	65 (day)
	Class C (industrial)	70 (day)

Notes:
[1] Based on source and receptor environmental designation for noise abatement designation.
L_{eq} = equivalent sound level
Source: WAC 173-60-040, DOE 1991

proposed intake structures were 47.7 and 52.1 dBA, as compared to noise levels of 45.9 dBA measured at a more remote location about 5 km (3 mi) upstream from the intake structures. By comparison, community noise levels in North Richland (at Horn Rapids Road and the Bypass Highway) were 60.5 dBA (NRC 1982).

I.9.1.2 Basalt Waste Isolation Project Studies

As part of the investigation for proposed Basalt Waste Isolation Project at the Hanford Site, background noise levels were determined at five locations. Noise levels can be expressed as L_{eq} for 24 hours (L_{eq}-24). Based on information provided in Cushing (Cushing 1994), wind was identified as the primary contributor to background noise levels with winds exceeding 19 km/hr (12 mi/hr), substantially impacting noise levels. As a result, it was concluded that background noise levels in undeveloped areas at the Hanford Site can best be described as having a mean L_{eq}-24 of 24 to 36 dBA. Periods of high wind, which normally occur in the spring; would elevate background noise levels.

I.9.1.3 Noise Levels of Hanford Field Activities

To protect Hanford Site workers and to comply with Occupational Safety and Health Administration standards for noise in the workplace, the Hanford Environmental Health Foundation monitors noise levels resulting from routine operations performed at the Hanford Site (DOE 1991 and Cushing 1992). Occupational sources of noise propagated in the field are summarized in Table I.9.1.2. These levels are reported because operations such as well sampling are conducted in the field away from established industrial areas and have the potential for contributing to environmental noise and disturbing sensitive wildlife.

Table I.9.1.2 Monitored Levels of Noise Propagated from Outdoor Activities at the Hanford Site [1]

Activity	Average Noise Level (dB)	Maximum Noise Level (dB)	Year Measured
Water Wagon Operation	104.5	111.9	1984
Well Sampling	74.8 to 78.2		1987
Truck	78 to 83		1989
Compressor	88 to 90		
Generator	93 to 95		
Well Drilling, Well 32-2	98 to 102	102	1987
Well Drilling, Well 32-3	105 to 11	120 to 125	1987
Well Drilling, Well 33-29	89 to 91		1987
Pile Driver (diesel 5 ft from source)	118 to 119		
Tank Farm Filter Building (30 ft from source)	86		1976

Notes:
[1] Noise levels measured in decibels (dB).
Source: Cushing 1992, DOE 1991

I.9.2 HANFORD SITE NOISE CONDITIONS

Existing noise conditions produced by current, routine operations at the Hanford Site do not violate any Federal or State standards. Measurements show that even near the current operating structures along the Columbia River noise levels are less than experienced in part of the community of Richland (less than 52.1 dBA versus 60.5 dBA). Noise levels measured near intake structures at the Columbia River

are well within the 60 dBA tolerance levels for daytime residential use. Five km (3 mi) upstream of the intake structures noise levels fell well within levels suited for daytime and nighttime residential use.

Moreover, the remoteness of the main areas of Hanford Site industrial activities from population centers means that there are no offsite populations within auditory range of Site industrial activities. However, Affected Tribal Nations use Site locations such as Gable Mountain for religious purposes.

I.10.0 TRANSPORTATION

The Tri-Cities area is served by air, rail, water, and road transportation networks. The majority of air passenger and freight services goes through the Tri-Cities Airport, located in Pasco (Cushing 1992). In addition, two smaller airports serving general aviation aircraft are located in Richland and Kennewick. No airport facilities are located on the Hanford Site.

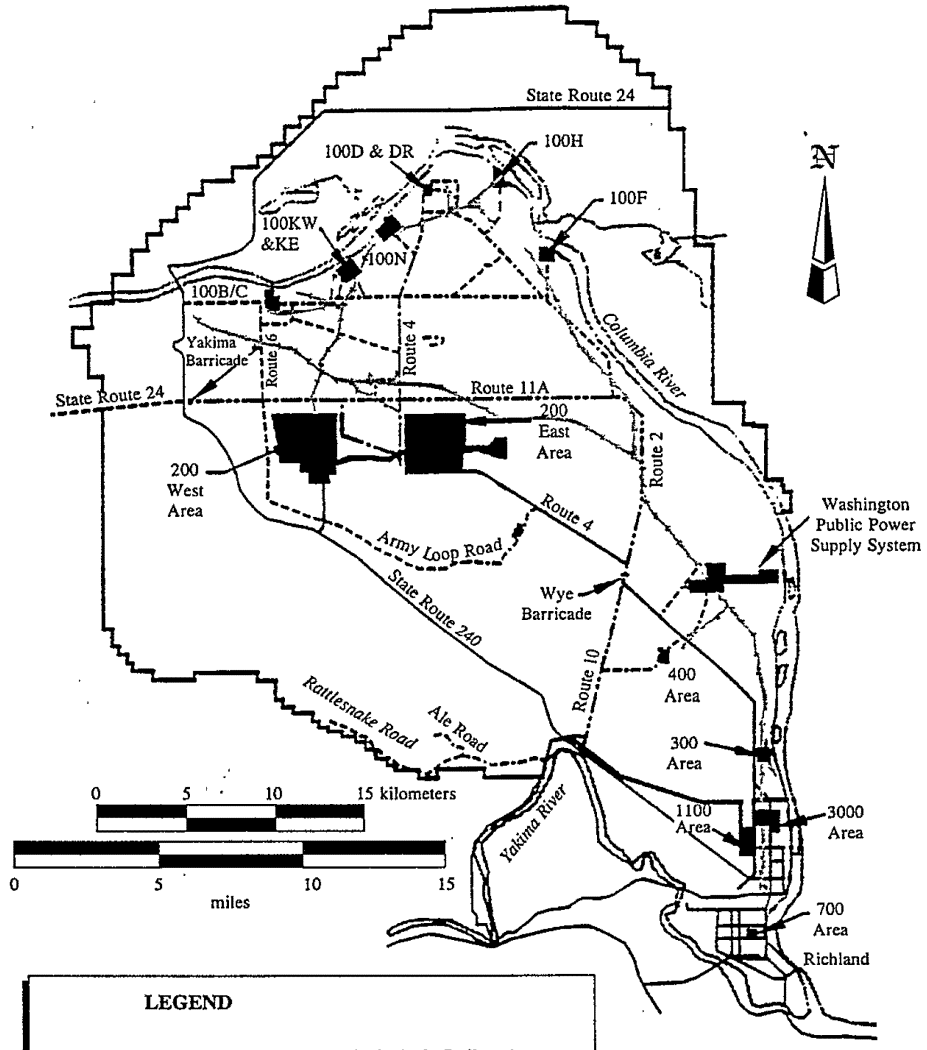
Water-borne transportation is accommodated by docking facilities at the Ports of Benton, Kennewick, and Pasco (Cushing 1992). The commercial waterways of the Snake and Columbia Rivers provide access to the deep-water ports of Portland, Oregon and Vancouver, Washington. The Port of Benton is the port-of-call for all vessel traffic to the Hanford Site.

The Hanford Site rail system consists of about 210 km (130 mi) of railroad track. Approximately 140 km (87 mi) of the system are considered in service to active Site facilities. Approximately 64 km (40 mi) of track are in standby condition. The standby trackage serves Site areas that have no current rail shipping needs. Although the standby track is not currently maintained, it could be restored if needed. The Hanford Site rail system extends from the Richland Junction (at Columbia Center in Kennewick) south of the Columbia River where it joins the Union Pacific commercial railroad track, to an abandoned commercial right-of-way near the Vernita Bridge in the northern portion of the Site (Figure I.10.0.1). There are currently about 1,400 railcar movements annually Sitewide, transporting a wide variety of materials including fuels (e.g., coal and oil), hazardous process chemicals, and radioactive materials and equipment. Radioactive waste has been transported by rail on the Site without incident for many years (DOE 1995i).

Regional road transportation is provided by a number of major highways including State Routes 240 and 24 and U.S. Interstate Highway 82. State Routes 240 and 24 are both two-lane roads that traverse the Hanford Site. State Routes 240 is a north-south highway that skirts the easternmost side of the FEALE Reserve. State Routes 24 is an east-west highway located in the northern portion of the Hanford Site. These roads are maintained by Washington State (Cushing 1992).

A DOE-maintained road network within the Hanford Site provides access to the various work centers (Figure I.10.0.1). The majority of these roads are paved and are two lanes wide. The primary access roads on the Hanford Site are Routes 2, 4, 10, and 11A. The 200 East Area is primarily accessed by Route 4 South from the east and from Route 4 North off Route 11A from the north and from Route 11A for vehicles entering the Site at the Yakima Barricade. A new access road was opened in late 1994 to provide access directly to the 200 Areas from State Route 240. The 200 West Area is

Figure I.10.0.1 Hanford Site Transportation Network



SOURCE: Adapted from DOE 1994a

primarily accessed from Route 6 off Route 11A from the north. Public access to the 200 Areas and interior locations of the Hanford Site has been restricted by guarded gates at the Wye Barricade (at the intersection of Routes 10 and 4) and the Yakima Barricade (at the intersection of State Route 240 and Route 11A). None of the previously listed roadways have experienced any substantial congestion except Route 4 (WHC 1994c).

Route 4 carries most of the traffic from the City of Richland to the 200 Areas. Traffic volumes during shift changes at the Hanford Site create severe traffic congestion. July 1994 traffic counts along Route 4 South just to the west of the Wye Barricade showed an average daily traffic (ADT) of approximately 9,200 vehicles, with morning peak hour volumes of nearly 2,400. By mid-1995 with reductions in Site employment, and the opening of the State Route 240 Access Road (Beloit Avenue), morning peak hour traffic had declined to slightly above 1,700 (Rogers 1995). Farther to the southeast, near the 1100 Area where Route 4 becomes Stevens Road, the 1992 ADT was approximately 24,800 with a peak hour volume of over 2,900. Level of Service (LOS) is a qualitative measure of a roadway's ability to accommodate vehicular traffic, ranging from free flow conditions (LOS A) to extreme congestion (LOS F). LOS D is considered the upper end of acceptable LOS. A 1994 report indicated that Route 4 was operating at LOS E and a 1993 report indicated that Stevens Road was operating at LOS F (WHC 1994c and BFRC 1993). The factors indicated previously, namely, Site employment reductions, and the heavy use of the new State Route 240 Access Road (peak hour volume of nearly 900 vehicles by mid-1995), have reduced the traffic congestion in these areas (Rogers 1995).

Traffic counts along Route 11A, which is just to the east of the Yakima Barricade off of State Route 240, show an ADT of approximately 1,260. Traffic counts along Route 10, just to the north of its terminus at State Route 240, show an ADT of approximately 2,440 (WHC 1994c).

I.11.0 RADIOLOGICAL ENVIRONMENT: OVERVIEW AND POTENTIAL RADIATION DOSES FROM 1994 HANFORD SITE OPERATIONS

This section provides a brief introduction to the subject of radioactivity and to some of the common terms used in radiological health evaluation. It also summarizes 1994 data on radiation doses from operations at the Hanford Site and estimates the potential future fatal cancers attributable to these radiation exposures.

I.11.1 INTRODUCTION TO RADIOACTIVITY

Radioactivity is a broad term that refers to changes in the nuclei of atoms that release radiation. Radiation is an energetic ray or energetic particle. For ionizing radiation, the ray or particle has enough energy to cause changes in the chemical structure of the materials it strikes. These chemical structure changes are the mechanisms by which radiation can cause biological damage to humans.

Radiation comes from many sources, some natural and some man-made. People have always been exposed to natural or background radiation. Natural sources of radiation include the sun, and radioactive materials present in the earth's crust, in building materials and in the air, food, and water. Natural radioactivity can even be found within the human body. Some sources of ionizing radiation

have been created by people for various uses or as by products of these activities. These sources include nuclear power generation, medical diagnosis and treatment, and nuclear materials related to nuclear weapons.

Radioactive waste is a result of the use and production of radioactive materials. At the Hanford Site, DOE manages radioactive waste that was generated primarily by the production of plutonium for nuclear weapons. These waste is classified as low-activity, high-level, or transuranic. When radioactive waste is combined with hazardous chemical wastes, it is referred to as mixed waste. High-level waste is the most dangerous type of radioactive waste and requires extensive shielding by materials such as lead and concrete and special handling. Transuranic waste is material contaminated with radioactive elements heavier than U. While long lasting, transuranic waste does not require the same degree of isolation as high-level waste. Low-activity waste is generally the least dangerous type of radioactive waste and requires fewer measures to isolate it from people and the environment. Depending on the particular radioactive material involved, radioactive waste can be harmful and thus require isolation for up to hundreds or even thousands of years. Plutonium-contaminated waste will be radioactive for thousands of years. Radioactive Cs, on the other hand, will be virtually gone in 250 years.

I.11.2 COMMON TERMS IN RADIOLOGICAL HEALTH EVALUATIONS

Radiation dose to individuals is usually expressed in rem or millirem (mrem), which is one-thousandth of a rem. The rem is a measure of the biological effects of ionizing radiation on people. It is estimated that the average individual in the United States receives an annual dose of about 300 millirem from all natural sources. The collective radiation dose to a population is termed the person-rem, which is calculated by adding up the radioactive dose to each member of the population.

Any dose of radiation can damage body cells. However, at low levels, such as are received from a medical x-ray, the damage to cells is so slight that the cells can usually repair themselves or can be replaced by the regeneration of healthy cells. Radiation exposures are often classified as acute (a dose received over a short time) or chronic (a dose received over a long time). Chronic doses are usually less harmful than acute doses because the body has time to repair or replace damaged cells; however, even low doses can have harmful effects.

Impacts from radiation exposure often is expressed using the concept of risk. The most substantial radiation-related risk is the potential for developing cancers that may cause death in later years. This delayed effect is measured in latent (future) cancer fatalities. The risk of a latent cancer fatality is estimated by converting radiation doses into possible numbers of cancer fatalities. For an entire exposed population group, the latent cancer fatality numerical value is the chance that someone in that group would develop an additional cancer fatality in the future because of the radiation exposure, (i.e., a cancer fatality that otherwise would not occur).

Radiological risk evaluations often refer to the maximally-exposed individual. This would be the member of the pubic or a worker who receives the highest possible dose in a given situation. As a

practical matter, the maximally-exposed individual likely would be a person working with radiological or hazardous materials.

I.11.3 POTENTIAL RADIATION DOSES AND LATENT CANCER FATALITIES FROM 1995 HANFORD SITE OPERATIONS

Each year potential radiation doses to the public are calculated for exposure to Hanford Site effluents. The 1995 information presented here was taken from the Hanford Site Environmental Report for calendar year 1995 (PNL 1996). Doses are calculated from reported effluent releases, from environmental surveillance results, and from information about operations at specific Hanford Site facilities.

The 1995 potential dose from Hanford Site operations to the hypothetical maximally-exposed individual member of the public was 0.02 mrem, compared to 0.05 mrem reported for 1994 (PNL 1996). The current DOE radiation dose limit for an individual member of the public is 100 mrem per year, and as stated previously, the national average dose from natural sources is 300 mrem per year. Thus, the maximally-exposed individual potentially received a small fraction of 1 percent of both the DOE dose limit and the natural background average dose.

The total population of the surrounding area (380,000 persons) received a potential dose from 1995 Hanford Site operations of 0.3 person-rem. The 1994 average dose to an individual member of the public was 0.0009 mrem. This is 0.001 percent of the 100 mrem/year standard and 0.0003 percent of the 300 mrem per year received from typical natural sources. Clean Air Act requirements specify a maximum radiation dose through the air of 10 mrem per year. The 1995 air emissions from the Hanford Site were 0.006 mrem, which is less than 0.1 percent of the 10 mrem standard.

Based on a dose-to-risk conversion of 0.0005 latent cancer fatalities per rem (each rem equates to 0.0005 latent cancer fatalities), there would be 0.0001 latent cancer fatalities in the general public attributable to exposure to effluents from 1995 Hanford Site operations.

APPENDIX I
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Appendix J
Consultation Letters

APPENDIX J
CONSULTATION LETTERS

The National Environmental Policy Act (NEPA) and the Washington State Environmental Policy Act (SEPA) implementing regulations require that Federal agencies consult with Federal, State, and local agencies and Tribes (as appropriate) regarding proposed actions addressed in Environmental Impact Statements (EIS). The U.S. Department of Energy (DOE) and the Washington State Department of Ecology (Ecology) have performed this consultation through informal meetings, discussions, and correspondence. DOE and Ecology have provided formal requests for information and consultations to Federal, State, and local agencies and Tribes that may have regulatory jurisdiction or special interest in the issues and alternatives to be addressed in the TWRS EIS. This appendix contains copies of the consultation letters sent by DOE and Ecology to agencies and Tribes and the responses by those agencies and Tribes.

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DEPARTMENT OF ECOLOGY
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October 30, 1995

Mr. Robert Turner
Director
Washington State Department of Fish and Wildlife
600 Capital Way North
Olympia, WA 98501-1091

Dear Mr. Turner:

Re: DOE HANFORD TANK WASTE REMEDIATION SYSTEM ENVIRONMENTAL IMPACT STATEMENT (TWRS EIS)

The U.S. Department of Energy (USDOE) and the Washington State Department of Ecology (Ecology) are jointly preparing the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS). The TWRS EIS will address USDOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the USDOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in USDOE's National Environmental Policy Act process and in accordance with the State Environmental Policy Act, USDOE and Ecology invite the Department of Fish and Wildlife (WDF&W) to identify specific issues and concerns your Department believes should be addressed in the TWRS EIS. To facilitate incorporation of WDF&W input into the Draft EIS, please provide any response in writing within 30 days.

If you have any questions, or to coordinate your response to this letter please contact: Geoff Tallent, TWRS EIS Project Lead, Washington Department of Ecology, P.O. Box 47600, Olympia, WA 98504-7600. Phone number (360) 407-7112.

Thank you for your interest in this matter.

Sincerely,

Mike Wilson, Manager
Nuclear Waste Program

MW:GT:djb

cc: Martin Baker, WDF&W - Olympia
Ted Clausing, WDF&W - Yakima
Jay McConnaughey, WDF&W - Hanford Site
Dave Nichols, Jacobs Engineering
Project File

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RECEIVED
NOV 22 1995

State of Washington
DEPARTMENT OF FISH AND WILDLIFE
Mailing Address: 600 Capitol Way N. Olympia WA 98501-1091 · (206) 902-2200; TDD (206) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia, WA

November 17, 1995

Mr. Mike Wilson
Nuclear Waste Program Manager
Washington Department of Ecology
P.O. Box 47600
Olympia, WA 98504-7600

Dear Mr. Wilson:

Thank you for the formal consultation opportunity you have given Washington Department of Fish and Wildlife concerning the DOE Hanford Tank Waste Remediation System Environmental Impact Statement (TWRS EIS). We have no additional substantive comments at this time. However, we would like to commend Ecology for the close coordination maintained with our technical staff throughout this EIS process. We appreciate the extra efforts Geoff Tallent of your staff has been making to take our concerns into consideration.

Additional technical questions should continue to be addressed by Jay McConnaughey, biologist for the Hanford Site, who works out of your Kennewick Office. We look forward to reviewing the Draft Environmental Impact Statement when it is released.

Sincerely,

Martin Baker
Assistant Director
Habitat Program

cc: Gordy Zillges
Ted Clausing
Jay McConnaughey

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600
(360) 407-6000 • TDD Only (Hearing Impaired) (360) 407-6006

October 30, 1995

Mr. Jerry Alb
Washington State Department of Transportation
Environmental Affairs Office
310 Maple Park East, P.O. Box 47331
Olympia, WA 98504-7301

Dear Mr. Alb:

Re: DOE HANFORD TANK WASTE REMEDIATION SYSTEM ENVIRONMENTAL IMPACT STATEMENT (TWRS EIS)

The U.S. Department of Energy (USDOE) and the Washington State Department of Ecology (Ecology) are jointly preparing the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS). The TWRS EIS will address USDOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the USDOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in USDOE's National Environmental Policy Act process and in accordance with the State Environmental Policy Act, USDOE and Ecology invite the Department of Transportation to identify specific issues and concerns your Department believes should be addressed in the TWRS EIS. To facilitate incorporation of DOT input into the Draft EIS, please provide any response in writing within 30 days.

If you have any questions, or to coordinate your response to this letter please contact: Geoff Tallent, TWRS EIS Project Lead, Washington Department of Ecology, P.O. Box 47600, Olympia, WA 98504-7600. Phone number (360) 407-7112.

Thank you for your interest in this matter.

Sincerely,

Mike Wilson, Manager
Nuclear Waste Program

MW:GT:djb

cc: Dave Nichols, Jacobs Engineering
Project File

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STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
P.O. Box 47600 • Olympia, Washington 98504-7600
(360) 407-6000 • TDD Only (Hearing Impaired) (360) 407-6006

October 30, 1995

Mr. Eric Slagle
Assistant Secretary of Environmental Health
Washington State Department of Health
AIRDUSTRIAL Center, Building #2
P.O. Box 47821
Olympia, WA 95804-7821

Dear Mr. Slagle:

Re: DOE HANFORD TANK WASTE REMEDIATION SYSTEM ENVIRONMENTAL IMPACT STATEMENT (TWRS EIS)

The U.S. Department of Energy (USDOE) and the Washington State Department of Ecology (Ecology) are jointly preparing the Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS). The TWRS EIS will address USDOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the USDOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in USDOE's National Environmental Policy Act process and in accordance with the State Environmental Policy Act, USDOE and Ecology invite the Department of Health (DOH) to identify specific issues and concerns your Department believes should be addressed in the TWRS EIS. To facilitate incorporation of DOH input into the Draft EIS, please provide any response in writing within 30 days.

If you have any questions, or to coordinate your response to this letter please contact Geoff Tallent, TWRS EIS Project Lead, Washington Department of Ecology, P.O. Box 47600, Olympia, WA 98504-7600. Phone number is (360) 407-7112.

Thank you for your interest in this matter.

Sincerely,

Michael A. Wilson

Mike Wilson, Manager
Nuclear Waste Program

MW:JT:djb

cc: T.R. Strong, DOH
Craig Lawrence, DOH
Dave Nichols, Jacobs Engineering
Project File

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-190

Mr. Russell Jim, Manager
Environmental Restoration/
Waste Management Program
Confederated Tribes and Bands
of the Yakama Indian Nation
P.O. Box 151
Toppenish, Washington 98948

Dear Mr. Jim:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

Consistent with various Federal and State laws, including the National Historic Preservation Act and the Native American Religious Freedom Act, among others, DOE and Ecology will analyze the proposed TWRS action and alternatives in terms of their impacts on cultural resources and traditional cultural properties. The EIS also will address a wide range of environmental, human health risk, and socioeconomic issues.

Based on these Federal laws and as part of DOE's National Environmental Policy Act process and Ecology's State Environmental Policy Act and the DOE American Indian Tribal Governmental Policy, DOE and Ecology requests formal consultation with the Yakama Nation so that the Nation can identify and comment on specific issues and concerns that it feels should be addressed in the TWRS EIS. To facilitate incorporation of the Yakama Nation's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please recognize that this consultation letter is only part of the overall process to which DOE and Ecology is committed to for involving the Yakama Nation the TWRS EIS. The Draft and Final EISs, of course, will be formally provided for your review and comment.

Further, DOE expects to consult with the Tribe throughout the TWRS EIS process. For example, DOE is prepared to have consultation meetings or briefings where you feel that such meetings or briefings will be useful to address specific issues of importance to the Tribe. DOE and Ecology would

welcome the opportunity to have such a meeting during the week of December 4-8, 1995, prior to the release of the draft EIS. To arrange a meeting date, time and location I will contact you by November 15, 1995.

As other useful information and consultation activities occur to you, please notify us and DOE will try to accommodate your request. Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-187

Mr. J. R. Wilkinson, Manager
Hanford Program
Confederated Tribes of the
Umatilla Indian Reservation
Pendleton, Oregon 97801

Dear Mr. Wilkinson:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

Consistent with various Federal laws, including the National Historic Preservation Act and the Native American Religious Freedom Act, among others, DOE will analyze the proposed TWRS action and alternatives in terms of their impacts on cultural resources and traditional cultural properties. The EIS also will address a wide range of environmental, human health risk, and socioeconomic issues.

Based on these Federal laws and as part of DOE's National Environmental Policy Act process and the DOE American Indian Tribal Governmental Policy, DOE requests formal consultation with the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) so that the Tribe can identify and comment on specific issues and concerns that it feels should be addressed in the TWRS EIS. To facilitate incorporation of CTUIR's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please recognize that this consultation letter is only part of the overall process to which DOE is committed for involving the CTUIR in the TWRS EIS. The draft and final EISs, of course, will be formally provided for your review and comment.

Further, DOE expects to consult with the Tribe throughout the TWRS EIS process. For example, DOE is prepared to have consultation meetings or briefings where you feel that such meetings or briefings will be useful to address specific issues of importance to the Tribe. DOE and Ecology would welcome the opportunity to have such a meeting during the week of December 4-8, 1995, prior to the release of the draft EIS. To arrange a meeting date, time and location I will contact you by November 15, 1995.

As other useful information and consultation activities occur to you, please notify us and DOE will try to accommodate your request.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-179

Ms. Donna Powaukee, Manager
Environmental Restoration/
Waste Management Program
The Nez Perce Tribe
P.O. Box 365
Lapwai, Idaho 83540

Dear Ms. Powaukee:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

Consistent with various Federal laws, including the National Historic Preservation Act and the Native American Religious Freedom Act, among others, DOE will analyze the proposed TWRS action and alternatives in terms of their impacts on cultural resources and traditional cultural properties. The EIS will also address a wide range of environmental, human health risk, and socioeconomic issues.

Based on these Federal laws and as part of DOE's National Environmental Policy Act process and the DOE American Indian Tribal Governmental Policy, DOE requests formal consultation with the Nez Perce Tribe so that the Tribe can identify and comment on specific issues and concerns that it feels should be addressed in the TWRS EIS. To facilitate incorporation of the Nez Perce Tribe's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please recognize that this consultation letter is only part of the overall process to which DOE is committed to involving the Nez Perce Tribe in the TWRS EIS. The Draft and Final EISs will of course be formally provided for your review and comment.

Further, DOE expects to consult with the Tribe throughout the TWRS EIS process. For example, DOE is prepared to have consultation meetings or briefings where you feel that such meetings or briefings will be useful to address specific issues of importance to the Tribe. DOE and Ecology would

welcome the opportunity to have such a meeting during the week of December 4-8, 1995, prior to the release of the draft EIS. To arrange a meeting date, time and location I will contact you by November 15, 1995.

As other useful information and consultation activities occur to you, please notify us and DOE will try to accommodate your request. Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-191

Mr. Richard Buck
Wanapum People
Grant County Public Utility District
P.O. Box 878
Ephrata, Washington 98823

Dear Mr. Buck:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

Consistent with various Federal laws, including the National Historic Preservation Act and the Native American Religious Freedom Act, among others, DOE and Ecology will analyze the proposed TWRS action and alternatives in terms of their impacts on cultural resources and traditional cultural properties. The EIS also will address a wide range of environmental, human health risk, and socioeconomic issues.

Based on these Federal laws and as part of DOE's National Environmental Policy Act process and Ecology's State Environmental Policy Act and the DOE American Indian Tribal Governmental Policy, DOE and Ecology requests formal consultation with the Wanapum People so that the Wanapum People can identify and comment on specific issues and concerns that it feels should be addressed in the TWRS EIS. To facilitate incorporation of the Wanapum People's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please recognize that this consultation letter is only part of the overall process to which DOE and Ecology are committed to for involving the Wanapum People in the TWRS EIS. The Draft and Final EISs, of course, will be formally provided for your review and comment.

Further, DOE expects to consult with the Wanapum People throughout the TWRS EIS process. For example, DOE is prepared to have consultation meetings or briefings where you feel that such meetings or briefings will be useful to address specific issues of importance to the Wanapum People. DOE and Ecology would welcome the opportunity to have such a meeting during the week of December 4-8, 1995, prior to the release of the draft EIS.

To arrange a meeting date, time and location I will contact you by November 15, 1995.

As other useful information and consultation activities occur to you, please notify us and DOE will try to accommodate your request.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-180

Ms. Anne Aldrich, Area Manager
U.S. Bureau of Land Management
1103 North Fancher
Spokane, Washington 99212-1275

Dear Ms. Aldrich:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in DOE's National Environmental Policy Act process, DOE invites the U.S. Bureau of Land Management (BLM) to identify specific issues and concerns that the agency feels should be addressed in the TWRS EIS. To facilitate incorporation of BLM comments into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

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United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Spokane District Office
1103 N. Fancher
Spokane, Washington 99212-1275
(509) 536-1200

IN REPLY REFER TO:
2300 (130)

December 12, 1995

Ms. Carolyn C Haass, NEPA Document Manager
U.S. Department of Energy
P.O. Box 550 MSIN S7-51
Richland, WA 99352-0550

Dear Ms. Haass:

Thank you for providing the Bureau of Land Management (BLM) the opportunity to review the Tank Waste Remediation System Environmental Impact Statement. We appreciate being kept informed of actions being considered at Hanford that might impact BLM administered lands withdrawn for Hanford operations since those lands may be returned to the Bureau.

In this case, however, there are no remaining BLM lands in the 200 Areas so we will not be commenting on the EIS.

Again, we appreciate the information and wish to remain on the mailing list for future documents as they will likely involve BLM.

Sincerely,

Ann Aldrich
Border Area Manager

15:D

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-181

Mr. Dave Fredrick
U.S. Fish and Wildlife Service
Washington State Office
3704 Griffin Lane, S.E., Suite 102
Olympia, Washington 98501-2192

Dear Mr. Fredrick:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives in terms of a wide variety of issues, including biological and ecological resources. Consistent with the Endangered Species Act, DOE requests that the U.S. Fish and Wildlife Service (USFWS) provide information on the presence of threatened and endangered plant and animal species, both listed and proposed, in the vicinity of the TWRS project area (the Hanford Site's Central Plateau, depicted on the attached map). Information on the habitats of these species also would be appreciated. DOE also requests any information the USFWS can provide on other species of concern that are known to occur in the TWRS project area.

As part of DOE's National Environmental Policy Act process, DOE also invites USFWS to identify any additional issues and concerns that your agency feels should be addressed in the EIS. To facilitate incorporation of USFWS input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy,
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

NOV 08 1995

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

Attachment

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Upper Columbia River Basin Field Office
11103 E. Montgomery Drive, Suite #2
Spokane, WA 99206

December 12, 1995

Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
PO Box 550 MSIN S7-51
Richland, Washington 99352-0550

FWS Reference: 1-9-96-SP-028

Dear Ms. Haass:

This is in response to your letter dated November 8, 1995, and received by the Fish and Wildlife Service (Service) on November 14, 1995. Enclosed is a list of listed threatened and endangered species, and candidate species (Attachment A), that may be present within the area of the proposed Tank Waste Remediation System in Benton County, Washington. The list fulfills the requirements of the Service under Section 7(c) of the Endangered Species Act of 1973, as amended (Act). We have also enclosed a copy of the requirements for Department of Energy (DOE) compliance under the Act (Attachment B).

Should the biological assessment determine that a listed species is likely to be affected (adversely or beneficially) by the project, the DOE should request Section 7 consultation through this office. If the biological assessment determines that the proposed action is "not likely to adversely affect" a listed species, the DOE should request Service concurrence with that determination through the informal consultation process. Even if the biological assessment shows a "no effect" situation, we would appreciate receiving a copy for our information.

Candidate species are included simply as advance notice to federal agencies of species which may be proposed and listed in the future. However, protection provided to candidate species now may preclude possible listing in the future. If early evaluation of your project indicates that it is likely to adversely impact a candidate species, the DOE may wish to request technical assistance from this office.

In addition, please be advised that federal and state regulations may require permits in areas where wetlands are identified. You should contact the Seattle District of the U.S. Army Corps of Engineers for federal permit requirements and the Washington State Department of Ecology for state permit requirements.

The Service has provided scoping comments in a letter addressed to Mr. Don Alexander and Mr. Geoff Tallent, dated March 16, 1994. The letter from you requesting information on the presence of threatened and endangered plant and animal species also invited the Service to identify any additional issues and concerns which should be addressed in this EIS. While it is difficult to provide meaningful comments prior to the release of the draft EIS, we make the following suggestions.

An EIS recently released by DOE developed several accident scenarios, but risk assessment was conducted only for human exposure. A risk assessment of environmental impacts from the accidental release of hazardous substances was not developed. We encourage the authors to ensure that risk assessment of environmental impacts in accident scenarios be included in this EIS.

We were informed in a recent briefing that the EIS proposes to conduct mitigation under a sitewide plan. The Biological Resources Mitigation Strategy (BRMiS), which is currently under development, has been plagued with delays and funding cuts throughout its existence. Even though the current draft of the BRMiS document is approaching completion, support for the project from various DOE programs has not been assured, and funding for implementation has not been acquired. The Service strongly recommends that the EIS commit to development and implementation of a project-specific Mitigation Action Plan in the event that the BRMiS has not been completed by the time facility construction is initiated.

Our previous letter addressed several habitat impact and mitigation issues. During the above mentioned briefing, we were informed that decisions regarding borrow sites would be made under the Hanford Remedial Action EIS. We recommend that the TWRS EIS commit to provide compensatory mitigation for any impacts to natural resources at the borrow sites even though the sites themselves have not been identified yet.

Finally, please note that Hanford issues are being handled out of our Upper Columbia River Basin Field Office in Spokane, Washington. Please send future correspondence and documents to this office.

Your interest in endangered species is appreciated. If you have additional questions regarding your responsibilities under the Act, please contact Linda Hallock at 509-921-0160, or about our comments, Liz Block at 509-765-6125.

Sincerely,

Robert J. Hallock

for Philip Laumeyer
Field Supervisor

LH

Enclosures

SE/DOE/FWS 1-9-96-SP-028/Benton

c: WDFW, Region 1

WNHP, Olympia

ATTACHMENT A

LISTED AND PROPOSED ENDANGERED AND THREATENED SPECIES AND CANDIDATE SPECIES WHICH MAY OCCUR IN THE VICINITY OF THE TANK WASTE REMEDIATION SYSTEM PROJECT IN BENTON COUNTY, WASHINGTON T13N R26E

FWS Reference: 1-9-96-SP-028

LISTED

Bald eagle *(Haliaeetus leucocephalus)* - Wintering bald eagles may occur in the vicinity from about October 31 through March 31. A communal roost site is known to occur in Section 6.

Major concerns that should be addressed in your biological assessment of project impacts to these listed species are:

1. Level of use of the project area by listed species.

2. Effect of the project on listed species' primary food stocks and foraging areas in all areas influenced by the project.

3. Impacts from project construction and implementation (e.g. increased noise levels, increased human activity and/or access, loss or degradation of habitat) which may result in disturbance to listed species and/or their avoidance of the project area.

DESIGNATED

None

PROPOSED

None

CANDIDATE

The following candidate species may occur in the vicinity of the project:

CATEGORY 2

Ferruginous hawk *(Buteo regalis)*
Fringed myotis (bat) *(Myotis thysanodes)*
*Loggerhead shrike *(Lanius ludovicianus)*
Northern sagebrush lizard *(Sceloporus graciosus graciosus)*
Olive-sided flycatcher *(Contopus borealis)*
Pale Townsend's (= western) big-eared bat *(Plecotus townsendii pallescens)*
Small-footed myotis (bat) *(Myotis ciliolabrum)*

Western burrowing owl *(Athene cunicularia hypugea)*
Western sage grouse *(Centrocercus urophasianus phaios)*
Yuma myotis (bat) *(Myotis yumanensis)*

*This species was erroneously omitted from the November 15, 1994 Animal Notice of Review

ATTACHMENT B

FEDERAL AGENCIES' RESPONSIBILITIES UNDER SECTIONS 7(a) AND 7(c) OF THE ENDANGERED SPECIES ACT OF 1973, AS AMENDED

SECTION 7(a) - Consultation/Conference

Requires:

1. Federal agencies to utilize their authorities to carry out programs to conserve endangered and threatened species;

2. Consultation with FWS when a federal action may affect a listed endangered or threatened species to ensure that any action authorized, funded, or carried out by a federal agency is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat. The process is initiated by the federal agency after it has determined if its action may affect (adversely or beneficially) a listed species; and

3. Conference with FWS when a federal action is likely to jeopardize the continued existence of a proposed species or result in destruction or an adverse modification of proposed critical habitat.

SECTION 7(c) - Biological Assessment for Construction Projects

Requires federal agencies or their designees to prepare a Biological Assessment (BA) for construction projects only. The purpose of the BA is to identify any proposed and/or listed species which is/are likely to be affected by a construction project. The process is initiated by a federal agency in requesting a list of proposed and listed threatened and endangered species (list attached). The BA should be completed within 180 days after its initiation (or within such a time period as is mutually agreeable). If the BA is not initiated within 90 days of receipt of the species list, please verify the accuracy of the list with our Service. No irreversible commitment of resources is to be made during the BA process which would result in violation of the requirements under Section 7(a) of the Act. Planning, design, and administrative actions may be taken; however, no construction may begin.

To complete the BA, your agency or its designee should: (1) conduct an onsite inspection of the area to be affected by the proposal, which may include a detailed survey of the area to determine if the species is present and whether suitable habitat exists for either expanding the existing population or potential reintroduction of the species; (2) review literature and scientific data to determine species distribution, habitat needs, and other biological requirements; (3) interview experts

including those within the FWS, National Marine Fisheries Service, state conservation department, universities, and others who may have data not yet published in scientific literature; (4) review and analyze the effects of the proposal on the species in terms of individuals and populations, including consideration of cumulative effects of the proposal on the species and its habitat; (5) analyze alternative actions that may provide conservation measures; and (6) prepare a report documenting the results, including a discussion of study methods used, any problems encountered, and other relevant information. Upon completion, the report should be forwarded to the Upper Columbia River Basin Field Office, 11103 E Montgomery Drive, Suite 2, Spokane, WA 99206.

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* "Construction project" means any major federal action which significantly affects the quality of the human environment (requiring an EIS), designed primarily to result in the building or erection of human-made structures such as dams, buildings, roads, pipelines, channels, and the like. This includes federal action such as permits, grants, licenses, or other forms of federal authorization or approval which may result in construction.

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-182

Mr. Stanley Speaks, Area Director
Bureau of Indian Affairs, Northwest Coast Area
911 Northeast 11th Avenue
Portlan, Oregon 97232-4169

Dear Mr. Speaks:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in DOE's National Environmental Policy Act process, DOE invites the Bureau of Indian Affairs (BIA) to identify specific issues and concerns that the agency feels should be addressed in the TWRS EIS. To facilitate incorporation of BIA input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-183

Mr. Robert Christiansen
Regional Environmental Officer
U.S. Department of Interior
Bureau of Reclamation
1160 North Curtiss Road
Boise, Idaho 83706-1234

Dear Mr. Christiansen:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of DOE's National Environmental Policy Act process, DOE invites your agency to identify specific issues and concerns that you feel should be addressed in the TWRS EIS. To facilitate incorporation of the Bureau of Reclamation's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

United States Department of the Interior

NATIONAL PARK SERVICE
Pacific Northwest Region
909 First Avenue
Seattle, Washington 98104-1060

IN REPLY REFER TO:

L7619(CCCSSO-RP)
Hanford Reach, WA-W&S

DEC 7 1995

Carolyn Haass
TWRS NEPA Document Manager
U.S. Department of Energy
Post Office Box 550
MSIN S7-51
Richland, Washington 99352-0550

Dear Ms. Haass:

Thank you for the opportunity to identify issues to be addressed in the environmental impact statement (EIS) being prepared for the planned Tank Waste Remediation System. Without a more complete description of the proposed project, we cannot provide anything more than a general overview of issues to be addressed. Our concerns center around potential impacts to the proposed wild and scenic river and national wildlife refuge. The EIS must address any impacts -- real and potential -- to the resources that make the river eligible for the National Wild and Scenic Rivers System and the upland eligible for the National Wildlife Refuge System. A complete description of these values -- including a free-flowing river and "outstandingly remarkable" resources -- can be found in the *Final Hanford Reach of the Columbia River Comprehensive River Conservation Study and Environmental Impact Statement* prepared by the National Park Service with the assistance of the U.S. Fish and Wildlife Service. If you do not already have a copy of this document, please let us know, and we would be happy to provide you with a copy. Due to an extremely limited supply, we would not be able to supply copies to your entire study team.

Once again, thank you for an early identification of issues that might impact the interests of the National Park Service. If you have any questions with regard to this letter or the potential river designations, please do not hesitate to contact Dan Haas at (206) 220-4120.

Sincerely,

Rory D. Westberg

Rory D. Westberg, Superintendent
Columbia Cascades System Support Office

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-184

Mr. Dirk Dunning
Oregon Department of Energy
625 Marion Street N.E.
Salem, Oregon 97310

Dear Mr. Dunning:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of DOE's National Environmental Policy Act process, DOE invites your agency to identify specific issues and concerns that you feel should be addressed in the TWRS EIS. To facilitate incorporation of the Oregon Department of Energy's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-185

Mr. Richard Truitt, Director
Environmental Health and Engineering
Portland Area Indian Health Service
1220 S.W. 3rd Avenue, Room 476
Portland, Oregon 92704

Dear Mr. Truitt:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of DOE's National Environmental Policy Act process, DOE invites your agency to identify specific issues and concerns that you feel should be addressed in the TWRS EIS. To facilitate incorporation of the Portland Area Indian Health Service's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS EIS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352
NOV 08 1995

95-PRI-186

Ms. Mary Thompson
State Historic Preservation Officer
Office of Archaeology and Historic
Preservations
Washington Departmentr of Community
Trade and Economic Development
P.O. Box 48343
Olympia, Washington 95804-8343

Dear Ms. Thompson:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 East or 200 West Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

In accordance with 36 CFR 800.4 and 35 CFR 800.4 (d) of the National Historic Preservation Act, DOE's Richland Operation Office (RL) has made a good faith effort to identify properties of potential prehistoric and historic significance in the areas where TWRS facilities are proposed for development. The TWRS facilities will be situated within the 200 East Area of the Central Plateau at the Hanford Site.

As indicated in letters from RL to your office dated August 25, 1994, and October 4, 1994 (Attachment), cultural resources surveys have been conducted in the areas that may be affected by the proposed action. DOE requests your determination whether these resources are eligible for inclusion on the National Register of Historic Places. Previous cultural resources literature and records searches, as well as Site surveys, indicate that no historic properties eligible for the National Register will be affected by the planned TWRS facilities.

Further, as part of DOE's National Environmental Policy Act process, DOE invites your agency to identify any additional issues and concerns that you feel should be addressed in the EIS. To facilitate incorporation of the Washington State Historic Preservation Office's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

As mentioned above, Ecology is co-preparer of the TWRS EIS with DOE. Please coordinate your response to this letter with Mr. Geoff Tallent, Ecology Project Manager for the TWRS EIS.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

Mr. Geoff Tallent, Project Manager
State of Washington
Department of Ecology
P.O. Box 47600
Olympia, Washington 98504-7600

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

Attachment

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-188

Mr. Charles Odegaard, Regional Director
National Park Service
National Park Service, Pacific Northwest
909 1st Avenue
Seattle, Washington 98104

Dear Mr. Odegaard:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed action and alternatives on a wide variety of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in DOE's National Environmental Policy Act process and Ecology's State Environmental Policy Act process, DOE and Ecology invites the National Park Service to identify specific issues and concerns that the agency feels should be addressed in the TWRS EIS. To facilitate incorporation of the National Park Service's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C. Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

NOV 08 1995

95-PRI-189

Mr. Forester Einarson
U.S. Army Corps of Engineers
Office of Environmental Policy
Pulaski Building, Room 7116
20 Massachusetts Avenue N.W.
Washington, D.C. 20314-1000

Dear Mr. Einarson:

THE U.S. DEPARTMENT OF ENERGY (DOE) TANK WASTE REMEDIATION SYSTEM (TWRS) ENVIRONMENTAL IMPACT STATEMENT (EIS)

The DOE and the Washington State Department of Ecology (Ecology) are jointly preparing the TWRS EIS. The TWRS EIS will address DOE's plans for safe management, treatment, storage, and disposal of radioactive, chemical, and mixed wastes stored in 177 underground storage tanks and of cesium and strontium wastes stored in capsules at the Waste Encapsulation Storage Facility. The tank wastes, strontium and cesium capsules, and the proposed TWRS project facilities, are all located in the 200 Areas of the Central Plateau at the DOE Hanford Site in Richland, Washington.

The TWRS EIS will address the impacts of the proposed actions and alternatives on a wide range of environmental, human health risk, and socioeconomic issues. As part of the intergovernmental consultation required in DOE's National Environmental Policy Act process and Ecology's State Environmental Policy Act process, DOE and Ecology invites the U.S. Army Corps of Engineers (USACE) to identify specific issues and concerns that the USACE feels should be addressed in the TWRS EIS. To facilitate incorporation of USACE's input into the Draft EIS, a written response is needed within 30 days upon receipt of this letter.

Please address your response to:

Ms. Carolyn Haass
TWRS NEPA Document Manager
Department of Energy
P.O. Box 550 MSIN S7-51
Richland, Washington 99352-0550

If you have any questions, please contact me on (509) 372-2731.

Sincerely,

Carolyn C Haass

Carolyn C. Haass
TWRS NEPA Document Manager

PRI:CCH

cc: D. Nichols, Jacobs
G. Tallent, Ecology
E. Cohen, EH-42
E. LeDuc, GC-51

Appendix K
Uncertainties Analysis

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ACRONYMS AND ABBREVIATIONS

ARF	airborne release fraction
ARR	airborne release rate
AWF	Aging Waste Facility
Chi/Q	atmospheric dispersion coefficient
DOE	U.S. Department of Energy
DR	damage ratio
DST	double-shell tank
ED	exposure duration
EDTA	ethylenediaminetetraacetic acid
EF	exposure frequency
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ERDF	Environmental Restoration Disposal Facility
FI	fraction ingested
HI	hazard index
HLW	high-level waste
HMS	Hanford Meteorological Station
HSRAM	Hanford Site Risk Assessment Methodology
HTI	Hanford Tanks Initiative
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
ILCR	incremental lifetime cancer risk
IR	ingestion or inhalation rate
K_d	distribution coefficient
LAW	low-activity waste
LCF	latent cancer fatality
LPF	leak path factor
MEI	maximally-exposed individual
MRA	modular risk assessment
NOAEL	no observed adverse effect level
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policy Act
NRC	Nuclear Regulatory Commission
PDF	probability density function
PF	pollutant-specific factor
PFP	Plutonium Finishing Plant
PUREX	Plutonium-Uranium Extraction
RCRA	Resource Conservation and Recovery Act

ACRONYMS AND ABBREVIATIONS (cont'd)

RF	respirable fraction
SGLS	spectral gamma logging system
SIF	summary intake factor
SST	single-shell tank
Tri-Party Agreement	Hanford Federal Facility Agreement and Consent Order
TWRS	Tank Waste Remediation System
ULD	unit liter dose
URF	unit risk factor
VF	volatilization factor
VOC	volatile organic compound

NAMES AND SYMBOLS FOR UNITS OF MEASURE, RADIOACTIVITY, AND ELECTRICITY/ENERGY

Length

cm	centimeter
ft	foot
in	inch
km	kilometer
m	meter
mi	mile

Area

ac	acre
ft^2	square foot
ha	hectare
km^2	square kilometer
mi^2	square mile

Volume

cm^3	cubic centimeter
ft^3	cubic foot
gal	gallon
L	liter
m^3	cubic meter
ppb	parts per billion
ppm	parts per million
yd^3	cubic yard

Mass

g	gram
kg	kilogram
lb	pound
mg	milligram
mt	metric ton

Radioactivity

Ci	curie
MCi	megacurie (1.0E+06 Ci)
mCi	millicurie (1.0E-03 Ci)
μCi	microcurie (1.0E-06 Ci)
nCi	nanocurie (1.0E-09 Ci)
pCi	picocurie (1.0E-12 Ci)

Electricity/Energy

A	ampere
J	joule
kV	kilovolt
kW	kilowatt
MeV	million electron volts
MW	megawatt
V	volt
W	watt

Temperature

°C	degrees Centigrade
°F	degrees Fahrenheit

APPENDIX K
UNCERTAINTIES ANALYSIS

K.1.0 INTRODUCTION

Uncertainty in risk analysis is a consequence of two factors: lack of data and natural variability (Figure K.1.0.1). The lack of data is reflected in the limited knowledge either about the value of constants, or about the statistical parameters (e.g., distribution shape, mean, variance) of things that are inherently variable (e.g., inhalation rates or body weights). Uncertainty due to the lack of data can be reduced in principle by more accurate measurements. Uncertainty due to natural variability cannot be reduced by improved measurement, but can be better estimated by acquiring data to characterize statistical distributions of measured variables and by using computer programs to simulate the effect of such variability in the components of equations on calculated values (e.g., risk estimates). These combined efforts can reduce systematic uncertainty in the Environmental Impact Statement (EIS) analyses and provide a more thorough understanding of the effects of the remaining uncertainty on the conclusions in the document.

The evaluation of systematic uncertainties is the most difficult aspect of determining the overall uncertainty of an analysis. A systematic error is the difference between the mean of an analysis and the true value. When true value is unknown, the systematic error only can be estimated. The estimated limit of the systematic error is called the systematic uncertainty of the analysis (Catland 1990). The systematic uncertainty is made up of multiple sources of systematic errors, each of which must be evaluated and quantified. When sources of systematic error are found and reduced, the systematic uncertainty is reduced.

Uncertainty in the conclusions of this EIS is a consequence of uncertainty in two major areas: the descriptions of the alternatives, with their associated assumptions about tank waste inventories, composition, and remediation technologies; and the consequences analyses, which include assumptions about waste source and release terms, future land uses, environmental transport parameters, and relationships between exposure and risk (Figure K.1.0.1). This appendix discusses the major sources of uncertainty in each of these areas. In addition, a less conservative (nominal) human health risk analysis is presented to illustrate the implications of relating some of the conservative assumptions made for the bounding case risk analyses in the EIS.

Section K.2 describes the uncertainties and assumptions in the alternative descriptions, including engineering, schedule, staffing, resources, and costs. Section K.3 discusses uncertainties and assumptions in the source terms and in the release terms for acute (accident) and chronic (routine) scenarios. Section K.4 describes the uncertainties and assumptions in estimating contaminant transport through soil, ground and surface water, and air. Sections K.5 and K.6 present the uncertainties and assumptions in the human health risk exposure assessment and risk characterization, respectively. Section 5.7 describes the results of a less conservative (nominal) human health risk analysis, focusing on the Ex Situ Intermediate Separations alternative as an example. Section K.7 describes the uncertainties in the ecological risk assessment (ERA) and their effects on the conclusions in the EIS.

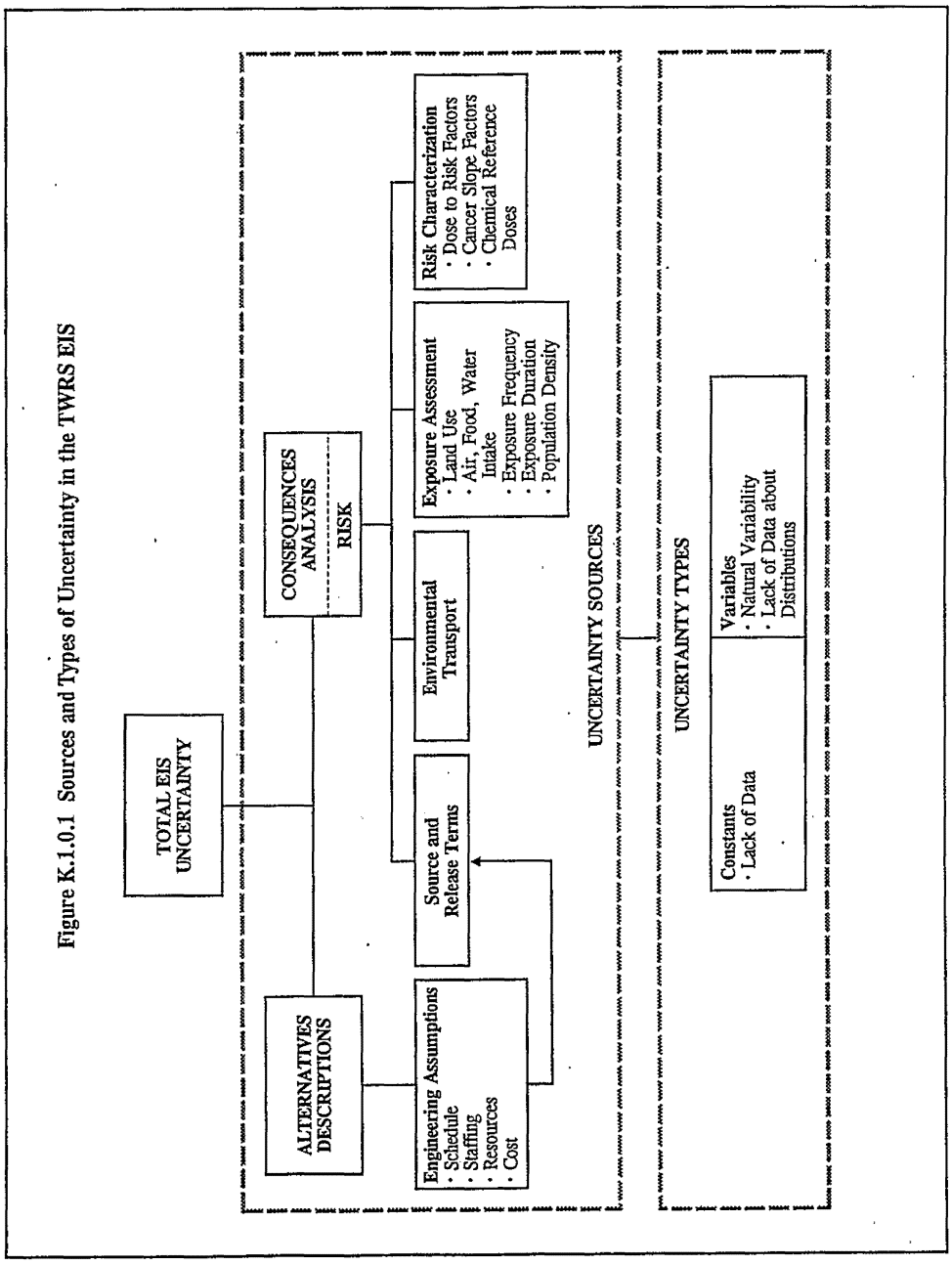


Figure K.1.0.1 Sources and Types of Uncertainty in the TWRS EIS

K.2.0 UNCERTAINTIES IN ALTERNATIVES

A full range of representative alternatives was developed for detailed analysis in the EIS. Upper, lower, and intermediate bounding alternatives were developed in terms of cost, risk, and technologies for the two primary decisions that affect environmental impacts: the amount of waste to be retrieved from the tanks and the degree of separations of retrieved waste into high-level waste (HLW) and low-activity waste (LAW).

The alternatives developed were chosen to be representative of many possible variations of the alternatives. The design information for all alternatives is at an early planning stage, and the details of the alternative ultimately selected and implemented are likely to change as the design process matures.

Each alternative developed for analysis in the EIS consists of a set of technologies, or building blocks, that have been engineered to work together, forming complete systems for accomplishing the remediation of the tank waste.

Engineering data were developed for each alternative in support of the environmental impact analysis. These data included the following major components:

- Conceptual design of the type and size of facilities required for waste treatment;
- Schedules and staffing requirements (radiological and nonradiological workers) for the construction and operation of waste treatment facilities;
- Resource requirements for the construction and operation of the waste treatment facilities;
- Air emissions for routine tank farm operations, waste treatment operations, and post remediation;
- Contamination releases to the soil during waste retrieval and during the post-remediation phase; and
- Land use requirements, both temporary and permanent, for the construction and operation of waste treatment facilities.

These major components were developed based on certain assumptions, general engineering information, and previous development work. The uncertainties associated with engineering assumptions for each alternative are presented in Section K.2.2, and the uncertainties related to general information such as schedule projection, staffing and resource prediction, and cost estimation are discussed in Sections K.2.3 through K.2.6, respectively.

K.2.1 OVERVIEW

There are many uncertainties associated with the alternatives for remediating the tank waste. These uncertainties involve the types of waste contained in the tanks, the effectiveness of the proposed retrieval techniques, and the processes used to separate and treat the waste. These uncertainties exist because some of the technologies that would be implemented are first-of-a-kind and have not previously been applied to the Hanford Site tank waste, or they have not been applied at the scale required for the tank waste.

K.2.2 UNCERTAINTIES FOR MAJOR ASSUMPTIONS

To develop the engineering data required to perform impact analyses for each of the alternatives discussed in the EIS, assumptions were made regarding the technologies that create a remediation alternative. These assumptions were based on either the best information available, applications of a similar technology, or engineering judgement. When an assumption is made, there is some level of uncertainty associated with it that can be expressed as a range that reasonably could be expected for the assumed value. This section identifies the major assumptions used for the alternatives, describes uncertainties associated with the assumptions, and presents the results of a waste loading sensitivity analysis for the Ex Situ Intermediate Separations alternative.

K.2.2.1 Long-Term Management and In Situ Alternatives

Tank Leakage

It was assumed that there would be no leaks from the single-shell tanks (SSTs) or double-shell tanks (DSTs) during the administrative control period for the No Action, Long-Term Management, or In Situ Fill and Cap alternatives because the ongoing process of removing the pumpable liquids from SSTs was assumed to be completed, and leaks would be recovered from the space between the inner and outer liners of the DSTs. The SSTs and DSTs were assumed to maintain their structural integrity throughout the administrative control period under the No Action and Long-Term Management alternatives. For the Long-Term Management alternative, replacement of the DSTs was assumed to be necessary to prevent leaks.

The uncertainty with this assumption is that a leak could develop or a structure failure could occur, resulting in a release of contaminants during the administrative control period. It is likely that corrective actions would be taken in the event of a leak or signs of structural deterioration. Corrective actions could include waste retrieval and retanking activities to minimize environmental releases. If these activities were to occur, increases in the release of contaminants of the air and vadose zone would be expected.

In Situ Vitrification

The In Situ Vitrification alternative is more conceptual in design and development than the ex situ vitrification alternatives and thus has a higher degree of uncertainty associated with the data developed for impact assessments. The in situ vitrification system was assumed to be capable of vitrifying each of the tanks to the required depth, resulting in a consistent waste form. It also was assumed that the variation in waste composition and inventory from tank to tank would not impact the ability to produce an acceptable waste form.

There is considerable uncertainty about the ability of the in situ vitrification system to vitrify the large volume required for the SSTs and DSTs. This uncertainty could be reduced through the use of smaller vitrification systems and the development of depth-enhancing techniques. This likely would result in increased staffing requirements and longer operating durations.

The air emissions estimates developed for the In Situ Vitrification alternative assumed that the entire inventory of iodine-129 (I-129) would be released to the atmosphere during the operating period. Off-gas treatment systems could be expected to remove part of the I-129 and reduce these emissions.

The long-term waste form performance for the vitrified waste was based on the assumption of a homogeneous waste form with properties similar to the glass produced by the Ex Situ No Separations alternative. Inspecting the final waste form to verify that all of the wastes were vitrified would be difficult and could result in undetected waste form variations. Variability in the waste form or fracturing of the waste form during cooling would be expected to result in increased contaminant release rates to the vadose zone.

The safety of drying some of the waste types is uncertain. Further evaluation of this issue could result in some tanks not being suitable for in situ vitrification.

In Situ Fill and Cap

Under the In Situ Fill and Cap alternative, the DST liquids would be concentrated using the 242-A Evaporator to remove as much water from the waste as possible, but the waste still would contain substantial volumes of liquid. It was estimated that concentration by the 242-A Evaporator would reduce the current liquid volumes contained in the tanks by approximately one-third (WHC 1995f). The concentrated liquid waste contained in the DSTs was assumed to be acceptable for gravel filling.

Additional development of this alternative could result in a requirement for additional liquid removal and drying of the waste in the tanks. If this were to occur, development of an in situ drying technology would be required and its use would result in increased volatile radionuclide and chemical emissions from the tanks, in addition to increases in staffing levels and operating schedule.

K.2.2.2 Ex Situ Alternatives

Waste Retrieval Efficiency

The waste retrieval function described for the ex situ alternatives was assumed to remove 99 percent of the waste volume contained in each tank during waste retrieval. Under this assumption, 1 percent of the tank volume would be left in-tank as residual. It was further assumed that the 1 percent waste volume represented 1 percent of the waste inventory on a chemical and radiological basis including soluble waste constituents. This assumption is conservative and will bound the impact from the tank residuals.

The amount and type of waste that would remain in the tanks after retrieval is uncertain. The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) (Ecology et al. 1994) set a goal for the SSTs that no more than 1 percent of the tank inventory would remain as residual following waste retrieval activities to the extent technically practicable. The engineering data for the waste retrieval and transfer function common to all ex situ alternatives was developed using 99 percent retrieval from SSTs and DSTs as an assumption.

It would be expected that the residual contaminants left in the tanks either would be insoluble and hardened on the tank walls and bottom or be of a size that could not be broken up and removed from the tanks without extraordinary measures. In either case, the residual waste would have low solubility because the retrieval technologies proposed would use substantial quantities of liquid to dissolve or suspend the waste during retrieval.

The effect of retrieving less than 99 percent of the waste volumes from the tanks during retrieval would be an increase in the amount of waste left in the tanks and corresponding increases in long-term contaminant releases. The in situ and combination alternatives would leave substantially more waste onsite for disposal and provide an upper bound on the impacts associated with the amount and type of waste that is disposed of onsite. Retrieval of more than 99 percent of the waste would reduce the impacts associated with residual waste.

A nominal case tank residual inventory was developed to evaluate the impacts that would result from a more nominal residual inventory. The nominal residual inventory was developed by accounting for the solubility of the mobile constituents of concern. The mobile constituents of concern were evaluated because of their contribution to post-remediation risk. The isotopes carbon-14 (C-14), technetium-99 (Tc-99), and I-129 were reduced for the nominal case to 10 percent of the bounding residual inventory. For additional information, refer to Volume Two, Appendix B.

The U.S. Department of Energy (DOE) currently is developing the Hanford Tanks Initiative (HTI) program that will provide information on the characteristics of the tank residuals and the capability of retrieval systems to handle difficult-to-remove SST wastes. This program will reduce the uncertainties associated with residual waste, demonstrate the capability to quantify residual waste volume, and demonstrate technologies for sampling and characterizing the residual waste.

Assumptions Affecting HLW Volume

The major factors that affect the volume of HLW produced by any of the ex situ alternatives include waste inventory, waste loading (glass specifications), blending, and the efficiency of the separations processes. The waste inventory that has been used for all alternatives is provided in Volume Two, Appendix A along with a discussion on data accuracy and uncertainty.

Waste loading is the mass fraction of the nonvolatile waste oxides in the vitrified waste. The waste oxide loading would be controlled by the amount of glass formers added during the vitrification process. The higher the waste loading, the more waste contained in the vitrified glass and the lower the waste volume.

Blending is the mixing of the waste from different tanks during retrieval to obtain an average waste feed stream for treatment. Because there are 177 tanks that contain waste, and the waste composition varies from tank to tank, it would be difficult to achieve a completely uniform blending of the waste during retrieval.

Separating the waste into HLW and LAW streams for treatment would involve various processes to physically or chemically separate specific constituents in the waste stream. The separations efficiency would be a measure of how well these processes work and would define the amount of each constituent that would be processed in the HLW and LAW treatment facilities.

The assumptions used for each of the previously described factors and their combined effect on the overall volume of HLW and LAW are discussed in the following sections.

Waste Loading

The waste loading for all ex situ treatment alternatives, except for the Ex Situ No Separations alternative was assumed to be 20 weight percent waste oxides for the HLW and 15 weight percent sodium oxide (Na_2O) for the LAW. The waste loading for the Ex Situ No Separations alternative was assumed to be 20 weight percent Na_2O.

Waste loading would affect the final volume produced from an initial amount of waste. This volume, along with the operating schedule and the assumed operating efficiency, would determine the size of the processing facilities and operating resources required to support the process. A decrease in waste loading would translate into a larger volume of vitrified waste, larger treatment facilities or longer operating schedules, increased resource requirements, and higher disposal cost.

Waste loading typically ranges from 20 to 40 weight percent waste oxides, with 30 to 35 weight percent loading used as a target value. The Savannah River Site Defense Waste Processing Facility glass has a design basis waste loading of 25 weight percent and a maximum waste loading of 38 percent (DOE 1995s).

The waste loading for all alternatives that would produce LAW was assumed to be 15 weight percent Na_2O. The volume of LAW produced would affect the size and number of LAW disposal vaults built onsite.

Waste Blending

Each of the ex situ alternatives that would use vitrification as an immobilization technology assumed a waste blending factor of 1.2 for the HLW to account for variations in the composition of the waste during retrieval operations. Variations in the waste feed composition would not affect the calcined product that would be produced by the Ex Situ No Separations (Calcination) alternative. Uniform blending would require simultaneous retrieval from specific groups of tanks to deliver a uniform average feed stream to the treatment facilities. The blending factor would be multiplied by the volume of HLW produced under uniform blending conditions to calculate the waste volume expected due to variation in the waste feed. One of the major sources of uncertainty associated with developing a retrieval sequence that would achieve a uniform blending is the lack of accepted tank-by-tank inventory data. Preliminary studies on retrieval sequences, waste blending, and the effects on HLW volume show that the volume of vitrified HLW with no blending would be approximately twice that with total blending (WHC 1995p).

The volume of HLW produced combined with the size of the HLW canisters would directly impact the number of HLW packages requiring disposal at the potential geologic repository, which in turn would affect the cost associated with disposal. The number of HLW packages produced would also determine the number of offsite shipments required to transport the immobilized HLW to the potential geologic repository. The waste loading would also determine the concentration of radiological contaminants in the waste form. There is a relationship between the waste loading, number of shipments (cumulative probability of an accident), and the concentration of contaminants in the waste form (consequence of an accident). As the waste loading increased, the cumulative probability of an accident would decrease because there would be fewer trips required to transport the waste. The consequences of an accident would increase because there would be a higher concentration of contaminants in the waste form (see Volume Four, Section E.16.0 for a discussion of accident uncertainties).

Releases to the Soil During Retrieval

Retrieval operations under each ex situ alternative was assumed to result in the release of 15,000 L (4,000 gal) of waste at full solution strength from each SST to the surrounding soil. No leakage from the DSTs was assumed to occur during retrieval operations. This assumption was based on the 67 known or suspected SSTs that have leaked in the past (Hanlon 1995) and no known or suspected leaks from DSTs to date. Most of the SSTs were built in the 1940's and now are about 50 years old. The leakage volume estimate assumed that the average leakage from an SST would be one order of magnitude lower than the maximum release estimated for tank 241-C-106 during sluicing operations. The maximum leak estimated from tank 241-C-106 during sluicing operations was 150,000 L (40,000 gal). This estimate also assumed that the leak occurred early in the sluicing operation, leak detection devices and controls failed, sluicing operations proceeded without these leak detection devices, the leak(s) occurred at the bottom of the tank, and the remaining sludge did not plug any leaks (DOE 1995d).

The most probable occurrence of a leak during sluicing would involve the sluicers opening a plugged leak in the tank wall. The waste leakage during sluicing would be any free-standing liquid above the level of the leak point and the sluicing stream as it impacted the tank wall.

A nominal retrieval release inventory was developed by assuming that the waste would be diluted by one-third by adding water during waste retrieval. Possible dilution ratios that would be used during waste retrieval range from 3:1 to 10:1, depending on waste type. The nominal retrieval release inventory accounts for partial dilution of the tank contents while retrieval operations are underway. The volume of waste released during retrieval was assumed to be the same for the nominal and bounding cases. There currently is insufficient basis to support a lower nominal case leakage estimate. DOE currently is developing criteria and technologies to identify leaks and limit releases during retrieval.

Sensitivity Analysis

A sensitivity analysis was performed for the Ex Situ Intermediate Separations alternative to show the range in the data expected if the volume of HLW and LAW produced were to increase or decrease based on waste loading assumptions. The following sensitivity parameters were assumed for analysis:

- HLW loading at 15 weight percent and 40 weight percent waste oxides;
- LAW loading at 10 weight percent and 25 weight percent Na_2O; and
- No variation in the separations efficiencies or the blending factor.

The results of the sensitivity analysis performed for the Ex Situ Intermediate Separations alternative are shown in Table K.2.2.1. Lower waste loading would require increased resources, land commitments, transportation, and cost. The facility sizes were held constant for the sensitivity analysis, resulting in constant capital cost and staffing levels and variable operating schedules. If the treatment schedule were held constant, the required treatment facilities, capital cost, and staffing levels would change.

K.2.3 SCHEDULE

Schedules for construction, operation, and closure were developed for each of the alternatives within the constraints of the Tri-Party Agreement (Ecology et al. 1994). Schedule constraints would affect the size of the treatment facilities required to process the waste. Following design and construction of a waste treatment facility, the major schedule uncertainty would be the operating duration.

Each of the ex situ alternatives was developed using 60 percent overall operating efficiency, except for Phase 2 of Phased Implementation, which used 70 percent overall operating efficiency. Operating at higher efficiencies would reduce the operating duration, and conversely, lower operating efficiencies would increase the operating duration. For the alternatives that would have multiple treatment components, such as retrieval, pretreatment, HLW treatment, and LAW treatment, the overall operating schedule would depend on the operating efficiency for each component.

Uncertainties in the operating schedule would be expected to result in longer operating durations. Previous analysis has shown that the operating duration for the ex situ alternatives would be sensitive to the rate at which waste can be retrieved from the SSTs. A low SST sludge retrieval rate could increase the operating duration by 50 percent (WHC 1995r).

K.2.4 STAFFING

Staffing estimates were developed for each alternative in support of risk, accident, and socioeconomic impact analysis. These staffing estimates were developed using conservative assumptions for both construction and operating staffing levels. The major uncertainty in overall staffing requirements would be associated with the operating schedule uncertainty. Staffing requirements would be affected by operating efficiencies because operating efficiency changes would increase or decrease the operating duration and the overall staffing requirements.

Table K.2.2.1 Ex Situ Intermediate Separations Sensitivity Summary

	Low Loading	Base Case	High Loading
HLW Glass Loading [1] LAW Glass Loading	15 weight percent waste oxides 10 weight percent Na_2O	20 weight percent waste oxides 15 weight percent Na_2O	40 weight percent waste oxides 25 weight percent Na_2O
Number of HLW canisters [2]	18,900	12,200	7,080
Number of LAW vaults	99	66	40
Duration of Treatment[3] Operations HLW LAW	 17 years 26 years	 11 years 17 years	 7 years 10 years
Land Commitments, ha (ac) Temporary Permanent	 270 (670) 49 (120)	 240 (590) 46 (110)	 220 (540) 46 (110)
Trips to Repository	473	303	177
Borrow Material Required Sand/Gravel (m^3) Riprap (m^3) Silt (m^3)	 7.86E+06 9.63E+05 5.55E+05	 2.47E+06 8.78E+05 5.19E+05	 2.14E+06 7.84E+05 4.57E+05
Resources: Kerosene (m^3) Concrete (m^3) Glass Formers, mt Steel, (total) mt	 9.90E+04 1.22E+06 9.08E+05 1.87E+06	 6.58E+04 1.04E+06 5.65E+05 1.83E+06	 3.94E+04 7.87E+05 2.91E+05 8.23E+05
Cost Summary (millions of dollars) Current Operations Research and Development Capital Operating Repository Fee Total Cost (1995)	 $8,600 $820 $6,049 $10,563 $7,190 $33,222	 $8,600 $820 $6,049 $9,368 $5,280 $30,117	 $8,600 $820 $6,049 $8,222 $2,967 $26,658

Notes:
[1] HLW glass loading is in terms of waste oxides (not counting silica or sodium).
[2] HLW canister size is 1.2 m^3 (41 ft^3).
[3] Treatment duration is based on 60 percent operating efficiency and fixed treatment plant sizes.

K.2.5 RESOURCES

The resources required to construct and operate waste treatment facilities were estimated for each alternative using a consistent methodology and common assumptions. The ex situ alternatives and the In Situ Vitrification alternative would have the largest uncertainty for estimated resources. The major uncertainties associated with the estimated resource requirements for the ex situ alternatives include the size and type of facilities required and the volume of LAW and HLW produced. Variations in operating resource requirements as a function of waste loading for the Ex Situ Intermediate Separations alternative are shown in Table K.2.2.1.

K.2.6 COST

Cost uncertainty for all of the tank waste alternatives has been evaluated and is discussed in Volume 2, Section B.8. Upper and lower ranges were estimated for the major cost components of each alternative. Upper and lower cost ranges were based on the technology, level of development, and degree of complexity. These cost ranges along with confidence levels were used as input to Decision Science Corporation's Range Estimating Program for personal computers to model the treatment cost range and total cost range including repository fee.

The cost uncertainty results in a cost range within which the alternative cost would be expected to fall. The cost range is the highest for the In Situ Vitrification alternative at 3.3 percent below to 66.5 percent above the target cost based on the uncertainties associated with implementing this technology for remediation of the tank waste. Cost ranges for the ex situ alternatives are generally 3 to 8 percent below to 20 percent above the target cost. The Ex Situ Extensive Separations alternative results in an upper cost range of 35 percent above the target cost based on the application of many first-of-a-kind technologies and the complexity of the separations process.

K.3.0 UNCERTAINTY IN SOURCE TERMS

Source terms refer to the waste inventory, which is the total quantity of the hazardous material within the tanks, and to the release term, which is the amount released to environmental media such as soil, groundwater, surface water, and soil under normal or accident conditions. The following sections describe the uncertainty associated with inventory and release terms.

K.3.1 WASTE INVENTORY DATA

There is considerable uncertainty associated with the inventory data used in the EIS. Tank waste data are available on a tank-by-tank basis, but the accuracy of these data are suspect because they primarily are based on historical records of transfers between tanks rather than statistically based sampling and analyses programs. However, while the inventory of any specific tank may be suspect, the overall inventory for all of the tanks combined is considered more accurate. The lack of accepted tank-by-tank inventory data would affect the Ex Situ/In Situ Combination 1 and 2 alternatives more than other alternatives because the tank selection criteria and the impact assessment of waste disposed of in situ are dependent on tank-by-tank data.

The waste inventory data used in developing the alternatives and their associated impacts are derived from model predictions and sample analysis. While the waste is currently undergoing additional characterization and the inventory may be revised as a result of ongoing analyses, the inventory used in the EIS is not expected to result in discrimination for or against any of the alternatives analyzed. DOE has identified the key radionuclides for tracking in development of a "best basis inventory" for Hanford tank waste. These include the radionuclides that dominate the risk estimates in this EIS: C-14, I-129, neptunium-237 (Np-237), protactinium-231 (Pa-231), selenium-79 (Se-79), Tc-99, and uranium (U) isotopes. This information will be incorporated into National Environmental Policy Act (NEPA) analysis of closure alternatives. For additional information on tank inventory data accuracy and its effect on the EIS see Volume Two, Section A.3.

K.3.2 RELEASE TERMS

Releases to the environment for both routine releases during remediation and acute releases during an accident are a function of the waste inventory. The inventory used for developing routine emissions is based on a nominal waste stream based on overall tank waste inventory. Acute releases were developed using both a nominal and bounding inventory.

K.3.2.1 Chronic Releases (Routine)

Chronic releases were developed for each alternative using average inventory data. The No Action and Long-Term Management tank waste alternatives include routine emissions from the tank farms. The In Situ Fill and Cap alternative includes routine tank farm emissions as well as tank emissions during tank filling. The In Situ Vitrification alternative includes routine tank farm emissions plus releases from the evaporator and vitrification processes. The ex situ alternatives include routine tank farm emissions, releases during waste retrieval, and releases during waste treatment.

The routine releases developed for the ex situ alternatives are based on material balance calculations and waste processing rates. Conservative assumptions were made for the release of certain volatile radionuclides. It was assumed for each alternative that included vitrification that the entire inventory of I-129 and C-14 would be released to the atmosphere during waste treatment. Some capture of the I-129 in the off-gas treatment system could be expected and would result in lower I-129 releases.

Uncertainties associated with the chronic releases are based on the available inventory data. Increased inventory of any constituent would be expected to result in some increase in chronic releases. This especially would be true for the volatile contaminants.

K.3.2.2 Acute Releases (Accident)

The respirable fraction of inventory released from an accident, from which the receptor dose is calculated, is referred to as the source term. The source term depends on a variety of release fractions associated with the mechanics of the accident scenario. Uncertainties associated with each of these release fractions are based on available data, and in some cases may depend on engineering judgement. For specific scenarios, nominal and bounding values were estimated for the applicable release fractions as follows:

- Damage ratio (DR) - The fraction of the material at risk impacted by the event;
- Leak path factor (LPF) - The fraction that escapes the confinement boundary by design, natural causes, or degradation caused by the event;
- Airborne release fraction (ARF) - The fraction of released material made airborne by the event;
- Airborne release rate (ARR) - The fractional airborne release rate of material from the accident. ARR is converted to ARF by integrating over the time available for release; and
- Respirable fraction (RF) - The fraction of airborne droplets or particulate matter with individual particle aerodynamic equivalent diameter less than or equal to 10 microns (μm).

For the spray release scenario, the nominal and bounding applicable release fractions are presented in Table K.3.2.1. When a particular release fraction is well understood, the uncertainty diminishes, decreasing the difference between the bounding and nominal values. For purposes of this analysis, the DR is the only parameter with uncertainty. Setting LPF, ARF, and RF equal to 1.0 maintains conservatism even for the nominal case. The difference between the bounding and nominal cases is a factor of 7.

Table K.3.2.1 Bounding and Nominal Release Fractions Used in the Spray Release Scenario

Release Fraction	Bounding	Nominal	Ratio
Damage ratio	9.0 L/min · 24 hr = 374 L	0.054 L/min · 16 hr = 52 L	7
Leak path factor	1	1	1
Airborne release fraction	1	1	1
Respirable fraction	1	1	1

K.4.0 UNCERTAINTY IN ENVIRONMENT TRANSPORT

The estimated movement of contaminants through environmental media such as soil, groundwater, surface water, and air is associated with uncertainties. These uncertainties are described in Sections K.4.1 through K.4.4, respectively.

K.4.1 TRANSPORT IN SOIL

This discussion on potential transport mechanisms is provided because 1) there may be other vadose zone transport mechanisms in effect in addition to what has been calculated; 2) there is insufficient information to determine whether any or all of the other transport mechanisms are active.
The available data indicate that the primary vadose zone transport mechanism is advective flow through the interstitial spaces of the porous media. Recent observations of relatively immobile contaminants at depths of up to 38 m (125 ft) below the tanks are not fully explained with interstitial flow and may indicate there are other transport mechanisms in effect. These observations are currently the focus of a DOE program. The initial phase of the program is to determine if the observations are representative of extensive vadose zone contamination beneath the tanks or if they are related to other phenomena such as borehole contamination. The results from this program including subsequent phases are not expected to be available for several months.

All of the remedial alternatives would result in some waste tank release to the vadose zone. The impacts of these releases were predicted using the approach described in Volume One, Section 5.2.1. This approach required the mathematical definition of the waste tank releases (source terms), calculation of when and at what rate the release would move through the underlying vadose zone (vadose zone modeling), and calculation of when and at what rate the release would move through the underlying groundwater system and ultimately discharge to the Columbia River (groundwater models). A one-dimensional model capable of simulating partially saturated conditions was selected to calculate the transport of a waste tank release through the vadose zone to the underlying groundwater.

The impact assessment of all the alternatives relied on a common conceptual model of the vadose zone, which included the geometry of each site (i.e., number and thickness of strata) where the releases would occur, the assumption that each strata was an isotropic and homogenous porous medium, that contaminant transport would be driven primarily by advection downward through the interstitial spaces of the various strata, that contaminant transport would be an isolinear process (i.e., independent of contaminant concentration), and that contaminant mobility as expressed by the distribution coefficient (K_d) parameter would remain constant in the various strata of the vadose zone. The conceptual model is the basis of the one-dimensional model used in the assessment approach.

Provided in the following subsections are discussions of 1) data on migration of past tank leaks in the vadose zone; 2) calculated transport of a past tank leak from tank 241-T-106 using the impact assessment assumptions; 3) potential vadose zone transport mechanisms other than what is inherently assumed in the impact assessment analyses; and 4) how the other potential vadose zone transport mechanisms could impact each alternative.

K.4.1.1 Past Tank Leaks

Sixty-seven of the 149 SSTs are assumed to leak (Hanlon 1995). The assumed leaking tanks are fairly evenly distributed in the 200 Areas with 32 assumed leaking tanks in the 200 East Area and 35 in the 200 West Area. There are no reported leaks from the 28 DSTs. The range of leak volume is from approximately 1,300 liters (L) (350 gallons [gal]) from tank 241-C-204 in the 200 East Area to 435,000 L (115,000 gal) from tank 241-T-106 in the 200 West Area. Total leak volume from all 67 assumed leakers ranges from 2.27E+06 to 3.41E+06 L (600,000 to 900,000 gal). Interim stabilization has been completed on all but five assumed leaking tanks. The tank identification number, date the tank was declared a leaker, estimated leak volume, estimated activity of leak, and date the tank was stabilized are provided in Table K.4.1.1.

Cesium (Cs) and plutonium (Pu) were transported to the tank farms in various waste streams. Both contaminants are relatively immobile in subsurface materials at Hanford and because of this immobility, are expected to be found near waste disposal sites (especially under ambient infiltration conditions) dispersed throughout the unsaturated materials and in groundwater in some instances, depending on the volume of liquid associated with the waste discharge or leak.

Information has been emerging that associates migration of several radioisotopes, including Cs and Pu, to depths of 30 m (100 ft) or greater with leaks from the waste tanks. There are two major sources of this data as follows:

- Downhole logging of existing drywells; and
- Discrete samples from a borehole completed in multiple stages to avoid cross contamination.

Downhole Logging of Drywells

DOE has a system of monitoring wells called drywells installed in the vicinity of each waste tank. The depth of these drywells varies, but they do not extend to the water table of the unconfined aquifer.

Table K.4.1.1 Summary of Tank Leak Estimates from Single-Shell Tanks

Tank No.	Date Declared Confirmed or Assumed Leaker [3]	Volume [1, 2] (gallons)	Associated Kilocuries Cs-137 [8]	Interim Stabilized Date [9]
241-A-103	1987	5,500 [7]	--- [11]	6/88
241-A-104	1975	500 to 2,500	0.8 to 1.8	9/78
241-A-105	1963	10,000 to 277,000	85 to 760	7/79
241-AX-102	1988	3000 [7]	--- [11]	9/88
241-AX-104	1977	--- [5]	--- [11]	8/81
241-B-101	1974	--- [5]	--- [11]	3/81
241-B-103	1978	--- [5]	--- [11]	2/85
241-B-105	1978	--- [5]	--- [11]	12/84
241-B-107	1980	8,000 [7]	--- [11]	3/85
241-B-110	1981	10,000 [7]	--- [11]	3/85
241-B-111	1978	--- [5]	--- [11]	6/85
241-B-112	1978	2,000	--- [11]	5/85
241-B-201	1980	1,200 [7]	--- [11]	8/81
241-B-203	1983	300 [7]	--- [11]	6/84
241-B-204	1984	400 [7]	--- [11]	6/84
241-BX-101	1972	--- [5]	--- [11]	9/78
241-BX-102	1971	70,000	50	11/78
241-BX-108	1974	2,500	0.5	7/79
241-BX-110	1976	--- [5]	--- [11]	8/85
241-BX-111	1984	--- [5]	--- [11]	3/95 [4]
241-BY-103	1973	<5,000	--- [11]	N/A
241-BY-105	1984	--- [5]	--- [11]	N/A
241-BY-106	1984	--- [5]	--- [11]	N/A
241-BY-107	1984	15,100 [7]	--- [11]	7/79
241-BY-108	1972	<5,000	--- [11]	2/85
241-C-101	1980	20,000 [7]	--- [11]	11/83
241-C-110	1984	2,000	--- [11]	5/95
241-C-111	1968	5,500 [7]	--- [11]	3/84
241-C-201	1988	550	--- [11]	3/82
241-C-202	1988	450	--- [11]	8/81
241-C-203	1984	400 [7]	--- [11]	3/82
241-C-204	1988	350	--- [11]	9/82
241-S-104	1968	24,000 [7]	--- [11]	12/84
241-SX-104	1988	6,000 [7]	--- [11]	N/A
241-SX-107	1964	<5,000	--- [11]	10/79
241-SX-108	1962	2,400 to 35,000	17 to 140	8/79
241-SX-109	1965	<10,000	<40	5/81
241-SX-110	1976	5,500 [7]	--- [11]	8/79
241-SX-111	1974	500 to 2,000	0.6 to 2.4	7/79
241-SX-112	1969	30,000	40	7/79
241-SX-113	1962	15,000	8	11/78
241-SX-114	1972	--- [5]	--- [11]	7/79
241-SX-115	1965	50000	21	9/78
241-T-101	1992	7,500 [7]	--- [11]	4/93
241-T-103	1974	<1,000 [7]	--- [11]	11/83
241-T-106	1973	115,000 [7]	40	8/81
241-T-107	1984	--- [5]	--- [11]	N/A
241-T-108	1974	<1,000 [7]	--- [11]	11/78
241-T-109	1974	<1,000 [7]	--- [11]	12/84
241-T-111	1979,1994 [10]	<1,000 [7]	--- [11]	2/95

Table K.4.1.1 Summary of Tank Leak Estimates from Single-Shell Tanks (cont'd)

Tank No.	Date Declared Confirmed or Assumed Leaker [3]	Volume [1,2] (gallons)	Associated Kilocuries Cs-137 [8]	Interim Stabilized Date [9]
241-TX-105	1977	--- [5]	--- [11]	4/83
241-TX-107	1984	2,500	--- [11]	10/79
241-TX-110	1977	--- [5]	--- [11]	4/83
241-TX-113	1974	--- [5]	--- [11]	4/83
241-TX-114	1974	--- [5]	--- [11]	4/83
241-TX-115	1977	--- [5]	--- [11]	9/83
241-TX-116	1977	--- [5]	--- [11]	4/83
241-TX-117	1977	--- [5]	--- [11]	3/83
241-TY-101	1973	<1,000 [7]	--- [11]	4/83
241-TY-103	1973	3,000	0.7	2/83
241-TY-104	1981	1,400 [7]	--- [11]	11/83
241-TY-105	1960	35,000	4	2/83
241-TY-106	1959	20,000	2	11/78
241-U-101	1959	30,000	20	9/79
241-U-104	1961	55,000	0.09	10/78
241-U-110	1975	5,000 to 8,100 [7]	0.05	12/84
241-U-112	1980	8,500 [7]	--- [11]	9/79
67 Tanks		<600,000-900,000 [6]	--- [11]	

Source: Hanlon 1995

Notes:

N/A = Not applicable (not yet interim stabilized)

[1] One gallon is equal to 3.785 L.

[2] These leak volume estimates do not include (with some exceptions) such things as: (a) cooling/raw water leaks, (b) intrusions (rain infiltration) and subsequent leaks, (c) leaks inside the tank farm but not through the tank liner (surface leaks, pipeline leaks, leaks at the joint for the overflow or fill lines), and (d) leaks from catch tanks, diversion boxes, and encasements.

[3] In many cases, a leak was suspected long before it was identified or confirmed. For example, tank 241-U-104 was suspected of leaking in 1956. The leak was "confirmed" in 1961. This report lists the "assumed leaker" date as 1961. Using present standards, tank 241-U-104 would have been declared as assumed leaker in 1956. In 1984, the criteria designations of "suspected leaker," "questionable integrity," "confirmed leaker," "declared leaker," "borderline," and "dormant" were merged into one category now reported as "assumed leaker." It is highly likely that there have been undetected leaks from SSTs because of the nature of their design and instrumentation.

[4] Tank BX-111 was declared an assumed re-leaker in April 1993. Preparations for pumping were delayed, following an administrative hold placed on all tank farm operations in August 1993. Pumping resumed and the tank was declared interim stabilized on March 15, 1995.

[5] The total leak volume estimate for these tanks is 150,000 gallons (rounded to the nearest 10,000 gallons), for an average of approximately 8,000 gallons for each of the 19 tanks.

[6] The total has been rounded to the nearest 50 gallons. Upper bound values were used in many cases in developing these estimates. It is likely that some of these tanks have not leaked.

[7] Leak volume estimate is based solely on observed liquid level decreases in these tanks. This is considered the most accurate method for estimating leak volumes.

[8] The curie content listed is not decayed to a consistent date; therefore, a cumulative total is inappropriate.

[9] These dates indicate when the tanks were declared interim stabilized. In some cases, the official interim stabilization documents were issued at a later date. Also, in some cases, the field work associated with interim stabilization was completed at an earlier date.

[10] Tank T-111 was declared an assumed re-leaker on February 28, 1994, due to a decreasing trend in surface level measurement. This tank was pumped and interim stabilized on February 22, 1995.

[11] Activity of leak was not reported.

These drywells were installed as a way of detecting gamma emissions and serve as an indirect means of detecting or confirming waste tank leaks and mobilization of existing contamination in the vadose zone by other waste sources such a potable water line leaks. Until recently, the gamma emissions that were detected were indicative of undifferentiated radioisotopes. Such emissions have been detected in many of the drywells at depths ranging from ground surface to depths up to 38 m (125 ft) belowground surface. Recent improvements in the borehole logging detection equipment has resulted in the identification of specific gamma-emitting radioisotopes. Thus, previously characterized gross gamma contamination is now specifically linked to several radioisotopes. The most prevalent radioisotope detected was Cs-137, while other gamma-emitting radionuclides such as cobalt-60 (Co-60), europium-152 (Eu-152), and Eu-154 were generally found near the surface and are believed to be the result of spills (Brodeur 1996).

The improved geophysical logging uses a spectral gamma logging system (SGLS) with high-purity intrinsic germanium detection device to provide assays of gamma-emitting radionuclides near the drywells. The approach, data, and interpretation are provided in Brodeur 1995. Application of the improved logging equipment has resulted in additional information on conditions at the SX Tank Farm. Application of the improved logging equipment has resulted in additional information on conditions at the SX Tank Farm.

Ten of the 15 tanks in the SX Tank Farm are assumed or verified as leaking. Tanks in the SX Tank Farm have been verified as leaking as early as 1962 (Table K.4.1.1). The last reported tank to leak in the SX Tank Farm was in 1988. Cumulative estimated leak volume from this tank farm ranges from 5.02E+05 L (132,000 gal) to 6.31E+05 L (167,000 gal) as shown in Table K.4.1.1. Ninety-five drywells ranging in depth from 23 m (75 ft) to 38 m (125 ft) from ground surface were logged with the SGLS in the SX Tank Farm. The most abundant and highest-concentration radionuclide detected was Cs-137, which was detected in virtually every borehole (Brodeur 1995). The Cs-137 was detected at the following depths in several drywells: 23 m (75 ft) in drywells 41-09-03 and 41-08-07; 32 m (105 ft) in 41-09-04; 27 m (90 ft) in 41-11-10, and 38 m (125 ft) in 41-12-02.

Other human-made gamma-emitting radionuclides detected include Co-60, Eu-152, and Eu-154, which generally were found near the surface and are believed to be the result of spills (Brodeur 1995). The Co-60 was found in drywell 41-14-06 only and was detected a depth of 17 m (55 ft) to 23 m (76 ft) below ground surface.

The transport of Cs-137 in the vadose zone sediments at the Hanford Site is believed to be greatly retarded due to adsorption. The Cs would not be expected to be found at depths of up to 38 m (125 ft) if it were being transported via interstitial flow through the sediment pore spaces and under ambient conditions that include neutral pH and infiltration rates ranging from 2 millimeters (mm)/year to 10 centimeters (cm)/year. The detection of Cs-137 at this depth raises several questions concerning the active transport mechanisms. These questions and others are being addressed by DOE in a Resource Conservation and Recovery Act Groundwater Assessment of the S and SX Tank Farms (Caggiano et al. 1996) has recently been implemented. The improved borehole logging detection equipment provides

information on the specific contaminant in the vicinity of the drywells, but there is still uncertainty on the lateral distribution of these contaminants within the vadose zone.

Borehole Samples from Multiple-Stage Well

The borehole sample data were collected as a part of a 1993 investigation (Freeman-Pollard 1994) of contaminant migration from a leak from tank 241-T-106. The data from the 1993 investigation consist of 43 split-spoon samples from borehole 299-W10-196. These samples were taken for physical, chemical, and radiochemical analysis in addition to spectral gamma geophysical logging of the borehole on eight occasions.

The 1993 subsurface investigation of the tank 241-T-106 leak was the third to be performed since the initial leak was discovered in 1973. The first investigation was conducted from June to August 1973 in which 16 single-cased boreholes were drilled, the deepest to approximately 27 m (88 ft) below ground surface, as summarized in the 1993 investigation report (Freeman-Pollard 1994). Samples were collected at 1.5-m (5-ft) intervals as the boring was advanced. From this investigation, it was concluded that contamination penetrated to a maximum depth of about 27 m (88 ft).

Freeman-Pollard indicates that in 1979, a second investigation was completed based on numerous additional single-cased boreholes drilled between 1973 and 1978 (Freeman-Pollard 1994). One of the conclusions of this investigation was that there was no evidence that contaminants from the tank 241-T-106 leak had reached the underlying aquifer nor would it during the "hazardous lifetime" of the radionuclides. The 1993 investigation resulted in data on the vertical distribution of several radionuclides and chemicals. Most notably are the following results.

- The Pu concentrations increased greatly at the depth of the bottom of the tank 11 m (36 ft) below ground surface, reached a peak at 13 m (43 ft), decreased to less than 1 pCi/g at 28 m (92 ft), spiked at 29 m (95 ft), and then decreased to background at greater depths.
- The Cs-137 was the only radionuclide that had a high concentration within the fill around the tanks to a depth of 4 m (13 ft) below ground surface, above the presumed depth of the tank leak. The concentration decreased to a depth of 9 m (30 ft), then began to increase to a maximum at 14 m (46 ft), followed by a decrease to below background until two spikes were detected at 24 m (78 ft) and 30 m (100 ft).
- The spikes at approximately 30 m (100 ft) are observed for both mobile (e.g., Tc-99) and attenuated (e.g., Cs-137) contaminants and may be concentrated by a caliche layer that occurs at this depth. This may be due to a hydraulic conductivity contrast, adsorptive capacity from the increased clay content, and/or substitution of radionuclides in the calcium carbonate.

From the 1993 investigation, it was concluded that the mobile contaminants in the leading edge of the plume such as Tc-99 from the 1973 leak had penetrated to the contact with the Ringold unit E at 37 m (121 ft) below ground surface (Freeman-Pollard 1994). This represents a distance of 26 m (85 ft) over approximately 10 years. There was a spatial distribution of radioisotopes in the vadose zone that

reflected the differences in their mobility (Freeman-Pollard 1994). At shallow depths, 10 to 24 m (33 to 82 ft), the less mobile or relatively immobile contaminants Cs-137, americium-241 (Am-241), Pu-239/240, Eu-154, strontium-90 (Sr-90), and C-14 were found. Carbon is assumed to be a mobile ($K_d = 0$) contaminant in Hanford Site sediments, thus its inclusion here is unclear.

K.4.1.2 Transport of Mobile Contaminants Associated with Past Tank Leaks

As stated previously, the groundwater impact assessments all are based on the assumption that contaminant transport occurs as the downward advection of water through the interstitial pores spaces of the various strata. It is difficult to provide an intuitive comparison between contaminant distribution from past leaks and contaminant distributions in the vadose zone calculated for the Tank Waste Remediation System (TWRS) alternatives because the volumes and rate of volume released from the TWRS alternatives generally would be much lower than the past tank leaks, specifically, the leak from tank 241-T-106. The leak from tank 241-T-106 was estimated to be approximately 435,000 L (115,000 gal) over a 52-day period. Contaminants from this leak have been identified in the vadose zone at depths of up to 30 m (100 ft) below ground surface. Scoping calculations consisting of two vadose zone simulations of the tank 241-T-106 leak were performed using the major assumptions used for the impact assessment described in Volume Four, Appendix F to provide a comparison of predicted contaminant distribution from the leak to observed contaminant distribution. A brief description of the simulations and the results follow.

The vadose zone model (VAM2D) was used to perform two axi-symmetric simulations of the vadose zone transport of contaminants due to a leak from tank 241-T-106. The upper boundary of the model was taken as the bottom elevation of the tank. The model domain extended a distance of 52 m (170 ft) from the upper boundary to the water table. Strata thicknesses and properties were the same as assumed for source area 1WSS for the impacts assessments in Volume Four, Appendix F. The axis of symmetry is the centerline of the tank, which has a radius of 11 m (37 ft). For both simulations, the flow field is first equilibrated to steady-state conditions, assuming no flow from the lateral boundaries, a zero pressure head along the bottom boundary, which represents water table conditions, and a spatially varying infiltration rate along the surface domain. The infiltration rate is zero for the domain from the centerline to 11 m (37 ft) radially to represent the umbrella effect of the tank. From 11 m (37 ft) to 111 m (365 ft), infiltration is 10 centimeters (cm)/year (4 inches [in.]/year) to represent enhanced infiltration due to the gravel surface around the tank. From 111 m (365 ft) to 161 m (530 ft), the infiltration rate drops linearly from 10 cm/year to 2 millimeters (mm)/year (4 to 0.08 in./year). Beyond 161 m (530 ft) to 1,500 m (4,900 ft), the infiltration rate is 2 mm/year (0.08 in./year), representing ambient conditions on relatively undisturbed land.

Both simulations assumed the leak to be 435,000 L (115,000 gal) over a 52-day period infiltrating into an area of 10 square meters (m^2) (1,000 square feet [ft^2]) at the centerline of the tank. The first simulation assumed the leak as described is superimposed on the infiltration scenario (no infiltration under the tank). The second simulation assumed that there would be an infiltration rate of 10 cm/year (4 in./year) over the domain from the tank centerline to 11 m (37 ft). Beyond this distance, the infiltration rate was assumed to be the same as described above. Table K.4.1.2 summarizes the

calculated travel distance and elapsed time for the contaminant front from the tank 241-T-106 leak. This is for a mobile contaminant (K_d = 0) and the major assumptions used for the impact assessment.

Table K.4.1.2 Calculated Transport Distance and Time Based on Leak from Tank 241-T-106 for a Mobile Contaminant

Elapsed Time	Distance Below Tank Simulation One	Distance Below Ground Surface Simulation One	Distance Below Tank Simulation Two	Distance Below Ground Surface Simulation Two
5 days	7 m (23 ft)	21 m (69 ft)	7 m (23 ft)	21 m (69 ft)
1 year	25 m (82 ft)	38 m (125 ft)	26 m (85 ft)	40 m (131 ft)
10 years	27 m (89 ft)	41 m (135 ft)	28 m (90 ft)	42 m (136 ft)
beyond 10 years	<< slow movement		about 10 cm/year (4 in./year) movement	

Source: Jacobs 1996

For a mobile contaminant such as Tc-99, the above described simulations agree with the observation from the 1993 investigation of the tank 241-T-106 leak (Freeman-Pollard 1994) where it was found that Tc-99 had penetrated 37 m (120 ft) below ground surface. The 1993 investigation also indicates that normally much less mobile contaminants such as Cs-137 and Pu were found at nominal depths of 30 m (100 ft). This could be the result of an additional transport mechanism(s). Several potential transport mechanisms could be contributing to the transport of Cs-137 and Pu to depths of 30 m (100 ft). DOE currently has undertaken an investigation that should provide the information needed to ascertain if other transport mechanisms such as preferential flow paths and/or chemically enhanced mobility of selection contaminants are active.

K.4.1.3 Potential Vadose Zone Transport Mechanisms

In this section, potential vadose zone transport mechanisms are identified. The potential vadose zone transport mechanisms are divided into two categories: transport mechanisms controlled by physical processes and transport mechanisms controlled by chemical processes. Included in this discussion are occurrences or phenomena that could enhance or speed up contaminant transport in the vadose zone.

K.4.1.3.1 Potential Physical Vadose Zone Transport Mechanisms

Physical transport mechanisms can be either natural or human-made. Potential physical transport mechanisms and transport enhancing phenomena that could occur at the tanks include the following:

- Advective flow through clastic dikes and clastic sills that might naturally occur beneath and/or near the tank farms;
- Advective flow through breaks in the caliche layer (where it occurs) in the Plio-Pleistocene unit of the Ringold Formation that might naturally occur beneath and/or near the tank farms;
- Advective flow through the unsealed annular space surrounding the well casing and borehole in drywells/monitoring wells installed near the tanks;

- Infiltration of surface runoff into the unsealed annular space between the well casing and borehole in drywells/monitoring wells installed near the tanks;
- Inflow of surface water into the top of drywells and discharge out through casing perforations at depth;
- Movement of contamination during drilling from near-surface sources to various depths; and
- Near surface leaks from water lines and/or waste transfer lines.

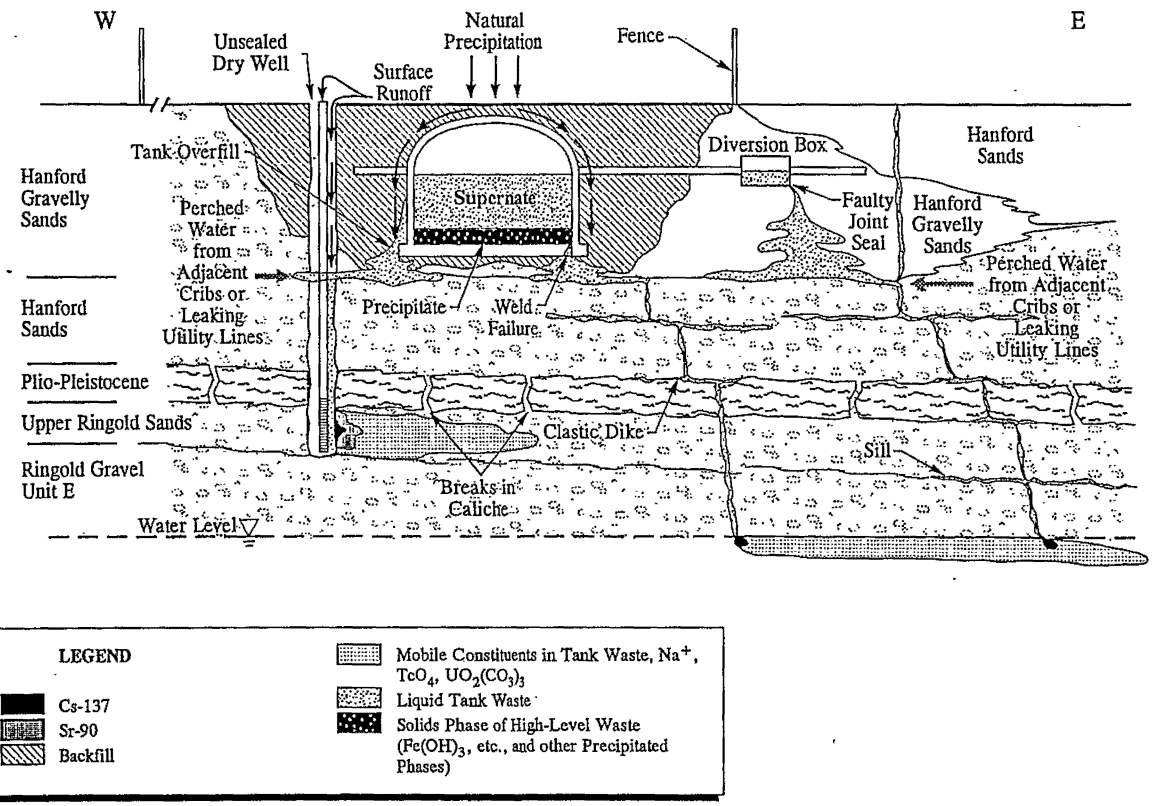
Each of the identified potential physical transport mechanisms listed are illustrated conceptually in Figure K.4.1.1. In the following paragraphs, a description of the potential transport mechanisms is provided.

Advective Flow Through Clastic Dike and Clastic Sills

Clastic dikes are ubiquitous in the 200 Areas and have been observed in the excavation of most major facilities in the 200 Areas including processing facilities and waste tanks (Fecht-Weekes 1996). Clastic dikes are lenses or tabular bodies, relatively narrow 18 to 38 cm (7 to 15 in.) (Fecht-Weekes 1996), with textural characteristics similar to the host sediment (clay and sand). Clastic dikes occur as near-vertical sediment-filled structures that cut across bedding planes of the Hanford Formation. Clastic sills are tabular structures of sedimentary material similar to clastic dikes but they are oriented parallel to the plane of the surrounding sediments. Figure K.4.1.1 depicts a conceptual cross section under a tank farm and includes an illustration of what a clastic dike and clastic sill would look like if exposed in an excavation. Clastic dikes have been observed to form polygons, based on observations of the Environmental Restoration Disposal Facility (ERDF) excavation (Fecht-Weekes 1996). A multisided polygonal cell encloses the host sediments. Individual polygonal cells are bounded by other polygons to form what is described as a honeycomb pattern when viewed from the air. The genesis of clastic dikes in not certain. There are several theories but the evidence is limited and does not conclusively support one theory. As with the genesis of clastic dikes, little is known about their hydraulic characteristics. Some inferences can be made from material descriptions where they have been intercepted by excavations and the lack of discernable impacts to groundwater levels and quality. The margins or vertical boundaries of clastic dikes are characterized by "clay skins," which are thin silt laminae that vary in thickness from 0.2 to 1 cm (0.08 to 0.4 in.). Internally, the dikes are composed of unconsolidated sedimentary infilling that trend parallel to the dike walls (Fecht-Weekes 1996).

The degree to which clastic dikes would function as a conduit (preferential flow path) or barrier to flow would depend on the relative amounts of clay and sand in the clastic dike and the continuity of any sand stringers within the clastic dike. Based on the observations of clastic dikes in excavations on the 200 Areas Plateau, the inferred hydraulic nature of the dikes is that of potentially a minor barrier to flow perpendicular to the dike. The clay content and lack of sand stringer continuity suggests that clastic dikes do not function as preferential flow paths for vertical flow.

Figure K.4.1.1 Conceptualization of Potential Vadose Zone Contaminant Transport Mechanisms



SOURCE: Adapted from Caggiano 1996

Advective Flow Through Breaks in the Caliche Layer in the Plio-Pleistocene Unit

Caliche layers generally would be a barrier to downward migration of contaminants in the vadose zone, if the layers were sufficiently extensive. Caliche layers were not included as discrete layers in the vadose zone modeling of contaminant transport. The Plio-Pleistocene unit, in which caliche layers generally are found, was included in the modeling assessment for source areas in the 200 West Area, and appropriate average material properties for this unit were used (Wood et al. 1995).

The presence of an intact, laterally extensive caliche layer would promote lateral spreading of infiltrating water. As a potential transport mechanism, breaks in the caliche layer in the Plio-Pleistocene unit would result in less lateral spreading and could allow for faster downward contaminant transport. Such breaks would function as a preferential flow path but only over a relatively short vertical distance. The overall thickness of the Plio-Pleistocene unit assumed for the vadose zone modeling assessments varies from approximately 4 to 5 m (13 to 16 ft) and caliche layers within this unit would be expected to be from 0 to 1 m (0 to 3 ft) thick.

Advective Flow Through the Unsealed Annular Space in Drywells and Groundwater Monitoring Wells

The unsealed annular space between the well casing and borehole in drywells affords the potential for 1) mobilizing contaminants that may be located at various elevations adjacent to the drywell; and 2) providing an additional driving force that could mobilize contaminants from past tank leaks that have migrated deeper into the vadose zone but not necessarily adjacent to the drywell.

Drywells and older groundwater monitoring wells have been installed near each tank for environmental monitoring and were drilled through near-surface contamination from tank leaks and other releases. These wells all were constructed with a cable tool drilling method in which the steel casing was driven down as the bottom of the borehole was cleaned out with the cable tool. A hardened steel drive shoe with a outside diameter larger than the casing diameter (diameters vary with driller and with available materials) by approximately 1.3 cm (0.5 in.) was attached to the bottom of the casing as it was being driven down the borehole. The annular space between the casing and borehole was not sealed. In the drywells, perforations in the steel casings have been made at various depths. The groundwater monitoring wells were installed with a screened section at the bottom that typically extended from 3 m (10 ft) above the water table to 6 m (20 ft) below the water table.

Drywells are similar to the older groundwater monitoring wells (Figure K.4.1.1) in the tank farm area except that drywells do not extend to the groundwater table and perforations in the drywells were made at various elevations. Drywells were installed to allow for periodic monitoring of radioactivity in the vadose zone from ground surface to the depth of the drywell. Increases in radioactivity detected in the drywells were indicative of a tank leak or migration of existing radioactivity in the vadose zone in response to another water source such as a leaking water line.

The hydraulic characteristics of the annular space between the well casing and borehole are not known. Because this space was not sealed and a drive shoe with larger outside diameter than the casing was

used, there exists the potential of voids and loosely packed sand and gravel that potentially could function as a preferential flow path for contaminant migration vertically through the vadose zone.

Infiltration of Surface Runoff into the Unsealed Annular Space of Drywells/Monitoring Wells

Infiltration of surface water or other near-surface liquid sources such as from a leaking water line (Figure K.4.1.1) has the potential for 1) mobilizing the near-surface contamination through which some of the wells were drilled; and 2) providing an additional driving force that could mobilize contaminants from past tank leaks that have migrated deeper into the vadose zone.

Large volumes of water, such as flooding of drywells, have been known to occur at some of the tank farms and water line leaks have been extensive enough to cause surface subsidence. Water sources such as described, combined with potential preferential flow paths created by unsealed annular spaces of drywells and monitoring wells could result in the mobilization of near-surface contaminants to greater depths within the vadose zone. Contaminants such as Cs-137, which are immobile in Hanford-type sediments under ambient conditions, would be expected to travel down the annular space with the saturation front and remain relatively close to the drywell. Mobile contaminants such as Tc-99 also would travel down the annular space with the saturation front but would be able to move farther laterally than less mobile contaminants, especially if lower conductivity units such as a caliche layer were encountered, which would promote lateral spreading. This potential phenomena is illustrated in Figure K.4.1.1.

The potential mobilization of near-surface contaminants as described also could apply to contaminants that are deeper in the vadose zone such as might occur from a past tank leak. The Cs is not expected to migrate far from the tank under ambient conditions and advective flow through the interstitial pore spaces of the sediments. Thus, a Cs plume from a past tank leak would have to intercept the annular space near the leak for Cs-137 to be mobilized and transported deeper in the vadose zone via the potential annular space pathway (Figure K.4.1.1).

Inflow of Surface Water into the Top of Drywells

This potential transport mechanism entails pipe flow down the inside of the drywell casings. The construction of drywells is discussed previously. Inflow of surface water into the drywell casings has the potential of mobilizing the deep-seated contaminants from past tank leaks or other sources by providing an addition driving force.

As discussed, large volumes of water such as flooding of drywells, which has been known to occur at some of the tank farms potentially could enter drywell casings. If sufficient water from sources such as this enter the drywell casings, they would flow out of casing perforations and/or the bottom the casing if unsealed. This could result in the mobilization of deep-seated contaminants. This potential transport mechanism would not affect contaminants such as Cs-137, which are immobile in Hanford-type sediments under ambient conditions unless there are casing perforations near the elevation of the

bottom of the tank leak and/or the Cs-137 was transported to a greater depth via a transport mechanism such as one involving a preferential flow path or chemically enhanced movement.

Movement of Contamination During Drilling

This potential transport mechanism involves the physical movement of particles during the drilling process from a higher elevation to a lower elevation. Many of the drywells were drilled through near-surface contamination. In addition, the drilling was not staged to prevent cross-contamination, the annular space between the single casing and the borehole was not sealed, and the cable tool drilling method potentially could carry near-surface contaminants to a greater depth. The impact on the underlying groundwater would be expected to be insignificant. Such occurrences could complicate data analyses or cause misinterpretation of data collected from the drywell monitoring programs.

Near-Surface Leaks from Water Lines And/Or Waste Transfer Lines

Even in the absence of potential preferential flow paths such as the annular space between well casings and boreholes or clastic dikes, large volumes of water such as from water line leaks, construction activities, or surface flooding could provide a driving force to quicken the transport of contaminants at all elevations.

K.4.1.3.2 Potential Chemical Vadose Zone Transport Mechanisms

As discussed in the introduction to this section, potential chemical-related transport mechanisms are the least understood of all the transport mechanisms especially considering the extremely high pH liquors present in the waste tanks. However, as will be discussed in the following paragraphs, chemical-related transport mechanism(s) may be responsible in part for the observation of contaminants such as Cs-137 at 38 m (125 ft) below the SX Tank Farm, which is deeper in the vadose zone than would have been expected based on the present understanding of the leak volume and contaminant mobility in the near-tank environment.

Potential chemical transport mechanisms may be associated with 1) sodium (Na) from the waste tanks and its effect on the mobility of some contaminants; 2) the reaction of hydroxide in the waste tanks with minerals in the vadose zone resulting in greater mobility of otherwise relatively immobile contaminants; and 3) the reaction of complexing agents that may be in the waste tanks with otherwise relatively immobile contaminants such as Co-60 and Sr-90 causing them to be more mobile. Potential chemical transport enhancing phenomena that could be in effect at the tanks include enhanced mobility resulting from; Na exchange, dissolution, and formation.

Enhanced Mobility Resulting from Sodium Exchange

Many of the defense mission processes involved acid dissolution. The resulting waste was neutralized with sodium hydroxide before being routed to the waste tanks. This practice has resulted in the presence of Na in the tank wastes at high concentrations and high pH (e.g., pH 12). As a consequence, Na may exchange for naturally occurring divalent cations such as calcium (Ca) and magnesium in the soil column. At high pH values, such as would occur when the tank contents had first exited the tanks, the surfaces of the mineral particles would be negatively charged and would attract cations. The

presence of high Na concentrations near these mineral surfaces could cause the desorption of other ions from the mineral surfaces as shown in the following equation modified from Caggiano 1996:

mNa^{+} (bulk solution) + nCa^{++} (mineral surface double-layer) =
xNa^{+} (mineral surface double-layer) + yCa^{++} (bulk solution)

This exchange process could result in more divalent cations reaching the groundwater and less Na than expected. This is consistent with observations and groundwater quality analyses from a well downgradient of the S and SX Tank Farms. An important consequence is that, under high Na conditions, Sr-90, which is chemically similar to Ca, may likewise be mobilized and migrate to a greater extent than previously expected. Other waste tank constituents may be affected similarly.

Enhanced Mobility Resulting from Silicate Mineral Dissolution

The neutralization of the wastes with sodium hydroxide meant that the tank contents were high pH, sometimes approaching a pH of 12. Many studies have shown that dissolution of silicate minerals such as those in the underlying vadose zone sediments would be accelerated at high pH and high temperature (Caggiano 1996). The dissolution reactions would occur when leaks from the tanks, some of which were self-boiling, contacted the mineral particles in the vadose zone. Such dissolution processes potentially could result in gelatinous reaction products that could cover the mineral exchange sites, which would enhance the mobility of contaminants such as Cs-137 that normally are retarded by exchange. However, the gelatinous reaction products could have the opposite effect by impeding moisture migration through the soil. This potentially could cause the soil permeability to be lower than that of the unaltered material, resulting in slower contaminant movement.

Another possible effect of silicate mineral dissolution is the leaching of previously adsorbed Cs-137. If the surface of silicate minerals in the vadose zone was dissolved, micro- and macropores could be opened. This in turn could lead to the leaching of Cs-137 that previously had been adsorbed. Heat from the tanks and the heat of leaking waste could increase the rate of silicate mineral dissolution and increase the Cs-137 release rate.

Enhanced Mobility Resulting from Complex Formation

Metal-organic complexes are compounds with a cyclic structure in which the organic components are bonded to the central metal ion. Millions of pounds of complex-forming organic chemicals such as citrate, glycolate and ethylenediaminetetraacetic acid (EDTA) were used for the recovery of U and Sr and subsequently discharged to the tanks. Once in the tanks, it would be possible for these complex-forming chemicals to react with other cationic constituents of the tank waste. Not all contaminants will react with organic complexing agents such as EDTA; generally, this interaction does not take place with monovalent cations such as Na, potassium, or Cs (Hill 1992). The Cs has very little potential for complexing with the organic chemicals found in the waste tanks. Complexing reactions may take place with other cations including the actinides and lanthanides. While it is known that metal-organic complexes will remain in solution under conditions where the metal ion itself would precipitate, there is a lack of data on the mobility of these complexes. Presumably, the complex would move relatively further and faster than the ion, but K_d values for metal-organic complexes remain a subject for future

study and investigation. Also, the ability of the complexing agents to remain active in the presence of high temperature and ionizing radiation is uncertain.

K.4.1.4 Potential Impact on TWRS Alternatives

Most of the potential vadose zone transport mechanisms, if active, would result in earlier contaminant first arrival at the vadose zone/groundwater interface, earlier peak concentrations, and higher peak concentrations for some or all of the contaminants, depending on the mechanisms. The following provides a qualitative description of the potential impact of the vadose zone transport mechanisms on each alternative and mitigation measures where applicable.

Preferential flow through clastic dikes and sills would result in earlier contaminant first arrival and peak times and higher peak concentrations in groundwater for all alternatives and contaminants and would be difficult to mitigate directly. The dikes first would have to be located with methods that possibly could include surface geophysics and test pits. Then, a sealing material that would withstand the chemicals in the tank waste would have to be injected effectively into the structure. Alternatively, a grout barrier could be considered. Overall, it may be unlikely that clastic dikes and sills could be directly mitigated. For ex situ alternatives, an effective indirect mitigation would be to reduce retrieval loss volume and contaminant concentrations.

Flow through breaks in a caliche layer is not expected to impact any of the alternatives because "credit" was not taken for caliche layer attenuation in the impacts analyses. Flow through drywell annular space from TWRS releases would have an effect on the No Action and Long-Term Management tank waste alternatives similar to that described for clastic dikes and sills. Mitigating the effect of flow through drywells would be relatively easily accomplished with a drywell removal (plugging) and/or drywell rehabilitation program. The other in situ and ex situ alternatives presumably would not be impacted because the drywells would be removed and plugged prior to installation of a cap over the tank farms.

Inflow of surface water into the drywell casings and annular space could decrease vadose zone contaminant transport time for the No Action and Long-Term Management alternatives. The effect on peak concentrations is uncertain. Peak concentrations could be reduced due to the dilution effect of surface water in flow. Mitigation such as plugging could be performed as described previously. The other in situ and ex situ alternatives would presumably not be affected because the drywells would be removed prior to installation of a cap over the tank farms. Cross contamination during drywell construction would not have an impact on any of the TWRS alternatives. Near-surface leaks from potable waste and waste water could decrease vadose zone contaminant transport time for the No Action and Long-Term Management alternatives. Mitigation would be relatively easy and would involve the removal of all utility lines from the tank farms area. The other in situ and ex situ alternatives would not be impacted because the utility lines would be removed prior to installation of a cap over the tank farms.

The three identified chemical transport mechanisms would result in earlier contaminant first arrival at the vadose zone/groundwater interface, earlier peak concentrations, and higher peak concentrations for some of the otherwise relatively immobile contaminants for all of the alternatives except the In Situ Vitrification alternative. The potential effects of the Na exchange and sediment dissolution transport mechanisms could be limited to near-tank due to the dilution of Na and hydroxide with natural water and would be rendered totally inactive at the saturated water located at 65 to 85 m (210 ft to 270 ft) below ground surface. The potential effect of enhanced mobility from complexing agents and the extent into the vadose zone and groundwater remain a subject for future study and investigation.

Depending on the resolution of the transport mechanisms that are currently active, it might or might not be necessary to take additional measures to control leaks during retrieval and remediate contaminants in the soil during tank farm closure.

It is not known if any of the potential transport mechanisms are active. Further, the potential transport mechanisms involving chemical enhancement are poorly understood. Mitigation of the chemical-related transport mechanisms could include indirect approaches such as reducing the volume and concentration of contaminants released during retrieval. Direct mitigation may be effective but much more information is needed about this type of potential transport mechanism.

K.4.2 TRANSPORT IN GROUNDWATER

The analyses of potential impacts on groundwater required several assumptions to address uncertainties. The major assumptions and uncertainties either are related to natural variables (e.g., vadose zone and aquifer parameter values) or are inherent to the assessment approach. Modeling assumptions are described in Section 4.2.1.

Post-remediation health risks to the public from TWRS alternatives would result from contaminants in the groundwater. The first arrival of any contaminant at the interface between the vadose zone and groundwater would occur between 140 and 250 years following remediation with the Long-Term Management and No Action alternatives. The tank inventory would be released faster for these alternatives than for any of the other alternatives, because it is assumed that there would be no engineered barriers to reduce infiltration or any attempt to remove or stabilize the tank waste. The first arrival of contaminants from the other alternatives would occur at about 2,000 years and the peak concentrations at about 5,000 years in the future.

Cumulative radionuclide concentrations that could occur in the groundwater from a potential combination of contamination from past disposal practices, currently anticipated future waste disposal, and the contamination from the TWRS alternatives are discussed in Volume Four, Appendix F.4.5. Peak groundwater concentrations from the various potential sources may occur at different times and different locations. However, to maximize the potential cumulative impacts, the peak concentrations of the past and reasonably foreseeable future sources were assumed to combine with the peak concentrations from the TWRS alternatives. This results in a conservative bounding of the maximum potential cumulative groundwater impact for each TWRS alternative. A more detailed modeling of the

potential cumulative impacts will be done in a future Hanford Site EIS. The results of the future analysis likely would indicate lower cumulative groundwater impacts than presented in this bounding analysis.

The highest cumulative groundwater concentrations occur for the No Action and Long-Term Management alternatives. The tank waste is the dominant contributor to the predicted concentrations. The other alternatives result in much lower cumulative radionuclide concentrations, and the dominant contributor is contamination from past disposal practices. The radiation dose and risk to the potential future user of the contaminated groundwater, the time at which it could occur, and the percent attributable to TWRS waste for each alternative are presented in Volume One, Table 5.13.5. The table is based on a hypothetical onsite farmer who is assumed to use the groundwater at the maximum cumulative point of concentration for each alternative. The groundwater is assumed to be used for all purposes, including drinking, washing, and gardening for 30 years. Future solid waste disposal at the 200 West Area solid waste burial ground and the ERDF collectively would contribute about 5 rem of the hypothetical 30-year resident farmer dose presented. Less than 10 mrem of the hypothetical 30-year resident farmer dose would be attributed to past and future solid waste disposal at the US Ecology solid waste burial ground.

K.4.2.1 Modeling Assumptions

Volume Four, Appendix F provides the basis of the groundwater impact analysis for the TWRS alternatives. The groundwater assessments in Volume Four, Appendix F required several assumptions to address uncertainties in some of the data. The major assumptions and uncertainties are related to either the natural system (i.e., an understanding and ability to assign vadose zone and aquifer parameter values) or uncertainties inherent to the assessment approach.

The most important assumptions and uncertainties are as follows:

- The rates of infiltration into natural ground and through a cap;
- Distribution coefficient (K_d) of contaminants;
- Uncertainty in future groundwater flow direction due to decay of groundwater mounds onsite and future land-use changes;
- Uncertainty in future groundwater flow direction and vadose zone thickness due to climate change;
- Uncertainty in vadose zone transport due to use of one-dimensional flow and transport simulation; and
- Uncertainty due to calculation of releases during retrieval.

Infiltration

Infiltration is one of the key driving forces for contaminant movement through the vadose zone. It affects the time of contaminant transport through the vadose zone: a higher rate results in a faster flow rate within the vadose zone and a shorter contaminant transport time.

Infiltration varies temporally and spatially. The temporal variation occurs seasonally with changes in temperature, plant activity, and precipitation and over longer periods as a result of climatic change. The spatial variation occurs with changes in vegetation type, surficial soil type, and human-made structures, such as paved parking lots. The vadose zone flow field varies temporally and spatially in response to infiltration rate changes. However, it is not directly measurable with conventional techniques and is modeled based on vadose zone parameters and the assumed infiltration rate. There is also a lag time between a change in infiltration rate at the surface and a change in the flow field in the vadose zone as the water percolates into the ground.

For each alternative, the initial infiltration rate (i.e., the rate before implementing remediation or no action) is assumed to be 5 cm/year (2 in./year). This rate is within the range of reported values for the Hanford Site and is appropriate given 1) the recent ground cover changes in the tanks' vicinity; 2) the uncertainties in future ground cover conditions; and 3) the one-dimensional vadose zone flow and transport model used for the simulations. Infiltration in the 200 Areas is reported to range from near zero, where the ground cover is a shrub-steppe type characteristic of predevelopment conditions, to 10 to 13 cm/year (4 to 5 in./year), where the ground is unvegetated sand and gravel, characteristic of conditions around the tank farms since the mid-1940's or later (Gee et al. 1992). For alternatives that incorporate a cap, limited sensitivity analysis has shown that the contaminant transport through the vadose zone is not sensitive to the initial infiltration rate (Volume One, Section 4.3.5).

The higher infiltration in the vicinity of the tanks is a relatively recent occurrence in response to ground cover modifications in the last 50 years. These modifications are not expected to have changed the flow field at depth within the vadose zone from that of predevelopment conditions. For alternatives involving a cap, conditions after the cap is installed are assumed to be representative of predevelopment conditions in that the infiltration in the tank vicinity would be low. Infiltration is assumed to remain at 5 cm/year (2 in./year) for the No Action and Long-Term Management alternatives.

Spatially, the rate would be expected to be lower away from the tanks where vegetation is present and surficial soils are of a finer texture. The one-dimensional model used for contaminant transport simulations through the vadose zone does not account for these infiltration changes with time and space. Thus, the assumed infiltration rate of 5 cm/year (2 in./year) was chosen as a conservative estimate.

The No Action and Long-Term Management alternatives are the only two tank waste alternatives that would not involve placement of a cap over the tanks. If a higher infiltration rate was assumed (i.e., greater than 5 cm/year [2 in./year]), the result would be earlier contaminant arrival in the groundwater with higher peak concentrations. Conversely, use of a lower infiltration rate would result in a delayed effect with somewhat lower peak contaminant concentrations.

Distribution Coefficients

The various contaminants in the tank waste each have their own chemical characteristics and would interact with the groundwater and geologic materials differently. An indication of a contaminant's

mobility in the vadose zone and groundwater aquifer is the distribution coefficient (K_d). A contaminant moves with the speed of water if its K_d is zero and progressively slower than water as the K_d value increases. This difference would result in different rates of contaminant movement in the vadose zone and groundwater, ranging from that of groundwater to no measurable movement over a period of hundreds of years.

The tanks contain more than 100 radioactive and nonradioactive contaminants that potentially would impact groundwater. Contaminants that are insoluble were assumed not to leach to groundwater. The K_d values for the contaminants range from zero (in which the contaminant's movement in water is not retarded) to more than 100 (in which the contaminant moves much more slowly than water). Therefore, the contaminants were grouped as follows based on their mobility in the vadose zone and underlying unconfined aquifer:

- Group 1 - Nonsorbing ($K_d = 0$); K_d values in this group ranged from 0 to 0.99 mL/g;
- Group 2 - Slightly sorbing ($K_d = 1$); K_d values ranged from 1 to 9.9 mL/g;
- Group 3 - Moderately sorbing ($K_d = 10$); K_d values ranged from 10 to 49.9 mL/g; and
- Group 4 - Strongly sorbing ($K_d = 50$); K_d values are 50 mL/g or greater.

Contaminant transport simulations were performed for each group, using the lowest value of the range. These results were used to design a limited sensitivity analysis (Volume Four, Section F.4.3.5).

The distribution coefficient for a given contaminant depends not only on the chemical characteristics of the contaminant but also on the chemistry of the aquifer (or vadose zone) and the water within. For example, a contaminant with a K_d value of 0 in saturated sands might have a nonzero K_d value in a clay-rich zone. There is a large uncertainty with regard to contaminant mobility in all the different material and water types at the Hanford Site. For example, the K_d value of U has a reported experimental value that varies from a low estimate of 0 to a high estimate of 79.3 mL/g (best estimate value is 0.6 mL/g) in Hanford Site sediments with waters of neutral to high pH, low ionic strength, low organic content, and toxic solutions. In Hanford Site sediments with waters of neutral to high pH levels, low ionic strength, low organic, and anoxic solutions, this same contaminant has a reported experimental value that varies from a low estimate of 100 to a high estimate of 1,000 mL/g (best estimate value is 100 mL/g) (Kaplan et al. 1994).

Given the uncertainty in the mobility of U, U was initially assumed to have a zero K_d. Assuming a high K_d would mean the contaminant did not reach groundwater within the 10,000-year period of interest.

Vadose zone simulations show that U with an assumed K_d of zero does reach groundwater within the 10,000-year period of interest for all the alternatives and that drinking water standards are potentially exceeded. Based on these results, the sensitivity of the U mobility assumption can be better understood with additional simulations with slightly higher values of K_d. Vadose zone simulations indicate that contaminants with a K_d of 0.125 mL/g do not reach the groundwater within the 10,000-year period of interest, using the Ex Situ Intermediate Separations alternative as the base case.

Future Groundwater Flow Direction

Under present land use conditions, groundwater flow direction and gradient on the Hanford Site is dynamic and changes primarily in response to wastewater disposal to the vadose zone and future land-use changes. Other factors could influence groundwater flow and gradient to a lesser degree. These factors include irrigation to the west of the Site and water level in the Columbia and Yakima Rivers.

The groundwater impact assessment for the TWRS EIS was based on a conceptual model with the following salient features: 1) water movement from surface infiltration, tank releases, and other near-surface sources is through the vadose zone, into the underlying aquifer, and ultimately to the Columbia River, 2) flow and transport of water and contaminants in the vadose zone and underlying aquifer are by advection through the interstitial pore spaces of the sediments, 3) the Columbia and Yakima Rivers form hydraulic boundaries: the Yakima River recharges the unconfined aquifer in the southern part of the Site and the Columbia River receives discharge from the unconfined aquifer, 4) the Cold Creek and Dry Creek valleys recharge the unconfined aquifer, part of which is derived from infiltrating irrigation waters to the west of the Site, 5) the Rattlesnake Hills to the west of the Site are a no-flow boundary, and 6) natural infiltration on the Hanford Site is assumed to be zero. This resulted in an expectation that most of the contaminants from the tank sources would move in a west to east/southeast direction with a small amount flowing northerly through the gap between Gable Butte and Gable Mountain. The December 1979 groundwater level data on which the impact assessments were based are the most recently available groundwater levels consistent with the conceptual model and have been extensively used and tested by other investigators (Wurstner-Devary 1993).

The December 1979 groundwater level data represent a period of relative steady conditions but also a period in which there were major groundwater mounds on the Site. These mounds are associated with wastewater disposal to B Pond, U Pond, and Gable Mountain Pond. Gable Mountain Pond has been closed, and waste disposal to the U and B Ponds has diminished. Both of these ponds ultimately will be closed. The groundwater mounds present in December 1979 have diminished with these changes and ultimately will totally dissipate.

The appropriateness of the December 1979 groundwater level data as a basis for impact analysis was tested in two ways: 1) qualitatively, by comparing the December 1979 groundwater level surface with predicted Site groundwater levels prior to Site development (i.e. hindcast) and 2) quantitatively, by calculating future Site groundwater levels using the VAM2D model and the same assumptions of boundary conditions and infiltration as used for the impact analysis, except that there was no water inflow from Site wastewater disposal to the vadose zone. Contaminant concentrations and associated risks were predicted for the Ex Situ Intermediate Separations alternative using this "no mound" predicted future flow field.

The differences among the December 1979 groundwater levels as simulated by the CFEST model (Volume Four, Figure F.2.4.2), the interpolated and contoured groundwater levels based on individual groundwater levels measured in site monitoring in December 1979, and the December 1979

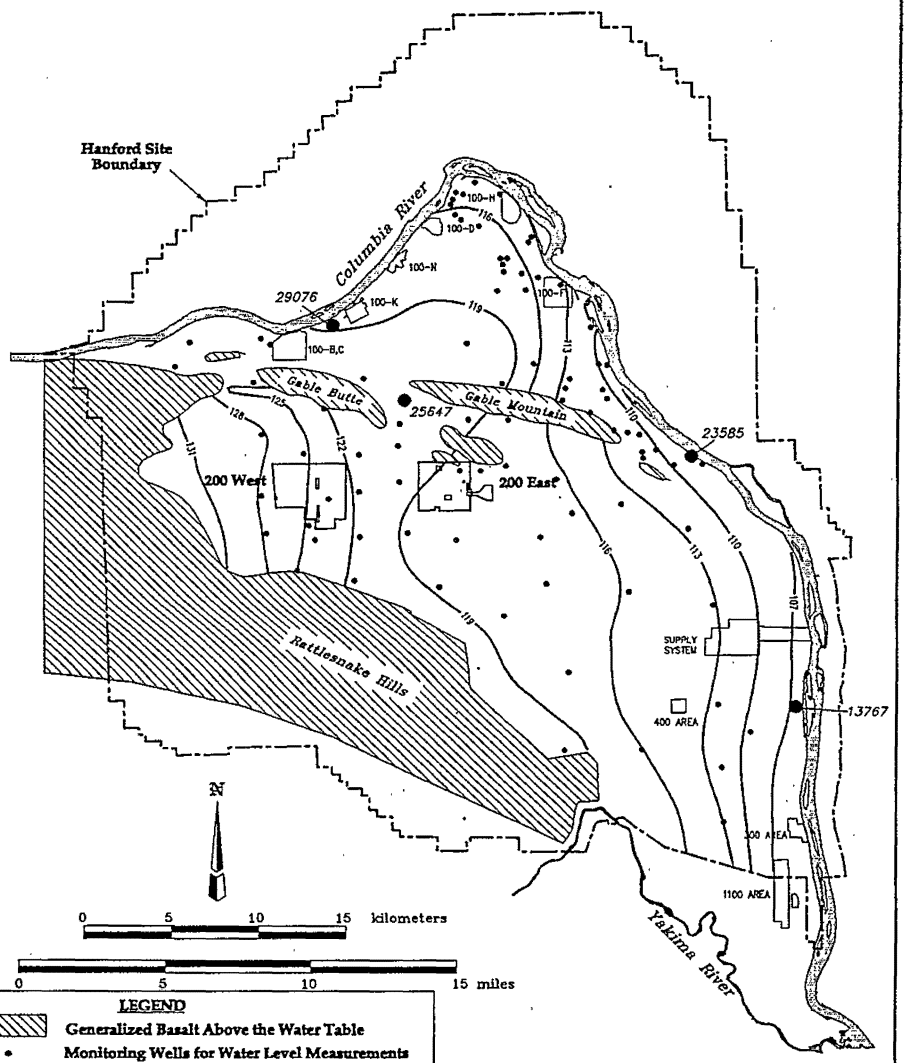
groundwater levels as simulated by the VAM2D model were insignificant. The inferred groundwater flow directions in the hindcast (Figure K.4.2.1) were similar to the December 1979 simulated groundwater levels (Volume Four, Figure F.4.3.1). Groundwater flow directions inferred in the December 1979 representation were generally southeast/east, with a small component flowing northeast through the gap between Gable Butte and Gable Mountain. Groundwater flow directions inferred in the hindcast were due east, with a slight component of flow to the southeast and a slight component flowing northeast through the gap between Gable Butte and Gable Mountain.

The appropriateness of the December 1979 groundwater levels as a basis for impact analysis was examined quantitatively by predicting future groundwater levels assuming no impacts (e.g., groundwater mounds) from Site wastewater disposal and analyzing the associated risks for the Ex Situ Intermediate Separations alternative. Future groundwater levels were predicted by a steady-state simulation of the groundwater flow system assuming no inflow from Site wastewater discharges. These wastewater discharges were active in December 1979 and their estimated flow rates are provided in Volume Four, Table F.2.4.1. All the sites listed in this table, except the Rattlesnake Mountain Springs site, are waste disposal sites. The predicted future groundwater levels for these assumed conditions are provided in Figure K.4.2.2.

The future predicted groundwater levels, the December 1979 groundwater representation, and the hindcast all were very similar. As expected, the groundwater mounds from U Pond and B Pond evident in the December 1979 groundwater levels are not evident in Figure K.4.2.2. Recharge on the western portion of the Site from the valley out of the Rattlesnake Hills, coupled with the relatively low hydraulic conductivity of the sediments west of the 200 West Area, resulted in a relatively large groundwater gradient as indicated by the close contour spacing in that area. The gradient magnitude and direction in the area midway between 200 West and 200 East to the Columbia River on the east side of the Site were similar to the hindcast, which indicated a primary easterly flow direction from the 200 Areas.

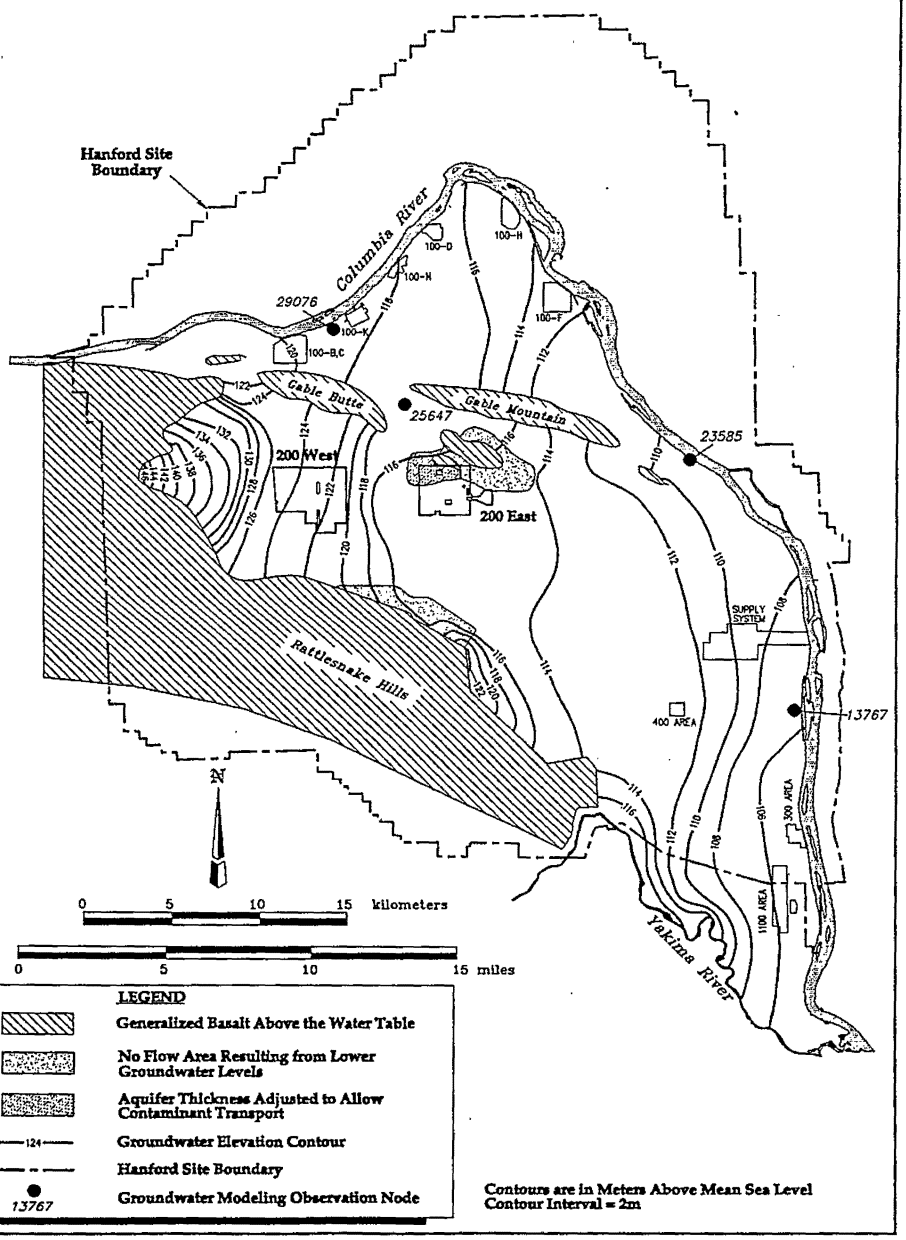
The dissipation of the groundwater mounds, which would occur when the wastewater discharge was terminated, and the overall groundwater level drop, resulted in a larger area of Gable Mountain extending above the groundwater table. This difference in the Gable Mountain area above the groundwater table for the December 1979 groundwater levels and the forecasted "no mound" groundwater levels is illustrated in Figure K.4.2.2. This resulted in a slightly smaller aquifer area in which contaminants released from the waste tanks would dilute. The change would tend to prevent contaminants from diluting as quickly in the area immediately east of the 200 East Area, compared to the prediction based on the December 1979 groundwater levels. The larger Gable Mountain area above the groundwater table was predicted to extend to the northern portion of the 200 East Area, including the area around waste tank source area 1ESS. For comparison purposes, the aquifer in this area (Figure K.4.2.2) was assumed to be thicker by approximately 1 to 3 m (3 to 10 ft). This was necessary to simulate the transport of contaminants from the 1ESS source area through the aquifer. This adjustment to aquifer thickness may have artificially resulted in higher contaminant concentrations in the area near 1ESS.

Figure K.4.2.1 Hindcast of Water Levels in the Unconfined Aquifer



Modified After: Delaney 1991

Figure K.4.2.2 Predicted Future Groundwater Levels in the Unconfined Aquifer After Affects from Discharge of Waste Water Have Dissipated



Section K.7.5 compares the calculated risks for the Ex Situ Intermediate Separations alternative based on December 1979 groundwater levels with those based on the predicted future groundwater levels shown in Figure K.4.2.2.

Climate Change

A climate change scenario was examined that included the return of an ice age. At present, the earth is in an interglacial phase. A transition to a glacial climate during the next few thousand years is highly unlikely. Such a transition during the next 10,000 years is more probable. Over a million-year time scale the global climate is virtually certain to pass through several glacial-interglacial cycles (National Research Council 1995).

Three potential changes associated with an ice age would likely impact waste disposed of onsite. These include 1) a cooler, wetter climate during early and late phases of the ice age that would increase infiltration through the waste and cause a faster movement of contaminants from onsite disposal locations to the Columbia River; 2) a cold, dry climate during the middle phase of the ice age that would reduce infiltration through the waste and slow migration of waste to the Columbia River; and 3) a catastrophic flood that would reach the Central Plateau and dislodge and scatter waste from the disposal site. During previous ice ages, ice dams have formed on upper tributaries of the Columbia River. These dams, when broken through, have resulted in floods of up to 2E+06 m^3 (5E+08 gal) of water in a period of a few weeks compared to the present average flow of the Columbia River of about 1E+05 m^3/year (3E+07 gal/year). Such floods would be likely to impact any waste disposed of near the surface on the Hanford Site, scouring out waste sites to a depth of several meters and then redepositing waste from the tanks throughout the Pasco Basin.

Radioactive decay would have reduced the hazard from wastes disposed of onsite under all of the alternatives by the time of the postulated glacial flood in the next 40,000 to 50,000 years. For all of the alternatives, peak impacts on groundwater beneath the 200 Areas would have occurred at 210 to 350 years from the present for the No Action and Long-Term Management alternatives for K_d=0 and at 3,600 to 8,900 years from the present for all other alternatives. Because of the low concentrations of Pu and other radionuclides that would remain at the time of the postulated flood, the radiological consequences of a glacial flood would be small in comparison to the effects of the flood itself (DOE 1987).

One-Dimensional Flow

Two-dimensional or three-dimensional simulations of contaminant flow and transport in the vadose zone could provide more accurate estimates of contaminant arrival time, peak time, and peak concentrations (compared to one-dimensional simulations), provided that the spatial vadose zone hydraulic and transport properties were known. However, adequate knowledge of these parameters for two- or three-dimensional modeling currently is not available.

The one-dimensional simulations provided for this assessment were conservative and resulted in comparable estimates for each alternative. The simulations were conservative compared to two- or

three-dimensional simulations using the same vadose zone properties. Because two- or three-dimensional flow and transport simulations allow for lateral flow and transport (slowing vertical movement), the transport times for the one-dimensional simulations were as fast or faster and the peak concentrations were higher because all transport and flow were in one direction only: downward within a uniformly porous medium.

Contaminants were assumed to move downward by advection with infiltration from precipitation and dissolution and leaching from tanks. The flow of water and transport of contaminants in the vadose zone would principally be in the vertical direction because of the hydraulic gradient and geologic structure (layering) in the vadose zone, which was assumed insufficient to result in extensive lateral spreading. Therefore, only one-dimensional modeling was performed in the vadose zone assuming a uniformly porous media and uniform hydraulic gradient.

Releases to the Soil During Retrieval

The ex situ alternatives were all assumed to result in contaminant releases from SSTs during retrieval operations. Each SST was conservatively assumed to lose 15,000 L (4,000 gal) during retrieval for a total of 2E+06 L (6E+05 gal) from the 149 SSTs. This assumption was based on current information from the waste retrieval program and the assumption that the average leakage volume from an SST would be one order of magnitude lower than the maximum release volume estimated for tank 241-C-106 during sluicing operations (DOE 1995d).

Based on the nominal retrieval scenario, all of the ex situ alternatives would have a contaminant first arrival time at the vadose zone/groundwater interface of approximately 1,000 years because of losses during retrieval. The lower bounding retrieval scenario would not change the time of release, and the contaminant first arrival time would not be expected to change either.

The rising limb of the concentration versus time curves at the vadose zone/groundwater interface (see Volume Four, Figure F.3.5.1 for characteristics of the ex situ alternatives) would shift to the right and calculated peak concentrations would be lower and could occur slightly later. Even though retrieval releases occur early compared to residual releases, the maximum peaks for the lower bounding scenario could be somewhat lower because the total mass released would be lower.

The following general alternative-specific assumptions were made for the modeling effort.

General Assumptions

- For the radioactive contaminants, the mass was estimated for each isotope based on the decay of that isotope to December 31, 1995.
- Some contaminants in the tank inventory are of little importance and were not considered further in the groundwater assessment (Volume Four, Table F.2.2.3 provides a list of these contaminants).

- Contaminants were assumed to be released by their desorption and dissolution into pore fluids (this assumption holds for tank saltcake/sludge (No Action), grouted, and vitrified waste forms) and then moved by advection and diffusion from the waste source into the surrounding natural material or engineered barrier. Contaminants that are insoluble were assumed not to leach to groundwater.
- The LAW disposal facility was considered one source area even though 41 vaults are anticipated. The vaults would be covered with a continuous Hanford Barrier and the contents of each vault were assumed similar.
- The 177 tanks were divided into eight source areas based on configuration, tank proximity, and groundwater flow direction.
- Ingrowth of decay products was not calculated.
- No preferential flow paths (e.g., macropore flow) exist in the vadose zone.

1) No Action (Tank Waste) and Long-Term Management alternatives assumptions included the following.

- Releases to the groundwater system were associated with the complete inventory of contaminants in the waste tanks (Volume Four, Table F.2.2.2) except for insoluble contaminants.
- Infiltration would be 5 cm/year (2 in./year) initially and throughout the period of interest.
- Contaminant releases for the five SST source areas were assumed to begin at the end of institutional control.
- Contaminant releases from the three DST source areas were assumed to begin 100 years after the end of institutional control.
- The duration of this release was based on a congruent dissolution model. In this model, all constituents in the waste inventory were assumed to be released in proportion to the most abundant material in the waste inventory, nitrate. The concentration of nitrate is 360 g/L (Serne-Wood 1990). The initial unit concentration assumed in modeling for K_d groups 1 and 2 (K_d equals zero and one) was 400 g/L. The only difference between these alternatives is that under the Long-Term Management alternative, DSTs would be replaced during the institutional control period and assumed to begin leaking 100 years after the institutional control.

2) In Situ Fill and Cap alternative assumptions included the following.

- Releases to the groundwater system were associated with the complete inventory of contaminants in the waste tanks (Volume Four, Table F.2.2.2).
- The initial vadose zone flow field was based on an infiltration rate of 5 cm/year (2 in./year).
- In 1997, the infiltration rate was assumed to decrease to 0.5 cm/year (0.2 in./year) in response to Hanford Site activities and decrease again to 0.05 cm/year (0.02 in./year) after the Hanford Barrier was installed. The Hanford Barrier was assumed to have lost integrity 1,000 years after installation, which would cause infiltration to increase to

0.1 cm/year (0.04 in./year) throughout the remainder of the 10,000-year period of interest.

- Five hundred years after the Hanford Barrier was installed, contaminant releases for the eight tank source areas were assumed to begin (NRC 1994).
- The principal constituent of the waste would be nitrate and the congruent dissolution release model was used to estimate release from the waste, which was the same approach as described for the No Action and Long-Term Management alternatives. The dissolution concentration of nitrate was assumed to remain constant at 360 g/L (Serne-Wood 1990), regardless of the water flux. The initial unit concentration assumed in modeling was 400 g/L.
- The initial contaminant inventory and concentrations were the same as for the No Action and Long-Term Management alternatives.

3) In Situ Vitrification alternative assumptions included the following.

- Releases to the groundwater system were associated with the contaminants in the waste tanks, but the vitrification process would result in a different waste form (Volume Four, Table F.2.2.4).
- The initial vadose zone flow field was based on an infiltration rate of 5 cm/year (2 in./year).
- The infiltration rate was assumed to decrease to 0.05 cm/year (0.02 in./year) after the Hanford Barrier was installed. The Hanford Barrier was assumed to lose integrity 1,000 years after installation, which would cause infiltration to increase to 0.1 cm/year (0.04 in./year) throughout the remainder of the 10,000-year period of interest.
- Five hundred years after the Hanford Barrier was installed, contaminant releases for the eight tank source areas were assumed to begin (NRC 1994).
- The release model for the vitrified mass was based on a constant total mass loss rate of 1.0E-03 g/m^2 per day (Shade et al. 1995). The mass loss rate was independent of the water flux from recharge. The composition of the vitrified mass was assumed to be identical to the soda-lime glass formed in the Ex Situ No Separations alternative (WHC 1995c). The release concentration of contaminants was then assumed to be proportional to their concentration in the soda-lime glass. Because the total mass loss rate would be constant, the composition of the released solution would be unaffected by the recharge rate. Because the infiltration rate would double after the barrier lost integrity, the mass flux would increase proportionately. The low value of the total mass loss rate, combined with the very large quantity of vitrified mass, would result in a release time measured in millions of years.

4) Ex Situ Intermediate Separations alternative assumptions included the following.

- Releases to the groundwater system were associated with 1) releases during retrieval from the SSTs; 2) releases from residuals that could not be removed from the waste tanks; and 3) releases from the LAW disposal facility.

- The amount of liquid released from each SST during retrieval operations would be 15,000 L (4,000 gal). The mass associated with retrieval operations at each source area is provided in Volume Four, Table F.2.2.5.
- The tank residual materials were assumed to be 1 percent of those for the No Action and Long-Term Management alternatives (Volume Two, Appendix A).
- The mass associated with the contaminants in the LAW vaults was based on the vitrified form of the retrieved waste (Volume Four, Table F.2.2.6).
- The initial vadose zone flow field was based on an infiltration rate of 5 cm/year (2 in./year) for tank source areas and the LAW source area.
- In 1997 the infiltration rate was assumed to decrease to 0.5 cm/year (0.02 in./year) in response to Site activities and decrease again to 0.05 cm/year (0.02 in./year) after the Hanford Barrier was installed at tank source areas and the LAW source area. The Hanford Barrier was assumed to lose integrity 1,000 years after installation, which would cause infiltration to increase to 0.1 cm/year (0.04 in./year).
- Contaminant releases for the five SST source areas were assumed to occur 1) during retrieval in 1997; and 2) from residual materials 500 years after Hanford Barrier construction.
- Contaminant releases for the three DST source areas were assumed to result from releases from residual materials 500 years after Hanford Barrier construction.
- Contaminant releases for the LAW facility were assumed to begin 500 years after the Hanford Barrier was constructed over the vaults (NRC 1994).
- The solubility of each contaminant for retrieval releases and tank residuals would be proportional to the solubility of nitrate. For the tank source areas, the initial unit concentration assumed in modeling was 400 g/L.
- The release model for the glass cullet was based on a constant corrosion rate of 3E-06 cm/year (1E-06 in./year) (Jacobs 1996). This corrosion rate would be independent of the water flux from infiltration. The composition of the LAW glass was taken from the engineering data package for this alternative (WHC 1995j). The release concentration of the contaminants was assumed to be proportional to their concentration in the LAW glass. Because the total mass loss rate would be constant, the composition of the released solution would be unaffected by the infiltration rate. Because the infiltration rate would double after the barrier lost integrity, the mass flux would increase proportionately. The low value of the corrosion rate, combined with the large quantity of vitrified mass, would result in a calculated release time of 170,000 years.
- For the tank source areas, the initial contaminant concentrations were the same as for the No Action and Long-Term Management alternatives. The initial concentrations for the LAW disposal facility are provided in Volume Four, Table F.2.2.17.

5) Ex Situ No Separations alternative assumptions included the following.
The assumptions for this alternative were the same as for the tank retrieval and tank residual components of the Ex Situ Intermediate Separations alternative (i.e., 1 percent of tank waste was assumed to remain as a residual in the tanks).

6) Ex Situ Extensive Separations alternative assumptions included the following.
The assumptions for this alternative were the same as for the tank retrieval and tank residual components of the Ex Situ Intermediate Separations alternative (i.e., 1 percent of tank waste was assumed to remain as a residual in the tanks). For this alternative, the contaminant inventory in the LAW vaults would be smaller than estimated for the LAW vault component of the Ex Situ Intermediate Separations alternative (see Volume Four, Table F.2.2.7).

7) Ex Situ/In Situ Combinations 1 and 2 alternatives assumptions included the following.
These alternatives would incorporate all of the assumptions listed for the Ex Situ Intermediate Separations alternative and the In Situ Fill and Cap alternative except as noted as follows. For the tanks remediated ex situ:

- Releases to the groundwater system would be due to losses during retrieval (Volume Four, Table F.2.2.8).
- Residual waste that could be left in a tank after retrieval was assumed to be 1 percent of the initial tank inventory.
- The 1 percent residual waste was added to the inventory of tanks remediated in situ.

For the tanks remediated in situ:

- Releases to the groundwater system would be due to leaching from the waste form within the tanks (Volume Four, Table F.2.2.9). Table F.2.2.9 contains the initial waste inventory.

8) Phased Implementation alternative assumptions included the following.

- There would be no groundwater impacts associated with the first phase of this alternative because there would be no contaminant releases from the tanks.
- The assumptions for the total alternative would be the same as those for the Ex Situ Intermediate Separations alternative.

K.4.2.2 Parameter Sensitivity

Parameter sensitivity was investigated for the following areas:

- The effect of higher glass surface areas for the In Situ Vitrification alternative;
- The effect of changing the performance period of the Hanford Barrier from 1,000 to 500 years;
- The effect of the decay of the potentiometric head from groundwater mounding due to discharge to the Hanford Site ponds;
- The effect of variations in infiltration rate; and
- The effect of variations in distribution coefficient (K_d).

In Situ Vitrification Surface Area

As part of the parameter sensitivity analysis, the vitrified glass surface area was assumed to have doubled to represent the case where extensive cracking of the waste form occurred. This higher surface area doubled the corrosion rate. The predicted U-238 concentrations in groundwater at

5,000 and 10,000 years, respectively, at the higher corrosion rate are provided in Figures K.4.2.3 and K.4.2.4. Comparing these figures with Volume Four, Figures F.4.3.4 and F.3.4.5, which were based on the original corrosion rate, shows that the estimated contaminant concentrations in groundwater at the higher surface area are almost indistinguishable from those calculated for the base case analysis.

500-Year versus 1,000-Year Hanford Barrier

There is some uncertainty concerning the long-term performance of the Hanford Barrier that would be placed over the tanks and the LAW vaults. This uncertainty was investigated using the In Situ Fill and Cap alternative as a basis for comparison. The Hanford Barrier was assumed to degrade 500 years after placement instead of after 1,000 years as assumed in Volume Four, Section F.3.3. At 500 years, the water flux through the Hanford Barrier was assumed to double from 0.05 to 0.1 cm/year (0.02 to 0.04 in./year). The calculated nitrate concentration at selected locations within the unconfined aquifer is provided in Figure K.4.2.5. Comparing Figure K.4.2.5 with Volume Four, Figure F.3.3.3 shows no significant difference in peak concentrations of nitrate, the most abundant and mobile contaminant. The time of arrival of contaminants (using nitrate as an example) is slightly earlier for the 500-year Hanford Barrier. A comparison of Figures K.4.2.6 and Volume Four, Figure F.3.3.16 indicates that U-238 concentrations in groundwater at 10,000 years from the present are low for both cases, and for the 500-year Hanford Barrier, U-238 concentrations are lower by a factor of approximately 5 to 10. This occurs because the higher water flux through the 500-year Hanford Barrier would allow U-238 to travel faster through the vadose zone and the groundwater system.

Variations in Infiltration Rate

An infiltration rate of 5 cm/year (2 in./year) was assumed as the initial condition for all the alternatives. For those alternatives involving active remediation, such as the In Situ Vitrification and Ex Situ Intermediate Separations alternatives, the infiltration rate was assumed to be reduced to 0.5 cm/year (0.2 in./year) during the remediation period (e.g., during waste removal and cap construction).

The assumed infiltration rate of 5 cm/year (2 in./year) is an appropriate value that is within the range of reported values. Prior to Site development in the early 1940's, the infiltration rate was likely much lower, on the order of a few millimeters per year, characteristic of the 200 Areas Plateau under naturally vegetated conditions. As the tank farms were constructed, the natural vegetation was removed and the vicinity around the tanks was covered with sand and gravel. The current infiltration rate in the vicinity of the tanks is believed to be on the order of 10 cm/year (4 in./year). This higher infiltration rate would be greatly reduced with the installation of a cap or return to natural shrub-steppe type ground cover.

Figure K.4.2.3 Predicted Uranium-238 Concentrations in Groundwater at 5,000 Years for the In Situ Virtification Alternative (High Glass Corrosion Concentration)

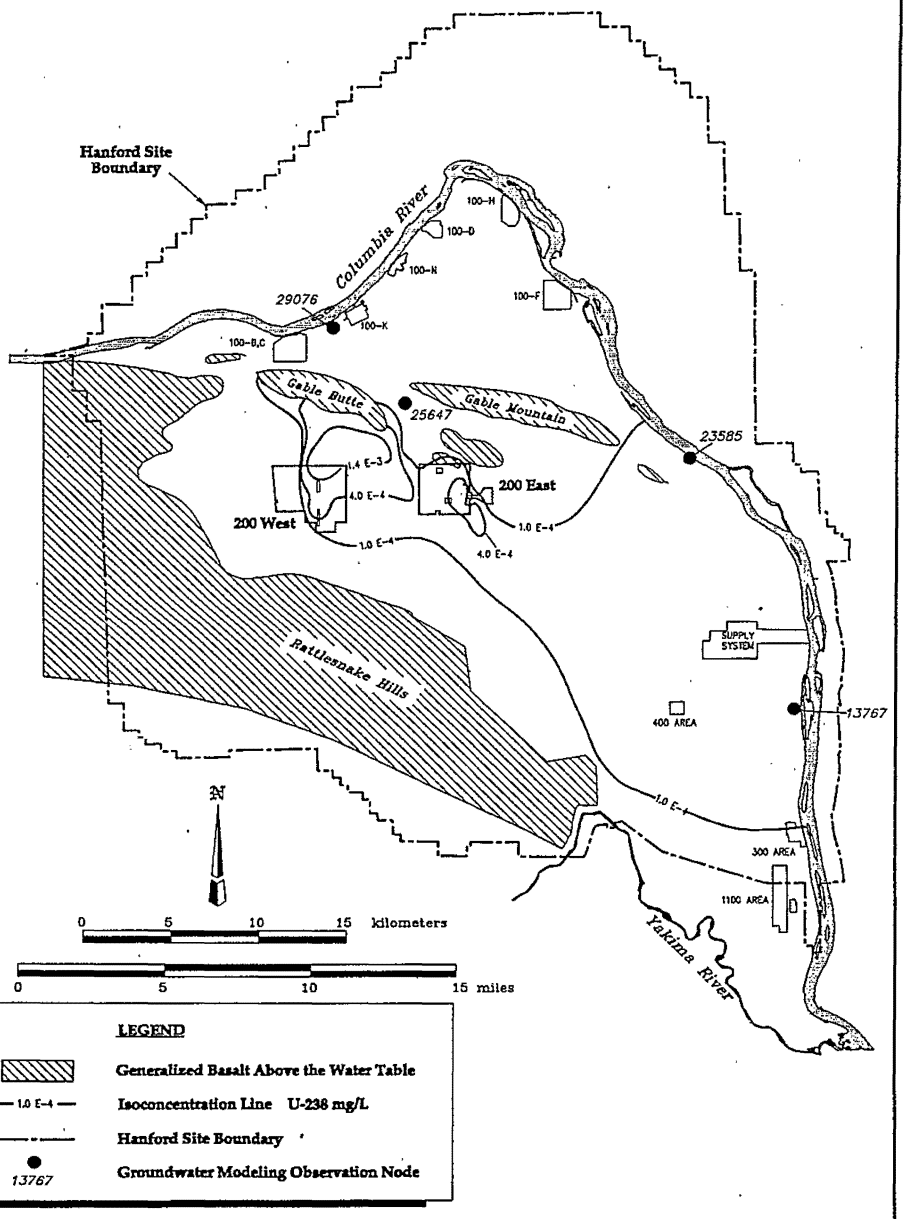


Figure K.4.2.4 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Vitrification Alternative (High Glass Corrosion Concentration)

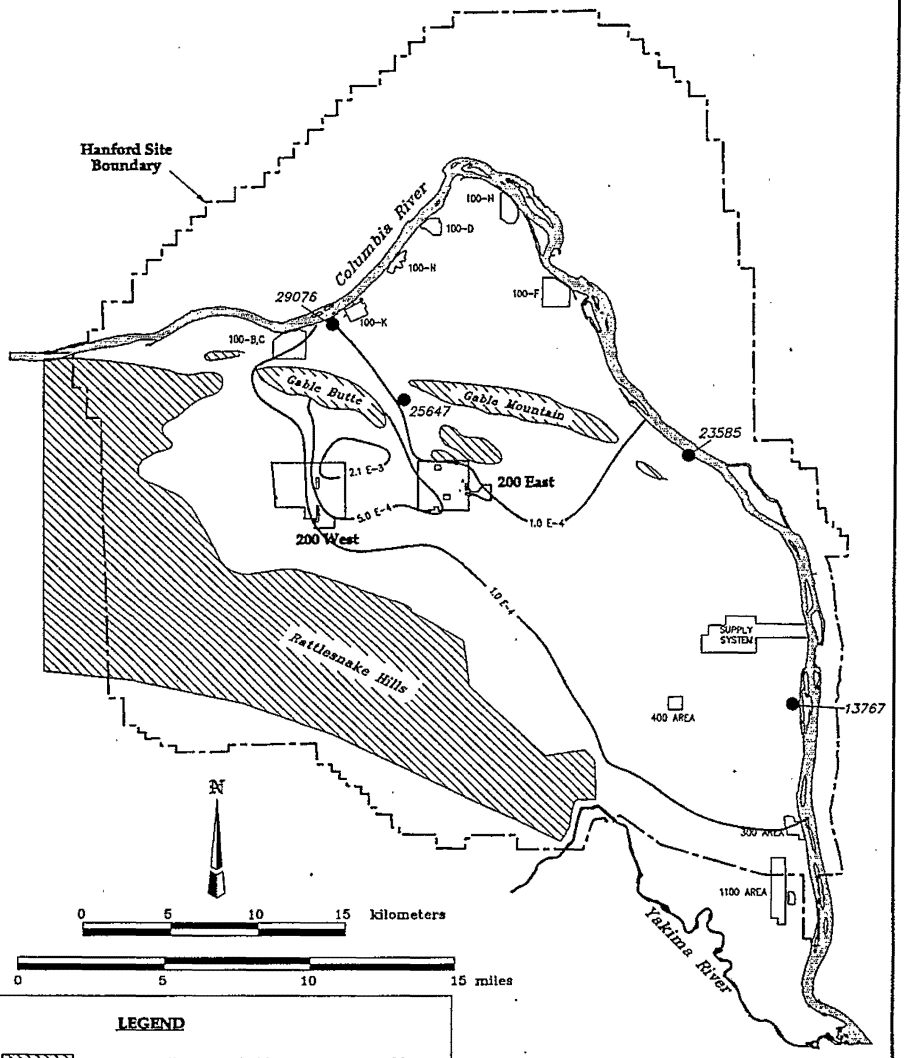
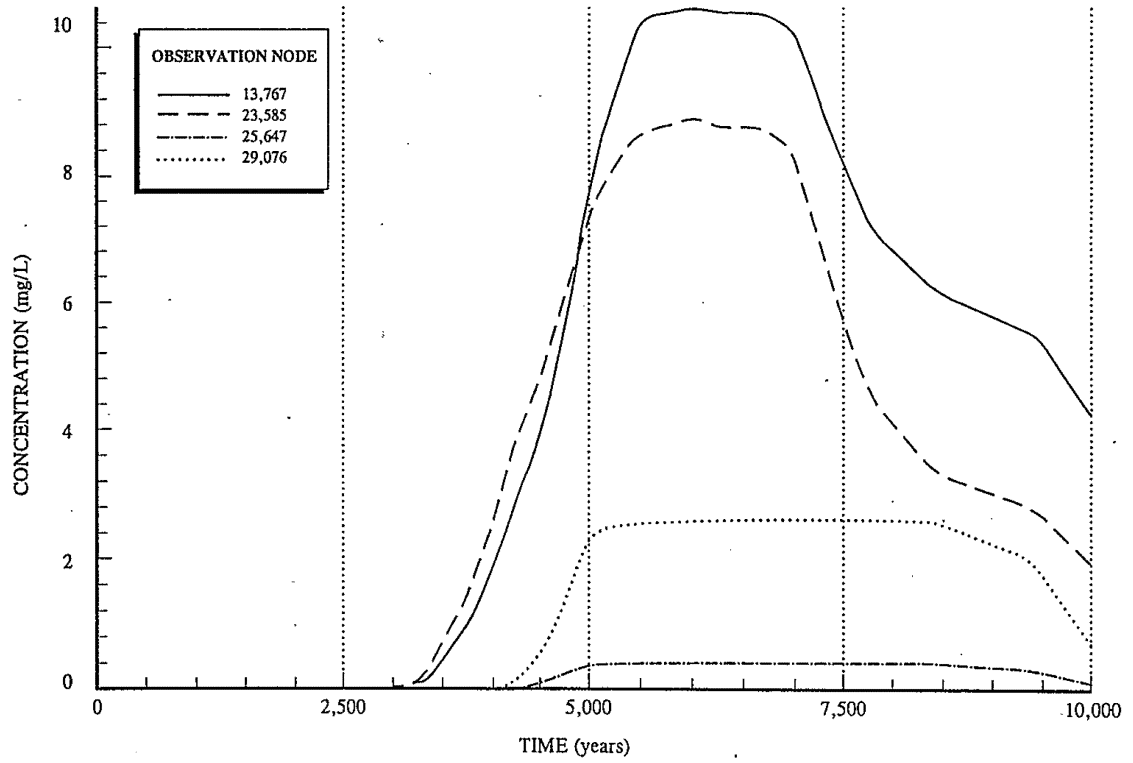
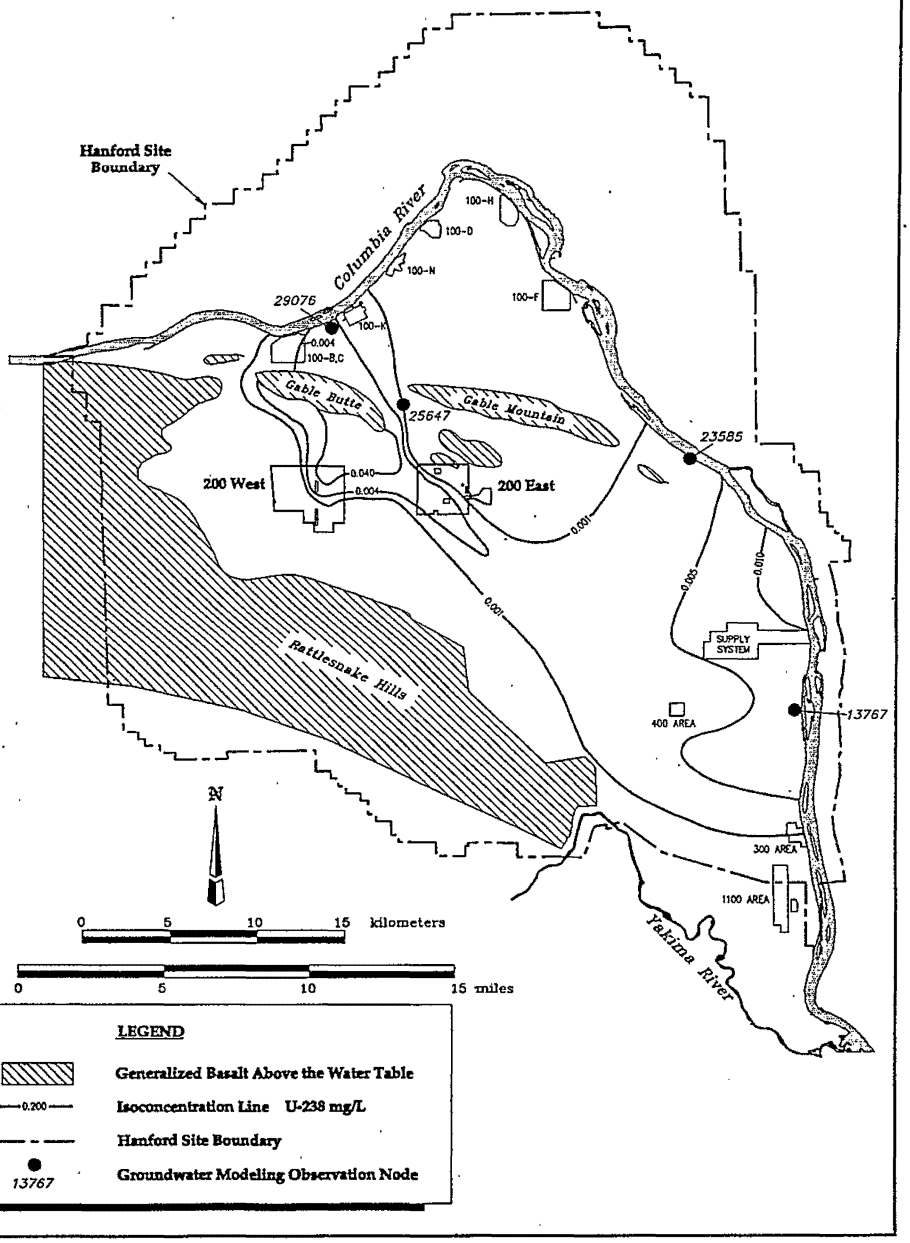


Figure K.4.2.5 Predicted Nitrate Concentration in Groundwater at Selected Locations for the In Situ Fill and Cap Alternative (500-Year Cap)



NOTE: See Figure K.4.2.4 for observation node locations.

Figure K.4.2.6 Predicted Uranium-238 Concentrations in Groundwater at 10,000 Years for the In Situ Fill and Cap Alternative (500-Year Cap)



To estimate the sensitivity of the overall results (e.g., concentration of tank wastes predicted in groundwater) to the initial infiltration rate of 5 cm/year (2 in./year), an alternative infiltration scenario was developed for the In Situ Fill and Cap alternative. For this scenario, the initial infiltration rate was assumed to be 1 cm/year (0.4 in./year) for the 200 Areas Plateau under natural vegetation. It was assumed that in 1955, the infiltration rate increased to 10 cm/year (4 in./year) and would remain at this rate until 2023, after the cap construction was complete for all source areas. At this time, the infiltration rate would be reduced to 0.05 cm/year (0.02 in./year) and would remain at this level for 1,000 years. All other aspects of the In Situ Fill and Cap alternative are the same as assumed in Volume Four, Section F.2.2.3.3. Contaminant flow and transport through the vadose zone were simulated using this infiltration scenario for three of the eight source areas. The source areas and their total vadose zone thicknesses (from the base of the tanks to the water table) are as follows:

Source Area	Vadose Zone Thickness m (ft)
1WSS	51 (170)
2WSS	48 (160)
5EDS	68 (220)

These source areas were chosen because they bound the range of vadose zone thicknesses. When the results of this alternative infiltration scenario, graphed as concentration versus time, were compared to the nominal case (i.e., initial infiltration rate of 5 cm/year [2 in./year]), they were nearly identical, with less than a 1 percent difference between estimated concentrations.

Variations in Distribution Coefficients

As explained in earlier sections, the distribution coefficient (K_d) for a specific contaminant is an indication of the mobility of the contaminant within the aquifer system. Contaminants with lower K_ds are more mobile, and contaminants with higher K_ds are less mobile. Contaminants with K_ds of 0 and 1 mL/g have been calculated to arrive at the interface between the vadose zone and groundwater within the 10,000-year period of interest for both the No Action and Long-Term Management alternatives. For the other alternatives, only contaminants in K_d Group 1 (K_d equal to 0) have been calculated to arrive at the vadose zone groundwater interface within 10,000 years because the influx of precipitation into the waste would be greatly reduced by the cap. Not all the contaminants in K_d Group 1 have a K_d of zero. Uranium is an example of a contaminant that, while conservatively placed in K_d Group 1, likely has a K_d between zero and one. The Ex Situ Intermediate Separations alternative was selected as representative of alternatives that incorporate a cap and was used as the basis for estimating the sensitivity of contaminant transport for K_d values between zero and one.

The sensitivity of contaminant travel time through the vadose zone to various K_d values was evaluated by varying K_d for this alternative and for the 1WSS source area and then tabulating the arrival time at the vadose zone/groundwater interface. The range of K_d values selected for analysis and the times of first arrivals calculated by the model is as follows:

K_d Value (mL/g)	First Arrival at Vadose Zone/ Groundwater Interface (years)
0.00	1,500
0.05	5,300
0.075	7,000
0.10	8,600
0.125	10,000

For K_d greater than 0.125 mL/g, first arrival did not occur until just after 10,000 years. This is important for contaminants such as U that are reported to have K_d values of approximately 0.6 mL/g at the Hanford Site, as they would not reach the groundwater within the period of interest for alternatives that include a cap.

K.4.3 TRANSPORT IN SURFACE WATER

The primary sources of uncertainty in estimating surface water transport are associated with the rate of dilution of contaminants in groundwater entering the Columbia River. These sources are the turbulence of river flow, which depends on the velocity; irregularities in the stream channel, including bends; and the width of the river. All these factors ultimately depend on the total flow in the river at the point(s) where contaminated groundwater would be discharged.

K.4.4 TRANSPORT IN AIR

Various assumptions and other factors can introduce uncertainty into air dispersion modeling studies. With regard to the modeling performed to analyze air impacts from the various EIS alternatives, these uncertainties can be separated broadly into the following categories:

- Uncertainty inherent in the air dispersion models;
- Uncertainty in data used as model inputs; and
- Uncertainty in interpretation of model output.

These categories are discussed in more detail in the following text.

K.4.4.1 Air Dispersion Modeling

Air dispersion models are mathematical tools designed to estimate pollutant concentration and/or deposition at specific locations. These predictions are based on various input parameters and physical assumptions, such as the following:

- Pollutant release characteristics (emission rate, temperature, flow rate);
- Meteorological conditions (ambient temperature, mixing height, stability, wind speed and direction, atmospheric temperature, and wind speed profile); and
- Pollutant transport behavior (dispersion, plume rise, interaction with terrain).

In an ideal case, the values entered into the model for these known parameters will closely duplicate the range of conditions that exist for a particular scenario. However, the stochastic nature of the

atmosphere results in other unknown factors (e.g., wind perturbations) that influence the dispersion at a particular time or place. It has been estimated that even when the known conditions are exactly duplicated in the model, the unknown factors can contribute to variations in concentration as much as ±50 percent.

Gaussian air dispersion models are accurate within a factor of two when properly executed with accurate data. In general, models are more reliable when estimating long-term average concentrations as opposed to short-term averages, and are reasonably reliable in estimating the highest concentration occurring, but are not capable of predicting the exact time or position of the occurrence. In other words, the highest concentration that can be expected in an area can be predicted with reasonable accuracy; the location and time that the maximum concentration will occur are less reliably predicted.

The air dispersion models used in this study are considered to be state-of the-art for regulatory modeling and are recommended by the U.S. Environmental Protection Agency (EPA) for this type of analysis. To compensate for the uncertainties in model results, conservative input values were used that provide conservative (higher than might occur under average conditions) results.

K.4.4.2 Model Input Data

Two types of input data were used for the air dispersion models: meteorological data and source data. Both types of input data are discussed in the following text.

Meteorological Data

Two types of meteorological data (i.e., long-term and short-term) were used in the dispersion modeling study. Long-term (i.e., annual) average concentrations were estimated using meteorological data collected at the Hanford Meteorological Station from 1989 to 1993. The assumption inherent in this choice is that these data represent future meteorological conditions. A 5-year record is generally accepted as an adequate sample set for modeling purposes. Although long-term climatic shifts may occur, many of the air pollutant emitting activities analyzed in this study are expected to occur within several decades of project initiation, which is a relatively short time frame on a climatic scale. Therefore, the use of these data is not expected to adversely affect the results.

Typically, short-term average (i.e., 1- 3- 8- and 24-hour) concentrations are predicted using hourly meteorological measurements from a station located at or near the site of interest. Because appropriate data were not available for this study, a screening approach was taken, and a standard set of hourly meteorological conditions were incorporated in the modeling. These standard conditions are accepted by the EPA to encompass the range of atmospheric stabilities and wind speeds that could be expected to occur anywhere. Each combination of wind speed and atmospheric stability was assumed to occur in every possible wind direction. The predicted concentrations represent the highest value that could reasonably be expected to occur anywhere. This approach is conservative because the meteorological conditions leading to the reported result may not occur at the site for all wind directions.

Source Data

Data describing the location, emission rate, and emission characteristics of the sources were input to the models. Information concerning pollutant emission rates was derived from data packages supplied by the Site Management and Operations contractor and analyzed by the EIS contractor. In general, conservative values were used to develop emissions estimates.

The location of the pollutant emitting sources was not known with complete certainty in all cases. Pollutant emitting activities associated with the existing tank farms will occur in the present locations. However, the exact location of future facilities is subject to some uncertainty. In general, the closer a source to a receptor, the higher the predicted concentration at that receptor. As a consequence, if the eventual location of an emitting activity is closer to a plant boundary than depicted in the model, the impacts may be higher. Of course, if the activity is located farther from the boundary than depicted in the model, the impacts may be lower.

The temporal arrangement of the pollutant emitting activities affects the predicted concentrations as well. The predicted concentration at any receptor includes the contributions from each individual emitting source. To properly analyze a scenario, all the pollutant emitting activities that could occur at the same time must be considered. In general, most of the scenarios analyzed involved a period of facility construction followed by an operational period.

In some cases, an emitting source is expected to move from place to place as the project progresses. An example of this would be emissions related to remedial activities at tank farm locations. In most cases at a given time, work would be occurring at one or two of the possible 17 locations. Given these uncertainties, a conservative analysis was ensured by assuming that activities that may or may not overlap would occur simultaneously. In addition, activities that are expected to move from place to place were modeled as if occurring in the location producing the highest potential impact.

Sources were modeled as either point or area sources. Point sources were used to approximate pollutant releases from a stack or other fixed, functional opening, or vent. The dispersion algorithms used for point sources modify the effective release height to take into account plume buoyancy (from a heated release) and momentum (from vertical release velocity). Typically, area sources were used to approximate pollutant releases that would not occur at a single, well-defined point, but instead can be defined as occurring within a defined area. For instance, an area source could include many small fixed point sources that were too numerous to model individually, or could be made up of several mobile sources that could move about within the fixed area. In this study, the construction activities were represented as area sources. The classification of the sources into these two categories involved some degree of uncertainty as well as some assumptions. The models used different algorithms to represent dispersion from point and area sources, and the predicted concentration at a receptor could vary depending on the algorithm chosen. In general, these effects would be more noticeable at locations close to the source and tend to diminish as the distance between source and receptor increased.

K.4.4.3 Interpretation of Model Output

The short-term model was run using screening meteorology to produce predicted maximum 1-hour average concentrations. These 1-hour average values were converted to 3- ,8-, and 24-hour average concentrations, when appropriate, to compare to applicable standards. This was accomplished by applying conversion factors to the 1-hour average values. Consistent with modeling guidelines (EPA 1988), the factors of 0.9, 0.7, and 0.4 were applied to convert to 3-, 8-, and 24-hour averages, respectively. These factors involve an implied assumption regarding the persistence of the meteorological condition producing the highest 1-hour impact. In other words, conservative meteorological conditions that produced the highest 1-hour concentration can be expected to persist for most of a 3-hour period, and to a lesser degree over an 8- or 24-hour period. The modeling guidelines indicate a range of values for each conversion factor: the 3-hour conversion factor can range from 0.8 to 1.0, the 8-hour factor from 0.5 to 0.9, and the 24-hour factor from 0.2 to 0.6. Use of the midpoint values was considered appropriate for this study.

Chronic (Routine) Air Dispersion

In the routine risk assessment, the airborne transport is based on the 9-year average (1983 to 1990) wind data measured at 10 m (33 ft) and 61 m (200 ft) at the Hanford Meteorological Station (HMS) in the 200 Areas. The variation in the chronic atmospheric dispersion coefficient (Chi/Q) was estimated using wind data collected at 10 m (33 ft). The values for joint frequency were computed by GXQ Version 4 (Hey 1993 and 1994).

The locations of the onsite maximum individuals were taken to be 100 m (330 ft) from the release point for ground level releases, and 800 m (2,640 ft) for stack releases. The locations of the site boundary maximum individuals were averages of the distances from the Plutonium Finishing Plant (PFP) and the Plutonium-Uranium Extraction (PUREX) Plant. These distances are shown in Table K.4.4.1.

The maximum normalized time-integrated exposures (Chi/Q) for each year estimated with available data are listed in Table K.4.4.2. The observed variation in the annual Chi/Q at the chosen locations is approximately a factor of 2. Population weighted Chi/Q values are subject to similar variation. The observed variation in population-weighted Chi/Q values is less than a factor of 2 (Table K.4.4.3).

Acute (Accident) Air Dispersion

Bounding Chi/Q values were generated consistent with the methods described in Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 (NRC 1982). The Chi/Q values were calculated assuming the receptor was located at the peak concentration. Because atmospheric conditions fluctuate, a bounding atmospheric condition was considered to be that which causes a downwind concentration of airborne contaminants that is exceeded for only a small fraction of time due to weather fluctuations. Regulatory Guide 1.145 defines this fraction as 0.5 percent for each sector or 5 percent for the overall site. The site is broken up into 16 sectors, which represent 16 compass directions (e.g., S, SSW, SW, ESE, SE, SSE). Chi/Q values are generated for weather conditions that result in downwind concentrations that are exceeded only 0.5 percent of the time in the maximum sector, or 5 percent of the time for the overall site. These Chi/Q values also are referred to as 99.5 percent maximum sector

Table K.4.4.1 Site Boundary Distance from PFP and PUREX

Transport Direction	Distance (m)	
	PFP	PUREX
S	14,200	19,520
SSW	14,530	16,780
SW	14,420	17,010
WSW	12,290	21,060
W	12,050	20,650
WNW	12,340	21,130
NW	15,280	21,300
NNW	16,180	21,160
N	17,840	24,550
NNE	26,240	23,590
NE	27,160	18,060
ENE	24,020	15,290
E	23,760	15,950
ESE	29,280	20,150
SE	23,880	24,250
SSE	19,450	19,720

Table K.4.4.2 Maximum Individual Annual Chi/Q for Selected Receptor Locations

Year	Ground Level Release		55-meter Stack Release	
	100 meters	Site Boundary	800 meters	Site Boundary
1982	3.17E-04 SE	4.11E-08 ESE	5.11E-08 SE	9.39E-09 SE
1983	3.98E-04 SE	6.07E-08 ESE	4.94E-08 SE	9.61E-09 SE
1984	3.81E-04 ESE	6.31E-08 ESE	7.15E-08 SE	1.05E-08 ESE
1985	4.23E-04 ESE	6.99E-08 ESE	6.87E-08 SE	1.01E-08 ESE
1986	4.73E-04 ESE	7.86E-08 ESE	5.98E-08 SE	1.22E-08 ESE
1987	4.61E-04 ESE	8.39E-08 E	4.80E-08 SE	1.10E-08 ESE
1988	4.80E-04 ESE	8.75E-08 E	6.95E-08 SE	1.11E-08 ESE
1989	4.51E-04 ESE	8.59E-08 E	3.45E-08 SE	9.88E-09 ESE
1990	3.77E-04 SE	7.81E-08 ENE	3.52E-08 SE	8.52E-09 SE
1991	4.34E-04 SE	7.30E-08 E	4.90E-08 SE	9.91E-09 SE
1992	4.89E-04 SE	7.71E-08 E	4.99E-08 SE	1.15E-08 SE
1993	5.17E-04 SE	6.65E-08 E	4.62E-08 SE	1.17E-08 SE
1994	4.71E-04 SE	7.21E-08 E	3.47E-08 SE	1.06E-08 SE
Maximum	**5.17E-04**	**8.75E-08**	**7.15E-08**	**1.22E-08**
Minimum	**4.17E-04**	**4.11E-08**	**3.45E-08**	**8.52E-09**

Notes:
Units are second per cubic meter

Table K.4.4.3 Maximum Population - Weighted Annual Chi/Q for Selected Receptors Locations

Year	Ground Level Release		55-meter Stack Release	
	100 meters	Site Boundary	800 meters	Site Boundary
1982	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1983	1.55E-02	3.26E-03	1.61E-04	7.64E-04
1984	1.45E-02	3.11E-03	1.85E-04	7.20E-04
1985	1.57E-02	3.23E-03	1.77E-04	6.95E-04
1986	1.64E-02	3.35E-03	1.73E-04	7.56E-04
1987	1.68E-02	3.61E-03	1.56E-04	7.61E-04
1988	1.84E-02	4.01E-03	1.85E-04	8.27E-04
1989	1.96E-02	4.37E-03	1.18E-04	8.74E-04
1990	1.66E-02	3.68E-03	1.15E-04	7.89E-04
1991	1.72E-02	3.84E-03	1.49E-04	8.65E-04
1992	1.82E-02	4.37E-03	1.65E-04	9.98E-04
1993	1.92E-02	4.63E-03	1.55E-04	1.01E-03
1994	1.73E-02	4.18E-03	1.26E-04	8.93E-04
Maximum	**1.96E-02**	**4.63E-03**	**1.85E-04**	**1.01E-03**
Minimum	**1.45E-02**	**3.11E-03**	**1.15E-04**	**6.95E-04**

Notes:
Units are second per cubic meter

or 95 percent overall site Chi/Q values. The greater of these is called the bounding Chi/Q value and was used to assess the bounding dose consequences for accident scenarios presented in this EIS (Table K.4.4.4). These bounding Chi/Q values represent minimum dispersing conditions that result in maximum downwind concentrations (i.e., concentrations that are exceeded only a small fraction of the time). These Chi/Qs will result in conservative estimates of potential accident consequences.

Annual average Chi/Q values also were generated for each sector. The sector with the highest annual average Chi/Q value was selected as presented in Table K.4.4.5. These values were used in conjunction with nominal source terms to calculate nominal dose consequences. The annual average Chi/Q values were calculated assuming the receptor was located at the peak concentration. The dose calculated using the annual average Chi/Q value for a particular sector represented the average dose to an individual located in that sector, accounting for the frequency of time that the wind blew in that direction during the year. This, it accounted for the fact that the receptor in a particular direction would experience no dose if the wind was blowing in a different direction at the time of the accident, and would receive a dose higher or lower than the annual average if the wind was blowing in the direction of the receptor. In summary, the dose based on annual average meteorology represented the average that an individual in a particular sector would receive for all meteorological conditions over the year. The ratio between the bounding and the annual average meteorology is presented in Table K.4.4.6.

Table K.4.4.4 Bounding Meteorology Chi/Q Values Generated for Ground Level Releases from Tank Farms

Release Duration	Chi/Q Values (s/m^3)		Chi/Q Values person (s/m^3)	
	MEI Nonworker [1]	MEI General Public [2]	Nonworker Population [3]	General Public Population [3]
Maximum Puff [4]	9.85E-03	3.92E-07	NA	NA
< 1 hr (no plume meander corrected)	3.44E-02	8.34E-05	4.83E-01	7.29E-02
1 to 2 hr (plume meander corrected)	1.13E-02	4.86E-05	NA	NA
8,760 hr (chronic annual avg)	4.03E-04	3.52E-07	8.01E-03	2.03E-03

Notes:
[1] Maximum onsite receptor located at 100 m (330 ft) in the direction of maximum dose.
[2] Maximum offsite receptor located at the site boundary in the direction of maximum dose.
[3] Population-weighted Chi/Q using the onsite or offsite population distribution. The direction with the highest population-weighted Chi/Q value was selected. Note that population-weighted Chi/Q values are not calculated with plume-meander because sector averaging is used. Therefore, the no plume meander value (< 1 hr) is used for 1- to 2-hour release durations.
[4] The maximum puff Chi/Q values are in units of s/m^3.

Table K.4.4.5 Annual Average Meteorology Chi/Q Values Generated for Ground Level Releases from Tank Farms

Release Duration	Chi/Q Values (s/m^3)		Chi/Q Values person (s/m^3)	
	MEI Nonworker [1]	MEI General Public [2]	Nonworker Population [3]	General Public Population [3]
Maximum Puff [3]	3.35E-04	6.30E-09	NA	NA
< 1 hr (no plume meander corrected)	1.26E-03	1.28E-06	8.01E-03	2.03E-03
1 to 2 hr (plume meander corrected)	5.84E-04	8.02E-07	NA	NA
8,760 hr (chronic annual avg)	4.03E-04	3.52E-07	8.01E-03	2.03E-03

Notes:
[1] Maximum onsite receptor located at 100 m (330 ft) in the direction of maximum dose.
[2] Maximum offsite receptor located at the site boundary in the direction of maximum dose.
[3] Population-weighted Chi/Q using the onsite or offsite population distribution. The direction with the highest population-weighted Chi/Q value was selected. Note that population-weighted Chi/Q values are not calculated with plume-meander because sector averaging is used. Therefore, the no plume meander value (< 1 hr) is used for 1- to 2- hour release durations.
[4] The maximum puff Chi/Q values are in units of s/m^3.

Table K.4.4.6 Ratio of Bounding and Annual Average Meteorology Chi/Q Values Generated for Ground Level Releases from Tank Farms

Release Duration	Ratio			
	MEI Nonworker [1]	MEI General Public [2]	Nonworker Population [3]	General Public Population [3]
Maximum Puff [4]	29.4	62.2	NA	NA
< 1 hr (no plume meander corrected)	27.3	65.2	60.3	35.9
1 to 2 hr (plume meander corrected)	19.3	60.6	NA	NA
8,760 hr (chronic annual avg)	same	same	same	same

Notes:
[1] Maximum onsite receptor located at 100 m (330 ft) in the direction of maximum dose.
[2] Maximum offsite receptor located at the site boundary in the direction of maximum dose.
[3] Population-weighted Chi/Q using the onsite or offsite population distribution. The direction with the highest population-weighted Chi/Q value was selected. Note that population-weighted Chi/Q values are not calculated with plume-meander because sector averaging is used. Therefore, the no plume meander value (< 1 hr) is used for 1- to 2- hour release durations.
[4] The maximum puff Chi/Q values are in units of s/m^3.

K.5.0 UNCERTAINTIES IN HUMAN EXPOSURE ASSESSMENT

In addition to source terms and contaminant transport, exposure assessment contributes to uncertainty in the risk estimates. Some of the contributing parameters are lifestyle, diet, land use patterns, exposure pathways, exposure frequency and duration, and biotransfer/bioaccumulation factors. These uncertainties are discussed in the following sections.

Humans may be exposed to hazardous substances in many ways, which may cause some degree of risk to health. The uncertainty in risk for each receptor increases as the variety of potential exposures increases. The risk analysis in the TWRS EIS includes multiple exposure scenarios that cover a wide spectrum of exposure pathways. Therefore, the likelihood that real future exposures lie outside the range estimated in the EIS is small.

The post-remediation land user scenario describes the long-term risk to an individual and the whole population from restricted to unrestricted use of the land. The Native American and residential farmer receptors use land without any restrictions, and the industrial worker and recreational users use land with some limited restrictions. The health impacts of short-term exposure (routine and accidental) that would occur during remediation add a layer to the analysis that reduces the systematic uncertainties in the risk assessment. Another health impact, exposure to hazardous substances by inadvertent intrusion, characterizes a different exposure category.

The uncertainty in exposure assessment is more fully characterized by incorporating several exposure scenarios and categories. The uncertainties within each of these scenarios and categories are diverse and can be large. There is a need to analyze each scenario and category on an individual basis. The following sections discuss the uncertainty in the risk assessment for post-remediation land use, routine and accidental exposures during remediation, and post-remediation intrusion.

K.5.1 POST-REMEDIATION LAND USER

This section describes the uncertainty analyses for the risks to potential post-remediation land users. Scenarios evaluated under the post-remediation land user scenario include: the Native American, residential farmer, industrial worker, and intruder.

K.5.1.1 Modular Risk Assessment Approach

The method used to assess the post-remediation risk at the Hanford Site was a modular risk assessment (MRA) approach. The MRA approach separates the four basic components of the risk assessment (i.e., source, transport, exposure, and risk) into discrete modules that can be assessed independently and then combined. This process is described by the following equation:

$$\text{Risk} = \text{Source} \cdot \text{Unit Transport Factor} \cdot \text{Unit Risk Factor}$$

This section focuses on the results of the uncertainty and sensitivity analysis as they pertain to the unit risk factor (URF). The uncertainty analyses with respect to the source term and the unit transport factors are presented in other sections of this appendix.

The calculation of the URF is simplified by dividing the equation into two terms, one term containing parameters independent of contaminant properties (i.e., summary intake factors) and the other term containing parameters dependent on contaminant-specific properties.

URFs are described in terms of exposure pathways, toxic endpoint (carcinogenic chemical, noncarcinogenic chemical, and radionuclide carcinogen), and exposure parameters (i.e., intake rate, exposure frequency, and exposure duration). The URF approach involved structuring the intake equations for each receptor and exposure pathway so that contaminant-independent parameters were separated from the contaminant-specific parameters. The general equation used to calculate the URF is as follows:

$$URF = Intake \cdot SF$$

Where:

URF	=	unit risk factor for a specific pathway
Intake	=	intake or exposure from a specific pathway
SF	=	pathway-specific slope factor

The pathway-specific slope factor is a toxicological contaminant-specific parameter that is specified by the regulatory agencies and generally not subjected to an uncertainty analysis, although there is considerable uncertainty associated with this parameter.

The intake term may be further described in terms of the following equation:

$$Intake = C \cdot PF \cdot SIF$$

Where:

Intake	=	average daily intake of pollutant
C	=	concentration of pollutant
PF	=	pollutant-specific factor for media of concern
SIF	=	summary intake factor for given scenario

The uncertainties associated with the concentration term and other pollutant-specific factors are discussed in other sections of this appendix. The uncertainty associated with the SIF or intake term is the subject of this section of the report.

The SIF is a scenario-specific term and generally is derived from exposure factors published by the EPA for generating upper-bound (i.e., 95th percentile) point estimates of exposure. The use of these upper-bound estimates in calculating point estimates for human health exposure has been shown to result in "compounding conservatisms," which often has led to risk estimates that are highly unlikely to be experienced by anyone in a population near a site (Burmaster-Harris 1993). Therefore, a knowledge of the uncertainty associated with the SIF and exposure factors used to generate risk estimates is important to place the risk estimates in perspective.

One approach for establishing the uncertainty in the SIF and exposure parameters is to use a Monte Carlo-based approach (PNL 1993). In this approach, the Monte Carlo technique adds several steps to estimate both point values and full distributions for the exposures. These extended techniques make the analyses more informative to risk managers and members of the public by giving some perspective on the uncertainty behind the point estimates.

K.5.1.2 Monte Carlo Uncertainty Analysis

The first step in the Monte Carlo uncertainty analysis was to identify the exposure medium (air, soil, groundwater) and exposure pathway (e.g., ingestion, inhalation, vegetable consumption) driving the risk. The next step involved constructing equations that would both represent the shortcomings identified in EPA methodology and correspond with the site-specific conditions. These preliminary equations were used, along with readily available input ranges, to conduct a sensitivity analysis to determine which inputs should be focused on in characterizing input distributions for use in the Monte Carlo-based approach.

The results of the sensitivity analysis allowed the inputs to be ordered in terms of their impact on the intake term or SIF using the Monte Carlo methodology. The magnitude of the impact that an input had on the intake term or SIF was a function of both the input's mathematical relationship to the SIF and the range identified for that input. The results of the sensitivity analysis were combined with an assessment of the quality of information available from the literature for characterizing each input. The final result of the sensitivity analysis was a list of those inputs that will receive special focus in characterizing distributions.

The next step in the Monte Carlo methodology was to generate continuous or discrete probability functions (PDFs) for all relevant inputs. In the Monte Carlo approach, each of many input variables can become a random variable with known or estimated PDF. Within this framework, a variable would take on a range of values with known probability. Some distributions, for instance, were based on known human variability and came into play in the analysis because of the uncertainty as to who will be involved in the scenario. Once the exposure models, variables, and constants for the models were defined, the next step was to use a suitable software to make a large number of realizations of the set of random variables in each model. For each realization, the computer drew one random value from the appropriate distribution for each of the random variables in the model and computed a single result. This computation was repeated a large number of times to produce complete distributions of modeled variables. Finally, the distributions were plotted and various statistical summaries of the results were produced to help interpret the data.

The final step in the development and evaluation of the Monte Carlo methodology was the generation of the SIF or intake distribution. The SIF generated using the EPA point estimate methodology then was compared to the distribution generated using the Monte Carlo approach. This comparison was useful in that the relative position of the point estimate on the probability density function provided a perspective as to the conservatism of the point estimate.

The computer software used in this Monte Carlo uncertainty analysis was Crystal Ball software program, which is an add-on to the Microsoft Excel spreadsheet program. The use of Crystal Ball software allows Excel spreadsheets to be incorporated directly into the Monte Carlo approach. The Crystal Ball program allows either Latin Hypercube Sampling or the default conventional sampling method usually used in Monte Carlo simulations. The default method generates random values for each distribution over the entire range defined for that distribution. This approach can accurately reflect the shape of distributions if enough iterations are completed in order to allow values in the more obscure "tail" regions of distributions to be sampled. The Latin Hypercube method divides distributions into regions of equal probability. Latin Hypercube Sampling was used in this evaluation to quickly stabilize the tail regions of the output distribution. This approach ensured that all regions of a distribution were sampled with equal frequency. Table K.5.1.1 provides a summary of the PDFs used in the Monte Carlo-based uncertainty analysis.

The number of iterations used in the Monte Carlo simulation was based on the work of Thompson (Thompson 1992). In this approach, a simulation is run twice, each time using 10,000 iterations. If the 95th percentiles from the resulting distributions differ by more than 1 percent from each other, the number of runs used in the simulation is increased until the differences between 95th percentile values falls below the arbitrary 1 percent mark. Runs of 10,000 iterations were found to produce stable risk distributions in this analysis.

Sections K.5.1.3 through K.5.1.9 provide the results of the Monte Carlo uncertainty analysis and sensitivity analysis as they pertain to the individual receptor of the specific exposure scenarios analyzed in the EIS. The uncertainties associated with the cumulative risk over 10,000 years for each exposure scenario are discussed in Section K.5.1.1.6.

K.5.1.3 Native American Scenario

The Native American scenario was intended to include a wide range of activities from traditional lifestyle activities (i.e., hunting and fishing) to contemporary lifestyle activities (i.e., irrigated farming). Specific activities include hunting, gathering, collecting, fishing, and processing of the catch along the shoreline, and pasturing of livestock, as well as ceremonial, educational, seasonal, social, and trade activities. A detailed description of the Native American scenario is provided in DOE (DOE 1996).

The focus of this section of the report is to evaluate the uncertainty associated with the SIF as it pertains to exposure pathways specific to the Native American scenario. The SIFs evaluated for the Native American scenario were based on Tribal input because currently there are no standards or data regarding Tribal-specific intake factors. Therefore, the SIFs for the Native American scenario were compared against the ICRP recommendations (e.g., ICRP 1975) or EPA standards (e.g., EPA 1989) for humans. This could result in more uncertainty than for the other scenarios that were based on EPA standards. The exposure pathways that would contribute the greatest risk to a Native American

Table K.5.1.1 Summary of Probability Density Functions

Parameter	Units	Scenario	Arithmetic Mean	Standard Deviation	Distribution	Minimum	Likeliest	Maximum	Reference
Exposure Duration	years	Industrial Worker	7.3	8.7	Lognormal	N/A	N/A	N/A	Department of Labor 1992
Exposure Frequency	days	Industrial Worker	N/A	N/A	Triangular	156	245	307	EPA 1989
Inhalation Rate	m^3/day	Industrial Worker	N/A	N/A	Triangular	6	18.9	32	EPA 1985
Exposure Duration	years	Residential	11.4	13.7	Lognormal	N/A	N/A	N/A	Israeli-Nelson 1992
Exposure Frequency	days	Residential	N/A	N/A	Triangular	180	345	365	Smith 1994
Ingestion Rate (water)	liters/day	Residential	1.12	1.63	Lognormal	N/A	N/A	N/A	Rosenberry-Burmaster 1992
Population Density	person/km^2	Hanford Site	N/A	N/A	Triangular	1	3	5	WSDFM 1994
Exposure Time	years	Hanford Site	74.7	7.47	Normal	N/A	N/A	N/A	EPA 1989
Soil Concentration	pCi/g	Intruder	N/A	N/A	Triangular	4.45E+05	9.96E+05	1.78E+06	Rittman 1994
Soil Density	g/cm^3	Intruder	N/A	N/A	Uniform	0.5		1.5	DOE 1996, Rittman 1994
External Exposure Time	hours	Intruder	N/A	N/A	Triangular	676	1986	3260	Rittman 1994, Professional Judgment
Depth of Contamination	cm	Intruder	N/A	N/A	Triangular	7.5	15	22.5	Rittman 1994, Professional Judgment
Inhalation Exposure Time	hours	Intruder	N/A	N/A	Triangular	2167	2891	4680	Rittman 1994, Professional Judgment
Surface Area	m^2	Intruder	N/A	N/A	Triangular	56	2000	2500	Rittman 1994, Professional Judgment
Exposure Duration	years	Native American	11.4	13.7	Lognormal	N/A	N/A	N/A	Israeli-Nelson 1992
Exposure Frequency	days	Native American	N/A	N/A	Triangular	180	345	365	Smith 1994
Inhalation Rate	m^3/day	Native American	N/A	N/A	Triangular	6	18.9	32	EPA 1985
Ingestion Rate (fish)	grams/day	Native American	N/A	N/A	Triangular	30	140	1080	DOE 1996, EPA 1989
Ingestion Rate (water)	liters/day	Native American	N/A	N/A	Triangular	1.1	2	3	Rosenberry-Burmaster 1992, DOE 1996, EPA 1989
Volatilization factor	liters/m^3	Native American	N/A	N/A	Triangular	0.1	0.3	0.5	Andelman 1990, DOE 1996
Soil to plant transfer factor (rooted plants)		Columbia River	0.5	0.25	Lognormal	N/A	N/A	N/A	PNL 1986 Professional Judgment

Table K.5.1.1 Summary of Probability Density Functions (cont'd)

Parameter	Units	Scenario	Arithmetic Mean	Standard Deviation	Distribution	Minimum	Likeliest	Maximum	Reference
Intake rate (rooted plants)	kg/year	Columbia River	N/A	N/A	Triangular	0	55	80	DOE 1996, Rittman 1994
River Flow Rate	ft^3/sec	Columbia River	N/A	N/A	Triangular	3.60E+04	1.20E+05	2.50E+05	Volume 1, Section 5.2
Total Population	persons	Columbia River	3.00E+06	6.00E+05	Normal	N/A	N/A	N/A	Volume 1, Section 5.2
Soil area density	kg/m^2	Columbia River	224	22.4	Lognormal	N/A	N/A	N/A	DOE 1996, Rittman 1994
Months/year irrigation	months	Columbia River	N/A	N/A	Triangular	5	6	7	Rittman 1994, Professional Judgment
Depth to Nuclide	cm	Columbia River	N/A	N/A	Triangular	7.5	15	22.5	Rittman 1994, Professional Judgment
Soil Bulk Density	g/cm^3	Columbia River	N/A	N/A	Uniform	0.5		1.5	DOE 1996, Rittman 1994
Irrigation rate	$liters/m^2$/ month	Columbia River	N/A	N/A	Triangular	1.35E+02	1.50E+02	1.65E+02	Rittman 1994, Professional Judgment
Yearly water ingestion rate	liters/year	Columbia River	N/A	N/A	Triangular	550	720	800	EPA 1989
Soil to plant transfer factor (leafy plants)	N/A	Columbia River	0.5	0.25	Lognormal	N/A	N/A	N/A	PNL 1986 Professional Judgment
Intake rate (leafy plants)	kg/year	Columbia River	N/A	N/A	Triangular	0	7.5	15	DOE 1996, Rittman 1994

N/A = Not applicable

include: groundwater ingestion, meat and fish ingestion, and the inhalation of volatile compounds (i.e., while in a sweat lodge). Please refer to Volume Three, Section D.2.1.3 for a complete discussion of the risk associated with each exposure pathway in the Native American scenario.

Uncertainty in the Groundwater Ingestion Summary Intake Factor

The Native American scenario groundwater ingestion SIF was based on exposures over a 70-year duration to an individual residing onsite. The exposed individual was assumed to ingest 3 L (0.8 gal) of water a day 365 days a year (DOE 1996). The groundwater ingestion SIF is expressed by the following equation:

$$SIF = IR \cdot EF \cdot ED$$

Where:

SIF = Summary intake factor (liters)
IR = Ingestion rate (liters/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)

Substitution of the fixed point estimate for IR, EF, and ED resulted in a groundwater ingestion SIF of 7.67E+04 L (DOE 1996).

The U.S. Army and EPA historically have used 2 L/day (0.5 gal/day) as an average water consumption rate (EPA 1989). However, the scientific literature suggests an average drinking water consumption rate of 1.4 L/day (0.37 gal/day) (EPA 1989). Burmaster has shown that drinking water ingestion rates follow a lognormal distribution with a mean value of 1.12 L/day (0.30 gal/day) and a standard deviation of 1.63 L/day (0.430 gal/day) (Burmaster 1992). For purposes of this uncertainty analysis, the drinking water ingestion rate was approximated by a triangular distribution. The maximum value was assumed to be 3 L/day (0.8 gal/day) (DOE 1996); most likely value 2 L/day (0.5 gal/day) (EPA 1989); and minimum value 1.1 L/day (0.29 gal/day) (Rosenberry-Burmaster 1992).

The exposure duration and exposure frequency parameters for the Native American scenario were assumed to follow distributions similar to those of United States populations. The time spent at a residence followed a lognormal distribution with a mean value of 4.55 years and a standard deviation of 8.68 years (Israeli-Nelson 1992). The exposure frequency for ingestion of drinking water was approximated using a triangular distribution with a maximum of 365 days/year, most probable value of 345 days/year and a minimum of 180 days/year (Smith 1994).

Monte Carlo uncertainty and sensitivity analyses were performed on the groundwater ingestion SIF. The sensitivity analysis indicated that the parameters that contributed the most to the uncertainty in the groundwater ingestion SIF as measured by rank order were exposure duration, ingestion rate, and exposure frequency. The results of the Monte Carlo analysis are summarized in Table K.5.1.2.

Table K.5.1.2 Native American Scenario Groundwater Ingestion SIF Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	6.9E+03	7.67E+04
Percentile	**Result**	
50th	4.3E+03	
75th	8.3E+03	
95th	2.1E+04	
100th	1.9E+05	

Notes:
[1] Units are liters.

Table K.5.1.2 contrasts the mean and percentile estimates of the PDF for the groundwater ingestion SIF for the Native American scenario with the value derived using upper-bound fixed point estimates for IR, EF, and ED. The results show that the SIF derived using the upper-bound values lies above the 95th percentile of the SIF PDF. The mean of the SIF probability distribution was one order of magnitude lower than the fixed point estimate. This result suggests that the Native American scenario drinking water SIF derived using default parameters is an upper-bound estimate and may not be representative of the typical intake of a hypothetical future Native American resident.

Uncertainty in the Fish Ingestion Summary Intake Factor

The Native American scenario fish ingestion SIF was based on exposures over a 70-year duration to an individual residing onsite. The exposed individual was assumed to consume 1,080 g/day (2.4 lb/day) of fish for 365 days/year (DOE 1996). The fish ingestion SIF is expressed by the following equation:

$$SIF = IR \cdot EF \cdot ED$$

Where:

SIF	=	Summary intake factor (kg)
IR	=	Ingestion rate (kg/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)

Substitution of the default estimates for IR, EF, and ED resulted in a fixed point estimate for the fish ingestion SIF of 2.76E+04 kg (6.1E+04 lb) (DOE 1996). Consumption rates for recreationally caught fish from large bodies of water have a 50th percentile average of 30 g/day (1 oz/day) and a 90th percentile average of 140 g/day (0.3 lb/day) (EPA 1989). Therefore, for purposes of this scenario, the fish ingestion PDF was approximated by a triangular distribution. The maximum value was assumed to be 1,080 g/day (2.4 lb/day) (DOE 1996); most likely value 140 g/day (0.3 lb/day) (EPA 1989); and minimum value 30 g/day (1 oz/day) (EPA 1989).

The time spent at a residence followed a lognormal distribution with a mean value of 4.55 years and a standard deviation of 8.68 years (Israeli-Nelson 1992). The exposure frequency for ingestion of fish was approximated using a triangular distribution with a maximum of 365 days/year, most probable value of 345 days/year and a minimum of 180 days/year (Smith 1994).

Monte Carlo uncertainty and sensitivity analyses were performed on the fish ingestion SIF. The sensitivity analysis indicated that the parameters that contributed the most to the uncertainty in the fish ingestion SIF as measured by rank order were exposure duration, ingestion rate, and exposure frequency. The results of the Monte Carlo analysis are summarized in Table K.5.1.3.

Table K.5.1.3 Native American Scenario Fish Ingestion SIF Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	1.4E+03	2.76E+04
Percentile	**Result**	
50th	7.5E+02	
75th	1.6E+03	
95th	4.8E+03	
100th	4.1E+04	

Notes:
[1] Units are kilograms.

Table K.5.1.3 contrasts the mean and percentile estimates of the SIF for the fish ingestion PDF for the Native American scenario with the fixed point estimate derived using the upper-bound values. The

results show that the SIF derived using the upper-bound values lies above the 95th percentile of the SIF probability distribution. The mean of the SIF probability distribution was one order of magnitude lower than the fixed point estimate. This suggests that the Native American Scenario fish ingestion SIF derived using default parameters is an upper-bound estimate and may not be representative of the typical intake by a Native American resident.

Uncertainty in the Groundwater Volatile Organic Compound Inhalation Summary Intake Factor
The Native American scenario groundwater volatile organic compound (VOC) inhalation SIF was based on exposures over a 70-year duration to an individual residing onsite. The exposed individual was assumed to have an inhalation rate of 15 L/day (4 gal/day) 365 days/year (DOE 1996). The VOC inhalation SIF is expressed by the following equation:

$$SIF = IR \cdot EF \cdot ED \cdot VF$$

Where:

SIF	=	Summary intake factor (liters)
IR	=	Inhalation rate (cubic meters/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
VF	=	Volatilization factor (liters/cubic meter)

The volatilization factor (VF) was used to approximate the quantity of water in indoor air based on the absolute humidity (Andelman 1990). This factor was used to account for activities such as showering, cooking, and time spent in a sweat lodge. The VF was assumed to be 0.1 for the purposes of this calculation (DOE 1996). The groundwater VOC inhalation SIF fixed point estimate using default parameters was 3.84E+04 L (1.01E+04 gal) (DOE 1996).

Indoor air inhalation rates have been shown to vary depending on the activity level of the exposed individual (Layton 1993). On average, inhalation rates for time spent indoors during showering have been shown to vary from a maximum value of 30 m^3/hr (1,060 ft^3/hr) to an average of 11 m^3/hr (390 ft^3/hr) to a minimum of 2 m^3/hr (71 ft^3/hr) (EPA 1989). For the purposes of this evaluation, a triangular distribution with these limits was used to describe the Native American scenario VOC inhalation SIF.

The exposure duration and exposure frequency parameters for the Native American scenario were assumed to follow distribution similar to those of populations in the rest of the United States. Israeli-Nelson (1992) showed that the time spent at a residence follows a lognormal distribution with a mean value of 4.55 years and a standard deviation of 8.68 years (Israeli-Nelson 1992). The exposure frequency for ingestion of drinking water was approximated using a triangular distribution with a maximum of 365 days/year, most probable value of 345 days/year, and a minimum of 180 days/year (Smith 1994).

Monte Carlo uncertainty and sensitivity analyses were performed on the groundwater VOC inhalation SIF. The sensitivity analysis indicated that the parameters that contributed the most to the uncertainty in the SIF as measured by rank order were exposure duration, inhalation rate, volatilization factor, and exposure frequency. The results of the Monte Carlo analysis are summarized in Table K.5.1.4.

Table K.5.1.4 Native American Scenario VOC Inhalation SIF Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	1.4E+04	3.84E+04
Percentile	Result	
50th	8.2E+03	
75th	1.7E+04	
95th	4.8E+04	
100th	5.2E+05	

Notes:
[1] Units are liters.

Table K.5.1.4 contrasts the mean and percentile estimates of the PDF for the groundwater VOC inhalation SIF for the Native American scenario with the fixed-point estimate derived by using the upper-bound values. The results indicated that the SIF derived using the upper-bound values lies at approximately the 95th percentile of the SIF probability distribution. Furthermore, the mean of the SIF probability distribution function was approximately one-third the magnitude of fixed-point estimate. This suggests that the groundwater VOC inhalation SIF derived using default parameters is an upper-bound estimate.

K.5.1.4 Residential Farmer Scenario

The residential farmer scenario was based on a 30-year exposure of an individual residing onsite. The individual was assumed to be exposed to contaminated soil, air, surface, and groundwater, and homegrown fruits and vegetables 365 days per year. The evaluation for the residential scenario indicated that the site risk to a resident was driven by the drinking water ingestion exposure pathway. The exposed individual was assumed to ingest 2 L (0.5 gal) of contaminated water per day, 365 days per year for 30 years. The drinking water ingestion SIF may be expressed by the following equation:

$$SIF = IR \cdot EF \cdot ED$$

Where:

SIF = Summary intake factor (L)
IR = Ingestion rate (L/day)
EF = Exposure frequency (day/year)
ED = Exposure duration (year)

The point estimate for the SIF for ingestion of drinking water was 2.2E+04 L (5.8E+03 gal) (DOE 1995). Drinking water ingestion rates were shown by Burmaster to following a lognormal distribution with a mean value of 1.12 L/day (0.3 gal/day) and a standard deviation of 1.63 L/day (0.43 gal/day) (Rosenberry-Burmaster 1993). Similarly, the time spent at a residence follows a

lognormal distribution with a mean value of 4.55 years and a standard deviation of 8.68 years (Israeli-Nelson 1992). The exposure frequency for ingestion of drinking water was approximated using a triangular distribution with a maximum value of 365 days/year, most probable value of 345 days/year and minimum value of 180 days/year (Smith 1994).

A Monte Carlo uncertainty and sensitivity analysis was performed on the SIF for drinking water ingestion. The results of the sensitivity analysis indicated that parameters that most influence the SIF for drinking water ingestion were in rank order: ingestion rate, exposure duration, and exposure frequency. The results of the Monte Carlo-based analysis are summarized in Table K.5.1.5.

Table K.5.1.5 contrasts the PDF percentile estimates of the SIF for groundwater ingestion for the residential farmer scenario with the point estimate derived using the EPA upper-bound values. The results show that the point estimate lies above the 95th percentile of the SIF probability distribution. The mean of the SIF probability distribution was approximately one order of magnitude lower than the EPA point estimate. This result demonstrates that the drinking water SIF derived using EPA default parameters is an upper-bound estimate and may not be representative of the typical intake of any hypothetical future resident.

Table K.5.1.5 Residential Farmer Scenario Drinking Water Ingestion SIF Estimates [1]

Monte Carlo-based Result		Fixed-Point Estimate
Mean	3.1E+03	2.2E+04
Percentile	Result	
50th	1.3E+03	
75th	3.3E+03	
95th	1.2E+04	
100th	9.3E+04	

Notes:
[1] Units are liters.

K.5.1.5 Industrial Worker Scenario

The industrial exposure scenario was based on worker exposure over a 20-year duration. The scenario involved mainly indoor activities, although outdoor activities (e.g., soil contact) also were included. Latent cancer fatalities (LCFs) for this scenario were shown to result principally from the inhalation of radiological atmospheric emissions. The SIF for the inhalation exposure route may be expressed by the following equation:

$$SIF = IR \cdot ED \cdot EF$$

Where:

- SIF = Summary intake factor (m^3)
- IR = Inhalation rate (m^3/day)
- ED = Exposure duration (years)
- EF = Exposure frequency (days/year)

The SIF using EPA default factors assumed that the air inhalation rate was 20 m^3 per day for a worker and external exposure occurred for 8 hours per day. Inhalation of radionuclides occurs 250 days per year and external exposure would occur 146 days per year. The point estimate SIF for inhalation of radionuclides was 1.0E+05 m^3 (3.5E+06 ft^3) (DOE 1995).

A Monte Carlo uncertainty and sensitivity analysis was conducted using the above algorithm for calculating the industrial worker SIF. The results of the sensitivity analysis indicated that parameters that most influence the industrial worker SIF were in rank order: exposure duration, inhalation rate, and exposure frequency. The results of the Monte Carlo-based analysis are summarized in Table K.5.1.6.

Table K.5.1.6 Industrial Worker Scenario Inhalation SIF Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	3.3E+04	1.0E+05
Percentile	**Result**	
50th	1.9E+04	
75th	3.9E+04	
95th	1.0E+05	
100th	1.4E+06	

Notes:
[1] Units are cubic meters.

Table K.5.1.6 contrasts the PDF percentile estimates of the air inhalation SIF distribution for the industrial worker scenario with the point estimate derived using the EPA upper-bound values. The results show that the point estimate is equal to the 95th percentile of the inhalation SIF probability distribution. The 50th percentile of the inhalation SIF probability distribution was one order of magnitude lower than the EPA point-estimate. This result demonstrates that the worker inhalation SIF derived using EPA default parameters is an upper bound estimate and may not be a realistic estimate of the true intake or exposure to an industrial worker at the Hanford Site.

K.5.1.6 Recreational Shoreline User and Recreational Land-User Scenarios

The recreational shoreline user scenario represented exposure to contamination in the Columbia River and shoreline from recreational swimming, boating, and other shoreline activities. The scenario involved mainly outdoor activities and would occur from exposure 14 days/year for 30 years.

The total adverse health impacts to a hypothetical future recreational shoreline user were expressed as the incremental lifetime cancer risk (ILCR) from the present to sometime in the future. The uncertainty associated with the adverse health effects predicted from this scenario can be attributed to the uncertainties in the source concentration, transport modeling, exposure parameters, and toxicological factors used to predict the total ILCR. However, the results of the risk analysis (Volume Three, Table D.5.1.2) indicated that the ILCR would be insignificant (i.e., less than 1E-10) for a period of 10,000 years. The uncertainties in the source concentration, and transport modeling would have to

have had a combined uncertainty on the order of 1E+04 to 1E+06 to have a significant effect on the final result. This degree of conservatism is not likely to have been introduced into the final risk calculation.

The total adverse health impacts to a hypothetical future recreational land user scenario were expressed as total cancer incidence from the present to a time 10,000 years in the future. The uncertainties in the exposure factors alone have been shown for other scenarios (i.e., residential farmer) to be a least one order of magnitude too high when compared to the mean of the exposure term. Factoring this uncertainty into the final cancer risk predictions for the future recreational land user would result in mean cancer incidences at least one order of magnitude less than the predicted incidence rate. This conclusion seems justified given the fact that there was considerable uncertainty in the intermittent exposure terms used for this scenario.

K.5.1.7 Intruder Scenario

The potential consequences of intrusion into a Hanford Site solid waste burial ground at some time in the future were estimated by assuming a "post-drilling resident" scenario in which someone has a vegetable garden in the soil resulting from the drilling of a 30-cm (1-ft) diameter well. Furthermore, in order to represent the potential dose from all pathways via irrigation, a combination of farming and garden irrigation was used. In this scenario, a farm over the waste site was assumed to have 1 percent of the plant roots in the waste. One-fourth (25 percent) of the farmer's vegetable intake and all (100 percent) of his meat and milk intake were assumed to be locally produced (i.e., contaminated). Furthermore, a well near the waste site was assumed to irrigate the vegetable garden. A more detailed description of the intruder scenario is presented in Volume Three, Section D.7.0. and in Rittman (Rittman 1994).

The results of the dose estimates for the intruder scenario (Rittman 1994) indicated that of the three principal routes of exposure (i.e., external, ingestion, and inhalation) the external would be the principal route of exposure followed by inhalation and ingestion. Thorium-232 (Th-232) was shown to be the radionuclide of concern (see Volume Three, Table D.7.3.1). The point estimate for the intruder scenario dose factor for Th-232 was 1.2E+04 mrem per year per curie exhumed. This point estimate was derived by assuming conservative upper-bound intake parameters. A Monte Carlo uncertainty and sensitivity analysis then was conducted on the algorithm used to calculate the intruder scenario effective dose factor (Rittman 1994). The sensitivity analysis indicated that parameters that contributed the most to the uncertainty in the intruder effective dose were in rank order: soil concentration, external exposure time, soil density, contamination depth, inhalation exposure time, and residential lot surface area. The results of the Monte Carlo analysis are summarized in Table K.5.1.7.

Table K.5.1.7 Intruder Scenario Dose Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	3.4E+03	1.2E+04
Percentile	Result	
50th	3.1E+03	
75th	4.2E+03	
95th	6.3E+03	
100th	1.3E+04	

Notes:
[1] Units are mrem per year per Curie exhumed.

Table K.5.1.7 contrasts the PDF percentile estimates of the dose estimates for the intruder scenario with the point estimate derived using the upper-bound values. The point estimate lies at approximately the 100th percentile of the dose probability distribution function. The mean of the intruder dose probability distribution function was approximately an order of magnitude lower than the point estimate. These results demonstrated that the dose estimates predicted for the intruder scenario by using default EPA exposure factors were conservative and could be an unrealistic estimate of the effective dose received by a hypothetical intruder.

Source terms from intrusion were probabilistic. The probability and consequences associated with the intruder scenario would be as follows: the intruder scenario in the TWRS EIS is the same as the intruder scenario in the Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes Final EIS, Sections R.3 and R.5. Both are based on Aaberg and Kennedy (Aaberg-Kennedy 1990). The Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes Final EIS conducted a comprehensive probability and consequence analysis of radionuclide release and transport after disposal as a result of human intrusion. The results of this study were applied directly to the TWRS EIS intruder scenario uncertainty analysis.

The existing estimated risk to the intruder was based on the consequences only. The basic advantage of a probabilistic approach is that the probabilities of events occurring and the consequences are both taken into account. This gives a broader perspective of the performance assessment than a consequence analysis alone.

The amount of waste exhumed was estimated for each aggregated area. Estimates of annual probabilities for drilling into a tank or capsule are given in Table K.5.1.8. Source terms (initial exhumed inventory) were estimated for each drilling for each alternative (Volume Three, Tables D.7.1.1 to D.7.1.6). The following equation was used for calculating the y^{th} percentile value of the accumulated release of constituent n from waste class w to the land surface due to drilling:

$$RQ_n [I_W(y)] = [Q_{on} \cdot \exp(-\lambda_n \cdot T_{drill})/A_W] \cdot A_{BH} \cdot I_W (y)$$

Where:

RQ_n = initial inventory (Ci) of radionuclide n in waste class w
T_{drill} = time of drilling (year) after the year 1995 (100 years)

A_W = surface area of waste class w (km^2)
A_{BH} = surface area of borehole (7.0E-08 km^2)
$I_W(y)$ = the y^{th} percentile value of the number of boreholes in waste class w

The term $[Q_{on} \cdot \exp(-\lambda_n \cdot T_{drill})/A_W] \cdot A_{BH}$ in the previous equation is the exhumed inventory as presented in Volume Three, Tables D.7.1.1 to D.7.1.6. Therefore, the y^{th} percentile value of the exhumed waste for each radionuclide and each alternative can be calculated as:

$$RQ_n [I_W(y)] = I_{exhumed} \cdot I_W(y)$$

The percentile values for each class of waste are presented in Table K.5.1.9. These values were estimated using the Poisson distribution.

Table K.5.1.8 Annual Probabilities of Drilling into the Waste and Waste Surface Area

Waste Class	Annual Probabilities, Intrusions/year	Surface Area (km^2)
Single-Shell Tanks	5.5E-04	0.055
Double-Shell Tanks	5.8E-05	0.0058
Grout (Future Waste)	3.3E-04	0.033
DWFS, Sr-90 Canisters	1.0E-06	0.0001
DWFS, Cs-137 Canisters (IPSD)	2.4E-06	0.00024
DWFS, Cs-137 Canisters (NDA)	1.3E-06	0.00013

Notes:
Source: Table S.5 of The Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes Final EIS.
DWFS = Drywell storage facility
IPSD = In-place stabilization and disposal
NDA = No disposal action

Table K.5.1.9 Percentile Values of Number of Boreholes in Each Waste Class (in a 10,000-year period)

Waste Class	50^{th} percent	90^{th} percent	99.9^{th} percent	99.99^{th} percent
Single-Shell Tanks	5	9	14	16
Double-Shell Tanks	0	2	14	15
Grout (Future Waste)	3	6	10	12
DWFS, Sr-90 Canisters	0	0	0	1
DWFS, Cs-137 Canisters (IPSD)	0	0	1	2
DWFS, Cs-137 Canisters (NDA)	0	0	1	2

Notes:
DWFS= Drywell storage facility
IPSD = In-place stabilization and disposal
NDA = No disposal action

Secondary sources of uncertainty are the transport and accumulation of radionuclides in the food chain, exposure pathways, and dose conversion factors. The exposure pathway parameters are the most easily quantified of these sources. The expected ranges and selected values for the exposure pathway parameters for drilling and post drilling are shown in Table K.5.1.10.

K.5.1.8 Total Health Impacts for Post-Remediation Land Users

The total adverse health impacts to a hypothetical future land user were expressed as the total calculated cancer fatalities over a 10,000-year period. The cancer fatalities were calculated by first computing the total cancer risk for a given population then dividing by the dose to risk conversion factor for cancer incidence and cancer fatalities (ICRP 1991). As shown in Volume Three, Section D.5.14.1, the total cancer fatalities for a given time span may be computed by the following equation:

$$F = (A \cdot P \cdot T \cdot ILCR)/(1.2 \cdot D)$$

Table K.5.1.10 Selected Parameter for Intruder Scenario

Pathway Parameter			Expected Range	Selected Value	Comments
Drilling	Inhalation	Duration [1]	0-40	1 40	Drilling through waste Overall operation
		Breathing Rate[2]	125-333	270	ICRP recommendations for standard human
		Concentration[3]	10^{-6}-10^{-2}	10^{-4}	Drilling through waste
		Particle Size[4]	0.1-10	1.0	ICRP 30 generic value
	External	Duration	0-40	40	Overall operation
Post Drilling	Inhalation	Duration	0-8760	100 1700 4380	Gardening Outdoors Indoors
		Breathing Rate	125-333	270	ICRP recommendation for standard human
		Concentration	10^{-6}-10^{-3}	$5x10^{-4}$ $1x10^{-4}$ $5x10^{-4}$	Gardening dust Yard work dust Indoors
		Breathing size	0.1-10	1.0	ICRP 30 generic value
	External	Duration	0-8760	1800 4380	Outdoors Indoors
		Shield Factor	0-1.0	0.33	House shielding factor
	Ingestion	Vegetables & Fruits[5]	0-660	73	25 percent of average diet
	Air Concentration	Leaf deposition[6]	10^{-6}-10^{-3}	10^{-4}	Garden dust

Notes:
[1] The unit for duration is hours (h)
[2] The unit for breathing rate is cm^3/sec
[3] The unit for concentration is g/cm^3
[4] The unit of particle size is μm AMAD
[5] The unit of ingestion is kg/year
[6] The unit of air concentration for leaf deposition is g/cm^3

Where:

F = Total cancer fatalities (persons)
A = Area corresponding to ILCR (km^2)
P = Population density (persons/km^2)
D = Duration of each generation (years)
T = Time span (thousand years)
ILCR = Incremental cancer risk for a given area
1.2 = Dose to risk conversion factor for cancer incidence and cancer fatalities

The total cancer fatalities for a given time span may be computed as shown in the example problem of Volume Three, Section D.5.14.1. Using the previous equation and the sample problem of Section D.5.14.1, the point estimate for total cancer fatalities (F) may be computed as follows:

$$F = (47 \cdot 4.97 \cdot 2{,}000 \cdot 0.05)/(70 \cdot 1.2)$$

$$F = 278$$

The uncertainty associated with the total cancer fatalities to a post-remediation residential farmer may be estimated using the Monte Carlo approach. The previous equation assumed that both population density (P) and duration of each generation (D) were fixed values when in fact there would be considerable uncertainty associated with each of these parameters. The Monte Carlo approach assumed that population density (P) would be a triangular distribution with a maximum value of 5 persons per km^2, most probable value of 3 persons per km^2, and a minimum value of 1 person per km^2. The expected life span of a generation was represented as a lognormal distribution with mean of 75 years and standard deviation of 7.5 years (EPA 1989). The results of the Monte Carlo analysis are summarized in Table K.5.1.11.

Table K.5.1.11 Post-Remediation Land Users Fatality Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	158	278
Percentile	Result	
50th	81	
75th	97	
95th	121	
100th	177	

Notes:
[1] Units are in persons.

Table K.5.1.11 contrasts the percentile estimates of the post-remediation land users fatality estimates with the point estimate value derived using the EPA upper-bound values. The total fatalities derived using the upper-bound values were greater than the 95th percentile of the fatality probability distribution. The mean of the fatality probability distribution was approximately 56 percent of the point estimate.

A note of qualification is appropriate with regard to the long-term, post-remediation collective doses and risks presented in the EIS. The National Council on Radiation Protection (NCRP) (NCRP 1995) cautions that the application of the concept of collective dose as a means of estimating prospective risks to populations from potential radiation exposures is subject to practical limitations. A calculated collective dose may contain such large inherent uncertainties that it would be a poor indicator of risk and therefore should not be considered as a basis for decision. The NCRP notes that neither population size and characteristics nor environmental exposure pathways for most radioactive elements are predictable with any degree of confidence for more than a few generations into the future (NCRP 1995). The NCRP also cautions that the summation of trivial average risks over very large populations or time periods into a single value may produce a distorted image of risk that is completely out of

perspective with risks accepted every day, both voluntarily and involuntarily. In many instances, the collective dose increases with increasing size of the exposed population, but the benefits and risks to individuals remain nearly constant. Population exposure pathways and other assumptions have been projected for this EIS out of 10,000 years using the best available data and considered judgment but clearly are subject to the considerable uncertainty suggested by the NCRP. Therefore, the collective dose projections presented in the EIS should not be considered an exact measure of the true (absolute) quantity of dose or risk for any alternative. However, they are useful for comparison of the relative risk of the alternatives because the parameters that contribute large uncertainties are constant across the alternatives.

Finally, the NCRP suggests that whenever the collective dose is smaller than the reciprocal of the relevant risk coefficient, the risk assessment should note that the most likely number of consequences (e.g., cancer deaths) is zero. For example, the most likely ILCR for a cumulative population dose of 1,000 person-rem would be zero because the reciprocal of the relevant risk factor of 5E-04 (i.e., $\frac{1}{5E\text{-}04} = 2{,}000$).

K.5.1.9 Total Health Impacts Along the Columbia River

This scenario was used to estimate the dose to a population of people exposed to contamination from the Columbia River. The contamination would enter the Columbia River as a result of groundwater flow into the river. Different contaminants would enter the groundwater and reach the Columbia River at varying times in the future. Transport of contaminants through the groundwater is described in detail in Volume Four, Appendix F.

Total cancer fatalities were calculated using factors that relate the number of fatal cancers to the curies of each contaminant released to the river. These factors were calculated using a computer program that estimated the time integral of collective dose over a period of up to 10,000 years for time variant radionuclide release to surface waters, such as rivers (DOE 1987). The results of the dose estimates for the Columbia River scenario indicated that of the three principal routes of exposure (i.e., external, ingestion, and inhalation), ingestion would be the principal route, followed by inhalation and external exposure. The Np-237 was shown to be the radionuclide of concern to hypothetical receptors along the Columbia River (Rittman 1994). The point estimate for the Columbia River scenario dose equivalent factor for Np-237 is 1.0E+04 person-rem. A Monte Carlo uncertainty and sensitivity analysis was conducted on the algorithm used to estimate the dose for the Columbia River scenario. The sensitivity analysis indicated that parameters that most influenced the equivalent dose were in order: root uptake factor, root ingestion rate, Columbia River flow rate, total population exposed, months per year of irrigation, and soil area density. The results of the Monte Carlo analysis are summarized in Table K.5.1.12.

Table K.5.1.12 contrasts the percentile estimates of the dose estimates for a hypothetical Columbia River receptor with the point estimate derived using the upper-bound values. The point estimate lies at approximately the 100th percentile of the probability distribution function. The mean of the Columbia

River probability distribution was approximately one order of magnitude less than that of the point estimate. Again, these results suggested that the dose estimates predicted for the Columbia River scenario were upper-bound estimates. The typical dose to a receptor could be an order of magnitude less than that predicted by the fixed-point estimate.

Table K.5.1.12 Columbia River Scenario Dose Estimates [1]

Monte Carlo Result		Fixed-Point Estimate
Mean	1.2E+03	1.0E+04
Percentile	Result	
50th	9.6E+02	
75th	1.5E+03	
95th	3.0E+03	
100th	1.3E+04	

Notes:
[1] Units are person-rem

K.5.2 REMEDIATION ROUTINE EXPOSURE

The range of possible unit dose factors for offsite receptors would primarily depend on individual consumption rates and environmental transport factors such as the soil-to-plant concentration ratio. Age-dependent variations were considered to have less effect because the generally higher internal dose factors for the lower age groups (ICRP 1975) were offset by the lower breathing and food consumption rates. Thus, age dependence was not expected to be as important as the factors mentioned.

To analyze the bounding range for the individual consumption rates, the standard maximum individual in GENII was considered to have the highest likely consumption rate. The lower end was taken to be the consumption rates used in recent low-level waste performance assessments at the Hanford Site (Kincaid et al. 1995; Wood et al. 1995). These were 25 percent of the average annual dietary intakes of garden produce and 50 percent of the average annual dietary intakes of meat, poultry, milk, and eggs. In the calculation of population dose, this variation disappeared in the population average consumption rates. Thus, for estimating the range of possible population unit dose factors, the only contributor was assumed to be the variation in agricultural transfer factors.

To analyze the bounding range for the various agricultural transfer factors, the values found in NUREG/CR-5512 (Kennedy-Strenge 1992) were used with scale factors. For the soil-to-plant concentration ratios, the scale factors were selected to be 0.1 and 10 to accommodate the large variation in the published values. The variation of the equilibrium transfer factors into animal products was taken to be 0.3 and 3, because there is more consistency in the reported values. To account for the smaller variation over population averages, these variations were reduced by a factor of 2. The food consumption rates (kg/year) from EPA and GENII are listed in Table K.5.2.1.

Scenario dose factors were computed using GENII Version 1.485 (Napier et al. 1988) with two exposure scenarios. The first was the air pathway chronic dose for the MEI at the site boundary.

The normalized integrated exposure (Chi/Q) was set equal to 1 and unit activities of each nuclide of interest were used. The second exposure scenario was for the total population, again with a unit Chi/Q. The dose results are shown in Table K.5.2.2.

Table K.5.2.1 Food Consumption Rates (kg/year) for 25 Percent of EPA and for GENII

Food Type	EPA 25 Percent	GENII	
		MEI	Population
Leafy	4.1	30	15
Root	13.9	220	140
Fruit	9.6	330	64
Grain	18.5	80	72
Meat	21.0	80	70
Milk	51.7	270	230
Poultry	5.3	18	9
Eggs	5.3	30	20

Table K.5.2.2 Dose Factor for the Offsite MEI and Population Using Best Estimates for Food Transfer Factors

Nuclide	MEI			Population		
	GENII	NUREG	Ratio	GENII	NUREG	Ratio
C-14	5.3E+01	5.3E+01	1.00	3.6E+00	3.6E+00	1.00
Co-60	1.7E+02	1.8E+02	1.06	1.3E+01	1.4E+01	1.08
Sr-90	4.4E+02	3.4E+02	0.77	2.5E+01	2.1E+01	0.84
Zr-93	9.7E+01	1.1E+02	1.13	9.5E+00	1.1E+01	1.16
Tc-99	4.4E+01	2.0E+01	0.45	2.2E+00	1.6E+00	0.73
I-129	1.1E+04	1.0E+04	0.91	7.5E+02	7.4E+02	0.99
Cs-137	2.8E+02	2.4E+02	0.86	2.2E+01	1.8E+01	0.82
Sm-151	8.9E+00	8.9E+05	1.00	8.6E-01	8.6E-01	1.00
Pu-239	1.2E+05	1.2E+05	1.00	1.2E+04	1.2E+04	1.00
Am-241	1.2E+05	1.2E+05	1.00	1.2E+04	1.2E+04	1.00

Notes:
Units are rem per Ci released per sec/m^3

Table K.5.2.2 compares the effect of changing food transfer factors from those currently in GENII to those in NUREG/CR-5512. The most significant change occurs for Tc-99, which would contribute little to the overall air pathway dose. Thus, for the TWRS comparisons, the two sets of food transfer factors can be considered the same.

Table K.5.2.3 shows the dose factors that resulted when the low consumption rates were combined with the low transfer factors, as well as when the high consumption rates were combined with the high transfer factors. The unit release dose factors for the offsite maximally-exposed individual (MEI) differed only in these two assumptions. The exposure times, average breathing rate, and other agricultural parameters were held constant.

Using the dose factors listed in Tables K.5.2.2 and K.5.2.3, the estimated dose factor range were reduced to a ratio of the low or high value divided by the expected value using the NUREG/CR-5512 transfer factors. These ratios are shown in Table K.5.2.4.

Table K.5.2.3 Dose Factors for the Offsite MEI and Population Using Adjusted Food Transfer Factors from NUREG/CR-5512

Nuclide	MEI		Population	
	Low	High	Low	High
C-14	9.0E+00	5.3E+01	3.6E+00	3.6E+00
Co-60	8.9E+01	3.0E+02	1.8E+01	1.7E+01
Sr-90	7.8E+01	8.1E+02	1.8E+01	3.2E+01
Zr-93	9.5E+01	1.4E+02	1.0E+01	1.1E+01
Tc-99	3.2E+00	2.4E+02	8.0E-01	5.8E+00
I-129	7.9E+02	2.4E+04	5.3E+02	1.0E+03
Cs-137	3.2E+01	6.1E+02	1.3E+01	2.6E+01
Sm-151	8.2E+00	9.3E+00	8.5E-01	8.7E-01
Pu-239	1.2E+05	1.2E+05	1.2E+04	1.2E+04
Am-241	1.2E+05	1.2E+05	1.2E+04	1.2E+04

Notes:
Units are rem per Ci released per sec/m³

Table K.5.2.4 Ratios of Bounding [1] and Expected [2] Dose Factor

Nuclide	MEI		Population	
	Low	High	Low	High
C-14	0.17	1.00	1.00	1.00
Co-60	0.49	1.67	0.86	1.21
Sr-90	0.23	2.38	0.86	1.52
Zr-93	0.86	1.27	0.91	1.00
Tc-99	0.16	12.00	0.50	3.62
I-129	0.08	2.40	0.72	1.35
Cs-137	0.13	2.54	0.72	1.44
Sm-151	0.92	1.04	0.99	1.01
Pu-239	1.00	1.00	1.00	1.00
Am-241	1.00	1.00	1.00	1.00

Notes:
[1] GENII transfer factors
[2] NUREG/CR-5512 transfer factors

The above ratios could not be used to determine the bounding range of doses for mixtures of nuclides unless one nuclide gives nearly all the dose. For other cases, the doses must be computed for the mixture and then the bounding ratios can be calculated from the total dose. An example is given in Table K.5.2.5. From this table, the MEI dose factor ranged from 0.1 to 2.3 times the reported dose, while the offsite population dose ranged from 0.7 to 1.3 times the reported dose. These ratios were calculated by dividing the low or high dose value for each receptor by the best dose estimate.

These results show small uncertainties in the estimated dose calculations. The overall uncertainties associated with airborne transport, accumulation of constituents in food products, and dose conversion factors were not as significant as the source and release terms.

Table K.5.2.5 Comparison of Routine Dose Calculation for Mixtures of Nuclides

Nuclide	Source (Ci/Year)	MEI			Population		
		Low	Best	High	Low	Best	High
C-14	5.80E+01	5.2E+02	3.1E+03	3.1E+03	2.1E+02	2.1E+02	2.1E+02
Sr-90	2.51E+00	2.0E+02	8.5E+02	2.0E+03	4.5E+01	5.3E+01	8.0E+01
Zr-93	1.41E-02	1.3E+00	1.6E+00	2.0E+01	1.4E-01	1.6E-01	1.6E-01
Tc-99	1.46E-03	4.7E-03	2.9E-02	3.5E-01	1.2E-03	2.3E-03	8.5E-03
I-129	3.64E+00	2.9E+03	3.6E+04	8.7E+04	1.9E+03	2.7E+03	3.6E+03
Cs-137	1.83E+00	5.9E+01	4.4E+02	1.1E+03	2.4E+01	3.3E+01	4.8E+01
Sm-151	2.46E-02	2.0E-01	2.2E-01	2.3E-01	2.1E-02	2.1E-02	2.1E-02
Pu-239	1.16E-03	1.4E+02	1.4E+02	1.4E+02	1.4E+01	1.4E+01	1.4E+01
Am-241	5.26E-03	6.3E+02	6.3E+02	6.3E+02	6.3E+01	6.3E+01	6.3E+01
Total	6.60E+01	4.4E+03	4.2E+04	9.4E+04	2.3E+03	3.1E+03	4.1E+03
Ratio		0.1		2.3	0.7		1.3

Notes:
Units for dose factors are rem per sec/m³

K.5.3 REMEDIATION ACCIDENTAL EXPOSURE

Radiological exposure to the receptor groups was based on the radiological activity concentrations in the source term. Activity concentrations for six composite inventories were used as the radiological source terms in the tank farms accident analyses. The bounding composite inventory bounds 100 percent of all the tank characterization sample data. The nominal inventory was a total tank farm average by volume based on the inventory of radioactive materials contained in the fuel from the single-pass reactors and N Reactor and transferred to the tank farms. GENII was used to generate a single unit liter dose (ULD) value for each composite source term. The bounding ULDs for the six composite inventories and the nominal ULD used in the accident analyses are presented in Table K.5.3.1. The greatest difference between bounding and nominal is the Aging Waste Facility (AWF) solids inventory with a ratio of 6.00E+02.

Table K.5.3.1 Accident Source Term Unit Liter Dose Values for Bounding and Nominal Scenarios

Tank waste type	Bounding ULDs (rem)	Nominal ULDs[1] (rem)	Ratio (Bounding/Nominal)
SST liquids	1.31E+06	3.45E+05	3.80E+00
SST solids	2.30E+07	3.45E+05	6.67E+01
DST liquids	7.10E+05	3.45E+05	2.01E+00
DST solids	6.45E+07	3.45E+05	1.87E+02
AWF liquids	1.39E+05[2]	3.45E+05	4.03E-01
AWF solids	2.07E+08	3.45E+05	6.00E+02

Notes:
[1] The nominal is based on total tank farm average
[2] The total tank farm average exceeds the bounding aging waste facility liquids

In Volume Four, Section E.15, analysis is presented regarding uncertainties associated with the accident analysis for the tank waste alternatives. For the operation accidents, uncertainties were associated with the inventory of waste in the tanks and the atmospheric conditions that would transport the waste released as a result of an accident. The tank waste inventory used in this EIS is presented in Volume Two, Appendix A along with uncertainties associated with the quality of the data. Because of this uncertainty, for tank farm accidents, a composite inventory was developed. This composite incorporated estimates of the historical tank contents, the results from prior individual tank analyses, and the results of recent tank characterization programs (Shire et al. 1995). This composite provided a bounding tank waste inventory for the accident analysis.

Atmospheric conditions would influence the dispersion of contaminants in air to potential receptors. The bounding case analyzed in the EIS used conservative atmospheric conditions (99.5th percentile). The uncertainty analysis compared the results of these bounding case conditions to typical atmospheric conditions (50th percentile).

There also were uncertainties associated with the analysis of consequences of an accident involving the transportation of vitrified HLW to the potential geologic repository under certain tank waste alternatives. The potential consequences would be influenced by the weight percent of HLW that would be mixed in the glass. The baseline analysis in the EIS assumed a 20 percent waste loading. However, waste loading could be as low as 15 percent or as high as 40 percent. Uncertainties associated with waste loading are discussed further in Volume Two, Section B.8. To address this uncertainty in Volume Four, Section E.15, the impacts of a transportation accident involving the baseline waste loading were compared to an accident involving vitrified glass with a 15 percent waste loading and with a 40 percent waste loading. In addition to the uncertainties associated with the accident analysis, a number of important assumptions influenced the results. These assumptions include the following:

- The offsite general public population for operation accidents was based on 1990 census data. While it is unlikely that the population would be constant throughout the operation phase of each alternative, the 1990 census provided a uniform basis for comparison of impacts among the alternatives.
- The onsite worker population for operation accidents was based on the 1995 Hanford Site work force. In the future, the Site work force would likely decline, resulting in proportionately lower impacts than presented in the EIS. However, use of the existing worker population provided a bounding analysis in terms of total impacts and provided a basis for uniform comparison of impacts among the alternatives.
- For transportation of HLW to a potential geologic repository, the accident scenarios were based on transportation of the waste from the Hanford Site to Yucca Mountain, Nevada by rail.
- For nonradiological occupational construction, operation, and transportation accidents, it was assumed that injuries, illnesses, and fatalities would occur at rates similar to historical rates for each activity.

- It was assumed that there would be no evacuation of Hanford Site personnel in the event of an accident. Emergency planning and evacuation programs are in place at the Hanford Site to mitigate potential consequences resulting from an accident.

The uncertainties in calculating the radiological doses and the toxicological exposures resulting from operation accidents included the tank inventory concentration and the atmospheric dispersion once the source term is in the air. A sample accident scenario is presented in Table K.5.3.2 to illustrate these uncertainties. The illustration shows the difference between the bounding and nominal parameters; the concentration of the inventory was a factor of 30; and the atmospheric dispersion coefficient was a factor of 12 for the MEI noninvolved worker, 30 for the noninvolved worker population, 22 for the MEI general public, and 15 for the general public population. For the noninvolved worker population, a bounding dose of 2.52E+03 person-rem was estimated. This was 3 orders of magnitude higher than the estimated nominal dose of 2.89E+00 person-rem.

Table K.5.3.2 Uncertainty Evaluation for Mispositioned Jumper - Common to All Tank Alternatives

Parameters	Bounding	Nominal
Inventory (activity concentration of inventory)	1.20E+06 rem/L (activity concentration bounding 100 percent of the sampled inventory by volume)	4.20E+04 rem/L (activity concentration bounding 50 percent of the sampled inventory by volume)
Source Term (respirable amount of waste to which the receptors are exposed)	26 L onsite (8-hr exposure) 52 L offsite (16-hr exposure)	26 L onsite (8-hr exposure) 52 L offsite (16-hr exposure)
Atmospheric dispersion coefficients (Chi/Q) - (determines the down wind concentrations)	99.5 percent maximum sector meteorology MEI nonworker = 6.51E-03 s/m^3 Nonworkers = 2.45E-01 s/m^3 MEI general public = 1.43E-05 s/m^3 General population = 3.00E-02 s/m^3	Annual average meteorology MEI nonworker = 5.49E-04 s/m^3 Nonworkers = 8.01E-03 s/m^3 MEI general public = 6.54E-07 s/m^3 General population = 2.03E-03 s/m^3
Breathing rate (typical acute breathing rate during light activity)	3.3E-4 m^3/s	3.3E-4 m^3/s
Dose - Is the product of the inventory · tank head space · head space concentration · LPF Chi/Q · breathing rate	MEI nonworker = 6.70E+01 rem Nonworkers = 2.52E+03 person-rem MEI general public = 2.94E-01 rem General population = 6.18E+02 person-rem	MEI nonworker = 1.98E-01 rem Nonworkers = 2.89E+00 person rem MEI general public = 4.71E-04 rem General population = 1.46E+00 person-rem

Notes:
Bounding:
[1] MEI nonworker = (1.20E+06 rem/L) · (2.60E+01 L) · (6.51E-03 s/m^3) · (3.3E-04 m^3/s) = 6.70E+01 rem.
[2] Nonworkers = (1.20E+06 rem/L) · (2.60E+01 L) · (2.45E-01 s/m^3) · (3.3E-04 m^3/s) = 2.52E+03 rem.
[3] MEI general public = (1.20E+06 rem/L) · (5.20E+01 L) · (1.43E-05 s/m^3) · (3.3E-04 m^3/s) = 2.94E-01 rem.
[4] General public = (1.20E+06 rem/L) · (5.20E+01 L) · (3.00E-02 s/m^3) · (3.3E-04 m^3/s) =6.18E+02 rem.
Nominal:
[5] MEI nonworker = (4.20E+04 rem/L) · (2.60E+01 L) · (5.49E-04 s/m^3) · (3.3E-04 m^3/s) = 1.98E-01 rem.
[6] Nonworkers = (4.20E+04 rem/L) · (2.60E+01 L) · (8.01E-03 s/m^3) · (3.3E-04 m^3/s) = 2.89E+00 rem.
[7] MEI general public = (4.20E+04 rem/L) ·(5.20E+01 L) · (6.54E-07 s/m^3) · (3.3E-04 m^3/s) = 4.71E-04 rem.
[8] General public = (4.20E+04 rem/L) · (5.20E+01 L) · (2.03E-03 s/m^3) · (3.3E-04 m^3/s) = 1.46E+00 rem.

The main uncertainty associated with estimating the radiological doses resulting from accidents while transporting vitrified HLW to a potential geologic repository was the weight percent of the waste that could be mixed with the glass matrix. A sample accident scenario is presented in Table K.5.3.3 to illustrate these uncertainties. The baseline analysis used in the EIS assumed a 20 percent loading. A range from 15 to 40 weight percent was used in the uncertainty evaluation in Table K.5.3.3. The population dose was calculated by RADTRAN 4 (Neuhauser-Kanipe 1992) and was based on the worst credible accident parameters in the urban population zone.

Table K.5.3.3 Uncertainty Evaluation for HLW Glass Transport Accident - Ex Situ Intermediate Separations Alternative

Inventory	Population Dose (person-rem)
HLW glass with 20 weight percent waste oxide loading (base case)	4.2E+03
HLW glass with 15 weight percent waste oxide loading	3.3E+03
HLW glass with 40 weight percent waste oxide loading	7.9E+03

The accident initiator frequencies were established using currently accepted sources such as natural phenomena statistics for the Hanford Site or recent analysis of the initiators from safety assessment reports. The frequencies of these accidents were presented as estimates and were provided as an aid in screening accident scenarios. Only 10-fold differences in frequencies would be significant. For example, accident frequencies of 1E-6 and 5E-05 should not be considered significantly different.

The nonradiological injuries and fatalities resulting from construction and operation accidents were based on incidence rates in the occupational injuries summary report (DOE 1994j). The transportation injuries and fatalities from trucks and trains were based on incidence rates in statistics compiled by the U.S. Department of Transportation (Rao et al. 1982). Injuries and fatalities resulting from employee vehicle accidents were based on incidence rates in the Washington State Highway Accident Report (WSDT 1993). Because these are widely accepted, statistically based incidence rates, there was no attempt to evaluate the uncertainties.

K.6.0 UNCERTAINTY IN HUMAN HEALTH RISK

Human health risk assessment results are conditional estimates that depend on the assumptions made to account for uncertainties in biological processes or a lack of information on source data, transport, or receptor behavior. It is important to recognize these uncertainties to place the risk estimates in proper perspective. The uncertainties associated with the TWRS EIS risk estimates include parameters involved in the models used and historical data on worker risks and accidents. Volume Three, Appendix D presents some parameter uncertainties associated with remediation risk (Section D.4.14), anticipated post-remediation risk (Section D.5.14), ecological risk (Section D.6.5), and intruder risk (Section D.7.5), which are briefly discussed as follows.

To estimate risk, information must be available on dose-response relationships, which define the biological response from exposure to a contaminant. Although human epidemiological data are used

for developing radiological and nonradiological chemical dose-response models, this information also is developed in laboratory tests using animals exposed to relatively high doses. Therefore, uncertainty is inherent in dose-response relationships, including extrapolating from effects in animals at high doses to potential effects in humans that most often are exposed at much lower doses.

Another important component of risk assessment is estimating exposure concentrations. Uncertainties associated with this component include estimating releases of contaminants from emission sources to different environmental media such as groundwater, soil, air, and surface water, the transport and transformation of contaminants in these media, and the pathway, frequency, and duration by which humans contact the contaminants.

The risk associated with the release of radionuclides or chemicals to ambient environmental media during routine operations was estimated using models. The risk estimates determined by these models have a greater uncertainty than those based on historical data. However, it is reasonable to assume that releases would occur on a routine basis over the operational lifetime of the facility. The risk estimates for post-remediation and intruder scenarios are associated with more uncertainty than facility routine operation risk and involve uncertainties associated with the hypothetical land use and intrusion in addition to modeling. Finally, the MEI risk estimates generally involve a greater level of uncertainty than population risk estimates.

K.6.1 POST-REMEDIATION LAND-USER RISK

The uncertainty analyses for post-remediation risk assessment were based on the Hanford Site Risk Assessment Methodology (HSRAM) uncertainty analysis. The carcinogenic and noncarcinogenic risks presented in the post-remediation risk evaluation were estimates based on multiple assumptions about exposures, toxicity, and other variables. Therefore, discussion of uncertainty was provided for this risk assessment. The uncertainties are inherent (e.g., toxicity values, default exposure parameters) or specific (e.g., data evaluation, contaminant identification) in the risk assessment process. Specific considerations in evaluating uncertainty were Site-specific factors, exposure assessment factors, toxicity assessment factors, and risk characterization factors, which are discussed as follows.

K.6.1.1 Site-Specific Uncertainty Factors

Uncertainty related to the source inventory, Site contamination, availability of information on Site-specific environmental conditions (e.g., climate, geology, and hydrogeology), and uncertainties in model application to the Site were important in assessment of risk associated with the Site. These uncertainties are addressed in Appendices A, B, and F.

K.6.1.2 Exposure Assessment Uncertainty Factors

Exposure assessment requires multiple assumptions that can affect the outcome of a risk assessment. Key factors contributing to uncertainty in the exposure assessment included the following:

- Identification of land use;
- Likelihood of future land use actually occurring;
- Model assumptions that affect exposure point concentrations;

- Use of standard default parameters (e.g., upper 95th percentile values for intake/contact rates, exposure frequency, and exposure duration);
- Uncertainty related to biotransfer factors;
- Uncertainty related to production and distribution of food; and
- Uncertainty related to lifestyle and diet of specific or referenced individuals.

K.6.1.3 Toxicity Assessment Uncertainty Factors

A high degree of uncertainty was associated with data used to derive toxicity values and resulted in less confidence in assessment of risk associated with exposure to a substance. Sources of uncertainty associated with published toxicity values include:

- Use of dose-response information from effects observed at high doses to predict effects at the low levels expected in the environment;
- Use of data from short-term exposure studies to extrapolate to long-term exposure or vice-versa;
- Use of data from animal studies to predict human effects; and
- Use of data from homogenous animal populations or healthy human populations to predict effects in the general population.

K.6.1.4 Risk Characterization Uncertainty Factors

The summation of cancer risk across pathways or for multiple pathways would result in more conservative risks. This is because the slope factor for each chemical carcinogen is an upper 95th percentile estimate and such probability distributions are not strictly additive. The risk values calculated for the post-remediation scenario in the TWRS EIS were a conservative bounding estimate. The uncertainty in the risk values for certain receptors would increase as the time in the future increased. Less uncertainty would be associated with the risk values at 300 years than the risk estimates at 500, 2,500, 5,000, and 10,000 years.

The best approach to more fully characterize the uncertainty would be to conduct a probabilistic risk assessment from the start of the evaluation. A probabilistic assessment uses the range of variation in contaminant information, exposure parameters, and toxicity data to provide a risk distribution curve. This appendix examines the effect of variations on these parameters on the risk estimates to provide a better understanding of the uncertainties.

K.6.2 POST-REMEDIATION INTRUDER RISK

The greatest uncertainty in calculating the intruder risk was associated with the source data. Source terms were based on the estimated inventory and an average tank within the eight aggregated tank farms of the 200 Areas. Additional information regarding the source term would decrease the uncertainty in the risk estimate.

The relative uncertainty associated with the dose conversion factor was not as important as the source data, source terms, and exposure pathway parameters. The GENII computer code was used for the intruder dose calculation. GENII used the dosimetry model recommended by the International

Commission on Radiation Protection (ICRP), in ICRP Publication 26 (ICRP 1977) and ICRP Publication 30 (ICRP 1979-1982), with updates from ICRP Publication 48 (ICRP 1986). The dose conversion factors used were equivalent to those currently recommended by the (DOE 1988). External dose factors were equivalent to Kocher (Kocher 1981; ORNL 1981). The overall uncertainty associated with risk in respect to GENII is discussed in Volume Three, Section D.4.14.

K.6.3 REMEDIATION ROUTINE RISK

By far the greatest uncertainty in the routine remediation risk was associated with the source data, which were based on the estimated inventory and source terms (i.e., the amount of chemicals and radionuclides released into the environment). The uncertainties associated with the source and source terms are discussed in Volume Two, Appendices A and B. Other contributors to the routine risk uncertainty were the airborne transport of the released chemicals and radionuclides, accumulation of contaminants in food products, production and distribution of food products, and lifestyle and diet of specific individuals, food consumption rates, and dose conversion factors which are discussed in this section.

Routine chemical emissions from the tank farm during remediation were based on existing tank farm emissions data (Jacobs 1996). Operational emissions from the tank farm, such as would occur while retrieving waste from tanks and gravel-filling the tanks, were appropriately scaled for potential increased emission rates during remediation.

The hazard index (HI) approach conservatively assumed that the noncarcinogenic health effects were additive for all chemicals (i.e., all chemicals would have the same mechanism of action and affect the same target organ). The HI is the sum of the hazard quotients (estimated intake/reference dose) for all chemicals. A HI greater than or equal to 1.0 indicates potential adverse health effects in the population of concern. Conversely, a HI less than 1.0 suggests that adverse health effects would be unlikely.

Carcinogenic risks were assumed to be additive. Consequently, the total ILCR is the sum of individual chemical cancer risks from each emission source for each alternative analyzed. Regulatory agencies have defined an acceptable level of risk to be between 1 in 10,000 (1.0E-04) and 1 in 1,000,000 (1.0E-06), with 1.0E-06 being the point of departure and referred to as de minimis (below which there is minimal concern) risk. For the purpose of this EIS, a risk below 1.0E-06 was considered low, and a risk greater than 1.0E-04 was considered high.

K.6.4 REMEDIATION ACCIDENT RISK

The objective of this section is to summarize the results of the Monte Carlo uncertainty and sensitivity analyses of the LCF predictions associated with the potential accidental release of contaminants from each TWRS EIS remedial alternative.

A detailed description of the general methodology used in the Monte Carlo approach is presented in Section K.5.0. The methodology used to estimate the uncertainty in the LCF predictions was similar to

that used to predict the uncertainty in the human health exposure factors (see Section K.5.0). In this approach, the variables used to predict the LCF were separated into variables which can be described as PDFs and those having constant or fixed point estimates. A computer simulation was then run in order to produce a PDF for LCF. The results of the computer simulation were then compared to the results of the fixed point estimate. The equation used to predict LCF from an accidental release is:

$$LCF = Chi/Q \cdot V \cdot IR \cdot ULD \cdot C$$

Where:

LCF	= latent cancer fatality
Chi/Q	= atmospheric dispersion coefficient (second/m^3)
V	= release volume (rem/liter)
IR	= inhalation rate (m^3/second)
ULD	= unit liter dose (committed effective dose equivalent/liter)
C	= conversion factor (LCFs/rem)

The Monte Carlo analysis described each of the variables in the above equation (i.e., Chi/Q, V, IR, ULD and C) as PDFs and not as a single value.

K.6.4.1 Accident Release Scenarios

This uncertainty analysis evaluated the consequences to four receptors as a result of the spray release accident scenario presented in Volume Four, Appendix E:

- MEI noninvolved worker;
- Noninvolved worker population;
- MEI general population; and
- General public population.

The radiological dose to a receptor would depend on the receptor's location relative to the point of release of the radioactive material. Doses for a MEI and population dose were computed for each receptor (noninvolved worker and general public). Noninvolved workers would be onsite workers not involved in the proposed action. The general public would be people located off the Hanford Site. The MEI for each of these receptor categories would be a single individual assumed to receive the highest exposure in the category. Volume Four, Appendix E of this report contains a more detailed description of the receptors associated with each accidental release scenario.

K.6.4.2 Monte Carlo Uncertainty Analysis

The PDFs for the variables in the equation used to calculate LCF were assumed to be triangular distributions (Finley et al. 1994). Triangular distributions can be viewed as conservative characterizations of truncated normal or lognormal distributions. The triangular distribution was conservative in that it resulted in more frequent selection of values in the extremes of the factor's distribution.

The inhalation rate triangular PDF was assumed to have a minimum value of 6.9E-05 m^3/s (6 m^3/day), mean value of 2.1E-04 m^3/s (18.9 m^3/day), and maximum value of 3.7E-04 m^3/s (32 m^3/day) based on worker ventilation rates under light activity levels (EPA 1985).

The remaining variables in the equation for calculating LCF were also assumed to have a triangular PDF. The values were chosen to correspond to conditions associated with a nominal accidental release value as well as an upper bounding value for accidental release. A more detailed description of the accidental release scenarios and the rationale for the selection of the nominal and bounding values is presented in Section K.6.5.

A Monte Carlo analysis was conducted based on the above algorithm for calculating the LCF. The sensitivity analysis indicated that the parameters which contributed the most to the uncertainty in the LCF were as measured by rank correlation: the unit limit dose, the atmospheric dispersion coefficient, the release volume, the inhalation rate, and the conversion factor. The detailed results of the Monte Carlo analysis are presented in Attachment 1 and are summarized in Table K.6.4.1.

Table K.6.4.1 contrasts the mean and percentile estimates of the LCF distributions for the four accidental release scenarios with the fixed point estimate derived using the upper-bound values. The results show that the LCF derived using the upper-bound values is in all cases greater than the 100th percentile of the LCF PDF. The mean of the LCF PDF was approximately one order of magnitude less than the upper-bound fixed point estimate. These results demonstrate that the predicted LCF estimates would be upper bound estimates of cancer probability and/or fatality rates. The true probability of contracting cancer or fatalities as a result of cancer could actually be much less than the predicted value.

K.6.5 ANALYSIS OF NOMINAL VERSUS BOUNDING RISK ESTIMATES

The bounding risk estimates in the TWRS EIS used a series of conservative assumptions about source and release terms, environmental transport parameters, and the effects of a given exposure on cancer risk and noncancer health effects to account for the uncertainties involved in the alternatives. This section analyses the effect of using less conservative values for several of the source term, release term, and environmental transport assumptions on the risk estimates. No change was made in the SIFs used to estimate the risk from each exposure.

Based upon available data, the assumption for the distribution coefficient (K_d) for Np-237, a major contributor to the groundwater risks, was changed from zero, which implies that Np would move at the same rate as water, to 1.0, which implies that interaction with the soil would slow its movement to and through the aquifer. For the ex situ alternatives, assumptions about tank residuals were changed, as described in the following sections.

Table K.6.4.1 Comparison of Monte Carlo-Based and Fixed Point Estimates

Monte Carlo Result		Fixed-Point Estimate
MEI Noninvolved Worker [1]		
Mean	0.6	9.9
Percentile	Result	
50th	0.29	
75th	0.75	
95th	2.3	
100th	9.6	
Noninvolved Worker Population [2]		
Mean	1.5	376
Percentile	Result	
50th	6.5	
75th	17.8	
95th	56.1	
100th	266	
MEI General Population [1]		
Mean	1.7E-03	3.5E-02
Percentile	Result	
50th	8.0E-04	
75th	2.1E-03	
95th	6.4E-03	
100th	3.2E-02	
General Public Population [2]		
Mean	2.9	79
Percentile	Result	
50th	1.4	
75th	3.6	
95th	10.7	
100th	52.6	

Notes:
[1] Units are probability.
[2] Units are persons.

K.6.5.1 Tank Residuals Nominal Case

A nominal case retrieval release and residual tank inventory was developed to assess the impacts that would result from nominal assumptions for tank releases during retrieval and the residual waste left in the tanks following retrieval. Details are presented in Volume Two, Appendix B. The nominal release inventory was developed by assuming that the waste would be diluted by one-third by adding liquids for sluicing during retrieval. Possible dilution ratios that would be used during waste retrieval ranged from 3:1 to 10:1. Thus, the dilution factor of one-third assumed for the nominal case was a conservative assumption. These dilution ratios represent the amount of liquid required to mobilize the waste solids and would be made of existing tank liquids and water additions. The nominal case retrieval release volume was assumed to be 15,000 L (4,000 gal) from each SST, and the contaminant

concentrations were assumed to be two-thirds of the bounding case. The average volume of waste released from each SST during retrieval was not reduced for the nominal case, because insufficient information was available to support a lower average release volume. The volume released would depend on the ability to detect a leak and take corrective action.

The nominal tank residual inventory was developed by modifying the bounding tank residual inventory to reduce the mobile constituents of concern based on solubility. The mobile constituents of concern were evaluated because of their contribution to post-remediation risk. The isotopes C-14, Tc-99, and I-129 were reduced to the nominal case residual inventory to 10 percent of the bounding residual inventory. This was based on the assumption that 90 percent of the residual inventory of these isotopes would be soluble in the retrieval liquids and would be retrieved from the tanks for ex situ treatment. Typical sludge wash factors, representing the water solubility of these isotopes, were as high as 99 percent. The nominal case residual was limited to 90 percent to account for conditions in which the scale and hardened sludges would not see the sluicing liquid during retrieval. Table K.6.5.1 shows the nominal and bounding residual inventories for select mobile constituents.

Table K.6.5.1 Tank Residual Inventory, Curies

Isotope	Existing Tank Inventory	Bounding Residual Inventory	Nominal Case Residual Inventory
C-14	5,340	53	5.3
Tc-99	32,100	320	32
I-129	38	0.38	0.038

K.6.5.2 Nominal vs. Bounding Risk Results

The ILCR and HI results for the nominal and bounding cases are presented in Volume One, Table 5.11.7. The overall effect of the changes in the nominal case was to reduce the estimated risks. The size of the effect would vary with the exposure scenario, the alternative, and the future time examined (Volume One, Table 5.11.7). For some scenarios, for some points in time, the nominal case risks were higher than those for the bounding case. For example, the No Action alternative showed higher risks for the nominal than the bounding case for all scenarios at 2,500 years. This occurred because one of the key assumptions, decreasing the mobility of Np-237, caused the exposure to Np in groundwater to be delayed, but did not change its ultimate impact on the risk. In the bounding case, the risk from Np occurred early, because the Np was assumed to move quickly, and then decreased as the Np was removed by attenuation and ultimate loss to the Columbia River. Thus, relaxing a conservative assumption about contaminant mobility could have more effect on the timing than on the degree of risk. Nonetheless, Volume One, Table 5.11.8 demonstrates that the total cancer incidence over the 10,000-year period of interest is decreased in the nominal case.

K.7.0 NOMINAL CASE ANALYSIS FOR EX SITU INTERMEDIATE SEPARATION ALTERNATIVE

This section describes the results of the nominal case risk analysis for the Ex Situ Intermediate Separation alternative. The primary changes in the nominal, compared to the bounding case, were that the distribution coefficient (K_d) for Np-237, a major contributor to the groundwater risk, was assumed to be 1.0 rather than zero, which slows its movement through interaction with the soils. In addition, the residual inventory of isotopes C-14, Tc-99, and I-129 were reduced to 10 percent of the bounding residual inventory. These changes are described in more detail in Section K.6.5. The inventory of contaminants assumed to be released during retrieval for the nominal case analysis is presented in Tables K.7.0.1 and K.7.0.2. Differences from the bounding case are shown in bold.

Table K.7.0.1 Nominal Case Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative

Constituents	Inventory (grams) [1]				
	1WSS	2WSS	1ESS	2ESS	4ESS
K_d Group 1 (K_d = 0.0 mL/g)					
C-14	**6.38E-02**	**1.10E-01**	**4.11E-01**	**4.83E-02**	**4.09E-02**
I-129	**9.66E+00**	**2.49E+01**	**5.19E+01**	**3.39E+00**	**9.72E-01**
Rn-219	3.30E-15	1.69E-15	7.84E-15	4.04E-14	2.37E-16
Rn-222	3.27E-15	1.68E-15	3.90E-15	6.54E-14	1.14E-15
Ru-106	1.52E-10	3.00E-08	2.80E-07	9.85E-06	1.32E-06
Sb-126m	5.99E-09	1.00E-08	7.05E-09	4.30E-07	4.00E-08
Se-79	1.16E+01	1.86E+01	8.64E+01	1.57E+02	1.52E+00
Tc-99	**6.92E+01**	**1.79E+02**	**3.72E+02**	**2.33E+01**	**6.80E+00**
U-233	**1.24E-03**	**1.82E-03**	**6.13E-03**	**8.37E-04**	**1.22E-03**
U-234	**7.86E-02**	**7.36E-02**	**6.91E-02**	**4.87E-02**	**4.04E-02**
U-235	**3.34E+04**	**1.36E+04**	**3.20E+04**	**1.30E+04**	**3.23E+03**
U-236	**3.35E-02**	**6.47E-02**	**5.67E-02**	**1.01E-01**	**9.55E-02**
U-237	**1.18E-08**	**1.91E-08**	**2.54E-08**	**3.96E-08**	**3.33E-08**
U-238	**5.12E+06**	**1.93E+06**	**4.85E+06**	**1.92E+06**	**4.91E+05**
Cl^-	1.81E+05	2.78E+04	1.45E+05	1.35E+04	6.72E+02
CO_3^{-2}	7.06E+06	1.60E+06	6.40E+06	6.19E+05	3.80E+05
Cr^{+3}	1.05E+04	4.29E+05	8.35E+03	5.56E+04	9.19E+03
CrO_4^{-2}	2.59E+03	1.06E+05	2.07E+03	1.38E+04	2.28E+03
F^-	1.19E+06	1.55E+05	2.67E+06	1.35E+08	3.44E+03
$Fe(CN)_6^{-4}$	1.82E+04	7.03E+03	2.86E+06	2.36E+07	5.90E+02
Hg^+	0.00	0.00	0.00	0.00	0.00
Na^+	1.21E+08	1.09E+08	1.33E+08	7.07E+08	4.21E+07
NO_2^-	1.46E+07	4.12E+06	2.37E+07	1.60E+05	2.59E+06

Table K.7.0.1 Nominal Case Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative (cont'd)

Constituents	Inventory (grams) [1]				
	1WSS	2WSS	1ESS	2ESS	4ESS
NO_3^-	2.18E+08	2.34E+08	2.18E+08	8.72E+07	5.45E+07
Np-238	4.10E-10	1.84E-09	4.01E-09	1.20E-07	1.78E-09
Rh-106	1.43E-16	2.46E-14	2.68E-13	9.26E-12	1.25E-12
SO_4^{-2}	5.26E+06	1.28E+06	6.37E+06	4.51E+07	9.31E+05
W^{+6}	3.42E+04	3.48E+04	4.38E+04	2.30E+06	6.68E+03
K_d Group 2 (K_d = 1.0 mL/g)					
Bi-210	1.00E-15	4.82E-16	1.25E-15	1.92E-14	2.53E-16
Ni-63	9.63E-01	4.26E+00	1.04E+01	3.38E+02	2.07E+01
Pa-231	1.69E-03	7.99E-04	3.73E-03	2.42E-02	1.50E-04
Pa-233	3.31E-06	2.74E-06	2.76E-05	5.50E-06	2.40E-07
Po-210	2.77E-14	1.33E-14	3.44E-14	5.29E-13	6.98E-15
Po-211	1.13E-18	5.76E-19	2.68E-18	1.38E-17	8.10E-20
Np-237	9.73E+01	8.05E+01	8.12E+02	1.62E+02	7.10E+00
Bi^{+3}	1.38E+06	1.44E+03	1.09E+06	2.00E+05	0.00
Ca^{+2}	1.65E+03	3.00E+04	6.30E+05	2.22E+07	1.72E+04
Cd^{+2}	0.00	0.00	0.00	0.00	0.00
Fe^{+3}	1.41E+06	4.21E+05	1.63E+06	1.87E+07	1.99E+06
Ni^{+2}	4.17E+04	1.72E+04	1.44E+06	1.48E+07	1.11E+04
K_d Group 3 (K_d = 10.0 mL/g)					
Pb-210	1.63E-12	7.82E-13	2.02E-12	3.11E-11	4.10E-13
Pd-107	1.46E+02	2.33E+02	1.11E+03	2.41E+03	2.11E+01
Pu-238	1.02E-01	8.92E-02	1.25E-01	3.93E+00	1.46E-01
Pu-239	2.79E+02	2.99E+02	5.40E+02	2.64E+04	8.27E+02
Pu-240	1.49E+01	1.79E+01	3.53E+01	1.85E+03	5.74E+01
Pu-241	3.15E-01	3.18E-01	9.47E-01	4.33E+01	1.20E+00
Pu-242	2.80E-05	1.26E-04	2.74E-04	8.51E-03	1.22E-04
Ra-223	8.38E-10	4.28E-10	1.99E-09	1.00E-08	6.03E-11
Ra-225	3.65E-13	3.78E-13	1.77E-12	1.94E-11	8.07E-13
Ra-226	5.10E-10	2.62E-10	6.08E-10	1.00E-08	1.78E-10
Ra-228	0.00	0.00	0.00	0.00	0.00
Sn-126	1.66E+01	3.03E+01	1.95E+01	1.19E+03	1.01E+02
Sr-90	8.95E+01	5.30E+02	6.90E+02	1.19E+04	1.52E+03
Th-229	7.00E-08	7.00E-08	3.30E-07	3.58E-06	1.50E-07
Th-230	3.69E-06	2.01E-06	4.29E-06	7.55E-05	1.72E-06

Table K.7.0.1 Nominal Case Inventory of Contaminants Released During Retrieval for the Ex Situ Intermediate Separations Alternative (cont'd)

Constituents	Inventory (grams) [1]				
	1WSS	2WSS	1ESS	2ESS	4ESS
Th-232	1.39E-09	1.67E-09	3.28E-09	1.70E-07	5.34E-09
Th-234	6.17E-05	1.44E-05	8.14E-05	9.44E-04	7.96E-06
Mn^{+4}	1.74E+05	5.81E+04	1.51E+05	1.72E+07	2.62E+05
Pb^{+4}	1.95E+04	1.99E+04	4.87E+06	2.30E+06	1.15E+03
PO_4^{-3}	2.22E+07	5.67E+05	2.09E+07	1.00E+07	9.60E+03
Sr^{+2}	7.78E+00	3.59E+02	4.13E+05	8.53E+03	6.44E+02
K_d Group 4 (K_d = 50.0 mL/g)					
Ac-225	2.47E-13	2.55E-13	1.20E-12	1.31E-11	5.46E-13
Ac-227	5.90E-07	3.00E-08	1.41E-06	7.26E-06	4.00E-08
Am-241	4.11E+00	1.42E+01	2.52E+01	9.58E+02	1.50E+01
Am-242	2.76E-06	1.24E-05	2.70E-05	8.40E-04	1.20E-05
Am-242m	2.30E+03	1.03E-02	2.25E-02	6.99E-01	1.00E-02
Am-243	4.23E-02	2.03E-01	5.55E-01	1.98E+01	1.75E-01
Ce^{+3}	9.62E+05	1.63E+05	1.02E+06	8.90E+04	1.95E+04
Cm-242	5.58E-06	2.51E-05	5.46E-05	1.70E-03	2.43E-05
Cm-244	3.30E-04	1.52E-03	7.15E-03	2.23E-01	9.94E-04
Cm-245	1.00E-05	5.22E-05	2.57E-04	8.04E-03	3.57E-05
La^{+}	1.23E+04	0.00	4.60E+03	0.00	0.00
Nb-93m	2.69E-03	1.32E-02	1.63E-02	5.20E-01	6.38E-02
Cs-135	1.49E+02	3.04E+02	5.29E+02	4.74E+02	2.06E+01
Cs-137	8.56E+01	2.38E+02	4.99E+02	5.22E+02	1.86E+01
Sm-151	1.97E+01	3.60E+01	2.40E+01	1.30E+03	1.05E+02
Y-90	2.32E+00	1.38E+01	1.79E+01	3.09E+02	3.95E+01
Zr-93	1.50E+02	1.64E+03	1.11E+03	7.58E+04	1.02E+04
Tl-209	7.55E-19	7.83E-19	3.67E-18	4.01E-17	1.67E-18
Al^{+3}	5.90E+05	3.73E+06	6.81E+06	1.95E+08	2.83E+05
Ba^{+2}	2.97E+02	8.73E+02	1.18E+03	3.68E+04	2.12E+04
Sn	0.00	0.00	6.18E+01	0.00	0.00
Zr^{+4}	1.16E+05	1.19E+05	7.48E+04	6.82E+07	1.42E+03

Notes:
[1] Refer to Appendix A for inventory in curies.

Table K.7.0.2 Inventory of Contaminants for the Low-Activity Waste Vaults
Ex Situ Intermediate Separations Alternative

Group 1 (K_d = 0)		Group 2 (K_d = 1)		Group 3 (K_d = 10)		Group 4 (K_d = 50)	
Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]	Constituent	Inventory (grams) [1]
Tc_2O_7	2.39E+06	Bi_2O_3	7.52E+07	MnO_2	2.16E+07	Am_2O_3	2.76E+03
U-233	5.75E-02	CaO	3.87E+10	PbO_2	2.26E+06	BaO	8.81E+05
U-234	1.58E+00	CdO	2.83E+06	PuO_2	3.26E+04	Ce_2O_3	2.79E+06
U-235	4.86E+05	CuO	2.21E+05	SrO	4.00E+05	Cs_2O	6.83E+03
U-236	1.80E+00	Fe_2O_3	2.06E+07	ZnO	4.46E+06	La_2O_3	2.58E+05
U-238	7.30E+07	MgO	1.60E+06			ZrO_2	6.49E+05
Ag_2O	3.52E+05	Ni_2O_3	5.72E+06				
As_2O_5	1.18E+06	NiO	1.50E+04				
B_2O_3	1.67E+06	P_2O_5	3.09E+09				
BeO	2.27E+05						
WO_2	2.91E+01						
WO_3	9.40E+05						
Cr_2O_3	2.11E+08						
K_2O	2.65E+05						
Li_2O	1.24E+04						
MoO_3	7.29E+06						
Na_2O	9.86E+10						
NpO_2	1.66E+04						
SiO_2	2.29E+11						
V_2O_5	1.11E+05						

Notes:
[1] Refer to Appendix A for inventory in curies

Atmospheric releases during remediation may be chronic or acute. A nominal case was analyzed only for the acute (accident) case, because risks for the chronic bounding case were already very low.

K.7.1 EX SITU INTERMEDIATE SEPARATIONS ALTERNATIVE EXPOSURE ASSESSMENT

Uncertainties in the Ex Situ Intermediate Separations alternative human health exposure assessment can be divided into two parts. The first part discusses the uncertainties associated with the exposure parameters used in the post remediation land use scenarios. The second part discusses the uncertainties associated with the accidental release scenarios. In both cases, a Monte Carlo approach was used to evaluate both the uncertainty in the exposure assessment and to establish the parameters which contribute the most to the uncertainty in the exposure assessment (i.e., sensitivity analysis).

In the Monte Carlo analysis, PDFs were used to represent the range of values of a given parameter. The Crystal Ball computer software was then used to simulate a large number of realizations of the set of random variables in each model. This computation was repeated a large number of times to produce complete PDFs of the output function. Statistical summaries of the results were then plotted to interpret the data.

K.7.2 POST-REMEDIATION LAND-USE SCENARIOS

The results of the uncertainty analysis of exposure parameters for the post-remediation land-use scenarios in the Ex Situ Intermediate Separations alternative are summarized in Table K.7.2.1. The mean or nominal value of the Monte Carlo result was computed and compared to the bounding or fixed-point estimate of the same function. The nominal (Monte Carlo) results were generally approximately one order of magnitude less than the bounding estimates. This result supports the statement that the bounding value used in the exposure assessment in the EIS is an upper bound estimate.

The ILCR for the nominal and bounding estimates are provided in Table K.7.2.2. These risk estimates reflected the changes in the source and transport assumptions only. They do not incorporate the Monte Carlo estimates of variation in exposure parameters. The changes in source and transport assumptions for the nominal case decreased the ILCR by one to two orders of magnitude for most of the exposure scenario - future time combinations considered (Table K.7.2.2). These risk probability differences decreased the total accumulative cancer risk incidence by approximately an order of magnitude over the 10,000-year period of analysis. Although using less conservative assumptions for the bounding case altered the distribution of the risk through time for some alternatives, especially No Action (see Section K.6.5); for Ex Situ Intermediate Separation, the two cases followed the same general pattern, with the nominal case covering a smaller area, consistent with its lower accumulative risk (Figure K.7.2.1). The spatial pattern of risk onsite was generally similar in the two cases, as illustrated for the residential farmer scenario in Figures K.7.2.2, K.7.2.3, and K.7.2.4. At 2,500 years, the nominal case risk would be confined to the 200 East Area (Figure K.7.2.2), but at 5,000 and 10,000 years, the spatial distributions of the bounding and nominal cases were similar. The bounding case risk at 5,000 years had a higher risk area between 200 West and 200 East Areas, and occupied more area to the north and west (Figure K.7.2.3), but at 10,000 years, the areas for the two cases were essentially identical (Figure K.7.2.4).

K.7.3 ACCIDENTAL RELEASE SCENARIOS

A Monte Carlo uncertainty and sensitivity analysis was also conducted on the parameters used to compute LCFs or the probability of contracting cancer as a result of an accidental air releases associated with the remedial actions. The sensitivity analysis indicated that the parameters which contribute the most to the uncertainty in the LCF for the accidental release scenarios were, as measured by rank correlation: the ULD, the atmospheric dispersion coefficient (Chi/Q), the release volume, the inhalation rate, and the LCF conversion factor. Table K.7.2.1 compares the mean value of the LCF distributions for the four accidental release scenarios with the bounding estimate derived using upper-bound exposure factors. The results indicated that the LCFs predicted using the upper-bound values were in all cases one to two orders of magnitude greater than the mean of the Monte Carlo result. These results demonstrated that the predicted LCF estimates were upper bound estimates of cancer probability and/or fatality rates. The true probability of contracting cancer or fatalities resulting from cancer could actually be much less than the predicted value.

Figure K.7.2.1 Bounding and Nominal Case for the Ex Situ Intermediate Separations Alternative Post Remediation Risk to the Residential Farmer

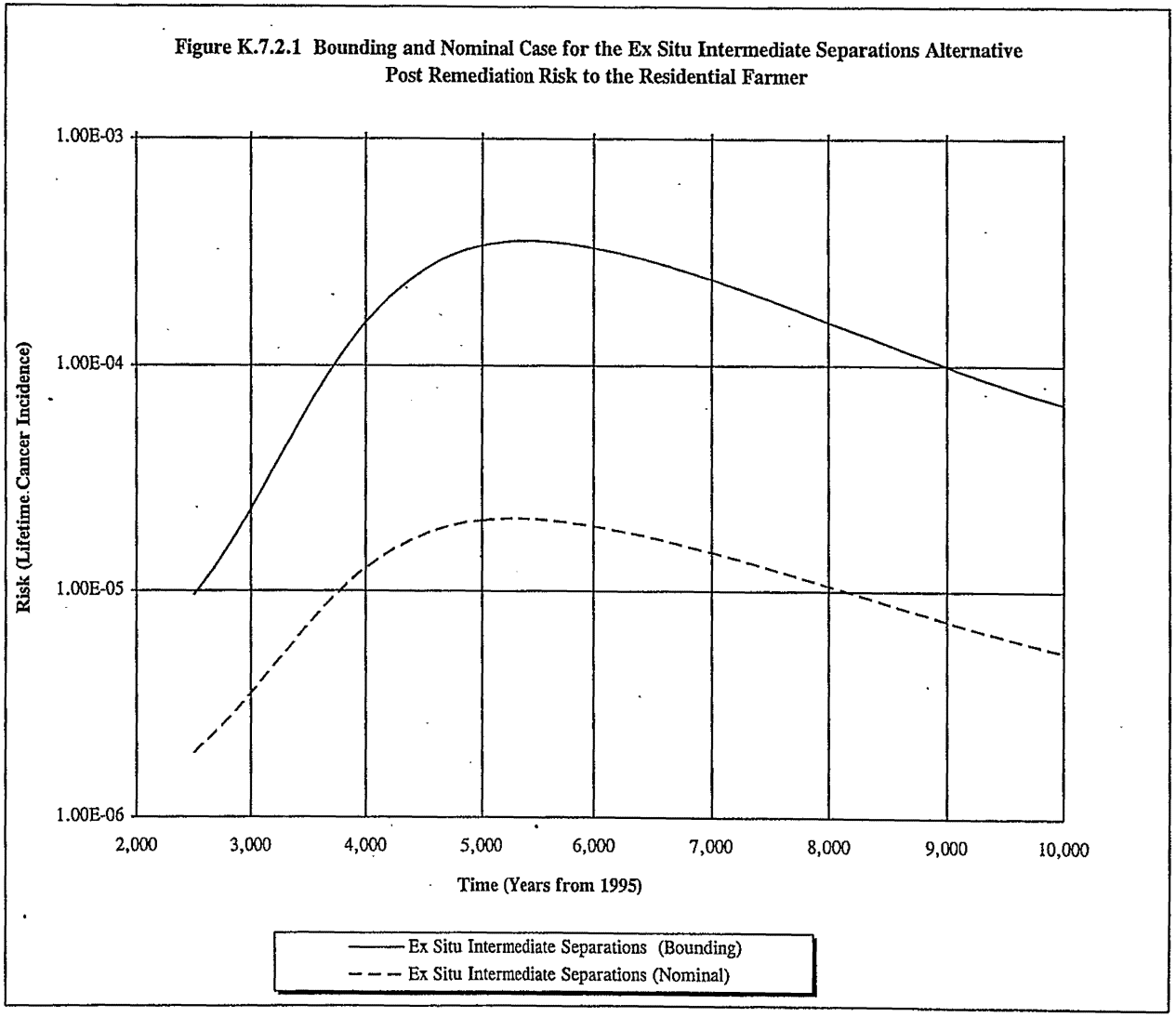


Figure K.7.2.2 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present

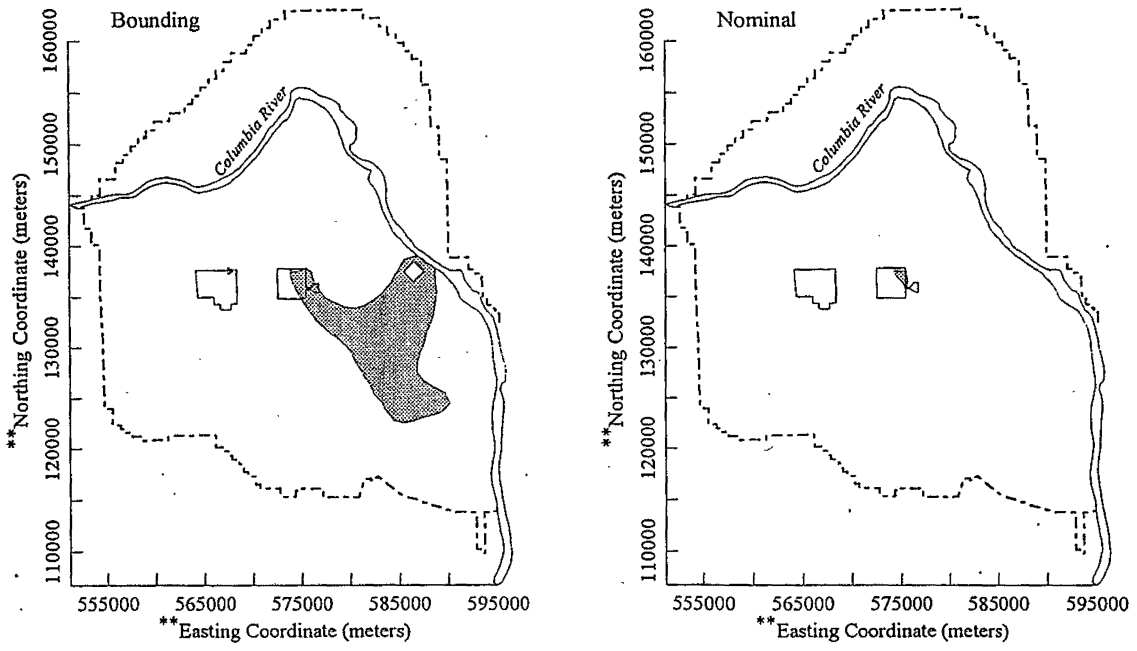


Figure K.7.2.3 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present

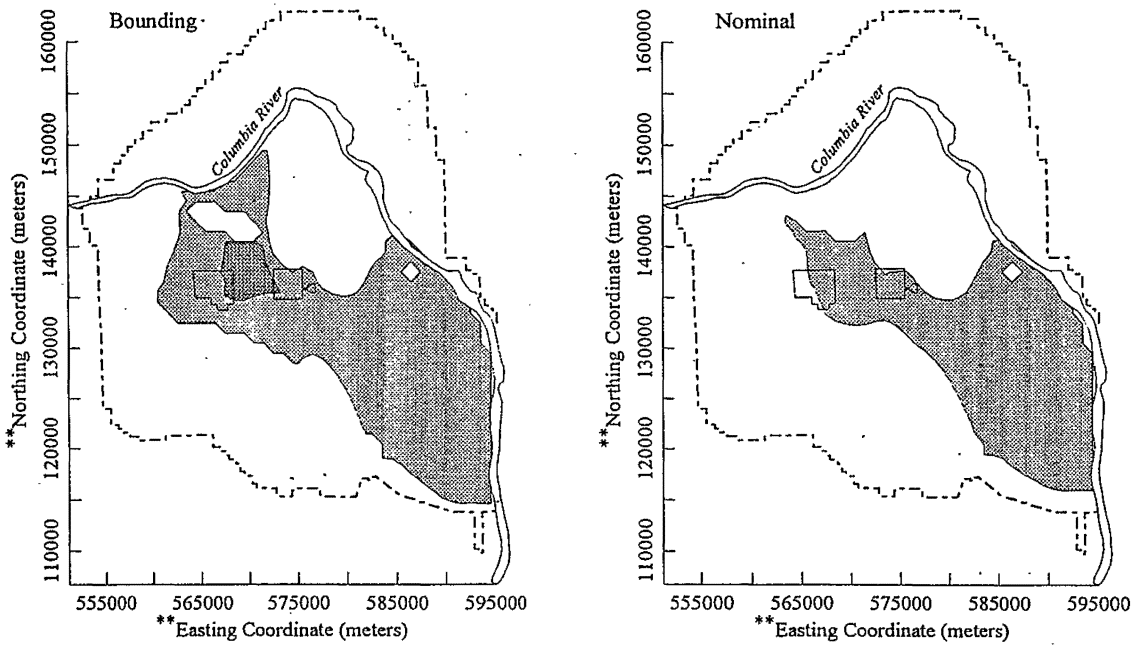


Figure K.7.2.4 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present

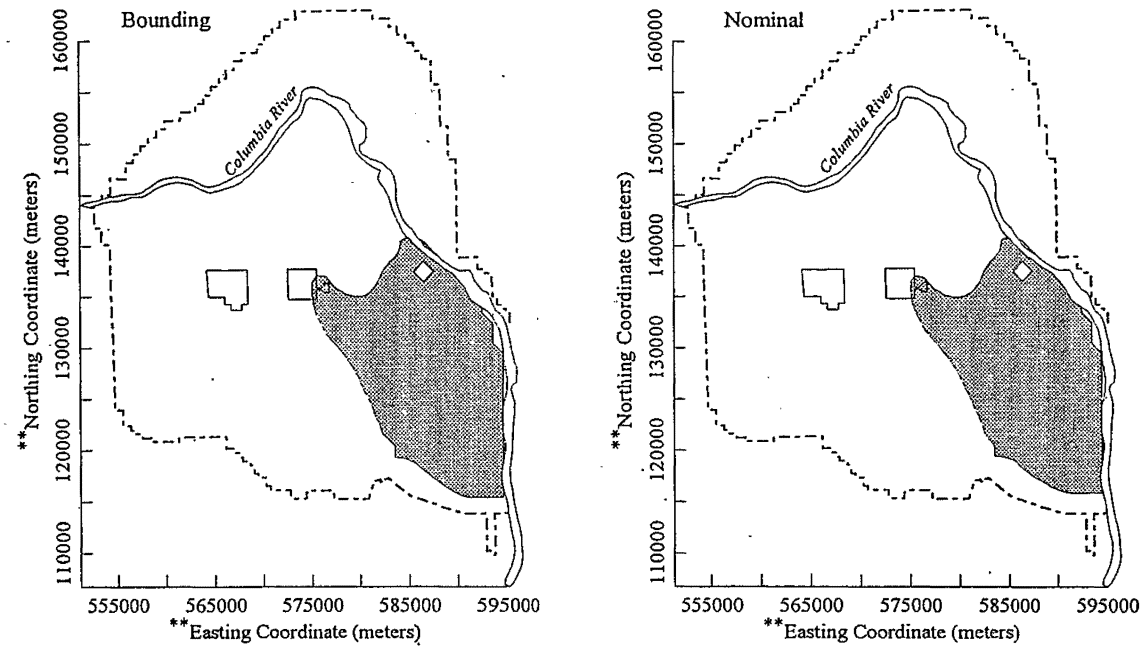


Table K.7.2.1 Summary of the Bounding and Nominal Exposure Parameters of Ex Situ Intermediate Separations Alternative

Scenario		Fish Ingestion[1]		Groundwater Ingestion[2]		Groundwater Inhalation[3]		Dose[4]		Latent Cancer Fatalities	
		Bounding[5]	Nominal[6]	Bounding	Nominal	Bounding	Nominal	Bounding	Nominal	Bounding	Nominal
Post Remediation	Native American	2.8E+04	1.4E+03	7.7E+04	7.0E+03	3.8E+04	1.4E+04	N/A	N/A	N/A	N/A
	Residential Farmer	N/A	N/A	2.2E+04	3.1E+03	N/A	N/A	N/A	N/A	N/A	N/A
	Industrial Worker	N/A	N/A	N/A	N/A	1.0E+05	3.3E+04	N/A	N/A	N/A	N/A
Post Remediation Intruder		N/A	N/A	N/A	N/A	N/A	N/A	1.2E+04	3.4E+03	N/A	N/A
Remediation Accident	Worker (MEI)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.9	1
	Worker (pop)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	376	2
	Public (MEI)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.035	0.002
	Public (pop)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	79	3

Notes:
[1] The values shown are for the summary intake factor (SIF) in units of kilograms.
[2] The values represent the SIF in units of liters.
[3] The values represent the SIF in units of cubic meters.
[4] Units are in mrem per year per curie exhumed.
[5] The bounding value corresponds to the "fixed-point" estimate calculated using default exposure parameters.
[6] The nominal value corresponds to the mean of the Monte Carlo distribution for the indicated parameter.
[8] Units are persons.
NA = Not applicable.
MEI = Maximally-exposed individual
Pop = Population

Table K.7.2.2 Bounding and Nominal Point Maximum and Total Accumulative Incremental Lifetime Cancer Incident for Ex Situ Intermediate Separations Alternative

Scenario	Years from 1995	Point Estimate ILCR		Total Accumulative ILCR	
		Bounding	Nominal	Bounding	Nominal
Native American	2,500	2.29E-04	2.57E-05	113	21
	5,000	1.05E-02	7.08E-04		
	10,000	9.12E-04	6.17E-04		
Residential Farmer	2,500	9.55E-06	1.91E-06	12	2
	5,000	3.39E-04	2.04E-05		
	10,000	6.76E-5	3.98E-5		
Industrial Worker	2,500	3.02E-06	7.24E-08	18	0
	5,000	1.02E-04	2.57E-06		
	10,000	7.41E-06	6.17E-06		
Recreational Shoreline	2,500	2.69E-07	1.15E-08	0	0
	5,000	9.55E-06	2.63E-07		
	10,000	7.76E-07	6.03E-07		

K.7.4 EFFECT OF ASSUMPTIONS ABOUT GROUNDWATER FLOW AND DIRECTION

As described in Section K.4.2.1, Future Groundwater Flow Direction, the groundwater modeling and risk assessment in the EIS assumed groundwater levels equivalent to those recorded in December 1979. The appropriateness of these data as a basis for impact analysis was tested quantitatively by running the model and calculating consequent risks for the Ex Situ Intermediate Separations Alternative using the same assumptions as in the bounding case analysis except that there was no water inflow from site waste water disposal to the vadose zone. This scenario was called the no mound case.

The effects of changing the assumptions for the Ex Situ Intermediate Separations alternative are illustrated for the residential farmer scenario in Figures K.7.4.1 through K.7.4.3. These changes eliminated the future risk north and west of the 200 Areas, consistent with the similar changes in groundwater flow, described in Section K.4.2.1 and Volume Four, Appendix F. However, the total risk increased in the no mound case (Table K.7.4.1). This effect was most pronounced at 5,000 years, when the risk for the bounding case was spread over a long southeast to northwest diagonal across the site, with a higher risk area between 200 West and East Areas (Figure K.7.4.2). The no mound case risk at 5,000 years was confined to a band running east from the Central Plateau, and most of the risk above 1.0E-06 was within the higher isopleth, above 1.0E-04 (Figure K.7.4.2, Table K.7.4.1). At 10,000 years, the areas of risk were comparable in the two cases, although the no mound risk occupied a smaller area with a higher risk level than the bounding case (Figure K.7.4.3, Table K.7.4.1). The total estimated cancer incidence over the 10,000 year period of interest was approximately four times higher in the no mound case than in the case used in the EIS (Table K.7.4.1).

The predicted flow field for this scenario tended to have a more pronounced west to east flow direction with similar gradient magnitude, compared to the December 1979 flow field on which the impact assessments were based. This resulted in a smaller groundwater contaminant plume. Figures K.7.4.1 through K.7.4.3 illustrate the risk that would be associated with the bounding case and no mound case.

Table K.7.4.1 Areas of Risk Contours and Total Concern Incidence, Bounding and No Mound Cases

Time Intervals	Risk Contour Area in Square Kilometers (km^2)					
	2,500 to 5,000 Years		5,000 to 10,000 Years		>10,000 Years	
Risk Contour Interval	Bounding	No Mound	Bounding	No Mound	Bounding	No Mound
5.0E-03>R>1.0E-03	-	-	-	12	-	-
1.0E-03>R>1.0E-04	-	-	30	219	-	52
1.0E-04>R>1.0E-05	-	-	364	61	254	171
1.0E-05>R>1.0E-06	123	26	116	30	62	30
1.0E-06>R>1.0E-07	232	185	154	29	30	21
1.0E-07>R>0.0E+00	430	574	121	434	439	511
Total Area, km^2	785	785	785	785	785	785
Total Risk [a]	0.13	0.04	12.02	50.66	N/C [b]	N/C

Notes:
[a] Total cancer incidence.
[b] N/C = Not calculated.

Figure K.7.4.1 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 2,500 Years from Present

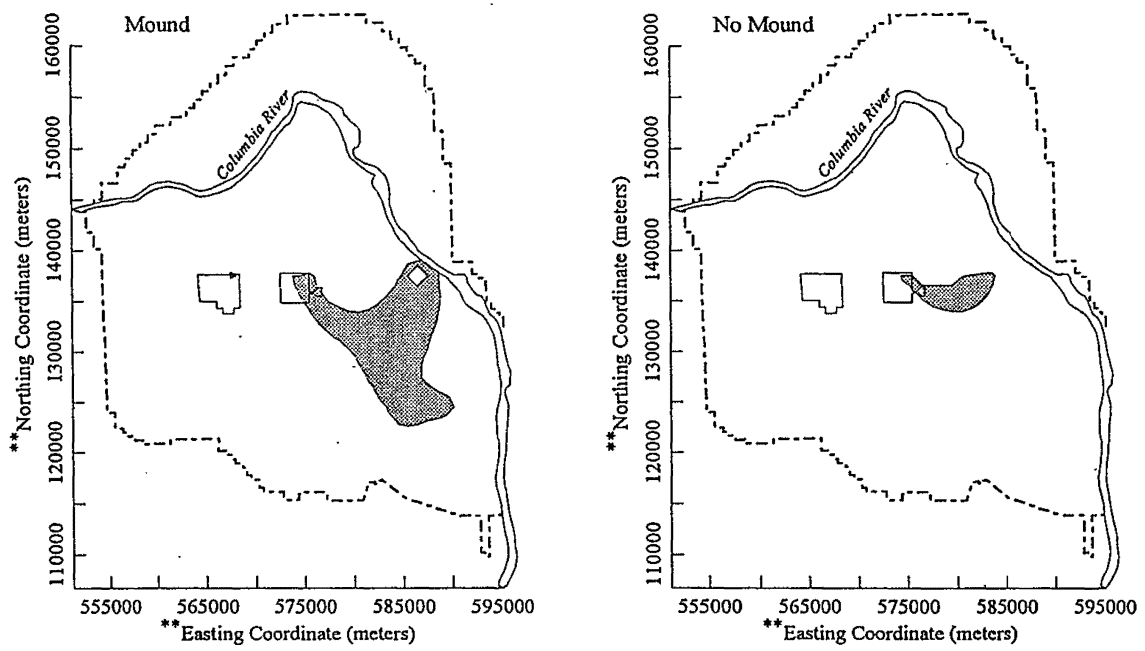


Figure K.7.4.2 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 5,000 Years from Present

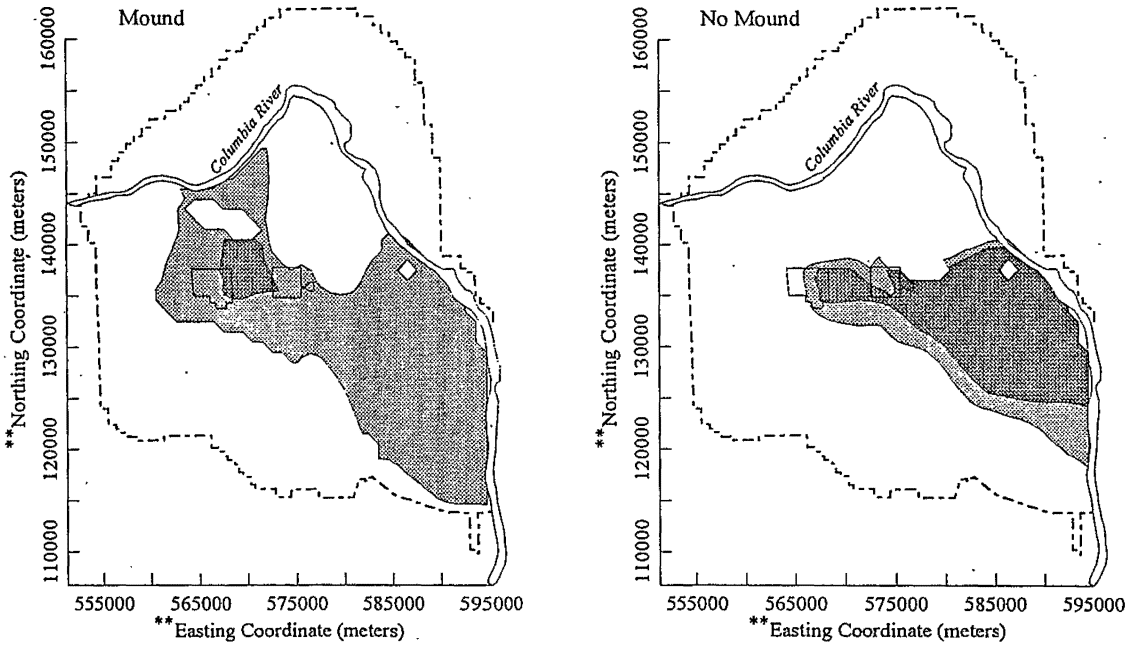
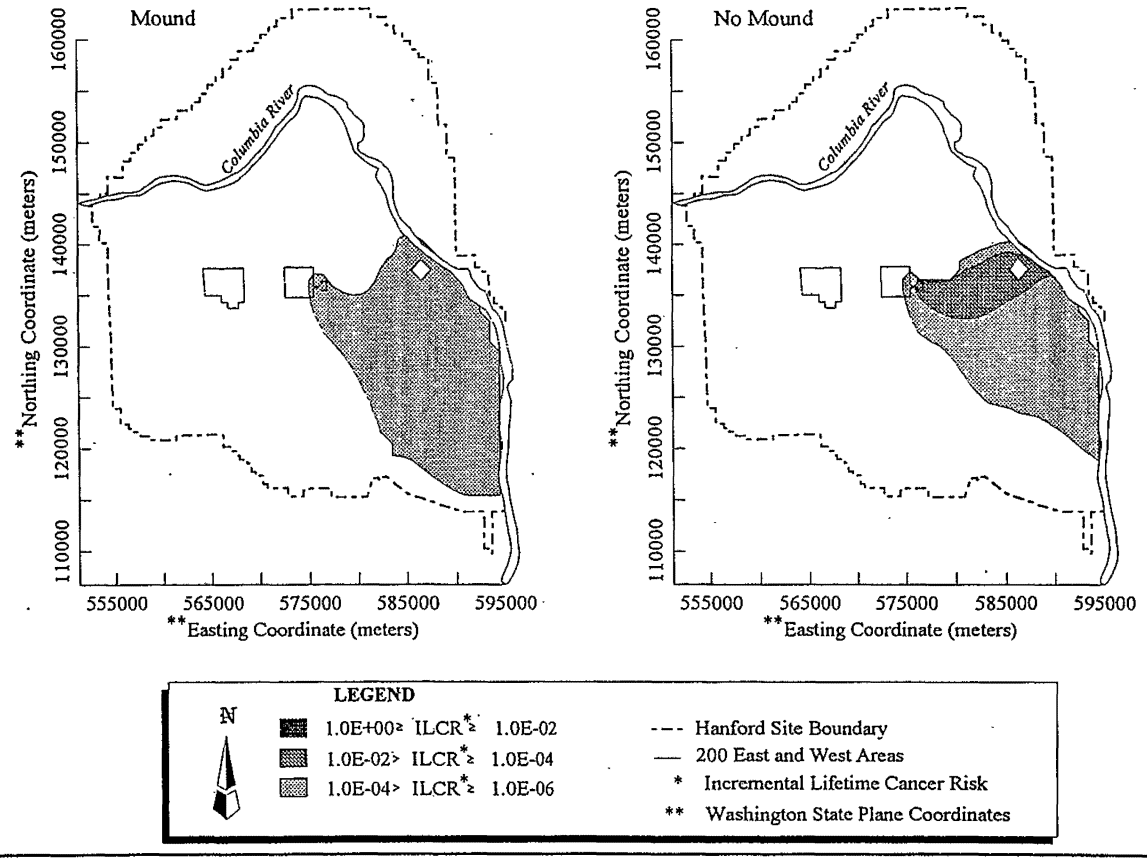


Figure K.7.4.3 Ex Situ Intermediate Separations Alternative, Residential Farmer Scenario, Post Remediation Risk from Tank Residuals and LAW Vaults at 10,000 Years from Present



Generally, a smaller contaminant plume would translate to higher contaminant concentrations and greater risk; however, the small plume would translate into few people being exposed. This effect would be partially offset by the longer vadose zone travel time and contaminant dispersion within the vadose zone.

K.8.0 ECOLOGICAL RISK UNCERTAINTY

This section provides a qualitative discussion of the uncertainties in the ERA. The ERA for this EIS used a screening level methodology to estimate potential radiological and chemical hazards to a suite of representative terrestrial receptors: the Great Basin pocket mouse, coyote, mule deer, red-tailed hawk, and loggerhead shrike (Volume Three, Section D.6). Pathways considered for the No Action alternative were food and water ingestion (all receptors except the mouse, which was assumed to obtain all water from metabolic sources), incidental soil ingestion (mouse and mule deer, coincident with consumption of vegetation), inhalation of routine releases (all), and direct external exposure (mouse, while in a burrow). Potential hazards to aquatic organisms were evaluated using the CRITRII program developed at the Pacific Northwest National Laboratory.

K.8.1 SOURCE TERMS

The source terms used for the ERA were the same as those used for the human health risk assessment. For the No Action alternative, the source terms were the inventory in the tanks for direct contact and food chain uptake, routine releases for air inhalation, and groundwater reaching the Columbia River in the future for water ingestion. Uncertainties in the source terms are described in Section K.3.
The estimated ecological risks were directly proportional to the source contaminant concentrations, and uncertainty about these terms was considered relatively high. Therefore, the source terms were considered likely major contributors to the uncertainty in the ecological risk estimates. However, for the pathways involving direct exposure to stored wastes, radionuclide concentrations would have to have been overestimated by a factor of at least 10,000 for the "true" radiation doses to approach the 0.1 rad/day benchmark recommended by International Atomic Energy Agency (IAEA1992) for protection of terrestrial organisms, since most of the estimated doses were greater than 1,000 rad/day (Volume Three, Table D.6.4.1). Chemical concentrations would have to have been overestimated by a factor of 10 to 1,000 for the true HI to approach the benchmark value of 1.0, since most of the estimated HIs were between 10 and 1,000. If the inventories used for the existing risk estimates were underestimates, the corresponding true risks would be even greater than stated. Therefore, although the source terms were probably important contributors to the uncertainty in the absolute values of the risk estimates, it is not likely that better or more data would alter the conclusion that direct contact with the waste, either externally or through food chain uptake, would be very hazardous to ecological receptors.

Similar but converse arguments would apply to the estimates of inhalation and groundwater ingestion pathway risks to ecological receptors under the No Action alternative. Estimated radiation doses from these two pathways were very low compared with the two benchmarks used [0.1 rad/day for terrestrial organisms and 1.0 rad/day for aquatic organisms (IAEA 1992, NCRP 1991)] (Volume Three, Tables D.6.4.2, D.6.4.3, and D.6.4.6). The true radionuclide concentrations in air and water would have to

be higher than those estimated by at least a factor of 10,000 for the maximum estimated doses to approach the lower of the two benchmarks of concern (0.1 rad/day). It is therefore unlikely that better estimates would alter the conclusion in the EIS that inhalation and groundwater ingestion would not be important sources of ecological risk under the No Action alternative. It is possible that more refined estimates of maximum future chemical concentrations in groundwater, assuming those estimates were 10-fold higher than the existing ones, could indicate potential chemical hazards to wildlife (Volume Three, Table D.6.4.5). This discussion would apply also to the estimated radiation doses resulting from inhalation of routine releases for the remediation alternatives. The true release terms would have to be higher than the existing estimates by several orders of magnitude for the estimated doses to approach the 0.1 rad/day benchmark of concern (Volume Three, Tables D.6.4.8 trough D.4.6.9). The exceptions would be the Ex Situ Intermediate Separation/Phased Implementation and the Ex Situ No Separation alternatives. The maximum radiation doses estimated for these two alternatives would exceed the 0.1 rad/day benchmark using the existing release estimates, and the real values would have to be 10- to 100-fold lower for the maximum radiation doses to fall below the level of concern. However, the minimum radiation doses for these two alternatives were approximately 100,000-fold lower than the maximum, supporting the claim that the existing dose values would be upper bound estimates.

K.8.2 ORGANISM VARIABLES

A number of species-specific variables contributed to the uncertainty in the ecological risk estimates: food, water, and soil ingestion rates; inhalation rates; body weights; home ranges; and the effective radius for absorption of energy from radioactive decay. Risk estimates for any given pathway are directly proportional to the associated contaminant intake rate. For example, a 10-fold difference in a food ingestion rate would produce a 10-fold difference in the estimated radiation dose or chemical HI. Therefore, the risk estimates would be expected to be sensitive to errors in the intake rates. However, as discussed in Section K.8.1, most of the risk estimates would need to be wrong by several orders of magnitude for the high values to fall below levels of concern or for the low values to exceed them. Errors of this size were considered unlikely for food ingestion rates, which were based on direct measures of various types (see sources for Volume Three, Table D.6.2.1). The exception would be the food ingestion rate for the loggerhead shrike, which was estimated from body weight using an empirical equation (Volume Three, Table D.6.2.1). Water and soil ingestion rates and inhalation rates were all estimated from body weight (water ingestion and inhalation) or dry matter intake (soil ingestion). Potential errors in these variables were likely greater than those for food ingestion, and the resulting risk estimates for the water and soil ingestion and the inhalation pathways could have a greater level of uncertainty than those for food ingestion. However, the food ingestion pathway has an additional source of uncertainty, biological transfer factors in the food chain (discussed in the following paragraphs), which the other pathways do not share.

Risk estimates for any given pathway would typically be inversely proportional to body weight, since body weight appears in the denominator of the equations for estimating intake of radionuclides or chemicals (Volume Three, Appendix D). However, as noted above, water ingestion rates and inhalation rates were estimated from empirical equations that are a function of body weight. This

causes weight to appear in both the numerator and denominator of the intake equations, reducing its overall effect on the risk estimate. For example, a simple equation for the intake of a chemical by water ingestion is:

1) $$I_i = [(C_i)(IR)(FI)]/(BW)]$$

Where:

I_i = Intake rate of the i_{th} contaminant, mg kg^{-1} day^{-1}
C_i = Contaminant concentration in water, mg L^{-1}
IR = Ingestion rate of water, L day^{-1}
BW = Body weight, kg
FI = Fraction ingested from contaminated source, unitless

Here, the intake rate of a contaminant in water would be inversely proportional to the body weight, if the water ingestion rate remained constant. However, larger animals generally drink more water than smaller animals (on a per organism basis), so that as the denominator, body weight, increases, IR in the numerator also increases. In the TWRS EIS, this was explicitly the case, because IR was estimated from body weight using empirical equations. For example, the equation used to estimate water ingestion by the coyote and mule deer is:

2) $$IR = (0.099)(BW)^{0.9}$$ (Equation 3-17, EPA 1993)

Where:

IR = Ingestion rate of water, L day^{-1}
BW = Body weight, kg

The equation used to estimate inhalation by the mouse, coyote, and mule deer is:

3) $$IR = (0.5458)(BW)^{0.8}$$ (Equation 3-20, EPA 1993)

Where:

IR = Inhalation rate, m^3 day^{-1}
BW = Body weight, kg

The overall effect of using these equations is to reduce the potential effect of body weight variability on the water ingestion and inhalation risk estimates and on the uncertainty in the estimates. In addition, in parallel with the previous discussions of source terms and intake rates, the body weight values would need to be wrong by orders of magnitude for the high risk values to fall below levels of concern or for the low values to exceed them. Errors of this size were considered unlikely, because the body weights were based on reported measured values of real organisms, and the body weights of adult mammals and birds do not vary by orders of magnitude within species.

Risk estimates in this ERA were also inversely proportional to the estimated home range, except that home ranges equal to or less than 100 hectares (ha) (250 acres [ac]), the unit cell size used for the risk assessment (see Volume Three, Appendix D), all have the same effect on the risk estimate. That is, FI,

the fraction of exposure to a contaminated source (see Equation 1 above), was set equal to the ratio of the cell size and the home range. For example, the coyote home range of 300 ha (750 ac) (Volume Three, Table D.6.2.1) results in an FI of (100/302) equals 0.33. Above a home range of 100 ha (250 ac), exposure would be directly proportional to home range size. Below this, all species have the limiting FI of 1.0. For example, the mouse and loggerhead shrike have home ranges of 0.09 and 10 ha (0.22 and 25 ac), respectively (Volume Three, Appendix D), but both have an FI of 1.0. The consequence is that potential variability or errors in the estimated home ranges would have different effects on different species' risks. A 1,000-fold error in the mouse home range (i.e., the real value is 90 ha [220 ac]) would not affect the mouse risk estimates, because the FI would still equal 1.0. However, any error or variability in the home ranges for the coyote, mule deer, or hawk, with estimated home ranges of 300, 1,200, and 222 ha, (750, 3,000 and 540 ac) respectively, would have a proportional effect on the risk estimates. Errors of 10-fold in estimates of home range would not be unlikely, given that home range is defined as an area in which an animal sleeps and/or breeds and might not be the same as the area over which the animal forages for food. However, if the estimated home ranges were too low, more accurate (higher) values would decrease the risk, assuming that the resulting FI fell below the limiting value of 1.0.

If the home ranges used were too high, more accurate values would increase the estimated risk only for the coyote, mule deer, or hawk (which have home ranges greater than 100 ha [250 ac]). The worst case increase would be about 10-fold for the deer, with a home range of 1,200 ha (3,000 ac). Decreasing this value to 100 ha (250 ac) would increase the deer FI to 1.0 and increase estimated risks by a factor of 12 (1,200/100). This would affect conclusions about risk to deer only marginally. For example, the HI for direct contact with the waste in Cell 1WSS is 0.7, which is close to but not above the 1.0 benchmark of concern. The HI 0.7 multiplied by the estimated rise 12 is 8.4, which is above the benchmark. However, direct contact with the waste was already characterized as very hazardous to deer, and this conclusion would be unchanged. Therefore, although home ranges are not known with high confidence, uncertainty or variation in them would be unlikely to affect the conclusions of the ERA.

The effective energy absorbed from radionuclide decay has a direct proportional effect on the estimated radiation dose. This energy in turn depends on the effective radius assumed for the organism. The smaller the radius, the less energy is absorbed, although this varies across radionuclides due to their different physicochemical characteristics and the relative importance of alpha, beta, and gamma decay. The effective radii assumed for the organisms used in this ERA ranged from 1.4 cm (0.55 in.) (plants) to 30 cm (12 in.) (coyote and deer). An examination of Table D.6.3.7 shows that effective absorbed energies vary by approximately 10-fold across this range, with a number of isotopes showing no difference. Therefore, the effect of the assumed radius on the radiation estimates would be at most 10-fold if the entire dose were due to isotopes with this range of variation in effective absorbed energy. Such differences would not affect the primary conclusions of the ERA.

K.8.3 BIOLOGICAL TRANSFER FACTORS, HALF-LIVES, AND RETENTION FACTORS

The ecological risk estimates for food ingestion in the EIS were directly proportional to the soil-to-plant transfer factors (which determine how much of a contaminant moves into the food chain), the biological half-lives or turnover times of contaminants within organisms, and the fraction of the contaminant retained in the organism at each step of the food chain. Soil-to-plant transfer factors are likely to vary depending on local soil conditions and different plant species. This ERA used published default values that may or may not be applicable to the specific types and locations of plants consumed by the pocket mouse or mule deer. Therefore, these factors therefore probably contribute substantially to the uncertainty in the food ingestion risk estimates. However, as discussed for the source terms, the error or variability would need to be several orders of magnitude before it would affect the conclusions of the ERA. A similar concern exists for biological half-lives and retention factors for chemicals and radionuclides, although again, these would have to be wrong by several orders of magnitude before they by themselves would affect the conclusions of the ERA. The biological half-lives for radionuclides include the radiological half-lives in their calculation. These latter values are known with very high confidence and would not contribute significantly to the uncertainty in the risk estimates.

K.8.4 NO OBSERVED ADVERSE EFFECT LEVELS

The conclusions about potential effects of radiation on ecological receptors relied on single benchmarks of 0.1 rad/day for terrestrial organisms and 1.0 rad/day for aquatic organisms (Volume Three, Appendix D). These benchmarks are independent of specific radionuclides, reflect intense study, and have been widely reviewed. It is therefore unlikely that they contribute importantly to uncertainty in the conclusions of the ERA. However, the estimates of risks due to hazardous chemical exposure are based on the ratio of the estimated intake to the No Observed Adverse Effect Level (NOAEL); see (Volume Three, Appendix D). These values were derived largely from laboratory studies of species other than those of interest in this EIS. There are potential uncertainties in extrapolating from the species used in the laboratory studies to those in the EIS, from the dose ranges used in the studies to those estimated in the field, and from the general conditions in the laboratory to those in the field. All these factors may contribute significantly to the uncertainty in the HI estimates. The HI is inversely proportional to the NOAEL. An examination of Tables D.6.4.4 and D.6.4.5 suggests that errors of 10-to 100-fold in the NOAEL could reduce the high HI values in Table D.6.4.4, for direct contact with the stored waste, to low values below the 1.0 benchmark, if the real NOAELs were higher than those used in the ERA. Similar errors in the opposite direction could increase the low HI values in Table D.6.4.5, for future consumption of groundwater reaching the Columbia River, to values above the 1.0 benchmark. It is therefore possible that uncertainty in the NOAELs for hazardous chemicals could affect the ERA conclusions about chemical hazards associated with direct contact with stored waste or future consumption of groundwater at the maximum concentrations reaching the Columbia River. This would not affect conclusions about the presence or absence of radiological hazards or general conclusions about the need to prevent contact with the tank wastes by ecological receptors.

K.8.5 ECOLOGICAL RISK ASSESSMENT UNCERTAINTY CONCLUSIONS

Overall, the parameters of the equations used to estimate ecological risks would need to vary or be in error by several orders of magnitude to affect the conclusions of the ERA by themselves. Simultaneous

variability in multiple parameters in the same direction could do so. For example, increasing IR and FI in Equation 1 above by 10-fold each would increase the estimated contaminant intake by a factor of 100. Such simultaneous variability is possible and would contribute to the overall uncertainty in the risk estimates. Nonetheless, because the ecological risk estimates in this EIS are so different for the various scenarios considered; very high for direct contact with stored wastes and very low for routine releases associated with either the No Action or various remedial alternatives, more detailed analysis would not be considered likely to alter those distinctions. Conversely, more detailed analysis would be unlikely to permit clear distinctions among the remedial alternatives based on potential radiological risks of routine releases, because these latter values are both low and similar to each other. The primary distinction in ecological risks thus remains between the No Action (assuming direct contact with the stored wastes at some future point) and remediation alternatives collectively.

K.9.0 RESULTS

Uncertainty in the conclusions of the TWRS EIS is a consequence of uncertainty in two major areas: the descriptions of the alternatives, with their associated assumptions about tank waste inventories, composition, and remediation technologies; and the consequences analyses, which included assumptions about waste source and release terms, future land uses, environmental transport parameters, and relationships between exposure and risk. The purpose of Appendix K is to discuss the major sources of uncertainty in each of these areas. In addition, a less conservative human health risk analysis is presented to illustrate the implications of making fewer conservative assumptions than were made for the bounding case analyses in the EIS.

Uncertainty in risk analysis is a consequence of two factors: lack of data and natural variability. Lack of data is reflected in our limited knowledge either about the value of constants (e.g., distribution coefficients), or about the statistical parameters (e.g., distribution shape, mean, variance) of things that are inherently variable (e.g., inhalation rates or body weights). Uncertainty due to lack of data can be reduced in principle by more accurate measurements. Uncertainty due to natural variability cannot be reduced by more data, but can be better estimated by acquiring data to characterize statistical distributions of measured variables and by using computer programs to simulate the effect of such variability in the components of equations on calculated values, for example, risk estimates. These combined efforts can reduce systematic uncertainty in the EIS analyses and provide a more thorough understanding of the effects of the remaining uncertainty on the conclusions in the EIS.

K.9.1 UNCERTAINTIES IN THE ALTERNATIVES

There were many uncertainties associated with the alternatives for remediating the tank waste. These uncertainties involved the types of waste contained in the tanks, the effectiveness of the proposed retrieval techniques, waste separations, waste immobilization, and the costs of implementing the alternatives. These uncertainties existed because some of the technologies that may be implemented would be first-of-a-kind technologies, would not have previously been applied to the tank waste, or would not have been applied on a scale as large as would be required for the tank waste, and because only conceptual designs would be available for the alternatives.

K.9.1.1 Major Assumptions

The impact analyses in the EIS required assumptions be made regarding the technologies used for each of the alternatives. These assumptions were based on either the best information available, applications of a similar technology, or engineering judgement. By definition, when an assumption was made, there was some uncertainty associated that was expressed as a reasonable expected range for the assumed value. This section identifies the major assumptions used for the alternatives, describes uncertainties associated with the cost estimates, and presents the results of an uncertainty analysis for the Ex Situ Intermediate Separations alternative.

K.9.1.2 Continued Management and In Situ Alternatives

The following assumptions were made for the Long-Term Management and in situ alternatives. It was assumed that there would be no leaks from the SSTs or DSTs during the administrative control period for the No Action, Long-Term Management, and In Situ Fill and Cap alternatives. The SSTs and DSTs were assumed to maintain their structural integrity throughout the administrative control period for the No Action and Long-Term Management alternatives. The In Situ Vitrification, In Situ Fill and Cap, and the in situ portion of the Ex Situ/In Situ Combination 1 and 2 alternatives were assumed to require additional characterization data to evaluate the acceptability of in-place disposal and to address Resource Conservation and Recovery Act (RCRA) land disposal requirements. The in situ vitrification system was assumed to be capable of vitrifying each tank to the required depth, with no impact of variation in waste composition and inventory on the ability to produce an acceptable waste form. The concentrated liquid waste contained in the DSTs was assumed to be acceptable for gravel filling under the In Situ Fill and Cap alternative.

K.9.1.3 Ex Situ Alternatives

The impact analysis for ex situ alternatives required assumptions about waste retrieval efficiencies, waste loading and blending factors, separations efficiencies, canister sizes and types, and releases to the soil during retrieval. The efficiency of waste retrieval was assumed to be 99 percent. The volume of HLW produced was calculated using the waste inventory, conservative assumptions for waste loading and blending factors, and separations efficiencies. Assumptions about volumes released to the soil during retrieval were made, which directly affected the predictions of the risk consequences resulting from such releases.

K.9.1.4 Schedule

Schedules for construction, operation, and closure were developed for each of the alternatives within the constraints of the Tri-Party Agreement. Schedule constraints would affect the size of the treatment facilities required to process the waste. Following design and construction of a waste treatment facility, the major schedule uncertainty would be the operating duration. Each of the ex situ alternatives was developed using 60 percent overall operating efficiency except for Phase 2 of Phased Implementation, which used 70 percent overall operating efficiency. Operating at higher efficiencies would reduce the operating duration and lower operating efficiencies would increase the duration.

For the alternatives with multiple components, such as retrieval, pretreatment, HLW treatment, and LAW treatment, the overall operating schedule would depend on the efficiency of each component. Uncertainties in the operating schedule would be expected to result in longer operating durations. The operating duration for the ex situ alternatives would be sensitive to the rate at which waste could be retrieved from the SSTs. A low SST sludge retrieval rate could increase the operating duration by 50 percent.

K.9.1.5 Staffing

Staffing estimates were developed for each alternative in support of risk, accident, and socioeconomic impact analysis. These estimates were developed using conservative assumptions for both construction and operating staffing levels. The major uncertainty was associated with the operating schedule. Staffing requirements would be affected by operating efficiencies because efficiency changes would increase or decrease the operating duration and the overall staffing requirements.

K.9.1.6 Resources

The resources required to construct and operate waste treatment facilities were estimated for each alternative using a consistent methodology and common assumptions. The ex situ alternatives and the In Situ Vitrification alternative would have the largest uncertainty for estimated resources. The major uncertainties associated with the estimated resource requirements for the ex situ alternatives included the size and type of facilities required and the volume of LAW and HLW produced.

K.9.1.7 Cost

Cost uncertainties for the various tank waste treatment alternatives were evaluated using a range estimating model. The Ex Situ No Separations (Vitrification) alternative had the largest estimated cost range due to the disposal cost for the large number of HLW packages that would be produced. The In Situ Vitrification alternative had the highest cost range on a percentage basis due to the uncertainties associated with implementing this technology for remediation of the tank waste.

K.9.2 UNCERTAINTIES IN SOURCE AND RELEASE TERMS

Source terms refer to the inventory, which is the total quantity of the hazardous material within the tanks, and to the release term, which is the amount released to environmental media such as air, groundwater, surface water, and soil under normal or accident conditions. Uncertainties associated with source terms included the characteristics and composition of the waste in the tanks and the specific performance capabilities of waste retrieval and processing technologies. Information needed to more thoroughly determine the composition and characteristics of the tank waste currently is being obtained through waste characterization studies. DOE has identified 46 key radionuclides for tracking in development of a "best basis inventory" for Hanford Site tank wastes. These include the radionuclides that dominate the risk estimates in this EIS: C-14, I-129, Np-237, Pa-231, Se-79, Tc-99, and U isotopes. This information will be incorporated into any NEPA analysis of tank farm closure alternatives.

K.9.3 UNCERTAINTIES IN TRANSPORT

Uncertainties in the human health and ecological exposure assessments depend in part on the uncertainties of estimated transport of contaminants from sources through air, soil, groundwater, and surface water to potential receptors. The principal sources of uncertainty of soil and groundwater transport include the physical and chemical mechanisms of contaminant transport through the vadose zone to the groundwater, the rates of infiltration into natural soil and through a protective barrier cap, distribution coefficients (K_d) of contaminants, assumptions about future groundwater flow direction due to assumed decay of groundwater mounds onsite and to climate change, assumptions about future vadose zone thickness due to climate change, assumptions about vadose zone transport in one-dimensional flow and transport simulations, and estimates of releases during retrieval.

The primary sources of uncertainty in estimating surface water transport were associated with the rate of dilution of contaminants in groundwater entering the Columbia River. These sources were the groundwater flow rate and river flow rate, including seasonal and diurnal fluctuations ranging from 2,300 m^3/s (81,000 ft^3/s) to 7,100 m^3/s (250,000 ft^3/s); plus turbulence of river flow, which depends on velocity; irregularities in the stream channel, including bends; and width of the river. All of these factors ultimately would depend on the total flow in the river at the point(s) where contaminated groundwater is discharged.

Estimation of transport through air depends on air dispersion modeling. Various assumptions and other factors can introduce uncertainty to these estimates. These uncertainties can be broadly separated into uncertainty inherent in the models, uncertainty in the data used as model inputs, and uncertainty in interpretation of model outputs. Input assumptions included pollutant release characteristics (form, particle size distribution, emission rate, temperature, flow rate), meteorological conditions (ambient temperature, mixing height, stability, wind speed and direction, atmospheric temperature, wind speed profile), and pollutant transport behavior (dispersion, plume rise, interaction with terrain). Model output interpretation required converting 1-hour average values to 3-, 8-, and 24-hour average values using conversion factors. These factors involved an implied assumption regarding the persistence of the meteorological condition producing the highest 1-hour impact. For example, conservative meteorological conditions that produced the highest 1-hour concentration could be expected to persist for most of a 3-hour period, and to a lesser degree, over an 8- or 24-hour period. The midpoint conversion factor values of 0.9. 0.7, and 0.4, respectively, were considered appropriate for this study.

K.9.4 UNCERTAINTIES IN HUMAN EXPOSURE ASSESSMENT

Uncertainties in the human health exposure assessment were divided into two parts. The first part was associated with the exposure parameters used in the post remediation land use scenarios. The second part was associated with the accidental release scenarios. In both cases, Monte Carlo simulations were used to evaluate the uncertainty in the exposure assessment and to establish the parameters that contributed the most to the uncertainty in the exposure assessment (i.e., sensitivity analysis).

In the Monte Carlo approach, PDFs were used to represent the range of values of a given parameter. The effects of simultaneous variations over these ranges on the exposure assessment then were

examined using a computer software package (Crystal Ball). These computations were repeated a large number of times to produce complete PDF of the output functions. Statistical summaries of the results then were plotted to help interpret the data.

K.9.4.1 Post-Remediation Land-Use Scenarios

The percentiles of the Monte Carlo-based PDFs were computed and compared to the fixed point estimates of the same function. Two important conclusions can be drawn from these results. First, as expected, the fixed point estimates in the exposure assessment generally lie at the high end of the PDF or approximately the 95th percentile. This is expected, because the fixed point estimate is intended to be an upper bound estimate. Second, the mean of the Monte Carlo-based PDF generally was approximately one order of magnitude lower than the fixed point estimate. This result suggests that the exposure estimates in the EIS were higher-than-expected values or best estimates by approximately an order of magnitude.

K.9.4.2 Accidental Release Scenarios

A Monte Carlo uncertainty and sensitivity analysis also was conducted on the parameters used to compute LCFs or the probability of contracting cancer from accidental releases associated with the remedial actions. The sensitivity analysis indicated that the parameters that contributed the most to the uncertainty in the LCF for the accidental release scenarios, as measured by rank correlation, were the ULD, atmospheric dispersion coefficient (Chi/Q), release volume, IR, and LCF conversion factor.

Comparing the mean and percentile estimates of the LCF distributions for the four accidental release scenarios with the fixed point estimates derived using the upper-bound values indicated that the LCFs based on the upper-bound values were in all cases greater than the 100th percentile of the LCF PDF. The means of the LCF PDFs were approximately one order of magnitude lower than the upper-bound fixed point estimates. These results suggest that the LCF estimates in the EIS are upper bound values. The true probability of contracting cancer or fatalities resulting from cancer actually could be much less than the predicted value.

K.9.5 UNCERTAINTIES IN HUMAN HEALTH RISK

The uncertainties associated with the TWRS EIS risk estimates included parameters used in the equations relating exposure to risk and the historical data on worker risks and accidents used in the evaluations of potential accident impacts. To estimate risk, information must be available on dose-response relationships, which would define the biological response from exposure to a contaminant. Although human epidemiological data were used for developing radiological and nonradiological chemical dose-response models, this information also was developed in laboratory tests using animals exposed to relatively high doses. Therefore, uncertainty is inherent in dose-response relationships, including extrapolating from effects in animals at high doses to potential effects in humans who most often are exposed at much lower doses.

Uncertainty associated with the derivation of toxicity values also affects the level of confidence in human health risk estimates. Sources of uncertainty associated with published toxicity values include the following:

- Use of dose-response information from effects observed at high doses to predict effects at low levels expected in the environment;
- Use of data from short-term exposure studies to extrapolate to long-term exposure or vice versa;
- Use of data from animal studies to predict human effects; and
- Use of data from homogeneous animal populations or healthy human populations to predict effects on the general population.

The summation of cancer risk across pathways or for multiple pathways makes the total cancer risk more conservative. This is because each slope factor for each chemical carcinogen is an upper 95th percentile estimate, and such probability distributions are not strictly additive. The risk values calculated for the post-remediation scenario in the TWRS EIS were a conservative bounding estimate. The uncertainty in the risk values for certain receptors increases as the time to the future increases. Less uncertainty was associated with the risk values at 300 years than the risk estimates at 500, 2,500, 5,000, and 10,000 years.

By far the greatest uncertainty in the routine remediation risk was associated with the source data, which were based on the estimated inventory and source terms (i.e., the amount of chemicals and radionuclides released to the environment). Other contributors to the routine risk uncertainty were airborne transport of the released chemicals and radionuclides; accumulation of contaminants in food products; production and distribution of food products; lifestyle and diet of specific individuals; food consumption rates; and dose conversion factors.

The risk estimates for the post-remediation and intruder scenarios were associated with more uncertainty than facility routine operation risk because they involved uncertainties associated with the future land use and intrusion into residual waste, in addition to modeling. Finally, the MEI risk estimates generally involved a greater level of uncertainty than population risk estimates. The greatest uncertainty in calculating the post-remediation intruder risk was associated with the source data. Source terms were based on the estimated inventory and an average tank within the eight aggregated tank farms of the 200 Areas (Volume Two, Appendix A). Additional information regarding the source term would decrease the uncertainty in the risk estimate. The relative uncertainties associated with the dose conversion factors were not as important as the source data, source terms, and exposure pathway parameters.

K.9.5.1 Uncertainties in Ecological Risk

The ERA for this EIS used a screening level methodology to estimate potential radiological and chemical hazards to a suite of representative terrestrial receptors: the Great Basin pocket mouse, coyote, mule deer, red-tailed hawk, and loggerhead shrike. Pathways considered for the No Action alternative were food and water ingestion (all receptors except the mouse, which was assumed to obtain

all water from metabolic sources), incidental soil ingestion (mouse and mule deer, coincident with consumption of vegetation), inhalation of routine releases (all), and direct external exposure (mouse, while in a burrow). Potential hazards to aquatic organisms were evaluated using the CRITRII program developed at the Pacific Northwest National Laboratory.

Overall, the parameters of the equations used to estimate ecological risks would need to vary or be in error by several orders of magnitude to affect the conclusions of the ERA by themselves. Simultaneous variability in multiple parameters in the same direction could do so. For example, increasing both water ingestion rates and the fraction of water obtained from a contaminated source by 10-fold would increase receptors' estimated contaminant intake by a factor of 100. Such simultaneous variability is possible and would contribute to the overall uncertainty in the risk estimates. Nonetheless, because the ecological risk estimates in this EIS were so different for the various scenarios considered (very high for direct contact with stored wastes and very low for routine releases associated with either the No Action or various remedial alternatives) more detailed analysis was not considered likely to alter those distinctions. Conversely, more detailed analysis was unlikely to permit clear distinctions among the remedial alternatives based on potential radiological risks of routine releases, because these latter values were both low and similar to each other. The primary distinction in ecological risks thus remains between the No Action (assuming direct contact with the stored wastes at some future point) and remediation alternatives collectively.

K.9.6 CONCLUSIONS

The scope of the tank waste disposal action and alternatives analyzed in the TWRS EIS was such that a number of components of actions and analyses contributed varying degrees of uncertainty to the assessment of impacts as discussed above. Some of the components were well characterized and the uncertainties were well known and documented. Other components were better characterized as estimates and the uncertainties were not known or were also estimated. However, the major sources of uncertainty were associated with a few major components of the proposed action and alternatives. Following is a brief discussion of those major components of uncertainty and DOE or other actions which would be expected, in time, to reduce the level or range of uncertainty for that component.

K.9.6.1 Engineering

Uncertainties related to engineering included facility, process, and equipment design, and performance. The flowsheets and facility designs for the TWRS alternatives were preconceptual, based on design information and performance criteria that are in the early planning stages and involve considerable engineering judgement. Engineering design uncertainties will be reduced or better defined as investigations are completed, disposal decisions are made, and engineering design proceeds to preliminary and ultimately definitive design. These efforts would include pilot-scale testing and process demonstration on the tank waste before full scale implementation.

K.9.6.2 Waste Inventory

Uncertainties regarding waste inventory relate to the waste type, form, and quantity of tank waste constituents. These uncertainties contributed in turn to the uncertainty of source terms, release rates

and transport estimates (Figure K.1.0.1). The waste inventory data used in developing the alternatives and their associated impacts were derived from model predictions and sample analyses performed to date. DOE has an ongoing waste characterization program in place to better define the quantity, content, form, and characteristics of the tank waste that will ultimately reduce the inventory-related uncertainties. DOE has identified key radionuclides for tracking in developing a "best basis inventory" for Hanford Site tank waste. These include the radionuclides that dominate the risk estimates in this EIS: C-14, I-129, Np-237, Pa-231, Se-79, Tc-99, and U isotopes. This information will be incorporated into any NEPA analysis of tank closure alternatives. As part of this program, DOE is currently developing the HTI program that will provide information on the characteristics of the tank residuals and the capability of retrieval systems to deal with difficult-to-remove SST wastes. This program, which will reduce the uncertainties associated with residual waste, includes demonstrations of capabilities to quantify residual waste volume and technologies for sampling and characterizing the residual waste.

K.9.6.3 Waste Transport

Uncertainties regarding waste transport include source terms (type, quantity, form, composition, concentration, solubility), and release rates for tank residuals and LAW, vadose zone characteristics, groundwater flow characteristics, transport mechanisms, and rates. Recent observations of relatively immobile contaminants at depths of up to 38 m (125 ft) below the tanks are not fully explained with interstitial flow and may indicate there are other transport mechanisms in effect. These observations are currently the focus of a DOE program. The initial phase of the program is to determine if the observations are representative of extensive vadose zone contamination beneath the tanks or if they are related to other phenomena such as borehole cross contamination. DOE is also currently developing criteria and technologies to identify leaks and limit releases during retrieval.

K.9.6.4 Exposure Scenarios

The TWRS EIS has assessed an extensive and well defined suite of potential human exposure scenarios including an array of potential remediation and post remediation receptors. The scenarios included a variety of Hanford land uses (farming, industry, recreation, Native American subsistence), a variety of receptors (resident, worker, farmer, recreational user, intruder) and a variety of pathways. Uncertainties related to exposure scenarios include the degree to which Hanford land or groundwater would be accessible or restricted, the location, timing, and duration of exposures to contaminants, and the density of user populations. DOE has an ongoing program to determine future land uses for the Hanford Site including preparation of a Comprehensive Land Use Plan. These efforts, in combination with those described in Sections K.9.1 through K.9.3, will both reduce the total uncertainty in the TWRS risk analyses and better characterize that which remains.

ATTACHMENT 1

Explanation of Input Distributions Used in the Monte Carlo Methodology

This attachment explains the information sources and rationale used in deriving the input distributions used in the Monte Carlo uncertainty and sensitivity exposure analysis. This attachment is ordered by exposure scenario (e.g., industrial, residential) with input distribution explanations given for the exposure route which resulted in the greatest risk for each particular exposure scenario.

Industrial Exposure Scenario

The industrial exposure scenario is based on worker exposure over a 20-year duration. The scenario involves mainly indoor activities, although outdoor activities (e.g., soil contact) are also included. The air inhalation rate is 20 m^3 per day for a worker and external exposure occurs 8 hours per day. Inhalation of contaminants occurs 250 days per year and external exposure occurs for 146 days per year.

EF (exposure frequency)

Units: days per year
Distribution used: triangular (likeliest 245, maximum 307, minimum 156)
Source: EPA 1989

This input represents the number of days per year that a "typical" worker would spend in the workplace. The likeliest value for EF was established using the rationale that the worker works two weekends per year and takes two weeks' vacation and two weeks' sick leave. The minimum value for EF was established by assuming that the worker is part-time and only at the site approximately 60 percent of the time. The maximum value for EF was based on a person taking two weeks' vacation, two weeks' sick leave, and working all but 15 weekends per year.

ED (exposure duration)

Units: years
Distribution: lognormal (mean 7.3, standard deviation 8.7)
Source: Department of Labor 1992

This input represents the number of years that the individual being modeled will spend at a particular job location within the contaminated area. After considering the information in the EPA's Exposure Factors Handbook (EPA 1989) and after considering various factors that could impact ED, it was determined that the input would be characterized using the data from a study conducted by the Department of Labor completed in 1992. The distribution used for ED is a lognormal distribution based on a mean standard deviation presented by the Department of Labor report. The maximum value is 30 years, which is the upper bound time specified by the report for a worker at any one given job, and which is also the value specified by the EPA.

IR (inhalation rate)

Units: cubic meters per day
Distribution: triangular (likeliest 18.9, maximum 32.0, minimum 6.0)
Source: EPA 1985

This input represents the amount of air that is breathed in during a typical day at work by an adult under an industrial exposure scenario. Layton (Layton 1993) has shown that inhalation rates vary with body weight and the type of activity (i.e., light, medium, or heavy). For this evaluation, a triangular distribution was used based on adults working at light activity levels.

Residential Exposure Scenario

The residential scenario is based on exposures over 30 years duration to an individual residing onsite. The individual is assumed to be exposed to contaminated soil, air, surface water, and groundwater, and homegrown fruits and vegetables 365 days per year. The exposed individual was assumed to ingest 2 L (0.5 gal) of contaminated water per day, 365 days per year for 30 years.

EF (exposure frequency)

Units: days per year
Distribution used: triangular (likeliest 345, maximum 365, minimum 180)
Source: Smith 1994

This input represents the number of days per year that the "typical" behavior being used to characterize risk to the target population takes place. Providing an example of a "nontypical" day that would be excluded from consideration when generating an EF input may be helpful in understanding the purpose of the input. Days taken during the year as vacation, where the person is away from work, would not be considered typical since exposure parameters are likely to differ from those associated with a typical day in that person's life.

The likeliest value for EF was established using the rationale that two weeks spent away from home was a plausible likeliest value for EF. The minimum value for EF assumes that a person spends 50 percent of his or her time at home and the rest away from home. The maximum value for EF assumes that the person spends all of his or her time at home.

ED (exposure duration)

Units: years
Distribution: lognormal (mean 11.4, standard deviation 13.7)
Source: Department of Labor 1992

This input represents the number of years that the individual being modeled will reside at a residence located within the contaminated area. After considering the information in the EPA's Exposure Factors Handbook (EPA 1989) and after considering various factors that could impact ED, it was determined that the input would be characterized using the data from a study conducted by the Department of

Labor completed in 1992. The distribution used for ED is a lognormal distribution based on the mean and standard deviation presented by this report. The maximum value is the upper bound time specified by the report for a worker at any one given job.

IR (drinking water ingestion rate)

Units: liters per day
Distribution: lognormal (mean 1.12, standard deviation 1.63)
Source: Rosenberry-Burmaster 1992

Direct ingestion of radionuclides in tap water is an important exposure pathway that often dictates groundwater remediation at contaminated sites. The IR input represents the amount of drinking water ingested during a typical day by an adult under a residential exposure scenario.

Native American Scenario

The Native American scenarios are intended to include a wide range of activities from reserved rights related to traditional lifestyles and preservation of natural and cultural resources to those specifically delineated in the Treaties. Specific activities include hunting, gathering, collecting, fishing and processing of the catch along the shoreline, and pasturing of livestock, as well as ceremonial, educational, seasonal, social, and trade activities.

EF (exposure frequency)

Units: days per year
Distribution used: triangular (likeliest 345, maximum 365, minimum 180)
Source: Smith 1994

This input is the number of days per year that the typical behavior being used to characterize risk to the target population takes place. An example of a nontypical day that would be excluded from consideration when generating an EF input may be helpful in understanding the purpose of the EF input. Days taken during the year as vacation, where the person is away from work, would not be considered typical since exposure parameters are likely to differ from those associated with a typical day in that person's life.

The likeliest value for EF was established using the rationale that two weeks spent away from home seemed a plausible likeliest value for EF. The minimum value was based on a scenario in which a person spends 50 percent of his or her time at home and the rest away from home. The maximum value was based on a person spending 100 percent of their time at home.

ED (exposure duration)

Units: years
Distribution: lognormal (mean 11.4, standard deviation 13.7)
Source: Israeli-Nelson 1992

This input is the number of years that the individual being modeled will reside at a residence located within the contaminated area. After considering the information in the EPA's Exposure Factors Handbook (EPA 1989) and various factors that could impact ED, it was determined that the input would be characterized using the data from a study conducted by the Department of Labor in 1992. The lognormal distribution used for ED is based on that report. The maximum value is 70 years, which is the upper bound time specified in the Native American scenario.

IR (fish ingestion rate)

Units: grams per day
Distribution used: triangular (likeliest 140, maximum 1,080, minimum 30.0)
Source: DOE 1996 and EPA 1989

Consumption rates for recreationally caught fish from large bodies of water have a 50th percentile average of 30 g/day and a 90th percentile average of 140 g/day (EPA 1989). Therefore, for purposes of this scenario, the fish ingestion PDF was approximated by a triangular distribution.

VF (volatilization factor)

Units: liters per cubic meter
Distribution: triangular (likeliest 0.1, maximum 0.3, minimum 0)
Source: Andelman 1990

For groundwater, an upper bound volatilization factor (VF) based on uses of household water (e.g., showering, laundering, dish washing) was used. A VF of 0.1 L/m^3 was used for household activities. The transfer of contaminants from water to a Native American in a sweat lodge was also estimated using a VF similar to that proposed by EPA (Andelman 1990). The steam in the sweat lodge is generated by pouring water onto heated rocks. A VF of 0.3 L/m^3 is used for all nonvolatile contaminants, a factor of 2.5 is used for all VOCs, and a factor of 0.5 is used for radon. Therefore, for the Native American scenario, the VF probability density function was modeled as a triangular PDF with a most likely value of 0.1 L/m^3, maximum value of 0.3 L/m^3, and minimum value of zero.

Total Health Impacts for Hanford Site Users

The total adverse health impacts to a hypothetical future resident of the Hanford Site is expressed as the total cancer fatalities over a 10,000-year period. The cancer fatalities are calculated by first computing the total cancer risk for a given population and then dividing by the dose to risk conversion factor for cancer incidence and cancer fatalities (ICRP 1991). The parameters driving the uncertainty are the population density and the length of time for a life span or generation.

P (population density)

Units: persons per square kilometer
Distribution used: triangular (likeliest 3, maximum 5, minimum 1)
Source: professional judgment and WSDFM (1994)

The population density describes the number of people in a given area that will live at some hypothetical time in the future at the Hanford site. The current estimates of the farming population density surrounding the site give a value of approximate 5 persons/km^2. The triangular distribution for population density was chosen in order to estimate the uncertainty in the cancer fatalities at a population density of as low as 1 person/km^2.

D (Duration of each generation)

Units: years
Distribution: normal distribution (mean 75 years, standard deviation 7.5 years)
Source: EPA 1989

This input is used to represent the life expectancy for the each generation. Although 70 years has been widely used in the past, current data suggest that 75 years would now be a more appropriate average value.

Intruder Scenario

The post drilling scenario has three exposure pathways: exposure to airborne contamination via inhalation, external exposure to penetrating radiation, and consumption of contaminated produce. For the post drilling scenario, 0.35 m^3 of waste are distributed throughout a 15-cm-deep plow layer in a garden that is 2,500 m^2 in area. The individual is assumed to spend 4,380 hr/year residing at home (indoors), 1,700 hr/year outdoors, and 100 hr/year outdoors in gardening activities on the Site. The sensitivity analysis for the intruder scenario indicated that the intruder effective dose is most dependent in order of rank upon soil concentration, external exposure time, depth to the contamination, and the soil density.

Soil Concentration

Units: picocuries per gram
Distribution used: triangular (likeliest 9.9 E+05 maximum 1.7 E+06 minimum 4.4 E+05)
Source: professional judgment and Rittman 1994

The concentration of the contaminant in soil is a function of the diameter of the well, the thickness of the waste layer, the garden surface area, and the soil density. The thickness of the waste layer is assumed to be a constant 5 m (16 ft), although some uncertainty is associated with this parameter. The uncertainty associated with the surface area of the garden and the soil density are treated separately below. The diameter of the well excavated at the site was assumed to vary as a triangular distribution. The maximum value was assumed to be the point estimate of 30 cm (12 in.) and the most probable and minimum values were selected to be 22.5 cm (9 in.) and 15 cm (6 in.), respectively. The rationale for this assumption is that the well diameter could conceivably be three-fourths or one-half the point estimate. The corresponding triangular distribution for the soil contaminants concentration had the values stated above.

External Exposure Time

Units: hours
Distribution used: triangular (likeliest 1,800, maximum 3,260, minimum 676)
Source: professional judgment and EPA 1989

For estimating external exposure from the soil contamination, the house was assumed to reduced the dose rate to one-third the direct dose rate. Therefore, the average time exposed at the unshielded dose rate is:

(1,800 hr/year)*1 + (4,380 hr/year)*(1/3) = 3,260 hr/year

For the purposes of the Monte Carlo assessment, the minimum external exposure time was based on EPA's analysis of activity patterns in United States households (EPA 1989). The most likely value was chosen to represent 100 percent shielding of the receptor by the house.

Depth to Contamination

Units: centimeters
Distribution used: triangular (likeliest 15.0, maximum 22.5, minimum 7.5)
Source: EPA 1989 and Rittman 1994

The likeliest depth to the contaminants was chosen to be 15 cm or the tilling depth (Rittman 1994). However, due to leaching and other factors, surface soil was considered to extend to 22.5 cm or to be as shallow as 7.5 cm.

Soil Density

Units: grams per cubic centimeter
Distribution used: uniform (maximum 1.50, minimum 0.50)
Source: Rittman 1994 and DOE 1996

Published soil densities for the Hanford Site range from 0.5 g/cm^3 (DOE 1996) to 1.5 g/cm^3 (Rittman 1994). Therefore, the soil density distribution was assumed to be uniform with likeliest value 1.0.

Total Health Impacts Along the Columbia River

This scenario is used to estimate the dose to a population exposed to contamination from the Columbia River. The contamination enters the Columbia River as a result of groundwater flow into the river. Different contaminants will enter the groundwater and reach the Columbia River at varying times in the future.

Total cancer fatalities are calculated using factors that relate the number of fatal cancers to the curies of each contaminant released to the river. These factors were calculated using a computer program which

estimates the time integral of collective dose over a period of up to 10,000 years for time variant radionuclide release to surface waters, such as rivers (DOE 1987).

The dose estimates for the Columbia River scenario indicate that of the three principal routes of exposure (i.e., external, ingestion, and inhalation), ingestion is the principal route, followed by inhalation and external exposure. A Monte Carlo sensitivity analysis indicated that the parameters which most affect the equivalent dose are in rank order: soil to plant transfer factor, root ingestion rate, Columbia River flow rate, total population exposed, months per year of irrigation, and soil area density.

Root Ingestion Rate

Units: kilogram per year
Distribution used: triangular (likeliest 55.7, maximum 73.0, minimum 0.0)
Source: DOE 1996 and Rittman 1994

The root ingestion rate is the quantity of rooted vegetables consumed on a yearly basis by a resident along the Columbia River. For nonleafy vegetables, this value is approximately 55.7 kg/year (Rittman 1994). A more recent publication which deals directly with potential impacts to the Columbia River by contaminants from the Hanford Site states a value of 200 g/day or approximately 73 kg/year (DOE 1996).

Columbia River Flow Rate

Units: cubic feet per second
Distribution used: triangular (likeliest 8.1E+04, maximum 2.5E+05 minimum 3.6E+04)
Source: Volume One

The flow rate of the Columbia River is important in that it is used to estimate the amount of dilution that a contaminant would undergo once groundwater discharges to the river. Flows through the Reach fluctuate significantly and are controlled by operations at Priest Rapids Dam. Daily average flows range from 3.6E+04 ft^3/sec to 2.5E+05 ft^3/sec.

Months Per Year of Irrigation

Units: months per year
Distribution used: triangular (likeliest 6.0, maximum 7.0, minimum 5.0)
Source: Rittman 1994 and professional judgment

This parameter is the number of months per year that plants are irrigated with contaminated Columbia River water. A default value of six months per year has been assumed for the Hanford Site (Rittman 1994). However, in order to place some uncertainty on this value, irrigation has been assumed to occur for six months plus or minus 1 month to account for dry and wet years.

Soil Area Density

Soil area density is the product of soil density and the depth to the contamination. The same distributions used in the Monte Carlo approach for the intruder scenario for these distributions were used in the present scenario.

Soil to Plant Transfer Factor (root)

Units: curie per kilogram dry weight of vegetable to curie per kilogram of soil
Distribution: lognormal (mean 0.50, standard deviation 0.25)
Source: professional judgment

The soil to plant transfer factor accounts for the amount of contaminant that will be taken up from the soil through the roots of a plant. The most recent published value for this factor is 1.0 (Rittman 1994) for Np which is two orders of magnitude larger than the last published value (PNL 1986). However, examination of the most recent published values for this factor for other radionuclides (Rittman 1994) indicates that in general, the soil to plant transfer factor is between 0.01 and 1.0. Therefore, the distribution used for the Monte Carlo analysis was a lognormal with a mean value of 0.50 and standard deviation of 0.25. Examination of this probability distribution reveals that the selected distribution captures the range of values between 0.01 and 1.0.

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