PNL-10725
UC-630
AD-902

# Integrated Risk Assessment Program:

# Scoring Methods and Results for Qualitative Evaluation of Public Health Impacts from the Hanford High-Level Waste Tanks

J. W. Buck
G. M. Gelston
W.T. Farris

September 1995

Prepared for
the U.S. Department of Energy
Under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

## DISCLAIMER

# DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

# Summary


The objective of this analysis is to qualitatively rank the Hanford Site high-level waste (HLW) tanks according to their potential public health impacts through various (groundwater, surface water, and atmospheric) exposure pathways. Data from all 149 single-shell tanks (SSTs) and 23 of the 28 double-shell tanks (DSTs) in the Tank Waste Remediation System (TWRS) Program were analyzed for chemical and radiological carcinogenic as well as chemical noncarcinogenic health impacts.

The preliminary aggregate score (PAS) ranking system was used to generate information from various release scenarios. Results based on the PAS ranking values should be considered relative health impacts rather than absolute risk values.

General results from the analysis follow:

- The dominant exposure pathway for both carcinogenic and noncarcinogenic contaminants is the groundwater pathway.
- Thirteen tanks account for 90% and 33 tanks account for 99% of the total relative carcinogenic health impacts through the groundwater pathway.
- Carbon-14, $^{129}$I, $^{99}$Tc, $^{79}$Se, $^{235}$U, and $^{238}$U account for 99% of the total relative carcinogenic health impacts through the groundwater and surface water pathways.
- Twenty-five tanks account for 90% and 40 tanks account for 99% of the total relative noncarcinogenic health impacts through the groundwater and surface water pathways.
- Nitrate accounts for more than 99% of the total relative noncarcinogenic health impacts through the groundwater and surface water pathways.
- Twenty-six tanks account for 90% and 79 tanks account for 99% of the total relative carcinogenic health impacts through the atmospheric pathway.
- Cesium-137, $^{237}$Np, $^{241}$Am, $^{90}$Sr, $^{239}$Pu, $^{240}$Pu, $^{243}$Am, and $^{106}$Ru account for 99% of the total relative carcinogenic health impacts through the atmospheric pathway.
- Nineteen tanks account for 90% and 50 tanks account for 99% of the total relative noncarcinogenic health impacts through the atmospheric pathway.
- Chromium VI accounts for over 98% of the total relative noncarcinogenic health impacts through the atmospheric pathway.

The results from this analysis could have significant implications for retrieval strategies associated with the TWRS system engineering efforts. The PAS ranking system can also be used to rank HLW tanks with other Hanford Site program areas. This ranking methodology has not yet been fully verified or reviewed and should not be used as a final analysis.

# Acknowledgments

The authors would like to acknowledge the support of Karl J. Castleton for his computer skills and analysis efforts to complete this study on time. We would also like to thank Brad R. Warren and Paul W. Eslinger for their efforts in producing unit risk factors, preliminary scoring indices, and preliminary aggregate score values. Thanks also goes to Dennis L. Strenge for his support on developing the required information to create unit exposure factors values and Robert D. Stenner for his peer review efforts. Finally, we would like to thank Robert A. Buchanan and Audrey Ingostov for their editorial skills and Phyllis Parker for her editorial and text processing efforts.

# Abbreviations and Acronyms

| | |
|---|---|
| DSTs | double-shell tanks |
| EDTA | ethylenediaminetetraacetic acid |
| HLW | high-level waste |
| HRA-EIS | Hanford Remedial Action Environmental Impact Statement |
| HSRAM | Hanford Site Risk Assessment Methodology |
| P | annual occurrence probability |
| PAS | preliminary aggregate score |
| PSI | preliminary scoring index |
| Q | quantity |
| RF | release fraction |
| SSTs | single-shell tanks |
| TWRS | Tank Waste Remediation System |
| UEF | unit exposure factor |
| URF | unit risk factor |
| UTF | unit transport factor |

# Contents

# Figures



# Tables

# 1.0 Introduction

The 177 high-level waste (HLW) tanks at the Hanford Site provide interim storage of radioactive and chemical wastes resulting from 46 years of weapons material production. The total volume of waste in these tanks is about 60 million gallons in the form of liquid, saltcake, and sludge; total radioactivity is approximately 120 million curies. The tanks are of two basic construction types: 149 single-shell (SSTs) and 28 double-shell tanks (DSTs).

Pacific Northwest Laboratory[1] conducted this analysis in support of the Tank Waste Remediation System (TWRS) System Engineering effort. The health impact based ranking information provided in this report can be used to support retrieval decisions associated with the Hanford Site HLW tanks.

Various scenarios of routine and accidental release from the HLW tanks through several exposure pathways have potential impacts on public health. A qualitative ranking system was developed to compare their relative health impacts. This report provides a ranking methodology and analysis that may be used in supporting decisions about environmental restoration and waste management/disposal.

This report describes various release scenarios and related data used to develop relative health impacts. The PAS ranking system includes the following two aggregate scoring indices:

$PAS_C$ - The preliminary aggregate score for carcinogenic health impacts (includes both radiological and chemical contaminants). The conceptual definition for $PAS_C$ is the health impact associated with excess cancer incidence for a contaminant.

$PAS_N$ - The preliminary aggregate score for the noncarcinogenic health impacts (includes chemical contaminants). The conceptual definition for $PAS_N$ is the ratio of the noncarcinogenic contaminant exposure to a defined reference dose.

Results based on the PAS ranking values should be considered relative health impact rather than being considered absolute risk values.

[1]Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

# 2.0 Computational Methods

The computational method used in the calculation of the ranking scores takes advantage of the modular risk analysis approach used for the Hanford Remedial Action Environmental Impact Statement (HRA-EIS) that is documented in Section 2.1 of Whelan et al. (1995). In brief, the approach assumes that health impact analyses can be divided into several segments. These segments include

- the quantity of hazardous chemical and/or radioactive material in the HLW tanks
- the release fraction associated with each release scenario
- the probability of that material being released
- the degree of transport of the released material in the environment
- the degree of human exposure to the released material.

Objectives in developing this ranking methodology were to devise a method capable of

- quickly evaluating a large number of HLW tanks
- accommodating radionuclide and chemical contaminants
- accommodating near-term and long-term release events
- examining long-term health impacts
- dealing with high and low probability events of large and small consequences
- being simple to understand, document, check, and revise.

## 2.1 Scoring Indexes

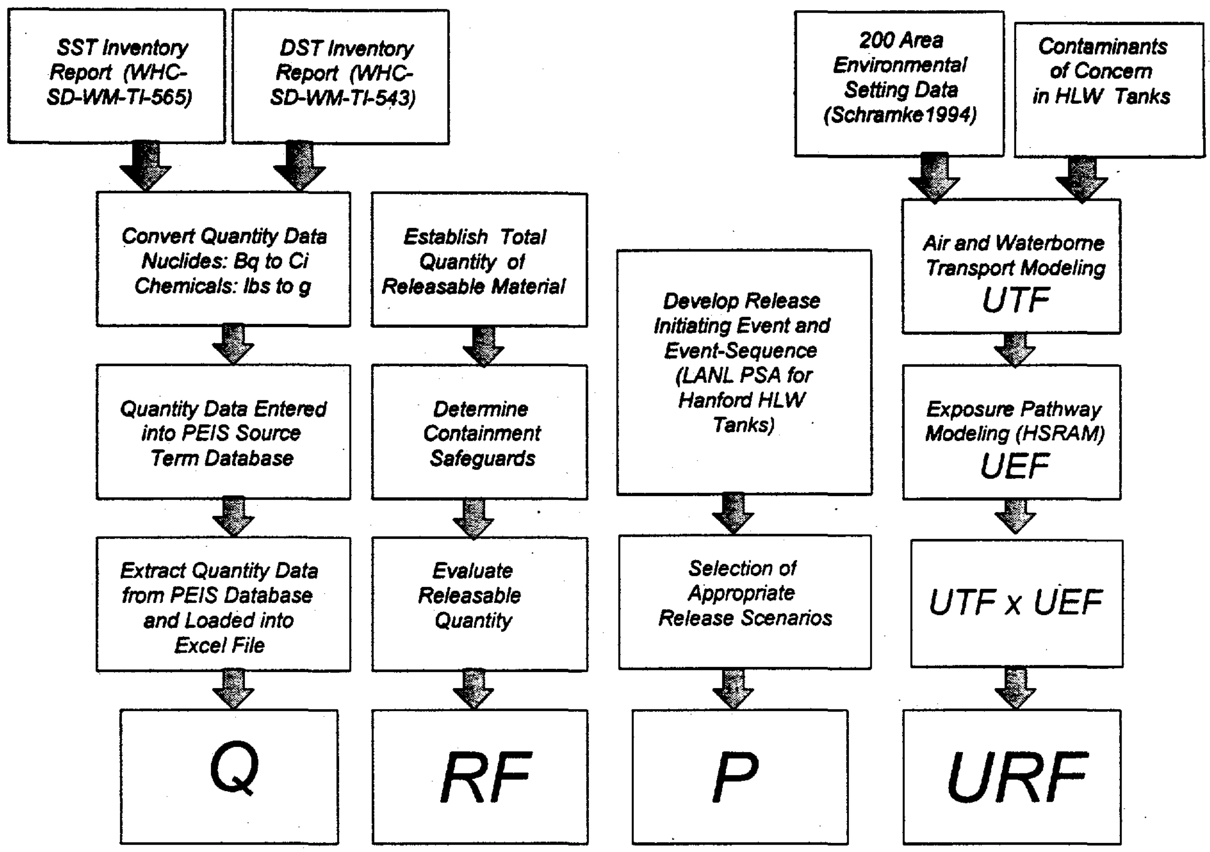
A computational method that implements the concepts described above was used to rank HLW tanks across the Hanford Site based on potential human health impacts. The output is called the preliminary scoring index (PSI), which is calculated using the following equation:

$$PSI = Q \ x \ RF \ x \ P \ x \ URF \tag{1}$$

where PSI is the ranking score by contaminant and HLW tank (health impacts/year), Q is the total quantity of the inventory of the contaminant in grams or curies, RF is the release fraction of the total quantity (dimensionless), P is the annual occurrence probability of the release scenario (year$^{-1}$), and URF is the unit risk factor for the contaminant and exposure pathway with units of health impact/gram or health impact/curie.

Figure 2.1 is a flowchart of the process used to develop each of the PSI parameters described in Equation 1.

**Figure 2.1**. Diagram of Process Used to Develop Health Impact Parameters




The calculated PSI is associated with each contaminant, release scenario, exposure pathway, and receptor location. There are two different types of PSIs calculated dependent upon health impact endpoint:

$PSI_C$ - The preliminary scoring index for carcinogenic health impact (includes both radionuclides and carcinogenic contaminants). The conceptual definition for $PSI_C$ is a preliminary scoring index associated with the health impact of excess cancer incidence.

$PSI_N$ - The preliminary scoring index for the noncarcinogenic health impact (includes chemical contaminants). The conceptual definition for $PSI_N$ is a preliminary scoring index associated with the ratio of the estimated daily exposure from hazardous materials to a defined reference dose.

However, because a detailed analysis was not performed for release of site-specific scenarios, the results of the PSIs should be used only in a relative ranking system rather than being considered absolute risk.

The $PSI_C$ and $PSI_N$ are computed for each combination of carcinogenic contaminant, exposure pathway, and receptor location. These values can be summed to give a carcinogenic and a noncarcinogenic scoring index for a HLW tank. The equations associated with the overall $PSI_C$ and $PSI_N$ are

$$PSI_C = \sum_C Q \times RF \times P \times URF_C \quad (2)$$

$$PSI_N = \sum_N Q \times RF \times P \times URF_N \quad (3)$$

where the $\sum_C$ of the $PSI_C$ extends over all radionuclides and carcinogenic chemicas contaminants and the $\sum_N$ of the $PSI_N$ extends over all of the chemical noncarcinogenic contaminants for a HLW tank associated with all exposure pathways and receptor location (both airborne and waterborne pathways).

Some contaminants, chromium VI and cadmium, for example, have both carcinogenic and noncarcinogenic effects. In these cases, both the calculated $PSI_C$ and $PSI_N$ values include the respective impacts associated with these contaminants.

## 2.2 Quantity

The quantity variable, denoted by Q, represents an estimate of the total inventory of a single contaminant in a specific HLW tank available for release. The units for Q are curies for radionuclides and grams for chemicals. For example, Q may be defined as a specific amount of nitrate ion in grams or $^{90}Sr$ in curies in a HLW tank.

## 2.3 Release Fraction

The release fraction, denoted by RF, represents an estimate of the fraction of the quantity (Q) for a HLW tank that is released under a postulated release scenario. The value for RF depends on the availability for release (i.e., physical form and containment) of the contaminant of interest. The RF may have a value between 0 and 1.0 and is a dimensionless number. It is used in both routine and accidental release scenarios.

For some release scenarios the scenario-specific RF values are unknown. In these cases, typical values, as shown in Table 2.1, were used to estimate the RF value. Table 2.1 provides RF values based on the physical form of the contamination and the exposure pathway that is being evaluated. The typical values in Table 2.1 are generally conservative and consider only the physical form of the material and not every type of containment that may hinder the release of the contaminant.

Both routine and accidental release scenarios associated with waterborne and airborne release pathways were evaluated under this ranking study. For all release scenarios, institutional control is assumed to exist for the entire modeling period. Therefore, only offsite receptor locations are used for this analysis. The waterborne release scenarios were developed based on UTF and UEF values associated with groundwater and surface water pathways for infiltration release mechanisms. The airborne release scenarios were developed based on UTF and UEF values for wind suspension and volatilization release mechanisms.

**Table 2.1.** Typical RF by Exposure Pathway and Physical Form of Contaminant

| Exposure Pathway | Physical Form | Release Fraction (RF) |
|---|---|---|
| Routine Air Release | Gas | 1 |
| | Liquid | $10^{-3}$ |
| | Powder, dust | $10^{-3}$ |
| | Solid | $10^{-6}$ |
| Routine Waterborne Release | Gas | n/a |
| | Liquid | 1 |
| | Powder, dust | $10^{-3}$ |
| | Solid | $10^{-6}$ |
| Accidental Airborne and Waterborne Releases | Gas | 1 |
| | Liquid | 0.1 |
| | Powder, dust | 0.1 |
| | Solid | 0.01 |

The waterborne release scenarios used site-specific geology, hydrology, and climatology data for the Hanford Site (Schramke et al. 1994) to develop environmental concentrations at the defined receptor location based on unit quantities (i.e., 1 gram or 1 curie). The infiltration to groundwater and infiltration to groundwater then to surface water were evaluated for the waterborne release scenarios. The overland pathway was not evaluated because it is generally considered an insignificant pathway at the Hanford Site. The direct discharge to surface water was also not evaluated because this scenario is not applicable under current operations at the Hanford Site and location of the HLW tanks.

The assumption that institutional control is kept for the duration of the modeling period reflects the current maintenance and operations procedures occurring at the Hanford Site. Under the present baseline assumptions, operational, natural phenomena, or external events can cause releases of waste and material into the environment. Once releases have occurred, it is assumed that mitigating actions will be implemented without delay. Existing contamination and buried solid waste from past practices are considered to be already released (probability and release fraction equal to 1.0).

## 2.4 Annual Occurrence Probability

The annual occurrence probability of an event, denoted by P, indicates the annual probability of release from a HLW tank for a specified release scenario. The units for P are ($year^{-1}$). The parameter P combines the probability of the initiating event and the event-sequence associated with the release of material. Note that initiating events that have a probability of occurrence of less than 1 x $10^{-6}$ $year^{-1}$ are considered not credible and are given no further consideration. The event-sequences represent physical phenomena, containment and equipment responses, and emergency and safeguard responses.

The combination of the probability of the initiating event and the probability of the event-sequence produces the P parameter or the annual occurrence probability of the release scenario. A routine release, or one that has already occurred (i.e., a currently leaking tank) or is continuing to occur, would have a probability of occurrence of 1.0 $year^{-1}$. The parameter P for accidental releases is generally much less than 1.0 because of containment, operation safeguards, and type of initiating event.

## 2.5 Unit Risk Factors

The unit risk factor, denoted by URF, represents a measure of the health impact from transport and exposure of a contaminant per unit quantity from a HLW tank at a receptor location. The URF values created for this study are based on the modular risk analysis approach developed for the HRA-EIS (Strenge and Chamberlain 1994; Whelan et. al. 1995). The environmental setting data and exposure factors used in this study are a subset of the values reported for the HRA-EIS.

The URF is the product of unit transport factor (UTF) and unit exposure factor (UEF) as shown in Equation 4. The UTF was computed for representative buried-waste-type release sites for airborne and waterborne receptor location. The UEF was computed based on different exposure routes and residential land use activities. There are carcinogenic URF ($URF_C$) and noncarcinogenic URF ($URF_N$) depending on the specific contaminant and its health effect. The units for the $URF_C$ are health impact/curies for radionuclides and health impact/gram for carcinogenic chemicals, while the units for the $URF_N$ are health impact/gram for noncarcinogenic chemicals.

$$URF = UTF \times UEF \tag{4}$$

The URF values developed for this ranking analysis are for the 177 HLW tanks associated with the Hanford Site and are based on representative release sites within the 200 Area environmental setting. The entire 200 Area, where the HLW tanks are located, is represented by the 200 East Area environmental setting for this analysis. The 200 East Area environmental setting used is based on the environmental settings report (Schramke et al. 1994).

### 2.5.1 Unit Transport Factor

The 177 SSTs and DSTs in the 200 Area (200 East and West Areas) were represented by the 200 East environmental setting data, with the HLW tank located in the middle of the 200 East Area. The groundwater and surface water UTF values were computed for selected receptor locations. The analysis used the 200 East climatological data to determine the dispersion and deposition for the atmospheric pathways. This climatological data is documented in the environmental settings report (Schramke et al. 1994).

The receptor locations represented for this analysis are groundwater wells at the Columbia River boundary, surface water intake at the City of Richland water intake location, and maximum air inhalation locations associated with the environmental setting modeled. The distance to the groundwater receptor location is 16,093 m (52,799 ft) due East to the Columbia River with the surface water receptor located 32,186 m (105,597 ft) down stream of that point to the City of Richland water intake. The atmospheric receptor was located 24,000 m (78,740 ft) ESE of the 200 Area.

The waterborne pathways, based on infiltration to groundwater and infiltration to groundwater to surface water release mechanisms, primarily result in long-term releases that may pose long-term health effects to humans through groundwater and surface water (Columbia River) uses. The airborne pathways, based on wind suspension and volatilization release mechanisms, are primarily short-term releases that may pose long-term health effects to humans though inhalation and crop uses.

The groundwater receptor location distances were computed from the location of the representative release for each area along the groundwater flow to the Columbia River. The surface water receptor location distances were computed from the point where the groundwater contamination is predicted to enter the Columbia River (starts at the groundwater receptor location) and measured to the City of Richland water intake location. The atmospheric receptor location distances and direction (sixteen compass points) were computed by running an atmospheric dispersion model with Hanford-specific climatology data and determining the closest offsite maximum air concentration for each area.

The UTF relates the concentration of a contaminant in a specific HLW tank to a receptor location based on a unit quantity of contaminant in a HLW tank. For example, a groundwater UTF can be defined for releases from the 200 Area with transport to the Columbia River (via shortest flow tube route). This example UTF can be described as follows:

| | |
|---|---|
| Location: | 200 Area |
| Receptor: | City of Richland water intake |
| Medium: | Surface water (from groundwater transport) |
| Pollutant: | Tritium |

In general, the UTF values used in this analysis were also taken from data produced in support of the HRA-EIS and were documented in detail by Whelan et al. (1995).

### 2.5.2 Unit Exposure Factor

The UEF values used for this analysis were based on residential land use activities as described in the Hanford Site Risk Assessment Methodology (HSRAM) (DOE 1995). These UEF values were combined with the appropriate UTF values described above to create contaminant URF values for each exposure pathway associated with the HLW tanks.

The waterborne exposure routes were drinking water eating irrigated crops, and eating fish (surface water only). The atmospheric exposure routes were inhalation, eating irrigated crops, and direct exposure from radionuclides via immersion in the contaminant plume. The airborne pathways, based on wind suspension and volatilization release mechanisms, are primarily short-term releases that pose long-term health effects to humans though inhalation and crop uses.

The UEF relates one unit of concentration in a medium to health impact for specific exposure pathways, scenarios, media, and contaminant. For example, a UEF can be defined for

| | |
|---|---|
| Scenario: | Residential land use |
| Medium: | Groundwater use |
| Exposure pathway: | Drinking water ingestion |
| Contaminant: | $^{234}U$ |
| Health Impact Measure: | Cancer incidence |

This example UEF gives the health impact from ingestion of one unit of drinking water containing $^{234}U$ taken from a groundwater well. The health impact is evaluated using parameters defined for the HSRAM residential scenario (DOE 1995). Two measures of health impact are included in this analysis: cancer incidence (radionuclides and carcinogenic chemicals) and hazard index (noncarcinogenic chemicals).

The UEF values used in this analysis were taken from the data produced in support of the HRA-EIS and were documented in detail by Strenge and Chamberlain (1994). The reader should note a change of nomenclature, the UEF values used in this discussion were called URF by Strenge and Chamberlain (1994).

## 2.6 Preliminary Aggregate Scores

Once the $PSI_C$ and $PSI_N$ values are computed for each HLW tank, the scores can be normalized using a parameter called the PAS. The PAS parameter for carcinogenic and noncarcinogenic contaminants is computed by normalizing the $PSI_C$ and $PSI_N$ values using the following equations:

$$\mathit{If}\ PSI_C \le 1x10^{-20}\ ;\ \mathit{Then}\ PAS_C = 0 \tag{5}$$

$$\mathit{If}\ PSI_C > 1x10^{-20}\ ;\ \mathit{Then}\ PAS_C = INTEGER[\log(PSI_C) + 20] \tag{6}$$

$$\mathit{If}\ PSI_N \le 1x10^{-14}\ ;\ \mathit{Then}\ PAS_N = 0 \tag{7}$$

$$If\ PSI_N > 1x10^{-14}\ ;\ Then\ PAS_N = INTEGER[\log(PSI_N) + 14] \quad (8)$$

In order to keep the carcinogenic and noncarcinogenic PAS separate (they represent very different health effects) the $PAS_C$ is denoted with a C (indicating carcinogenic effects) in front of the value (e.g., C12, C01, C04) and the $PAS_N$ is denoted with an N (indicating noncarcinogenic effects) in front of the value (e.g., N12, N01, N04). The larger the PAS value, the greater the health impact of the HLW tank based on human health impacts. For example, to illustrate how the PAS parameters are computed, if the $PSI_C$ value for a HLW tank is $3 \times 10^{-5}$, Equation 6 gives the log of $3 \times 10^{-5}$ as -4.52. This value is then added to 20 to produce 15.5, which is truncated to the nearest integer to give a $PAS_C$ value of C15.

Equations 5 and 6 provide $PAS_C$ parameters that have a scale that starts at 0 ($PSI_C \leq 1 \times 10^{-20}$) and is open on the upper limit to allow for additional results that may expand the scale. For the $PAS_C$ parameter, generally the upper limit is 20 ($PSI_C$ of 1.0), but it is possible to have $PSI_C$ greater than 1.0, which would produce a $PAS_C$ greater than 20. The $PAS_N$ also starts at 0 ($PSI_N \leq 1 \times 10^{-14}$) and is open on the upper limit to allow for additional results that may expand the scale. Generally, the $PAS_N$ upper limit is 20 ($PSI_N$ of $1 \times 10^{+6}$), but it is possible to have a $PSI_N$ greater than $1 \times 10^{+6}$, which would produce a $PAS_C$ greater than 20. This open-ended upper scale allows for new values to be included that may change the upper range of the scale .

Section 3.0 contains the PAS values for each HLW tank associated with the Hanford Site. The PAS values normalize the health impacts from the HLW tanks and allow comparison across tanks and tank farms. Thus, the ranking methodology allows for a qualitative site-wide assessment of HLW tank health impacts.

# 3.0 Application and Results

This section provides ranking results for the 177 HLW tanks at the Hanford Site. The quantity, release fraction, and annual occurrence probability are specific for each tank and will be discussed in detail. The URF values used in the ranking calculation are specific to the 200 Area environmental setting and are generally independent of the release scenario and HLW tank. Therefore, discussion of the URF values precedes the specific HLW tank decisions.

The URF values created for this study are based on the modular risk analysis approach developed for the HRA-EIS (Strenge and Chamberlain 1995; Whelan et al. 1995). The environmental setting data and exposure factors are those used and reported in the HRA-EIS. The URF values for tanks assumed that contaminant releases to the subsoil were equivalent to buried waste sources after the tank structure was compromised.

This study evaluated both routine and accidental release scenarios associated with waterborne and airborne release pathways. In all release scenarios, institutional control is assumed to exist for the entire modeling period. Therefore, the analysis uses only offsite receptor locations. The waterborne release scenarios were based on UTF and UEF values associated with groundwater and surface water pathways for the infiltration release mechanism. The airborne release scenarios were based on UTF and UEF values for wind suspension and volatilization release mechanisms.

The 200 East Area environmental setting data, with a representative tank (located in the middle of the 200 East Area) represented all 200 Area release HLW tanks (200 East and West Areas). The receptor location for the groundwater was the straight-line groundwater flow to the shore of the Columbia River, due East of the 200 Area. The receptor location for the surface water receptors was the straight-line groundwater flow to the shore of the Columbia River and then to the City of Richland water intake downstream of the Hanford Site.

The atmospheric UTF values were developed from the climatological data from the Hanford Meteorological tower in the 200 East Area (Schramke et al. 1994). These data were used to determine the dispersion and deposition for the atmospheric pathway and to locate the maximum offsite air concentration for all areas (generally a person on the Columbia River). The airborne pathways, based on wind suspension and volatilization release mechanisms, are primarily short-term releases that pose long-term health effects to humans through inhalation and crop uses.

The UEF values used for this analysis were based on residential land use activities as described in the HSRAM (DOE 1995). The UEF values were combined with the appropriate UTF values to create URF values for each exposure pathway. The waterborne exposure routes were drinking water, eating irrigated crops, and eating fish (surface water only). The atmospheric exposure routes were inhalation and eating irrigated crops.

The uncertainty associated with these results is generally plus or minus one order of magnitude (e.g., $\pm$ 1 category). This uncertainty range accounts for the specific uncertainty associated with each parameter: Q, RF, P, and URF.

## 3.1 Analysis of Tanks

The 177 HLW tanks at the Hanford Site were built to provide interim storage of radioactive wastes resulting from 46 years of weapons material production. The total volume of waste in these tanks is about 60 million gallons in the form of liquid, saltcake, and sludge; total radioactivity is approximately 120 million curies.

The SSTs have a history of leaking into the soil column; 67 tanks are known or suspected to have leaked. All SSTs have been inactive from operations since 1980. The DSTs are still in operation, and there is no indication that any have leaked. There are currently 54 HLW tanks on the Watch List. Watch List Tanks have been identified as having safety issues/situations that contain most of the necessary conditions that could lead to worker or offsite radiation exposure through an uncontrolled release of fission products (WHC 1995f). Specific safety issues include structural failure from high heat, uncontrolled oxidation by nitrates/nitrites of organic chemicals, potential reactions of ferrocyanides in waste, possible ignition of hydrogen-generation gases, and combustion of organic solvents in the saltcake (DOE 1993).

### 3.1.1 Release Scenarios for Tanks

The accident scenarios were derived from a draft Probabilistic Safety Assessment report for the Hanford HLW tanks (Los Alamos National Laboratory [LANL] 1995) that described the possible accident initiators and their potential frequencies. Accidental release scenarios include events that are caused by operational, natural phenomena, or external events. The LANL report evaluated 22 release categories for airborne and waterborne releases.

The 22 release categories are associated with three release pathways: airborne, waterborne, and airborne/waterborne. The airborne releases are unfiltered release, high-efficiency particulate air filter breach, and dome collapse. The waterborne releases are subterranean leaks, and the airborne/waterborne releases are surface spills, spray leaks, dome collapse, and subterranean leaks. The initiating events analyzed are lightning strike, criticality of fissile material, air compressor failure, plugged air line, aircraft crash, earthquake, tornado, corrosion failure, thermal stress failure, heavy object dropped, energetic chemical reaction, in-tank electric spark, and range fires.

### 3.1.2 Quantity

Many different sources of information about the HLW tanks at the Hanford Site have been developed and collected. Much is project-specific and may not be completely applicable to other projects. Other, more generic information can be applied to most projects where the health impact of the HLW tanks is being considered. The key data required to assess the impacts from these tanks for different release scenarios are contaminants of concern, their quantity, and type of waste.

The quantity data for the 149 SSTs were developed from a document prepared for Westinghouse Hanford Company by WASTREN, Inc. (WHC 1993a). This report contains the quantity information from radionuclide and chemical analyses of the contents of the SSTs. When laboratory data or samples were not available, Track Radioactive Components data were used.

The quantity data for the 28 DSTs were obtained from a document prepared for Westinghouse Hanford Company by WASTREN, Inc. (WHC 1993b). This report contains the quantity information from radionuclide and chemical analyses of the contents of the DSTs. Data for 241-AP-101, 241-AP-105, 241-AP-106, 241-AP-107, and 241-AP-108 tanks were not available in this report or any other source. Tanks 241-AP-101, 241-AP-106, 241-AP-107, and 241-AP-108 are known to contain dilute non-complexed waste and tank 241-AP-105 contains double-shell slurry feed.

Appendix A is a description of an electronic file that contains the quantity information for each HLW tank by contaminant. This electronic file is available on a 3.5" floppy disk and the information can be read into most spreadsheet software (Lotus, Excel, dBASE, etc.). Requests should be sent to Gariann Gelston, PNL via e-mail (gm_gelston@pnl.gov) or phone (509-946-7860).

Since completion of this study several other quantity-related reports have become available. Some of these reports are historical tank content estimates for the four quadrants where the tanks are located (WHC 1995a,b,c,d). Another report (WHC 1995e) provides recent sampling data. These reports are more up-to-date, but it is not obvious whether the changes would influence the health impact rankings presented in this study.

### 3.1.3 Release Fractions for Tank Contaminants

Release factions are the estimated fraction of the total quantity released under the postulated release scenario. The release fractions used here were based on the physical form of the waste in the SSTs and DSTs. The release fractions of the waterborne release scenarios are provided in Table 3.1. The waste in the SSTs is primarily saltcake and sludge; an average of about 20% of the waste is in liquid form and a release fraction of 0.2 was used for waterborne releases. The waste in the DSTs is primarily liquid, and a conservative release fraction of 1.0 was used for waterborne release scenarios.

For the airborne release scenarios, the release fractions can be categorized by Watch List and non-Watch List tanks. The release fractions for the airborne release scenarios are provided in Table 3.1.

**Table 3.1.** Release Fraction for the HLW Tanks

| Tank Type | Waterborne Release | Airborne Release |
|---|---|---|
| SSTs | 0.2 | --- |
| DSTs | 1.0 | --- |
| Watch List Tanks | --- | 0.1 |
| Non-Watch List Tanks | --- | .01 |

### 3.1.4 Annual Occurrence Probabilities

The 149 SSTs and 28 DSTs at the Hanford Site have the potential to release their contents into the environment as a result of internal or external events. Internal events that might result in release of radioactive and hazardous waste are based on the six safety issues associated with the tanks: ferrocyanide (20), organic (9), high heat (11), criticality (all), noxious vapors (Farms C, BX, and BY), and flammable gases (24) (values in parenthesis are the number of tanks involved). External events include lightning strikes, fire, airplane crash, earthquake, human intruder, animal intruder, and natural deterioration of vessel (67 tanks are assumed to be leaking).

#### 3.1.4.1 Probabilities for Airborne Releases

A range fire in the 200 Area is the most significant airborne release scenario for the tanks. The information on the probability of such an event was derived from a study on SY-101 called "Risk Assessment for Hanford High-Level Waste Tank 241-SY-101" (LANL 1993).

The Hanford Site has a dry arid climate, and range fires frequently occur in such climates. The fires can burn out of control if driven by strong winds. The annual occurrence probabilities of an external fire on a tank farm are related to the occurrence probability of a range fire, fraction of range fires that occur in a tank farm area, conditional probability of a fire size S (i.e., considered minimum size to impact a tank farm), conditional probability of a strong wind given a size S fire, conditional probability of wind direction that pushes a fire of size S toward the tank farm, conditional probability of a fire barrier failure given fire size S in the tank farm area, and the probability that fire fighters fail to control the fire given failure of a fire barrier. Although these parameters were used for tank 241-SY-101, it was assumed that they were representative of other tanks and tank farms.

The estimated occurrence probability of a range fire, based on historical data at the Hanford Site is about 0.85 $year^{-1}$ (WHC 1994a). There is no information on the size and location of these range fires. Therefore, the spatial distribution was estimated by dividing the tank farm into three equal-width annular areas. This provides a probability of 0.11 that a random fire of size S would occur near any given tank. Thus, the probability of a range fire of sufficient size to cause an impact in the tank area is 0.85 * 0.11.

A wind of greater than 20 mph was considered to cause the fire to spread quickly. The probability of such a fire at the Hanford Site is 0.059 (WHC 1994a). There is no information on wind direction during fires, but a conservative estimate is that fire can come from any direction (16 general directions) and wind from 2 directions will push fire into the tank farm (probability 0.125 for a fire to be pushed into a tank farm).

The effectiveness of fire barriers and fire suppression (fire fighters response) are difficult to estimate because of lack of information and the number of variables. Removal of vegetation and construction of fire breaks near the tank farms are precautions routinely used on the Hanford Site. The combined effect of fire precautions and suppression is expected to reduce the external fire impact on the tank farm by at least a factor of 10.

The combination of occurrence of range fire (0.85), aerial distribution of fires (0.11), high winds (0.059), wind direction (0.125), and fire precaution and suppression (0.10) provides an estimated probability of a S-size fire of 7 x $10^{-5}$ $year^{-1}$. This value was used for all tanks.

### 3.1.4.2 Probabilities for Waterborne Releases

The SSTs are generally older than the DSTs and only have one shell (as the name indicates). The Tank Farm Surveillance Report (WHC 1994b) provides data on the year a tank was built, the year it began to leak, and the year it was interim stabilized (supernatant liquid reduced to about 5000 gallons). The difference in failures of the different series of SSTs (series 100 and 200) is considered to be insignificant. The leak data indicated that the estimate of tank shell failure is related to aging and leak size (WHC 1994a).

The aging process leads to shell failure through a set of initiating mechanisms, such as corrosion, fatigue from thermal cycling, embrittlement of the liner, flaws, crack propagation, and impacts. The rate of degradation of the liner is affected by design, operation conditions, environment, manufacturing process, and installation process.

The annual occurrence probability of waterborne release from the 67 SSTs known or suspected to have leaked is assumed to be 1.0 (already released to the environment). Twelve of the reported leak events were actually transfer-line leaks or tank overflows. The probability of waterborne releases from SSTs that are not suspected of leaking was provided in the draft LANL Probabilistic Safety Assessment for the Hanford High-Level Waste Tanks report (LANL 1995). Past (pre-1980) and recent (post-1980) experience and information was used to predict future leak probabilities. Using the 80th percentile value, the annual occurrence probability of release from a nonleaking SST to the waterborne pathway is assumed to be 5 x $10^{-2}$ $year^{-1}$ per tank.

The DSTs are newer than the SSTs and none are known to be leaking. Information from the leaking SSTs was used to estimate the probability of release of a DST to the waterborne pathway. The inner shell of the DST was assumed to have a more conservative probability of release, 1 x $10^{-2}$, which is the 95th percentile probability for SST liner. The outer shell leak analysis was also based on SST information. The outer shell is not subject to as wet and corrosive of an environment as the inner shell, therefore the leak rate of the outer shell was reduced by a factor of 10. The annual occurrence probability of both liners leaking in a given year is $5 \times 10^{-2} * 1 \times 10^{-3} = 5 \times 10^{-5}$ $year^{-1}$.

The URF values developed for the HLW tanks assumed that contaminant releases to the subsoil were equivalent to buried waste sources after the tank structure was compromised. The release point was assumed to be the center of the 200 East Area for all tanks. Therefore, the environmental setting data for the 200 East Area from the environmental settings report (Schramke et al. 1994) was used to develop UTF values. The receptor locations were the straight-line groundwater flow to the Columbia River and the City of Richland water intake location downstream of the Hanford Site. This required calculating groundwater and surface water UTF values for each tank.

## 3.2 Summary Analysis of Hanford High-Level Waste Tanks

This ranking analysis evaluated the Hanford HLW tanks for public health impacts through atmospheric, groundwater, and surface water pathways to offsite receptor locations. The ranking analysis of this report is specifically for the HLW tanks, but may also be applied site-wide to other Hanford program areas to develop a ranking analysis for the Hanford Site. The ranking is based on normalized parameters called the PAS values which are divided into two separate categories, carcinogenic and noncarcinogenic.

The groundwater pathway dominates the other exposure pathways for both carcinogenic and noncarcinogenic contaminant ranking scores. For the groundwater pathway, less than 10% of all the HLW tanks account for more than 90% of cumulative carcinogenic ranking scores, and less than 15% of the HLW tanks account for over 90% of cumulative noncarcinogenic ranking scores. For both groundwater and surface water pathways, the highly mobile contaminants (e.g., $^{14}C$, $^{99}Tc$, $^{129}I$, $^{79}Se$, $^{235}U$, $^{238}U$, and nitrate) result in the highest ranking scores (greatest health impacts). In general, the highest ranking HLW tanks for the atmospheric pathway are several ranking categories below the groundwater pathway scores. The top contributing contaminants for the atmospheric pathway are $^{137}Cs$, $^{237}Np$, $^{241}Am$, $^{90}Sr$, $^{239}Pu$, $^{240}Pu$, $^{243}Am$, and $^{106}Ru$ for carcinogenic, and chromium VI, nitrite, EDTA, lead, aluminum, chromic acid (modeled as Chromium III), and phosphate for noncarcinogenic ranking scores. A top contributing contaminant is not synonymous with a significant health impact contributor.

### 3.2.1 Summary of HLW Tanks Based on Groundwater Pathway

Table 3.2 lists the HLW tanks by their groundwater pathway $PAS_C$ ranking values. Note that 5 tanks (241-AP-101, 241-AP-105, 241-AP-106, 241-AP-107, and 241-AP-108) are not included in the ranking because of lack of adequate quantity data. Tanks 241-AP-101, 241-AP-106, 241-AP-107, and 241-AP-108 contain dilute noncomplexed waste, and tank 241-AP-105 contains double-shell tank slurry feed. The absence of these tanks from the ranking results is not expected to affect the order of the higher ranking tanks (top 50%). Appendix B is a description of two electronic files that contain the $PSI_C$ and $PSI_N$ values associated with each tank for each exposure pathway. One file described contains $PSI_C$ and $PSI_N$ values for each HLW tank by contaminant and the other file described contains $PSI_C$ and $PSI_N$ values summed over contaminant for each HLW tank. These electronic files are available on a 3.5" floppy disk. Requests should be sent to Gariann Gelston, PNL via e-mail (gm_gelston@pnl.gov) or phone (509-946-7860).

The highest ranking tank based on $PAS_C$ values is 241-B-111 (e.g., C15 category), which accounts for approximately 36% of the cumulative carcinogenic ranking scores of all the tanks. The contaminants that contributed the most to 241-B-111's high ranking were $^{14}C$, $^{99}Tc$, $^{129}I$, and $^{79}Se$, which are all relatively mobile in the subsurface soil and aquifer and present in significant quantities: 2110, 2970, 5, and 89 curies, respectively. Thirteen tanks account for 90% of the cumulative carcinogenic ranking scores through the groundwater pathway, while 33 tanks account for 99%, 65 tanks account for 99.9%, and 91 tanks account for 99.99% of the cumulative carcinogenic ranking scores through the groundwater pathway. Thus, selection of key tanks over others for remediation (pretreatment, retrieval, disposal, and closure) may provide significant health impact reduction.

There are several dominant carcinogenic contaminants associated with the groundwater pathway ranking that account for 99% of the cumulative carcinogenic ranking scores from the HLW tanks. These carcinogenic contaminants are $^{14}C$, $^{129}I$, $^{99}Tc$, $^{79}Se$, $^{235}U$, and $^{238}U$. These contaminants ranked high mainly because of large URF values caused by a combination of high mobility in the subsurface soil and aquifer and their high toxicity. Of course, high values of Q, RF, and P also may contribute to the high ranking.

Table 3.3 lists 172 HLW tanks by their groundwater pathway $PAS_N$ ranking. Appendix B provides a description of the $PSI_N$ values for the groundwater pathway summed over all contaminants per HLW tank and for each HLW tank by contaminant in an electronic file form.

Five tanks account for approximately 44% of the cumulative noncarcinogenic ranking scores, based on $PAS_N$ values (e.g., all of these tanks are in the N13 category). These tanks are 241-SX-108, 241-SX-109, 241-SX-110, 241-SX-114, and 241-SX-115. Nitrate is the dominant contaminant associated with $PAS_N$ values for these tanks because it is highly mobile in the subsurface soil and aquifer and is present in significant quantities ($8.3 \times 10^{+10}$ grams). Twenty-five tanks account for 90% of the cumulative noncarcinogenic ranking scores through the groundwater pathway, while 40 tanks account for 99%, 75 tanks account for 99.9%, and 104 tanks account for 99.99% of the cumulative noncarcinogenic ranking scores through the groundwater pathway. Thus, selection of key tanks for remediation (pretreatment, retrieval, disposal, and closure) may provide significant health impact reduction.

The dominant hazardous materials are nitrate (which accounts for over 99% of the overall noncarcinogenic ranking scores for all the tanks), EDTA, fluoride, sodium hydroxide, nitrite, sulfate, and sodium. Nitrite is not a dominant contaminant compared to nitrate because its toxicity value (based on U.S. Environmental Protection Agency values rather than Washington State Department of Ecology waste classification values) for ingestion from groundwater and surface water pathways is several orders of magnitude less than nitrate.

### 3.2.2 Summary of HLW Tanks Based on Surface Water Pathway

Table 3.4 lists the HLW tanks by their surface water pathway $PAS_C$ ranking. Appendix B provides a description of the $PSI_C$ values for the surface water pathway summed over all contaminants per HLW tank and for each HLW tank by contaminant available in an electronic file form.

The high ranking tank (greatest health impact) based on $PAS_C$ values is 241-B-111 (e.g., C12 category), which accounts for approximately 36% of the cumulative carcinogenic ranking scores of all the tanks. The contaminants that contributed the most to the 241-B-111's high ranking were $^{14}C$, $^{99}Tc$, $^{129}I$, and $^{79}Se$, which are all relatively mobile in the subsurface soil and aquifer and present in significant quantities: 2110, 2970, 5, and 89 curies, respectively. Thirteen tanks account for 90% of the cumulative carcinogenic ranking scores through the groundwater pathway, while 33 tanks account for 99%, 65 tanks account for 99.9%, and 91 tanks account for 99.99% of the cumulative carcinogenic ranking scores through the surface water pathway.

The dominant carcinogenic contaminants associated with the surface water pathway ranking, which accounts for 99% of the cumulative carcinogenic ranking scores from the HLW tanks, are $^{14}C$, $^{129}I$, $^{99}Tc$, $^{235}U$, $^{79}Se$, and $^{238}U$. These carcinogenic contaminants contribute to high ranking mainly because of large URF values caused by a combination of high mobility in the subsurface soil and aquifer and their high toxicity. Of course, high values of Q, RF, and P also may contribute to the high ranking.

Table 3.5 provides a list of the HLW tanks by their surface water pathway $PAS_N$ ranking. Appendix B provides a description of the $PSI_N$ values for the surface water pathway summed over all contaminants per HLW tank and for each HLW tank by contaminant available in an electronic file form.

There are 5 tanks that account for approximately 44% of the cumulative noncarcinogenic ranking scores, based on $PAS_N$ values (e.g., all of these tanks are in the N11 category). These tanks are 241-SX-108, 241-SX-109, 241-SX-110, 241-SX-114, and 241-SX-115. Nitrate is the dominate contaminant associated with the $PAS_N$ values for these tanks because it is highly mobile in the subsurface soil and aquifer and is present in significant quantities (8.3 x $10^{+10}$ grams). Twenty-five tanks account for 90% of the cumulative noncarcinogenic ranking scores through the groundwater pathway, while 40 tanks account for 99%, 75 tanks account for 99.9%, and 104 tanks account for 99.99% of the cumulative noncarcinogenic ranking scores through the groundwater pathway. The dominant hazardous materials are nitrate, which accounts for over 99% of the overall noncarcinogenic ranking scores for all the tanks, EDTA, fluoride, sodium hydroxide, nitrite, sulfate, and sodium.

### 3.2.3 Summary of HLW Tanks Based on Atmospheric Pathway

Table 3.6 lists the HLW tanks by their atmospheric pathway $PAS_C$ ranking score. Appendix B provides a description of the $PSI_C$ values for the atmospheric pathway summed over all contaminants per HLW tank and for each HLW tank by contaminant available in an electronic file form.

The highest ranking tanks (greatest health impact) based on $PAS_C$ values (all are in the C13 category) are 241-S-112, 241-AN-104, and 241-SY-103, which account for approximately 34% of the cumulative carcinogenic ranking scores of all the tanks. The contaminants that contributed the most to high ranking for these three tanks were $^{137}Cs$ and $^{241}Am$, which have relatively high inhalation dose factors and are present in significant quantities: 1.1 x $10^{+7}$ and 3.9 x $10^{+4}$ curies, respectively. Twenty-six tanks account for 90% of the cumulative carcinogenic ranking scores through the atmospheric pathway, while 79 tanks account for 99%, 116 tanks account for 99.9%, and 139 tanks account for 99.99% of the cumulative carcinogenic ranking scores through the atmospheric pathway.

The dominant carcinogenic contaminants associated with the atmospheric pathway ranking that account for 99% of the cumulative carcinogenic ranking scores from the HLW tanks are $^{137}Cs$, $^{237}Np$, $^{241}Am$, $^{90}Sr$, $^{239}Pu$, $^{240}Pu$, $^{243}Am$, and $^{106}Ru$. These carcinogenic contaminants ranked high mainly because of their high toxicity values for inhalation, and they are present in significant quantities. Of course, high values of Q, RF, and P also may contribute to the high ranking.

Table 3.7 lists the HLW tanks by their atmospheric pathway $PAS_N$ ranking score. Appendix B provides a description of the $PSI_N$ values for the atmospheric pathway summed over all contaminants per HLW tank and for each HLW tank by contaminant available in an electronic file form

Five tanks account for approximately 44% of the cumulative noncarcinogenic ranking scores, based on $PAS_N$ values (e.g., all of these tanks are in the N08 category). These tanks are 241-BY-104, 241-SX-101, 241-SX-109, 241-SY-101, and 241-TY-101. Chromium VI is the dominate contaminant associated with the $PAS_N$ values for these tanks because of its high toxicity values for ingestion and inhalation, and its significant quantity (7.54 x $10^{+8}$ grams). All the chromium reported in the HLW tanks was assumed to be chromium VI, which is a conservative assumption but resulted in relatively low ranking scores (e.g., N08 for chromium VI in atmospheric pathway compared to N13 for nitrate in groundwater pathway).

Nineteen tanks account for 90% of the cumulative noncarcinogenic ranking scores through the groundwater pathway, while 50 tanks account for 99%, 87 tanks account for 99.9%, and 123 tanks account for 99.99% of the cumulative noncarcinogenic ranking scores through the atmospheric pathway. The dominant hazardous materials are chromium VI, which accounts for over 98% of the overall noncarcinogenic ranking scores for all the tanks, nitrite, EDTA, lead, aluminum, chromic acid, and phosphate. Although these contaminants accounted for most of the ranking scores, this does not mean that the health impacts are significant.

### 3.2.4 Summary of HLW Tanks Based on Atmospheric and Surface Water Pathways

Table 3.8 lists the HLW tanks by their atmospheric and surface water pathways which associated $PAS_C$ values summed. These pathways were combined to provide a ranking of tanks based on current conditions (e.g., institutional control with no groundwater use on- or off-site). Appendix B provides a description of the $PSI_C$ values for the atmospheric and surface water pathways summed over all contaminants per HLW tank and for each HLW tank by contaminant available in an electronic file form.

The highest ranking tanks (greatest health impacts) based on $PAS_C$ values (all of these tanks are in the C13 category) are 241-S-112, 241-AN-104, and 241-SY-103. The contaminants that contributed the most to the high ranking of these three tanks were $^{137}Cs$ and $^{241}Am$, which have relatively high inhalation dose factors and are present in significant quantities: 1.1 x $10^{+7}$ and 3.9 x $10^{+4}$ curies, respectively. Thirty-one tanks account for 90% of the cumulative carcinogenic ranking scores through the groundwater pathway, while 84 tanks account for 99%, 118 tanks account for 99.9%, and 139 tanks account for 99.99% of the cumulative carcinogenic ranking scores through the surface water pathway.

The dominant carcinogenic contaminants associated with the atmospheric pathway ranking that account for 99% of the cumulative carcinogenic ranking scores from the HLW tanks are $^{137}Cs$, $^{241}Am$, $^{237}Np$, $^{14}C$, $^{90}Sr$, $^{129}I$, $^{239}Pu$, and $^{99}Tc$. These carcinogenic contaminants ranked high mainly because of large URF values for the atmospheric pathway. Of course, high values of Q, RF, and P also may have contributed to the high ranking.

Table 3.9 provides a list of the HLW tanks by their atmospheric and surface water pathways $PAS_N$ ranking. Appendix B provides a description of the $PSI_N$ values for the atmospheric and surface water pathways summed over all contaminants per HLW tank and for each HLW tank by contaminant available in an electronic file form.

There are six tanks that account for approximately 50% of the cumulative noncarcinogenic ranking scores, based on $PAS_N$ values (e.g., all of these tanks are in the N11 category). These tanks are 241-SX-110, 241-SX-115, 241-SX-114, 241-SX-109, 241-SX-108, and 241-B-111. Nitrate is the dominate contaminant associated with the $PAS_N$ values for these tanks because it is highly mobile in the subsurface soil and aquifer and present in significant quantities (8.3 x $10^{+10}$ grams). Twenty-four tanks account for 90% of the cumulative noncarcinogenic ranking scores through the surface water and atmospheric pathways, while 39 tanks account for 99%, 79 tanks account for 99.9%, and 109 tanks account for 99.99% of the cumulative noncarcinogenic ranking scores through the surface water and atmospheric pathways. The dominant hazardous chemicals are nitrate (which accounts for over 99% of the overall noncarcinogenic ranking scores for all the tanks), chromium VI, EDTA, fluoride, sodium hydroxide, and thallium.

Table 3.10 is a summary of the $PAS_C$ ranking scores by the different exposure pathways. This table indicates that the groundwater pathway has the highest ranking scores by several categories over surface water and atmospheric pathways. Note that the $PAS_C$ categories are on a logarithmic scale (e.g., C12 category is approximately one order of magnitude higher in carcinogenic health impact than C11).

Table 3.11 is a summary of the $PAS_N$ ranking scores by the different exposure pathways. This table indicates that the groundwater pathway has the highest ranking scores by two categories over the surface water pathway, and by five categories over the atmospheric pathway. Note that the $PAS_N$ categories are on a logarithmic scale (e.g., N12 category is approximately one order of magnitude higher in noncarcinogenic health impacts than N11).

The uncertainty associated with these results is generally plus or minus one order of magnitude (e.g., $\pm$ 1 PAS category). This uncertainty range accounts for the specific uncertainty associated with each parameter; Q, RF, P, and URF. Uncertainties associated with modular risk analysis require that the results be used for scoping and preliminary analysis. Detailed analysis must be done to support formal decisions on HLW tank cleanup.

**Table 3.2.** List of HLW Tanks by Groundwater Pathway $PAS_C$ Ranking Value

| $PAS_C$ | # of Tanks | List of Tank Names |
|---|---|---|
| C15 | 1 | B-111 |
| C14 | 8 | A-104, BX--110, BX-111, S-104, SX-104, TX-110, TY-103, TY-104 |
| C13 | 17 | A-103, B-112, BY-103, BY-105, BY-107, BY-108, C-101, SX-113, SX-115, TX-105, TX-113, TX-115, TX-117, TY-105, U-101, U-110, U-112 |
| C12 | 26 | A-102, A-105, B-101, B-103, B-105, B-107, BX-102, BX-104, BX-106, BY-104, C-103, C-111, S-109, S-112, SX-103, SX-105, SX-108, SX-110, SX-111, SX-112, SX-114, TX-109, TX-114, TX-116, TX-118, TY-101 |
| C11 | 31 | AX-104, B-110, BX-103, BX-112, BY-101, BY-102, BY-106, BY-109, BY-110, BY-111, BY-112, C-105, C-202, S-101, S-106, S-108, S-110, S-111, SX-102, SX-106, SX-107, SX-109, T-101, T-106, T-107, T-108, T-109, T-111, TY-106, U-102, U-107 |
| C10 | 32 | A-101, A-106, AN-102, AN-103, AN-106, AW-101, AX-103, AZ-101, AZ-102, B-108, B-109, BX-101, BX-105, BX-109, C-102, C-104, C-107, C-112, C-203, S-105, S-107, T-103, TX-101, TX-102, TX-106, TX-108, TX-111, TX-112, U-109, U-111, U-201, U-202 |
| C09 | 23 | AP-102, AW-103, AX-101, B-102, B-104, B-106, B-202, BX-107, C-106, C-108, C-109, C-201, SX-101, SY-102, T-102, T-104, T-105, T-112, TX-103, TY-102, U-108, U-203, U-204 |
| C08 | 7 | AX-102, AY-102, BX-108, C-110, S-102, T-110, U-105 |
| C07 | 4 | AW-105, C-204, S-103, U-103 |
| C06 | 2 | AP-104, SY-101 |
| C05 | 0 | |
| C04 | 1 | TX-104 |
| C03 | 0 | |
| C02 | 0 | |
| C01 | 0 | |
| C00 | 20 | AN-101, AN-104, AN-105, AN-107, AP-103, AW-102, AW-104, AW-106, AY-101, B-201, B-203, B-204, SY-103, T-201, T-202, T-203, T-204, TX-107, U-104, U-106 |

**Table 3.3.** List of HLW Tanks by Groundwater Pathway $PAS_N$ Ranking Value

| $PAS_N$ | # of Tanks | List of Tank Names |
|---|---|---|
| N13 | 5 | SX-108, SX-109, SX-110, SX-114, SX-115 |
| N12 | 28 | A-104, B-101, B-105, B-107, B-111, B-112, BY-105, BY-107, BY-108, C-101, S-104, SX-102, SX-104, SX-107, SX-111, SX-112, SX-113, TX-105, TX-107, TX-110, TX-113, TX-115, TX-116, TX-117, TY-101, TY-105, U-110, U-112 |
| N11 | 12 | A-102, A-103, B-103, BY-103, C-111, S-112, SX-103, T-106, T-109, TX-114, TX-118, TY-103 |
| N10 | 32 | A-101, A-105, AX-103, B-204, BX-102, BX-106, BX-111, BY-101, BY-110, BY-111, C-105, C-204, S-102, S-105, S-106, S-108, S-109, S-110, S-111, SX-105, SX-106, TX-101, TX-104, TX-108, TX-109, TX-112, TY-106, U-102, U-105, U-106, U-107, U-108 |
| N09 | 40 | AN-102, AN-103, AN-106, AN-107, AW-101, AW-103, AW-104, AX-101, B-104, B-108, B-109, B-110, B-203, BX-101, BX-110, BY-104, BY-106, C-103, C-106, C-107, C-201, S-101, S-103, S-107, SX-101, SY-101, SY-103, T-101, T-104, T-108, T-111, TX-102, TX-103, TX-106, TX-111, TY-102, TY-104, U-103, U-109, U-111 |
| N08 | 30 | AN-101, AN-104, AN-105, AW-102, AY-101, AZ-101, AZ-102, B-102, B-106, B-202, BX-103, BX-104, BX-105, BX-107, BX-112, BY-102, BY-109, BY-112, C-102, C-104, C-112, SY-102, T-103, T-105, T-107, T-202, T-203, U-101, U-201, U-202 |
| N07 | 13 | A-106, AW-105, AW-106, AX-104, BX-108, BX-109, C-108, C-109, C-110, T-102, T-110, U-104, U-203 |
| N06 | 6 | AP-103, AY-102, B-201, T-112, T-204, U-204 |
| N05 | 3 | AP-102, AX-102, C-202 |
| N04 | 2 | AP-104, C-203 |
| N03 | 0 | |
| N02 | 0 | |
| N01 | 1 | T-201 |
| N00 | 0 | |

**Table 3.4.** List of HLW Tanks by Surface Water Pathway $PAS_C$ Ranking Value

| $PAS_C$ | # of Tanks | List of Tank Names |
|---|---|---|
| C12 | 4 | A-104, B-111, S-104, TY-103 |
| C11 | 14 | A-103, B-112, BX-110, BX-111, BY-105, BY-107, BY-108, SX-104, SX-113, SX-115, TX-105, TX-110, TX-113, TY-104 |
| C10 | 20 | A-105, B-101, B-103, B-105, B-107, BX-102, BX-106, BY-103, C-101, S-112, SX-103, TX-114, TX-115, TX-116, TX-117, TX-118, TY-105, U-101, U-110, U-112 |
| C09 | 33 | A-102, AX-104, B-110, BX-103, BX-104, BY-101, BY-104, BY-106, BY-109, BY-110, BY-111, C-103, C-111, S-101, S-108, S-109, S-110, S-111, SX-102, SX-105, SX-106, SX-107, SX-108, SX-109, SX-110, SX-111, SX-112, SX-114, T-101, T-106, T-109, TX-109, TY-101 |
| C08 | 27 | AN-102, AN-103, AX-103, AZ-101, B-108, B-109, BX-101, BX-105, BX-109, BX-112, BY-102, BY-112, C-102, C-105, C-202, S-105, S-106, T-103, T-107, T-108, T-111, TX-101, TX-108, TX-111, TY-106, U-102, U-107 |
| C07 | 35 | A-101, A-106, AN-106, AP-102, AW-101, AZ-102, B-102, B-104, B-106, B-202, BX-107, C-104, C-106, C-107, C-108, C-109, C-112, C-203, S-107, SY-102, T-102, T-104, T-105, T-112, TX-102, TX-103, TX-106, TX-112, TY-102, U-109, U-111, U-201, U-202, U-203, U-204 |
| C06 | 9 | AW-103, AX-101, AY-102, BX-108, C-201, S-102, SX-101, T-110, U-108 |
| C05 | 4 | AX-102, C-110, S-103, U-105 |
| C04 | 5 | AP-104, AW-105, C-204, SY-101, U-103 |
| C03 | 0 | |
| C02 | 1 | TX-104 |
| C01 | 0 | |
| C00 | 20 | AN-101, AN-104, AN-105, AN-107, AP-103, AW-102, AW-104, AW-106, AY-101, B-201, B-203, B-204, SY-103, T-201, T-202, T-203, T-204, TX-107, U-104, U-106 |

**Table 3.5.** List of HLW Tanks by Surface Water Pathway $PAS_N$ Ranking Value

| $PAS_N$ | # of Tanks | List of Tank Names |
|---|---|---|
| N11 | 6 | B-111, SX-108, SX-109, SX-110, SX-114, SX-115 |
| N10 | 28 | A-104, B-101, B-105, B-107, B-112, BY-105, BY-107, BY-108, C-101, S-104, SX-102, SX-104, SX-107, SX-111, SX-112, SX-113, T-106, TX-105, TX-107, TX-110, TX-113, TX-115, TX-116, TX-117, TY-101, TY-105, U-110, U-112 |
| N09 | 8 | BY-103, C-111, S-112, SX-103, T-109, TX-114, TX-118, TY-103 |
| N08 | 35 | A-101, A-102, A-103, A-105, AW-103, AX-101, AX-103, B-103, B-110, B-204, BX-102, BX-111, BY-101, BY-110, BY-111, C-105, C-204, S-102, S-105, S-106, S-108, S-109, S-110, S-111, SX-105, TX-101, TX-104, TX-108, TX-109, TX-112, TY-106, U-102, U-105, U-106, U-108 |
| N07 | 40 | AN-102, AN-103, AN-105, AN-107, AW-101, AW-104, AZ-101, AZ-102, B-104, B-108, B-109, B-203, BX-101, BX-106, BX-110, BY-104, BY-106, C-104, C-106, C-201, S-101, S-103, S-107, SX-101, SX-106, SY-101, SY-103, T-101, T-104, T-108, TX-102, TX-103, TX-106, TX-111, TY-102, TY-104, U-103, U-107, U-109, U-111 |
| N06 | 29 | AN-101, AN-104, AN-106, AW-102, AX-104, AY-101, B-102, B-106, B-202, BX-103, BX-104, BX-105, BX-107, BX-112, BY-102, BY-109, BY-112, C-102, C-103, C-107, C-112, SY-102, T-103, T-111, T-202, T-203, U-101, U-201, U-202 |
| N05 | 12 | AW-105, AW-106, BX-108, BX-109, C-108, C-109, C-110, T-102, T-105, T-107, T-110, U-203 |
| N04 | 6 | A-106, AP-103, AY-102, T-112, U-104, U-204 |
| N03 | 4 | AP-102, AX-102, B-201, T-204 |
| N02 | 2 | AP-104, C-202 |
| N01 | 1 | C-203 |
| N00 | 1 | T-201 |

**Table 3.6.** List of HLW Tanks by Atmospheric Pathway $PAS_C$ Ranking Value

| $PAS_C$ | # of Tanks | List of Tank Names |
|---|---|---|
| C13 | 3 | AN-104, S-112, SY-103 |
| C12 | 22 | AN-103, AN-105, AW-101, AW-104, AX-103, AX-104, AZ-101, AZ-102, BX-102, BY-104, BY-106, BY-110, BY-111, C-106, S-111, SX-102, SX-103, SX-105, SY-101, TY-102, U-105, U-109 |
| C11 | 41 | A-101, A-103, A-104, A-105, A-106, AN-101, AN-102, AN-106, AN-107, AW-106, AY-101, AY-102, B-111, BY-101, BY-103, BY-105, BY-107, BY-108, C-103, C-104, C-105, C-111, S-101, S-104, S-110, SX-101, SX-104, SX-106, SX-107, SX-109, SX-111, SX-113, SX-114, SX-115, TX-104, TX-109, TX-110, TY-103, U-102, U-106, U-108 |
| C10 | 51 | A-102, AW-102, AW-103, AX-101, B-101, B-103, B-108, B-109, B-110, B-112, BX-104, BX-105, BX-106, BY-102, BY-112, C-101, C-102, C-108, C-112, S-102, S-103, S-106, S-107, S-108, S-109, SX-108, SX-110, SX-112, SY-102, T-104, T-106, T-110, TX-101, TX-105, TX-106, TX-107, TX-108, TX-111, TX-112, TX-114, TX-115, TX-116, TX-118, TY-101, TY-104, TY-105, U-101, U-103, U-107, U-110, U-112 |
| C09 | 33 | AW-105, AX-102, B-102, B-104, B-105, B-106, B-107, B-201, B-202, B-204, BX-101, BX-103, BX-111, BX-112, BY-109, C-107, C-109, C-110, S-105, T-101, T-103, T-105, T-109, T-111, T-112, TX-102, TX-103, TX-113, TX-117, TY-106, U-111, U-201, U-202 |
| C08 | 11 | AP-103, B-203, BX-107, BX-108, BX-109, BX-110, C-201, T-102, T-107, T-108, U-104 |
| C07 | 4 | C-203, C-204, T-203, T-204 |
| C06 | 5 | AP-102, C-202, T-202, U-203, U-204 |
| C05 | 1 | AP-104 |
| C04 | 0 | |
| C03 | 0 | |
| C02 | 0 | |
| C01 | 0 | |
| C00 | 1 | T-201 |

**Table 3.7.** List of HLW Tanks by Atmospheric Pathway $PAS_N$ Ranking Value

| $PAS_N$ | # of Tanks | List of Tank Names |
|---|---|---|
| N08 | 5 | BY-104, SX-101, SX-109, SY-101, TY-101 |
| N07 | 27 | AN-103, AN-104, AW-101, AX-101, S-101, S-102, S-104, S-107, S-110, S-111, S-112, SX-102, SX-103, SX-105, SX-107, SX-108, SX-110, SX-111, SX-112, SX-114, SX-115, SY-102, SY-103, T-110, TX-118, TY-103, U-110 |
| N06 | 33 | A-101, A-103, A-106, AN-102, AN-105, AN-106, AX-103, AY-102, AZ-101, AZ-102, B-104, B-110, BX-102, BX-106, BY-103, BY-105, BY-107, BY-108, BY-110, BY-111, C-104, C-105, S-105, S-106, S-108, S-109, SX-104, SX-106, T-104, T-111, TX-109, TX-113, U-111 |
| N05 | 45 | A-102, A-104, AN-107, AW-103, AW-104, AX-104, B-101, B-103, B-105, B-107, B-108, B-111, B-112, B-202, B-204, BY-101, BY-106, C-103, C-106, C-108, C-109, C-111, C-112, S-103, SX-113, T-105, T-107, T-112, T-203, TX-101, TX-104, TX-105, TX-108, TX-110, TX-114, TX-116, TX-117, TY-104, U-103, U-105, U-106, U-107, U-108, U-109, U-112 |
| N04 | 37 | AN-101, AP-102, AP-104, AW-102, AW-106, AY-101, B-102, B-106, B-109, B-203, BX-101, BX-104, BX-105, BX-107, BX-108, BX-111, BX-112, BY-112, C-101, C-107, C-110, T-101, T-103, T-106, T-108, T-109, T-202, TX-102, TX-103, TX-106, TX-107, TX-111, TX-112, TX-115, TY-102, TY-105, U-102 |
| N03 | 15 | A-105, AP-103, AW-105, AX-102, BX-103, BX-109, BX-110, BY-102, BY-109, C-102, TY-106, U-101, U-201, U-202, U-203 |
| N02 | 5 | C-201, C-204, T-102, T-204, U-204 |
| N01 | 0 | |
| N00 | 5 | B-201, C-202, C-203,T-201, U-104 |

**Table 3.8.** List of HLW Tanks by Atmospheric and Surface Water Pathway $PAS_C$ Ranking Value

| $PAS_C$ | # of Tanks | List of Tank Names |
|---|---|---|
| C13 | 3 | AN-104, S-112, SY-103 |
| C12 | 29 | A-104, AN-103, AN-105, AW-101, AW-104, AX-103, AX-104, AZ-101, AZ-102, B-111, BX-102, BY-104, BY-106, BY-107, BY-108, BY-110, BY-111, C-106, S-104, S-111, SX-102, SX-103, SX-105, SY-101, TY-102, TY-103, TY-104, U-105, U-109 |
| C11 | 42 | A-101, A-103, A-105, A-106, AN-101, AN-102, AN-106, AN-107, AW-106, AY-101, AY-102, B-112, BX-110, BX-111, BY-101, BY-103, BY-105, C-101, C-103, C-104, C-105, C-111, S-101, S-110, SX-101, SX-104, SX-106, SX-107, SX-109, SX-111, SX-113, SX-114, SX-115, TX-104, TX-105, TX-109, TX-110, TX-113, U-102, U-106, U-108, U-112 |
| C10 | 49 | A-102, AW-102, AW-103, AX-101, B-101, B-103, B-105, B-107, B-108, B-109, B-110, BX-104, BX-105, BX-106, BY-102, BY-112, C-102, C-108, C-112, S-102, S-103, S-106, S-107, S-108, S-109, SX-108, SX-110, SX-112, SY-102, T-104, T-106, T-110, TX-101, TX-106, TX-107, TX-108, TX-111, TX-112, TX-114, TX-15, TX-116, TX-117, TX-118, TY-101, TY-105, U-101, U-103, U-107, U-110 |
| C09 | 30 | AW-105, AX-102, B-102, B-104, B-106, B-201, B-202, B-204, BX-101, BX-103, BX-112, BY-109, C-107, C-109, C-110, S-105, T-101, T-103, T-105, T-107, T-108, T-109, T-111, T-112, TX-102, TX-103, TY-106, U-111, U-201, U-202 |
| C08 | 9 | AP-103, B-203, BX-107, BX-108, BX-109, C-201, C-202, T-102, U-104 |
| C07 | 7 | AP-102, C-203, C-204, T-203, T-204, U-203, U-204 |
| C06 | 1 | T-202 |
| C05 | 1 | AP-104 |
| C04 | 0 | |
| C03 | 0 | |
| C02 | 0 | |
| C01 | 0 | |
| C00 | 1 | T-201 |

**Table 3.9.** List of HLW Tanks by Atmospheric and Surface Water Pathway $PAS_N$ Ranking Value

| $PAS_N$ | # of Tanks | List of Tank Names |
|---|---|---|
| N11 | 6 | B-111, SX-108, SX-109, SX-110, SX-114, SX-115 |
| N10 | 28 | A-104, B-101, B-105, B-107, B-112, BY-105, BY-107, BY-108, C-101, S-104, SX-102, SX-104, SX-107, SX-111, SX-112, SX-113, T-106, TX-105, TX-107, TX-110, TX-113, TX-115, TX-116, TX-117, TY-101, TY-105, U-110, U-112 |
| N09 | 8 | BY-103, C-111, S-112, SX-103, T-109, TX-114, TX-118, TY-103 |
| N08 | 40 | A-101, A-102, A-103, A-105, AW-103, AX-101, AX-103, B-103, B-110, B-204, BX-102, BX-111, BY-101, BY-104, BY-110, BY-111, C-105, C-204, S-101, S-102, S-105, S-106, S-107, S-108, S-109, S-110, S-111, SX-101, SX-105, SY-101, TX-101, TX-104, TX-108, TX-109, TX-112, TY-106, U-102, U-105, U-106, U-108 |
| N07 | 39 | AN-102, AN-103, AN-104,AN-105, AN-106, AN-107, AW-101, AW-104, AZ-101, AZ-102, B-104, B-108, B-109, B-203, BX-101, BX-106, BX-110, BY-106, C-104, C-106, C-201, S-103, SX-106, SY-102, SY-103, T-101, T-104, T-108, T-110, TX-102, TX-103, TX-106, TX-111, TY-102, TY-104, U-103, U-107, U-109, U-111 |
| N06 | 31 | A-106, AN-101, AW-102, AX-104, AY-101, AY-102, B-102, B-106, B-202, BX-103, BX-104, BX-105, BX-107, BX-112, BY-102, BY-109, BY-112, C-102, C-103, C-107, C-108, C-112, T-103, T-105, T-107, T-111, T-202, T-203, U-101, U-201, U-202 |
| N05 | 9 | AW-105, AW-106, BX-108, BX-109, C-109, C-110, T-102, T-112, U-203 |
| N04 | 5 | AP-102, AP-103, AP-104, U-104, U-204 |
| N03 | 3 | AX-102, B-201, T-204 |
| N02 | 1 | C-202 |
| N01 | 1 | C-203 |
| N00 | 1 | T-201 |

**Table 3.10.** $PAS_C$ Ranking Scores by Exposure Pathway

| $PAS_C$ | Groundwater Pathway | Surface Water Pathway | Atmospheric Pathway |
|---|---|---|---|
| C15 | 1 | 0 | 0 |
| C14 | 8 | 0 | 0 |
| C13 | 17 | 0 | 3 |
| C12 | 26 | 4 | 22 |
| C11 | 31 | 14 | 41 |
| C10 | 32 | 20 | 51 |
| C09 | 23 | 33 | 33 |
| C08 | 7 | 27 | 11 |
| C07 | 4 | 35 | 4 |
| C06 | 2 | 9 | 5 |
| C05 | 0 | 4 | 1 |
| C04 | 1 | 5 | 0 |
| C03 | 0 | 0 | 0 |
| C02 | 0 | 1 | 0 |
| C01 | 0 | 0 | 0 |
| C00 | 20 | 20 | 1 |

**Table 3.11.** $PAS_N$ Ranking Scores by Exposure Pathway

| $PAS_N$ | Groundwater Pathway | Surface Water Pathway | Atmospheric Pathway |
|---|---|---|---|
| N13 | 5 | 0 | 0 |
| N12 | 28 | 0 | 0 |
| N11 | 12 | 6 | 0 |
| N10 | 32 | 28 | 0 |
| N09 | 40 | 8 | 0 |
| N08 | 30 | 35 | 5 |
| N07 | 13 | 40 | 27 |
| N06 | 6 | 29 | 33 |
| N05 | 3 | 12 | 45 |
| N04 | 2 | 6 | 37 |
| N03 | 0 | 4 | 15 |
| N02 | 0 | 2 | 5 |
| N01 | 1 | 1 | 0 |
| N00 | 0 | 1 | 5 |

# 4.0 References

Los Alamos National Laboratory (LANL). 1993. *Risk Assessment for Hanford High-Level Waste Tank 241-SY-101*. Draft Report, Los Alamos National Laboratory, Los Alamos, New Mexico.

Los Alamos National Laboratory (LANL). 1995. *Probabilistic Safety Assessment for Hanford High-Level Waste Tanks*. Draft Report, Los Alamos National Laboratory, Los Alamos, New Mexico.

Schramke, J. A., C. S. Glantz and G. R. Holdren. 1994. *Hanford Site Environmental Setting Data Developed for the Unit Risk Factor Methodology in Support of the Programmatic Environmental Impact Statement (PEIS)*. PNL-9802, Pacific Northwest Laboratory, Richland, Washington.

Strenge, D. L. and P. J. Chamberlain II. 1994. *Evaluation of Unit Risk Factors in Support of the Hanford Remedial Action Environmental Impact Statement*. PNL-10190, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy (DOE). 1993. *Tank Waste Remediation System Integrated Technology Program*. DOE/RL-92-61, Rev. 2, U.S. Department of Energy, Richland, Washington.

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

Westinghouse Hanford Company (WHC). 1993a. *Radionuclide and Chemical Inventories for the Single Shell Tanks*. WHC-SD-WM-TI-565, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1993b. *Radionuclide and Chemical Inventories for the Double Shell Tanks*. WHC-SD-WM-TI-543, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1994a. *Hanford Waste Vitrification Plant Preliminary Safety Analysis Report*. WHC-EP-0250, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1994b. *Tank Farm Surveillance and Waste Status Survey Report for September 1994*. WHC-EP-0182-78, Rev. 1, Westinghouse Hanford Company, Richland, Washington.Westinghouse Hanford Company (WHC). 1995a. *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 East Area*. WHC-SD-WM-ER-349, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1995b. *Historical Tank Content Estimate for the Southeast Quadrant of the Hanford 200 Areas*. WHC-SD-WM-ER-350, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1995c. *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 West Area*. WHC-SD-WM-ER-351, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1995d. *Historical Tank Content Estimate for the Southeast Quadrant of the Hanford 200 East Area*. WHC-SD-WM-ER-352, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1995e. *Tank Waste Source Term Inventory Validation*. WHC-SD-WM-ER-400, Volume 1 and 2, Rev. 0, Westinghouse Hanford Company, Richland, Washington. (Letter Report E01595LR, prepared by ICF Kaiser Hanford Company, Richland, Washington.)

Westinghouse Hanford Company (WHC). 1995f. *Waste Tank Summary Report for Month Ending January 31, 1995*. WHC-EP-0182-82, Westinghouse Hanford Company, Richland, Washington.

Whelan, G., J. W. Buck, K. J. Castleton, J. P. McDonald, C. Sato, G. M. Gelston, A. deHammer, R. J. Serne, S. K. Wurstner, R. N. Kickert. 1995. *Unit Environmental Transport Assessment of Contaminants from Hanford's Past-Practice Waste Sites*. PNL-10233, Pacific Northwest Laboratory, Richland, Washington.

# Appendix A

# Summary of High-Level Waste Tank Quantity Data

# Appendix A

## Summary of High-Level Waste Tank Quantity Data

This appendix is a description and excerpt of an electronic file that contains the quantity information associated with each tank by contaminant. This electronic file is available on a 3.5" floppy disk by request. Requests should be sent to Gariann Gelston, PNL via e-mail (gm_gelston@pnl.gov) or phone (509-946-7860). The electronic information is stored in a comma separated format (CSV) and can be read into most spreadsheet software (Lotus, Excel, Dbase, etc.). The following is a description of the data format and excerpt of the tank quantity data file.

**File Name: Qnt_Tank.CSV**

| Column # | Title | Description |
|---|---|---|
| 1 | Tank | This is the Tank Identification number (i.e. SY-101, B-111, etc.) |
| 2 | CAS | This is the contaminant identification number, which is based on the Chemical Abstract Services number for chemicals and the common alpha numeric nomenclature for radionuclides. |
| 3 | Name | This is the contaminant name. (This name may be left blank*) |
| 4 | Q | This is the quantity used in the PSI calculations. The units of Q are grams for chemicals and curies for radionuclides. |

* Because the data was tracked by CAS only, the existence of a name in the Name column was not necessary and therefore if a name was not entered in the input data files no name was added later.

**Excerpt of Qnt_Tank.CSV**

| Tank | CAS | Name | Q |
|---|---|---|---|
| A-101 | 7429905 | ALUMINUM | 1.83E+08 |
| A-101 | AM241 | AMERICIUM-241 | 1.00E+03 |
| A-101 | AM242 | AMERICIUM-242 | 9.00E-01 |
| A-101 | AM242M | AMERICIUM-242M | 8.92E-01 |
| A-101 | AM243 | AMERICIUM-243 | 2.97E-01 |
| A-101 | SB126 | | 3.00E+01 |
| A-101 | SB126M | | 3.00E+01 |
| A-101 | 7440393 | BARIUM | 1.90E+04 |
| A-101 | 7440702 | CALCIUM ION | 4.00E+02 |
| A-101 | 7440473 | CHROMIUM VI | 1.00E-02 |

# Appendix B

## Summary of $PSI_C$ and $PSI_N$ Values for High-Level Waste Tanks

# Appendix B

## Summary of $PSI_C$ and $PSI_N$ Values for High-Level Waste Tanks

This appendix is a description and excerpt of a set of two electronic files that contain the $PSI_C$ and $PSI_N$ values associated with each tank for each exposure pathway. One file contains $PSI_C$ and $PSI_N$ values for each HLW tank by contaminant and the other file contains $PSI_C$ and $PSI_N$ values summed over contaminant for each HLW tank. This electronic file is available on a 3.5" floppy disk by request. Requests should be sent to Gariann Gelston, PNL via e-mail (gm_gelston@pnl.gov) or phone (509-946-7860). The electronic information is stored in a comma separated format (CSV) and can be read into most spreadsheet software (Lotus, Excel, Dbase, etc.). The following is a description of each file's data format and excerpt of the tank PSI data files.

**File Name: PSI_Tank.CSV**

| Column # | Title | Description |
|---|---|---|
| 1 | Tank | This is the Tank Identification number (i.e. SY-101, B-111, etc.) |
| 2 | Name | This is the contaminant name. (This name may be left blank*) |
| 3 | CAS | This is the contaminant identification number, which is based on the Chemical Abstract Services number for chemicals and the common alpha numeric nomenclature for radionuclides. |
| 4 | GW $PSI_C$ | This is the Groundwater $PSI_C$ for each tank by contaminant. |
| 5 | GW $PSI_N$ | This is the Groundwater $PSI_N$ for each tank by contaminant. |
| 6 | SW $PSI_C$ | This is the Surface Water $PSI_C$ for each tank by contaminant. |
| 7 | SW $PSI_N$ | This is the Surface Water $PSI_N$ for each tank by contaminant. |
| 8 | Air $PSI_C$ | This is the Atmospheric $PSI_C$ for each tank by contaminant. |
| 9 | Air $PSI_N$ | This is the Atmospheric $PSI_N$ for each tank by contaminant. |
| 10 | Air + SW $PSI_C$ | This is the Surface Water $PSI_C$ for each tank by contaminant. |
| 11 | Air + SW $PSI_N$ | This is the Surface Water $PSI_N$ for each tank by contaminant. |

* Because the data was tracked by CAS only, the existence of a name in the Name column was not necessary and therefore if a name was not entered in the input data files no name was added at a later time.

**Excerpt of PSI_Tank.CSV**

| Tank | Name | CAS | GW $PSI_C$ | GW $PSI_N$ | SW $PSI_C$ | SW $PSI_N$ | Air $PSI_C$ | Air $PSI_N$ | Air + SW $PSI_C$ | Air +SW $PSI_N$ |
|---|---|---|---|---|---|---|---|---|---|---|
| A-101 | ALUMINUM | 7429905 | -- | -- | -- | -- | -- | 8.80E-09 | -- | 8.80E-09 |
| A-101 | AMERICIUM-241 | AM241 | -- | -- | -- | -- | 2.46E-09 | -- | 2.46E-09 | -- |
| A-101 | AMERICIUM-242 | AM242 | -- | -- | -- | -- | 5.95E-16 | -- | 5.95E-16 | -- |
| A-101 | AMERICIUM-242M | AM242M | -- | -- | -- | -- | 1.99E-12 | -- | 1.99E-12 | -- |
| A-101 | AMERICIUM-243 | AM243 | -- | -- | -- | -- | 7.26E-13 | -- | 7.26E-13 | -- |
| A-101 | ANTIMONY-126 | SB126 | -- | -- | -- | -- | 2.12E-14 | -- | 2.12E-14 | -- |
| A-101 | BARIUM | 7440393 | -- | -- | -- | -- | -- | 1.96E-11 | -- | 1.96E-11 |
| A-101 | CALCIUM ION | 7440702 | -- | -- | -- | -- | -- | 2.60E-18 | -- | 2.60E-18 |
| A-101 | CHROMIUM VI | 7440473 | -- | -- | -- | -- | 1.46E-20 | 1.80E-15 | 1.46E-20 | 1.80E-15 |
| A-101 | CURIUM-242 | CM242 | -- | -- | -- | -- | 1.63E-13 | -- | 1.63E-13 | -- |
| A-101 | LEAD | 7439921 | -- | -- | -- | -- | -- | 1.53E-12 | -- | 1.53E-12 |
| A-101 | MANGANESE | 7439965 | -- | -- | -- | -- | -- | 5.77E-13 | -- | 5.77E-13 |
| A-101 | NEPTUNIUM-237 | NP237 | -- | -- | -- | -- | 9.02E-15 | -- | 9.02E-15 | -- |
| A-101 | NICKEL | 7440020 | -- | -- | -- | -- | 3.58E-15 | 2.08E-13 | 3.58E-15 | 2.08E-13 |
| A-101 | NICKEL-63 | NI63 | -- | -- | -- | -- | 3.11E-12 | -- | 3.11E-12 | -- |

**File Name: Tot_Tank.CSV**

| Column # | Title | Description |
|---|---|---|
| 1 | Tank | This is the Tank Identification number (i.e. SY-101, B-111, etc.) |
| 2 | GW $PSI_C$ | This is the Groundwater $PSI_C$ cumulative by tank. |
| 3 | GW $PSI_N$ | This is the Groundwater $PSI_N$ cumulative by tank. |
| 4 | SW $PSI_C$ | This is the Surface Water $PSI_C$ cumulative by tank. |
| 5 | SW $PSI_N$ | This is the Surface Water $PSI_N$ cumulative by tank. |
| 6 | Air $PSI_C$ | This is the Atmospheric $PSI_C$ cumulative by tank. |
| 7 | Air $PSI_N$ | This is the Atmospheric $PSI_N$ cumulative by tank. |
| 8 | Air + SW $PSI_C$ | This is the Surface Water $PSI_C$ cumulative by tank. |
| 9 | Air + SW $PSI_N$ | This is the Surface Water $PSI_N$ cumulative by tank. |

**Excerpt of Tot_Tank.CSV**

| Tank | GW $PSI_C$ | GW $PSI_N$ | SW $PSI_C$ | SW $PSI_N$ | Air $PSI_C$ | Air $PSI_N$ | Air+SW $PSI_C$ | Air+SW $PSI_N$ |
|---|---|---|---|---|---|---|---|---|
| A-101 | 1.85E-10 | 3.00E-04 | 5.21E-13 | 3.37E-06 | 9.99E-09 | 2.16E-08 | 9.99E-09 | 3.39E-06 |
| A-102 | 1.07E-08 | 1.11E-03 | 6.34E-11 | 2.27E-06 | 7.10E-10 | 6.89E-09 | 7.73E-10 | 2.27E-06 |
| A-103 | 7.69E-07 | 2.24E-03 | 1.69E-09 | 4.67E-06 | 2.33E-09 | 5.06E-08 | 4.02E-09 | 4.72E-06 |
| A-104 | 3.24E-06 | 8.79E-02 | 2.08E-08 | 9.88E-04 | 3.34E-09 | 1.88E-09 | 2.42E-08 | 9.88E-04 |
| A-105 | 4.70E-08 | 3.91E-04 | 2.04E-10 | 4.38E-06 | 2.21E-09 | 3.84E-11 | 2.41E-09 | 4.38E-06 |
| A-106 | 1.28E-10 | 1.50E-07 | 3.95E-13 | 2.95E-10 | 1.37E-09 | 7.03E-08 | 1.37E-09 | 7.06E-08 |
| AX-101 | 3.18E-11 | 9.30E-05 | 9.73E-14 | 1.04E-06 | 2.76E-10 | 1.87E-07 | 2.76E-10 | 1.23E-06 |
| AX-102 | 1.19E-12 | 7.50E-09 | 3.33E-15 | 1.47E-11 | 1.35E-11 | 4.28E-11 | 1.35E-11 | 5.75E-11 |
| AX-103 | 3.29E-10 | 1.73E-04 | 1.62E-12 | 1.94E-06 | 6.25E-08 | 1.33E-08 | 6.25E-08 | 1.96E-06 |
| AX-104 | 2.41E-09 | 9.60E-07 | 1.40E-11 | 1.05E-08 | 7.86E-08 | 2.34E-09 | 7.86E-08 | 1.28E-08 |
| B-101 | 6.04E-08 | 3.35E-02 | 2.56E-10 | 3.77E-04 | 1.48E-10 | 7.81E-09 | 4.04E-10 | 3.77E-04 |
| B-102 | 6.65E-11 | 3.78E-06 | 2.98E-13 | 4.24E-08 | 1.91E-11 | 4.08E-10 | 1.94E-11 | 4.28E-08 |

# Distribution

| No. of Copies | | |
|---|---|---|
| **OFFSITE** | | |
| 2 | DOE/Office of Scientific and Technical Information | |
| **ONSITE** | | |
| 4 | DOE Richland Operations Office | |
| | S. E. Clarke | A5-52 |
| | D. J. Francis | K6-51 |
| | S. T. Hwang | A5-18 |
| | J. D. Kautzky | A5-58 |
| 1 | Advanced Sciences, Inc. | |
| | A. M. Nazarali | G6-75 |
| 8 | Westinghouse Hanford Company | |
| | S. S. Bath | A6-54 |
| | P. A. Baynes | H6-33 |
| | J. S. Davis | H5-49 |
| | G. Jenson, Jr. | H6-33 |
| | D. J. Garbrick | H6-33 |
| | B. J. Knutson | H6-33 |
| | A. K. Lee | H6-33 |
| | R. S. Wittman | H6-33 |
| 76 | Pacific Northwest Laboratory | |
| | G. R. Bilyard | K8-03 |
| | J. W. Buck (10) | K6-80 |
| | K. J. Castleton | K6-80 |
| | P. G. Doctor | K8-37 |
| | J. G. Droppo, Jr. | K6-80 |
| | J. S. Dukelow, Jr. | K8-37 |
| | R. M. Ecker | K6-91 |
| | P. W. Eslinger | K3-54 |
| | W. T. Farris (10) | K3-54 |
| | S. W. Gajewski | K8-03 |
| | G. M. Gelston (25) | K6-80 |
| | C. S. Glantz | K6-80 |
| | B. L. Harper | K3-54 |
| | S. W. Heaberlin | K8-31 |
| | J. L. Huckaby | K6-80 |
| | T. A. Ikenberry | K3-54 |
| | T. T. Jarvis | K8-03 |
| | J. A. Mahaffey | P7-82 |
| | M. J. Quadrel | K9-60 |
| | R.K. Quinn | K9-69 |
| | D. A. Seaver | S7-71 |
| | M. R. Shay | K7-94 |
| | R. D. Stenner | K3-54 |
| | T. L. Stewart | K9-91 |
| | W. G. Stillwell | K9-09 |
| | D. L. Strenge | K3-54 |
| | G. Whelan | K9-36 |
| | M. K. White | K7-94 |
| | T. W. Wood | K7-94 |
| | Technical Report Files (5) | |