

**IMMOBILIZED LOW ACTIVITY TANK WASTE
INVENTORY DATA PACKAGE**

RECEIVED
JUL 03 2010
EDMC

D2-11

TABLE OF CONTENTS

1.0	INTRODUCTION	1
1.1	Background	1
1.2	Objectives	1
2.0	LAW PROCESSING	2
2.1	Tank Inventories	2
2.2	Liquid and Solid Partitioning	4
2.3	Feed delivery	4
2.4	Phase 1 and Phase 2	4
2.5	Pretreatment	5
2.6	Vitrification	5
2.7	Offgas Losses and Recycle	5
2.8	Phase 1 Privatization Contract Limitations	6
3.0	NOMINAL INVENTORIES	7
4.0	UPPER BOUNDS FOR RADIONUCLIDES AND CHEMICALS	8
4.1	Total ILAW Inventories	8
4.2	ILAW Package Upper Bounds	19
4.3	Hazardous Chemicals	27
5.0	CONCLUSIONS	29
6.0	REFERENCES	29

APPENDICIES

Appendix A	A-1
Appendix B	B-1
Appendix C	C-1
Appendix D	D-1
Appendix E	E-1
Appendix F	F-1

RECEIVED
JUL 10 1978

EDMC

IMMOBILIZED LOW ACTIVITY WASTE INVENTORY DATA PACKAGE

1.0 INTRODUCTION

1.1 Background

Radionuclide and chemical inventories in the Immobilized Low Activity Waste (ILAW) product are needed to support the 2001 Low Level Tank Waste Performance Assessment (ILAW PA). Previously, radionuclide inventories were generated for the Performance Assessment (Mann 1998) based on ORIGEN2 calculations of total radionuclide production, with adjustments for estimated losses to obtain total glass inventories (Schmittroth 1995). New inventories are needed that reflect current operational planning and include nominal and reasonable bounding values that account for the variability between individual ILAW packages.

1.2 Objectives

The objective of this study is to provide radionuclide and chemical inventories for the 2001 ILAW PA that are based on 1) the Tank Waste Retrieval System (TWRS) Characterization Program tank-by-tank Best Basis Inventories (BBI), 2) the latest U.S. Department of Energy – Office of River Protection guidance, 3) the privatization contract for Phase 1 waste retrieval and vitrification, 4) available information on the BNFL, Inc. pretreatment and vitrification processes, and 5) proposed operating scenarios for retrieval of waste from double shell tanks (DST) and single shell tanks (SST) and delivery of feed to BNFL, Inc. and future low level waste vitrification contractors. These inventories address variability between individual ILAW packages as a function of time due to processing sequence. Both nominal and reasonable upper bounding values, along with a general assessment of uncertainties for key inventory components, are provided.

1.3 Approach

Nominal ILAW package radionuclide and chemical inventories are based on the latest edition of the Tank Waste Remediation System Operation and Utilization Plan (TWRSO&UP) (Kirkbride 1999), which incorporates BBI tank inventories, DOE guidance, the privatization contract requirements for Phase 1, and waste retrieval operations planning studies. The project planning case (Case 3) is used, which is based on the April 1, 1999, DOE Guidance (Taylor 1999), and completes processing in 2034. The TWRSO&UP provides processed inventories at the time of vitrification for each batch of LAW feed vitrified into ILAW. These batchwise inventories included losses associated with tank retrieval and feed preparation, but did not include offgas losses. For this study, the ILAW inventories were adjusted for estimated losses of volatile species during the vitrification process.

Inventories of trace organic and dangerous waste constituents not covered by the TWRSO&UP are treated as bounded by the land disposal restriction treatment standards described in the Tank Waste Remediation System - Privatization Project Dangerous Waste Permit Application (BNFL 1999).

Reasonable upper bounds are developed for the total ILAW inventory and representative ILAW package inventory for key inventory components based on Best Basis tank inventories, global process based tank inventories, total reactor production, batch-to-batch variations from the tank processing operations, and Phase 1 contract specifications. The bounding values and uncertainties are based on qualitative considerations and conservative assumptions since consistent quantitative uncertainty information on the tank inventories, separation factors, and process losses are not available at this time.

2.0 LAW PROCESSING

The LAW processing involves 1) retrieval of tank contents, 2) producing LAW feed through separation of solid and liquid components by water washing and caustic leaching, 3) pretreating the liquid LAW feed to concentrate and remove selected components as required in the Phase 1 contract, and 4) vitrification of the pretreated LAW feed with recycle of captured offgasses. Figure 1 provides a simplified process flow diagram for the ILAW processing.

Feed material transferred to BNFL Inc. and Phase 2 treatment contractors is subjected to a series of pretreatment and treatment operations, such as caustic leaching, radionuclide separations, and immobilization. Current models are based on the Project Hanford Management Contract (PHMC) understanding of these operations (Kirkbride 1999). As discussed in Kirkbride 1999,

"It is unlikely that future Private Contractors will propose drastically different flowsheets or come to drastically different conclusions about the final product volume unless DOE's long term strategy undergoes major changes. Those volumes are driven by a relatively small number of parameters that are for the most part understood and not expected to change."

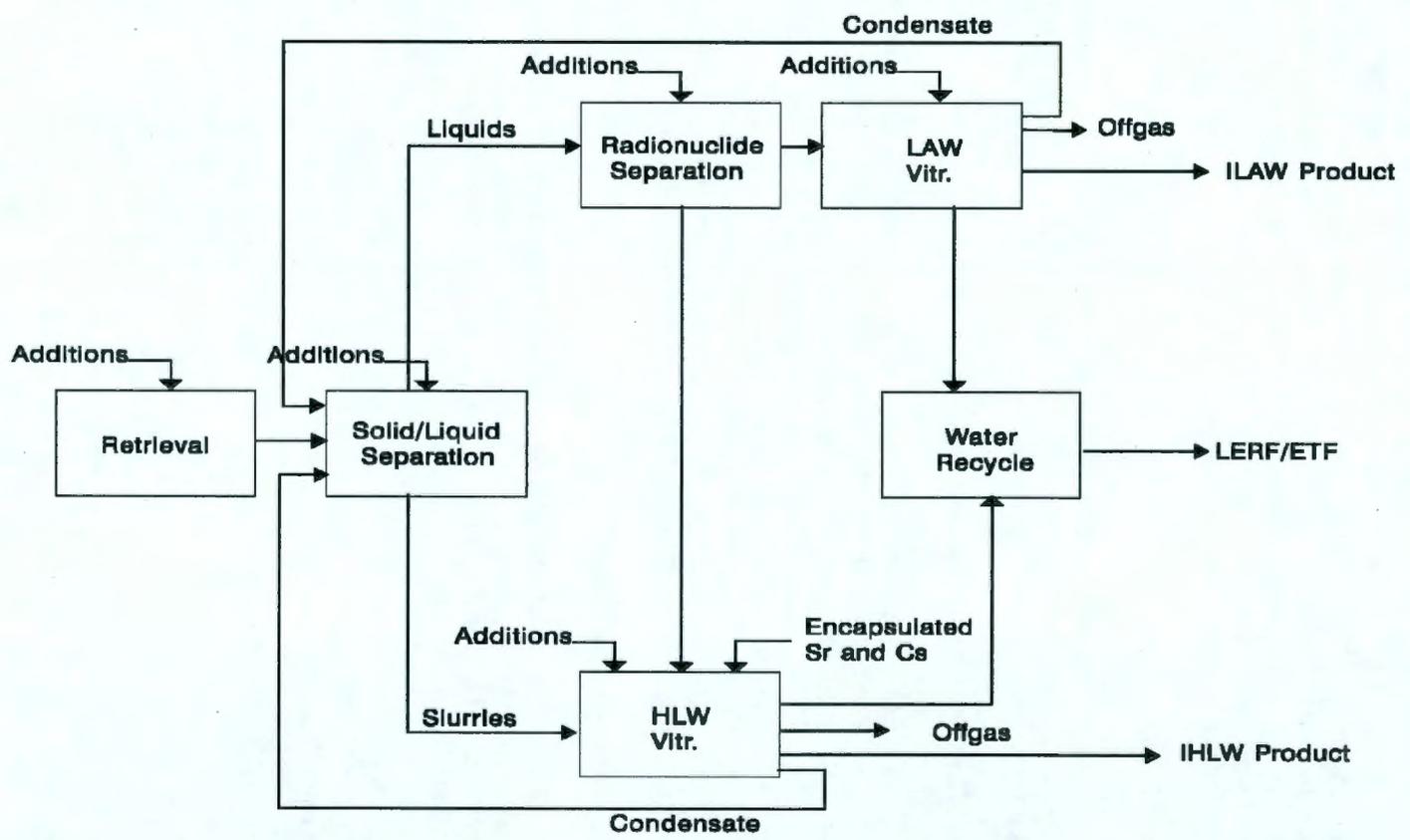
These models could be improved by more specific details of the Phase 1 and Phase 2 processes from BNFL Inc. and the Phase 2 contractor as they become available.

2.1 Tank Inventories

The DST and SST inventories developed for the TWRSO&UP (Kirkbride 1999) provide the starting point for the ILAW inventories. The tank inventory for the TWRSO&UP is based on the tank-by-tank best basis inventory (BBI) data as of October 1, 1998, (LMHC 1998). The BBI includes 46 radionuclides and 25 chemicals. For the TWRSO&UP studies, the BBI values were adjusted for waste transfers not accounted for in the BBI, data were added for non-BBI analytes that are in the BNFL contract, and the BBI inventories were adjusted to a common date (October 1, 1998). Details of these adjustments can be found in the TWRSO&UP (Kirkbride 1999).

The BBIs were developed by considering and reconciling all sources of tank inventory information (sample results, engineering assessments, and inventory predictions from the Hanford Defined Waste (HDW) model). The HDW model (Agnew 1997) supports the BBI effort by providing the basis for distribution on a tank-by-tank basis for radionuclides that were not represented by tank specific sample data.

Figure 1 Simplified Process Flowsheet for ILAW Processing



2.2 Liquid and Solid Partitioning

In the TWRSO&UP the BBI tank-by-tank inventories were partitioned into water soluble and water-insoluble phases using the most recent water wash data for each tank (Hendrickson 1998). Caustic wash data (Colton 1997) were applied to the HLW feed calculations (Kirkbride 1999). The tank inventory components were distributed between liquid and solid phases in the TWRSO&UP by applying tank specific wash factors for every BBI analyte (Hendrickson 1998). Global caustic leach factors were applied to the water-insoluble phases to model the LAW generated as part of the HLW feed preparation.

2.3 Feed delivery

The project planning case (Case 3) in the TWRSO&UP is based on the April 1, 1999, DOE Guidance (Taylor 1999). This option completes processing in 2034 assuming Glass Property Model oxide loadings in HLW (Kirkbride 1999).

This processing scenario assumes the following (Kirkbride 1999):

- BNFL Inc. will start processing by their Integrated Master Plan (IMP) dates.
- The BNFL Inc. facilities can start up and operate at their proposed maximum production rates (i.e., no capacity ramp up) as given in the contract.
- BNFL Inc. stores the entrained solids at their facility rather than returning them to the DST system.
- Phase 2 starts in 2018 with 60 MT ILAW/day rates
- A transition period (Phase 1B-Prime) bridges the completion of Phase 1 contract quantities in 2012 and the start of Phase 2 in 2018.

2.4 Phase 1 and Phase 2

Based on Case 3 of the TWRSO&UP, Phase 1 produces a total of 117,605 MT of ILAW, which corresponds to approximately 19,295 ILAW packages. The Phase 1 contractor will deliver the ILAW product in 1.4 m cubic packages. Each package contains 2.3 m³, or 6095 kg, of glass. Phase 2 produces a total of 301,374 MT of ILAW, which corresponds to approximately 49,446 ILAW packages. Since no specific guidance is provided for Phase 2 ILAW packaging, the Phase 1 standard package was used for Phase 2. Table 2.1 summarizes the ILAW volume, mass, and number of packages for the reference case (Case 3 of the TWRSO&UP) (Kirkbride 1999).

Table 2.1. Summary of Phase 1 and Phase 2 ILAW Package Production

	Total m ³ glass	Total MT glass	Total Packages
Phase 1	44379	117605	19295
Phase 2	113726	301374	49446
Total	158105	418979	68741

Phase 1 actually consists of two phases, as specified in the BNFL contract. Phase 1B meets minimum order quantities specified by contract and Phase 1B-Prime is for additional BNFL Inc. operations through February 2018, the period of performance for the Phase 1 contract.

2.5 Pretreatment

The following description of the LAW pretreatment process is summarized from the TWRS-P Project Dangerous Waste Permit Application (BNFL 1999). Pretreatment of LAW feed involves concentrating the waste feed and removing strontium, transuranics (TRU), cesium, technetium, sulfates, and entrained solids from the waste feed prior to vitrification. The LAW feed stream is concentrated in the LAW Feed Evaporator. The LAW Feed Evaporator is a continuous, forced-circulation evaporator that concentrates the feed to provide consistent feed for the ion-exchange process. Condensate is collected, analyzed, and transferred to the 200 Area Effluent Treatment Facility. Non-condensable gases extracted from the evaporator system are routed to the pretreatment building offgas treatment system. Following evaporation, the concentrated LAW is sent to the ultrafiltration process to separate entrained solids. For certain wastes, strontium and TRU removal is accomplished by adding reagents to precipitate the strontium and TRU out of solution, where they are removed by ultrafiltration. The liquid fraction is passed through successive ion exchange systems to remove cesium and technetium. If required, sulfate is removed by a further ion exchange process.

2.6 Vitrification

The concentrated LAW from the melter feed evaporator is combined with glass forming chemicals and mixed. Dry glass formers (e.g., silica, alumina, boric acid, calcium silicate) are tailored to the waste feed of each batch to obtain the desired glass formulation. The waste and glass former slurry is transferred as a continuous feed to LAW joule-heated melters. The operating temperature in the LAW melters is expected to be approximately 1050-1200 °C. The chemically active region of the melt is the cold cap, which will be at 600-800 °C. Superheated gases and volatile feed components are released into the melter offgas treatment system. The solids and a fraction of the semi-volatile components entrained in the offgas are captured and recycled back into the process. The glass content of an ILAW package is 6095 kg. The density of the LAW glass is 2.65 MT/m³ which correlates with the net glass volume per package of 2.3 m³ (Kirkbride 1999). The ILAW package is a 1.4 m cube with an external volume of 2.74 m³ (Kirkbride 1999).

2.7 Offgas Losses and Recycle

Pretreated LAW vitrification feed contains large amounts of material that, because of boiling point, decomposition temperature, or low solubility in the glass melt, become volatile during vitrification. Over half of the mass in LAW feed is volatile under melter conditions. Nearly all inorganic constituents (e.g., carbonate, nitrate, nitrite, water) and perhaps small molecular weight organics containing carbon, hydrogen, and nitrogen are likely to volatilize or decompose, and be released as an emission source during vitrification. Steam distillation is another pathway for analytes to be transported from the melter (cold cap) to the offgas treatment system. Some semi-volatile components are partially recaptured and recycled so there is a net loss to the volatiles streams. The balance of the semi-volatiles is completely recaptured and vitrified. Table 2.2 shows the fraction of each volatile or semi-volatile feed component that is retained in the ILAW product based on current limited knowledge of the BNFL Inc. offgas treatment process (Kirkbride 1999).

Table 2.2. Net Volatility Around Low-Activity Waste Vitrification

Feed Component	Fraction Retained in ILAW
Volatiles lost during vitrification	
Water	0.0
Carbon	0.0
Hydrogen	0.0
Nitrogen	0.0
Noble gases	0.0
Hydroxide	0.0
Nitrite	0.0
Nitrate	0.0
Cyanide	0.0
Carbonate	0.0
Ammonia	0.0
Semi volatiles partially captured and recycled	
Sulfur	0.9
Mercury	0.2
Iodine	0.25
Selenium	0.9
Semi volatiles captured by offgas scrubbing and recycled	
Cesium	1.0
Technetium	1.0
Boron	1.0
Silver	1.0
Ruthenium	1.0
Molybdenum	1.0
Chlorine	1.0
Fluorine	1.0

2.8 Phase 1 Privatization Contract Limitations

The Phase 1 privatization contract with BNFL Inc. (DOE-RL 1996 MOD A006 1998) specifies radionuclide and dangerous waste concentration limits in the ILAW product. These specifications include:

- Class C limits as defined in 10 CFR 61.55 and as described in NRC's Branch Technical Position on Concentration Averaging and Encapsulation. (alpha emitting transuranic nuclides with half-life greater than 5 years < 100 nCi/g)
- Average concentration of ^{137}Cs < 3 Ci/m³, average concentration of ^{90}Sr < 20 Ci/m³, and average concentration of ^{99}Tc < 0.1 Ci/m³.
- On average, remove at least 80% of the ^{99}Tc present in the LAW feed.
- The ILAW product shall be acceptable for land disposal under the State of Washington Dangerous Waste Regulations, WAC 173-303, and RCRA LDR in 40 CFR 268.

Phase 2 requirements are assumed to be the same as Phase 1.

3.0 NOMINAL INVENTORIES

The batch-by-batch ILAW radionuclide and chemical inventories are listed in Appendix A for the reference Phase 1 and Phase 2 operating scenario. These are based on the TWRSO&UP inventory that was the basis for Table 3.5.1 in Kirkbride 1999, with additional factors from Table 2.2 applied to account for offgas losses during vitrification. These are based on processing both the water-soluble and insoluble fractions of the tank inventories, with sufficient pretreatment to remove technetium, cesium, strontium, and TRU to meet specifications on average concentrations. The requirement to remove 80% of the ^{99}Tc in the LAW feed was not imposed on these batch inventories. Every batch is at or below the average concentration specification limit for ^{99}Tc , ^{137}Cs , ^{90}Sr , and TRU. No hazardous organic chemicals are included in the nominal inventories because they are not expected to survive the vitrification process (Kirkbride 1999). Radionuclide batch inventories have been decayed to the time of processing. These inventory values represent partitioning of the tank wastes, and do not include any additives to the waste feed such as glass formers or other chemicals for removals (except for sodium added for feed processing).

The following components of the original batch inventories were reduced to zero by the offgas removal correction: ^{14}C , ^3H , CO_3 , H , H_2O , NO_2 , NO_3 , OH , NH_3 , and TOC.

The batch inventory data values were zero for several components that were identified in Kirkbride 1999 as being required for characterizing the HLW feed Envelope D. These components included CN-, Co+3, Nd+3, Pd+2, Pr+3, Pu+4, Rb+, Rh+3, Ru+3, Sb+5, Ta+5, Tc+7, Te+6, Th+4, Tl+3, V+5, W+6, and Y+3.

The TWRSO&UP inventory as currently configured does not remove ^{134}Cs or Cs+ from the LAW feed along with ^{137}Cs removals. Therefore the ^{134}Cs and Cs+ values were adjusted so that the ILAW to BBI ratios were the same as for ^{137}Cs . This adjustment was also applied to the Appendix A values.

The batch inventory values for ^{79}Se and ^{126}Sn have the same half-life basis as the BBI, which are based on ORIGEN2 values (see Appendix C for a list of relevant half lives from the ORIGEN2 library). Recent studies have indicated that improved half-life values could be used for these radionuclides (Harmsen 1998). Table 3.1 shows the old and new half-life values and the factor that could be used to adjust the activity values for these radionuclides. The amounts of ^{79}Se and ^{126}Sn expressed in curies in Appendix A and in the remaining tables in this report should be multiplied by the adjustment factor in Table 3.1 to reflect these improved half-lives. The values in this report are based on the old half-lives for consistent comparisons with the BBI and existing data.

Table 3.1 Half-Life Corrections for ^{79}Se and ^{126}Sn

Component	ORIGEN2 Half-life (years)	New Half-life (years)	Activity Adjustment Factor
^{79}Se	6.50E+04	8.05E+05	0.08
^{126}Sn	1.00E+05	2.46E+05	0.40

4.0 UPPER BOUNDS FOR RADIONUCLIDES AND CHEMICALS

4.1 Total ILAW Inventories

The major sources of uncertainty for the total ILAW inventory are the uncertainties in the tank inventories, the split between HLW and LAW (the wash and leach factors and radionuclide removal factors, and offgas losses of volatile and semi-volatile components. Currently, uncertainties for the total tank inventories, wash and leach factors, and offgas losses during vitrification have not been consistently quantified. Therefore, the approach was taken to estimate bounding inventories for most components by neglecting the processing losses.

The batchwise nominal inventories described in Section 3 are decayed to the processing date. For comparison with other inventory values and the development of bounding values, each batch inventory was decay corrected to a common date of 1/1/94, the date for the BBI radionuclide values. The individual batch inventories were then summed for Phase 1, Phase 2, and total ILAW inventories. The chemical inventories were also converted from kg-moles to kg.

For comparison, the total tank inventories (adjusted tank-by-tank BBI from the TWRSO&UP, including both LAW and HLW feed tanks) were separated into Phase 1 and Phase 2 inventories. The Phase 1 tanks are those shown in Table 4.1, which are based on the Case 3 tank operations described in Kirkbride 1999. The tanks are shown in the approximate order of retrieval. All other tanks were taken to be Phase 2. This is not precise, since some of the wastes in these tanks will be processed in phase 2, and some of the wastes will end up in HLW. The actual tank retrieval sequence and selection of tanks for Phase 1B and Phase 1B-Prime has not been approved by DOE. The tank sequence will be finalized in the multiyear work plan. It is likely that some changes will be made to the tanks listed in Table 4.1. Such changes may affect the distribution of inventory between Phase 1 and Phase 2 but should not affect the total inventory.

Table 4.1 Phase 1 Tanks

	LAW Tanks	HLW Tanks
Phase 1B	AN107	AZ101
	AN104	SY102
	AN102	AW103
	AN105	AZ102
	SY101	AY102
	AN103	C106
	AZ101*	AY101
	AZ102*	
Phase 1B-Prime	AW101	C104
	AW104	AW104
	AP105	C102
	AP104	AW105
	AP101	

*pretreated, staged waste

Note: The actual tank retrieval sequence and selection of tanks for Phase 1B and Phase 1B-Prime has not been approved by DOE.

Table 4.2 lists these ILAW inventories and compares them with the TWRSO&UP total tank inventories, the Global tank inventories based on process knowledge (Kupfer 1999), and the total radionuclide production in the fuel in the reactors before it was processed (Watrous 1997). The difference between the ILAW inventory and the tank inventory can be attributed to the high level waste (HLW) fraction, residual tank heel, radionuclide separations to meet contract specifications, and losses to the offgas stream. The global tank inventory values and the reactor production values generally provide support to the BBI sum-of-tank values. Additional discussion for selected components can be found in Appendix B.

Table 4.3 shows the resulting upper bounding values for Phase 1, Phase 2, and Total ILAW inventories based on these comparisons. For most components, the upper bound limit on total ILAW inventory was taken as the BBI tank inventory, neglecting any processing and separations losses. For radionuclides limited by the contract specifications (^{99}Tc , ^{137}Cs , ^{90}Sr , and TRU), the contract limits were used as upper bounds. Neglecting the processing losses between the tank inventory and the ILAW inventory provides a very conservative bounding value, but was used to compensate for the lack of uncertainty information on the separations factors (wash and leach effectiveness, offgas treatment, solids retention). Additional discussion for several special case components follows.

^{99}Tc

The ^{99}Tc values for the batch-by-batch Phase 1 and Phase 2 ILAW inventories from the TWRSO&UP did not include the contract requirement to reduce the feed ^{99}Tc by 80%. Therefore, The ^{99}Tc summation value for the total ILAW was adjusted downward to be 20% of the BBI total tank inventory. The Phase 1 and Phase 2 totals for ^{99}Tc were scaled proportionately. This overestimates the ILAW inventory since it assumes that all of the ^{99}Tc in the tanks is represented in the feed. The resulting total inventory is 48% less than the total of the TWRSO&UP ILAW inventory in Appendix A (1.21E4 Ci). Users should be aware that use of the ^{99}Tc values from Appendix A will result in a total inventory that is high by about a factor of 2. It is likely that BNFL will meet the 80% reduction requirement by applying separations to selected batches or types of feed, so that many of the batch inventories may not be affected. Upper bound values in Table 4.3 are 15% higher than the nominal inventories to allow for uncertainties in the tank inventories, but not exceed the total reactor production. Consistent with the assumption that the Phase 1 requirements will be applied to Phase 2 as well, these limitations provide reasonable bounding inventory values.

The best basis value for ^{99}Tc agrees reasonably well with the process knowledge based (global) estimate. The best basis value is likely the more valid since the global estimate does not account for known losses of ^{99}Tc that occurred during fuel separation operations (Kupfer 1999). There is good evidence that 20% or more of the technetium produced was separated from the waste stream during initial fuel reprocessing, mainly co-processed with the UO_3 and sent offsite, but with minor losses to the environment as well (Schmittroth 1995). The HDW global inventory for ^{99}Tc may be biased high by about 32% due to it's not accounting for the fractional separation of Tc to the uranium product stream in the uranium recovery, PUREX and REDOX processes (cribbing, offsite shipment, U contaminant). Approximately 60% of the tank summation inventory is based on the HDW model (Kupfer 1999). The BBI ^{99}Tc total tank inventory of 28,900 Ci is 87% of the total reactor production. The total production value for ^{99}Tc is likely known

within 10% since it depends primarily on well known fission product yields and the production reactor histories.

The only way the nominal total ^{99}Tc ILAW inventory could be larger would be for the tank inventory to be higher. However, the tank inventory is constrained by the total reactor production. The ILAW inventory could be smaller due to any ^{99}Tc not retrieved from the tanks or incorporated into IHLW, or to smaller than expected tank inventories. A reasonable estimated uncertainty in the ILAW ^{99}Tc total inventory would be on the order of 15% to account for these effects, with the assumption that the Phase 1 requirements will be applied to Phase 2 as well.

^{137}Cs , ^{90}Sr

The ^{137}Cs and ^{90}Sr inventory in the ILAW are also constrained by the BNFL Inc. Phase 1 contract specifications. The ILAW inventory values are the sum of the batch values that include the decay correction to the reference date of 1/1/1994. This explains why they are higher than strictly applying the concentration limit to the entire ILAW volume at the reference date. BNFL could exceed the ^{137}Cs and ^{90}Sr ILAW inventory in Table 4.2 by simply making more glass at the concentration limit. The upper bound values in Table 4.3 were created by increasing the contract limited values based on the nominal ILAW glass volume of 158105 m^3 by a factor of 1.3 to allow for uncertainty in the total volume of ILAW glass produced. Based on these constraints, the uncertainty in the ^{137}Cs and ^{90}Sr total ILAW inventory in Table 4.2 is estimated to be on the order of 30%.

The best-basis values for ^{137}Cs and ^{90}Sr agree with the global values. The majority of the tank summation inventory is based on samples.

The TWRSO&UP inventory as currently configured does not remove ^{134}Cs or Cs+ from the LAW feed along with ^{137}Cs removals. Therefore the ^{134}Cs and Cs+ values were adjusted so that the ILAW to BBI ratios were the same as for ^{137}Cs . This adjustment was also applied to the Appendix A values.

TRU

Bounding values for the TRU isotopes (as defined in the Phase 1 privatization contract limits for TRU isotopes with half-lives greater than five years as interpreted in Kirkbride 1999) neptunium, plutonium, americium, and curium inventories (except ^{242}Cm and ^{241}Pu) were developed by adjusting the sum of these component inventories to the contract limit of 100 nCi/g (contract limit). The upper bound values in Table 4.3 were created by increasing the contract limited values based on the nominal ILAW mass of 418979 metric tons by a factor of 1.3 to allow for uncertainty in the total mass of ILAW glass produced. The relative proportions of these components were kept the same as in the sum of batch inventory. The inclusion of ^{241}Pu in the TRU limits in the TWRSO&UP is questionable because ^{241}Pu decays primarily by emitting a beta particle. Only 0.0024% of the decays result in alpha particle emission. Since the ^{241}Pu curie inventory is comparable to the major TRU isotopes ^{239}Pu and ^{241}Pu , the ILAW inventory values for the TRU isotopes could be as much as 30% higher than the values in Appendix A and still be within the 100 nCi/g limit. An overall uncertainty for the total TRU would thus be on the order of 30%. Individual component uncertainty could be higher.

¹²⁶Sn

Most of the best-basis (tank-by-tank summation) and all of the global inventory estimate for ¹²⁶Sn are based on the HDW model. The HDW curie value of ¹²⁶Sn could be reduced by a factor of 0.4 to account for a recently updated half life value, and by a factor of 0.78 to account for a better fission yield value. The nominal ILAW inventory value of 423 Ci is approximately 36% of the tank inventory. The tank inventory is approximately 75% of the total reactor production. An overall uncertainty on the order of 300% is likely for the ¹²⁶Sn inventory to cover the uncertainty in the fraction of the tank waste that makes it to the ILAW product.

⁷⁹Se

Most of the best-basis (tank-by-tank summation) and all of the global inventory estimate for ⁷⁹Se are based on the HDW model. These ORIGEN2 based calculations of ⁷⁹Se production could be reduced by a factor of 0.85 to account for a lower fission yield and by a factor of 0.08 to account for a recently updated half life value. The total BBI tank value is only 20% greater than the ILAW inventory. To provide an additional safety margin, the upper bounding ILAW inventory was created by increasing the tank inventory by a factor of 1.3 to be comparable to the total production value. The uncertainty in the nominal ILAW inventory is estimated to be on the order of 70% to account primarily for the tank inventory uncertainties.

¹²⁹I

The best-basis of ¹²⁹I is somewhat larger than the global estimate. The global (HDW model) estimate conservatively assumes that all of the ¹²⁹I in the fuel was routed to the waste tanks. Thus the reason for the higher tank sum is not inherently obvious. The difference could be due to sample error, but is likely not due to underestimated model values. Both best basis and global inventory values are likely to be significantly higher than actual values (Kupfer 1999). The calculated ¹²⁹I production in the fuel could be reduced by a factor of 0.76 to account for a better fission yield value (Harmsen 1998). The nominal ILAW inventory is based on the TWRSO&UP assumption that only a fraction of the ¹²⁹I would be incorporated into the ILAW product, with the bulk of the ¹²⁹I diverted through the offgas system to the atmosphere or other solid waste forms. If the ¹²⁹I cannot be released to atmosphere or a secondary waste product, then the ILAW inventory would be comparable to the tank inventory. The BBI sum of tank value was used as the upper bound total ILAW ¹²⁹I inventory. Since this 101 Ci value is a factor of 1.6 higher than the total produced, an adequate safety margin is assured to account for uncertainties in production and tank inventories. The uncertainty in the nominal ILAW ¹²⁹I inventory is large, in the range of 300-500%, to reflect the uncertainty in the amount of ¹²⁹I returned to the ILAW glass from the offgas treatment system.

²²⁶Ra, ²²⁸Ra, ²²⁷Ac, ²²⁹Th, ²³¹Pa

The tank summation inventories for these isotopes (alpha decay chain daughters of uranium and thorium isotopes) are based essentially on the HDW model estimates, due to lack of any direct analytical data from samples. The estimate for these daughter radionuclides is substantially overpredicted due to the lack of proper second-order decay

functions in the HDW model (Kupfer 1999). The buildup of these daughter products from decay of the uranium and thorium in the ILAW will overshadow the initial inventories (Kupfer 1999).

Table 4.2 Comparison of Nominal ILAW Inventory With Tank Inventory and Total Production

	ILAW Inventory (radionuclides are in Ci at 1/1/94 chemicals are in kg)			BBI Sum of Tanks (radionuclides are in Ci at 1/1/94 chemicals are in kg)			Global Inventory (Kupfer 1999)	Total Produced (Watrous 1997)
	Phase 1	Phase 2	Total	Phase 1	Phase 2	Total	Total	Total
3-H	0.00E+00	0.00E+00	0.00E+00	6.17E+03	1.84E+04	2.46E+04	3.40E+04	2.38E+05
14-C	0.00E+00	0.00E+00	0.00E+00	1.19E+03	3.20E+03	4.38E+03	4.81E+03	2.56E+03 ^a
59-Ni	6.86E+01	9.82E+01	1.67E+02	2.39E+02	6.19E+02	8.58E+02	9.34E+02	1.14E+03 ^a
60-Co	2.02E+03	2.16E+03	4.18E+03	1.27E+04	7.22E+03	1.99E+04	1.23E+04	3.47E+04 ^a
63-Ni	6.70E+03	9.49E+03	1.62E+04	2.38E+04	6.07E+04	8.45E+04	9.20E+04	1.14E+05 ^a
79-Se	2.16E+02	3.84E+02	6.00E+02	2.73E+02	4.44E+02	7.17E+02	7.73E+02	1.00E+03
90-Sr ^d	8.58E+05	3.64E+06	4.50E+06	1.89E+07	4.10E+07	5.99E+07	7.16E+07	1.04E+08 ^c
93-Zr	5.22E+02	7.33E+02	1.25E+03	1.49E+03	2.63E+03	4.12E+03	3.63E+03	4.74E+03
93m-Nb	3.64E+02	4.72E+02	8.36E+02	8.34E+02	1.69E+03	2.53E+03	2.69E+03	3.48E+03
99-Tc ^d	1.75E+03	4.03E+03	5.79E+03	7.96E+03	2.10E+04	2.89E+04	3.26E+04	3.32E+04
106-Ru	2.35E+02	6.58E+02	8.94E+02	1.26E+05	5.62E+02	1.27E+05	1.04E+05	1.14E+05
113m-Cd	3.20E+03	4.77E+03	7.97E+03	7.60E+03	9.05E+03	1.67E+04	1.69E+04	2.24E+04
125-Sb	4.14E+04	1.07E+04	5.20E+04	2.30E+05	1.61E+04	2.47E+05	2.08E+05	2.19E+05
126-Sn	2.10E+02	2.12E+02	4.23E+02	4.54E+02	7.02E+02	1.16E+03	1.19E+03	1.53E+03
129-I	1.12E+01	1.08E+01	2.20E+01	5.54E+01	4.53E+01	1.01E+02	6.30E+01	6.41E+01
134-Cs ^e	2.87E+02	8.89E+01	3.76E+02	8.59E+04	1.18E+03	8.71E+04	8.89E+04	8.89E+04
137-Cs ^d	1.91E+05	7.20E+05	9.11E+05	3.70E+07	2.67E+07	6.37E+07	4.64E+07	1.20E+08 ^c
151-Sm	3.56E+05	4.23E+05	7.80E+05	9.24E+05	1.68E+06	2.61E+06	2.75E+06	3.54E+06
152-Eu	1.34E+02	1.74E+02	3.07E+02	7.42E+02	7.07E+02	1.45E+03	1.48E+03	1.89E+03
154-Eu	1.05E+04	2.72E+04	3.77E+04	9.40E+04	8.91E+04	1.83E+05	1.47E+05	1.74E+05
155-Eu	1.46E+04	1.69E+04	3.15E+04	1.23E+05	5.29E+04	1.76E+05	1.36E+05	1.60E+05
226-Ra	2.64E+02	7.69E+02	1.03E+03	1.81E+02	9.61E+02	1.14E+03	6.31E-02	7.72E-02 ^b
227-Ac	2.86E-02	3.19E-02	6.05E-02	8.72E+01	3.17E-01	8.75E+01	8.76E+01	1.08E+02 ^b
228-Ra	1.22E+01	2.10E+01	3.32E+01	3.92E+01	3.83E+01	7.75E+01	7.71E+01	6.44E+01 ^b
229-Th	1.66E-01	1.74E-01	3.40E-01	9.19E-01	8.87E-01	1.81E+00	1.81E+00	2.92E+01 ^b
231-Pa	1.51E-01	1.86E-01	3.37E-01	1.52E+02	7.50E-01	1.53E+02	1.56E+02	1.91E+02 ^b
232-Th	6.93E-01	5.87E-01	1.28E+00	2.46E+00	1.95E+00	4.40E+00	2.11E+00	6.88E+01 ^c
232-U	9.25E+00	2.54E+01	3.46E+01	2.31E+01	1.26E+02	1.49E+02	1.23E+02	3.02E+03 ^c
233-U	3.50E+01	9.56E+01	1.31E+02	8.40E+01	4.88E+02	5.72E+02	4.76E+02	1.17E+04 ^c
234-U	1.28E+01	3.13E+01	4.41E+01	1.02E+02	2.39E+02	3.42E+02	3.46E+02	3.56E+04 ^c
235-U	5.21E-01	1.27E+00	1.79E+00	3.92E+00	1.07E+01	1.46E+01	1.45E+01	1.47E+03 ^c
236-U	5.39E-01	8.89E-01	1.43E+00	7.54E+00	4.87E+00	1.24E+01	9.57E+00	1.17E+03 ^c
237-Np	4.47E+01	3.63E+01	8.10E+01	1.10E+02	7.49E+01	1.85E+02	1.41E+02	2.76E+02 ^c
238-Pu	4.40E+01	6.23E+01	1.06E+02	1.84E+03	8.51E+02	2.70E+03	2.77E+03	1.30E+05 ^c
238-U	1.32E+01	3.51E+01	4.83E+01	7.91E+01	2.49E+02	3.28E+02	3.22E+02	3.29E+04 ^c
239-Pu	8.81E+02	2.16E+03	3.05E+03	2.36E+04	3.19E+04	5.55E+04	3.91E+04	3.72E+06 ^c
240-Pu	1.60E+02	3.65E+02	5.25E+02	5.82E+03	5.43E+03	1.13E+04	8.93E+03	6.79E+05 ^c
241-Am	4.61E+03	6.23E+03	1.08E+04	7.35E+04	3.32E+04	1.07E+05	6.99E+04	7.99E+05 ^f
241-Pu	2.93E+03	4.24E+03	7.17E+03	1.27E+05	3.97E+04	1.66E+05	2.29E+05	9.98E+06
242-Cm	1.05E+01	4.70E+01	5.76E+01	9.99E+01	7.20E+01	1.72E+02	7.70E+01	1.10E+02
242-Pu	2.08E-02	2.41E-02	4.49E-02	8.37E-01	2.35E-01	1.07E+00	1.16E+00	4.25E+01

HNF-4921 Rev.0

	ILAW Inventory (radionuclides are in Ci at 1/1/94 chemicals are in kg)			BBI Sum of Tanks (radionuclides are in Ci at 1/1/94 chemicals are in kg)			Global Inventory (Kupfer 1999)	Total Produced (Watrous 1997)
	Phase 1	Phase 2	Total	Phase 1	Phase 2	Total	Total	Total
243-Am	5.40E-01	1.49E-01	6.89E-01	1.63E+01	1.31E+00	1.76E+01	9.34E+00	4.19E+01
243-Cm	2.76E+00	3.97E+00	6.73E+00	2.58E+01	8.85E+00	3.47E+01	1.00E+01	1.37E+01
244-Cm	5.10E+01	4.96E+01	1.01E+02	6.45E+02	1.38E+02	7.84E+02	2.42E+02	3.14E+02
Ag+	8.91E+01	1.89E+01	1.08E+02	1.49E+03	2.08E+01	1.51E+03	8.93E+03	
Al(OH)4-	3.53E+05	4.96E+06	5.31E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Al+3	1.44E+06	2.62E+06	4.05E+06	1.84E+06	6.43E+06	8.27E+06	7.85E+06	
As+5	4.37E+00	1.33E+01	1.76E+01	5.24E+00	1.55E+01	2.08E+01	0.00E+00	
B+3	5.06E+02	1.49E+02	6.54E+02	6.41E+03	1.25E+02	6.53E+03	0.00E+00	
Ba+2	7.05E+00	1.15E+01	1.86E+01	1.11E+03	5.86E+02	1.70E+03	0.00E+00	
Be+2	0.00E+00	6.14E-01	6.14E-01	1.08E+02	6.04E-01	1.09E+02	0.00E+00	
Bi+3	3.61E+02	9.59E+03	9.96E+03	6.27E+03	6.25E+05	6.31E+05	5.80E+05	
Ca+2	6.64E+03	4.12E+04	4.78E+04	4.23E+04	2.77E+05	3.19E+05	2.14E+05	
Cd+2	4.05E+01	2.25E+01	6.30E+01	3.69E+02	4.91E+01	4.18E+02	8.20E+03	
Ce+3	1.08E+02	2.22E+03	2.33E+03	2.98E+03	2.35E+05	2.38E+05	8.80E+03	
Cl-	2.78E+05	6.53E+05	9.31E+05	2.60E+05	6.77E+05	9.37E+05	5.00E+05	
CN-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.09E+05	1.09E+05	0.00E+00	
CO3-2	0.00E+00	0.00E+00	0.00E+00	2.69E+06	6.76E+06	9.46E+06	4.83E+06	
Cr(OH)4-	2.49E+04	3.81E+05	4.05E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Cr (TOTAL)	6.15E+04	2.12E+05	2.74E+05	7.83E+04	5.94E+05	6.72E+05	7.85E+05	
Cs+ ^e	4.54E+02	6.67E+02	1.12E+03	1.17E+05	8.88E+02	1.18E+05	0.00E+00	
Cu+2	6.34E-01	9.86E-02	7.33E-01	3.15E+02	6.18E-01	3.15E+02	0.00E+00	
F-	2.25E+05	7.69E+05	9.94E+05	3.74E+05	8.28E+05	1.20E+06	1.36E+06	
Fe+3	7.37E+03	3.74E+04	4.48E+04	2.59E+05	1.14E+06	1.40E+06	1.23E+06	
H2O	0.00E+00	0.00E+00	0.00E+00	4.84E+07	3.86E+07	8.70E+07	0.00E+00	
Hg+2	2.49E+01	1.67E+02	1.92E+02	4.55E+02	1.64E+03	2.10E+03	2.10E+03	
K+	4.98E+05	3.36E+05	8.33E+05	5.68E+05	3.07E+05	8.75E+05	4.81E+05	
La+3	3.93E+02	1.13E+02	5.06E+02	1.29E+04	3.84E+04	5.13E+04	5.10E+04	
Li+	2.92E+01	9.55E-01	3.02E+01	2.81E+01	2.32E+00	3.04E+01	0.00E+00	
Mg+2	1.89E+02	9.54E+01	2.84E+02	3.29E+03	9.10E+01	3.38E+03	0.00E+00	
Mn+4	5.85E+03	7.93E+03	1.38E+04	4.23E+04	1.54E+05	1.96E+05	1.05E+05	
Mo+6	5.99E+02	2.20E+01	6.21E+02	1.31E+03	5.56E+00	1.31E+03	0.00E+00	
Na+	1.26E+07	4.43E+07	5.69E+07	1.20E+07	3.70E+07	4.90E+07	5.42E+07	
NH3	0.00E+00	0.00E+00	0.00E+00	2.48E+05	2.53E+05	5.01E+05	0.00E+00	
Ni+2	7.70E+03	2.28E+04	3.05E+04	3.74E+04	1.42E+05	1.80E+05	1.11E+05	
NO2-	0.00E+00	0.00E+00	0.00E+00	4.74E+06	7.90E+06	1.26E+07	0.00E+00	
NO3-	0.00E+00	0.00E+00	0.00E+00	8.39E+06	4.41E+07	5.25E+07	0.00E+00	
OH (BOUND)	0.00E+00	0.00E+00	0.00E+00	5.90E+06	1.52E+07	2.11E+07	0.00E+00	
OH-	0.00E+00	0.00E+00	0.00E+00	1.45E+06	2.21E+06	3.66E+06	2.30E+07	
Pb+2	3.55E+03	4.28E+03	7.83E+03	1.78E+04	6.62E+04	8.40E+04	2.79E+05	
PO4-3	2.73E+05	4.88E+06	5.16E+06	2.19E+05	5.34E+06	5.56E+06	6.00E+06	
Rh+3	NA	NA	NA	5.19E+01	0.00E+00	5.19E+01	0.00E+00	

	ILAW Inventory (radionuclides are in Ci at 1/1/94 chemicals are in kg)			BBI Sum of Tanks (radionuclides are in Ci at 1/1/94 chemicals are in kg)			Global Inventory (Kupfer 1999)	Total Produced (Watrous 1997)
	Phase 1	Phase 2	Total	Phase 1	Phase 2	Total	Total	Total
Ru+3	NA	NA	NA	1.21E+00	0.00E+00	1.21E+00	0.00E+00	
Se+6	4.29E-01	1.04E-01	5.33E-01	5.53E-01	5.86E-02	6.11E-01	0.00E+00	
Si+4	3.79E+04	3.83E+05	4.20E+05	1.37E+05	8.03E+05	9.41E+05	5.70E+05	
SO4-2	4.95E+05	2.90E+06	3.39E+06	4.61E+05	3.45E+06	3.91E+06	5.00E+06	
Sr+2	1.34E+02	2.07E+03	2.20E+03	9.96E+02	4.45E+04	4.55E+04	3.13E+04	
Te+6	NA	NA	NA	3.04E+02	0.00E+00	3.04E+02	0.00E+00	
Th+4	NA	NA	NA	NA	NA	NA	2.56E+04	
Ti+4	1.39E+01	1.04E+00	1.49E+01	2.60E+02	2.87E-01	2.60E+02	0.00E+00	
Tl+3	NA	NA	NA	2.54E+04	0.00E+00	2.54E+04	0.00E+00	
TOC	0.00E+00	0.00E+00	0.00E+00	7.43E+05	1.25E+06	2.00E+06	4.00E+06	
U(TOTAL)	7.41E+03	9.92E+03	1.73E+04	8.36E+03	6.78E+04	7.61E+04	9.65E+05	
V+5	NA	NA	NA	1.68E+01	0.00E+00	1.68E+01	0.00E+00	
W+6	NA	NA	NA	NA	NA	NA	1.59E+04	
Zn+2	1.43E+03	5.53E+02	1.98E+03	2.45E+03	4.44E+02	2.89E+03	0.00E+00	
Zr+4	6.48E+03	5.80E+03	1.23E+04	4.24E+05	4.09E+04	4.65E+05	4.40E+05	

- a) These were corrected values based on improved activation calculations described in Harmsen 1998.
- b) These are daughter products of uranium and thorium that were not treated correctly in the HDW model because uranium, thorium, and plutonium were decayed prior to separations (Kupfer 1999). The inventory values for these radioisotopes may be significantly in error and their long term growth should be calculated concurrently with the calculation of waste migration and elemental retardation. The reason for the discrepancy between BBI and Global Inventory needs further investigation.
- c) These are total production values with no product separations.
- d) Isotope quantity limited by contract (see Section 2.8). Values in table for ILAW inventory may exceed contract concentration limits due to decay between the reference date (1/1/94) and the date of batch processing.
- e) The TWRSO&UP inventory as currently configured does not remove ^{134}Cs or Cs^+ from the LAW feed. Therefore the ^{134}Cs and Cs^+ ILAW values were adjusted so that the ILAW to BBI ratio was the same as for ^{137}Cs .
- f) ^{241}Am is overestimated by approximately a factor of 10 in Watrous 1997 because the parent ^{241}Pu was not separated. The HDW model corrected for this.
- g) Zero entries in the ILAW inventory indicate the component was 100% released to the offgas system.
- h) NA entries refer to components where inventory information is not available.
- i) The ^{90}Sr will have ^{90}Y daughter in equilibrium. The ^{137}Cs will have $^{137\text{m}}\text{Ba}$ daughter in equilibrium.
- j) U (total) was treated in TWRSO&UP as Total U - U radionuclides

Table 4.3 Upper Bound Inventories for ILAW

Upper Bound Inventories (Ci for radionuclides and kg for chemicals)				
Component	Phase 1	Phase 2	Total	Basis
3-H	6.17E+03	1.84E+04	2.46E+04	In Tank Inventory
14-C	1.19E+03	3.20E+03	4.38E+03	In Tank Inventory
59-Ni	2.39E+02	6.19E+02	8.58E+02	In Tank Inventory
60-Co	1.27E+04	7.22E+03	1.99E+04	In Tank Inventory
63-Ni	2.38E+04	6.07E+04	8.45E+04	In Tank Inventory
79-Se	3.55E+02	5.77E+02	9.32E+02	In Tank Inventory*1.3
90-Sr	1.11E+06	4.74E+06	5.85E+06	contract limit
93-Zr	1.49E+03	2.63E+03	4.12E+03	In Tank Inventory
93m-Nb	8.34E+02	1.69E+03	2.53E+03	In Tank Inventory
99-Tc	2.02E+03	4.64E+03	6.65E+03	contract limit; 20% of BBI
106-Ru	1.26E+05	5.62E+02	1.27E+05	In Tank Inventory
113m-Cd	7.60E+03	9.05E+03	1.67E+04	In Tank Inventory
125-Sb	2.30E+05	1.61E+04	2.47E+05	In Tank Inventory
126-Sn	4.54E+02	7.02E+02	1.16E+03	In Tank Inventory
129-I	5.54E+01	4.53E+01	1.01E+02	In Tank Inventory
134-Cs	3.73E+02	1.16E+02	4.89E+02	Adjusted to ¹³⁷ Cs
137-Cs	2.48E+05	9.36E+05	1.18E+06	contract limit
151-Sm	9.24E+05	1.68E+06	2.61E+06	In Tank Inventory
152-Eu	7.42E+02	7.07E+02	1.45E+03	In Tank Inventory
154-Eu	9.40E+04	8.91E+04	1.83E+05	In Tank Inventory
155-Eu	1.23E+05	5.29E+04	1.76E+05	In Tank Inventory
226-Ra	1.81E+02	9.61E+02	1.14E+03	In Tank Inventory
227-Ac	8.72E+01	3.17E-01	8.75E+01	In Tank Inventory
228-Ra	3.92E+01	3.83E+01	7.75E+01	In Tank Inventory
229-Th	9.19E-01	8.87E-01	1.81E+00	In Tank Inventory
231-Pa	1.52E+02	7.50E-01	1.53E+02	In Tank Inventory
232-Th	2.46E+00	1.95E+00	4.40E+00	In Tank Inventory
232-U	2.31E+01	1.26E+02	1.49E+02	In Tank Inventory
233-U	8.40E+01	4.88E+02	5.72E+02	In Tank Inventory
234-U	1.02E+02	2.39E+02	3.42E+02	In Tank Inventory
235-U	3.92E+00	1.07E+01	1.46E+01	In Tank Inventory
236-U	7.54E+00	4.87E+00	1.24E+01	In Tank Inventory
237-Np	1.66E+02	1.35E+02	3.00E+02	contract limit
238-Pu	1.63E+02	2.31E+02	3.94E+02	contract limit
238-U	7.91E+01	2.49E+02	3.28E+02	In Tank Inventory
239-Pu	3.26E+03	8.02E+03	1.13E+04	contract limit
240-Pu	5.94E+02	1.35E+03	1.95E+03	contract limit
241-Am	1.71E+04	2.31E+04	4.01E+04	contract limit
241-Pu	1.27E+05	3.97E+04	1.66E+05	In Tank Inventory
242-Cm	9.99E+01	7.20E+01	1.72E+02	In Tank Inventory
242-Pu	7.70E-02	8.93E-02	1.66E-01	contract limit
243-Am	2.00E+00	5.53E-01	2.55E+00	contract limit
243-Cm	1.02E+01	1.47E+01	2.49E+01	contract limit
244-Cm	1.89E+02	1.84E+02	3.73E+02	contract limit
Ag+	2.98E+03	4.16E+01	3.03E+03	In Tank Inventory

Upper Bound Inventories (Ci for radionuclides and kg for chemicals)				
Component	Phase 1	Phase 2	Total	Basis
Al(OH)4-	4.52E+05	1.22E+07	1.08E+07	TWRSO&UP normalized to Al+3
Al+3	1.84E+06	6.43E+06	8.27E+06	In Tank Inventory
As+5	1.05E+01	3.10E+01	4.15E+01	In Tank Inventory
B+3	1.28E+04	2.51E+02	1.31E+04	In Tank Inventory
Ba+2	2.22E+03	1.17E+03	3.39E+03	In Tank Inventory
Be+2	2.16E+02	1.21E+00	2.18E+02	In Tank Inventory
Bi+3	6.27E+03	6.25E+05	6.31E+05	In Tank Inventory
Ca+2	4.23E+04	2.77E+05	3.19E+05	In Tank Inventory
Cd+2	7.38E+02	9.82E+01	8.36E+02	In Tank Inventory
Ce+3	5.96E+03	4.69E+05	4.75E+05	In Tank Inventory
Cl-	2.60E+05	6.77E+05	9.37E+05	In Tank Inventory
CN-	0.00E+00	1.09E+05	1.09E+05	In Tank Inventory
CO3-2	2.69E+06	6.76E+06	9.46E+06	In Tank Inventory
Cr(OH)4-	3.17E+04	1.06E+06	9.95E+05	TWRSO&UP normalized to Cr(total)
Cr(TOTAL)	7.83E+04	5.94E+05	6.72E+05	In Tank Inventory
Cs+	1.17E+05	8.88E+02	1.18E+05	Adjusted to ¹³⁷ Cs
Cu+2	6.30E+02	1.24E+00	6.31E+02	In Tank Inventory
F-	3.74E+05	8.28E+05	1.20E+06	In Tank Inventory
Fe+3	2.59E+05	1.14E+06	1.40E+06	In Tank Inventory
H2O	4.84E+07	3.86E+07	8.70E+07	In Tank Inventory
Hg+2	4.55E+02	1.64E+03	2.10E+03	In Tank Inventory
K+	5.68E+05	3.07E+05	8.75E+05	In Tank Inventory
La+3	1.29E+04	3.84E+04	5.13E+04	In Tank Inventory
Li+	5.62E+01	4.64E+00	6.09E+01	In Tank Inventory
Mg+2	6.57E+03	1.82E+02	6.75E+03	In Tank Inventory
Mn+4	4.23E+04	1.54E+05	1.96E+05	In Tank Inventory
Mo+6	2.61E+03	1.11E+01	2.62E+03	In Tank Inventory
Na+	1.20E+07	3.70E+07	4.90E+07	In Tank Inventory
NH3	2.48E+05	2.53E+05	5.01E+05	In Tank Inventory
Ni+2	3.74E+04	1.42E+05	1.80E+05	In Tank Inventory
NO2-	4.74E+06	7.90E+06	1.26E+07	In Tank Inventory
NO3-	8.39E+06	4.41E+07	5.25E+07	In Tank Inventory
OH (BOUND)	5.90E+06	1.52E+07	2.11E+07	In Tank Inventory
OH-	1.45E+06	2.21E+06	3.66E+06	In Tank Inventory
Pb+2	1.78E+04	6.62E+04	8.40E+04	In Tank Inventory
PO4-3	2.19E+05	5.34E+06	5.56E+06	In Tank Inventory
Rh+3	1.04E+02	0.00E+00	1.04E+02	In Tank Inventory
Ru+3	2.43E+00	0.00E+00	2.43E+00	In Tank Inventory
Se+6	1.11E+00	1.17E-01	1.22E+00	In Tank Inventory
Si+4	1.37E+05	8.03E+05	9.41E+05	In Tank Inventory
SO4-2	4.61E+05	3.45E+06	3.91E+06	In Tank Inventory
Sr+2	9.96E+02	4.45E+04	4.55E+04	In Tank Inventory
Te+6	6.08E+02	0.00E+00	6.08E+02	In Tank Inventory
Th+4			2.56E+04	Global
Ti+4	5.19E+02	5.75E-01	5.20E+02	In Tank Inventory

Upper Bound Inventories (Ci for radionuclides and kg for chemicals)				
Component	Phase 1	Phase 2	Total	Basis
Ti+3	5.08E+04	0.00E+00	5.08E+04	In Tank Inventory
TOC	3.25E+05	8.33E+05	1.16E+06	Organic chemicals from Table 4.6
U(TOTAL)	8.36E+03	6.78E+04	7.61E+04	In Tank Inventory
V+5	3.36E+01	0.00E+00	3.36E+01	In Tank Inventory
W+6			3.18E+04	Global
Zn+2	4.90E+03	8.89E+02	5.79E+03	In Tank Inventory
Zr+4	4.24E+05	4.09E+04	4.65E+05	In Tank Inventory

4.2 ILAW Package Upper Bounds

The main contributor to the variability in the inventory in an ILAW package or group of packages are the tank-to-tank variations in inventories. Each batch of LAW feed represents one or more tank contents after it has been retrieved and subjected to the wash and leach processes. The approach taken was to combine the bounding ILAW total inventory and batch-to-batch variations in inventory values along with the Phase 1 BNFL Inc. contract radionuclide limits to determine bounding concentrations for the ILAW packages. The Phase 2 limits are assumed to be the same as for Phase 1. The intent was not to identify the extreme concentration limits of an individual package, but to provide reasonable bounding values. There could be situations where recycle buildup, filter cleanouts, or other situations provide small amounts of ILAW that approach the acceptability limits for some components. However, reasonable variations for groups of packages were judged to be adequately represented by the batch to batch variability, which primarily reflects the variability in the tank concentrations.

Table 4.4 shows concentration values for the average Phase 1, average Phase 2, and the maximum batch concentration based on the batchwise inventories described in Section 3, but decay corrected to the reference date of 1/1/94. The processing assumptions used in the TWRSO&UP for Case 3 included both small batches representing internal processing by BNFL Inc. as well as the major batches. Individual batches may be pretreated LAW, ion exchange column wash, HLW caustic wash, etc. As such the averaging effect that normally occurs due to the internal parallel treatment and blending operations of the vitrification facility are not apparent. Thus the maximum to average ratio shown in Table 4.4 should be greater than what actually will occur in the vitrification plant. With the exception of Be, which has a maximum to average concentration ratio of 140, caused by the segregation of zirconium cladding waste, the ratios are all well under 100 and frequently under 10.

The second and third columns of Table 4.5 show the average concentrations based on the total nominal ILAW inventory and the total upper bound inventory from Table 4.3. The nominal average package concentration is determined by dividing the total nominal ILAW inventory (Table 4.2) by the total volume of waste produced (Table 2.1). The upper bound for a package or group of packages was determined by increasing the average concentration based on the total upper bound inventory by the ratio of the maximum batch concentration to the average batch concentration. An additional multiplicative factor representing the uncertainty in an individual tank inventory was then applied. This approach is shown in Table 4.5. The ratio of the maximum batch to average batch was taken from Table 4.4. The tank uncertainty factors were roughly based on the BBI tank inventory uncertainties (Ferryman 1998). These tank-by-tank uncertainties were examined for the major components of concern to the performance assessment, and in general, a factor of 3 characterized the typical variations between the 90% confidence values and the nominal values for tanks with substantial inventories of a given component. Much larger values can be found, but these generally applied to tanks with relatively small inventories of the given component, or where discrepancies exist between the inventory used in the uncertainty studies and the BBI tank inventories used for this study. This factor was assumed to be a factor of 10 for the components that were not based on BBI data. The contract limits for ^{99}Tc , ^{90}Sr , and ^{137}Cs of 0.1, 20, and 3 Ci/m^3 can be exceeded as long as the average is maintained below these values. The 10CFR 61.55 Class C limits cannot be exceeded. The Class C limits for ^{99}Tc , ^{90}Sr , and ^{137}Cs are 3, 7000, and 4600 Ci/m^3 . Other radionuclides with Class C limits are ^{129}I

(0.08 Ci/m³), ¹⁴C (8 Ci/m³, ⁶³Ni (700 Ci/m³), ²⁴¹Pu (3500 nCi/g - which corresponds to 9.28 Ci/m³ at 2.65 MT/m³ glass density), and ²⁴²Cm (20,000 nCi/g - which corresponds to 53 Ci/m³ at 2.65 MT/m³ glass density). The Class C limits provide the ultimate upper bounds for these isotopes for a single package or group of packages. The TRU (alpha emitting Np, Pu, Am, and Cm radionuclides with half life greater than 5 years) concentration is limited by contract to 100 nCi/g (this is also the Class C limit). There is no exception within the contract for ILAW with greater than 100 nCi/g TRU. With a glass density of 2.65 MT/m³, the 100 nCi/g limit corresponds to 0.265 Ci/m³. Thus, the sum of the ²³⁷Np, ²³⁸Pu, ²³⁹Pu, ²⁴⁰Pu, ²⁴²Pu, ²⁴¹Am, ²⁴³Am, ²⁴²Cm, and ²⁴⁴Cm curie inventory must be within this limit for every package. The upper bound for a package or group of packages is shown in the last column of Table 4.5

**Table 4.4 Average and Maximum Radionuclide and Chemical Concentrations
Based on Nominal Inventories**

Component	Phase 1 average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Phase 2 average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Total average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Maximum batch concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Ratio of Maximum/Average batch concentration
3-H	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
14-C	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
59-Ni	1.55E-03	8.64E-04	1.06E-03	4.02E-03	3.8
60-Co	4.56E-02	1.90E-02	2.64E-02	3.07E-01	11.6
63-Ni	1.51E-01	8.34E-02	1.02E-01	3.91E-01	3.8
79-Se	4.86E-03	3.38E-03	3.79E-03	6.84E-02	18.0
90-Sr	1.93E+01	3.20E+01	2.85E+01	5.43E+01	1.9
93-Zr	1.18E-02	6.44E-03	7.94E-03	3.37E-02	4.3
93m-Nb	8.20E-03	4.15E-03	5.29E-03	4.47E-02	8.5
99-Tc ^a	4.55E-02	4.08E-02	4.21E-02	9.96E-02	2.4
106-Ru	5.30E-03	5.79E-03	5.65E-03	2.59E-01	45.8
113m-Cd	7.21E-02	4.20E-02	5.04E-02	2.14E-01	4.3
125-Sb	9.32E-01	9.39E-02	3.29E-01	6.50E+00	19.7
126-Sn	4.74E-03	1.87E-03	2.67E-03	1.04E-02	3.9
129-I	2.52E-04	9.52E-05	1.39E-04	1.81E-03	13.0
134-Cs	1.25E+00	2.90E-02	3.73E-01	1.35E+01	36.2
137-Cs	4.30E+00	6.33E+00	5.76E+00	7.80E+00	1.4
151-Sm	8.03E+00	3.72E+00	4.93E+00	2.42E+01	4.9
152-Eu	3.01E-03	1.53E-03	1.94E-03	4.21E-02	21.7
154-Eu	2.36E-01	2.39E-01	2.38E-01	6.13E+00	25.7
155-Eu	3.30E-01	1.49E-01	1.99E-01	7.36E+00	36.9
226-Ra	5.95E-03	6.76E-03	6.53E-03	2.82E-01	43.2
227-Ac	6.45E-07	2.81E-07	3.83E-07	1.76E-06	4.6
228-Ra	2.75E-04	1.84E-04	2.10E-04	1.07E-03	5.1
229-Th	3.75E-06	1.53E-06	2.15E-06	1.14E-05	5.3
231-Pa	3.40E-06	1.64E-06	2.13E-06	1.03E-05	4.8
232-Th	1.56E-05	5.16E-06	8.09E-06	5.97E-05	7.4
232-U	2.08E-04	2.23E-04	2.19E-04	1.64E-03	7.5
233-U	7.89E-04	8.41E-04	8.26E-04	6.22E-03	7.5
234-U	2.87E-04	2.75E-04	2.79E-04	1.95E-03	7.0
235-U	1.17E-05	1.11E-05	1.13E-05	7.97E-05	7.1
236-U	1.21E-05	7.81E-06	9.03E-06	3.68E-05	4.1
237-Np	1.01E-03	3.19E-04	5.13E-04	1.78E-03	3.5
238-Pu	9.90E-04	5.48E-04	6.72E-04	2.69E-03	4.0
238-U	2.98E-04	3.09E-04	3.06E-04	2.02E-03	6.6
239-Pu	1.99E-02	1.90E-02	1.93E-02	9.50E-02	4.9
240-Pu	3.61E-03	3.21E-03	3.32E-03	1.34E-02	4.0
241-Am	1.04E-01	5.48E-02	6.85E-02	1.69E+00	24.6
241-Pu	6.61E-02	3.73E-02	4.53E-02	1.98E-01	4.4
242-Cm	2.37E-04	4.13E-04	3.64E-04	1.16E-02	31.7

HNF-4921 Rev.0

Component	Phase 1 average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Phase 2 average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Total average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Maximum batch concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Ratio of Maximum/Average batch concentration
242-Pu	4.68E-07	2.12E-07	2.84E-07	1.69E-06	6.0
243-Am	1.22E-05	1.31E-06	4.36E-06	9.01E-05	20.7
243-Cm	6.21E-05	3.49E-05	4.26E-05	5.18E-04	12.2
244-Cm	1.15E-03	4.36E-04	6.36E-04	6.77E-03	10.6
Ag+	2.01E-03	1.66E-04	6.83E-04	5.68E-03	8.3
Al(OH)4-	7.95E+00	4.36E+01	3.36E+01	2.51E+02	7.5
Al+3	3.24E+01	2.30E+01	2.56E+01	8.65E+01	3.4
As+5	9.85E-05	1.17E-04	1.12E-04	7.42E-03	66.5
B+3	1.14E-02	1.31E-03	4.14E-03	5.20E-02	12.6
Ba+2	1.59E-04	1.01E-04	1.17E-04	7.24E-03	61.6
Be+2	0.00E+00	5.40E-06	3.89E-06	5.48E-04	141.0
Bi+3	8.13E-03	8.44E-02	6.30E-02	1.72E+00	27.3
Ca+2	1.50E-01	3.62E-01	3.03E-01	3.27E+00	10.8
Cd+2	9.13E-04	1.98E-04	3.98E-04	5.13E-03	12.9
Ce+3	2.44E-03	1.95E-02	1.47E-02	3.89E-01	26.4
Cl-	6.26E+00	5.75E+00	5.89E+00	1.55E+01	2.6
CN-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Co+3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
CO3-2	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Cr(OH)4-	5.61E-01	3.35E+00	2.56E+00	3.14E+01	12.2
Cr(TOTAL)	1.39E+00	1.87E+00	1.73E+00	1.27E+01	7.3
Cs+	1.98E+00	2.18E-01	7.13E-01	1.81E+01	25.3
Cu+2	1.43E-05	8.67E-07	4.63E-06	2.54E-05	5.5
F-	5.06E+00	6.76E+00	6.28E+00	2.75E+01	4.4
Fe+3	1.66E-01	3.29E-01	2.83E-01	2.86E+00	10.1
H+	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
H2O	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Hg+2	5.61E-04	1.47E-03	1.22E-03	3.38E-02	27.8
K+	1.12E+01	2.95E+00	5.27E+00	2.08E+01	4.0
La+3	8.85E-03	9.90E-04	3.20E-03	2.99E-02	9.3
Li+	6.59E-04	8.40E-06	1.91E-04	2.47E-04	1.3
Mg+2	4.26E-03	8.39E-04	1.80E-03	6.43E-02	35.7
Mn+4	1.32E-01	6.97E-02	8.71E-02	4.20E-01	4.8
Mo+6	1.35E-02	1.93E-04	3.93E-03	1.32E-02	3.4
Na+	2.84E+02	3.89E+02	3.60E+02	3.93E+02	1.1
NH3	5.08E+00	1.53E+00	2.53E+00	4.24E+01	16.8
Ni+2	1.73E-01	2.00E-01	1.93E-01	2.96E+00	15.4
NO2-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
NO3-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
OH(BOUND)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
OH-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Pb+2	8.00E-02	3.76E-02	4.95E-02	2.73E-01	5.5

Component	Phase 1 average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Phase 2 average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Total average concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Maximum batch concentration (Ci/m ³ for radionuclides, kg/m ³ for chemicals)	Ratio of Maximum/Average batch concentration
PO4-3	6.14E+00	4.30E+01	3.26E+01	2.28E+02	7.0
Rh+3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Ru+3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Sb+5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Se+6	9.67E-06	9.12E-07	3.37E-06	2.96E-05	8.8
Si+4	8.54E-01	3.36E+00	2.66E+00	2.29E+01	8.6
SO4-2	1.12E+01	2.55E+01	2.15E+01	9.12E+01	4.3
Sr+2	3.02E-03	1.82E-02	1.39E-02	1.29E-01	9.3
Tc+7	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Te+6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Th+4	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Ti+4	3.12E-04	9.10E-06	9.42E-05	1.15E-03	12.2
Tl+3	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
TOC	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
U(TOTAL)	1.67E-01	8.72E-02	1.10E-01	2.16E+00	19.7
V+5	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
W+6	0.00E+00	0.00E+00	0.00E+00	0.00E+00	N/A
Zn+2	3.21E-02	4.86E-03	1.25E-02	1.19E-01	9.5
Zr+4	1.46E-01	5.10E-02	7.76E-02	7.03E-01	9.0

a) Concentrations are for ILAW glass based on glass density of 2.65 MT/m³.

Table 4.5 Package Upper Bound Concentrations

Component	Nominal average package concentration (Ci/m ³ for radionuclides and kg/m ³ for chemicals)	Upper bound average package (Ci/m ³ for radionuclides and kg/m ³ for chemicals)	Ratio of Maximum batch/Average batch	Tank Inventory Uncertainty Factor	Maximum Upper Bound Package (Ci/m ³ for radionuclides and kg/m ³ for chemicals)
3-H	0.00E+00	1.55E-01	NA	3.0	4.66E-01
14-C	0.00E+00	2.77E-02	NA	NA	8.00E+00
59-Ni	1.06E-03	5.42E-03	3.8	3.0	6.20E-02
60-Co	2.64E-02	1.26E-01	11.6	3.0	4.39E+00
63-Ni	1.02E-01	5.34E-01	3.8	NA	7.00E+02 ^a
79-Se	3.79E-03	5.89E-03	18.0	3.0	3.19E-01
90-Sr	2.85E+01	3.70E+01	1.9	NA	7.00E+03 ^a
93-Zr	7.94E-03	2.61E-02	4.3	3.0	3.32E-01
93m-Nb	5.29E-03	1.60E-02	8.5	3.0	4.05E-01
99-Tc	3.66E-02	4.21E-02	2.4	NA	3.00E+00 ^a
106-Ru	5.65E-03	8.01E-01	45.8	3.0	1.10E+02
113m-Cd	5.04E-02	1.05E-01	4.3	3.0	1.34E+00
125-Sb	3.29E-01	1.56E+00	19.7	3.0	9.23E+01
126-Sn	2.67E-03	7.31E-03	3.9	3.0	8.53E-02
129-I	1.39E-04	6.37E-04	13.0	NA	8.00E-02 ^a
134-Cs	3.73E-01	3.09E-03	36.2	3.0	3.36E-01
137-Cs	5.76E+00	7.49E+00	1.4	NA	4.60E+03 ^a
151-Sm	4.93E+00	1.65E+01	4.9	3.0	2.43E+02
152-Eu	1.94E-03	9.16E-03	21.7	3.0	5.96E-01
154-Eu	2.38E-01	1.16E+00	25.7	3.0	8.92E+01
155-Eu	1.99E-01	1.11E+00	36.9	3.0	1.23E+02
226-Ra	6.53E-03	7.22E-03	43.2	3.0	9.36E-01
227-Ac	3.83E-07	5.53E-04	4.6	3.0	7.63E-03
228-Ra	2.10E-04	4.90E-04	5.1	3.0	7.49E-03
229-Th	2.15E-06	1.14E-05	5.3	3.0	1.82E-04
231-Pa	2.13E-06	9.68E-04	4.8	3.0	1.40E-02
232-Th	8.09E-06	2.79E-05	7.4	3.0	6.17E-04
232-U	2.19E-04	9.42E-04	7.5	3.0	2.11E-02
233-U	8.26E-04	3.62E-03	7.5	3.0	8.18E-02
234-U	2.79E-04	2.16E-03	7.0	3.0	4.54E-02
235-U	1.13E-05	9.26E-05	7.1	3.0	1.96E-03
236-U	9.03E-06	7.85E-05	4.1	3.0	9.60E-04
237-Np	5.13E-04	1.90E-03	3.5	NA	1.46E-03 ^a
238-Pu	6.72E-04	2.49E-03	4.0	NA	1.91E-03 ^a
238-U	3.06E-04	2.08E-03	6.6	3.0	4.12E-02
239-Pu	1.93E-02	7.14E-02	4.9	NA	5.49E-02 ^a
240-Pu	3.32E-03	1.23E-02	4.0	NA	9.47E-03 ^a
241-Am	6.85E-02	2.54E-01	24.6	NA	1.95E-01 ^a
241-Pu	4.53E-02	1.05E+00	4.4	NA	9.28E+00 ^a
242-Cm	3.64E-04	1.09E-03	31.7	NA	5.30E+01 ^a
242-Pu	2.84E-07	1.05E-06	6.0	NA	8.09E-07 ^a

HNF-4921 Rev.0

Component	Nominal average package concentration (Ci/m ³ for radionuclides and kg/m ³ for chemicals)	Upper bound average package (Ci/m ³ for radionuclides and kg/m ³ for chemicals)	Ratio of Maximum batch/ Average batch	Tank Inventory Uncertainty Factor	Maximum Upper Bound Package (Ci/m ³ for radionuclides and kg/m ³ for chemicals)
243-Am	4.36E-06	1.61E-05	20.7	NA	1.24E-05 ^a
243-Cm	4.26E-05	1.58E-04	12.2	NA	1.21E-04 ^a
244-Cm	6.36E-04	2.36E-03	10.6	NA	1.81E-03 ^a
Ag+	6.83E-04	1.91E-02	8.3	10.0	1.59E+00
Al(OH)4-	3.36E+01	6.85E+01	7.5	3.0	1.53E+03
Al+3	2.56E+01	5.23E+01	3.4	3.0	5.29E+02
As+5	1.12E-04	2.63E-04	66.5	10.0	1.75E-01
B+3	4.14E-03	8.27E-02	12.6	10.0	1.04E+01
Ba+2	1.17E-04	2.15E-02	61.6	10.0	1.32E+01
Be+2	3.89E-06	1.38E-03	141.0	10.0	1.94E+00
Bi+3	6.30E-02	3.99E+00	27.3	3.0	3.27E+02
Ca+2	3.03E-01	2.02E+00	10.8	3.0	6.54E+01
Cd+2	3.98E-04	5.29E-03	12.9	10.0	6.81E-01
Ce+3	1.47E-02	3.00E+00	26.4	10.0	7.93E+02
Cl-	5.89E+00	5.93E+00	2.6	3.0	4.67E+01
CN-	0.00E+00	6.88E-01	NA	3.0	2.06E+00
CO3-2	0.00E+00	5.98E+01	NA	3.0	1.79E+02
Cr(OH)4-	2.56E+00	6.29E+00	12.2	3.0	2.31E+02
Cr(TOTAL)	1.73E+00	4.25E+00	7.3	3.0	9.37E+01
Cs+	7.13E-01	7.45E-01	25.3	3.0	5.67E+01
Cu+2	4.63E-06	3.99E-03	5.5	10.0	2.19E-01
F-	6.28E+00	7.60E+00	4.4	3.0	9.97E+01
Fe+3	2.83E-01	8.84E+00	10.1	3.0	2.68E+02
H2O	0.00E+00	5.50E+02	NA	3.0	1.65E+03
Hg+2	1.22E-03	1.33E-02	27.8	3.0	1.11E+00
K+	5.27E+00	5.53E+00	4.0	3.0	6.57E+01
La+3	3.20E-03	3.25E-01	9.3	3.0	9.10E+00
Li+	1.91E-04	3.85E-04	1.3	10.0	4.98E-03
Mg+2	1.80E-03	4.27E-02	35.7	10.0	1.53E+01
Mn+4	8.71E-02	1.24E+00	4.8	3.0	1.79E+01
Mo+6	3.93E-03	1.66E-02	3.4	10.0	5.58E-01
Na+	3.60E+02	3.10E+02	1.1	3.0	1.01E+03
NH3	2.53E+00	3.17E+00	16.8	3.0	9.51E+00
Ni+2	1.93E-01	1.14E+00	15.4	3.0	5.25E+01
NO2-	0.00E+00	7.99E+01	1.0	3.0	2.40E+02
NO3-	0.00E+00	3.32E+02	NA	3.0	9.96E+02
OH(BOUND)	0.00E+00	1.34E+02	NA	3.0	4.01E+02
OH-	0.00E+00	2.32E+01	NA	3.0	6.95E+01
Pb+2	4.95E-02	5.31E-01	5.5	3.0	8.77E+00
PO4-3	3.26E+01	3.52E+01	7.0	3.0	7.36E+02
Rh+3	0.00E+00	6.56E-04	NA	10.0	6.56E-03
Ru+3	0.00E+00	1.53E-05	NA	10.0	1.53E-04

HNF-4921 Rev.0

Component	Nominal average package concentration (Ci/m ³ for radionuclides and kg/m ³ for chemicals)	Upper bound average package (Ci/m ³ for radionuclides and kg/m ³ for chemicals)	Ratio of Maximum batch/ Average batch	Tank Inventory Uncertainty Factor	Maximum Upper Bound Package (Ci/m ³ for radionuclides and kg/m ³ for chemicals)
Se+6	3.37E-06	7.73E-06	8.8	10.0	6.80E-04
Si+4	2.66E+00	5.95E+00	8.6	3.0	1.54E+02
SO4-2	2.15E+01	2.47E+01	4.3	3.0	3.16E+02
Sr+2	1.39E-02	2.88E-01	9.3	3.0	8.01E+00
Te+6	0.00E+00	3.84E-03	NA	10.0	3.84E-02
Th+4	0.00E+00	1.62E-01	NA	3.0	4.86E-01
Ti+4	9.42E-05	3.29E-03	12.2	10.0	4.00E-01
Tl+3	0.00E+00	3.21E-01	NA	10.0	3.21E+00
TOC	0.00E+00	1.26E+01	NA	3.0	3.79E+01
U(TOTAL)	1.10E-01	4.82E-01	19.7	3.0	2.85E+01
V+5	0.00E+00	2.13E-04	NA	10.0	2.13E-03
W+6	0.00E+00	2.01E-01	NA	10.0	2.01E+00
Zn+2	1.25E-02	3.66E-02	9.5	10.0	3.48E+00
Zr+4	7.76E-02	2.94E+00	9.0	3.0	7.98E+01

a) Class C Limits

4.3 Hazardous Chemicals

The ILAW packages must meet the land disposal restriction (LDR) treatment standards for compliance with the Washington State Dangerous Waste Regulations contained in Chapter 173-303 of the Washington Administrative Code (WAC). The LDR regulations are found in 40 CFR 268 and WAC173-303-140. The privatization regulatory Data Quality Objectives (DQO) (Wiemers 1998) identified a set of regulatory constituents plausible to be in the tank waste and which might be considered during permitting activities in support of the treatment facility. The TWRS-P Project Dangerous Waste Permit Application (BNFL 1999) compared these constituents to the "Universal Treatment Standards" (40 CFR 268.48) and provided a list of components and LDR treatment standards. These LDR treatment standards provide an upper bound concentration for acceptability of the ILAW product. These maximum concentrations were multiplied by the glass mass produced in Phase 1 and Phase 2 from Table 2.1, along with a safety factor of 1.3 to allow for uncertainty in the total glass mass, to provide bounding inventories of trace hazardous organic chemicals in the ILAW product. These are summarized in Table 4.6 for Phase 1, Phase 2, and total ILAW inventories. The 1,160,000 kg total inventory of organic chemicals is a little more than half of the total 2,000,000 kg tank inventory of TOC.

Table 4.6 Bounding Limits for Organic Chemicals in ILAW Packages

Organic Compounds	LDR Treatment Standard (mg/kg)	Upper Bound Organic ILAW Inventory (MT)		
		Phase 1	Phase 2	Total
1,1,1-trichlorethane	6	9.17E-01	2.35E+00	3.27E+00
1,1,2-trichloro-1,2,2-trifluoroethane	30	4.59E+00	1.18E+01	1.63E+01
1,1,2-trichloroethane	6	9.17E-01	2.35E+00	3.27E+00
1,1-dichloroethylene	6	9.17E-01	2.35E+00	3.27E+00
1,2-dichloroethane	6	9.17E-01	2.35E+00	3.27E+00
acetone	160	2.45E+01	6.27E+01	8.71E+01
benzene	10	1.53E+00	3.92E+00	5.45E+00
carbon tetrachloride	6	9.17E-01	2.35E+00	3.27E+00
chlorobenzene	6	9.17E-01	2.35E+00	3.27E+00
chloroform	6	9.17E-01	2.35E+00	3.27E+00
ethyl acetate	33	5.05E+00	1.29E+01	1.80E+01
ethyl benzene	10	1.53E+00	3.92E+00	5.45E+00
hexachlorobutadiene	5.6	8.56E-01	2.19E+00	3.05E+00
methyl ethyl ketone	36	5.50E+00	1.41E+01	1.96E+01
methyl isobutyl ketone	33	5.05E+00	1.29E+01	1.80E+01
methylene chloride	30	4.59E+00	1.18E+01	1.63E+01
n-butyl alcohol	2.6	3.98E-01	1.02E+00	1.42E+00
nitrobenzene	14	2.14E+00	5.49E+00	7.63E+00
o-dichlorobenzene	6	9.17E-01	2.35E+00	3.27E+00
pyridine	16	2.45E+00	6.27E+00	8.71E+00
tetrachloroethylene	6	9.17E-01	2.35E+00	3.27E+00
toluene	10	1.53E+00	3.92E+00	5.45E+00
trichloroethylene	6	9.17E-01	2.35E+00	3.27E+00
trichloromonofluoromethane	30	4.59E+00	1.18E+01	1.63E+01

Organic Compounds	LDR Treatment Standard (mg/kg)	Upper Bound Organic ILAW Inventory (MT)		
		Phase 1	Phase 2	Total
vinyl chloride	6	9.17E-01	2.35E+00	3.27E+00
xylenes-mixed isomers	30	4.59E+00	1.18E+01	1.63E+01
1,1,2,2-tetrachloroethane	6	9.17E-01	2.35E+00	3.27E+00
1,1-dichloroethane	6	9.17E-01	2.35E+00	3.27E+00
1,2,4-trichlorobenzene	19	2.90E+00	7.44E+00	1.03E+01
1,2-dichloropropane	18	2.75E+00	7.05E+00	9.80E+00
1,3-dichlorobenzene	6	9.17E-01	2.35E+00	3.27E+00
1,4-dichlorobenzene	6	9.17E-01	2.35E+00	3.27E+00
1,4-dioxane	170	2.60E+01	6.66E+01	9.26E+01
2-sec-butyl-4,6-dinitrophenol	2.5	3.82E-01	9.79E-01	1.36E+00
3-chloropropene	30	4.59E+00	1.18E+01	1.63E+01
acetonitrile	38	5.81E+00	1.49E+01	2.07E+01
acetophenone	9.7	1.48E+00	3.80E+00	5.28E+00
acrylonitrile	84	1.28E+01	3.29E+01	4.58E+01
aldrin	0.066	1.01E-02	2.59E-02	3.59E-02
benzo(a)pyrene	3.4	5.20E-01	1.33E+00	1.85E+00
chloroethane	6	9.17E-01	2.35E+00	3.27E+00
cis-1,3-dichloropropene	18	2.75E+00	7.05E+00	9.80E+00
cyanide	590	9.02E+01	2.31E+02	3.21E+02
dibenzo(a,h)anthracene	8.2	1.25E+00	3.21E+00	4.47E+00
dichlorodifluoromethane	7.2	1.10E+00	2.82E+00	3.92E+00
dieldrin	0.13	1.99E-02	5.09E-02	7.08E-02
dimethylnitrosamine	2.3	3.52E-01	9.01E-01	1.25E+00
diphenylamine	13	1.99E+00	5.09E+00	7.08E+00
endrin	0.13	1.99E-02	5.09E-02	7.08E-02
ethylene dibromide	15	2.29E+00	5.88E+00	8.17E+00
heptachlor	0.066	1.01E-02	2.59E-02	3.59E-02
hexachlorobenzene	10	1.53E+00	3.92E+00	5.45E+00
hexachlorocyclohexane alpha bhc	0.066	1.01E-02	2.59E-02	3.59E-02
hexachlorocyclohexane beta bhc	0.066	1.01E-02	2.59E-02	3.59E-02
isodrin	0.066	1.01E-02	2.59E-02	3.59E-02
lindane (all isomers)	0.066	1.01E-02	2.59E-02	3.59E-02
methacrylonitrile	84	1.28E+01	3.29E+01	4.58E+01
methyl bromide	15	2.29E+00	5.88E+00	8.17E+00
methyl chloride	30	4.59E+00	1.18E+01	1.63E+01
p-dinitrobenzene	2.3	3.52E-01	9.01E-01	1.25E+00
pentachloronitrobenzene	4.8	7.34E-01	1.88E+00	2.61E+00
pentachlorophenol	7.4	1.13E+00	2.90E+00	4.03E+00
phenol	6.2	9.48E-01	2.43E+00	3.38E+00
polychlorinated biphenyls (PCB)	10	1.53E+00	3.92E+00	5.45E+00
propionitrile	360	5.50E+01	1.41E+02	1.96E+02
toxaphene	2.6	3.98E-01	1.02E+00	1.42E+00
trans-1,3-dichloropropene	18	2.75E+00	7.05E+00	9.80E+00
triethylamine	0.081	1.24E-02	3.17E-02	4.41E-02
Total		3.25E+02	8.33E+02	1.16E+03

5.0 CONCLUSIONS

Nominal and bounding inventories for radionuclides, tank chemicals, and organic chemicals for the Phase 1, Phase 2, and total ILAW processing have been generated. Uncertainties in the nominal ILAW inventory were addressed qualitatively using engineering judgment for selected components. Nominal and bounding concentrations for ILAW packages have also been generated. The bounding values and uncertainties were based on qualitative considerations and conservative assumptions since consistent quantitative uncertainty information on the tank inventories, separation factors, and process losses are not available at this time.

6.0 REFERENCES

- Agnew, S. F., J. Boyer, R. A. Corbin, T. B. Duran, J. R. FitzPatrick, K. A. Jurgensen, T. P. Ortiz, B. L. Young, 1997, *Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4*, LA-UR-96-3860, Los Alamos, New Mexico.
- BNFL, 1999, *TWRS-P Project Dangerous Waste Permit Application*, BNFL-5193-RCRA-01, Rev. 0A
- Chen, G., T. A. Ferryman, K. M. Remund, S. A. Hartley, F. Gao, C. A. Lo Presti, T. J. DeForest, J. G. Hill, C. A. Weier, B. G. Amidan, D. K. Gemeinhart, 1998, *Methodology for Uncertainty Estimation of Hanford Chemical and Radionuclide Inventories and Concentrations*, PNNL-11842, Pacific Northwest National Laboratory, Richland, Washington
- Colton, N. G., 1997, *Status Report: Pretreatment Chemistry Evaluation FY1997—Wash and Leach Factors for the Single-Shell Tank Waste Inventory*, PNNL-11646, Pacific Northwest National Laboratory, Richland, Washington.
- DOE-RL, 1996, *Phase 1 Request for Proposal*, U. S. Department of Energy, Richland, Washington.
- DOE-RL, 1998, *TWRS Privatization Contract Amendment, Contract DE-AC06-96RL13308, Modification A-006*, dated August 24, 1998, U. S. Department of Energy-Richland Operations Office, Richland, Washington.
- Ferryman, T. A., B. G. Amidan, G. Chen, S. A. Hartley, C. A. Lo Presti, J. G. Hill, T. J. DeForest, F. Gao, K. M. Remund, B. C. Simpson, 1998, *Summary of Uncertainty Estimation Results for Hanford Tank Chemical and Radionuclide Inventories*, PNNL-12003, Pacific Northwest National Laboratory, Richland, Washington.
- Harmsen, R. W., J. W. Cammann, M. J. Kupfer, R. A. Watrous, S. L. Lambert, 1998, *Hanford Defined Waste Model Limitations and Improvements*, HNF-3273, Rev. 0A, Lockheed Martin Hanford Corporation, Richland, Washington.
- Hendrickson, D. W., D. E. Place, G. T. MacLean, S. L. Lambert, 1998, *Best-Basis Wash and Leach Factor Analysis*, HNF-3157, Rev. 0, COGEMA Engineering, Richland, Washington.

- Kirkbride, R. A., G. K. Allen, R. M. Orme, R. S. Wittman, J. H. Baldwin, T. W. Crawford, J. Jo, L. J. Fergstrom, T. M. Hohl, D. L. Penwell, 1999, *Tank Waste Remediation System Operation and Utilization Plan*, HNF-SD-WM-SP-012, Rev. 1, Vol. I and II, Numatec Hanford Corporation, Richland, Washington.
- Kupfer, M. J., A. L. Boldt, K. M. Hodgson, L. W. Shelton, B. C. Simpson, R. A. Watrous, M. D. LeClair, G. L. Borsheim, R. T. Winward, B. A. Higley, R. M. Orme, N. G. Colton, S. L. Lambert, D. E. Place, W. W. Schulz, 1999, *Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes*, HNF-SD-WM-TI-740, Rev. 0C, Lockheed Martin Hanford Corporation, Richland, Washington.
- LMHC, 1998, Best Basis Inventory/TWRS Planning Baseline as of 10/1/98. Tank Characterization Database, Internet at <http://twins.pnl.gov:8001/TCD/main.html>, Lockheed Martin Hanford Corporation, Richland, Washington.
- Mann, F. M., R. J. Puigh, II, P. D. Rittmann, A. H. Lu, G. F. Williamson, N. W. Kline, J. A. Voogd, Y. Chen, C. R. Eiholzer, C. T. Kincaid, B. P. McGrail, N. R. Brown, P. E. LaMont, 1998, *Hanford Immobilized Low-Activity Tank Waste Performance Assessment*, DOE/RL-97-69, U. S. Department of Energy, Richland, Washington.
- Schmittroth, F. A., T. H. De Lorenzo, D. W. Wootan, D. Y. Garbrick, 1995, *Inventories for Low-Level Waste Tank Waste*, WHC-SD-WM-RPT-166, Rev. 0, Westinghouse Hanford Company, Richland, Washington.
- Taylor, W. J., 1999, *Contract No. DE-AC06-96RL13200 – Planning Guidance Revisions for Development of Contract Deliverables Required by Performance Agreement TWR1.3.5., letter 99-AMPD-006*, (correspondence control no. 9952261 A), Department of Energy, Richland, Washington.
- Watrous, R. A., D. W. Wootan, 1997, *Activity of Fuel Batches Processed Through Hanford Separations Plants, 1944 Through 1989*, HNF-SD-WM-TI-794, Rev. 0., Lockheed Martin Hanford Corporation, Richland, Washington.
- Wiemers, K. D., M. E. Lerchen, M. Miller, K. Meier, 1998, *Regulatory Data Quality Objectives Supporting Tank Waste Remediation System Privatization Project*, PNNL-12040, Rev. 0., Pacific Northwest National Laboratory, Richland, Washington.

HNF-4921 Rev.0

Appendix A

Phase 1 and Phase 2 ILAW Inventory by Batch

This page intentionally left blank

HNF-4921 Rev.0

HNF-4921 Rev.0

Appendix B

Additional Information on Biases and Uncertainties for Selected Radionuclides

Discussion on Selected ILAW Inventory Components

Tritium. The global and model estimates for tritium are highly dependant on vapor/liquid partitioning assumptions that distribute tritium between airborne releases, process condensate releases to cribs and evaporator bottoms sent to the tanks. The HDW model assumes that 100 percent of tritium in fuel is routed to tank wastes. Due to losses to atmosphere and condensate, actual tank inventories are significantly less.

The best basis inventory (tank by tank summation) includes some tritium sample-based estimates for individual tanks, but nearly all values are estimated by the HDW model. Since most of the best-basis values are from the HDW model the best basis inventory is expected to be conservative relative to the actual inventory.

No tritium is expected to survive the vitrification process to end up in the ILAW packages (Kirkbride 1999). Tritium is expected to be discharged from the pretreatment and waste vitrification facilities in the process condensates as tritiated water. The excess process condensates that are not recycled are routed to Effluent Treatment Facility.

Carbon-14. The activation product ^{14}C is produced primarily from neutron activation of nitrogen impurities in the fuel and cladding. Most of the individual tank best-basis estimates and all of the global inventory are derived from HDW model results (Kupfer 1999). HDW predictions of ^{14}C production have a likely bias of 0.80. Additional uncertainty may exist, associated with losses of ^{14}C to atmospheric emissions (Harmsen 1998).

Nickel-59 and Nickel-63. These radionuclides are generated by neutron activation of nickel impurities in the fuel cladding. Nearly all the best basis inventory values are derived from the HDW model results. Beginning in 1959 the aluminum alloy fuel cladding contained 9,000 to 13000 ppm nickel. Prior to 1959 the fuel cladding alloy contained no more than 100 ppm nickel. The HDW model assumes a constant 800 ppm, thus ^{59}Ni and ^{63}Ni activation products are biased high for pre-1959 wastes and biased low for post 1959 wastes. Modeling of the effect of this variation in nickel impurity in the fuel cladding resulted in higher total inventory values by a factor of 1.18 for ^{59}Ni and a factor of 1.35 for ^{63}Ni (Harmsen 1998). The best basis inventory is considered accurate although few sample results are available.

Co-60. The ORIGEN2 estimates for activation product, ^{60}Co , assume a cobalt impurity level of 10 ppm in cladding and 0 ppm in core uranium. Since the actual levels of cobalt in uranium are unknown but probably not zero, it is predictable that the HDW model results are low. Improved modeling of the cobalt impurity increased the HDW tank inventory by a factor of 2.75. The best-basis tank sum is considered to be the more accurate estimate, since almost half of the tank sum is based on sample data.

Selenium-79. Most of the best-basis (tank-by-tank summation) and all of the global inventory estimate for ^{79}Se are based on the HDW model. Recent Chinese measurements indicate the half life of ^{79}Se should be increased from 0.65×10^5 years to 8.05×10^5 years (Harmsen 1998). Curie values for ^{79}Se based on the HDW model can be reduced by about a factor of twelve by using the updated half life value. ORIGEN2 based calculations of ^{79}Se production should be reduced by a factor of 0.85 to account for a lower fission yield. The total tank inventory is considered to be conservative, since it neglects previous removals such as cribbing.

Strontium-90 and Yttrium-90. The tank summation and global inventories for ^{90}Sr agree within 20%. These inventories account for the quantity of ^{90}Sr separated in B-Plant and routed to capsules, offsite, plant residuals, and solid waste. The majority of the tank summation inventory is based on samples.

Zirconium-93, Niobium-93m, Cadmium-113m, Tin-126, and Samarium-151. The ^{93}Sr , $^{93\text{m}}\text{Nb}$, $^{113\text{m}}\text{Cd}$, ^{126}Sn , and ^{151}Sm values in the best basis inventory are almost entirely derived from the HDW Rev 4 model and are subject to the model limitations. The HDW model over-estimates the distribution of these isotopes to tanks 241-AZ-101 and 241-AZ-102 based on the special ORIGEN2 run for these tanks and under-estimates the inventory of these isotopes in the rest of the tanks. The tank-by-tank summation corrects the inventory of 241-AZ-101 and 241-AZ-102 but does not adjust the inventory of the rest of the tanks (i.e., HDW values are used). The result is that the best-basis inventory slightly under-estimates the ^{93}Zr , $^{93\text{m}}\text{Nb}$, $^{113\text{m}}\text{Cd}$, ^{126}Sn , and ^{151}Sm inventories (Kupfer 1999).

The HDW curie value of ^{126}Sn should be reduced by a factor of 0.4 to account for a recently updated half life value, and by a factor of 0.78 to account for better fission yield value (Harmsen 1998). The HDW calculated values for $^{113\text{m}}\text{Cd}$ should be reduced by a factor of 0.66 to account for better fission yield and cross section values (Harmsen 1998).

Technetium-99. The best basis value for ^{99}Tc agrees reasonably well with the process knowledge based (global) estimate. The best basis value is likely the more valid since the global estimate does not account for known losses of ^{99}Tc that occurred during fuel separation operations (Kupfer 1999).

There is good evidence that 20% or more of the technetium produced was lost to the waste stream during initial fuel reprocessing, mainly co-processed with the UO_3 and sent offsite, but with minor losses to the environment as well (Schmittroth 1995).

The HDW global inventory for ^{99}Tc may be biased high by about 32% due to it's not accounting for the fractional separation of Tc to the uranium product stream in the uranium recovery, PUREX and REDOX processes (cribbing, offsite shipment, U contaminant). Approximately 60% of the tank summation inventory is based on the HDW model (Kupfer 1999).

The batchwise ILAW inventory for Case 3 from the TWRSO&UP meets the Phase 1 contract specifications for average activity, but not the 80% removal requirement.

Ruthenium-106. Ninety-nine percent of the ^{106}Ru inventory is found in tanks 241-AZ-101 and 241-AZ-102 (Kupfer 1999).

Antimony-125. Eighty-nine percent of the ^{125}Sb inventory is found in tanks 241-AZ-101 and 241-AZ-102. The best basis inventory estimates from the special ORIGEN2 run for these tanks shows about 25 percent more ^{125}Sb than does the global (HDW model) for these tanks. The ^{125}Sb best-basis inventory of the rest of the tanks is nearly all from the HDW model values (Kupfer 1999).

Iodine-129. The best-basis of ^{129}I is somewhat larger than the global estimate. The global (HDW model) estimate conservatively assumes that all of the ^{129}I in the fuel was

routed to the waste tanks. Thus the reason for the higher tank sum is not inherently obvious. The difference could be due to sample error, but is likely not due to underestimated model values. Both best basis and global inventory values are likely to be significantly higher than actual values (Kupfer 1999).

The calculated ^{129}I production in the fuel could be reduced by a factor of 0.76 to account for a better fission yield value (Harmsen 1998).

Cesium-134. Then ^{134}Cs values in the best-basis inventory are primarily derived from the HDW Rev 4 model and are subject to the model limitations. The HDW model slightly under-estimates the distribution of ^{134}Cs to tanks 241-AZ-101 and 241-AZ-102. The tank-by-tank summation corrects the inventory of 241-AZ-101 and 241-AZ-102 but does not adjust the inventory of the rest of the tanks. The result is that the best-basis inventory slightly under-estimates the ^{134}Cs inventory (Kupfer 1999).

The TWRSO&UP inventory as currently configured does not remove ^{134}Cs or Cs+ from the LAW feed along with ^{137}Cs removals. Therefore the ^{134}Cs and Cs+ values were adjusted so that the ILAW to BBI ratios were the same as for ^{137}Cs . This adjustment was applied to the Appendix A values.

Cesium-137 and Barium-137m. The ^{137}Cs inventory in the ILAW is constrained by the the BNFL Inc. Phase 1 contract specifications.

The best-basis values for ^{137}Cs and $^{137\text{m}}\text{Ba}$ agree with the global values.

Europium-152. The ^{152}Eu values in the best-basis inventory are primarily derived from the HDW Rev 4 model and are subject to the model limitations. The HDW model overestimates the inventory of ^{152}Eu to tanks 241-AZ-101 and 241-AZ-102 based on the special ORIGEN2 run for these tanks and underestimates the ^{152}Eu inventory in the rest of the tanks. The tank-by-tank summation corrects the inventory of 241-AZ-101 and 241-AZ-102 but does not adjust the inventory of the rest of the tanks, i.e., HDW values are used. Tanks 241-AZ-101 and 241-AZ-102 contain 28 percent of the ^{152}Eu inventory. The result is that the best-basis inventory slightly underestimates the ^{152}Eu inventory (Kupfer 1999).

Europium-154. The best basis of ^{154}Eu is significantly larger than the global estimate. The global ^{154}Eu estimates for 241-AZ-101 and 241-AZ-102 from the HDW model are 30 percent lower than the best-basis ORIGEN2 estimates. Tanks 241-AZ-101 and 241-AZ-102 account for 40 percent of the best-basis inventory. The balance of the best basis inventory, which includes sample values and engineering estimates is about 25 percent higher than the balance of the global HDW model estimate (Kupfer 1999).

Europium-155. The best basis of ^{155}Eu is significantly larger than the global estimate. The ORIGEN2 estimates of ^{155}Eu in tanks 241-AZ-101 and 241-AZ-102 are about 90 percent higher than the respective global (HDW model) estimates. The best basis inventory uses an ORIGEN2 ^{155}Eu value for 241-AZ-101 and a HDW model value for 241-AZ-102. The engineering estimate for 241-AZ-102 included a sample-based heel inventory of ^{155}Eu that was determined to be ludicrous. Most of the best-basis estimates for the remaining tanks (152) are from the HDW model with only 23 tanks based on sample data or engineering estimates. The best basis inventory of the remaining tanks

is about 23 percent higher than the balance of the global HDW model estimate (Kupfer 1999).

Neptunium-237. The best-basis value for ^{237}Np is about 30 percent higher than the global ^{237}Np estimate. This difference appears to be due to the ^{237}Np inventories in 241-AN-103 and 241-AN-105 which account for 30 percent of the best-basis total tank inventory. The best-basis values for these two tanks are the largest contributors to the tank-summation value and are several times larger than the values estimated by the HDW model. The best-basis values for 241-AN-103 and 241-AN-105 are based on "bounding value estimates" that are derived from analytical detection limit data (Kupfer 1999).

For most of the Hanford processing history, more than 70% of the neptunium was recovered (Schmittroth 1995).

The HDW global inventory for Np may be significantly uncertain due to the use of approximate factors, which account for extraction losses (Harmsen 1998).

Plutonium-238, -239, -240, -241, -242. Plutonium inventories in the BBI are primarily based on accountability records and samples. The tank sum ^{239}Pu and ^{240}Pu inventories are significantly higher than those estimated by the global inventories.

Americium-241 and -243, and Curium-242, -243, and -244. The tank summation inventories for this group of radionuclides are significantly higher (50 percent to 3-fold) than those estimated by the global model (HDW). Comparisons of sample based and model predicted ^{241}Am inventories for selected tanks suggests that sample results are biased high. This could be the reason for the tank summation inventory of ^{241}Am being 1.5 times greater than the global model prediction. A major reason for the discrepancy in sample versus model based inventory values for ^{243}Cm and ^{244}Cm is traced to sample results for tank 241-AW-105. Here the sample based inventory is essentially equivalent to the model based inventory for all 177 tanks. The large sample based inventory value for tank 241-AW-105 appears to be an anomaly since the other zircaloy cladding waste receiver tank (241-AW-103) contains 4000 fold less by sample determination. There is possibility of analytical errors for both Am and Cm isotopes (Kupfer 1999).

Uranium-233, -234, -235, -236, and -238. Many of the uranium isotopic inventory estimates are based on the total uranium analysis of samples. The global basis uses accountability and sample data, with the result that global inventory values closely match tank summation values. These inventories are significantly lower than those estimated from total uranium by the HDW Rev. 4 model. The HDW model assumes that significant amounts of TBP (uranium recovery process) waste remain in the tanks while sample results and observations from Rodenhizer (1987) and MacCready (1957) confirm that recovery of uranium was more efficient (Kupfer 1999).

Thorium-232. There are no analytical data for ^{232}Th . The best-basis tank summation thus reflects HDW inventory values which are about two-fold higher than estimates based on accountability measurements made during the thorium fuel processing campaigns in 1966 and 1970 (Kupfer 1999).

Radon-226, Actinium-227, Radon-228, Thorium-229, and Protactinium-231. The tank summation inventories for these isotopes (alpha decay chain daughters of ^{232}Th ,

^{233}U , ^{234}U , and ^{235}U) are based essentially on the HDW model estimates, due to lack of any direct analytical data from samples. The estimate for these daughter radionuclides is in error due to the lack of proper second-order decay functions in the HDW model. With the exception of ^{228}Ra , these daughter nuclides are expected to slowly buildup in Hanford tank wastes, not reaching peak activity levels until thousands of years in the future (Kupfer 1999).

The HDW model performs separations of uranium, plutonium, and neptunium after decaying the reactor production values to 1/1/1994, rather than at the time of fuel separation. Thus, the uranium, plutonium, and neptunium decay daughters ^{226}Ra , ^{227}Ac , ^{228}Ra , ^{229}Th , ^{231}Pa , and ^{232}Th , are overpredicted by as much as a factor of 50.

Conversely, the ^{233}U that builds in from the decay of ^{237}Np is removed along with the rest of the uranium in the HDW model, resulting in a ^{233}U prediction that is low by as much as a factor of 84 for some tanks (Harmsen 1998).

Tungsten and Thorium. For the tungsten and thorium components, there were no batch inventories or Best Basis tank inventories. For these cases, the global estimate (Kupfer 1999) was the only inventory.

HNF-4921 Rev.0

Appendix C
Radioisotope Half Lives

Radioisotope Half Lives

Table C-1 lists the half life values from the ORIGEN2 library. These are the half lives used in generating the input to the HDW model from the reactor production. Slightly different half lives may have been used for other steps in arriving at the ILAW inventories.

Table C-1. Half Lives from ORIGEN2 Library for Selected Radionuclides

Isotope	Half-life, years
3-H	1.23E+01
14-C	5.73E+03
59-Ni	7.60E+04
60-Co	5.27E+00
63-Ni	1.00E+02
79-Se	6.50E+04
90-Sr	2.88E+01
90-Y	7.31E-03
93-Zr	1.53E+06
93m-Nb	1.61E+01
99-Tc	2.11E+05
106-Ru	1.02E+00
113m-Cd	1.41E+01
125-Sb	2.76E+00
126-Sn	1.00E+05
129-I	1.57E+07
134-Cs	2.06E+00
137-Cs	3.01E+01
137m-Ba	4.85E-06
151-Sm	9.00E+01
152-Eu	1.35E+01
154-Eu	8.59E+00
155-Eu	4.76E+00
226-Ra	1.60E+03
227-Ac	2.18E+01
228-Ra	5.75E+00
229-Th	7.34E+03
231-Pa	3.28E+04
232-Th	1.41E+10
232-U	6.89E+01
233-U	1.59E+05
234-U	2.46E+05
235-U	7.04E+08
236-U	2.34E+07
237-Np	2.14E+06
238-Pu	8.77E+01
238-U	4.47E+09
239-Pu	2.41E+04
240-Pu	6.56E+03
241-Am	4.32E+01
241-Pu	1.44E+01
242-Cm	4.46E-01
242-Pu	3.73E+05
243-Am	7.37E+03
243-Cm	2.91E+01
244-Cm	1.81E+01

HNF-4921 Rev.0

Appendix D

Comparison with Interim PA ILAW Inventory

Comparison with Interim PA ILAW Inventory

Table D-1 compares the nominal ILAW inventory values from Table 4.2 and the bounding ILAW values from Table 4.3 with the ILAW inventories developed for the Interim PA (Schmittroth 1995). Some of the differences can be attributed to the contract controls on components such as ^{137}Cs , ^{90}Sr , ^{99}Tc , and TRU. Other differences can be attributed to different assumptions on the losses to product and removals during the fuel processing and on the fraction of the tank waste components that are incorporated into the ILAW product.

Table D-1. Comparison of Nominal and Bounding ILAW Radionuclide Inventory with Interim PA Inventory.

Component	Nominal Total Ci	Upper Bound Total Ci	Interim PA ILAW Inventory Ci
3-H	0.00E+00	2.46E+04	8.94E+04
14-C	0.00E+00	4.38E+03	7.73E+00
59-Ni	1.67E+02	8.58E+02	
60-Co	4.18E+03	1.99E+04	
63-Ni	1.62E+04	8.45E+04	
79-Se	6.00E+02	9.32E+02	1.03E+03
90-Sr	4.50E+06	5.85E+06	1.61E+06
93-Zr	1.25E+03	4.12E+03	4.87E+03
93m-Nb	8.36E+02	2.53E+03	4.20E+03
99-Tc	5.79E+03	6.65E+03	2.23E+04
106-Ru	8.94E+02	1.27E+05	
113m-Cd	7.97E+03	1.67E+04	
125-Sb	5.20E+04	2.47E+05	
126-Sn	4.23E+02	1.16E+03	1.58E+03
129-I	2.20E+01	1.01E+02	6.62E+00
134-Cs	5.89E+04	4.89E+02	
137-Cs	9.11E+05	1.18E+06	4.51E+05
151-Sm	7.80E+05	2.61E+06	3.16E+06
152-Eu	3.07E+02	1.45E+03	
154-Eu	3.77E+04	1.83E+05	
155-Eu	3.15E+04	1.76E+05	
226-Ra	1.03E+03	1.14E+03	4.70E-03
227-Ac	6.05E-02	8.75E+01	1.08E+02
228-Ra	3.32E+01	7.75E+01	2.76E+00
229-Th	3.40E-01	1.81E+00	9.79E-01
231-Pa	3.37E-01	1.53E+02	1.45E+02
232-Th	1.28E+00	4.40E+00	2.68E+00
232-U	3.46E+01	1.49E+02	
233-U	1.31E+02	5.72E+02	2.58E+01
234-U	4.41E+01	3.42E+02	1.80E+01
235-U	1.79E+00	1.46E+01	7.36E-01
236-U	1.43E+00	1.24E+01	4.47E-01
237-Np	8.10E+01	3.00E+02	3.74E+00
238-Pu	1.06E+02	3.94E+02	
238-U	4.83E+01	3.28E+02	1.78E+01
239-Pu	3.05E+03	1.13E+04	2.23E+03
240-Pu	5.25E+02	1.95E+03	4.31E+02
241-Am	1.08E+04	4.01E+04	4.25E+03
241-Pu	7.17E+03	1.66E+05	
242-Cm	5.76E+01	1.72E+02	
242-Pu	4.49E-02	1.66E-01	
243-Am	6.89E-01	2.55E+00	2.70E+00
243-Cm	6.73E+00	2.49E+01	
244-Cm	1.01E+02	3.73E+02	

HNF-4921 Rev.0

Appendix E
Quality Assurance

Quality Assurance

Quality assurance for this report is provided through the following peer review process. A peer review plan was established that identified three technical reviews to be performed on the Inventory Data Package for the Immobilized Low-Activity Tank Waste Performance Assessment. Fluor Daniel Northwest, Inc. (FDNW) was responsible for an internal review of the document. The Pacific Northwest National Laboratory (PNNL), Numatec Hanford Company (NHC), and Lockheed Martin Hanford Company (LMHC) were responsible for the Hanford technical reviews of this document. NHC is responsible for the TWRSO&UP inventory studies. LMHC is responsible for developing the BBI inventories. PNNL is responsible for the privatization regulatory DQO.

The Hanford reviewers, upon completion of their reviews, provided the author (D. Wootan) with written documentation of their comments. Acceptance of the comment resolutions was indicated by reviewer's signature on the Engineering Data Transmittal (EDT).

The peer review members were selected based on their experience and knowledge of specific subject areas. The internal peer review was provided by Donald Hammervold and R. Puigh. Bruce Higley was chosen from NHC to provide the technical review based on his knowledge of the TWRSO&UP inventory studies. Robert Watrous was chosen from LMHC for his knowledge of BBI inventory studies. Karyn Wiemers was chosen from PNNL for her knowledge of the characterization requirements for the LAW feed.

HNF-4921 Rev.0

Appendix F
Peer Review Checklist

FLUOR DANIEL NORTHWEST

TECHNICAL PEER REVIEWS

CHECKLIST FOR TECHNICAL PEER REVIEW

Document Reviewed: HNF-4921
 Title: Immobilized Low Activity Waste Inventory Data Package
 Author: David W. Wootan
 Date: July 28, 1999
 Scope of Review: Full Document

Yes	No*	NA	
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Problem completely defined.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Accident scenarios developed in a clear and logical manner.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Necessary assumptions explicitly stated and supported.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Computer codes and data files documented.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Data used in calculations explicitly stated in document.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Data checked for consistency with original source information as applicable.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Mathematical derivations checked including dimensional consistency of results.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Models appropriate and used within range of validity or use outside range of established validity justified.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Software input correct and consistent with document reviewed.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Software output consistent with input and with results reported in document reviewed.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Safety margins consistent with good engineering practices.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Conclusions consistent with analytical results and applicable limits.
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Results and conclusions address all points required in the problem statement.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Review calculations, comments, and/or notes are attached.
<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Traceability
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Document approved (i.e., the reviewer affirms the technical accuracy of the document).

Donald J. Hammervold
 Reviewer: (Printed and Signed) Donald J. Hammervold Date 7/29/99

* All "NO" responses must be explained below or on an additional page.

** Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

This page intentionally left blank.

Administrative Record, H6-08

TSD#: D-2-11

Load document from CD

HNF-4921, Rev. 0

Immobilized Low Activity Tank Waste Inventory Data Package

Author: Wootan, D. W