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Revision 0

Hanford Site Composite Analysis Technical Approach Description: Radionuclide Inventory and Waste Site Selection Process

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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~~**MODELING GROUNDWATER FLOW AND FATE AND TRANSPORT**~~ eGW	

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Terms

BBI	best basis inventory
BIO	basis for interim operation
CA	composite analysis
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC	contaminant of potential concern
CSB	Canister Storage Building
DOE	U.S. Department of Energy
ERDF	Environmental Restoration Disposal Facility
FFTF	Fast Flux Test Facility
HDW	Hanford Defined Waste (model)
HISS	Hanford Inactive Site Surveillance
IDF	Integrated Disposal Facility
LLBG	low-level burial ground
MTU	metric tons of uranium
OU	Operable Unit
PFP	Plutonium Finishing Plant
PUREX	Plutonium-Uranium Extraction (plant)
RI/FS	remedial investigation/feasibility study
SEPA	State Environmental Protection Act
SIM	soil inventory model
SNF	spent nuclear fuel
SWIFT	solid waste information forecast tool
SWITS	solid waste information and tracking system
TC&WM EIS	Tank Closure and Waste Management Environmental Impact Statement
TRAC	track radioactive components
WESF	Waste Encapsulation and Storage Facility
WIDS	waste information data system
WMA	waste management area
WMIS	waste management information system

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1 Introduction

The updated Hanford Site Composite Analysis will provide an all-pathways dose projection to a hypothetical future member of the public from all planned low-level radioactive waste disposal facilities and potential contributions from all other projected end-state sources of radioactive material left at Hanford following site closure. Its primary purpose is to support the decision-making process of the U.S. Department of Energy (DOE) under DOE O 435.1-1, *Radioactive Waste Management* (DOE, 2001), related to managing low-level waste disposal facilities at the Hanford Site.

Two of the key aspects of conducting a composite analysis (CA) are selecting the radionuclides to be analyzed and waste sites to be included in the analysis. This document describes the proposed technical approach for selecting radionuclides and waste sites to be included in the quantitative analysis, along with the planned next steps in the process.

This report will be revised as the approach is further developed. Expected future revisions include adding more specific details on the processes that were used to identify the selected constituents and waste sites, describe the fill-in rules used for inventory estimates, and update Appendix A, Primary I-129 Mass Balance, with more detailed information.

2 Background

The disposed inventory estimate is perhaps the most important component of the composite analysis, as it directly affects the future radiological impacts following site closure. The primary purpose is to estimate radionuclide inventory from site inception to closure. Because of the inclusive nature of a composite analysis, all waste sites and relevant contaminants are identified and initially considered. Then, subsets of sites and contaminants appropriate for quantitative analysis are selected. Reducing the number of radionuclides for inclusion in the quantitative analysis helps focus budget and resources on simulating only those radionuclides that are likely to contribute to the total dose to the receptor above a threshold value. Similarly, using a waste site screening process can reduce the number of waste sites to include in the quantitative evaluation by a factor of five to ten by excluding sites whose inventory will result in an inconsequential contribution to the total radiological dose.

3 Screening Methodology

To develop radionuclide and waste site selection screening process for the Composite Analysis, the approaches adopted in the three prior site-wide studies were evaluated.

For the Hanford Site CA update, the methodology for selecting radionuclides and waste sites to be included is based, in part, on the following aspects that influence the scope and approach:

- Use information from past Hanford site-wide studies to guide the methodology for screening radionuclides and waste sites. In particular, three past studies related to waste site evaluation and radionuclides inventories provide valuable insights into the radionuclide and waste site selection process:

    1. Composite analysis of radionuclides conducted in 1998, documented in PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200-Area Plateau of the Hanford Site*, and PNNL-11800, *Addendum to Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*.

    2. A site-wide inventory of radionuclides conducted in 2005, documented in PNNL-15829, *Inventory Data Package for Hanford Assessments*, hereinafter referred to as the 2005 Data Package.

3. A site-wide analysis of cumulative impacts from radionuclides and chemicals, documented in DOE/EIS-0391, *Final Environmental Impact Statement Tank Closure and Waste Management for the Hanford Site*, Richland, Washington (DOE/EIS-0391), hereinafter referred to as the TC&WM EIS.

- Include any new information since the past studies were conducted to update radionuclide inventory and waste sites from the analysis. Examples include dispositions of waste sites in interim and final Records of Decision, detailed inventory estimates from the Environmental Restoration Disposal Facility (ERDF) and Integrated Disposal Facility (IDF) performance assessments, an updated version of the Soil Inventory Model (SIM) (currently in preparation), and updated tank waste inventories.

3.1 Approaches Considered in Past Site-wide Studies to Select Radionuclides

The approaches used in past site-wide studies (the 1998 CA, the 2005 Data Package , and the TC&WM EIS) are considered in the following subsections.

3.1.1 Initial 1998/2001 Composite Analysis

In the 1998 CA, radionuclides were selected primarily based on those identified as potentially significant contributors to the dose in the 200 West and 200 East performance assessments and ERDF remedial investigation/feasibility study (RI/FS). In addition, other studies were reviewed to identify radionuclides unique to specific types of wastes or closed facilities, and to identify key radionuclides in immobilized low-activity radioactive waste from single- and double-shell tanks and residing in burial grounds. Different lists of radionuclides were developed for groundwater and air pathways.

The selection process assumed that sources outside of the Central Plateau would be remediated and not represent significant sources of radionuclides following site closure. It also assumed eight of the nine production reactors would be disposed on the Central Plateau; the ninth reactor had been declared a national historic monument and was expected to remain along the Columbia River.

3.1.2 2005 Data Package

In the 2005 Data Package, radionuclides were selected using the data quality objective process. The intent was to identify those radionuclides that had been observed in the environment or had sufficient inventory in waste sites to potentially impact human or ecological health. The screening process reviewed all groundwater monitoring data from 1990 to December 2002 using the following steps:

- Retain all sample results above detection levels.
- Retain all samples not rejected by data quality assurance checks.
- Retain all radionuclides with a half-life greater than 10 years.
- Identify all samples above drinking water standards.
- Identify all radionuclides that have regional or Hanford Site scale distribution (specifically, radionuclides present at more than one or two points in the aquifer).
- Identify all radionuclides with a temporal distribution of more than a single moment in time.
- Add radionuclides that could have a future impact as indicated by performance assessments and environmental impact statement studies.

This process resulted in 16 radionuclides being retained for quantitative analysis.

3.1.3 Tank Closure and Waste Management Environmental Impact Statement

The intent of the TC&WM EIS screening processes was to focus attention on the constituents that control the impacts to groundwater. Separate screening processes were conducted for sites evaluated for cumulative impacts, for the alternatives analysis, and for human health impacts. Contaminants of potential concern (COPCs) assessed for ecological impacts are also summarized below.

3.1.3.1 Cumulative Impacts Analysis

For the sites evaluated under the cumulative impacts analysis, the initial list included radionuclides with half-lives greater than 10 years and chemicals with a health risk from ingestion. Constituents were considered to pose a potential health risk from ingestion if they had a maximum contaminant level or were listed in the Integrated Risk Information System as having a health-based ingestion standard. As described in Appendix S of the TC&WM EIS, the screening process was intended to select those constituents appropriate for a groundwater release scenario; thus, for radionuclides, "…only groundwater consumption was considered, release was assumed to be partition limited, and decay during transport was considered" (DOE/EIS-0391, p. S-16). Relative impacts were based on the distribution of radionuclides in the cumulative impacts inventory. The initial list was screened, removing radionuclides contributing less than one percent of the impacts under drinking water consumption scenarios and chemicals present at levels below health-based limits. The screening resulted in a final set of 14 radioactive and 26 chemical constituents (DOE/EIS-0391, p. S-16).

3.1.3.2 Alternatives Impacts Analysis

For sites evaluated under the alternative analysis, different processes were used to select constituents for tank closure, Fast Flux Test Facility (FFTF) decommissioning, and waste management alternatives.

The Best Basis Inventory (BBI), which included 46 radionuclides and 24 chemicals, was used as the initial list of constituents to consider for evaluating the tank closure and waste management alternatives. Constituents were screened out if they contributed less than one percent of impacts on drinking water ingestion for the chemicals, and on intruder or drinking water consumption scenarios for the radionuclides. As described in Appendix D of the TC&WM EIS,

> "Not all constituents are important in the exposure scenarios used to assess TC & WM EIS alternative implementation impacts. Thus, to focus attention on the constituents that control the impacts, DOE performed an initial screening analysis. For radionuclides, groundwater release and direct intrusion scenarios were considered. For the groundwater release screening scenario, only drinking water consumption was considered. Release was assumed partition limited, and decay during transport was considered. For the direct intrusion screening scenario, inadvertent soil ingestion and inhalation pathways were considered."
>
> "The analysis estimated relative impacts based on distribution of radionuclides in the BBI for all tanks. Radionuclides contributing less than 1 percent of impacts under intruder or well scenarios were eliminated from the detailed analysis. To screen for hazardous chemicals, drinking water ingestion impacts were estimated for the 24 BBI chemical constituents, and those contributing more than 99 percent of impacts were selected for detailed analysis. In addition, reported tank concentrations were reviewed and compared with health-based limits (DOE 2003a)[1]; chemical

[1] DOE 2003a from the quoted material references: DOE (U.S. Department of Energy), 2003a, *Environmental Impact Statement for Retrieval, Treatment, and Disposal of Tank Waste and Closure of Single-Shell Tanks at the Hanford Site, Richland, WA: Inventory and Source Term Data Package*, DOE/ORP-2003-02, Rev. 0, Office of River Protection, Richland, Washington, April 17.

> COPCs, when compared with health-based limits (DOE 2003a), were added to the initial list of screened chemicals." (DOE/EIS-0391, p. D-3).

The screening resulted in ten radionuclides and ten chemicals being selected for detailed analysis, listed in Table D-2 in the TC&WM EIS (p. D-4). One of the radionuclides, Amercium-241, is applied to the intruder scenarios only via the inhalation pathway. Although Appendix D mentions other COPCs were added to the list from the screening conducted for the cumulative impact analysis (last paragraph, p. D-3), the tables comparing tank alternatives only list nine radionuclides and ten chemicals (for examples, see Tables D-35 through D-60).

For the waste management alternatives, three categories of waste were considered: secondary low-level waste and mixed low-level wastes managed at three Hanford facilities; onsite non-*Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (non-CERCLA) waste, non-tank-activity waste; and offsite waste.

Secondary low-level waste and mixed low-level wastes from the operation of three sites were evaluated -- low-level burial ground (LLBG) 218-W-5 (trenches 31 and 34), the Waste Receiving and Processing Facility, and the T Plant complex. To evaluate the waste management alternatives, the same nine radionuclides and ten chemicals as the tank alternatives were considered, but only three of the chemicals were evaluated because inventories for the other seven chemicals were not included in the cited report (p. D-129, footnote 'a' to Table D-82).

No screening process was described in section D.3.5, "Radionuclide and Chemical Inventory Estimates for Onsite Non-CERCLA, Non-Tank-Activity Waste." In the table summarizing the inventory of non-CERCLA, non-tank-activity waste, the same nine radionuclides as in the tank alternatives are reported, but an expanded list of 19 chemicals is reported, based on a Solid Waste Information Tracking System (SWITS) forecast from FY2006-FY2035 as reported in *Waste Inventories Reference Mapping* (SAIC 2011).

Similarly, no screening process was described in section D.3.6 "Projected Volumes, Radionuclide and Chemical Inventories for Offsite Waste." Inventories from projected waste volumes that could be shipped to Hanford list the same nine radionuclides as in the tank alternatives but list 15 chemical constituents.

To evaluate the FFTF alternatives, inventories of various radionuclides and chemicals were obtained from existing reports, such as *FFTF Radioactive and Hazardous Materials Inventory* (in DOE/EIS-0391), *Technical Information Document for the Fast Flux Test Facility Closure Project Environmental Impact Statement* (FFTF-18346), *Activation of the FFTF Biological Shield Wall* (Kidd 2005). The process used to screen the many reported constituents to the selected four radionuclides and three chemical constituents was described in the TC&WM EIS as follows: "Matching the list of radionuclides and chemicals identified in the above tables with the COPCs identified in Appendix D, Section D.1.1, resulted in a report of the following radionuclides (in curies)…" (p. D-119). The "above tables" refers to tables of inventories reported from the various sources, with differing numbers of COPCs, from seven to 31. Section D.1.1 is "Current Tank Inventory of Radioactive and Chemical Constituents" and includes Table D-2, "Constituents Selected for Detailed Analysis," which lists the ten radionuclides and ten chemicals mentioned above. In the FFTF alternatives analysis, four radionuclides and three chemicals were reported in the tables and figures showing the inventories of COPCs.

3.1.3.3 Human Health Impacts Analysis

In Appendix Q of the TC&WM EIS, "Long-term Human Health Dose and Risk Analysis," the screening process is described as follows: Using the inventories in Appendix D for the alternatives analysis and Appendix S for the cumulative impacts analysis, relative impacts were estimated based on the distribution of radionuclides in wastes associated with tanks, FFTF decommissioning, the IDF, the proposed River

Protection Project Disposal Facility, and cumulative analysis sites. Radionuclides contributing less than one percent of impacts for intruder (inadvertent soil ingestion and inhalation) or drinking water scenarios and chemicals contributing less than one percent of drinking water impacts were screened out. The result was a list of 14 radionuclides and 26 chemical constituents (Table Q-1, p. Q-2).

3.1.3.4 Ecological Impacts Analysis

A screening process to select COPCs to assess ecological impacts was not described in Appendix P, "Ecological Resources and Risk Analysis." Appendix P describes potential ecological impacts of airborne releases during operations and groundwater discharges under various alternatives. Appendix P states "Concentrations of radionuclides and chemicals resulting from deposition of airborne contaminants during construction and operations associated with the alternatives were predicted, as described in Appendix G." (p. P-6). However, Appendix G, "Air Quality Analysis," states "This appendix presents information on the nonradiological air quality impacts that could result from emissions associated with construction, operations, deactivation, and closure activities under the various alternatives…" (p. G-1). The only constituents described in Appendix G are nonradiological ambient air pollutants such as carbon monoxide; PM_{10}; and sulfur dioxide and other pollutants such as benzene, mercury, formaldehyde, and 1,3-butadiene.

Appendix P also describes that predicted seep, sediment pore water, sediment, and surface water "…concentrations were calculated from the modeled groundwater concentrations at the Columbia River resulting from the varying radioactive and chemical COPC inventories in place under the different alternatives (see Appendix O)." (p. P-46). Appendix O, "Groundwater Transport Analysis," describes the particle-tracking method used to implement the contaminant transport model. Radionuclides included in the particle-tracking analysis were the same as the screened COPCs to assess human health in Appendix Q, except that plutonium-239 and uranium-238 were listed instead of plutonium and uranium isotopes. For chemicals, Appendix P again points to Appendix G.

3.1.3.5 Comparison of Different TC&WM EIS Screening Results

In the TC&WM EIS, the tables of constituents selected for detailed analysis were the same for the human health impacts analysis and the cumulative impacts analysis (DOE/EIS-0391) as shown in Table 1, despite key differences in the screening methodologies. The human health impacts screening considered groundwater release and intruder scenarios while the cumulative impacts screening only considered groundwater consumption. In the human health impacts screening, relative impacts were estimated based on the distribution of radionuclides in multiple types of sources (tanks, FFTF decommissioning, waste proposed for disposal at IDF and the River Protection Project Disposal Facility, and cumulative analysis sites), while in the cumulative analysis screening, the distribution of radionuclides was based only from cumulative analysis sites. This suggests the inventories in the cumulative impact waste sites were the major driver of impacts.

Screening processes conducted to evaluate the tank closure alternatives and human health impacts both considered groundwater release and intruder scenarios. However, the tank closure screening was based on the distribution of radionuclides in the BBI, which includes fewer radionuclides and chemicals than in the initial lists used for the human health screening, and would help explain the shorter screened list for tank closure (Table 1).

Table 1. Selected COPCs Based on Screening Evaluations Conducted in the TC&WM EIS

Analyte	Analysis of Human Health Impacts (Appendix Q, Table Q-1) and Cumulative Impacts (Appendix S, Table S-8)	Analysis of Tank Closure Alternatives (Appendix D, Table D-2)
Radionuclides		
Americium-241	X	*
Carbon-14	X	X
Cesium-137	X	X
Gadolinium-152	X	
Hydrogen-3 (tritium)	X	X
Iodine-129	X	X
Neptunium-237	X	X
Plutonium isotopes	X	X
Potassium-40	X	
Strontium-90	X	X
Technicium-99	X	X
Thorium-232	X	
Uranium isotopes	X	X
Zirconium-93	X	
Chemicals		
1,2-Dichloroethane	X	
1,4-Dioxane	X	
1-Butanol	X	
2,4,6-Trichlorophenol	X	X
Acetonitrile	X	X
Arsenic, inorganic	X	
Benzene	X	X
Boron and compounds	X	
Butanol		X
Cadmium	X	
Carbon tetrachloride	X	

Table 1. Selected COPCs Based on Screening Evaluations Conducted in the TC&WM EIS

Analyte	Analysis of Human Health Impacts (Appendix Q, Table Q-1) and Cumulative Impacts (Appendix S, Table S-8)	Analysis of Tank Closure Alternatives (Appendix D, Table D-2)
Chromium	X	X
Dichloromethane	X	
Fluoride	X	
Hydrazine/hydrazine sulfate	X	
Lead	X	X
Manganese	X	
Mercury	X	X
Molybdenum	X	
Nickel (soluble salts)	X	
Nitrate	X	X
Polychlorinated biphenyls	X	X
Silver	X	
Strontium (stable)	X	
Total uranium	X	X
Trichloroethylene	X	
Vinyl chloride	X	

*Applies to the inhalation pathway for the intruder scenario analyzed in Appendix Q but not to the EIS alternatives analysis (p. D-3).

3.2 Proposed Approach to Select Radionuclides

The proposed approach for the current study is to develop an initial list of potentially important radionuclides based on the evaluations conducted by 1998 Composite Analysis, the 2005 Data Package , the TC&WM EIS, and approved performance assessments for the 200 West LLBGs, 200 East LLBGs, ERDF, and Waste Management Area C. The list is presented in Table 2.

Table 2. Contaminants of Potential Concern Identified from Prior Analyses

COC	Site-Wide Analyses			Performance Assessments			
	1998 CA*	2006 2005 Data Package	2012 TC&WM EIS	1995 200-W LLBGs	1996 200-E LLBGs	2013 ERDF	2016 WMA C
Americium-241			X				
Carbon-14	X	X	X	X	X	X	X
Cesium-137		X	X				
Chlorine-36	X	X		X	X	X	
Europium-152, -154, -155		X					
Gadolinium-152			X				
Hydrogen-3 (tritium)	X	X	X	X	X	X	X
Iodine-129	X	X	X	X	X	X	X
Molybdenium-93						X	
Neptunium-237		X	X		X		
Niobium-94				X		X	
Plutonium isotopes			X				
Polonium-209				X			
Potassium-40			X				
Protactinium-231				X			
Rhenium-187				X	X		
Selenium-79	X	X		X	X		X
Strontium-90	X	X	X				
Technetium-99	X	X	X	X	X	X	X
Thorium-232			X				
Tin-126							X
Uranium isotopes		X	X	X	X		
Uranium-238	X	X	X				X
Zirconium-93			X				

*CA = composite analysis.

The initial list will be screened to identify key radionuclides that could potentially affect a receptor via the groundwater within 10,000 years after site closure. The initial list also will be evaluated against current

information on site-wide inventories and contaminant mobility. Additional screening will be performed using a 1-D transport model and conservative hydraulic parameters to determine the threshold K_d value, above which breakthrough at the water table will not occur within 10,000 years. Short-lived radionuclides with a half-life of less than 10 years will be screened out.

One example of how the initial list of COPCs will be evaluated is by considering the information in the TC&WM EIS regarding gadolium-152. Although the TC&WM EIS included gadolinium-152 in its list of selected COPCs, the TC&WM EIS concluded its relative contribution to risk was negligible, with vadose zone modeling results showing this contaminant did not breakthrough to groundwater within 10,000 years. Specifically, in Appendix O, "Groundwater Transport Analysis," sections O3, O4, and O5 reporting the results of groundwater transport analysis, the TC&WM EIS states, "If the concentration value for a COPC was zero at all lines of analysis, then, for brevity, the COPC was not reported" (pp. O-58, O-86, and O-87). Gadoliumn-152 was not reported in any of the results tables in Appendix O. Additionally, in the inventory tables in the TC&WM EIS, only one site was reported with an inventory of gadolium-152 -- 3.39 x 10^{-3} curies at the 218-W-3A Burial Ground (p. S-79). Gadolium-152, which is naturally occurring, may have been included in the list of COPCs because of its potential presence in grout used at Hanford. Table M-7, "Values of Distribution Coefficient for Radioactive Constituents in Hanford Grout," includes gadolinium (p. M-18).

3.3 Approaches Considered in Past Studies to Select Waste Sites

Out of the thousands of contaminated waste sites and facilities at the Hanford Site that have radionuclide contaminants present, most contain negligible inventories. To develop the screening approach for waste sites, the methodologies in three prior site-wide studies were evaluated. The scope of study, geographical extent, types of wastes of interest, site selection process, and outcomes of the three inventories varied widely (Table 3).

The geographical extents considered were the Central Plateau (for the 1998 CA), the entire Hanford Site (for the 2005 Data Package), and the entire Hanford Site plus a few sites outside of the Hanford Site (for the TC&WM EIS).

The types of contaminants considered in the study were radionuclides for the 1998 CA and the 2005 Data Package , while both chemicals and radionuclides were considered in the TC&WM EIS.

For the site selection process, in the 1998 CA, sites were selected if contaminants released from the site could superimpose with contaminants from the burial grounds. The 2005 Data Package and the TC&WM EIS cumulative impacts analysis began primarily with a list of waste sites from the Waste Information Data System (WIDS), then screened out sites using a variety of considerations (waste form, composition, or quantity, potential for release to groundwater, etc.). The TC&WM EIS cumulative effects analysis also added sites not included in WIDS based on a literature review, removed sites included in the TC&WM EIS alternative analysis (such as single-shell tanks, double-shell tanks, ancillary tank equipment, FFTF, and auxiliary FFTF facilities), and screened out sites using a variety of considerations.

The processes used in the 2005 Data Package and the TC&WM EIS screened out waste sites based on characteristics such as the WIDS waste site status (closed out, rejected, etc.), lack of transport to groundwater (e.g., river outfall, no potential for release, etc.), type of constituents (e.g., PCBs, petroleum, nonhazardous), and waste quantity (*de minimis* or negligible). In addition, the 2005 Data Package screened out waste sites such as remediated unplanned releases, biological transport, and test or no waste received. The TC&WM EIS screened out waste sites such as those containing radionuclides with a half-life of less than 10 years, constituents with a K_d of greater than 10, non-liquid waste sites where contamination would be removed, and several specific waste types (e.g., ash that passes the toxicity characteristic leaching procedure, containers not clearly associated with nuclear materials or processing,

demolition waste, non-liquid effluent area no longer posted, etc.). Table 3 provides more details on the screening considerations.

To compare the lists of sites included in each of the past three studies, the list of sites was copied into an Excel®[2] spreadsheet first. Next, rows of non-inventory related information were deleted, such as rows calculating cumulative totals, waste sites included solely for water balance purposes (in the 2005 Data Package), no longer relevant waste sites or non-real waste site identification numbers such as "unk." Identification numbers were revised to be consistent between lists. The resulting numbers of sites with inventory estimates were 220 in the 1998 CA, 686 in the 2005 Data Package (of which 379 were generated by SIM), and 384 with inventories greater than *de minimis* quantities in the 2012 TC&WM EIS. Table 3 summarizes the information.

When the three lists of sites with inventories were combined and duplicates removed, 793 sites were listed. Of these 793 sites, 414 were not included in SIM, and 155 were common to all studies. Of the 350 waste sites without inventory estimates listed in the initial 1998 CA, 56 now have inventory estimates.

The apparently substantial differences in the outcomes of the 2005 Data Package and the TC&WM EIS cumulative impacts analysis – 686 and 384 sites with identified inventories, respectively – illustrate the importance of defining the scope of waste sites to be considered. The 2005 Data Package and the cumulative impacts analysis for the TC&WM EIS begin with similar lists of waste sites – the 2003 and 2004 lists of WIDS sites, respectively. While the two processes use different screening criteria, it appears the scope of the cumulative impacts analysis in the TC&WM EIS is the most significant cause of the TC&WM EIS having 302 fewer sites with inventory than the 2005 Data Package. The waste site screening conducted for the cumulative impacts analysis in the TC&WM EIS excluded the tank farms because they were addressed separately in the tank closure alternatives analysis. There are 177 waste sites with WIDS identification numbers beginning with 241(indicating a waste site located in a tank farm) listed as having inventories in the 2005 Data Package , which were not included in the inventories supporting the cumulative impact analysis in the TC&WM EIS. An unknown number of other waste sites associated with ancillary equipment located in the tank farms are not in 241- series but would also not have been included in the TC&WM EIS cumulative impacts inventory. Even if the waste sites considered in the tank closure alternatives analysis were included in the comparison, the TC&WM EIS would still have far fewer waste sites listed than the 2005 Data Package because the TC&WM EIS evaluated the tanks by tank farm, not by individual tanks (for example, see the inventory estimates in Appendix D of the TC&WM EIS, "Waste Inventories").

3.4 Proposed Approach to Select Waste Sites

The proposed approach for the current study is to begin with a list of the 414 non-SIM waste sites with reported inventories from any of the three previously described studies (Table 4) combined with all SIM waste sites. Then the list will be screened to select waste sites with inventories of radionuclides selected in the screening process described in section 3.2 equal to or greater than the *de minimis* limit used in the TC&WM EIS of one curie (1 Ci). Fill-in rules will be developed where only partial information is available on the inventory of a given waste site.

Updated estimates from the soon-to-be released revision 2 of SIM will replace the older SIM estimates. For modeling efforts specific to the Central Plateau, the list will be reduced to waste sites located on the Central Plateau.

[2] Excel is a registered trademark of Microsoft Corporation in the United States and in other countries.

Table 3. Waste Site Screening for Previous Site-wide Inventories

Characteristic	1998 Composite Analysis	2005 Data Package	TC&WM EIS Waste Inventories for Cumulative Impacts Analysis (Appendix S)
Scope	Radionuclide sources in the 200 Areas that could interact with LLBGs	All radiological sources remaining at Hanford and 32 future wastes from the Hanford Tank Waste Operations Simulator	All Hanford radiological and chemical waste sites and a few offsite waste sites which potentially contribute to cumulative impacts on groundwater
Started with	Solid waste burial grounds ERDF Tank waste remediation system waste Sources that could superimpose (190 Central Plateau CERCLA sources, excluding tank farms) Graphite reactor cores US Ecology	2,730 WIDS sites as of Jan. 2003 and 10 non-DOE sites and 14 water balance sites	> 2,800 waste sites, from WIDS annual report for 2004 and technical baseline review
Excluded	Canyons Wastes sites w/o inventory data (151 waste sites + >200 UPRs* on the Central Plateau)		Sites not expected to contribute significantly to cumulative impacts
Screened out based on			
Site status		880 sites: status of closed out, deleted from National Priorities List, no action, interim closed out, rejected (consolidation), or rejected + no inventory. Consolidated UPRs	Closed out, no action, rejected, consolidated, closed out
Not a release of contaminant of interest		530 sites: septic tanks, fabrication shops, offices, control structures, loading docks, storage pads, burn pits, coal ash pits, sanitary sewers (releases would be included as an UPR), satellite accumulation area	No potential for a release. Satellite accumulation area [included in this row for consistency with 2006 radionuclide analysis]. Radionuclides with ½ life < 10 years. Release consists primarily of a petroleum product or polychlorinated biphenyls.
Not a release to groundwater			K_d>10 (therefore no release to groundwater). Not a groundwater source (ex: outfall to river). Non-liquid waste sites where contamination would be removed and therefore not contribute to groundwater. Sites for which process knowledge indicates a lack of contamination.
Surface contamination, surface run-off		45 sites	Surface-only contamination.
Remediated UPRs		18 sites	
Waste contained only haz but non-rad wastes		77 sites: asbestos, ash, batteries, construction debris, demolition and inert waste, misc. trash & debris, oil, sanitary sewage, vegetation, etc.	
Nonhazardous or non-rad waste streams		42 sites	
Waste type			Abandoned pipe trench if remediation is expected. Petroleum or PCB releases. Asbestos-only waste. Batteries-only. Ash that passes the Toxicity Characteristic Leaching Procedure. Barrels/drums/containers if clearly not associated with nuclear materials or processing. Chemicals if not production-related. Other types of wastes if not process- or production-related. Petroleum-carrying bunker pipeline. Surface-only contaminated areas. Demolition/inert waste, dry well, dumping area (unless evidence of chemical/radionuclide production). Electrical substation if content only petroleum or PCBs. Non-liquid effluent area previously identified as contaminated but not currently posted. Active regulated sodium storage facility. Etc.
Small quantity contaminants/inventory		15 sites: negligible quantities	*De minimis* inventory (< 1 lb chemical, < 1 ci radionuclide, < 100 gal, < 50,000 dpm). Lab or bench-scale abandoned chemicals.
Biological transport		11 sites	
Test or no waste received		3 sites	
UPRs within waste sites		7 sites	
Constituents not of interest		3 sites	
Assorted		6 sites (dose from sand filter; conveyance only (pipe trench), etc.)	
Hanford SIM & tank farm UPRs		33 sites	
Facility type			Non-process or non-production-related facilities (retain if unknown) Facility included in TCWM EIS alternatives (e.g., tank farms, FFTF, etc.)
Failed risk/hazard analysis			Screen out sites without inventory of selected 14 radionuclides and 26 chemical constituents
Ended with	**570 sites** **With inventory: 220** **Without inventory: 350**	**1,045 sites** **With inventory: 686 (379 of which came from SIM)** **Without inventory: 359**	**2,309 sites** **With inventory greater than *de minimis* quantities: 384** **No inventory or inventory not used in the EIS: 1,925** **From EIS: Unknown inventory expected to be greater than *de minimis* quantities: 403** **Process knowledge indicates lack of contaminant or *de minimis* contamination: 1,429** **Non-liquid waste sites where contaminant would be removed and not contribute to groundwater: 106**

*UPR = unplanned release

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Table 4. Non-SIM Waste Sites with Inventories

List of Waste Sites				
4843	116-B-6	116-F-9	118-DR-2	216-B-2-2
100-B-5	116-B-6A	116-H-1	118-F-1	216-B-2-3
100-D-25	116-B-6B	116-H-2	118-F-4	216-B-3A
100-D-3	116-B-7	116-H-3	118-F-5	216-B-3B
100-D-32	116-C-1	116-H-4	118-F-6	216-B-3C
100-D-40	116-C-2A	116-H-5	118-F-8	216-S-11P
100-D-47	116-C-2C	116-H-6	118-H-1	216-S-16D
100-F-23	116-C-5	116-H-7	118-H-6	216-SX-2
100-F-25	116-D-1A	116-H-9	118-K-1	216-T-13
100-F-36	116-D-1B	116-K-1	118-KE-1	216-T-4-2
100-H-10	116-D-5	116-K-2	118-KW-1	216-T-4B
100-H-33	116-D-7	116-KE-1	118-KW-2	216-TY-201
100-H-5	116-DR-1&2	116-KE-2	120-KE-1	216-U-21
100-H-7	116-DR-3	116-KE-3	132-C-2	216-Z-11
100-H-8	116-DR-4	116-KE-4	1908-NE	216-Z-1D
100-H-9	116-DR-5	116-KW-1	200-E-102	218-C-9
100-K-2	116-DR-6	116-KW-2	200-E-136	218-E-1
100-K-5	116-DR-7	116-KW-3	200-E-137	218-E-10
100-N-60	116-DR-8	116-N-1	200-E-30	218-E-12A
100-N-66	116-DR-9	116-N-3	200-W-20	218-E-12B
116-B-1	116-F-1	118-B-1	200-W-40	218-E-14
116-B-11	116-F-10	118-B-6	200-W-43	218-E-15
116-B-2	116-F-11	118-B-7	200-W-44	218-E-2
116-B-3	116-F-14	118-B-8	200-W-45	218-E-2A
116-B-4	116-F-16	118-C-1	200-W-52	218-E-3AE
116-B-5	116-F-2	118-C-3	200-W-69	218-E-4
116-B-6	116-F-3	118-C-4	201-C	218-E-5
116-B-6A	116-F-4	118-D-1	202-S	218-E-7
116-B-6B	116-F-5	118-D-2	207-U	218-E-8
116-B-7	116-F-6	118-D-3	212-B Cask Loading Station	218-E-9
4843	116-F-7	118-D-4	216-A-29	218-E-LLW
116-B-5	116-F-8	118-D-6	216-B-2-1	218-E-RCRA

Table 4. Non-SIM Waste Sites with Inventories

List of Waste Sites				
218-W-1	218-W-4B	225-B	241-AX-104	241-BY-111
218-W-11	218-W-4C	231-Z	241-AY-101	241-BY-112
218-W-1A	218-W-5	232-Z	241-AY-102	241-C-102
218-W-2	218-W-7	233-S	241-AZ-101	241-C-103
218-W-2A	218-W-8	234-5Z	241-AZ-102	241-C-104
218-W-3	218-W-9	236-Z Plutonium Reclamation Facility	241-B-101	241-C-106
218-W-3A	221-B	241-A-101	241-B-102	241-C-107
218-W-3AE	221-T	241-A-102	241-B-103	241-C-108
218-W-4A	221-U	241-A-106	241-B-104	241-C-109
218-W-4B	222B vaults	241-AN-101	241-B-105	241-C-112
218-W-4C	222-SD	241-AN-102	241-B-106	241-CX-72
218-W-5	222T vaults	241-AN-103	241-B-108	241-CX-TK-71
218-W-7	224-B	241-AN-104	241-B-109	241-CX-TK-72
218-W-8	224-T	241-AN-105	241-B-111	241-S-101
218-W-9	224-U	241-AN-106	241-B-202	241-S-102
221-B	225-B	241-AN-107	241-B-361	241-S-103
221-T	231-Z	241-AP-101	241-BX-103	241-S-105
221-U	218-W-4B	241-AP-102	241-BX-104	241-S-106
222B vaults	218-W-4C	241-AP-103	241-BX-105	241-S-107
222-SD	218-W-5	241-AP-104	241-BX-106	241-S-108
222T vaults	218-W-7	241-AP-105	241-BX-107	241-S-109
224-B	218-W-8	241-AP-106	241-BX-109	241-S-110
224-T	218-W-9	241-AP-107	241-BX-110	241-S-111
218-W-1	221-B	241-AP-108	241-BX-111	241-S-112
218-W-11	221-T	241-AW-101	241-BX-112	241-SX-101
218-W-1A	221-U	241-AW-102	241-BY-101	241-SX-102
218-W-2	222B vaults	241-AW-103	241-BY-102	241-SX-103
218-W-2A	222-SD	241-AW-104	241-BY-104	241-SX-105
218-W-3	222T vaults	241-AW-105	241-BY-105	241-SX-106
218-W-3A	224-B	241-AW-106	241-BY-106	241-SX-114
218-W-3AE	224-T	241-AX-101	241-BY-109	241-SY-101

Table 4. Non-SIM Waste Sites with Inventories

List of Waste Sites				
218-W-4A	224-U	241-AX-103	241-BY-110	241-SY-102
241-SY-103	241-U-103	300-224	TRUSAF	UPR-200-W-47
241T Facility	241-U-105	300-24	UPR-100-D-4	UPR-200-W-53
241-T-102	241-U-106	300-264	UPR-100-F-1	UPR-200-W-59
241-T-104	241-U-107	300-28	UPR-100-K-1	UPR-200-W-72
241-T-105	241-U-108	309-WS-1	UPR-100-N-1	UPR-200-W-8
241-T-107	241-U-109	316-3	UPR-100-N-12	UPR-200-W-84
241-T-110	241-U-111	331_LSLT2	UPR-100-N-25	UPR-300-1
241-T-112	241-U-201	400 RFD	UPR-100-N-3	UPR-300-13
241-T-201	241-U-202	600 NRDWL	UPR-100-N-30	UPR-300-2
241-T-202	241-U-203	600-118	UPR-100-N-35	US Ecology
241-T-203	241-U-204	600-148	UPR-100-N-5	WESF
241-T-204	241-U-361	600-211	UPR-100-N-7	Z Plant BP
241-T-361	241-WR-VAULT	618-1	UPR-200-E-138	Z plant, PFP
241-TX-101	241-Z	618-10	UPR-200-E-14	
241-TX-102	241-Z-361	618-11	UPR-200-E-23	
241-TX-103	241-Z-TK-8	618-13	UPR-200-E-24	
241-TX-104	242-A	618-2	UPR-200-E-34	
241-TX-105	242-Z Americium Recovery Facility	618-3	UPR-200-E-41	
241-TX-106	2706T	618-4	UPR-200-E-51	
241-TX-108	2736-Z PFP	618-5	UPR-200-W-104	
241-TX-109	276-S	618-7	UPR-200-W-105	
241-TX-110	276-U	618-8	UPR-200-W-106	
241-TX-111	291-C-1	618-9	UPR-200-W-107	
241-TX-112	291-S	B_PLANT_FILTER	UPR-200-W-11	
241-TX-113	291-S-1	CWC	UPR-200-W-125	
241-TX-114	291-WTP	FFTF Reactor Containment Bldg	UPR-200-W-134	
241-TX-115	291-Z Exhaust Fan	Flammable storage units 1 - 20	UPR-200-W-137	

Table 4. Non-SIM Waste Sites with Inventories

List of Waste Sites				
241-TX-116	293-S	Greater-Than-Class C Proposed Disp. Facility	UPR-200-W-16	
241-TX-117	296-A-13	GTF	UPR-200-W-160	
241-TX-118	300-19	GTFL	UPR-200-W-26	
241-TY-102	300-224	IDF	UPR-200-W-30	
241-U-102	300-24	RMWSF	UPR-200-W-34	

4 Sources of Information on Estimated Inventories in Past Studies

The sources of information used to estimate inventories in the three past studies varied widely.

In the initial 1998 CA, estimated inventories relied on published values in existing reports that were largely based on process knowledge and plans for environmental restoration. The types of data sources included the following:

- Maximum concentrations of radionuclides in soils as documented in the ERDF RI/FS,
- Tank waste inventories based on the Hanford Defined Waste Model and the BBI,
- A data package in support of the interim performance assessment for low-level tank waste,
- Reported volumes and waste types of leaking single-shell tanks,
- An assumption of the volume of residuals present in each tank used in conjunction with a release model,
- The type and concentration of contaminants likely to be present in wastes sites in the 200 Areas,
- The inventory in the closure plan for US Ecology, and,
- For the reactor cores, the inventory in the surplus production reactor EIS.

In the 2005 Data Package, the types of data sources included the following:

- Tank waste inventories were modeled using Hanford Tank Waste Operations Simulator, which relies on current tank inventories and the processes planned to be used to retrieve the waste from the tanks, separate it into high-level and low-level fractions, and vitrify it into a glass product.
- Liquid discharges and unplanned releases to soil were simulated with SIM, which combines process knowledge, waste transfer records, estimates of waste stream compositions, and estimates of spent fuel inventories processed on the Central Plateau. In the 2005 SIM Rev. 1, the estimated inventories were modeled probabilistically based on fuel production, chemical process knowledge, and waste transfer information. SIM Rev. 1 relied on updated Hanford Defined Waste Model composition estimates. Uncertainty bounds around mean inventories were provided as part of a Monte Carlo simulation using uncertainties defined in the input data.

- Releases not included in SIM were estimated based on published records, including some waste sites in the 100 and 300 Areas.
- The inventory in cooling water released to the environment which had been contaminated by fuel element failures relied on the estimates in the Hanford Environmental Dose Reconstruction project.
- Inventories for the reactor cores were obtained from the *Draft Environmental Impact Statement on Decommissioning Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE/EIS-0119D).
- Inventories in past solid waste disposals and forecasts of future disposals were obtained from the SWITS.
- The inventory for US Ecology was obtained from its environmental impact statement (DOH Publication 320-031, *Commercial Low-Level Radioactive Waste Disposal Site Richland, Washington)*.
- Inventories of spent nuclear fuel were provided by the Characterization of Systems Project, including inventories for K Basin, Shipping port, FFTF, and some spent fuel used in research.
- Inventories of special nuclear material at the Plutonium Finishing Plant (PFP) came from the final EIS on the stabilization of PFP.
- The inventory of capsules storage at the Waste Encapsulation and Storage Facility was based on *Waste Encapsulation and Storage Facility (WESF) Documented Safety Analysis* (HNF-8758) and other informal information sources.
- FFTF inventories were taken from a document supporting the environmental impact statement for FFTF closure (FFTF-18346).
- The inventory of atmospheric releases was based in part on the Hanford Environmental Dose Reconstruction project.
- Inventories for canyons, tunnels, stacks, and filters were based on safety analysis and similar reports.

As described in Appendix S of the TC&WM EIS, Table S-5 “Content of Inventory Worksheet of Excel Workbooks,” inventories of radionuclides supporting the cumulative impacts analysis were based on the following:

- Inventories in WIDS,
- The 1987 *Hanford Site Waste Management Units Report* (DOE 1987),
- SIM Rev. 1,
- *Radionuclide Inventories of Liquid Waste Disposal Sites on the Hanford Site* (HNF-1744),
- *Summary of Radioactive Solid Waste Received in the 200 Areas During Calendar Year 1995* (WHC-EP-0125-8), and
- Other technical documents.

The proposed approach to estimating inventories for the 2019 Composite Analysis is described in the next section.

5 Proposed Inventory Modeling and Validation for Quality Assurance

For the 2019 CA, a technical approach for inventory data package is planned to model screened sites inventory under two main waste type classes: (1) liquid discharges during Hanford waste generation and disposition process and (2) solid waste forms. The first class will group sites that received liquid discharges during the nuclear production mission at Hanford. There were four distinct steps in the nuclear material production process: fuel fabrication, fuel irradiation, chemical separation, and plutonium processing. Waste streams generated from these production processes were stored in underground storage tanks (with subsequent leaks into the subsurface in several events) and directly to soil. These past tanks leaks and past practice liquid discharges constitute a significant risk to future human health and the environment, primarily through the groundwater pathway. The CA must place both past practice discharges and tank leaks in context with future releases from low-level waste disposal facilities. The first group of sites requires significant attention and more efforts are planned in estimating uncertainty associated with their inventories. The second class of sites requires collection of inventory data from prior reported studies and databases while filling the gaps using mass balance/continuity rules and accounting for radionuclides decay and ingrowth. The proposed technical approach is described for each class and source in the following subsections.

5.1 Proposed Approach for Development of the Radionuclide Inventory

Our proposed approach is to develop a structured inventory data package using object-oriented programming in Matlab®[3]. Based on the current understanding, the inventory of sites that pass the waste site screening will be built into a unified data structure. The data structure will include fields to define site type and waste forms in addition to analyte inventories to inform release and vadose zone modeling. The inventory will be structured and checked as depicted in the hierarchy depicted in Figure 1. The bottom level of the hierarchy presents the screened sites being built as data sub-structure for each site. Sites will be grouped in the unified structure by Operable Units (OUs) to complete and to check inventory consistency comparing with reported data packages/databases, or in categories defined by the next level up in the hierarchy chart. Upper levels in the hierarchy will be considered for further grouping, e.g. grouping tanks according tank farms Waste Management Areas (WMAs) to compare with tank leak reports and estimated residual inventories. The documentation of sources to be revised for inventories defined on this level are discussed in the next sections. As inventory of liquid discharge sites are structured, it will be communicated with vadose zone modeling at early stages to check and determine data gaps and interfacing requirements.

Ultimately, inventories are grouped into liquid and solid form categories. For the liquid discharges, SIM will be utilized to model the inventory of in ground discharges as well as tank leaks and unplanned releases. Uncertainty around the reported tank leaks will be estimated from the defined waste stream feed in Hanford Defined Waste (model) (HDW) model during leak periods. An upgrade of the HDW will be investigated to estimate uncertainty around tank inventories sourced by the BBI. While the HDW upgrade is not part of the current inventory or the CA scope, the upgrade is needed to evaluate the historical waste transport among the tanks as source of uncertainty of individual tank inventory. In addition, the upgrade would help the forecast of inventory uncertainties due to disposition/retrieval scenarios.

For the solid forms inventory, the TC&WM EIS inventories will be the starting point. Both estimates of alternative and cumulative analyses of the TC&WM EIS will be considered then updated with recent changes in solid waste databases such as SWITS as well as WIDS and BBI updates. Non-DOE generated wastes will be sourced mainly from the reported inventory and acquiring updates of recent US Ecology

[3] MatLab is a registered trademark of The Mathworks, Inc.

disposal. As inventory of solid forms are completed, it will be communicated with release modeling to test and assess further needs to define forms and inventories.

On a higher level, the model will check consistency and continuity on a site-wide scale. The inventory consistency check will be done in comparison to the available performance assessment reports. Results from the parallel performance assessment studies of tank farms, ERDF, and IDF will be considered in the consistency check for quality assurance of the estimated inventory. After passing the final consistency check and completing the data structure, the inventory of the screened radionuclides that drive the risk will be exported as a data package to be integrated with the CA integration frame work and software.

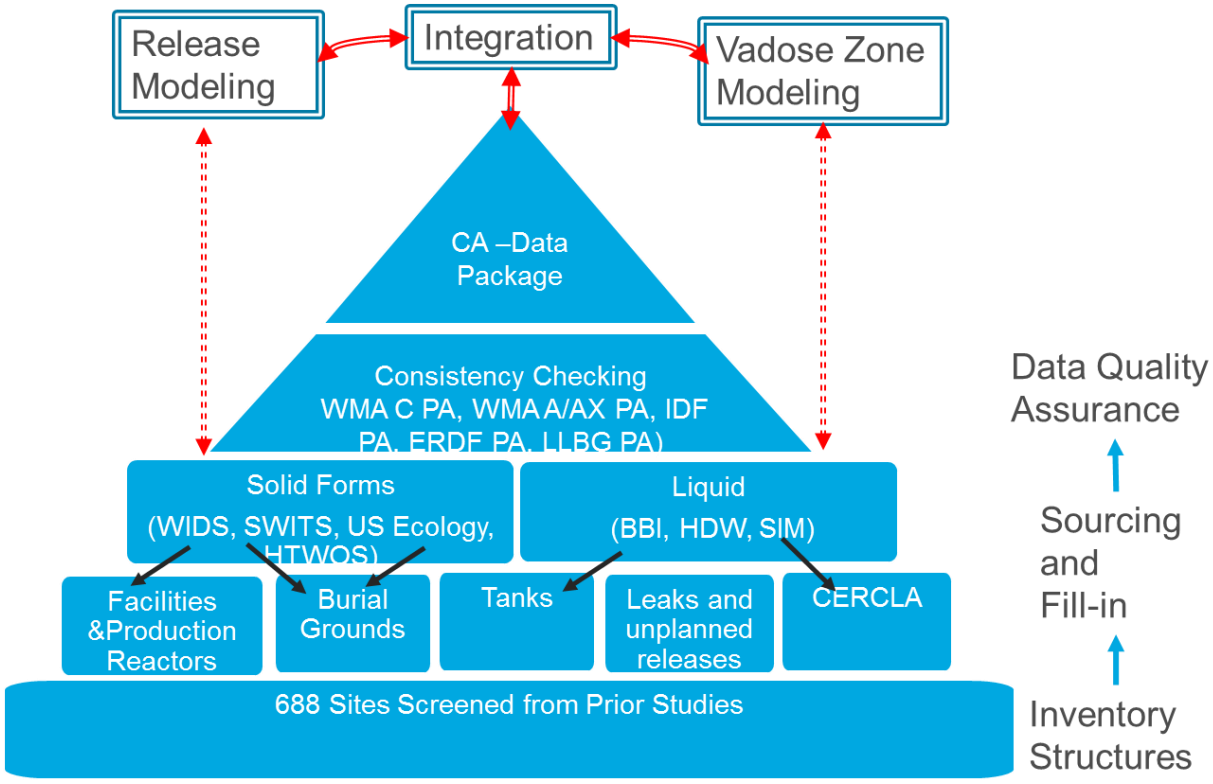

Figure 1. Hierarchy of Radionuclide Inventory Development

5.2 Liquid Discharges

As mentioned above, liquid discharges were the main source of radionuclides to the groundwater pathway. Water is the main waste matrix of these discharges that were reported in previous studies as classified in the following three sections.

5.2.1 CERCLA Liquid Discharges

In 2005, information on sites that received liquid discharges (e.g., HNF-1744) were documented in the Hanford Soil Inventory Model (SIM-v1) (RPP-26744, *Hanford Soil Inventory Model Rev 0*). The model implementation was upgraded in GoldSim®[4] (SIM-v2) to provide inventory and uncertainty estimates of inventories sent to cribs, specific retention trenches, French drains, and ponds. These model estimates will be updated by reviewing process knowledge, composition updates and uncertainty estimates of discharge

[4] GoldSim is a registered trademark of GoldSim Technologies, Issaquah, Washington.

volumes and characteristics as were documented for SIM-v1 inputs. The discharges of cooling water from single-pass reactors were summarized as part of the Hanford Environmental Dose Reconstruction Project (PNWD-2223-HEDR, *Radionuclide Releases to the Columbia River from Hanford Operations*). The *Handbook 200 Areas Waste Sites* (RHO-CD-673) and, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford (*PNL-6456)*,* summarize information on all of the past-practice or inactive waste sites, and the WIDS database are also valuable resource to utilize when reviewing liquid discharge sites. WHC-MR-0227, *Tank Wastes Discharged Directly to the Soil at the Hanford Site*, identified cribs and trenches that received tank waste during Hanford's early operational era and provided a disposal volume for each facility. This report further provided an estimate of the total inventory of select radioisotopes discharged (carbon-14, strontium-90, technetium-99, iodine-129, cesium-137, americium-241, plutonium, tritium, and uranium). The inventory estimates in WHC-MR-0227 are based on the Track Radioactive Components (TRAC) Model simulations (RHO-CD-1019, *Hanford High-Level Defense Waste Characterization - A Status Report*; HNF-SD-WM-TI-058, *Supplementary Information for the Preliminary Estimation of Waste Tank Inventories in Hanford Tanks through 1980*).

5.2.2 Tank Waste

Tank waste inventories are viewed as contained waste (meaning not released to the environment). The BBI (HNF-SD-WM-TI-740) is the official database that will be used to define the inventory of all single-shell and double-shell tank waste inventories. The BBI is updated quarterly to reflect new data and data interpretations, and provides inventories for each tank. The BBI represents a controlled process of data evaluation and inventory estimation that values tank waste characterization data over process knowledge based model estimates. That is, where tank waste characterization data exist, they are used to arrive at the inventory estimate. If characterization data are not available, then estimates generated by the Hanford Defined Waste Model (RPP-19822) are employed to develop the inventory estimate.

The quarterly updated BBI is available online at http://twins.pnl.gov:8001/ from the Tank Waste Inventory Network System, which is maintained by the Tank Farm Contractor for the Hanford Site.

5.2.3 Unplanned Releases

Discharges to unplanned release sites (such as transfer line leaks, spills, etc.) have not been estimated and reported as thoroughly as was the case for intentional or planned releases. Sources of information to be reviewed for information on inventories in unplanned releases include the following: PNL-6456, RHO-CD-673, the 200-IS-1 Operable Unit scoping report (SGW-59881, *200-IS-1 Operable Unit Scoping*), and WIDS will be utilized to provide volume and inventory estimates for some release sites, volume estimates for some sites, and no information for other sites. Where sufficient information is available (for example, time of release, volume, source or origin of released waste stream or fluid), an estimate can be established and incorporated into source inventories.

5.3 Solid Waste

Solid wastes are relatively immobile radionuclides that were disposed in solid form or locked in place after closure. The release of these radionuclides needs to be estimated as function of different barriers that diversify with source types such as solid waste burial grounds, production reactors and naval reactor compartments, cesium/strontium capsules, canyon buildings and tunnels, and commercial waste.

5.3.1 Solid Waste Burial Grounds

Inventories disposed in solid waste burial grounds are recorded in the SWITS database, which includes burial grounds used since Hanford Site startup in 1944 through today. It is a record of annual disposals to each waste trench within burial grounds and associated facilities, and it includes information on the disposal waste form, (for example, caisson disposal is noted). Forecasts of solid waste disposals are

available from the Solid Waste Information Forecast Tool (SWIFT). The primary purpose of SWIFT is to generate a forecast of disposal volume to ensure space is available for planned activities. However, SWIFT is used to forecast solid waste disposal inventories also.

5.3.2 Production Reactors and Naval Reactor Compartments

The graphite cores of Hanford's eight single-pass production reactors are described in the Surplus Production Reactor EIS (DOE/EIS-0119D, *Draft Environmental Impact Statement; Decommissioning of Eight Surplus Production Reactors at the Hanford Site*; DOE/EIS 0119F-SA-01, *Supplement Analysis; Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*) and the supporting inventory documentation (UNI-3714, *Radionuclide Inventory and Source Terms for the Surplus Production Reactors at Hanford*). An estimate of the N Reactor inventory was reported in the CA for Hanford's Central Plateau sites (PNNL-11800).

Inventories of naval reactor compartments being permanently disposed of at the Hanford Site are included in the SWITS database as the compartments are received. The overall number of compartments to be disposed of and the cumulative inventory they represent are available from the original environmental impact statement (DOE/EIS-0259, *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, Ohio Class and Los Angeles Class. Naval Reactor Plants*) and supplemental analysis of nickel migration (PNL-9791, *Estimation of Release and Migration of Nickel through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground*). Inventories for reactor compartments from the USS Enterprise can be refined based on the ~~*U.S. Department of the Navy*~~ *Final Environmental Assessment on the Disposal of Decommissioned, Defueled Naval Reactor Plants from USS Enterprise (CVN 65)* (EA-1889).

5.3.3 Cesium/Strontium Capsules

The Waste Encapsulation and Storage Facility stores strontium-90 and cesium-137 in the stable solid forms of strontium fluoride and cesium chloride respectively. The solid forms are encapsulated and stored in several pools within the Waste Encapsulation and Storage Facility. Cesium recovery and encapsulation was completed in 1983, and strontium recovery and encapsulation was completed in 1985. The inventories of strontium-90 and cesium-137 in the capsules can be found in the DOE complex integrated database report (DOE/RW-0006, *Integrated Data Base Report – 1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*) and in the hazards assessment for the facility (HNF-4013, *Waste Encapsulation and Storage Facility (WESF) Hazards Assessment*). The *Hanford Cs-Sr Repository Disposal Performance Analysis Using the TSPA-FEIS Model* (EDF-NSNF-072) provides an assessment of the option of directly disposing of the capsules at the National High-Level Waste Repository.

5.3.4 Facilities: Canyon Buildings and Tunnels

Development and maintenance of facility inventory estimates requires a review of current safety analysis reports, hazard analysis reports, etc., to ensure up-to-date inventory data are used during this period of facility decontamination and decommissioning in preparation for final remedial action. Table 5 lists recent versions of examples of these reports.

Table 5. Recent Documentation of Estimated Inventories in Facilities

Facility	Document
B Plant	HNF-3358, *B Plant Surveillance and Maintenance Phase Safety Analysis Report*

	HNF-3208, *Documentation of Remaining Hazardous Substances/Dangerous Wastes in B Plant*
224-B	BHI-01156, *224-B Facility Safety Analysis Report*
PUREX	CP-14977, 2017, *Plutonium Uranium Extraction Facility Documented Safety Analysis, Rev. 9* WHC-IP-0977, *Estimation of PUREX Equipment and Materials That Are Candidates for Removal and Waste Processing During PUREX Plant Closure* HNF-SD-CP-ISB-004, *Plutonium Uranium Extraction (PUREX) End State Basis for Interim Operation (BIO) for Surveillance and Maintenance* HNF-SD-CP-HIE-004, *PUREX Deactivated End-State Hazard Analysis*
PUREX Tunnels	CHPRC-03325, PUREX Tunnel 1 and 2 Data Quality Objectives Information Summary, Draft A WA7890008967, *Hanford Facility RCRA Permit Dangerous Waste Portion, PUREX Storage Tunnels Chapter 3.0 Waste Analysis Plan and Chapter 11.0, Closure Plan*
REDOX	DOE/RL-2016-16, *Engineering Evaluation/Cost Analysis for the REDOX Complex*
U Plant	HNF-13829, 2012, *U Plant Documented Safety Analysis*, Rev. 5
T Plant	HNF-14741, *Solid Waste Operations Complex Master Documented Safety Analysis*, Rev. 10*

* A more recent version of this document exists (Rev. 12) but is considered sensitive information. A request to access the document will made during the inventory development phase of the CA.

5.3.5 Commercial Waste

The Hanford Site is home to one of the nation's commercial low-level radioactive waste disposal sites. US Ecology, Inc., operates the site, maintains a record of inventory, and periodically publishes that inventory in reports to the State of Washington. US Ecology submitted a site stabilization and closure plan (US Ecology, 1996). In response to license renewal, naturally occurring or accelerator-produced radioactive material, and site closure issues, the State of Washington Departments of Health and Ecology prepared a State Environmental Protection Act (SEPA) Draft Environmental Impact Statement. As part of this activity, the Department of Health prepared an inventory based on regulatory files. The Department of Health continues to study the commercial inventory. An initial version of this inventory was published in the SEPA EIS (DOH Publication 320-031).

6 Summary

The proposed approach for development of an updated and maintainable site-wide inventory to support the Hanford Site CA has been presented in this technical approach description. This approach will provide the needed input for waste-form release models that will predict the rate at which inventory available for

environmental transport is released into the vadose zone for consideration in the groundwater pathway, as well as potentially the air pathway.

7 References

BHI-00990, 1997, *Auditable Safety Analysis for the Surveillance and Maintenance of the REDOX Complex*, Bechtel Hanford, Inc., Richland, Washington.

BHI-01142, 2001, *REDOX Facility Safety and Analysis Report*, Rev 3, Bechtel Hanford, Inc., Richland, Washington.

BHI-01156, 2001, *224-B Facility Safety Analysis Report*, Bechtel Hanford, Inc., Richland, Washington.

BHI-01157, 2000, *U Plant Facility Safety Analysis Report*, Rev. 2, Bechtel Hanford, Inc., Richland, Washington.

CHPRC-03325, 2017, *Purex Tunnel 1 and 2 Data Quality Objectives Information Summary*, Draft A, CH2M, Richland, WA 99352.

DOE O 435.1-1, 2001, *Radioactive Waste Management*, U.S. Department of Energy, Washington, D.C. Available at: https://www.directives.doe.gov/directives-documents/400-series/0435.1-BOrder-chg1/view

DOE, 1987, *Hanford Site Waste Management Units Report*, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=E0004690.

DOE/EIS-0119D, 1989. *Draft Environmental Impact Statement on Decommissioning Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*, U.S. Department of Energy, Washington, D.C. Available at: http://www.hanford.gov/files.cfm/Draft%20EIS%20-%20Decomm%208%20Production%20Reactors%20(D195062296).pdf.

DOE/EIS-0119F-SA-01, 2010, *Supplement Analysis; Decommissioning of Eight Surplus Production Reactors at the Hanford Site*, U.S. Department of Energy, Richland, Washington. Available at: http://www.hanford.gov/files.cfm/EIS-0119F-SA_01.pdf.

DOE/EIS-0259, 1996, *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Cruiser, Ohio Class and Los Angeles Class Naval Reactor Plants*, U.S. Department of the Navy, Puget Sound Naval Shipyard, Bremerton, Washington. Available at: https://energy.gov/sites/prod/files/nepapub/nepa_documents/RedDont/EIS-0259-FEIS-Summary-1996.pdf.

DOE/EIS-0391, 2012, *Final Environmental Impact Statement Tank Closure and Waste Management for the Hanford Site, Richland, Washington (TC & WM EIS),* U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://www.hanford.gov/page.cfm/FinalTCWMEIS

DOE/RW-0006, 1997, *Integrated Data Base Report – 1996: U.S. Spent Nuclear Fuel and Radioactive Waste Inventories, Projections, and Characteristics*, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Available at: https://www.nrc.gov/docs/ML1028/ML102850100.pdf.

DOH Publication 320-031, *Commercial Low-Level Radioactive Waste Disposal Site Richland, Washington*, Washington State Department of Health, Office of Radiation Protection, Olympia,

Washington. Available at: http://www.doh.wa.gov/Portals/1/Documents/Pubs/320-031_vol1_w.pdf.

EA-1889, 2012, *Final Environmental Assessment on the Disposal of Decommissioned, Defueled Naval Reactor Plants from USS Enterprise (CVN65)*, U.S. Department of the Navy. Available at: https://energy.gov/sites/prod/files/EA-1889-FEAandFONSI-2012.pdf

EDF-NSNF-072, 2007, *Hanford Cs-Sr Repository Disposal Performance Analysis Using TSPA-FEIS Model*, National Spent Nuclear Fuel Program Engineering Design File, Available at:
Section 1 of 2 http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA05305145
Section 2 of 2 http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=DA05305224

FFTF-18346, 2005, *Technical Information Document for the Fast Flux Test Facility Closure Project Environmental Impact Statement*, Rev. 1, Fluor Hanford, Richland, Washington.HNF-1744, 1999, *Radionuclide Inventories of Liquid Waste Disposal Sites on the Hanford Site*, Fluor Daniel Hanford Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=00099930.

HNF-3208, 1998, *Documentation of Remaining Hazardous Substances/Dangerous Wastes in B Plant*, B&W Hanford Company, Richland, Washington.

HNF-3358, 1999, *B Plant Surveillance and Maintenance Phase Safety Analysis Report*, B & W Hanford Company, Richland, Washington. Available at: http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/34/004/34004062.pdf?r=1.

HNF-4013, 2013, *Waste Encapsulation and Storage Facility (WESF) Hazards Assessment*, CH2M HILL, Plateau Remediation Company, Richland, Washington.

HNF-14741, 2013, *Solid Waste Operations Complex Master Documented Safety Analysis*, Rev. 10, CH2M HILL Plateau Remediation Company, Richland, Washington.

HNF-SD-WM-TI-058, 2010, *Supplementary Information for the Preliminary Estimation of Waste Tank Inventories in Hanford Tanks through 1980*, Rev. 1, Washington River Protection Solutions LLC, Richland, Washington.

HNF-SD-CP-HIE-004, 1999, *PUREX Deactivated End-State Hazard Analysis*, B & W Hanford Company, Richland, Washington.

HNF-SD-CP-ISB-004, 1999, *Plutonium Uranium Extraction (PUREX) End State Basis for Interim Operation (BIO) for Surveillance and Maintenance*, B & W Hanford Company, Richland, Washington.

HNF-SD-WM-TI-740, 1999, *Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes*, Rev. 0C, Lockheed Martin Hanford Corporation, Richland, Washington.

Kidd, CC, 2005, *Activation of the FFTF Biological Shield Wall*, FFTF-26790, Rev. 0, Fluor Hanford, Inc., Richland, Washington, October, as referenced in DOE/EIS-0391, 2012, *Final Environmental Impact Statement Tank Closure and Waste Management for the Hanford Site, Richland, Washington (TC & WM EIS),* U.S. Department of Energy, Richland Operations Office, Richland, Washington.

PNL-6456, 1988, *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford*, DE-AC06 -76RL0, Pacific Northwest Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/pdf.cfm?accession=D196006954.

PNL-9791, 1994, *Estimation of Release and Migration of Nickel through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground*, Rhoads, Pacific Northwest Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196079340.

PNNL-11800, 1998, *Composite Analysis for Low-Level Waste Disposal in the 200-Area Plateau of the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0079141H

PNNL-11800 Addendum 1, 2001, *Addendum to Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*., Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0084085

PNNL-15829, 2006, *Inventory Data Package for Hanford Assessments*, Rev.0, Pacific Northwest National Laboratory, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0911300004

PNWD-2223-HEDR, 1994, *Radionuclide Releases to the Columbia River from Hanford Operations, 1944-1971*, Draft, Pacific Northwest Laboratories, Richland, Washington. Available at: https://www.osti.gov/scitech/servlets/purl/10153736.

RHO-CD-673, 1979, *Handbook 200 Areas Waste Sites*, Rockwell International Operations, Energy Systems Groups, Department of Energy, Richland Operations Office, Richland, Washington.

RHO-CD-673, 1979, *Handbook 200 Area Waste Sites*, Vols. I-III, Rockwell Hanford Operations, Richland, Washington.

RHO-CD-1019, 1980, *Hanford High-Level Defense Waste Characterization - A Status Report*, Rockwell International Rockwell, Hanford, Energy Systems Group, Richland, Washington

RHO-RE-ST-30P, 1985, *Hanford Defense Waste Disposal Alternatives: Engineering Support Data for the Hanford Defense Waste – Environmental Impact Statement*, Rockwell Hanford Operations, Richland, Washington.

RPP-19822, 2004, *Hanford Defined Waste Model Revision 5*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081017H.

RPP-26744, 2005, *Hanford Soil Inventory Model Rev 1*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081114H.

SAIC (Science Applications International Corporation), 2011, *Waste Inventories Reference Mapping,* Germantown, Maryland, December 2, as referenced in DOE/EIS-0391, 2012, *Final Environmental Impact Statement Tank Closure and Waste Management for the Hanford Site, Richland, Washington (TC & WM EIS),* U.S. Department of Energy, Richland Operations Office, Richland, Washington.

SGW-59881, 2016, *200-IS-1 Operable Unit Scoping*, Rev. 0, CH2M-HILL Plateau Remediation Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0075570H.

UNI-3714, 1987, *Radionuclide Inventory and Source Terms for the Surplus Production Reactors at Hanford*, Rev. 1, UNC Nuclear Industries, Inc., Richland, Washington.

US Ecology, 1996, *Richland Closure Plan*, US Ecology, Richland, Washington. Available at: https://www.nrc.gov/docs/ML1020/ML102020484.pdf.

WHC-EP-0125-8, 1996, *Summary of Radioactive Solid Waste Received in the 200 Areas during Calendar Year 1995*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: https://www.osti.gov/scitech/servlets/purl/341252-7WzP77/webviewable/.

WHC-IP-0977, 1993, *Estimation of PUREX Equipment and Materials That Are Candidates for Removal and Waste Processing During PUREX Plant Closure*, Los Alamos Technical Associates, Westinghouse Hanford Company, Richland, Washington.

WHC-MR-0227, 1991, *Tank Wastes Discharged Directly to the Soil at the Hanford Site*, Westinghouse Hanford Company, Richland, Washington.

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APPENDIX A

Preliminary I-129 Mass Balance

by

Curtis Stroup, CHPRC

WORK-IN-PROGRESS: MASS BALANCE OF IODINE-129

The following information is highly preliminary and intended only to illustrate the scope and level of detail of the mass balances planned for key radionuclides as part of the Composite Analysis. The inventories presented below will change as additional information is reviewed.

Iodine-129 was brought onto the Hanford Site in uranium (U) used during the years of plutonium production and in wastes accepted by US Ecology. Iodine-129 (I-129) left the Hanford Site in releases to the atmosphere and in uranium product delivered to the Fernald Feed Materials Production Center, Oak Ridge National Laboratory, and other end users. The current inventory of I-129 at Hanford resides in tank farms, the Environmental Restoration Disposal Facility (ERDF), low-level burial grounds (LLBGs), three canyons (T Plant, REDOX, and PUREX), PUREX Tunnel #2, cribs, settling tanks, reverse wells, the Canister Storage Building (CSB), and US Ecology. Figure A-1 summarizes the results of the literature search conducted to estimate the I-129 inventory.

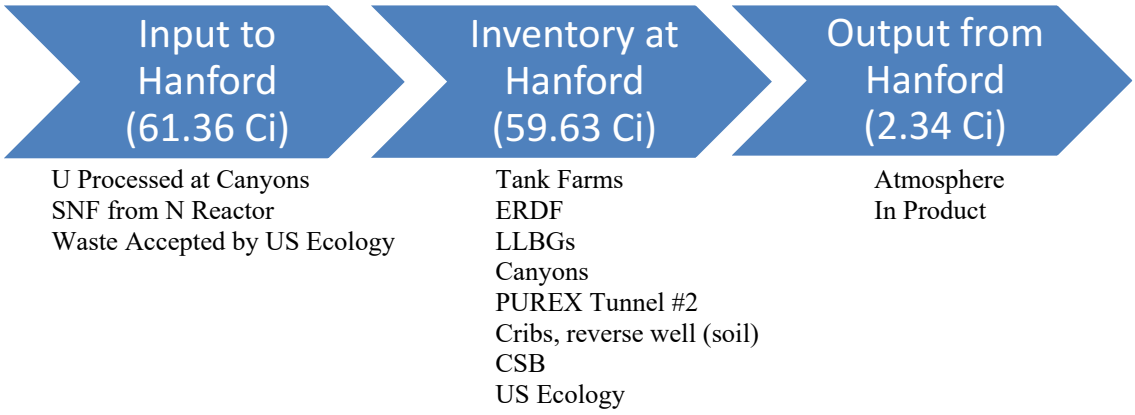

Figure A-1. Preliminary I-129 Mass Balance

The single largest source of I-129 at Hanford was the result of uranium processing conducted at B Plant, T Plant, PUREX, and REDOX. When irradiated uranium metal was dissolved, I-129 was present in the canyon process waste streams and the dissolver off-gas system. The canyon process waste streams were sent to the tank farms. In addition to waste streams from the canyons, I-129 was present in spent nuclear fuel (SNF) from the N Reactor (currently stored at the CSB).

In the early years of B Plant and T Plant operations, the off-gas system released I-129 directly to the atmosphere without treatment. Later at B Plant and T Plant, and for all years at REDOX and PUREX, off-gas scrubbers were used which significantly reduced atmospheric releases but resulted in a new waste stream -- wastewater from the scrubbers, which was sent to settling tanks and reverse wells. Also in later years at B Plant and T Plant, and for all years at PUREX and REDOX, an air treatment device called a silver reactor was used to reduce iodine emissions by adsorption of iodine to silver. The silver reactors further decreased emissions of iodine to the atmosphere, but the silver reactors frequently had to be regenerated. The regeneration process involved flushing with water and sodium thiosulfate, generating a wastewater which was discharged to the tank farms and to cribs, and sometimes involved replacing the silver nitrate coated Berl saddles, which were disposed in burial grounds. The regeneration process was conducted at REDOX and U Plant; it is unknown if it was also conducted at PUREX. Spent silver reactors were disposed in burial grounds. After the plants ceased operations, several silver reactors were

placed into long-term storage in three of the canyons. Negligible releases of I-129 to the atmosphere under current waste management practices occur from the PUREX stack.

7.1 A1. URANIUM PROCESSING

I-129 was released during uranium processing at T Plant, B Plant, REDOX, and PUREX. I-129 was also released during reclamation at U-plant of an air treatment device called a 'silver reactor.' At the uranium processing plants, I-129 was released to the atmosphere and to soil at waste management units as part of liquid effluents and was present in wastes transferred to tank farms.

A1.1 Plant Processing

The four processing plants operated during the following periods (HWN-1991, *Hanford Production Logs 1944 to 1972*; PNNL-13524, *Historical Time Line and Information about the Hanford Site*; HNF-SD-WM-TI-794, *Activity of Fuel Batches Processed Through Hanford Separations Plants, 1944 through 1989*; and PNWD-2222-HEDR, *Radionuclide Releases to the Atmosphere from Hanford Operations, 1944 – 1972*):

- T Plant: December 26, 1944 to February 1956;
- B Plant: April 13, 1945 to June 1952;
- REDOX: January 9, 1952 to November 1966; and
- PUREX: January 12, 1956 to December 1970, March 1971 to August 1972, November 1983 to August 1986 and February 1987 to December 1989.

The amount of material processed through the plants included the following (HWN-1991, RPP-13489, HNF-SD-WM-TI-794, PNWD-2222-HEDR, DOE/RL-2000-43):

- Uranium: 99,693 metric tons of uranium (MTU)
    - T Plant: 5,5034 MTU
    - B Plant: 2,765 MTU
    - REDOX: 19,692 MTU
    - PUREX: 72,202 MTU
- I-129: 279,000 grams (49.4 curies) (RPP-13489 Tables 3 and 4) (note that HNF-SD-WM-TI-794 estimated 64.1 Ci of I-129)
    - T Plant: 1.03 Curies (RPP-13489 Table H-1)
    - B Plant: 0.58 Curies
    - REDOX: 9.18 Curies
    - PUREX: 38.60 Curies
- I-131: 5.7 grams (740,000 Curies) released to the atmosphere (PNWD-2222-HEDR)

A.1.2 Silver Reactors

To reduce I-131 emissions, a new treatment process was developed. In September 1947, testing of an adsorption system using hot silver bed (below the melting point of silver) to deposit iodine was being

planned (HW-7795). In October 1947, installation of equipment to adsorb radioiodine using silver was in progress in the 292 Building (HAN-45802). In November 1947, satisfactory results were obtained from testing the silver bed reactor (HAN-45802). It was determined that complete removal of iodine could be made in temperature ranges of 115° F to 465° F on the silver bed reactor (HAN-45802 & HAN-45807). A 20 to 24 molar solution of silver nitrate was used to initially coat the silver reactor bed composed of Berl saddles (HW-59702).

A.1.2.1 Installation

Silver reactors were installed on the T Plant and B Plant dissolver off-gas systems in October 1950 (HAN-42598, pages 73 and 95) and January 1951 (HAN-63671-DEL, page 4), respectively. At B Plant, a second silver reactor was installed January 31, 1951 and at T Plant, a second silver reactor was installed December 28, 1950.

The silver nitrate coated Berl saddles (reactive packing medium) were susceptible to damage from high temperature (HW-21826). Three of the silver reactors were heated to temperatures above the melting point of silver nitrate (414° F) (HW-21957). All three of the silver reactors experienced a decrease in iodine collection efficiency (two of the three were replaced) and the operating temperature was decreased to 375° F. The efficiency of the new silver reactors was over 99.99% (HW-21937) but decreased with use. Regeneration was required by adding more silver nitrate (spraying the bed through the top of the silver reactor). A regeneration solution of 5 molar silver nitrate was used to coat the Berl saddles in the silver reactors (HW-59702).

The collection efficiency of silver reactors installed at B Plant and T Plant varied from 99.9 percent to 88 percent. The iodine removal efficiencies in two silver reactors containing 220 pounds of silver nitrate dropped below 99 percent following dissolution of 75 and 110 MTU (HW-59702 Page 3).

A.1.2.2 Reclamation Process

The normal silver reactor life was approximately seven regenerations before plugging problems start to occur (HW-41053). When regeneration attempts failed to restore the required iodine removal efficiency, the silver reactors were buried or stored for flushing (reclamation), and new or reclaimed silver reactors were installed (HW-59702). In the regeneration process, old saddle coating material was removed by flushing with water and sodium thiosulfate; sometimes Berl saddles were discarded. Reclamation began in 1958 when two silver reactors from REDOX were shipped to U Plant for reclamation and regeneration. Silver reactors were successfully flushed from 1958 to 1989 before they plugged. Known exceptions are the silver reactors buried or placed in PUREX Tunnel 2, which were not regenerated. In the provided inventory in Table A-2, low and high inventories are listed for three of the plants. A zero inventory indicates the silver reactors which were flushed and a high inventory indicates the silver reactors were not flushed.

The estimated curies of I-129 generated at U Plant during the reclamation of silver reactors is as follows: 0.52 Ci = 2 silver reactors from REDOX flushed x (800 MTU/19,692 MTU) × 9.18 Ci × 0.70 fraction of I-129 sent to off-gas x 0.999 fraction of I-129 retained on silver reactors.

Details follow on the reclamation process:

Conclusions from a 1959 report on silver reactor regeneration, reclamation and operations (HW-59702) include the following:

- The amount of chloride present, which likely originated primarily from essential materials used during the coating removal and dissolution steps, affects silver reactor life more than the radioiodine present.
- Compounds of $AgNO_3$, AgI, and AgCl have melting point eutectics lower than the normal operating temperatures of a silver reactor. Therefore, following a period of operation the saddle coating will become fluid, bridge across the saddles and plug the support screen, causing channeling and loss of efficiency. Repeated regeneration increases the amounts of solids present until the silver reactor is completely plugged.
- Laboratory tests (1959) indicate that more iodine is absorbed per mole of Silver nitrate with saddles coated with 5-molar silver nitrate than with the 20 – 24 molar being used.
- A spent silver reactor can be safety and successfully flushed and regenerated.

The following two chemical equations represent the reclamation process (HW-59702)

1. $S_2O_3^{(2-)} + 2Ag^+ \text{---> } Ag_2S_2O_3$
2. $Ag_2S_2O_3 + H_2O \text{----> } Ag_2S + H_2SO_4$

The hot alkaline peroxide encourages the completion of these reactions starting from the two reactants to completion to silver sulfide, Ag_2S, as a precipitate.

The iodine associated with the $2Ag^+$ (Eq. 1) prior to the thiosulfate flushing may be present as the silver iodide (I^-), tri-iodide (I_3^-), iodate (IO_3^-), and possibly periodate (IO_4^-); but the thiosulfate flushing converts all iodine species into iodide (I^-). So, iodide (I^-) is the only iodine species remaining and stays dissolved in the water after the thiosulfate flush as sodium iodide.

Other notes about iodine and iodide:

- Iodine (by itself) is not very soluble in water but greatly soluble in water if there is any iodide (KI, or NaI) already dissolved in the water.
- Solubility of NaI: 84.2 g/100 mL (25 °C) water, more with higher temperature.
- Iodine is appreciably soluble in carbon tetrachloride and other organics.

A.1.2.3 Number of Silver Reactors

After the plants ceased production, silver reactors were stored in the canyons. The estimated number of silver reactors in storage as of 2016 is as follows:

- T Plant – One (from cell pictures/inventory records - HNF-8812, *T Plant Cell Investigation Phase II Report*). A few of the cells have not been opened due to stuck cover blocks and/or limited crane access.
- B Plant – None. In the 1960s, the B Plant Canyon was cleaned and the silver reactors removed.
- REDOX – Four (similar to PUREX [HW-18700 & REDOX Technical Manual])
- PUREX – Four (three dissolver off-gas silver reactors [T-A2, T-B-2 & T-C2], each with 250 pounds of silver nitrate, and one vessel vent silver reactor (T-F2) with no silver or raschig rings

[WHC-IP-0977, *Estimation of PUREX Equipment and Materials That Are Candidates for Removal and Waste Processing During PUREX Plant Closure*]).

- PUREX Tunnel 2 – Two (WHC-IP-0977). One F2 silver reactor was placed in storage on February 26, 1971, and another silver reactor, with a possible inventory of 7.4 Ci of I-129, was placed in storage on May 13, 1988.

The estimated number of silver reactors in burial grounds are as follows:

- 218-W-2A Burial Ground: received three silver reactors from REDOX on January 1, 1959 (HW-63703, SWITS)
- 218-E-5 Burial Ground: received two silver reactors from PUREX on December 31, 1957 (HW-63703, SWITS)
- 218-W-1A Burial Ground: received two silver reactors from REDOX on December 19, 1953 (SWITS) and received one from REDOX on October 7, 1953 (SWITS).

Other indications of silver reactors needing to be disposed: Two silver reactors, 4-5L and 3-5R, were immediately replaced at T Plant (HW-21957, issued August 20, 1951). Of the two REDOX silver reactors placed in operations in November 1951, one was replaced in August 1952 and the other in January 1953. Two new silver reactors were installed in REDOX on April 15, 1958 in the A-3 and B-3 positions. Two silver reactors were from T Plant processing mission completion and two silver reactors were from B Plant processing mission completion.

Table A-1. Number of Silver Reactors

Canyon	Canyon	PUREX Tunnel 2	Burial Grounds	TOTAL
T Plant	1	0	3	**4**
B Plant	0	0	2	**2**
REDOX	4	0	10	**14**
PUREX	4	2	2	**8**
TOTAL	**9**	**2**	**17**	**28**

Although the number of silver reactors is uncertain, the I-129 inventories in the silver reactors are even more uncertain. The calculations used to estimate the inventories were as follows:

T Plant: 0.45 Ci = number of MTUs produced when silver reactors were used divided by total number of MTUs processed at T Plant multiplied by total number of curies in fuel produced by T Plant (RPP-13489) multiplied by the fraction that did not remain in the dissolver solution = (3,115 MTU/5,034 MTU) × 1.03 Ci × 0.70 fraction of I-129 sent to off-gas × 0.999 fraction of I-129 retained on silver reactors.

B Plant: 0.08 Ci = number of MTUs produced when silver reactors were used divided by total number of MTUs processed at B Plant multiplied by total number of curies in fuel produced by B Plant (RPP-13489) multiplied by the fraction that did not remain in the dissolver solution = (568 MTUs/2,765 MTUs) × 0.58 × 0.70 × 0.999.

REDOX: 1.43 Ci = ([7 silver reactors replaced – 2 silver reactors sent to U Plant, from 1952 to 1957] × [800 MTU per silver reactor/2] {to account for limited REDOX processing during 1952 to 1953 when the silver reactors were replaced}/19,692 MTU) × 9.18 Ci × 0.70 × 0.999
+
3 silver reactors in burial grounds after CY 1957 × (800 MTU/19,692 MTU) × 9.18 Ci x 0.70 × 0.999.

For In-Canyon High value: Assume that three of the four silver reactors in the REDOX canyon have not been flushed (= 3 silver reactors in the REDOX Canyon × [800 MTU/19,692 MTU] × 9.18 Ci × 0.70 × 0.999).

PUREX: 1.20 Ci = ([2 silver reactors replaced from 1952 to 1957 × 800 MTU per silver reactor] / 72,202 MTU) × 38.6 Ci × 0.70 × 0.999
+
2 silver reactors in PUREX Tunnel × (800 MTU/72,202 MTU) × 38.6 Ci × 0.70 × 0.999

For high value: The silver reactor in the PUREX Tunnel 2 position 15 has 7.4 Ci of I-129 (WHC-IP-0977); also assume that three of the four silver reactors in the PUREX canyon have not been flushed.

Table A-2. I-129 Inventory in Silver Reactors

Canyon	Curies of I-129						
	In Canyon		In PUREX Tunnel 2		In Burial Grounds	Total	
	Low	High	Low	High		Low	High
T Plant	0	0.11	0	0	0.34	**0.34**	**0.45**
B Plant	0	0	0	0	0.08	**0.08**	**0.08**
REDOX	0	0.78	0	0	1.43	**1.43**	**2.21**
PUREX	0	0.9	0.6	7.7	0.6	**1.2**	**9.2**
TOTAL	**0**	**1.79**	**0.6**	**7.7**	**2.45**	**3.05**	**11.94**

A.1.3. I-129 Releases

A.1.3. Releases to the Atmosphere

I-129 and I-131 were released to the atmosphere from the dissolution of irradiated uranium metal in the processing plants. Iodine-131 was a major health issue because of the initial (1944 to 1948) direct releases of off-gases from the dissolver to the atmosphere, its high specific activity (130,000 Ci/g) and the limited aging time for decay employed before dissolving the uranium due to production needs. Iodine-131 is not an issue for current remediation efforts because its half-life is eight days, decaying to the stable

xenon-131. In contrast, the half-life of I-129 is 16 million years (2007 Fact Sheet) and the specific activity is 0.00018 Ci/g.

A linear scaling has been applied to many of the following estimates, based on the ratio of the total I-129 inventory of 49.4 Ci before processing in the canyons as estimated in 2002 (RPP-13489) to the total I-129 inventory of 64.11 Ci before processing in the canyons as estimated in 1997 (HNF-SD-WM-TI-794). The 1997 report included monthly production data while the 2002 report did not. The monthly production data allow the calculation of inventories for pre- and post-installation of air emission control devices, so the 1997 values have been scaled down to match the magnitude of the more recent 2002 values.

From December 1944 to April 1948, the dissolver off-gas system released I-129 directly to the atmosphere. The estimated number of curies released are based on the following:

- T Plant: (923 MTU/5,034 MTU) × 1.03 Ci results in 0.19 Ci.
- B Plant: (1,026 MTU/2,766 MTU) × 0.58 Ci results in 0.25 Ci.

Off-gas scrubbers (HAN-45807) were installed on the dissolver off-gas systems at T Plant on April 25, 1948 (HW-9922, page 33) and B Plant in May 1948 (HW-10166, page 34; and HAN-45807, page 56). Wastewater from the scrubbers was discharged to the 5-6 cribs (now called the 216-B-9 and 216-T-6 cribs), the 241-T-361 settling tank, 216-T-3 reverse well, 241-B-361 settling tank, and 216-B-5 reverse well. The B Plant cell drainage waste discharge was near the 241-B-361 tank (HAN-45907 pages 56, 79, 95, and 102). In June 1948, iodine removal was 99 percent efficient using the dissolver off-gas scrubbers (HAN-45807). Thus, one percent of the I-129 from the T Plant and B Plant dissolver off-gas systems passed through the scrubbers to the atmosphere from May 1948 to January 1951, when silver reactors were installed, with estimated activities released to the atmosphere as follows:

- T Plant: (996 MTU/5,034 MTU) × 1.03 Ci × 0.01 results in 0.002 Ci.
- B Plant: (991 MTU/2,765 MTU) × 0.58 Ci × 0.01 results in 0.002 Ci.

The remaining 99 percent of the I-129 from the dissolver off-gas system scrubbers from May 1948 to January 1951 was discharged to the soil via cribs/settling tanks/reverse wells and estimated as follows:

- T Plant: (996 MTU/5,034 MTU) × 1.03 Ci × 0.99 results in 0.20 Ci.
- B Plant: (991 MTU/2,765 MTU) × 0.58 Ci × 0.99 results in 0.21 Ci.

The tank farms received I-129 via process waste streams from the plants. The current BBI of I-129 in the tank farms is 30.1 Ci (retrieved online on October 10, 2015 at http://twins.pnl.gov:8001/).

Mercury was added to the dissolver solution to reduce iodine in the off-gas (HW-23043). The T Plant and B Plant 1951 flowsheet states that 15 percent of the iodine remained in dissolver solution and 85 percent was in the dissolver off-gas (HW-23043) but this proportion was not used in the following estimates. Instead, the information in HW-27580 was used, which assumed 30 percent of the iodide remained in dissolver solution and 70 percent was in the dissolver off-gas.

The estimated amount of I-129 released to the atmosphere from 1951 to 1989, when silver reactors were in use, is based on the following:

- T Plant: 0.0004 Curies = (3,115 MTU/5,034 MTU) × 0.7 × 0.001
- B Plant: 0.0001 Curies (568 MTU/2,765 MTU) × 0.7 × 0.001

- REDOX: 0.006 Curies = 9.18 Ci × 0.7 × 0.001
- PUREX: 0.03 Curies = 38.6 Ci × 0.7 × 0.001

The estimated total I-129 released to the atmosphere from 1944 to 1989, all years of production, is based on the following:

- T Plant: 0.19 Ci = (0.19 Ci + 0.002 Ci + 0.0004 Ci) = curies released from 1944 to April 1948 plus curies released from May 1948 through 1950 plus curies released from 1951 to 1989.
- B Plant: 0.25 Ci = (0.25 Ci + 0.002 Ci + 0.0001 Ci) = curies released from 1944 to April 1948 plus curies released from May 1948 through 1950 plus curies released from 1951 to 1989.
- REDOX: 0.006.
- PUREX: 0.03 Ci
- TOTAL: 0.48 Ci

A.1.3. Releases to Soil and/or Transfers to Tank Farms

The estimated amount of I-129 disposed in liquid to the soil and/or transferred to tank farms is based on the following:

T Plant: 0.20 Ci (from scrubbers). Note: Waste sent to tank farms was later transferred to U Plant to recover U using the FeCN process. The FeCN supernatant containing I-129 was disposed to soil.

B Plant: 0.21 Ci (from scrubbers). Note: Waste sent to tank farms was later transferred to U Plant to recover U using the FeCN process. The FeCN supernatant containing I-129 was disposed to soil.

U Plant: 0.52 Ci = 2 silver reactors from REDOX flushed x (800 MTU/19,692 MTU) × 9.18 Ci × 0.70 fraction of I-129 sent to off-gas x 0.999 fraction of I-129 retained on silver reactors

REDOX: 6.03 Ci = 30.1 Ci x [(19,692 REDOX MTU processed from 1952 through 1966) - (2 silver reactors sent to U Plant × 800 MTU per silver reactor)] / (19,692 REDOX MTU processed from 1952 through 1966 – (2 silver reactors sent to U Plant × 800 MTU per silver reactor) + 72,202 PUREX MTU processed from 1956 through 1988). I-129 disposed in liquid to soil is by difference.

PUREX: 24.07 Ci = 30.1 Ci x (72,202 PUREX MTU processed from 1956 through 1988)/(19,692 REDOX MTU processed from 1952 through 1966 – (2 silver reactors sent to U Plant × 800 MTU per silver reactor) + 72,202 PUREX MTU processed from 19568 through 1989). I-129 disposed in liquid to soil is by difference.

FeCN Waste: T Plant: 0.19 Ci = 3,115 MTU/5,034 MTU × 1.03 Ci × 0.30

B Plant: 0.04 Ci = 568 MTU/2,765 MTU × 0.58 Ci × 0.30

The above description of iodine releases to soil is not intended to be exhaustive. It is believed to reflect the most significant releases. However, for example, one report briefly mentions that iodine was sent down the chemical sewer [ISO-651] to the B Swamp (now called 216-B-3, B Pond). No other information on this release has been found.

A.1.3. Summary of All Releases

Table A-3 summaries past releases to the atmosphere and soil, and present storage in the tank farms, canyons and PUREX Tunnel 2. A separate analysis will be conducted to calculate the dose for the atmospheric pathway. The analysis will determine if the I-129 inventory released to the soil could significantly contribute to atmospheric releases.

Table A-3. Disposition of I-129 from Canyon Processing of Uranium

Canyon	Curies of I-129							
	Tank Farms	Atmosphere	Solids to Burial Ground	Canyons & PUREX Tunnel 2		Liquid to Soil		Total
T Plant	0	0.19	0.34	0	0.11	0.11	0.22	**0.84**
B Plant	0	0.25	0.08	0		0.16		**0.54**
REDOX	6.03	0.01	1.43	0	0.78	0.04	0.82	**8.66**
U Plant	0	0	0	0		0.52		**0.52**
FeCN Waste	0	0	0	0		0.23		**0.23**
PUREX	24.07	0.04	0.6	0.6	8.6	3.95	11.95	**38.6**
TOTAL	**30.1**	**0.49**	**2.45**	**0.6**	**9.49**	**5.01**	**13.9**	**49.39**
				Low	**High**	**Low**	**High**	

7.2 A.2 OTHER SOURCES/DISPOSITIONS

In addition to canyon processing related wastes, I-129 is present in the following:

- 6.4 Ci in spent fuel at the CSB and in K Basin Sludge;
- 0.0599 Ci in waste disposed at the ERDF, based on the waste management information system (WMIS) inventory; and
- 5.6 Ci in waste disposed at US Ecology through 2002.

The estimated amount of 1.85 Ci of I-129 in uranium product shipped offsite is based on the following:

> 99,693 MTU processed × 1,000,000 grams U per MTU × 18.6 pCi I-129 per gram of U + 1 Ci per 10^{12} pCi = 1.85 Ci. Based on the amount of U processed at each of the four plants, the proportions of I-129 in product from each of the plants calculates to the following:
>
> - T Plant: 0.09 Ci
> - B Plant: 0.05 Ci

- REDOX: 0.37 Ci
- PUREX: 1.34 Ci

Waste management processes resulting in negligible inventories include the following:

200 West Pump and Treat. Although I-129 is present in groundwater under portions of the Central Plateau, the current 200 West Pump and Treat facility does not produce trackable amounts of I-129 in air emissions or spent resin. The unabated calculated potential release to the atmosphere by the 200 West Pump and Treat facility is 1.08E-02 Ci/yr of I-129 (DOE/RL-2009-124, *200 West Pump and Treat Operations and Maintenance Plan*, p. C-5). Because of this negligible release potential, stack samples at the pump and treat facility are not analyzed for I-129. Instead, gross beta values from near-facility monitoring are used to confirm the negligible release potential (DOE/RL-2009-124, p. C-10). In 2014, I-129 was detected at low levels (less than 1 pCi/g) in the influent to the radiological treatment system and was removed by the Purolite resin to concentrations less than the detection limit of approximately 0.6 pCi/L (DOE/RL-2016-20, *Calendar Year 2015 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations*, p. 3-61). The calculated mass balance for solid wastes (spent resin and VPGAC [vapor phase granular activated carbon]) from pump and treat operations is 3.89E-06 Ci total mass in and 3.89E-06 Ci total mass out (382519-CALC-050, *Integrated Mass Balance: 200 West Area Pump and Treat*).

Releases to the Atmosphere at Canyons Currently Storing Silver Reactors. Negligible releases to the atmosphere under current waste management practices occur from the PUREX stack (e.g., 9.8E-04 Ci in 2016 [DOE/RL-2017-17, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2016*]). Current air emissions from the main REDOX and T Plant stacks are not analyzed for I-129 due to negligible emissions in the past. At REDOX and T Plant, the cumulative dose from all radionuclides was so low a facility effluence monitoring plan was not required (WHC-EP-0440, *Facility Effluent Monitoring Plan Determinations for the 200 Area Facilities*, Vol. 1, p. iv and p. 19 of Part 7). At the REDOX main stack, 291-A-1, based on the averaged and normalized 2nd, 3rd, and 4th quarter preliminary concentrations and flow in 1990, the I-129 activity from the stack would be 1.86 E-02 Ci, less than 10 percent of the total calculated activity (Table 6-1, WHC-EP-0440) and therefore analysis specific to I-129 is not required.

Releases to the Atmosphere from the Hot Semiworks. While processes conducted at the Hot Semiworks included the same types of fuel processing as conducted at PUREX and REDOX, historical records of radionuclide inventories at the Hot Semiworks and at the waste sites receiving Hot Semiworks liquid wastes do not list I-129 (WHC-SD-EN-ES-019, *Semi-Works Aggregate Area Management Study Technical Baseline Report*, p. 17, Table 3, and RHO-CD-673 Vol. 1, *Handbook 200 Areas Waste Sites*). However, because the processes were similar, it is reasonable to assume the composition of the wastes was roughly similar. Using the same approach to estimate I-129 inventory as used for the four canyons, and based on the following estimates, the I-129 inventory would have been very small. At the Hot Semiworks, up to 4,083 pounds of uranium was dissolved in the updraft condenser and 1,429 pounds in the downdraft condenser during REDOX-type studies (HW-31767, *Hot Semiworks REDOX Studies*, Table 3), and 8,069 liters (2,132 gallons) were neutralized during PUREX-type studies (HW-55963, *The Self-Concentration of High Level PUREX Wastes in the Hot Semiworks Waste Concentrator*, p. 20). The tank which received the waste concentrator waste, 241-CX-72, is estimated to have received 8,724 liters (2,304 gallons) which contained 61.22 pounds of uranium and 48.5 grams (0.1 pounds) of plutonium (HW-52860, *Standby Status Report – Hot Semiworks Facility*, p. 56). Adding 4083 + 1429 + 61 pounds results in an estimated 5,573 pounds (2.5 metric tons) of uranium processed -- five orders of magnitude smaller than the 99,693 metric tons of uranium processed by the four plants. The total inventory released to the atmosphere by the four canyons is estimated to be 0.49 curies (Table A-3). If a release occurred

from the Hot Semiworks, and if the cause of that release was at all similar in nature to atmospheric releases from the uranium processing plants, the amount released by the Hot Semiworks would have been negligible.

7.3 A.3 MASS BALANCE

The overall Hanford Site I-129 material balance is as follows:

Input to Hanford: 61.36 Ci

- 49.39 Ci from silver reactors in material processed through the four plants (T Plant, B Plant, REDOX, and PUREX) [HWN-1991, RPP-13489, HNF-SD-WM-TI-794, PNWD-2222-HEDR, and DOE/RL-200-43]
- 6.37 Ci from N Reactor in spent nuclear fuel inventory at the CSB [HNF-SD-SNF-TI-009 Volume 1 Revision 3]
- 5.6 Ci received at US Ecology (Appendix IV, Table 2 in DOH Publication 32-031, *Commercial Low-Level Radioactive Waste Disposal Site Richland, Washington*)

Inventory at Hanford: 59.63 Ci (Figure A-2 and A-3)

- 30.1 Ci in tank farms (Retrieved online on October 10th, 2015 at http://twins.pnl.gov). As noted on the Tank Waste Information Network System (TWINS) webpage, the Best-Basis Inventory is undergoing an update of the decay date for radionuclide analytes from 1/1/2008 to 7/1/2015; decay dates after 2015 are not yet available from the TWINS webpage.)0.06 Ci in ERDF (WCH-479, *Inventory Data Package ERDF Waste Disposal*)
- 0.55 Ci in LLBG (Retrieved online from Solid Waste Information and Tracking System (SWITS) in 2016; HNF-5860, *Solid Waste Information and Tracking System (SWITS) Software Requirements Specification*)
    - Ci in unaccounted silver reactor inventory in LLBG
- 0.60 to 9.49 Ci in canyons and PUREX Tunnel 2
- 5.01 to 13.9 Ci in liquids to soils
- 6.37 Ci from N Reactor in spent nuclear fuel inventory at the CSB (HNF-SD-SNF-TI-009 Volume 1 Revision 3)
- 5.6 Ci received at US Ecology (Appendix IV, Table 2 in DOH Publication 32-031)

Output from Hanford: 2.34 Ci

- 0.49 Ci to atmosphere
- 1.85 Ci in product

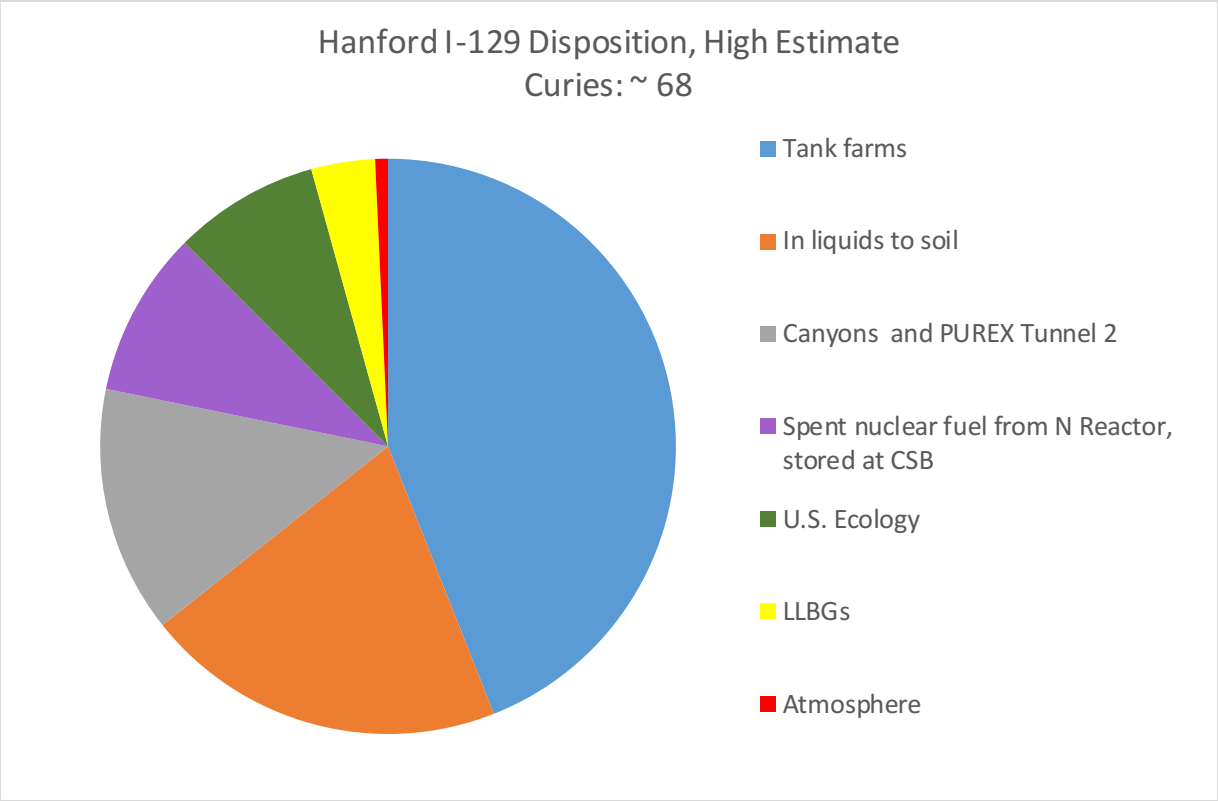

Figure A-2. I-129 Inventory, High Estimate

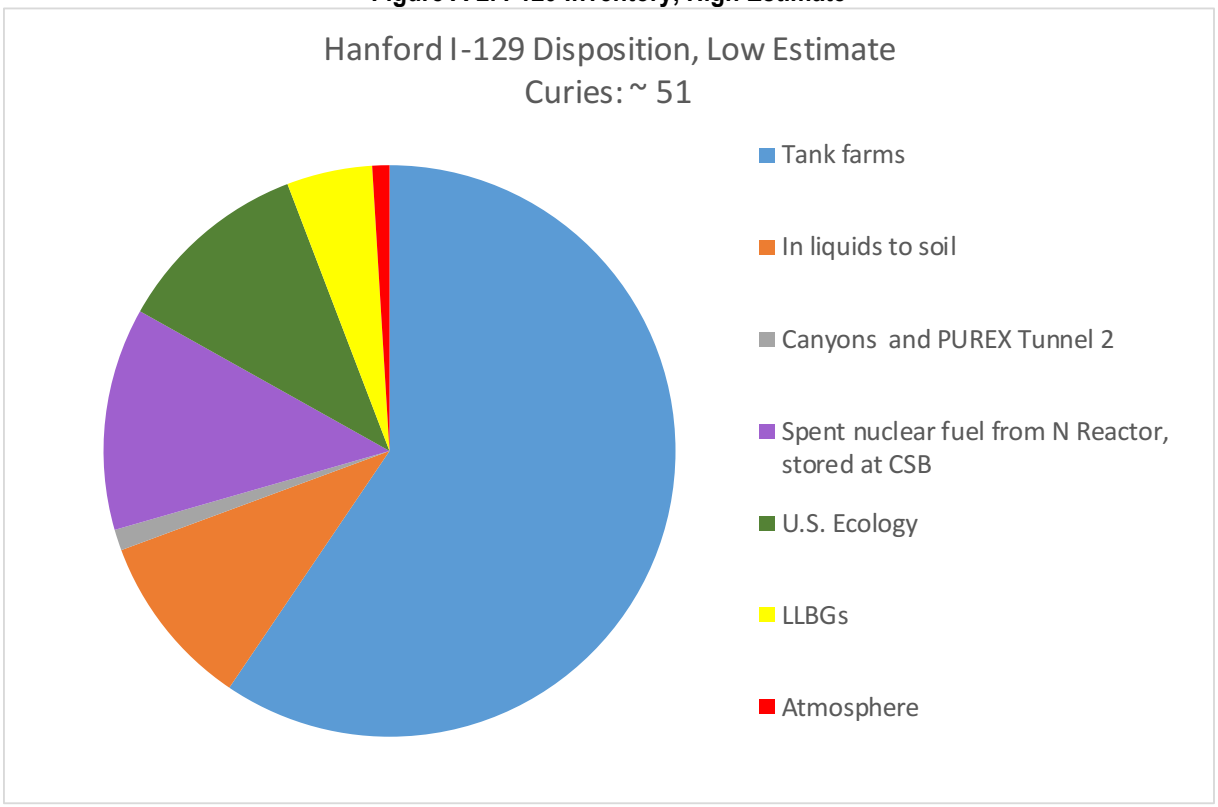

Figure A-3. I-129 Inventory, Low Estimate

7.4 A.4 References

382519-CALC-050, 2010, *Integrated Mass Balance: 200 West Area Pump and Treat*, Rev. 1, CH2M HILL [no publication location provided].

J. Peterson, M. MacDonell, L. Harown, and F. Monette, 2007, *Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas*, Argonne National Laboratory Environmental Science Division, Chicago, Illinois.

DOE/RL-2000-43, 2000, *Review of Generation and Flow of Recycled Uranium at Hanford*, Richland Operations Office, Richland, Washington.

DOE/RL-2009-124, 2016, *200 West Pump and Treat Operations and Maintenance Plan*, Rev. 5, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0077130H

DOE/RL-2016-20, 2016, *Calendar Year 2015 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump and Treat Operations,* Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0074339H.

DOE/RL-2017-17, 2017, *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2016*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

DOH Publication 320-031, *Commercial Low-Level Radioactive Waste Disposal Site Richland, Washington*, Washington State Department of Health, Office of Radiation Protection, Olympia, Washington. Available at: http://www.doh.wa.gov/Portals/1/Documents/Pubs/320-031_vol1_w.pdf.

G. E. Desetti, 1945, *Flow Sheets for 200 Area Processes*, Du Pont, Richland, Washington.

HAN-42598, 1950, *200 Areas Monthly and Weekly Reports – 1950*, General Electric, Richland, Washington.

HAN-45802, 1947, *8 – 200 Area Monthly Reports July – Dec. 1947*, General Electric, Richland, Washington.

HAN-45807-DEL, 1948, *200 Area Monthly Reports 1948*, General Electric, Richland, Washington.

HAN-63671-DEL, 1951, *200 Area Monthly Reports for January 1, 1951 to December 31, 1951,* U.S. Atomic Energy Commission Richland Operations Office, Richland Washington.

HNF-5860, 2000, *Solid Waste Information and Tracking System (SWITS) Software Requirements Specification*, Rev. 0, Fluor Hanford, Richland, Washington. Available at; https://www.osti.gov/scitech/servlets/purl/801859.

HNF-8812, 2002, *T Plant Cell Investigation Phase II Report*, Rev. 1, Fluor Hanford, Richland, Washington.

HNF-SD-SNF-TI-009, 2000, *105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Facilities, Volume 1, Fuel*, Revision 3, Fluor Hanford, Richland, Washington.

HNF-SD-WM-TI-794, 1997, *Activity of Fuel Batches Processed Through Hanford Separations Plants, 1944 through 1989*, Rev. 0, Lockheed Martin Hanford Company and Fluor Daniel Northwest, Richland, Washington.

HW-7795, 1947, *Hanford Works Monthly Report for September 1947*, General Electric Company, Richland, Washington.

HW-9922, 1948, *Hanford Works Monthly Report for April 1948*, General Electric Company, Richland, Washington.

HW-10166, 1948, *Hanford Works Monthly Report for May 1948*, General Electric Company, Richland, Washington.

HW-21826, 1951, *Variation in Silver Reactor Performance,* General Electric Company, Richland, Washington.

HW-21937, 1951, *Shielding – Ball–X Storage Container*, General Electric Company, Richland, Washington.

HW-21957, 1951, *Performance of Replacement and Regenerated Silver Reactors – Operated at 375ºF*, General Electric, Richland, Washington.

HW-23043, 1951, *Flow Sheets and Flow Diagrams of Precipitation Separations Process*, General Electric, Richland, Washington.

HW-27580, 1953, *Review of Silver Reactor Performance in the Separations Facilities*, General Electric, Richland, Washington.

HW-31767, 1954, *Hot Semiworks REDOX Studies*, General Electric, Hanford Atomic Products Operation, Richland, Washington.

HW-41053, 1955, *Regeneration of Silver Reactors*, General Electric, Richland, Washington.

HW-52860, 1957, *Standby Status Report – Hot Semiworks Facility,* General Electric, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081071H.

HW-55963, 1959, *The Self-Concentration of High Level PUREX Wastes in the Hot Semiworks Waste Concentrator,* General Electric, Richland, Washington.

HW-59702, 1959, *Silver Reactor Reclamation*, General Electric, Richland, Washington.

HW-63703, 1960, *Disposition of Contaminated Processing Equipment at Hanford Atomic Products Operation 1958 to 1959*, General Electric, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=0081634H.

HWN-1991, *Hanford Production Logs 1944 to 1972*, Richland, Washington.

PNNL-13524, 2001, *Historical Time Line and Information about the Hanford Site,* Pacific Northwest National Laboratory, Richland, Washington.

PNWD-2222-HEDR, 1994, *Radionuclide Releases to the Atmosphere from Hanford Operations, 1944 – 1972*, Pacific Northwest Laboratories, Richland, Washington.

RHO-CD-673, 1979, *Handbook for 200 Areas Waste Sites,* Vol. 1, Rockwell International, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196039027.

RPP-13489, 2002, *Activity of Fuel Batches Processed Through Hanford Separations Plants, 1944 Through 1989*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

WCH-479, 2013, *Inventory Data Package ERDF Waste Disposal*, Rev. 1, Washington Closure Hanford.

WHC-EP-0440, 1991, *Facility Effluent Monitoring Plan Determinations for the 200 Area Facilities*, Vol. 1, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at: http://pdw.hanford.gov/arpir/index.cfm/viewDoc?accession=D196082314.

WHC-IP-0977, 1993, *Estimation of PUREX Equipment and Materials That Are Candidates for Removal and Waste Processing During PUREX Plant Closure*, Los Alamos Technical Associates, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-EN-ES-019, 1992, *Semi-Works Aggregate Area Management Study Technical Baseline Report*, Rev. 0 [no publisher information or publication location provided]