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Rev. 0

River Corridor
Closure Contract

Vertical Pipe Unit Disposition for 618-10 and 618-11 Burial Grounds

March 2012

For Public Release

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Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Assistant Manager for River Corridor

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TABLE OF CONTENTS

1.0 INTRODUCTION 1-1

1.1 SUMMARY 1-1

1.2 PURPOSE 1-2

1.3 BACKGROUND 1-2

1.3.1 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* 1-2
1.3.2 Defense Determination 1-2

1.4 HISTORY 1-3

1.4.1 618-10 Burial Ground 1-3
1.4.2 618-11 Burial Ground 1-4

2.0 PROCESS KNOWLEDGE 2-1

2.1 PHYSICAL FORM 2-2

3.0 HAZARDOUS/DANGEROUS WASTE 3-1

3.1 LISTED WASTES 3-1

3.2 CHARACTERISTIC WASTES 3-5

3.2.1 Ignitability, Corrosivity, and Reactivity 3-5
3.2.2 Toxicity Characteristic 3-9

3.3 POLYCHLORINATED BIPHENYLS 3-10

4.0 RADIOACTIVE WASTES 4-1

4.1 VPU SOURCE TERM METHODOLOGY – DOCUMENTED SAFETY BASIS ... 4-1

4.1.1 618-10 VPU Inventory 4-2
4.1.2 618-11 VPU Inventory 4-2

4.2 VPU NONINTRUSIVE CHARACTERIZATION 4-2

4.3 TRU DETERMINATION AND WASTE CLASSIFICATION 4-3

4.4 WASTE TRANSPORTATION 4-3

4.5 SPENT NUCLEAR FUEL 4-3

4.6 DISPOSAL PATH 4-4

5.0 CONCLUSION 5-1

6.0 REFERENCES 6-1

APPENDICES

A 618-10 VPU INVENTORY ..... A-i
B 618-11 VPU INVENTORY ..... B-i

TABLES

2-1. 618-10 and 618-11 Soil Chemical Contaminant of Concern List 2-1
3-1. 618 Burial Ground Sampling. 3-2
3-2. Summary of 618 Burial Grounds Totals Results. 3-3
3-3. Summary of 618 Burial Grounds TCLP Results. 3-4
3-4. Summary of 618 Burial Grounds pH Measurements 3-8
3-5. Summary of 618 Burial Ground Polychlorinated Biphenyls 3-10

ACRONYMS

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
CWC	Central Waste Complex
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
ERDF	Environmental Restoration Disposal Facility
HEIS	Hanford Environmental Information System
MDP	multidetector probe
MLLW	mixed low-level waste
NIC	nonintrusive characterization
NPL	National Priorities List
OU	operable unit
PCB	polychlorinated biphenyl
ROD	record of decision
RSR	radiological survey record
SAP	sampling and analysis plan
SIS	Stewardship Information System
SNF	spent nuclear fuel
TQ	threshold quantity
TRU	transuranic
UCL	upper confidence limit
UHC	underlying hazardous constituent
VPU	vertical pipe unit
WCH	Washington Closure Hanford
WIPP	Waste Isolation Pilot Plant

1.0 INTRODUCTION

1.1 SUMMARY

Vertical pipe units (VPU) in the 618-10 and 618-11 Burial Grounds were specifically created for the disposal of high-dose radioactive wastes; wastes with dose rates that required shipment in heavily shielded casks. The VPUs were designed for quick unloading and disposal with the earth providing the shielding from the high dose rates. Access to the VPUs was through the tops of the vertically-oriented pipes and 209-L (55-gal) drums that were used as VPUs; these openings were compatible with shipping casks used during the 1950s and 1960s. The waste deposited in the VPUs could be covered with soil, rocks, or concrete to quickly reduce dose rates and allow operations to continue in the open trenches of the burial grounds. The VPUs received a narrow and select high-dose waste stream – space was a resource not to be wasted; that was the purpose of the larger open trenches.

The conceptual design for VPU remediation is to install a steel overcasing around each VPU and then size reduce the VPU, VPU contents, and the interstitial soil within the overcasing using an auger/drill based technology. The objective of the design is to neutralize and stabilize the hazards contained in the VPUs in situ, thereby minimizing any potential for exposure of personnel or release to the environment. The process is designed to:

- Open/size reduce any containers or bottles; rendering all containers nonintact
- Incorporate container and/or bottle contents into the matrix
- Deactivate potential reactive components using air, water, heat, friction, and shock
- Control energetic releases/chemical reactions
- Control radioactive particulate emissions
- Provide radiation shielding
- Provide a means for radiological characterization to verify waste acceptance
- Prepare waste matrix for extraction and packaging.

The extraction method is dependent on the radiological classification of the waste as mixed low-level waste (MLLW) or suspect transuranic (TRU) waste. The MLLW waste will be stabilized/treated for disposal at the Environmental Restoration Disposal Facility (ERDF). The suspect TRU waste will be packaged for acceptance and storage at the Central Waste Complex (CWC) pending shipment to the Waste Isolation Pilot Plant (WIPP) for disposal.

No listed wastes codes were identified, but the waste stream is presumed to exceed the toxicity characteristic limit for lead. The MLLW must be treated to meet the concentration-based treatment standard for lead for ERDF disposal. The *Treatment Plan and Protocol for Treatment of Lead-Contaminated Soils* (WCH-252), currently approved at ERDF, bounds the lead concentration expected in the VPU wastes and the wastes can be stabilized using the mixture specified in the treatment plan. Field testing of the in situ grouting process, "cold testing," will be conducted to ensure the WCH-252 mixture can be used to stabilize potential lead sources in the VPU matrix. The TRU waste stream will be acceptable for storage at CWC in its processed form.

1.2 PURPOSE

The purpose of this document is to provide a bounding waste document to be used in the designation and profiling of the VPUs found in the 618-10 and 618-11 Burial Grounds. Designation and profiling will be based on the results of the radiological characterization and process knowledge compiled from literature and records searches, coupled with historical sampling information taken from previous and on-going 618-10 and 618-11 Burial Grounds remediation. This information supports low-level waste disposal at ERDF and the storage of TRU waste at CWC.

1.3 BACKGROUND

1.3.1 *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

In July 1989, the Hanford Site was listed on the National Priorities List (NPL) under the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) as amended by the *Superfund Amendments and Reauthorization Act of 1986*. The Hanford Site was divided and listed as four NPL sites: the 100 Area, the 200 Area, the 300 Area, and the 1100 Area. The 300 Area NPL site consists of the following operable units (OUs): 300-FF-1, 300-FF-2, and 300-FF-5. The 300-FF-1 and 300-FF-2 OUs address contaminated soils in the unsaturated vadose zone, structures, debris, and burial grounds. The 300-FF-5 OU addresses the groundwater beneath 300-FF- 1 and 300-FF-2. The 618-10 and 618-11 Burial Grounds fall within the 300-FF-2 OU and the associated U.S. Environmental Protection Agency (EPA) *Record of Decision for the 300-FF-2 Operable Unit, Hanford Site, Benton County, Washington,* (ROD) (EPA 2001) and *Explanation of Significant Difference for the 300-FF-2 Operable Unit Record of Decision* (EPA 2004). As such, the low-level waste streams are eligible for disposal at ERDF.

1.3.2 Defense Determination

The 300 Area waste, the source of the 618-10 and 618-11 Burial Ground waste, is contaminated with materials generated from the following defense activities:

- Defense nuclear material production
- Defense nuclear waste and materials by-products management
- Defense research and development.

The waste qualifies as defense-related on the basis of historical commingling and infeasibility of segregating defense from nondefense waste. The primary mission of Hanford pertaining to national defense and nuclear weapons included fuel and target fabrication, plutonium production reactor operation, radionuclide and chemical separations, component fabrication, research and development, and testing. Hanford's solid waste legacy can be traced back to early weapons production activities in 1944. The 300 Area buildings had an ongoing history of supporting production reactors and reprocessing activities at the Hanford Site, including N Reactor operations. The 300 Area buildings were constructed as part of the Manhattan Project in the 1940s and were used for defense research and development.

Any TRU waste generated by the 300 Area is contaminated with radiological materials examined in support of defense nuclear materials production and defense materials research and development, and also contains materials generated from defense nuclear waste and materials by-products management. Due to the nature of the work performed at the 300 Area facilities, all defense project work was carried out in conjunction with other project needs across the Hanford Site. Waste management practices made no attempt to segregate the wastes originating from nondefense and defense-related campaigns. Since defense waste was commingled with nondefense waste and segregation of the waste is no longer feasible, the waste is eligible for storage in the CWC and disposal at WIPP. The defense determination is supported in CCP-AK-RL-105, *Central Characterization Project Acceptable Knowledge Summary Report for Hanford 300 Area Contact-Handled Transuranic Debris Waste.*

1.4 HISTORY

1.4.1 618-10 Burial Ground

The 618-10 Burial Ground consists of 12 trenches and 94 VPUs. It was operated from March 1953 until September 1963, receiving an estimated 3,680 to 5,670 m^3 (4,800 to 7,400 yd^3) of waste.

Limited records were kept of the burial ground disposal practices. The examination of all available records indicates that the 618-10 Burial Ground wastes included radiologically contaminated laboratory instruments, bottles, boxes, filters, metal (uranium, zirconium, thorium, and aluminum) cuttings, irradiated fuel element samples, metallurgical samples, electrical equipment, lighting fixtures, barrels, laboratory equipment and hoods, and low- and high-level liquid waste sealed in containers.

Waste containers were surveyed before they were transported to the 618-10 Burial Ground. The actual contents of the containers were uncertain, but the radiological survey records indicate the number of waste shipments and the types of containers used. From mid-1950 to about 1960, the 618-10 Burial Ground trenches generally received low-level waste in cardboard boxes. Materials with higher radioactivity were packaged in "cement barrels" (concrete and lead-shielded drums). Around 1960, the radioactivity of the waste from the 325 and 327 Laboratory hot cells increased due to the examination of fuel rod and tank waste samples. Cardboard containers were replaced with remote-handled containers that were loaded into lead-shielded casks for transport to the burial grounds. The waste was then remotely released from the casks into the VPU.

The following four types of VPUs were used at the 618-10 Burial Ground:

- 4.6-m (15-ft) lengths of 35.6-cm (14-in.) diameter pipe
- 3-m (10-ft) lengths of 30.5-cm (12-in.) diameter pipe
- Culvert pipes
- 4.6-m (15-ft) long VPUs constructed by welding five 208-L (55-gal) bottomless drums together end-to-end (most common configuration).

All VPUs were open to soil at the bottom.

The 618-10 Burial Ground had several documented, unplanned releases during operations. After each of the releases at the 618-10 Burial Ground, the ground was either washed down with water or additional gravel was placed over the contaminated area to prevent the spread of contamination.

1.4.1.1 Waste Disposed in 618-10 VPUs. The *618-10 Burial Grounds Records Search Results and Review* (WCH-424) identified a review of all available radiation surveys and waste disposal information searches and provides a detailed description of wastes disposed to the 618-10 VPUs.

WCH-424, Appendix D contains data sheets and descriptions of casks used to transport waste to the 618-10 VPUs. The general waste stream consisted of "milk pail" containers, which were 6-L (1.58-gal) open-top pails. Waste was placed in milk pails and filled with gelatin to hold waste in place until disposed. These containers were typically shipped in a waste cask or "milk pail" cask, which had a payload of one milk pail. Additionally, 1-quart juice cans (waste placed in a juice can and sealed with a pressed-on lid), were shipped in the Gatling gun cask, which had a payload of 12 juice cans.

Earlier disposals to the VPUs (prior to the use of milk pails and juice cans) would have been shipped to the 618-10 VPUs in a shielded box, which was placed on the back of a flatbed trailer, although descriptions on radiological surveys are not sufficiently detailed to determine which surveys may apply. To be conservative, it was assumed that all disposals to VPUs were contained in a waste cask.

When dose rates became a personnel safety issue, site soil, gravel, or concrete was introduced into the VPU to reduce readings to an acceptable level. A typical backfilling activity started with a dose rate at grade of up to 15 R/hr. When backfill was added it resulted in readings in the 50 mR/hr range.

With very few exceptions, wastes disposed to the 618-10 VPUs were generated in the 327 Building. These exceptions included:

- HAPO Capsule from 3706 on October 1, 1955
- Disposal from 3707-C on January 30, 1963
- Hanger ends and fuel rod extenders from 309 Building on July 16 and 17, 1963
- Bottle of 325 Building waste to a VPU on October 12, 1956
- Broken tensile wire on September 21, 1961
- Hot sample on May 4, 1962
- Hot sample from pig on September 24 and September 26, 1962, from the 326 Building.

1.4.2 618-11 Burial Ground

The 618-11 Burial Ground consists of three slope-sided trenches, four large caissons, and 50 VPUs. It was opened in March 1962 and accepted waste into Trench 1 until October 1962 when it was taken out of service. While out of service, Trench 2 and 40 VPUs were added and the 618-11 Burial Ground was brought back online in September 1963. Trench 3 had received waste only in the east and west ends when the site was closed in December 1967.

The trenches are 270 m (900 ft) long by 15 m (50 ft) wide and 7.6 m (25 ft) deep. The VPUs were constructed with five 208-L (55-gal) bottomless drums, like those in the 618-10 Burial Ground. Two of the caissons were constructed of 2.4-m (8-ft)-diameter corrugated metal pipe, 3 m (10 ft) long, with the top of the caisson being 4.6-m (15-ft) below grade, and connected to the surface by an offset 91-cm (36-in.)-diameter pipe with a dome cap lid. A third caisson was similar, except for a 61-cm (24-in.) offset pipe. These units were buried with about 4.6 m (15 ft) of space between them. The caissons are also open to the soil at the bottom. The fourth caisson is believed to be a 2.4-m (8-ft)-diameter corrugated metal pipe, 6.4 m (12 ft) long, and installed horizontally with timbers blocking the open ends. This caisson is equipped with two evenly spaced 61-cm (24-in.)-diameter offset chutes. The burial ground received a minimum of 0.6 m (2 ft) of soil when it was closed. This was in addition to the soil cover used to close the trenches. An additional 0.6 m (2 ft) of topsoil was added to the site for surface stabilization in 1983.

The VPUs at the 618-11 Burial Ground were all constructed from 208-L (55-gal) drums.

The 618-11 Burial Ground contains a broad spectrum of low-level radioactive waste including fission products, byproduct waste (thorium and uranium), and plutonium, similar to the 618-10 Burial Ground. It was used for the disposal of 300 Area laboratory solid wastes. Low- to high-activity wastes were received from the 305, 306, 309, 313, 315, 317, 324, 325, 325-A, 325-B3, 326, 327, 329, 340 Complex, 1171, 3700, 3706, 3707-C, 3708, 3718, and 3730 facilities. These facilities handled radioactively contaminated, or potentially-contaminated waste from operations or laboratory areas, including hot cells. Moderate- and high-activity (remote-handled) wastes were received from the 327 Building (radio-metallurgy) hot cells, 325-A hot cells, the 325-B (analytical) hot cells, occasionally from the Plutonium Recycle Test Reactor 309 Building, and later from 324 hot cells.

The low- to moderate-activity wastes described above were disposed to trenches (with some exceptions), and the moderate- to high-activity wastes were disposed to VPUs and caissons. The 325-A hot cells disposed of moderate- to high-activity waste to the trenches in concrete lead-shielded drums. The 325-B hot cells also used concrete-shielded drums to dispose of hot cell waste, used laboratory containers and glassware, and spent instruments and equipment. Some plutonium residues from various organizations and facilities (including the 308 Building) were encapsulated in concrete and placed in lead- and concrete-shielded drums for disposal at the 618-11 Burial Ground.

The 618-11 Burial Ground had several documented unplanned releases during its operational life. After each release, the ground was either washed down with water or gravel was spread over the contaminated area to prevent the spread of contamination.

1.4.2.1 Waste Disposed in 618-11 VPUs. The *618-11 Burial Grounds Records Search Results and Review* (WCH-403) provides a detailed description of wastes disposed to VPUs as identified in a review of all available radiation surveys and waste disposal information searches.

WCH-403, Appendix G contains data sheets and descriptions of casks used to transport waste to 618-11 VPUs and/or caissons, and provides a description of a VPU, which is found in the three rows of VPUs in the northeast and north sections of the 618-11 Burial Ground.

Containers consisted of "milk pails", which were 6-L (6.3-gal) open-top pails. Waste was placed in the milk pail and filled with gelatin to hold waste in place until disposed. These containers were typically shipped in a waste cask or "milk pail" cask, which had a payload of a single milk

pail. Additionally, one-quart juice cans (waste placed in juice can and sealed with a pressed-on lid) were shipped to the burial ground in the Gatling gun cask, which had a payload of 12 juice cans. Later (mid-1964), larger containers consisting of 4-L (1-gal) and 19-L (5-gal) paint cans, were added and used for disposal of waste to the 618-11 caissons and VPUs.

When dose rates became a personnel safety issue, site soil, gravel, or concrete was introduced into the VPU to reduce readings to an acceptable level. A typical backfilling activity started with a dose rate at grade of up to 15 R/hr and, when backfill was added, resulted in readings in the 50 mR/hr range.

With few exceptions, wastes disposed to 618-11 VPUs were generated in the 327 or 325 Buildings. These exceptions include the following:

- Gatling gun cask from the 309 Building on September 10, 1964
- Disposal of a bare probe from the 324 Building on November 11, 1966.

In addition to individual radiological surveys, records were retrieved that contained routine and repetitive survey records. Of specific interest were multiple surveys logged on these survey records, which documented the loading of individual milk pails into casks for shipment to the 618-11 Burial Ground. A total of 892 line item surveys of milk pails are documented including the date/time of survey, the hot cell where the waste was generated, surveys at the cask port, to the body, to hands, and through the cask (WCH-403 Appendix E).

2.0 PROCESS KNOWLEDGE

Little is known about the exact contents of the shipments to an individual VPU, but much is known about the types of wastes, the processes generating the waste, the containers used to store/transport the waste, the stabilization/treatment of specific wastes like acids and reactives, and the radioactive and chemical composition of wastes characterized during past and on-going burial ground remediation. This reconstructed history combined with actual burial ground remediation experience forms the basis for the VPU process knowledge.

Previous studies undertaken by WCH and subcontractor staff reviewed all available information to identify dangerous/hazardous wastes that may have been introduced into the waste stream, as well as the potential for restrictive physical parameters that may have been introduced into the VPUs. Based on the studies, DOE/RL-2008-27, *Sampling and Analysis Plan for 618-10 and 618-11 Nonintrusive Sampling*, identified the contaminants of concern (COCs) for the 618-10 and 618-11 Burial Grounds in Table 2-1.

Table 2-1. 618-10 and 618-11 Soil Chemical Contaminant of Concern List. (2 Pages)

Final COCs	Rationale for Inclusion
Metals	
Aluminum	Fuel cladding component
Arsenic	EPA toxic
Barium	EPA toxic
Cadmium	EPA toxic metal used in lead-dipped cladding
Chromium	EPA toxic reactor component
Chromium (VI)	EPA toxic used for cleaning
Copper	Metal used in triple-dip process of cladding and cladding waste stream
Iron	Reactor component
Lead	EPA toxic metal used in lead-dipped cladding and cladding waste stream
Mercury	EPA toxic laboratory uses
Nickel	Reactor component
Selenium	EPA toxic
Silver	EPA toxic miscellaneous laboratory uses
Zinc	Reactor component
General Inorganic	
Chloride	Several compounds contained chloride. The most widely used included ferrous chloride, which was used as a carrier, and potassium/sodium chloride used as salting agents.
Nitrate	Most widely used included sodium nitrite (a salting agent during the cladding removal), nitric acid (used throughout the bismuth-phosphate process and uranium recovery process), and bismuth-subnitrate (used to create the bismuth-phosphate/ plutonium solid during the first and second decontamination cycles).

Table 2-1. 618-10 and 618-11 Soil Chemical Contaminant of Concern List. (2 Pages)

Final COCs	Rationale for Inclusion
Phosphate	Several compounds contained phosphate. The most widely used included phosphoric acid, which was used throughout bismuth-phosphate process.
Sulfate	Several compounds contained sulfate. The most widely used included sulfuric acid, which was used in the dissolving of the fuel rod during the bismuth-phosphate process. Many other sulfate complexes were used as carriers for various metals.
Organics	
Polychlorinated biphenyls	Extensive use in electrical equipment and as hydraulic fluids.
Paraffin hydrocarbons (TPH)	Extensive use in solvent extraction operation as the dilutant for TBP.
TBP	Extensive use in solvent extraction operation as a complexant.

COC= contaminant of concern
EPA = U.S. Environmental Protection Agency
TBP = tributyl phosphate
TPH = total petroleum hydrocarbons

2.1 PHYSICAL FORM

Studies showed that the VPUs were primarily filled with debris; however, soil, gravel, and concrete were added to reduce personnel exposure. The initial volume ratio of debris to soil is unknown and, arguably, assumed to be greater than 50% soil, but the final processed form will be "soil-like" following size-reduction, grinding, and mixing by the drill/auger. The waste matrix will be composed of iron-based alloys, metals, lead, plastics, rubber, cellulosics, soil, gravel, concrete, glass, ceramics, diatomaceous earth, irradiated specimens, irradiated hardware, gelatin, treated/absorbed liquids. Liquids and/or reactive wastes will be incorporated into the matrix being stabilized/deactivated in the process.

Organic materials were used in small quantities. Any residuals are expected to be present as a trace material. Free liquids are not expected to be present in containers other than small ampoules and vials since limited quantities or liquids were used within the hot cells. Waste management practices may have included packaging of free liquids or unused reagents, which in practice were neutralized, absorbed, and cemented, but still could be present due to dewatering or condensation. Unpunctured aerosol cans were not segregated from the waste until the early 1980s and may be present in this waste, though unlikely. Liquids and reactive materials were thought to be solidified, evaporated, and/or neutralized prior to disposal with the exception of small volumes of liquids disposed in milk pails in sealed containers and, potentially, old scintillation cocktail solutions disposed in vials. The majority of these wastes from the 300 Area facilities were placed in the trenches in the burial grounds since the VPUs were focused on receiving high-dose rate items.

Waste information found in the previous studies was sufficient to develop a "proof of concept" model to test the conceptual remediation design. A description of the model is found in "618-10 and 618-11 Burial Grounds Vertical Pipe Unit In-Situ Stabilization and Size Reduction Proof of Concept Test Requirements" (WCH 2012). The test simulated the placement of VPU debris waste (surrogate materials) in both partial and full scale VPU assemblies and demonstrated that drill/auger was capable of the required size reduction and container breaching.

3.0 HAZARDOUS/DANGEROUS WASTE

The *Washington Administrative Code* (WAC) 173-303 regulates the designation of solid wastes that are dangerous or extremely hazardous to the public health and environment. The VPUs will be designated in accordance with this regulation. DOE/RL-2008-27 identifies the COCs for the 618-10 and 618-11 Burial Grounds. The COCs identify no listed wastes, eight regulated constituents that could be assigned toxicity characteristics wastes codes, and 10 potential underlying hazardous constituents (UHC).

Much is known about the 618-10 and -11 Burial Ground sites due to the extensive remediation sampling conducted to ensure compliant waste disposal. During the preparation of this document, a query of the Washington Closure Hanford (WCH) Stewardship Information System (SIS) was conducted to obtain the results of all samples, 5,035 samples with approximately 93,750 data points, taken from the 618-10 and 618-11 Burial Grounds. The SIS is one of the information systems WCH uses to track and store sampling information. The SIS integrates geophysical, document tracking, global positioning system (GPS), and sampling information to facilitate cleanup activities. The SIS sampling data is ultimately transferred to the Hanford Environmental Information System (HEIS) for record retention. Table 3-1 shows the location, purpose, and number of samples taken to date and includes both radiological and chemical results.

Table 3-1 shows sample data analyzed to determine the worst case and 90% upper confidence limit (UCL) values for the 618-10 and 618-11 Burial Ground COCs. The contaminants found during the past and present 618 Burial Grounds remediation are chemically representative of the 300 Area waste disposal activities.

Table 3-2 and 3-3 provide the bounding values expected for the VPU and caisson remediation based on the Table 2-1 COCs. Both Tables 3-2 and 3-3 calculate a 90% UCL using the average standard deviation and number (count) of the available samples. Table 3-2 is the summary of total results for each of the COCs excluding verification samples and "blanks" (purpose not specified). Incorporation of verification and blanks lowered the 90% UCL significantly, primarily due to the verification samples being post-cleanup samples. All laboratory qualifiers are included in the analysis. Table 3-3 is a summary of TCLP results for each of the COCs and includes all available data.

3.1 LISTED WASTES

Hazardous waste listings are based on the sources of, or the processes that generated, the wastes rather than the concentrations of the hazardous constituents; therefore, analytical testing alone, without information on a waste's source, will not produce information that will conclusively indicate whether a given waste is a listed waste. The EPA guidance on listed waste determinations at CERCLA sites indicates that reasonable efforts must be taken to determine whether a waste is a *Resource Conservation and Recovery Act*-listed waste.

Table 3-1. 618 Burial Ground Sampling.

Samples Site Code	Purpose									
	Characterization	Industrial Hygiene	In-Process	Routine	Special	Transportation	Verification	Waste Management	(Blank) Not Identified	Total
618-1			170			2,465	1,997	9,426		14,058
618-10			12,493			16		72		12,581
618-12							193			193
618-13	8					208	1,316	92		1,624
618-2	2,916		1,711			2,520	1,522	2,016		10,685
618-3	1,612		18			48	77	23		1,778
618-4	4,307		149	1		22	1,399	963	1,476	8,317
618-5	3,788		130		158		210		1,208	5,494
618-7	195	16	4	94		8,862	2,628	22,831		34,630
618-8	254		376			60	77			767
618-9							3,622			3,622
Grand Total	13,080	16	15,051	95	158	14,201	13,041	35,423	2,684	93,749

Table 3-2. Summary of 618 Burial Grounds Totals Results.

Contaminant of Concern		Units RPTD Values								90% UCL - Totals	
		mg/kg				µg/kg					
CAS	NAME	Maximum	Average	Standard Deviation	Count	Maximum	Average	Standard Deviation	Count	mg/kg	µg/kg
126-73-8	Tributyl phosphate					666.00	343.07	70.36	58		358.26
14265-44-2	Phosphate	194,000.00	1,542.19	16,823.58	132					3,950.75	
14797-55-8	Nitrate	357,000.00	4,755.36	38,197.73	132					10,223.98	
14808-79-8	Sulfate	350,000.00	2,463.11	27,582.91	160					6,049.91	
16887-00-6	Chloride	160,000.00	2,550.16	13,830.94	160					4,348.69	
18540-29-9	Hexavalent chromium	0.47	0.16	0.09	57					0.18	
7429-90-5	Aluminum	856,000.00	12,927.67	69,677.89	593					17,634.13	
7439-89-6	Iron	809,000.00	16,923.00	35,088.39	593					19,293.08	
7439-92-1	Lead	103,000.00	272.43	4,335.44	655					551.07	
7439-97-6	Mercury	77.00	0.50	4.07	571					0.78	
7440-02-0	Nickel	15,000.00	71.32	747.36	588					122.02	
7440-22-4	Silver	464.00	1.48	18.89	652					2.70	
7440-38-2	Arsenic	81.60	2.76	5.12	655					3.09	
7440-39-3	Barium	110,000.00	313.35	4,303.32	655					589.93	
7440-43-9	Cadmium	26.00	0.53	1.42	652					0.62	
7440-47-3	Chromium	6,560.00	55.49	421.67	652					82.65	
7440-50-8	Copper	235,000.00	524.67	9,717.50	593					1181.05	
7440-66-6	Zinc	4,030.00	67.71	222.69	593					82.75	
7782-49-2	Selenium	180.00	2.16	8.09	655					2.68	
TPH	Total petroleum hydrocarbons	1,430,000.00	762,637.20	628,257.12	10					108,9424.13	
TPH oil H	Total petroleum hydrocarbons - motor oil (high boiling)	19,000.00	1,445.97	3,222.63	51	22,000,000.00	790,436.55	3,165,642.70	55	2,188.23	1,492,550.83
TPH diesel	Total petroleum hydrocarbons - diesel range	17,000.00	1,013.00	2,603.36	68	3,000,000.00	108,513.68	486,431.10	57	1,532.29	214,490.57
TPH kerosene	Total petroleum hydrocarbons - kerosene range	13,000.00	1,893.53	4,534.61	7	103,000.00	18,347.78	19,056.08	54	4,712.68	22,613.22

CAS = Chemical Abstract Services
RPTD = reported
TPH = total petroleum hydrocarbons
UCL = upper confidence limit

Table 3-3. Summary of 618 Burial Grounds TCLP Results.

Contaminant of Concern		Units RPTD Values								90% UCL - TCLP	
		mg/L				µg/L					
CAS	Name	Maximum	Average	Standard Deviation	Count	Maximum	Average	Standard Deviation	Count	mg/L	µg/L
14265-44-2	Phosphate	133.00	59.26	47.42	7					88.738	
14797-55-8	Nitrate	61,500.00	9,325.72	21,334.14	7					22,589.075	
14808-79-8	Sulfate	64,100.00	14,499.08	25,278.07	16					24,893.763	
16887-00-6	Chloride	25,200.00	2,097.73	5,986.65	16					4,559.521	
7429-90-5	Aluminum	160.00	59.89	40.20	9	245,000.00	43,460.33	72,160.45	12	81.932	77,724.162
7439-89-6	Iron	610.00	149.56	187.60	9	260,000.00	73,637.93	93,326.06	14	252.412	114,664.588
7439-92-1	Lead	5.31	0.21	0.69	144	267,000.00	3,342.61	14,302.67	482	0.305	4,414.182
7439-97-6	Mercury	0.05	0.00	0.01	132	3,010.00	16.90	197.82	277	0.002	36.450
7440-02-0	Nickel	1.10	0.30	0.33	9	16,300.00	3,909.53	5,558.08	12	0.475	6,548.657
7440-22-4	Silver	0.04	0.02	0.02	144	6,000.00	32.59	307.69	477	0.021	55.760
7440-38-2	Arsenic	7.50	0.12	0.63	144	6,000.00	54.20	307.65	482	0.202	77.250
7440-39-3	Barium	3,300.00	27.48	274.41	144	12,200,000.00	27,560.10	555,102.50	482	65.093	69,148.952
7440-43-9	Cadmium	0.18	0.01	0.02	144	51,400.00	417.40	2,634.78	482	0.014	614.796
7440-47-3	Chromium	4.80	0.07	0.41	144	166,000.00	711.12	8,655.49	482	0.125	1,359.597
7440-50-8	Copper	23.00	3.14	7.06	9	12,000.00	2,168.85	3,430.52	12	7.009	3,797.757
7440-66-6	Zinc	380.00	46.35	118.04	9	40,400.00	7,206.92	10,685.28	15	111.064	11,744.951
7782-49-2	Selenium	0.40	0.07	0.06	144	6,000.00	66.56	307.85	479	0.076	89.698

CAS = Chemical Abstract Services
RPTD = reported
TCLP = toxicity characteristic leaching procedure

A study conducted in 1997 resulted in the "300-FF-2 Listed Waste Issue Letter Report" (BHI 1997). The report addressed the listed waste history as applicable to 300-FF-2 OU waste sites. The effort was executed, at the request of the U.S. Department of Energy (DOE) prior to the 300-FF-2 OU Focused Feasibility Study to provide input for the evaluation of remedial alternatives in response to comments from the regulators. The purpose of the study was to compile evidence of solvent sources and disposal practices in the 300 Area that could lead to a listed waste determination. The report consisted of reviews of historical references, available documents, and interviews with current and former 300 Area personnel. Between the document reviews and interviews, linkages between specific chemical use and specific disposal methods and locations, needed to positively identify listed waste, could not be made except for in the 618-9 and 316-4 Crib.

Following the BHI (1997) study, numerous additional document and record searches were performed and have found no inconsistencies with the 1997 study. Document and record searches include the following:

- *Characterization of the 618-11 Solid Waste Burial Ground, Disposed Waste, and Description of the Waste Generating Facilities* (HNF-EP-0649)
- Integrated Hazards Evaluation (IHE) -2009-006 and IHE-2011-006
- WCH-125, *600 Area Remediation Design Solution Waste Volume and Inventory*
- WCH-424, *618-10 Burial Grounds Records Search Results and Review*
- WCH-403, *618-11 Burial Grounds Records Search Results and Review.*

The 2010 records search and review reports provided a detailed summary of all available radiological survey records (RSR) recovered from the records search efforts conducted between 1997 and 2010. The summaries describe each RSR reviewed, buildings where waste was generated, general burial ground disposal, and includes information for the different transport and disposal containers and casks used to move the waste to the VPUs. The RSRs revealed a number of chemicals that were disposed, however, as in the case of the BHI (1997) study, chemicals were identified but they do not identify the specific use prior to disposal.

No listed waste codes will be applied to VPU or caisson wastes.

3.2 CHARACTERISTIC WASTES

Dangerous waste characteristics are broken down into four types – ignitability (D001), corrosivity (D002), reactivity (D003), and toxicity (D004-D043). The first three types are based on specifically identified physical properties with the last type based on the toxicity concentration of "listed" contaminants.

3.2.1 Ignitability, Corrosivity, and Reactivity

Ignitable, corrosive, or reactive waste codes are not applicable to the final waste form since the constituents are not expected, or if present are expected in small quantities, which when coupled with the technology process (e.g., exposure to strong vibration and/or shock, mixing

with surrounding soil, exposure to air, exposure to liquids in the form of dust suppression or moisture in surrounding soil) are deactivated and no longer characteristic wastes.

The treatment standard for D001, D002, and D003 is deactivation (DEACT) and meets the 40 CFR 268.48 standards for UHCs. The EPA has additionally determined that many technologies can achieve the treatment standard and 40 CFR 268 Appendix VI provides a list of technologies. WTRRX, controlled reaction with water, can be used for D001 and D003 reactives. Stabilization with reagents (STABL) (e.g., Portland cement) can be used for D001 and D002 reactives and corrosives. Neutralization (NEUTR) is acceptable for D002 acid and alkaline subcategories. The process of drill/augering with the addition of soil moisture and dust suppression combines all of these technologies to ensure the final form is deactivated. The non-TRU wastes will be stabilized for lead with cement for ERDF disposal. The TRU wastes will receive additional screening prior to packaging; further stabilization is not required.

D001, D002, and D003 waste codes will not be applied to the processed waste form.

3.2.1.1 Sodium-Potassium Alloy – NaK. Sodium-potassium alloy, or NaK, is a silver-colored liquid metal with no odor. It was used as a high-temperature heat transfer fluid in test capsules. NaK reacts violently with water and water vapor, liberating and igniting the flammable hydrogen gas produced. In air, NaK may ignite spontaneously or form a potassium superoxide (potassium dioxide - KO_2; a strong Class 5.1 oxidizer in pure form) that reacts violently with organics. Both NaK and potassium superoxide are water reactive and will react to moisture in the air and soil.

Research has been ongoing to determine presence and quantity on unreacted NaK in the 618-10 and 618-11 VPUs. The worst case condition was estimated to be a single can of unreacted NaK per VPU where the can contained 270 grams of unreacted NaK, which has oxidized to 120 grams of potassium superoxide. The estimate is documented in the calculation, 0600X-CA-N0081, *Energy Associated with Potential NaK Reaction in Vertical Pipe Unit*. The estimate is based on the following:

> An estimated number of capsules to be examined in the 327 Building in FY 1959 is provided in HW-59889, Project Proposal High Level Utility Cell - 327 Building; "approximately 100 NaK capsules are scheduled for examination". Per documentation, including HW-56588, Results of NaK Capsule Failures in Hot Water Flow Tube, HW-67263, Cladding Studies Capsule Design, and HW-67717, Failure Test of Double Chambered NaK-Filled Irradiation Capsule, a pre-calculated amount of NaK was used in capsules and although it varied, it remained small in volume. An estimated mass was assumed based on expected alloy composition and density as well as limitations outlined in documentation regarding sample size. The rate at which the VPUs would have received NaK was calculated from both the dates the VPUs were believed to be in operation and the documentation in regards to opening the first capsule containing NaK. Based on that information a conservative estimate of 8 capsules per month at 34 grams NaK per capsule was utilized.

In general, records indicate unreacted NaK was <u>not</u> disposed of in the VPUs but rather that NaK was neutralized before disposal. Documents including HW-29460, *327 Building Procedure*, outline steps for neutralization of metals including potassium and sodium prior to disposal. It is assumed that although NaK is not specifically mentioned, it would have been treated in the same manner. Summary reports of post-irradiation testing (including but not limited to HW-46468, HW-46470, HW-49002, and HW-51973) give a brief summary of the steps taken to conduct the examination and specify that cans were opened while submerged in tetraethyl

alcohol or tertiary butyl alcohol. At least one report, *Examination of Uranium Tensile Samples Irradiated in the MRT According to GEH-3-5 and GEH-3-11* (HW-46470), outlines the purpose of the step to "passivate the NaK contained in capsules."

Research concluded that the use of terms such as "NaK waste," "waste (NaK)," and "NaK material" in RSRs were generalizations and did not pertain to unreacted NaK. In the cases where an uncontrolled energetic reaction of NaK occurred, monthly reports indicate the routine procedure was to react NaK in a controlled manner. The review of quarterly reports revealed test capsule immersion in butyl alcohol and that equipment was installed for the purpose of opening capsules allowing for the safe disposal of NaK.

Based on an interview with a former worker in WCH-125 and a 1976 reactive event that occurred due to the accumulation of NaK, the presence of NaK could not be excluded. An individual recalled NaK was accumulated and that "the NaK left the building unreacted." As a result of the interview and the 1976 event, a conservative value of 270 grams of unreacted NaK was estimated to be present in a VPU. The basis for 270 grams of NaK, and its subsequent oxidation to 120 grams of potassium superoxide, was estimated and evaluated in 0600X-CA-N0081 to determine the energy associated with a potential NaK reaction. This bounding energy release was used in the VPU technology design to mitigate and contain potential NaK reactions.

NaK and potassium superoxide, if present and unreacted, will be deactivated by size-reducing its container, exposure to both air and water (water in air, soil, and from dust suppression), and mixing with soil.

3.2.1.2 Picric Acid – TNP. Picric acid, 2,4,6-trinitrophenol (TNP), is a yellow crystalline solid; an acidic (corrosive) phenol. As with other nitrated compounds it is explosive. It is normally used and stored as an aqueous solution and can be classed as an explosive (Class 1) or flammable solid (Class 4.1) depending on the percentage of water present. Picric acid was used in a number of the 300 Area buildings for electro-polishing metallographic specimens. Picric acid in the dehydrated crystalline form is shock sensitive and poses an explosion or fire risk.

Picric acid, if present and unreacted, will be deactivated by size-reducing its container, exposure to air, heat and mechanical shock, and mixing with soil.

3.2.1.3 Acids – Specimen Dissolution. The largest volume of chemicals disposed to the VPUs appears to be associated with fuel element specimen dissolution activities. Acids used in dissolution (mainly nitric, but also hydrochloric, sulfuric, and hydrofluoric) in volumes ranging from about 100 to 200 mL/dissolution may have been disposed to a VPU in the same container in which the dissolution was performed, after removal of a small volume for analysis. Additional references note materials dissolved in chemical reagents and cell cleansers, which included carbon tetrachloride, acetone, ethanol, kerosene, and commercial products. Initially, documentation indicates these cans were "stabilized" before disposal using gelatin. Later, most of these cans were sealed with a screwed-on cap. Hundreds of these dissolutions were performed over the lifetime of the 618-10 Burial Ground based on historical documentation, implying that the total volume of acid disposed may have been on the order of several hundred liters. This implies that an individual VPU could have received several liters of acid.

It is estimated that the volume of these dissolution "cans" was probably in the range of 0.5 to 1.0 L (0.13 to 0.26 gal) based on the dissolution procedure. This procedure indicates solution

volume varied with sample size and ranged from about 125 mL (typical) to close to 400 mL for the largest sample. The "standard" container could handle a sample that would have produced slightly more than 210 mL of solution.

In general, liquid waste was not disposed to the VPUs. However, some liquid waste related to metallographic specimen grinding/polishing (use of an oil-based solution prevented disposal via the radioactive liquid waste system) was disposed for about the first 2 years the VPUs were open. A water-based solution replaced the oil-based solution in late 1955 to early 1956, which allowed this liquid waste stream to then be disposed via the radioactive liquid waste system.

Several documents strongly imply or show that the remainder of the dissolver solution was disposed in the same can where the dissolution was performed. The first is from HW-47168, *Reactor and Fuels Research and Development Operation Monthly Report*, during the design of the remote dissolver. The document states that a 1-mL sample will be removed to a sample vial and no other solution transfer will be made. It is then stated that the dissolver "tank" will serve as a disposal container for the remaining solution and a new tank will be provided for each new sample. This dissolver was first used in HW-54408, *Monthly Report – December 1957 Radiation Monitoring Operation Hanford Laboratories Operation,* and was removed from use in August 1959 (HW-61731, *Monthly Report – August 1959 Radiation Monitoring Operation Hanford Laboratories Operation*), to be replaced with newer design that was easier to maintain. The *Monthly Report – July 1958 Radiation Monitoring Operation Hanford Laboratories Operation (*HW-56941) indicates that "dose rates of 1 R/hr were encountered while filling dissolver cans with gelatin." A procedure for remote dissolving of irradiated uranium and uranium oxide, dated February 18, 1960, is included as an appendix to *Analysis of Burnup Data (*HW-72005). The procedure states that "after the sample cask has been returned from analytical, the dissolver can from that run can be placed in a milk pail for disposal." *Radioactive Waste Handling at the Hanford Laboratories Radio-metallurgy Facility (*HW-72103), circa 1961/1962, states that "all highly radioactive liquids, such as dissolver solution are sealed in plastic or stainless steel containers and disposed of in milk pails."

Table 3-4 summarizes the measured pH values for all 618 Burial Grounds. Table 3-4 includes all available 618 Burial Ground samples for pH. It is unlikely that wastes disposed in the VPUs will differ significantly from the burial ground values since acidic liquids were not generally disposed of in the burial grounds.

Table 3-4. Summary of 618 Burial Grounds pH Measurements.

Constituent Identification	Name	Units RPTD Values				90% UCL - pH
		pH				
		Maximum	Average	Standard Deviation	Count	pH
pH	pH Measurement	13.2	7.81	1.62	341	7.95

RPTD = reported
UCL = upper confidence limit

Acids, if present and unneutralized, will be deactivated and neutralized by size-reducing its container, exposure to both air and water (water in air, soil, and from dust suppression), and mixing with soil.

3.2.1.4 Pyrophoric. 10 CFR 61.2 defines a pyrophoric material as:

> " ... any solid material, other than one classed as an explosive, which under normal conditions is liable to cause fires through friction, retained heat from manufacturing or processing, or which can be ignited readily and when ignited bums so vigorously and persistently as to create a serious transportation, handling, or disposal hazard. Included are spontaneously combustible and water-reactive materials."

If present, pyrophoric materials are likely to be in extremely small quantities as most of that waste was packaged in drums and suspended in oils/emulsions and buried in the trenches. Pyrophoric materials such as zirconium or depleted uranium fines and/or turnings would be stable due to mixing with interstitial soil, gravel, or concrete. NaK and potassium superoxide, if present and unreacted, will be deactivated by size-reducing its container, exposure to both air and water (water in air, soil, and from dust suppression), and mixing with soil. Radioactive pyrophoric materials are expected to be present in residual amounts (<1% by weight) due to the mixing of the soils in the processed form. The TRU wastes will receive additional screening prior to packaging.

3.2.2 Toxicity Characteristic

Tables 3-2 and 3-3 summarize the total metals and TCLP for the COCs identified in Table 2-1. Lead is the only COC that exceeds the toxicity characteristic concentration limit based on the total metals 90% UCL converted to TCLP; 551.07 mg/kg ÷ 20 = 27.55 mg/L. While the lead TCLP value is below the toxicity characteristic limit, the D008 waste code will be conservatively applied based on the total metal determination.

The treatment standards for wastes that exhibit or are expected to exhibit the toxicity characteristic for lead is 0.75 mg/L and meet the 40 CFR 268.48 standards for UHCs. Based on Table 3-3, all UHCs are below their respective universal treatment standard limit; no UHCs apply and the only treatment required for land disposal is for the stabilization of lead.

The *Treatment Plan and Protocol for Treatment of Lead-Contaminated Soils* (WCH-252) is an EPA-approved treatment plan for the stabilization of lead-contaminated soils at ERDF. In WCH-125 Table 1 the results of bench scaling testing and the associated concentrations/reductions factors based on the mixture ratios tested are shown. Mixture 1 and 2 are based on lead-contaminated soils with a total metals concentration of 2,136 mg/kg (30.6 mg/L). Mixture 3 is based on a TCLP of 53 mg/L (1.7 times greater than expected for the VPUs). Lead-contaminated soil from the VPUs, 551.07 mg/kg, is easily bounded by the Mixture 1 and 2 test cases and would meet the reduction needed to meet the treatment standard for land disposal. It should be noted that Mixtures 1 and 2 are based on the 618-7 Burial Ground, Sample #J169C7. The 618-7 Burial Ground accounted for the majority of lead values >1,000 mg/kg.

An onsite "cold" test will be performed on a full-scale mocked up VPU to demonstrate the VPU matrix can be adequately stabilized to meet the treatment standard for macroencapsulation. Additionally, elemental lead, simulating lead "pigs", will be added to the mocked up VPU prior to drill/augering. The resultant encapsulated mass will be visually examined and tested for lead (TCLP) to demonstrate the lead treatment standard is met.

3.3 POLYCHLORINATED BIPHENYLS

Waste containing polychlorinated biphenyl (PCB) concentrations of greater than 50 parts per million (ppm) shall be managed in accordance with 40 CFR 761.

Segregation of PCBs did not begin until sometime after the VPUs were in operation; however, PCBs in the form of ballasts, transformers, capacitors, etc. are not expected to be associated with the disposal of high dose wastes, but more likely would be found in the general waste trenches. Multiple documents address the disposal of "water-insoluble oily waste solutions" and given the time-frame and the application, these solutions may be a source of PCBs but it is not likely that they would be disposed of in large quantities. PCBs are not expected to be present in concentrations any greater than seen in any of all 618 Burial Grounds.

Table 3-5 provides a summary of PCB samples taken in all 618 Burial Grounds. Several samples were excluded since they were not representative of the waste matrix - J10WB3 (618-2 oil drum liquid sample), J10WB5 (618-2 oil drum liquid sample), and J16M66 (618-7 smashed oil drum sample). While not shown in Table 3-5, the values are driven by the 618-4 and 618-7 Burial Grounds, where numerous chip/oil drums were found. Individual samples rarely have all forms present at the same time since they have differing carbon and chlorine percentages.

PCBs, if present, will be nonliquid and present in low concentrations <500 ppm.

Table 3-5. Summary of 618 Burial Ground Polychlorinated Biphenyls.

Contaminant of Concern		Units RPTD Values µg/kg				90% UCL - Aroclor	
CAS	Name	Maximum	Average	Standard Deviation	Count	µg/kg	ppm
11096-82-5	Aroclor-1260	8,000,000	23,664.71	422,835.47	357	60,474.61	60.47
11097-69-1	Aroclor-1254	42,000,000	122,857.45	2,220,485.16	357	316,161.53	316.16
11104-28-2	Aroclor-1221	16,000,000	46,158.95	845,601.05	357	119,772.65	119.77
11141-16-5	Aroclor-1232	8,000,000	23,493.97	422,841.57	357	60,304.39	60.30
12672-29-6	Aroclor-1248	8,000,000	26,489.32	425,725.95	357	63,550.84	63.55
12674-11-2	Aroclor-1016	8,000,000	23,494.45	422,841.54	357	60,304.87	60.30
53469-21-9	Aroclor-1242	8,000,000	23,503.19	422,841.07	357	60,313.57	60.31

CAS = Chemical Abstract Services
RPTD = reported
UCL = upper confidence limit

4.0 RADIOACTIVE WASTES

4.1 VPU SOURCE TERM METHODOLOGY – DOCUMENTED SAFETY BASIS

The radioactive source term associated 618-10 and 618-11 Burial Grounds was calculated by identifying the individual waste items disposed, determining the waste stream(s) within each waste item, calculating the mass of each waste stream within each waste item, calculating the isotope activities within each waste item, and then summing the isotopic activities.

The calculation proceeded in six distinct phases:

- Reference review
- Fundamental data
- Waste stream calculations
- Dose rate to waste mass calculations
- Waste mass to isotope activity calculations
- Threshold quantity (TQ) calculations.

The reference review phase included obtaining and archiving the references applicable to the 618-10 and -11 Burial Grounds, extraction of key information from each reference, and entry of the information in a specially designed Microsoft Access Waste Items database.

The fundamental data phase included developing the physical constants, atomic and elemental masses, specific activities, and material densities required by the subsequent phases.

The waste stream calculations phase included developing those characteristics of the radioactive waste streams needed to input the remaining phases. Activities per gram calculations were performed using Oak Ridge National Laboratory ORIGEN2 software. Test specimens were modeled using N Reactor characterization data.

The dose rate to waste mass calculations phase converted dose rate measurements associated with certain waste items into the mass of a particular waste stream responsible for the measured dose rate. The conversion process made use of the characteristics of the radioactive waste stream within the waste item, the physical configuration of the waste item at the time of the dose rate measurement, and the matrix of the waste within the waste item. These factors were combined to generate a dose rate per gram waste versus distance curve for each unique situation. The curves were used to interpolate the dose rate from a gram of waste at the appropriate distance. The measured dose rate divided by the dose rate per gram then represents the mass of waste in the waste item. Dose rate per gram conversion factors were calculated using Los Alamos National Laboratory MCNP computer code. Dividing the dose rate measurements by the appropriate conversion factors was performed using a modified version of the Waste Items database.

The waste mass to isotope activity calculations phase converted waste mass values into isotope activities. Waste mass values were either entered during the reference review phase as waste entries, or calculated as part of the dose rate to waste mass calculations phase. The mass of each waste stream within a waste item was multiplied by a vector of isotope activities per gram from the waste stream calculations phase.

The TQ calculations phase converted a vector of isotope activities into a single TQ value that is used to determine the category of a facility. The TQ calculations were performed on both a waste item and an entire trench basis.

4.1.1 618-10 VPU Inventory

The total radionuclide inventory for the 618-10 VPUs is found in *Radiological Inventory in the 618-10 Burial Ground* in Table 16 (0600X-CA-N0083). The inventory was calculated using an SQL query of the Waste Items database and represents the total inventory for all 618-10 VPUs. This inventory is used in the project documented safety analysis and provides isotopic scaling factors for use in preliminary dose modeling, waste classification, and transportation calculations.

Appendix A contains copy of Table 16 inventory.

4.1.2 618-11 VPU Inventory

The total radionuclide inventory for the 618-11 VPUs is found in *Radioactive Inventory in the 618-11 Burial Ground* in Table 18 (0600X-CA-N0079). The inventory was calculated using an SQL query of the Waste Items database and represents the total inventory for all 618-11 VPUs. This inventory is used in the project documented safety analysis and provides isotopic scaling factors for use in preliminary dose modeling, waste classification, and transportation calculations.

Appendix B contains copy of Table 18 inventory.

4.2 VPU NONINTRUSIVE CHARACTERIZATION

The scope of the 618-10 and 618-11 nonintrusive characterization (NIC) is described in DOE/RL-2008-27. For the purposes of the SAP, NIC is defined as activities that can be performed without removing materials from inside the 618-10 and -11 VPUs or trenches. Characterization results were obtained using an in situ radiological multidetector probe (MDP). The MDP system was configured with five standard commercial radiation detectors including a gross rate meter, two gamma spectroscopy detectors, two neutron detectors, and associated vendor software. The detectors were configured to meet the SAP requirements. The MDP was designed to be deployed in a cone penetrometer.

At the 618-10 Burial Ground, four cone penetrometers were installed approximately 15.2 cm (6 in.) from the outer edge and equally spaced around the perimeter of the VPU with the penetrometers extending to a depth of 0.6 m (2 ft) below the VPU. Of the five detectors present in the MDP, the majority of the data captured was gross gamma from the AMP-100 GM detector. Due to the lack of isotopic speciation and density compensation in the NIC data, the gross gamma data provides only an estimate of relative dose rates and the vertical proximity of radiological "hot spots."

At the 618-11 Burial Ground, the SAP required only the collection and analysis of gross gamma data acquired by the MDP system through two cone penetrometers installed at each VPU location. The cone penetrometers were installed approximately 15.2 cm (6 in.) from the outer edge and nominally 180 degrees apart (on opposite sides) of each VPU. The cone penetrometers extend to a depth of 0.6 m (2 ft) below the VPU.

The cone penetrometer data will be used to rank order VPUs based on their average measured dose rates. The ranking will guide the selection of VPUs selected for further sampling and assaying.

4.3 TRU DETERMINATION AND WASTE CLASSIFICATION

During discussions with DOE and EPA, the following methodology was agreed upon for determining the VPU TRU concentration and waste classification:

- Rank the VPUs using an analysis of the NIC data collected and the inventories developed for both the 618-10 and 618-11 Burial Grounds.
- Based on the ranking, select two consecutively-ranked VPUs to sample and perform nondestructive assay (NDA) using the Waste Receiving and Processing Facility (WRAP) assay equipment (SGS - Segmented Gamma Scanner [GEA – Gamma Energy Assay] and IPAN – Imaging Passive/Active Neutron Assay).
- Evaluate the results and determine if each VPU meets the ERDF WAC (pass) or does not (fail). The possibilities for the two consecutively-ranked VPUs are pass/pass, pass/fail, fail/pass, or fail/fail.
- At the ranking point where two consecutively-ranked VPUs pass, then subsequent lower-ranked VPUs are, thereby, determined to all pass and do not require sampling.
- If at least one of the two consecutively-ranked VPUs fails, then VPUs above that ranking point would be considered to fail unless specifically sampled.
- A minimum of four VPUs will be sampled.

The data quality objective (DQO) process will be used to document and finalize the radiological characterization process for determining whether the VPUs meet the low level radioactive waste criteria and can be disposed at the ERDF. Those VPUs not meeting the ERDF criteria will be processed as TRU for storage at CWC.

4.4 WASTE TRANSPORTATION

All VPU samples and waste streams will be packaged and shipped in accordance with Department of Transportation and/or DOE/RL-2001-36, *Hanford Site Transportation Safety Document,* requirements.

4.5 SPENT NUCLEAR FUEL

WCH-466, *Spent Nuclear Fuel and Remediation of the 618-10 and 618-11 Burial Grounds*, provides the following conclusion on spent nuclear fuel:

> Wastes from examination of fuel specimens and other laboratory activities conducted in the 300 Area were disposed in the 618-10 and 618-11 Burial Grounds. Unlike 100-Area burial

grounds where SNF may have been accidently disposed with irradiated spacers and other reactor hardware, the fuel elements sent to 300 Area laboratory facilities were first processed into specimens for examination. Metals and collected fines from the cutting operations were disposed in the burial grounds as laboratory wastes. When laboratory examination was complete, the fuel elements and any remaining fuel specimens were returned to process in the 200 Area. Elements and specimens of fuels received from other DOE laboratories were returned to the sender. In some cases, trace fuel samples considered valuable for future reference were retained in the 300 Area laboratories until dispositioned to Treatment, Storage and Disposal Facilities as legacy waste in the 1990s.

Consequently, there is a very low potential to exhume discrete, identifiable, and separable SSNF items in the 618-10 and 618-11 Burial Grounds. The technology being developed for retrieval of waste contained in VPUs will further reduce the likelihood of finding SSNF. Nonetheless, WCH will continue to employ the observational approach and anomalous item investigations where practicable during waste handling activities. These methods have been in use for years and are considered adequate for the identification of SSNF items during 618-10 and 11 remediation operations. Any suspect items that might be discovered will be handled, secured, transported and ultimately disposed using existing processes that have been proven to be safe and compliant.

The DOE, as the lead regulatory agency for the project, will provide a letter to EPA stating SNF is not present in the VPU waste streams.

4.6 DISPOSAL PATH

The extraction method is dependent on the radiological classification of the waste as MLLW or suspect TRU based on the radiological characterization DQO. Mixed low-level waste will be stabilized and macroencapsulated for disposal at ERDF. The final transportation form is still to be determined but may include monoliths, containerization, and/or mass excavation with shipments of bulk material in roll-off containers. The suspect TRU waste will be characterized and packaged for acceptance and storage at CWC in accordance with HNF-EP-0063, Hanford Site Solid Waste Acceptance Criteria.

No prohibited items have been identified in accordance with WCH-191, *ERDF Waste Acceptance Criteria*, or HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, at this time.

5.0 CONCLUSION

The VPUs were primarily filled with debris; however, soil, gravel, and concrete were added to stabilize and reduce personnel exposure. The final processed form will be a solid soil matrix with debris present at between 25% and 40%. The overcasing contents, having been shredded, ground, and mixed by the drill/auger, will be relatively uniform with good horizontal and some vertical mixing. The consistency and particle/debris size will be relatively uniform but will be determined by the final drill/auger selected in the design process.

Liquids, acids, and reactives present will be stabilized/deactivated in the remediation process. The drill/auger will open all containers in the matrix and render them nonintact and reduce their volume significantly. Liquids and acids, if present, will be absorbed and mixed into the soil matrix. Reactives and corrosives, if present, will be reacted and neutralized during the drill/augering process through mechanical means (heat and shock) and the addition of water (air, soil, and dust suppression).

No listed wastes codes are identified and the waste stream exceeds the toxicity characteristic limit for lead. Mixed low-level waste must be treated to meet the concentration-based standard for lead for ERDF disposal. WCH-252 bounds the lead concentration expected in the VPU wastes and the wastes can be stabilized using the mixture specified in the treatment plan. The suspect TRU waste stream is acceptable for storage at CWC in its processed form.

6.0 REFERENCES

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APPENDIX A

618-10 VPU Inventory

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator	W. Josephson	Date	01/25/2012	Calc. No.	0600X-CA-N0083	Rev. No.	0
Project	FR	Job No.	14655	Checked	J. Tang	Date	01/25/2012
Subject	Radiological Inventory in the 618-10 Vertical Pipe Units					Sheet No.	64 of 70

9.0 Summary

The characteristics of the 618-10 VPUs were calculated by executing the SQL queries discussed in previous sections. The isotope activities and masses were calculated by executing DisposerInvQry in Section 7.0, and the TQ fractions were calculated by executing DisposerCat3TQQry and DisposerCat2 TQQry in Section 8.3. The results from executing these queries are summarized Table 16. These results were calculated with the Waste Items Database time stamped 01/16/2012 09:09:33.

Table 16. 618-10 VPU Inventory Summary

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
H-3	1.066E+01	1.105E-03	6.665E-04	3.555E-05
Be-10	5.625E-04	2.517E-02	5.409E-06	1.308E-09
C-14	1.456E+02	3.266E+01	3.467E-01	1.040E-04
Cl-36	5.218E-04	1.581E-02	1.535E-06	3.727E-07
Ca-41	2.360E-03	2.191E-02	1.475E-06	5.488E-09
Co-60	1.050E+01	9.281E-03	3.749E-02	5.525E-05
Ni-59	8.799E+00	1.161E+02	7.457E-04	2.046E-05
Ni-63	7.511E+02	1.217E+01	1.391E-01	1.669E-04
Se-79	1.193E-02	1.712E-01	3.315E-05	2.775E-08
Kr-85	1.068E+01	2.721E-02	5.341E-04	3.815E-07
Sr-90	6.758E+02	4.951E+00	4.223E+01	3.072E-02
Y-90	6.761E+02	1.242E-03	4.761E-01	1.572E-03
Zr-93	2.806E+00	1.116E+03	4.525E-02	3.152E-05
Nb-93m	2.477E+00	8.758E-03	1.238E-03	5.760E-06
Nb-94	4.071E-05	2.172E-04	2.036E-07	4.734E-10
Mo-93	1.790E-02	1.629E-02	8.950E-06	4.163E-08
Tc-99	3.994E-01	2.355E+01	2.349E-04	1.051E-07
Pd-107	2.039E-03	3.964E+00	4.856E-07	4.743E-09
Sn-121m	7.124E+00	1.204E-01	4.002E-03	1.657E-05
Sn-126	2.096E-02	7.385E-01	1.233E-04	6.351E-08
Sb-126	2.934E-03	3.508E-08	1.048E-05	1.174E-09
Sb-126m	2.096E-02	2.667E-10	8.732E-07	4.874E-08
I-129	8.604E-04	4.872E+00	1.434E-02	2.001E-09
Cs-134	2.970E-05	2.295E-08	7.071E-07	4.950E-10
Cs-135	1.069E-02	9.284E+00	2.546E-05	2.487E-08
Cs-137	8.782E+02	1.009E+01	1.464E+01	9.868E-03
Ba-137m	8.307E+02	1.544E-06		1.932E-03
Sm-151	2.181E+01	8.288E-01	2.181E-02	2.203E-05
Eu-152	2.374E-02	1.372E-04	1.187E-04	1.826E-07
Eu-154	9.043E-01	3.349E-03	4.521E-03	8.221E-06
Re-187	1.128E-06	2.949E+01	3.318E-12	2.623E-12

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator	W. Josephson	Date	01/25/2012	Calc. No.	0600X-CA-N0083	Rev. No.	0
Project	FR	Job No.	14655	Checked	J. Tang	Date	01/25/2012
Subject	Radiological Inventory in the 618-10 Vertical Pipe Units					Sheet No.	65 of 70

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
Tl-207	3.331E-06	1.748E-14		7.746E-12
Tl-208	4.143E-05	1.406E-13		9.636E-11
Pb-209	8.423E-17	1.853E-23	1.359E-22	1.959E-22
Pb-210	2.948E-07	3.860E-09	8.190E-07	1.340E-10
Pb-211	3.340E-06	1.352E-13	5.387E-10	7.768E-12
Pb-212	1.153E-04	8.298E-11	3.604E-07	2.682E-10
Pb-214	7.784E-07	2.373E-14	9.493E-11	1.810E-12
Bi-210	2.949E-07	2.376E-12	9.215E-10	1.966E-12
Bi-211	3.340E-06	7.981E-15		6.073E-08
Bi-212	1.153E-04	7.873E-12	5.767E-08	2.097E-06
Bi-213	8.423E-17	4.353E-24	2.632E-20	1.531E-18
Bi-214	7.784E-07	1.762E-14	9.493E-11	1.810E-12
Po-210	2.949E-07	6.561E-11	1.552E-07	8.425E-10
Po-211	1.583E-09	1.657E-20		2.878E-11
Po-212	7.390E-05	4.164E-22		1.344E-06
Po-213	8.240E-17	6.529E-33		1.498E-18
Po-214	7.784E-07	2.425E-21		1.415E-08
Po-215	3.340E-06	1.133E-19		6.073E-08
Po-216	1.153E-04	3.311E-16		2.097E-06
Po-218	7.787E-07	2.753E-15		1.416E-08
At-217	8.423E-17	5.232E-29		1.531E-18
Rn-219	3.340E-06	2.567E-16		6.073E-08
Rn-220	1.153E-04	1.250E-13	5.767E-05	2.097E-06
Rn-222	7.787E-07	5.060E-12	7.787E-08	4.867E-15
Fr-221	8.423E-17	4.751E-25		1.531E-18
Fr-223	4.604E-08	1.190E-15	5.615E-12	1.071E-13
Ra-223	3.340E-06	6.520E-11	5.387E-08	8.790E-10
Ra-224	1.153E-04	7.240E-10	5.767E-07	1.165E-08
Ra-225	8.423E-17	2.148E-21	1.170E-18	2.217E-20
Ra-226	7.787E-07	7.873E-07	6.490E-08	1.416E-08
Ac-225	8.423E-17	1.451E-21	2.632E-18	2.904E-20
Ac-227	3.336E-06	4.610E-08	7.943E-05	7.758E-07
Th-227	3.294E-06	1.071E-10	1.029E-07	5.989E-08
Th-228	1.153E-04	1.407E-07	1.153E-04	1.254E-06
Th-229	8.423E-17	3.958E-16	8.961E-16	1.531E-18
Th-230	6.911E-05	3.423E-03	1.115E-04	7.765E-07
Th-231	5.705E-03	1.073E-08	4.754E-07	1.327E-08
Th-234	1.156E-01	4.990E-06	4.129E-05	2.689E-07
Pa-231	6.431E-06	1.361E-04	3.215E-05	1.169E-07
Pa-233	8.640E-03	4.162E-07	1.878E-06	2.009E-08

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator	W. Josephson	**Date**	01/25/2012	**Calc. No.**	0600X-CA-N0083	**Rev. No.**	0
Project	FR	**Job No.**	14655	**Checked**	J. Tang	**Date**	01/25/2012
Subject	Radiological Inventory in the 618-10 Vertical Pipe Units					**Sheet No.**	66 of 70

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
Pa-234	1.503E-04	7.515E-11	9.888E-08	3.495E-10
Pa-234m	1.156E-01	1.683E-10		2.689E-07
U-232	1.123E-04	5.243E-06	1.369E-04	2.041E-06
U-233	2.270E-06	2.344E-04	5.405E-07	1.032E-08
U-234	1.470E-01	2.352E+01	3.500E-02	6.682E-04
U-235	5.705E-03	2.639E+03	1.358E-03	2.377E-05
U-236	1.983E-02	3.063E+02	4.721E-03	3.605E-04
U-237	4.222E-03	5.170E-08	2.932E-07	9.818E-09
U-238	1.156E-01	3.438E+05	2.753E-02	4.817E-04
U-240	6.760E-15	7.296E-21	4.829E-20	1.572E-20
Np-237	8.640E-03	1.225E+01	2.057E-02	1.490E-04
Np-238	6.611E-05	2.550E-10	5.085E-08	7.265E-11
Np-239	7.683E-03	3.310E-08	9.850E-07	1.787E-08
Np-240m	6.760E-15	6.383E-23		1.572E-20
Pu-238	9.603E+00	5.606E-01	1.549E+01	1.549E-01
Pu-239	3.799E+01	6.108E+02	7.305E+01	6.783E-01
Pu-240	1.824E+01	8.000E+01	3.508E+01	3.257E-01
Pu-241	1.720E+02	1.669E+00	5.376E+00	5.932E-02
Pu-242	4.863E-03	1.273E+00	7.844E-03	8.242E-05
Am-241	6.073E+01	1.769E+01	1.168E+02	1.104E+00
Am-242	1.315E-02	1.626E-08	1.604E-06	3.059E-08
Am-242m	1.322E-02	1.360E-03	2.542E-02	2.360E-04
Am-243	7.683E-03	3.853E-02	1.477E-02	1.397E-04
Cm-242	1.088E-02	3.289E-06	3.400E-04	6.399E-06
Cm-243	1.330E-03	2.575E-05	1.622E-03	2.418E-05
Cm-244	2.002E-02	2.473E-04	1.925E-02	3.639E-04
Cm-245	2.746E-06	1.598E-05	5.280E-06	5.180E-08
Cm-246	7.656E-08	2.491E-07	1.472E-07	1.392E-09
Total	4.333E+03	3.489E+05	3.039E+02	2.370E+00

APPENDIX B

618-11 VPU Inventory

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator	W. Josephson	Date	09/28/2011	Calc. No.	0600X-CA-N0079	Rev. No.	0
Project	FR	Job No.	14655	Checked	J. Tang	Date	09/28/2011
Subject	Radiological Inventory in the 618-11 Burial Grounds					Sheet No.	84 of 96

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
Th-232	1.293E-01	1.179E+06	1.293E+00	7.183E-03
Th-234	6.119E-02	2.641E-06	2.185E-05	1.423E-07
Pa-231	1.682E-06	3.559E-05	8.409E-06	3.058E-08
Pa-233	2.719E-04	1.310E-08	5.911E-08	6.324E-10
Pa-234	7.954E-05	3.977E-11	5.233E-08	1.850E-10
Pa-234m	6.119E-02	8.905E-11		1.423E-07
U-232	3.616E-06	1.689E-07	4.409E-06	6.574E-08
U-233	7.110E-08	7.342E-06	1.693E-08	3.232E-10
U-234	2.839E-02	4.542E+00	6.760E-03	1.291E-04
U-235	1.527E-03	7.063E+02	3.636E-04	6.362E-06
U-236	5.987E-04	9.250E+00	1.425E-04	1.088E-05
U-237	1.378E-04	1.688E-09	9.571E-09	3.205E-10
U-238	6.119E-02	1.819E+05	1.457E-02	2.549E-04
U-240	2.227E-16	2.404E-22	1.591E-21	5.179E-22
Np-237	2.719E-04	3.856E-01	6.474E-04	4.688E-06
Np-238	2.106E-06	8.123E-12	1.620E-09	2.315E-12
Np-239	2.450E-04	1.055E-09	3.140E-08	5.697E-10
Np-240m	2.227E-16	2.103E-24		5.179E-22
Pu-238	5.355E-01	3.126E-02	8.637E-01	8.637E-03
Pu-239	1.204E+00	1.936E+01	2.316E+00	2.150E-02
Pu-240	5.899E-01	2.587E+00	1.134E+00	1.053E-02
Pu-241	5.617E+00	5.448E-02	1.755E-01	1.937E-03
Pu-242	1.598E-04	4.183E-02	2.577E-04	2.708E-06
Am-241	1.981E+00	5.770E-01	3.809E+00	3.602E-02
Am-242	4.191E-04	5.182E-10	5.111E-08	9.746E-10
Am-242m	4.212E-04	4.332E-05	8.099E-04	7.521E-06
Am-243	2.450E-04	1.228E-03	4.711E-04	4.454E-06
Cm-242	3.466E-04	1.048E-07	1.083E-05	2.039E-07
Cm-243	4.243E-05	8.217E-07	5.175E-05	7.715E-07
Cm-244	6.388E-04	7.892E-06	6.142E-04	1.161E-05
Cm-245	8.765E-08	5.102E-07	1.685E-07	1.654E-09
Cm-246	2.445E-09	7.955E-09	4.701E-09	4.445E-11
Total	1.978E+02	1.361E+06	1.210E+01	9.794E-02

Table 18. 618-11 VPU Inventory Summary

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
H-3	4.933E+00	5.109E-04	3.083E-04	1.644E-05
Be-10	2.492E-04	1.115E-02	2.396E-06	5.796E-10

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator	W. Josephson	**Date**	09/28/2011	**Calc. No.**	0600X-CA-N0079	**Rev. No.**	0
Project	FR	**Job No.**	14655	**Checked**	J. Tang	**Date**	09/28/2011
Subject	Radiological Inventory in the 618-11 Burial Grounds					**Sheet No.**	85 of 96

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
C-14	6.449E+01	1.446E+01	1.535E-01	4.606E-05
Co-60	4.650E+00	4.112E-03	1.661E-02	2.448E-05
Ni-59	3.898E+00	5.145E+01	3.304E-04	9.066E-06
Ni-63	3.328E+02	5.393E+00	6.163E-02	7.395E-05
Se-79	8.601E-03	1.234E-01	2.389E-05	2.000E-08
Kr-85	7.687E+00	1.959E-02	3.844E-04	2.745E-07
Sr-90	4.863E+02	3.563E+00	3.039E+01	2.210E-02
Y-90	4.865E+02	8.938E-04	3.426E-01	1.131E-03
Zr-93	1.258E+00	5.004E+02	2.029E-02	1.414E-05
Nb-93m	1.111E+00	3.927E-03	5.553E-04	2.583E-06
Nb-94	1.501E-05	8.011E-05	7.506E-08	1.746E-10
Mo-93	7.931E-03	7.216E-03	3.965E-06	1.844E-08
Tc-99	2.877E-01	1.696E+01	1.692E-04	7.571E-08
Pd-107	1.482E-03	2.881E+00	3.529E-07	3.447E-09
Sn-121m	3.157E+00	5.337E-02	1.774E-03	7.341E-06
Sn-126	1.514E-02	5.336E-01	8.908E-05	4.589E-08
Sb-126	2.120E-03	2.535E-08	7.572E-06	8.480E-10
Sb-126m	1.514E-02	1.927E-10	6.310E-07	3.522E-08
I-129	6.215E-04	3.519E+00	1.036E-02	1.445E-09
Cs-134	2.173E-05	1.679E-08	5.174E-07	3.622E-10
Cs-135	7.711E-03	6.693E+00	1.836E-05	1.793E-08
Cs-137	6.333E+02	7.277E+00	1.055E+01	7.115E-03
Ba-137m	5.990E+02	1.113E-06		1.393E-03
Sm-151	1.554E+01	5.903E-01	1.554E-02	1.569E-05
Eu-152	1.727E-02	9.981E-05	8.634E-05	1.328E-07
Eu-154	6.618E-01	2.451E-03	3.309E-03	6.016E-06
Re-187	4.997E-07	1.306E+01	1.470E-12	1.162E-12
Tl-207	2.052E-06	1.077E-14		4.772E-12
Tl-208	2.968E-05	1.007E-13		6.902E-11
Pb-209	3.101E-12	6.822E-19	5.002E-18	7.212E-18
Pb-210	1.853E-07	2.425E-09	5.146E-07	8.421E-11
Pb-211	2.058E-06	8.331E-14	3.319E-10	4.785E-12
Pb-212	8.261E-05	5.943E-11	2.582E-07	1.921E-10
Pb-214	4.881E-07	1.488E-14	5.953E-11	1.135E-12
Bi-210	1.853E-07	1.493E-12	5.790E-10	1.235E-12
Bi-211	2.058E-06	4.917E-15		3.741E-08
Bi-212	8.261E-05	5.639E-12	4.131E-08	1.502E-06
Bi-213	3.101E-12	1.603E-19	9.691E-16	5.638E-14
Bi-214	4.881E-07	1.105E-14	5.953E-11	1.135E-12
Po-210	1.853E-07	4.123E-11	9.752E-08	5.294E-10

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator W. Josephson **Date** 09/28/2011 **Calc. No.** 0600X-CA-N0079 **Rev. No.** 0

Project FR **Job No.** 14655 **Checked** J. Tang **Date** 09/28/2011

Subject Radiological Inventory in the 618-11 Burial Grounds **Sheet No.** 86 of 96

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
Po-211	2.256E-11	2.362E-22		4.101E-13
Po-212	5.293E-05	2.982E-22		9.624E-07
Po-213	3.034E-12	2.404E-28		5.516E-14
Po-214	4.881E-07	1.521E-21		8.875E-09
Po-215	2.058E-06	6.978E-20		3.741E-08
Po-216	8.261E-05	2.372E-16		1.502E-06
Po-218	4.883E-07	1.726E-15		8.879E-09
At-217	3.101E-12	1.926E-24		5.638E-14
Rn-219	2.058E-06	1.582E-16		3.741E-08
Rn-220	8.261E-05	8.953E-14	4.131E-05	1.502E-06
Rn-222	4.883E-07	3.173E-12	4.883E-08	3.052E-15
Fr-221	3.101E-12	1.749E-20		5.638E-14
Fr-223	2.837E-08	7.332E-16	3.460E-12	6.597E-14
Ra-223	2.058E-06	4.017E-11	3.319E-08	5.415E-10
Ra-224	8.261E-05	5.186E-10	4.131E-07	8.345E-09
Ra-225	3.101E-12	7.907E-17	4.307E-14	8.161E-16
Ra-226	4.883E-07	4.937E-07	4.070E-08	8.879E-09
Ac-225	3.101E-12	5.341E-17	9.691E-14	1.069E-15
Ac-227	2.055E-06	2.841E-08	4.894E-05	4.780E-07
Th-227	2.029E-06	6.600E-11	6.342E-08	3.690E-08
Th-228	8.261E-05	1.007E-07	8.261E-05	8.979E-07
Th-229	3.101E-12	1.457E-11	3.299E-11	5.638E-14
Th-230	4.321E-05	2.140E-03	6.970E-05	4.855E-07
Th-231	3.479E-03	6.542E-09	2.899E-07	8.091E-09
Th-234	7.246E-02	3.127E-06	2.588E-05	1.685E-07
Pa-231	3.947E-06	8.354E-05	1.974E-05	7.177E-08
Pa-233	5.990E-03	2.885E-07	1.302E-06	1.393E-08
Pa-234	9.419E-05	4.710E-11	6.197E-08	2.191E-10
Pa-234m	7.246E-02	1.055E-10		1.685E-07
U-232	8.041E-05	3.755E-06	9.805E-05	1.462E-06
U-233	1.567E-06	1.619E-04	3.732E-07	7.125E-09
U-234	9.170E-02	1.467E+01	2.183E-02	4.168E-04
U-235	3.479E-03	1.609E+03	8.284E-04	1.450E-05
U-236	1.291E-02	1.995E+02	3.074E-03	2.347E-04
U-237	3.051E-03	3.736E-08	2.119E-07	7.095E-09
U-238	7.246E-02	2.155E+05	1.725E-02	3.019E-04
U-240	4.979E-15	5.374E-21	3.556E-20	1.158E-20
Np-237	5.990E-03	8.494E+00	1.426E-02	1.033E-04
Np-238	4.861E-05	1.875E-10	3.739E-08	5.342E-11
Np-239	5.658E-03	2.438E-08	7.254E-07	1.316E-08

Washington Closure
Hanford LLC

CALCULATION SHEET

Originator	W. Josephson	**Date**	09/28/2011	**Calc. No.**	0600X-CA-N0079	**Rev. No.**	0
Project	FR	**Job No.**	14655	**Checked**	J. Tang	**Date**	09/28/2011
Subject	Radiological Inventory in the 618-11 Burial Grounds					**Sheet No.**	87 of 96

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
Np-240m	4.979E-15	4.701E-23		1.158E-20
Pu-238	6.911E+00	4.035E-01	1.115E+01	1.115E-01
Pu-239	2.573E+01	4.137E+02	4.947E+01	4.594E-01
Pu-240	1.292E+01	5.665E+01	2.484E+01	2.307E-01
Pu-241	1.243E+02	1.206E+00	3.885E+00	4.287E-02
Pu-242	3.562E-03	9.324E-01	5.745E-03	6.037E-05
Am-241	4.389E+01	1.279E+01	8.441E+01	7.981E-01
Am-242	9.672E-03	1.196E-08	1.179E-06	2.249E-08
Am-242m	9.720E-03	9.998E-04	1.869E-02	1.736E-04
Am-243	5.658E-03	2.837E-02	1.088E-02	1.029E-04
Cm-242	7.999E-03	2.418E-06	2.500E-04	4.705E-06
Cm-243	9.811E-04	1.900E-05	1.197E-03	1.784E-05
Cm-244	1.477E-02	1.825E-04	1.420E-02	2.686E-04
Cm-245	2.027E-06	1.180E-05	3.899E-06	3.825E-08
Cm-246	5.656E-08	1.840E-07	1.088E-07	1.028E-09
Total	2.860E+03	2.184E+05	2.154E+02	1.676E+00

Table 19. 618-11 Caisson Inventory Summary

Isotope	Activity (Ci)	Mass (g)	Cat 3 TQ Fraction	Cat 2 TQ Fraction
H-3	4.806E+00	4.978E-04	3.004E-04	1.602E-05
Be-10	1.866E-05	8.347E-04	1.794E-07	4.339E-11
C-14	4.979E+00	1.117E+00	1.185E-02	3.556E-06
Co-60	3.475E-01	3.073E-04	1.241E-03	1.829E-06
Ni-59	2.916E-01	3.849E+00	2.471E-05	6.782E-07
Ni-63	2.491E+01	4.037E-01	4.613E-03	5.536E-06
Se-79	6.333E-02	9.087E-01	1.759E-04	1.473E-07
Kr-85	5.822E+01	1.483E-01	2.911E-03	2.079E-06
Sr-90	3.689E+03	2.702E+01	2.305E+02	1.677E-01
Y-90	3.690E+03	6.779E-03	2.599E+00	8.581E-03
Zr-93	3.822E-01	1.520E+02	6.164E-03	4.294E-06
Nb-93m	3.375E-01	1.194E-03	1.688E-04	7.849E-07
Nb-94	3.718E-05	1.984E-04	1.859E-07	4.323E-10
Mo-93	5.937E-04	5.402E-04	2.969E-07	1.381E-09
Tc-99	2.110E+00	1.244E+02	1.241E-03	5.554E-07
Pd-107	9.300E-03	1.808E+01	2.214E-06	2.163E-08
Sn-121m	2.470E-01	4.175E-03	1.387E-04	5.743E-07
Sn-126	1.066E-01	3.756E+00	6.270E-04	3.230E-07
Sb-126	1.492E-02	1.784E-07	5.330E-05	5.969E-09

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