HNF-20503
Revision 3

Tank 241-Z-361 Documented Safety Analysis

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

CH2MHILL
Plateau Remediation Company

P.O. Box 1600
Richland, Washington 99352

Approved for Public Release;
Further Dissemination Unlimited

HNF-20503
Revision 3
EDC#: ECR-18-000591

Tank 241-Z-361 Documented Safety Analysis

Document Type: DSA Program/Project: CPRM

M. A. Waller
CH2M HILL Plateau Remediation Company

Date Published
March 2019

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

CH2MHILL
Plateau Remediation Company
P.O. Box 1600
Richland, Washington 99352

APPROVED
By Julia Raymer at 4:02 pm, Mar 19, 2019

DATE:
Mar 21, 2019
HANFORD RELEASE

Release Approval Date Release Stamp

Approved for Public Release;
Further Dissemination Unlimited

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

Total pages: 108

CHPRC RECORD OF REVISION (ROR)	(1) Document Number HNF-20503
(2) Title Tank 241-Z-361 Documented Safety Analysis	

Change Control Record

(3) Revision	(4) Description of Change – Replace, Add, and Delete Pages ADD ROW	Authorized for Release (5) DA/TA Date
0	Initial Release per HNF-EDC-03-16685	B.E.Hey
0A	Page change per HNF-EDC-06-29026. Minor editorial and consistency changes, reference updates, and clarifications for annual updates. Editiorial changes are not identified with change bar/track change.	B.E.Hey
0B	Annual Update per HNF-EDC-07-33711.	B.E.Hey
1	Annual Update per PRC-EDC-09-41732.	B.E.Hey
2	Annual Update per ECR-15-001047.	M.A.Waller 8/16/15
RS 3	Annual Update per ECR-18-000591.	M.A.Waller 3/11/19

HNF-20503, Rev. 3

Tank 241-Z-361 Documented Safety Analysis

Prepared by:

CH2M HILL Plateau Remediation Company
Richland, Washington

September 2018

This page intentionally left blank.

Executive Summary

ES.1 Facility Background and Mission

The Plutonium Finishing Plant (PFP) was built in 1948 and began processing plutonium in mid-1949 with Tank 241-Z-361 as part of the low salt waste disposal path from all PFP processes, including the incinerator, the Plutonium Reclamation Facility, and the Waste Treatment Facility. If the plutonium content was analyzed to be more than 10 g per batch, generally the batch was reprocessed. Below the plutonium discard limit, caustic was added and the material was sent to the cribs via Tank 241-Z-361, where solids settled out and the liquid overflowed by gravity to the cribs. Accordingly, the materials discharged via Tank 241-Z-361 would have been expected to be low in plutonium concentration. In addition to drain lines, a large un-quantified amount of process water was discharged from the retention basins to the cribs through Tank 241-Z-361.

Tank 241-Z-361 is shut down and isolated in Surveillance and Maintenance (S&M) mode, and no process operations are occurring or planned. However, it is expected that additional characterization activities may be required in the future, as Tank 241-Z-361 remediation plans are finalized.

ES.2 Facility Overview

The Tank 241-Z-361 is located approximately 36 km (22 mi) north-northwest of Richland, Washington, in the 200 West Area of the Hanford Site near PFP. Highway 240 is to the southwest of Tank 241-Z-361, and the Columbia River is north-northeast. Public access to the Hanford Site is currently restricted and controlled at the Wye Barricade on Route 4 and the Yakima and Rattlesnake Barricades on State Highway 240. Unauthorized access to the Tank 241-Z-361 is prohibited.

The interior dimensions of the tank are 7.93 m (26 ft) long, 3.96 m (13 ft) wide, and from 5.2 m (17 ft) deep at the inlet (north end) to 5.49 m (18 ft) deep at the outlet (south end). The base mat is 22.9 cm (9 in.) thick with grout and waterproofing added for a total thickness of 30.5 cm (12 in.). All walls are 30.5 cm (12 in.) thick and the roof is 25.4 cm (10 in.) thick. The top of the tank was sealed with 0.64-cm (0.25-in.) mastic and approximately 10.2 cm (4 in.) of concrete was poured over the mastic with 5.1-cm by 5.1-cm (2-in. by 2-in.) 14-gauge reinforcement mesh.

The tank structure is not "airtight"; the tank is nearly 70 years old and has small cracks in it which allow the tank to atmospherically breathe. A passive high-efficiency particulate air (HEPA) filter vent was attached to one of the 7.6-cm (3-in.) riser pipes on Tank 241-Z-361 to ensure that the tank would not become pressurized during the Justification for Continued Operations (JCO) activities. The HEPA filter vent was left after JCO activities were completed.

Tank 241-Z-361 has no local fire protection system.

The process inlet and outlet pipes attached to Tank 241-Z-361 have been isolated and plugged or flanged at a distance of 0.61 m (2 ft) from the outer wall of the tank. The tank has no electrical utilities attached. The tank filtered ventilation system is passive.

ES.3 Facility Hazard Categorization

Tank 241-Z-361 is a Hazard Category 2 nuclear facility.

ES.4 Safety Analysis Overview

Tank 241-Z-361 is shut down and isolated in S&M mode, and no process operations are occurring or planned. The activities analyzed here for Tank 241-Z-361 include the ongoing storage of tank contents, S&M, and limited characterization of tank contents in support of the final tank cleanup and future area restoration projects.

The significant hazards associated with Tank 241-Z-361 are a tank collapse, tank pool fire, and a beyond design basis earthquake. The consequences for the tank collapse and pool fire scenarios do not reach the consequence thresholds used in the hazards analysis.

The Technical Safety Requirement (TSR) controls include: Material Management (SAC 5.6.1), Safety Management Programs (AC 5.5.1), Nuclear Criticality Safety (AC 5.7.1), Vehicle Access Control (AC 5.7.2), and Excavation & Sampling (AC 5.7.3).

ES.5 Organizations

The contractor responsible for maintenance of Tank 241-Z-361 and development of this Documented Safety Analysis (DSA) is CH2M HILL Plateau Remediation Company (CHPRC).

ES.6 Safety Analysis Conclusions

The Tank 241-Z-361 safety basis is appropriate and no issues have been identified that are significant to the Tank 241-Z-361 safety basis.

ES.7 DSA Organization

This DSA complies with the 2016 revision of DOE-STD-1120, *Preparation of Documented Safety Analysis for Decommissioning and Environmental Restoration Activities*, supplemented with DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*.

Contents

Appendices

Figures

Tables

Terms

AA	Accident Analysis
AC	Administrative Control
ACI	American Concrete Institute
ARF	Airborne Release Fraction
BDBE	Beyond Design Basis Earthquake
CFR	*Code of Federal Regulations*
CHPRC	CH2M HILL Plateau Remediation Company
CPRM	Central Plateau Risk Management
CPS	Criticality Prevention Specification
CSP	Criticality Safety Program
CW	co-located worker
DA	Directive Action
DBBP	dibutyl butyl phosphonate
DBP	dibutyl phosphate
DF	Design Features
DOE	U.S. Department of Energy
DSA	documented safety analysis
EDE	effective dose equivalent
FSAR	Final Safety Analysis Report
GRE	gas release event
HA	Hazard Analysis
HEPA	high-efficiency particulate air (filter)
ICRP	International Commission on Radiological Protection
ISMS	Integrated Safety Management System
JCO	justification for continued operation
KA	Key Attributes
LCO	limiting condition for operation
LFL	lower flammability limit
MAR	material at risk
MOI	maximally exposed offsite individual
NPH	natural phenomenon hazard
OTC	onsite transfer cask
PCB	polychlorinated biphenyl
PFP	Plutonium Finishing Plant
PHA	preliminary hazards analysis
QA	Quality Assurance
RF	Respirable Fraction

RL	U.S. Department of Energy, Richland Operations Office
S&M	Surveillance and Maintenance
SAC	Specific Administrative Control
SC	Safety Class
SMP	Safety Management Program
SS	Safety Significant
SSC	system, structure, or component
TBP	tributyl phosphate
TCLP	Toxic Characteristic Leaching Procedure
TED	total effective dose
TOC	total organic carbon
TRU	transuranic
TSR	Technical Safety Requirements
USQ	unreviewed safety question

This page intentionally left blank.

1.0 Introduction

This Documented Safety Analysis (DSA) and the associated *Tank 241-Z-361 Technical Safety Requirements* (HNF-20504) document the safety basis for Tank 241-Z-361. This DSA is prepared in accordance with DOE-STD-1120-2016, *Preparation of Documented Safety Analysis for Decommissioning and Environmental Restoration Activities*, and is compliant with 10 CFR 830, "Nuclear Safety Management." Guidance documents used in the preparation of this document include DOE-STD-3009-2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analysis*; and DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.

1.1 Rationale for DSA Methodology

The Tank 241-Z-361 has been in Surveillance and Maintenance (S&M) since 1973. DOE-STD-1120-2016, supplemented with DOE-STD-3009-2014 where referenced, is an approved "safe harbor" methodology provided in 10 CFR 830.

As a U.S. Department of Energy (DOE) nuclear facility transitions from operations through the decommissioning process, the facility undergoes many life cycle changes and the safety basis is required to be maintained whenever the Hazard Category is 1, 2, or 3. The following sequential phases are described for this transition: deactivation, decommissioning, decontamination, and demolition.

Per DOE-STD-1120-2016, decommissioning is defined as, "Takes place after deactivation and includes surveillance and maintenance, decontamination and/or dismantlement. These actions are taken at the end of the life of a facility to retire it from service with adequate regard for the health and safety of workers and the public and for the protection of the environment. The ultimate goal of decommissioning is unrestricted release or restricted use of the site."

The Tank 241-Z-361 has been deactivated, currently in surveillance and maintenance as part of the decommissioning phase, and waiting for direction for future decontamination/demolition activities. This DSA will have to be updated to support future activities relating to decontamination/demolition.

1.2 General Description

This DSA provides an analysis of the hazards and describes the controls for the storage and monitoring of Tank 241-Z-361 and its contents. Tank 241-Z-361 is an inactive, reinforced concrete, rectangular, underground settling tank located near the east end of the south fence line of the Plutonium Finishing Plant (PFP). This settling tank received all low salt, liquid effluent from the PFP processes from 1949 to May 1973. The tank contents are expected to include constituents from nearly all PFP processes used during that period, and to be dominated by those from Buildings 234-5Z, 236-Z, and 232-Z.

The scope of this DSA includes Tank 241-Z-361, its components, and the operations associated with the continued safe storage and surveillance of the tank contents. Information is provided in this DSA on previous characterization efforts of the tank contents, the tank design, and the potential hazards involved in storing the tank contents. This DSA does not provide information on activities required to remove and/or process the tank contents for remediation.

2.0 Facility Description

The objective of this chapter is to provide facility descriptions, anticipated activities, and relationships of structures, systems, and components (SSCs) to support assumptions used in the hazard and accident analyses. A graded approach was established for this chapter by providing a model of the facilities that would allow an independent reader to develop an understanding of facility operations and appreciation of facility structure without extensive consultation of references. The level of detail required in the facility description is based on the degree of facility complexity necessary to understand the analyses. These descriptions are intended as a general reference and reference documents are cited for further details.

No deactivation and decommissioning activities are authorized at this time. Authorized S&M activities are described in Section 2.1.2 below.

2.1 Facility and Work Description

2.1.1 Tank 241-Z-361

The Tank 241-Z-361 is located on the Hanford Site (Figure 2-1) near the south fence line of PFP (Figure 2-2 and Figure 2-3). This settling tank received all low salt (caustic) liquid effluent discharged from PFP.

The following facility description is a summary of the results from the tank's Justification for Continued Operations (JCO), HNF-2024.

Tank 241-Z-361 has undergone extensive characterization efforts since the 1970s, with the most recent and extensive occurring in 1999. Data from the 1999 characterization campaign shows that Tank 241-Z-361 has a total plutonium inventory of 29 kg (63.9 lb) (HNF-2024). This result is consistent with process history and across Tank 241-Z-361 characterization activities. The plutonium is likely distributed in layers in the Tank 241-Z-361 with concentrations within a factor of approximately 2 of the average 0.38 g/L. No evidence suggests time related phenomena are causing a change in the plutonium distribution.

The Tank 241-Z-361 atmosphere does not contain flammable concentrations of hydrogen or other flammable constituents in steady state conditions or during local waste disturbing activities.

The sludge contains a number of hazardous constituents of regulatory concern, including polychlorinated biphenyls (PCBs). As suggested by process history, there is no evidence of a significant nitrate or organic constituent that would support a strong exothermic reaction that could challenge the Tank 241-Z-361 structure.

The walls and roof show signs of degradation. The degradation suggests that the structural capacity of Tank 241-Z-361 is reduced from its design values, although there is significant uncertainty in the degree of reduction. The condition of Tank 241-Z-361 cannot be evaluated below the level of the sludge. The conclusion of the last integrity assessment was that the tank was not at risk of failure (HNF-2024).

2.1.2 Surveillance and Maintenance

Tank 241-Z-361 is shut down and isolated in S&M mode, and no process operations are occurring or planned.

The activities analyzed here for Tank 241-Z-361 include the ongoing storage of tank contents, S&M, and limited characterization of tank contents in support of the final tank cleanup and future area restoration projects. These activities may include:

- Storage of the tank contents
- Performing atmospheric sampling
- Local waste disturbing activities such as taking samples of the tank's contents by grab sample (tank sampling is limited to those activities that are incapable of puncturing a hole through the tank bottom, e.g. no core drilling or direct push mode core samples)
- Measuring the height of tank waste
- Characterization of the tank's contents through nondestructive analysis such as neutron or gamma logging
- Performing structural evaluations
- Maintenance activities such as high-efficiency particulate air (HEPA) filter replacement

Currently, no activities are planned in preparation for remediation. However, it is expected that additional characterization activities may be required in the future, as Tank 241-Z-361 remediation plans are finalized. Should tank characterization activities require operations beyond the scope of the activities identified in this DSA and analyzed in CP-58851, *2015 Tank 241-Z-361 Hazards Analysis*, a revision to the tank's Safety Basis will be required.

2.2 Site Location

The Tank 241-Z-361 is located approximately 36 km (22 mi) north-northwest of Richland, Washington, in the 200 West Area of the Hanford Site near PFP. Highway 240 is to the southwest of the Tank 241-Z-361, and the Columbia River is north-northeast (Figure 2-1).

Public access to the Hanford Site is currently restricted and controlled at the Wye Barricade on Route 4 and the Yakima and Rattlesnake Barricades on State Highway 240. Unauthorized access to the Tank 241-Z-361 is prohibited. Detailed site characteristics are provided in Section 1.0 of HNF-11724, *CH2M HILL Plateau Remediation Company Safety Management Program*.

2.3 Systems, Structures, and Components

2.3.1 Tank 241-Z-361 Structure

The interior dimensions of the tank are 7.93 m (26 ft) long, 3.96 m (13 ft) wide, and from 5.2 m (17 ft) deep at the inlet (north end) to 5.49 m (18 ft) deep at the outlet (south end). The base mat is 22.9 cm (9 in.) thick with grout and waterproofing added for a total thickness of 30.5 cm (12 in.). All walls are 30.5 cm (12 in.) thick and the roof is 25.4 cm (10 in.) thick. The top of the tank was sealed with 0.64-cm (0.25-in.) mastic and approximately 10.2 cm (4 in.) of concrete was poured over the mastic with 5.1-cm by 5.1-cm (2-in. by 2-in.) 14-gauge reinforcement mesh. The elevation of the top of the tank is 205 m (672.5 ft) above mean sea level (Figure 2-4). Grade-level elevation is 205.6 m (674.5 ft) above mean sea level.

The interior of the tank was lined with 0.95 cm (3/8 in.) carbon steel on the bottom and up the sides to within 15.2 cm (6 in.) of the roof. A protective coating was placed between the liner and the concrete as a corrosion barrier. Two 15.2-cm (6-in.) stainless steel pipes lead into the tank (from the retention basin and 241-Z) at the north end of the tank, and one 20.3-cm (8-in.) stainless-steel pipe forms the discharge at the south end of the tank. Baffle boxes were installed around the inlet and discharge pipes and attached to the liner. The bottom of the inlet piping is at elevation 203.9 m (669 ft) and the bottom of the discharge pipe is at elevation 203.6 m (668 ft).

The tank roof has three large penetrations and eight riser penetrations (Figure 2-4 and Figure 2-5). There is a 0.91-m (3-ft) manhole at the north end of the tank on the centerline, centered 0.61 m (2 ft), 20.3 cm (8 in.) from the outside of the north wall of the tank. A second manhole is centered 0.38 m (1.25 ft) west of the centerline, 0.81 m (2.67 ft) from the outside of the south wall of the tank. The third large penetration is a 1.22-m (4-ft) diameter concrete plug in the geometric center of the tank roof. There are two 20.3-cm (8-in.) risers, one 5.1-cm (2-in.) riser and one 7.6-cm (3-in.) riser built into the southwest corner of the tank, and one 7.6-cm (3-in.) riser built into the northeast corner of the tank. One 15.2-cm (6-in.) riser penetration was installed through the concrete plug, and two 20.3-cm (8-in.) riser penetrations were installed north of the center plug (Figure 2-5) (CO-98-099, *Engineering Load Evaluation of the Riser on Tank 241-Z-361*).

Photographs show that the liner plate (elevation 203.6 m [668 ft]) appears to be corroded away down to the level of the sludge (Figure 2-6). Videographs taken during activities authorized by Phase I of the JCO show that five dry wells are installed in the tank. Dry wells appear to be installed in both 0.91-m (3-ft) concrete manholes (Figure 2-4). Dry wells are also installed in Risers F and G. The dry wells are not sealed (closed) at the top; instead, they are open to the tank headspace.

The sludge is approximately 2.39 m (94 in.) deep. One of the south end 20.3-cm (8-in.) risers had a dry well installed, but it has been removed or corroded away. The inlet and outlet pipes have been isolated and plugged or flanged 0.61 m (2 ft) from the outer wall of the tank. The reinforced concrete poured over the top of the tank has been removed from over the two manholes and the tank was opened for sampling in the mid-1970s. The manhole covers were subsequently reinstalled, covered with weather covers, and buried. The tank is covered with approximately 0.61 m (2 ft) of soil (HNF-2024).

The Tank 241-Z-361 area is cordoned off to restrict personnel access.

2.3.1.1 Tank Physical Condition

The tank's physical condition has been evaluated several times in the past. A structural analysis (FDNW, *Structural Integrity Assessment for PFP Tank 241-Z-361*) was performed on Tank 241-Z-361 in 1997 which evaluated the tank as-built and with 50 percent rebar degradation. Later, in 1998, a load test was conducted using an approved test plan (CO-99-BWHC-010, *Dome Load Test Results Summary*). This load test applied 1,814 kg (4,000 lb) to the tank top and 272 kg (600 lb) (moving) to the regions outside the tank. This evaluation concluded that the tank response to increasing load was linear and the maximum deflection observed was well within acceptable values. The load test confirmed that the tank top was structurally adequate for a working load up to 907 kg (2,000 lb) anywhere above the tank. No sagging or other failure mechanisms were observed as a result of the 272 kg (600 lb) load test performed outside the tank top area. Then, during Phase I of the JCO, a videograph was taken of the interior of the tank. This videograph was qualitatively evaluated (CO-2000-BWHC-307, "Transmittal of Letter Report, Contract 5204, Release 55") to help clarify the structural condition of Tank 241-Z-361. Appendix A includes this evaluation.

There are no previously documented photographs taken of the interior side of the tank top. As such, comparisons with previous photographs cannot be made. The evaluation noted the following, regarding the condition of the interior side of the tank top.

- Widespread surface etching of the tank roof was observed that has reduced the concrete cover for the bottom reinforcing bars, which could reduce the bond strength between the bottom reinforcing bars and the surrounding concrete.
- Several of the bottom reinforcing bars show indications of corrosion.
- The top cover has some splitting cracks, but the cracks have not progressed to spalling of the concrete cover.
- The tank vertical walls can only be seen above the sludge level in the tank. Accordingly, there is no information from the evaluation regarding the condition of the vertical tank walls for approximately the bottom 2.39 m (94 in.). There is also no information regarding the condition of the tank base mat. The evaluation noted the following, regarding the condition of the interior of the vertical tank walls.
  - The conditions do not appear markedly different from those shown in 1985 photographs. The 0.95-cm (3/8-in.)-thick steel liner was dissolved below the maximum liquid level. However, much of the water proofing material originally installed between the steel liner and the concrete remains.
  - A limited number of small areas were visible where both the steel liner and the water proofing material had been removed. Exposed aggregate was observed in some of these locations, potentially reducing the concrete wall structural capacity.

Only portions of the tank have been observed, and extensive conclusions cannot be drawn based on qualitative evaluation of photographs. Significant uncertainty remains regarding the structural condition of the tank. However, the qualitative evaluation performed did not identify any conditions indicative of imminent structural failure.

As a result of the Tank's structural uncertainty gathered by the qualitative analysis performed in 1999, and the fact that the Tank inevitably continues to age and degrade with time, the 907 kg (2,000 lb) load limit has since been replaced with more conservative controls to protect the Tank's structure as well as ensure the safety of facility personnel.

Since the 1999 qualitative analysis, evaluations have been performed on a periodic basis and documented in HNF-24256, *Tank 241-Z-361 Qualitative Evaluation to Identify Indications of Imminent Tank Failure*. These evaluations include observation of tank soil cover, the inclination of the risers, and inspection of the remaining bridge beams. These evaluations have found no indication of change in physical condition or imminent failure of Tank 241-Z-361.

2.3.1.2 Tank Sludge

Prior to the extensive characterization activities that took place in 1999, past PFP processes were evaluated to determine the range of potential sludge constituents and their inventories in Tank 241-Z-361 (HNF-1989, *Tank 241-Z-361 Process and Characterization History*). Results of more recent characterization are documented in HNF 8735, *241-Z-361 Tank Characterization Report*. Low salt waste going through Tank 241-Z-361 generally consisted of large volumes of water containing relatively low concentrations of chemicals in contrast to the "high-salt" waste that went to the 216-Z-9 or 216-Z-18 Cribs. Table 2-1 lists the process streams' volumes and plutonium mass contributing to the low-salt waste for a typical year (in this case, 1969). Table 2-2 provides the range of potential chemical constituents that were expected to be found in Tank 241-Z-361 sludge based on this analysis of process history.

Many different effluent streams flowed through Tank 241-Z-361 while it was in service, and these effluent streams are not well documented. Using 1969 as a typical year, the following summary characteristics were developed.

- Each of the process streams contributed some unique waste constituents and would only be discharged to Tank 241-Z-361 while that process was in use.
- Cooling water was sanitary water in closed lines that did not come in contact with chemicals or radioactive material.
- Laboratory wastes were representative of the broad-range of process development and analytical chemistry being conducted. There is essentially no information on its constituents. The small volume coupled with large dilutions with the process streams make it unlikely they contributed enough material to be of concern.
- The incinerator burned a variety of materials including organic chemicals, paper, and plastic. A caustic off-gas scrub solution was used to trap acid fumes, combustion products, and fine particles. The incinerator operated intermittently from December 1961 to May 1973.
- Little is known about reclamation condensate except that the chemical contaminants were considered "slight."
- Fluorinator off-gas jet and scrubber solutions from hood HC-9A and HC-9B on the "Button Lines" contributed the largest volume of waste to 241-D-6 Drain. These were responsible for the failure of the 241-D-6 Drain because of corrosion. The hydrofluoric acid concentration was approximately 0.06 M.

Large amounts of water were flushed through Tank 241-Z-361. The discharges to the tank were generally diluted. Accordingly, even slightly soluble materials and suspended materials were likely flushed from Tank 241-Z-361 and discharged to the cribs. Moreover, materials sent to Tank 241-Z-361 were steam jetted. Compounds with low boiling points would be expected to have been vaporized and released through vents then existing in the tank. Other than the laboratories, no processes discharged reactants that would be reasonably capable of generating rapid, large, exothermic reactions. The laboratory chemicals discharged would be small quantities, well diluted, and not likely to present a significant hazard. Combined, these factors suggested there would be very little if any significantly reactive chemicals in this tank.

Table 2-1. Typical Low-Salt Aqueous Process Streams in the Plutonium Finishing Plant (1969)

Stream	Drain	Source	Thousands of gal/yr	Plutonium, g/yr	Chemical Contaminant
Uncontaminated lab wastes	D-4,5	Cooling water for equipment in labs	127	0	None
Contaminated lab wastes	D-4,5	Lab drains	174	100	Miscellaneous lab chemicals
Waste treatment aqueous waste	D-6	Ion exchange process	86	60	Principally Al, Ca, Mg, nitrate
Incinerator scrubber solution	D-6	Spent caustic from scrubber	6	600	Considerable Na
Reclamation condensate	D-6	Process concentrators	54	12	Slight
Fluorinator off-gas jet	D-6	Water for vacuum jet	1906	100	Hydrogen fluoride
Total			**2,353**	**872**	
Source: HNF-IP-0263-PFP, *Building Emergency Plan for Plutonium Finishing Plant Complex.*					

Table 2-2. Known and Probable Components of 241-Z-361 Tank Sludge Based on Process History

Type of Component	Component	Probable Source
Known Metals	Al	Waste Treatment
	Na	Incinerator Off-gas Treatment
	Ca	Waste Treatment
	Si	Incinerator Off-gas Treatment
	Cd	Most likely an analytical artifact
Known Non-Metals	F^-	Hydrogen Fluorinator
	Cl^-	Waste Treatment
	C	Incinerator Off-gas Treatment
	H_2O	All
	H^+	All
Probable Metals	Pb	Incinerator Off-gas Treatment
	Mg	Waste Treatment
	Mn	Waste Treatment
	Cr	Corrosion of SS Equipment

Table 2-2. Known and Probable Components of 241-Z-361 Tank Sludge Based on Process History

Type of Component	Component	Probable Source
	Ni	Corrosion of SS Equipment
	Ag	Lab Film Processing
Probable Non-Metals	NO_3	Waste Treatment
	NO_2	Radiolysis of NO_3^-
	SO_4^{2-}	Waste Treatment
	PO_4^{3-}	Degradation of TBP
	CO_3^2	Incinerator Off-gas Treatment
Probable Organics	CCl_4	Waste Treatment
	DBBP	Waste Treatment
	TBP	Waste Treatment
	DBP	Degradation of TBP
	MBP	Degradation of TBP
	Butanol	Degradation of TBP
	Urea	Incinerator Off-gas Treatment
	Lard Oil (Triolein)	Waste Treatment
	Oxalic Acid	Waste Treatment
	Acetic Acid	Incinerator Off-gas Treatment
	Benzene	Incinerator Off-gas Treatment
	Phthalic Acid	Incinerator Off-gas Treatment
Known Radionuclides	Pu	All
	Am	Decay of Pu^{241}
	U	Waste Treatment

Source: HNF-IP-0263-PFP, *Building Emergency Plan for Plutonium Finishing Plant Complex.*
DBBP = dibutyl butyl phosphonate.
MBP = methyl butyl phosphate.
TBP = tributyl phosphate.

2.3.1.2.1 Plutonium Inventory

The plutonium inventory in Tank 241-Z-361 was evaluated using process history, and has been the subject of three characterization efforts starting in about 1974.

2.3.1.2.2 Plutonium Inventory Based on Process History

Several records were used to refine the estimated plutonium concentration of Tank 241-Z-361. Extrapolating the plutonium discharged in 1969, the expected Tank 241-Z-361 plutonium inventory would be on the order of 20 kg (44 lb).

Records of material unaccounted for were used to refine this estimate. These records identify material that was discharged to various PFP cribs. There was no measurement performed at the cribs that provides the actual plutonium received in the cribs. Conservatively assuming that all of the plutonium settled in Tank 241-Z-361 and none got to the cribs, then the records of discharges with Tank 241-Z-361 in the flow path provides a conservative estimate of the plutonium in Tank 241-Z-361 based on records of unaccounted for material. Using the assumption that all plutonium settled in Tank 241-Z-361, then about 31.2 kg (68.8 lb) of plutonium is in this tank, as shown in Table 2-3 (HNF-2012, *Engineering Study of the Criticality Issues Associated with Tank 241-Z-361*).

If the Tank 241-Z-361 sludge deposition rate is assumed to be proportional to the volume discharge, these discharge records can be further developed into annual plutonium discharges as a function of sludge depth in Tank 241-Z-361 (Table 2-4 [HNF-2014]). Figure 2-7 (HNF-2024) shows this analysis. This analysis projected that the plutonium is deposited in layers with plutonium concentrations varying within a factor of 2 of the average.

Table 2-3. Discharges with Tank 241-Z-361 in the Flow Path

Crib Recorded as Having Received the Discharge	Plutonium (g)
Z-1 & Z-2	199
Z-3	5,698
Z-12	25,300
Total	**31,197**

Source: HNF-2012, *Engineering Study of the Criticality Issues Associated with Tank 241-Z-361*

Table 2-4. Calculated Plutonium Concentration in Tank 241-Z-361 if Sludge Deposition is Assumed Proportional To Volume Discharged[a]

Year	Volume Percent	Plutonium (g)		Plutonium Concentration (g Pu/L)	Layer Top (cm from bottom)
		Estimated[b]	Adjusted[c]		
1949 – 1958	8.4[d]	2,000	2,302	0.357	20.5
1959	13.7	1,276	1,469	0.140	54.0
1960	14.5	2,508	2,887	0.260	89.4
1961	13.7	3,592	4,135	0.394	122.7
1962	8.2	2,844	3,274	0.519	142.8
1963	7.5	3,842	4,422	0.772	161.1
1964	6.2	3,199	3,682	0.772	176.2
1965	5.7	1,864	2,145	0.495	190.0
1966	5.0	767	883	0.232	202.2

Table 2-4. Calculated Plutonium Concentration in Tank 241-Z-361 if Sludge Deposition is Assumed Proportional To Volume Discharged[a]

Year	Volume Percent	Plutonium (g)		Plutonium Concentration (g Pu/L)	Layer Top (cm from bottom)
		Estimated[b]	Adjusted[c]		
1967	3.9	1,035	1,191	0.396	211.8
1968	2.0	680	783	0.517	216.6
1969	2.2	517	595	0.360	221.9
1970	1.2	650	748	0.842	224.7
1971	2.8	1,067	1,228	0.583	231.4
1972	3.9	939	1,081	0.359	241.0
1973	1.2	327	376	0.421	243.8
Total or Average	**100.0**	**27,100**	**31,200**	**0.408**	**243.8**

[a]Solids deposited assumed proportional to total waste passing through tank.

[b]This column is for wastes routed to Crib Z-12.

[c]Plutonium quantities adjusted to make total equal to estimated total discharged to Tank 241-Z-361 from all sources.

[d]Volume of solids for 1949 – 1958 chosen to make plutonium concentration equal to measured value of 0.36 g/L.

2.3.1.2.3 Plutonium Inventory Based on Characterization Data: 1975 and 1977

Extensive work was performed to determine the plutonium concentration in Tank 241-Z-361 between 1974 and 1978. Two families of sample data were generated for the contents of this tank: up to 1975 and from 1977. Plutonium concentrations for 1975 data are more than twice as high as data starting in 1977. In 1976, corrected plutonium concentrations were calculated. The correction involved recalculating the percent volume solids. This recalculation of the earlier results yielded 17 to 86 percent reductions in the plutonium concentrations. The recalculated plutonium concentrations still have a significant error that yields values that are high by about a factor of two. This error was caused by the volume of water evaporating from the filtered solids not being accounted for in the calculated sludge volume (HNF-2024).

The plutonium concentration and neutron measurements for 1977 data are more consistent. Discharge records and material accountability records are more consistent with measured plutonium inventories for the 1977 data. The 1977 data was judged as the most reliable. This analysis identified that the average plutonium concentration is 0.38 g Pu/L. The 99 percent confidence interval concentration is 0.61 g Pu/L. The average plutonium concentration translates to a total plutonium inventory of 29 kg (63.9 lb), and the 99 percent confidence interval concentration equates with 46 kg (101.4 lb). This inventory range is consistent with the inventory expected from review of the discharge records (HNF-2024). Figure 2-8 (HNF-2024) shows the spatial distribution of this plutonium inventory. Figure 2-9 (HNF-2024) shows that this characterization data compares favorably to the plutonium concentration versus depth predicted by review of the discharge records.

2.3.1.2.4 Plutonium Inventory based on Characterization Data: 1999

Characterization sampling of Tank 241-Z-361 was performed again in 1999. This analysis was designed to address uncertainties in prior data sets and would help evaluate whether any time related phenomena were potentially affecting the distribution of plutonium in the tank.

Two full-depth core samples were collected from Tank 241-Z-361 using push mode core sampling during Phase II of the JCO. Once the activities authorized by the JCO were completed, the tank bridge was dismantled and the onsite transfer cask (OTC) and OTC weather enclosure were removed. One core (Core 263) was taken from Riser E. The second core (Core 264) was taken from Riser F. However, Core 264 exhibited a 32 cm (12.6 in.) section where no samples were recovered. Distinct layers were observed in both core samples. Nineteen individual strata were detected in Core 263, while eleven strata were observed in Core 264 (HNF-8735). Table 2-5 summarizes the results of the laboratory analysis.

Table 2-5. Characterization Data Summary

Analyte	Analytical Method	Result Range	Minimum Detection Limit
% Water	Gravimetric	52.2% - 84.4%	0.01
Aluminum	ICP (Fusion Digest)	1390 – 46,500 µg/g	965
Americium - 241	Alpha Energy Analysis (ion exchange separation)	0.306 – 14.1 µCi/g	0.0658
Ammonia/Ammonium	Ion-selective electrode	<490 – 656 µg/g	490
Arsenic	ICP (Acid Digest)	<9.8 – 23.4 µg/g	9.8
Barium	ICP (Acid Digest)	93 – 197 µg/g	4.9
Beryllium	ICP (Acid Digest)	<0.49 - <2.01	0.49 – 2.01
Bromide	Ion chromatography of water extract	280 – 3110 µg/g	149.5
Cadmium	ICP (Acid Digest)	1.48 – 112 µg/g	0.996
Calcium	ICP (Fusion Digest)	28,500 – 103,000 µg/g	1910
Chloride	Ion chromatography of water extract	482 – 907 µg/g	19.68
Chromium	ICP (Acid Digest)	691 – 10,000 µg/g	0.98
Chromium	ICP (Fusion Digest)	815 – 8560 µg/g	191
Cyanide	EDTA Distillation / Spectrophotometry	<0.65 – 1.41 µg/g	0.65
Dibutyl phosphate – derivitized	GC/MS	<39 µg/g (Note: all results qualified)	39
Dibutyl Phosphonate	GC/MS	<14 - <18 µg/g	<14 - <18
Fluoride	Ion chromatography of water extract	1070 – 10,800 µg/g	13.99
Gross Alpha of Digested Solid	Alpha proportional count of fusion digest	3.87 – 42.6 µCi/g	0.00803
Gross Beta of Solid Sample	Beta proportional count of fusion digest	0.146 – 3.96 µCi/g	0.0221

Table 2-5. Characterization Data Summary

Analyte	Analytical Method	Result Range	Minimum Detection Limit
Hydroxide	Potentiometric Titration	<8010 - <8510 μg/g	<8010 - <8510
Iron	ICP (Fusion Digest)	3730 – 44,800 μg/g	956
Lead	ICP (Acid Digest)	32 – 446 μg/g	9.8
Lithium	ICP (Acid Digest)	13.8 – 374 μg/g	0.98
Magnesium	ICP (Fusion Digest)	4890 – 10,800 μg/g	1910
Manganese	ICP (Fusion Digest)	<191 – 771 μg/g	191
Mercury	Cold Vapor Atomic Absorption	18.65 – 82.96 μg/g	0.6
Neptunium - 237	TTA Extraction / Alpha proportional counting	<0.00196 – 0.00523 μCi/g (Note: all results qualified)	0.00357
Nickel	ICP (Acid Digest)	56.7 – 3360 μg/g	1.96
Nitrate	Ion chromatography of water extract	<164 – 1230 μg/g	163.6
Nitrite	Ion chromatography of water extract	362 – 1540 μg/g	125
pH on Solid Samples	pH electrode in 1:1 sludge / water suspension	8.16 – 9.18 pH	0.01
Phosphate	Ion chromatography of water extract	<139 - <147 μg/g	<139 - <147
Phosphorus	ICP (Acid Digest)	133 – 831 μg/g	19.6
Phthalate	Ion chromatography of water extract	<1100 - <4460 μg/g	<1100 - <4460
Plutonium - 238	Alpha Energy Analysis (ion exchange separation of fusion digest)	<0.201 – 2.3 μCi/g	0.67
Plutonium - 239	ICP/MS	69.07 – 578 μg/g	23.42
Plutonium - 239	ICP/MS (ion exchange separation of fusion digest)	70.84 – 551 μg/g	0.313
Plutonium – 239/240	Alpha Energy Analysis (ion exchange separation of fusion digest)	4.21 – 42.2 μCi/g	0.201
Plutonium - 240	ICP/MS (Fusion Digest)	<23.82 – 37.23 μg/g	23.82
Plutonium – 240	ICP/MS (ion exchange separation of fusion digest)	3.543 – 60.97 μg/g	0.313
Plutonium - 241	ICP/MS (ion exchange separation of fusion digest)	<0.318 – 0.87 μg/g	0.318
Plutonium / Americium – 241	ICP/MS (Fusion Digest)	<23.42 - <24.68 μg/g	<23.42 - <24.68
Potassium	ICP (Acid Digest)	<49 – 270 μg/g	49
Silicon	ICP (Fusion Digest)	<978 – 2470 μg/g	978
Silver	ICP (Acid Digest)	15.6 – 182 μg/g	0.98
Sodium	ICP (Fusion Digest)	3290 – 39,200 μg/g	1910
Specific Conductance of Liquid	Electrode	98.8 – 139 μS/cm	1

Table 2-5. Characterization Data Summary

Analyte	Analytical Method	Result Range	Minimum Detection Limit
Specific Gravity – Solid/Sludges	Gravimetric	1.02 – 1.65	0.0499
Strontium – 89/90	Extraction/Beta proportional counting	0.00236 – 0.044 µCi/g	0.000672
Sulfate	Ion chromatography of water extract	974 – 1980 µg/g	159.8
Sulfur	ICP (Acid Digest)	362 – 1090 µg/g	9.8
Technetium – 99	Solvent extraction/liquid scintillation	<0.00149 – 0.0279 µCi/g	0.00149
Titanium	ICP (Fusion Digest)	<191 - 276 µg/g	191
Total Dissolved Solids	Gravimetric	<0.00028 g/mL	0.00028 g/ml
Uranium	ICP (Acid Digest)	<49 – 142 µg/g	49
Uranium - 235	Fusion Digest/ICP/MS	<18.74 - <19.74 µg/g	18.74
Uranium – 238	Fusion Digest/ICP/MS	<19.7 – 62.62 µg/g	18.74
Zinc	ICP (Acid Digest)	58.5 – 622 µg/g	0.98
Zirconium	ICP (Acid Digest)	<1.99 – 75.7 µg/g	0.98
Total Inorganic Carbon	Acid Digestion/Coulometry	1440 – 24,500 µg/g	5
Total Organic Carbon	Persulfate Digestion / Coulometry	662 – 8410 µg/g	40

Source: *FH-0002791, Submittal of Documentation in Fulfillment of TPA Milestone M- 15-37B.*

EDTA = ethylenediamine tetraacetic acid.
GC = gas chromatograph.
ICP = inductively coupled plasma.
MS = mass spectrometer.
TTA = 2-thenoyltrifluoroacetone.

As a result of this new characterization data, Tank 241-Z-361 is estimated to contain a total plutonium inventory of 29 kg (63.9 lb). This inventory compares favorably with the inventory of 31.2 kg (68.8 lb) predicted based on process history, and the 29 kg (63.9 lb) predicted based on past tank sampling activities. The layering of the plutonium in Tank 241-Z-361 shown in earlier analyses is also seen in the recent characterization data. Plutonium-239 concentrations vary from 0.0939 g/L in the bottom core segment to 0.7919 g/L about 1 m (39 in.) below the surface of the sludge. The plutonium-239 concentration decreased to 0.4667 g/L in the uppermost portion of the sludge in Core 263. In Core 264, the plutonium-239 concentrations varied from 0.1716 g/L in the bottom of the tank to a maximum recovered segment of 0.5906 g/L occurring approximately 1.7 m (5.58 ft) below the top of the sludge. The plutonium-239 concentration decreased to 0.1499 g/L at the uppermost sampled layer in the tank (FH-0002971).

The layering of plutonium within the tank shows the same general shape as previous sampling results and that predicted by process history. In comparison to Figure 2-9, the plutonium concentrations are least at the bottom of Tank 241-Z-361. The maximum plutonium concentrations peak at a vertical height corresponding to between 1 m (3.28 ft) and 0.8 m

(2.62 ft) below the sludge surface. The plutonium concentration decreases from this point toward the surface of the sludge. Core 263 was from tank center, the plutonium concentrations for Core 263 also compare favorably with, albeit somewhat lower than, the spatial distribution of plutonium provided in Figure 2-8.

Including past and current plutonium concentration measurements, the average plutonium concentration in Tank 241-Z-361 is 0.38 g/L and the 99 percent upper bound average concentration is 0.61 g/L. The new characterization data can still be seen to be varying within a factor of slightly greater than two from the average concentration.

Comparison of current sampling results to past sampling results and the results predicted by process history shows strong commonality. No evidence exists to support significant time related changes in the plutonium distribution over the greater than 20 years between sampling efforts.

2.3.1.2.5 Other Tank 241-Z-361 Sludge Constituents and Physical Characteristics

The primary objective of early Tank 241-Z-361 characterization efforts was focused on determining the potential for inadvertent criticality. More extensive characterization was performed in 1999 that focused on assessing the concentration of hazardous constituents and other constituents potentially important to selection of a remediation approach.

2.3.1.2.6 Early Tank 241-Z-361 Characterization Results

Tank 241-Z-361 was characterized in the mid to late 1970s as described in HNF-1989 and HNF-2012. The sludge was found to vary greatly in solids content, but to be on average 30 percent solid material with the rest being liquid (mostly water). The sludge was deposited in many layers from the various operating campaigns, and it exhibits considerable variability in consistency. Tables 2-6 and 2-7 portray the sludge appearance and nonradioactive content based on core sampling (HNF-2024).

Table 2-6. Sample Descriptions for 1977 Sludge Sample

	Sample Description
NW-1	Dark Brown – almost Black –loose - wet
NW-2	Color of Sample 1 – thicker
NW-3	Small amount of free liquid on top Color of sample 1 – thicker than 2
NW-4	Dark brown – lighter than 2 – thinner
NW-5	Lighter color than 4 – very watery – thin soup
NW-6	Thicker than 5 – lighter color than 5 – gritty – sandy
NW-7	Thicker than 6 – dark tan color – pasty, creamy consistency
NW-8	Same as 7 except lighter color
NW-9	Free liquid on top – slightly darker color than 8 – same consistency
NW-10	Same as 9
NW-11	Tan-brown. Same as 10 – slightly darker
NW-12	Lot of liquid on top. Lt. Brown darker than the five samples above

Table 2-7. Component Concentrations in Air Dried Tank 241-Z-361 Solids (1977)

Component	Northeast Core, g/L	Southwest Core, g/L	Center Manhole Bottle, g/L	
			Sample #8	Sample #9
Aluminum	71.8	304.0	---	290.3
Calcium	345.0	460.0	322.4	213.6
Cadmium	< 3.8	< 3.4	< 0.4	0.9
Iron	230.9	562.2	59.0	74.0
Sodium	18.6	40.5	6.3	200.4
Silicon	10.5	10.4	4.4	8.3
Oxygen	20.	200.	---	---
Hydrogen	0.6	60.	---	---
Carbon	46.	87.2	---	---
Chloride	---	34.2	---	---
Fluoride	---	3.9	---	---

Little is known regarding the routine acidity of the wastes sent to the settling tank, other than the general guidance that the waste was to be neutralized. However, one pH sample was measured at 4.0 in March 1975. The corroded carbon steel liner indicates that some wastes were not completely neutralized or the acidic flushes of Tank 241-D-7 caused a low tank pH, or more likely both. Likewise, while some organic materials have likely entered the tank, carbon has not been found except for in a few samples. In the past, the carbon detected was about 1 percent, but the carbon concentration was as high as 6 percent in one sample. This could be carbon from fly ash in the incinerator scrubber solution, carbonate from neutralization and absorption into caustic solution, or from organic compounds. Most likely it is from a combination of all of these sources. There has been no separate organic phase observed in the tank

2.3.1.2.7 Recent Characterization Results

Tank characterization efforts for nonradioactive constituents were more extensive in 1999 than previous characterization efforts. Table 2-5 provides a summary of the tank characterization laboratory analysis results (FH-0002791, "Submittal of Documentation in Fulfillment of TPA Milestone M-15-37B").

Tank 241-Z-361 constituents and pH are not conducive to mobilizing the plutonium. Tank Farm operations define pH greater than 8.0 as the target pH to ensure precipitation of plutonium salts (FH-0002791). The pH measured in the core samples taken from Tank 241-Z-361 varied from 8.0 to 9.2. Accordingly, the pH of Tank 241-Z-361 will maintain the plutonium salts at their minimum water solubility.

Historically, PFP processes used tributyl phosphate (TBP) and dibutyl butyl phosphonate (DBBP) in plutonium separation and recovery processes. Dibutyl phosphate (DBP) is a degradation product of TBP encountered at the Hanford Site. These compounds can increase the solubility of plutonium in water. Sludge samples were analyzed for TBP, DBBP, and DBP. Concentrations ranged from non-detectable at various detection limits to 3 µg/g. These low concentrations are not expected to increase the solubility of plutonium in water.

Tank 241-Z-361 contains hazardous waste constituents. The Toxic Characteristic Leaching Procedure (TCLP) has not been performed on the sludge samples, but the results of the total metal analysis of the sludge were compared to the applicable TCLP extract concentration limit. This comparison shows several hazardous constituents that may exceed regulatory thresholds (Table 2-8).

Table 2-8. Tank 241-Z-361 Hazardous Waste Constituents Detected

Regulated Metal	Concentration Range Reported (mg/kg)	TCLP Level Equivalent (mg/kg)
Arsenic	<10-23.4	100
Barium	87.1-197	2,000
Cadmium	1.48-112	20
Chromium	691-10,000	100
Lead	32-446	100
Mercury	19-177	4
Silver	15.6-182	100

Tank 241-Z-361 sludge also was analyzed for PCBs. The two highest PCB concentrations analyzed were 50.6 and 160 parts per million, on a dry weight basis. The source of the PCBs is unknown.

Total organic carbon (TOC) was analyzed, and the TOC was found to range between 662 µg/g to 8410 µg/g. Nitrates were found in similarly low concentrations ranging from less than the detection limit of 164 µg/g up to 1,230 µg/g. With these low concentrations and the high water content (65% to 84%), organic and nitrate reactions that could challenge tank integrity are extremely unlikely.

2.3.1.2.8 Tank 241-Z-361 Dome Headspace Atmosphere Constituents

The Tank 241-Z-361 headspace was extensively characterized when the tank was opened in 1998 during Phase I of the JCO and during Phase II tank characterization activities. FH-0002791 presents the results of headspace monitoring and sampling.

Tank 241-Z-361 headspace monitoring was conducted via samples drawn through a sampling tube inserted during initial opening of the tank and installation of a HEPA filter on a 7.6-cm (3-in.) riser. This sampling tube was lowered into the tank to a depth approximately 0.3 m (1 ft) above the surface of the sludge. The maximum concentration of flammable vapor reported was 3 percent of the lower flammability limit (LFL), using a field combustible gas meter calibrated to hydrogen. The LFL of hydrogen is 4 percent, yielding a total hydrogen volume of 0.12 percent.

No significant increases in the concentration of flammable vapor, such as that associated with a gas release event (GRE), were reported during monitoring performed while conducting push mode core sampling of Tank 241-Z-361, which is a local waste disturbing activity.

In addition to field monitoring, samples were collected from the tank headspace for laboratory analysis of volatile organic compounds. Seventeen volatile organic compounds were detected. The concentration of vapors in the headspace remained very stable from the time of the initial headspace sample through collection of the last air sample during sludge sampling. Seven compounds accounted for 5.67 ppmV, or 93 percent of the total 6.08 ppmV compounds detected in laboratory analysis (Table 2-9).

Table 2-9. Tank 241-Z-361 Volatile Organic Compounds Detected

Compound	Range Reported (ppmV)	OSHA Permissible Exposure Limit (ppmV)
Freon 11	0.24-0.83	1,000
Chloroform	0.32-1.10	50
Tetrachloroethylene	0.32-2.00	100
Isobutane	0.22-0.50	No Limit Established
Methylcyclopentane	0.05-0.20	No Limit Established
Trichloroethylene	0.35-0.88	100
Carbon Tetrachloride	0.05-0.15	10

OSHA = Occupational Safety and Health Administration.

Carbon dioxide was detected in the tank headspace at 13,000 ppmV. The carbon dioxide content of the Tank 241-Z-361 headspace exceeds the Occupational Safety and Health Administration (OSHA) limit by a factor greater than 2. The elevated carbon dioxide likely resulted from historical reaction of acidic waste constituents with neutralizing agents added to the waste, or with the concrete structure of the tank itself. Nitrous oxide was detected in the tank headspace at a concentration of 110 ppmV, which exceeds the National Institute for Occupational Safety and Health's recommended exposure limit of 25 ppmV. Based on these observed concentrations, the tank headspace does not appear to be acutely toxic. The oxygen content of the tank headspace was consistently near 19.5 volume percent, slightly below ambient air content. The tank headspace also was monitored during field activities with a photoionization detector to evaluate the presence of volatile compounds. These measurements indicated that the tank headspace vapor is composed primarily of air. The results of the field monitoring are consistent with the laboratory analyses (FH-0002791).

2.3.2 Tank Ventilation System

The tank structure is not "airtight"; the tank is nearly 70 years old and has small cracks in it which allow the tank to atmospherically breathe. These cracks were confirmed during the videograph taken in 1999. However, before the videograph was taken of the tank, it could not be ensured that the tank was passively ventilated. As such, a passive HEPA filter vent was attached to one of the 7.6-cm (3-in.) riser pipes on Tank 241-Z-361 to ensure that the tank would not become pressurized during the JCO activities. The HEPA filter vent was left after JCO activities were completed.

2.3.3 Fire Protection System

Tank 241-Z-361 has no local fire protection system.

2.3.4 Utilities

The process inlet and outlet pipes attached to Tank 241-Z-361 have been isolated and plugged or flanged at a distance of 0.61 m (2 ft) from the outer wall of the tank. The tank has no electrical utilities attached. The tank filtered ventilation system is passive.

2.4 Operational History

PFP was built in 1948 and began processing plutonium in mid-1949 with Tank 241-Z-361 as part of the low salt waste disposal path from all PFP processes, including the incinerator, the Plutonium Reclamation Facility, and the Waste Treatment Facility. The incinerator (232-Z) operated from December 1961 until May 1973. The Plutonium Reclamation Facility (236-Z) began operation in May 1964. The Waste Treatment Facility (242-Z) operated from August 1964 until August 1976. Waste from some processes and laboratories went through transfer lines to Building 241-Z sump tanks. High salt and organic waste were sent to the 216-Z-9 or 216-Z-18 Cribs under normal operation.

The transfer lines to Building 241-Z were numbered 241-D-4 to 241-D-6 (Figure 2-3). (Note: There were several different configurations of the PFP drain system.) The 241-Z Sump Tanks were numbered 241-D-4 through 241-D-8. The 241-D-4, 241-D-5, and 241-D-6 drains went to the 241-D-6 sump tank. When the 241-D-6 tank was full, it was transferred to the 241-D-7 tank. The 241-D-6 sump tank eventually failed and D-7 was used in its place. Prior to transfer to cribs, the 241-D-7 tank contents were sampled. If the plutonium content was analyzed to be more than 10 g per batch, generally the batch was reprocessed. Below the plutonium discard limit, caustic was added and the material was sent to the cribs via Tank 241-Z-361, where solids settled out and the liquid overflowed by gravity to the cribs. Accordingly, the materials discharged via Tank 241-Z-361 would be expected to have been low in plutonium concentration. In addition to drain lines, a large un-quantified amount of process water was discharged from the retention basins to the cribs through Tank 241-Z-361.

Waste liquids that passed through the Tank 241-Z-361 settling tank flowed from PFP to ground in the following sequence: processes to 241-D-4, 241-D-5, and 241-D-6 Drains to 241-D-6 Sump Tank to 241-D-7 or 241-D-8 Sump Tank to Tank 241-Z-361, and then to the cribs.

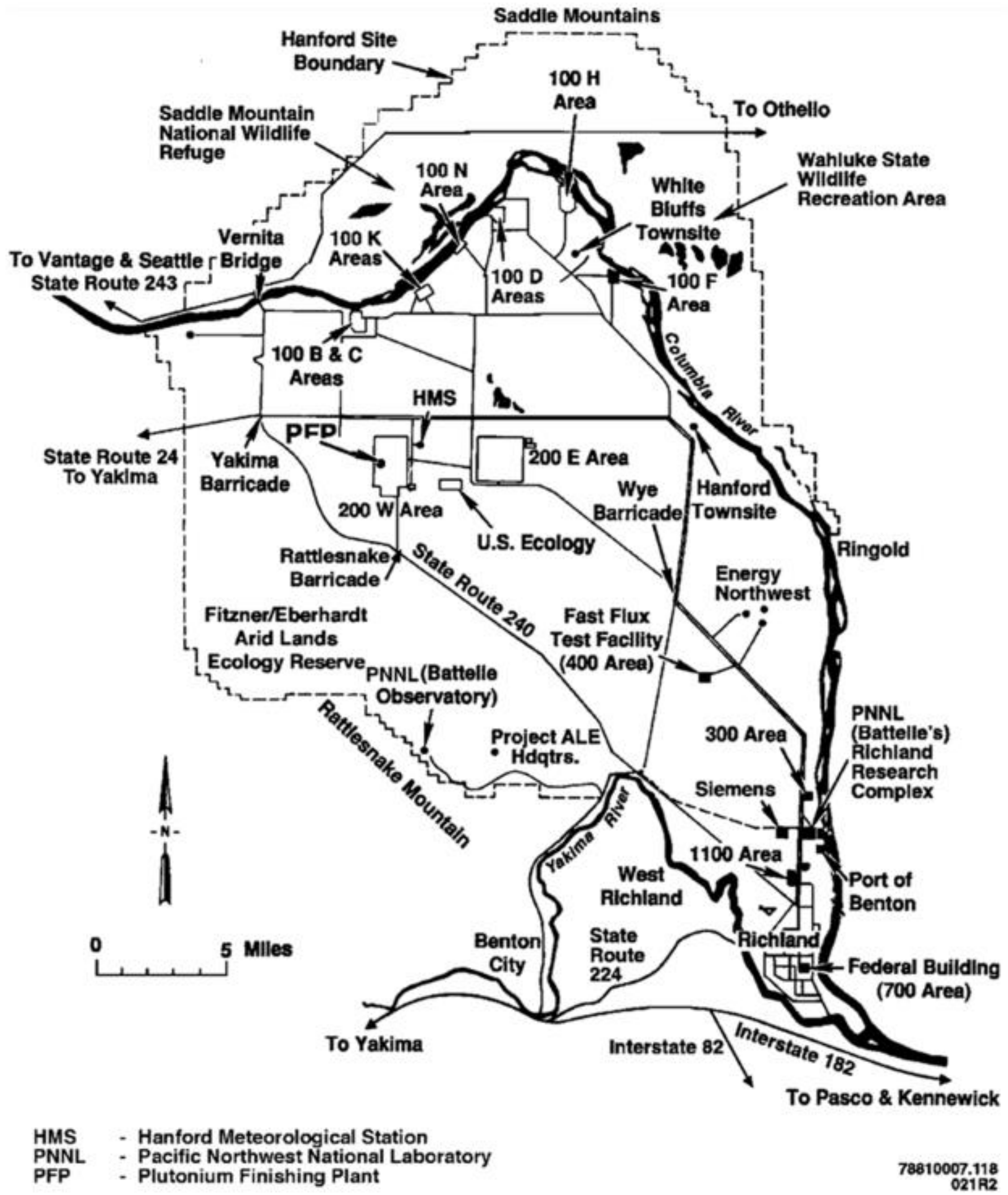

Figure 2-1. Hanford Site Map

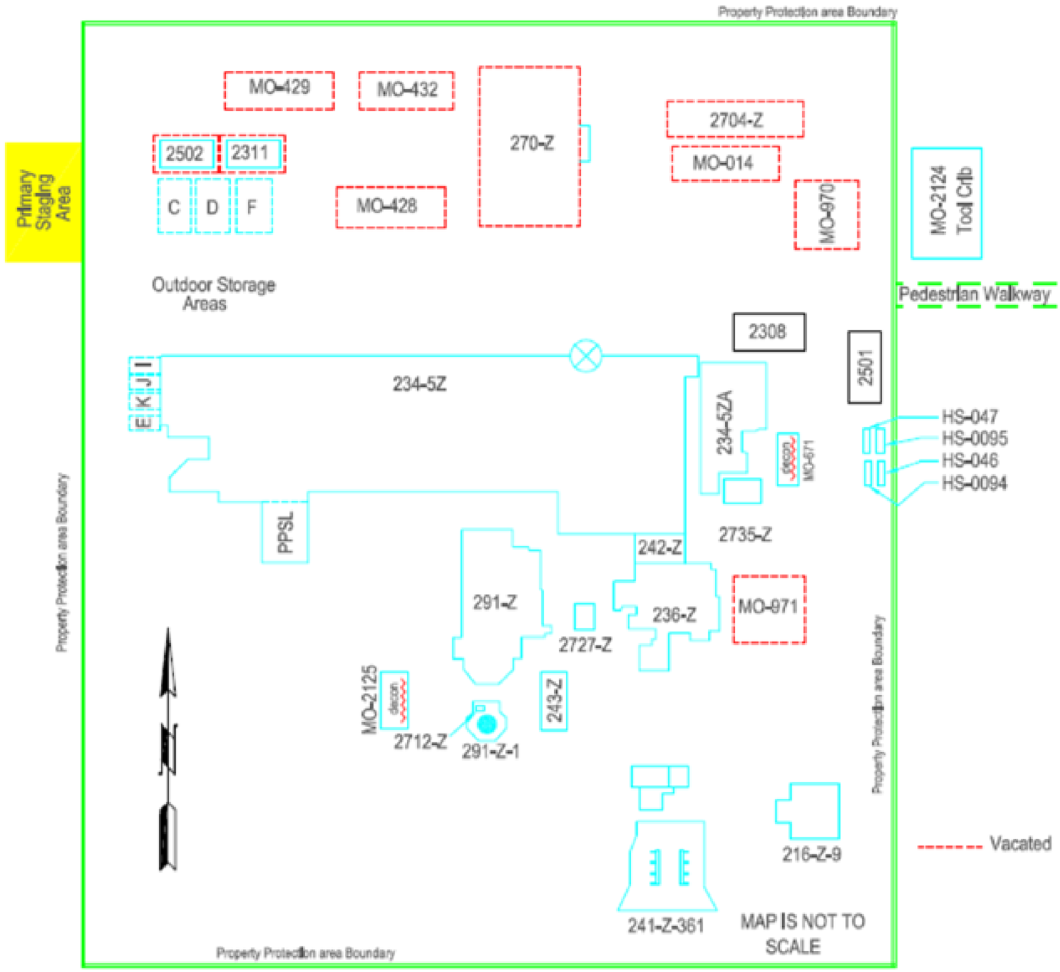

Figure 2-2. Tank 241-Z-361

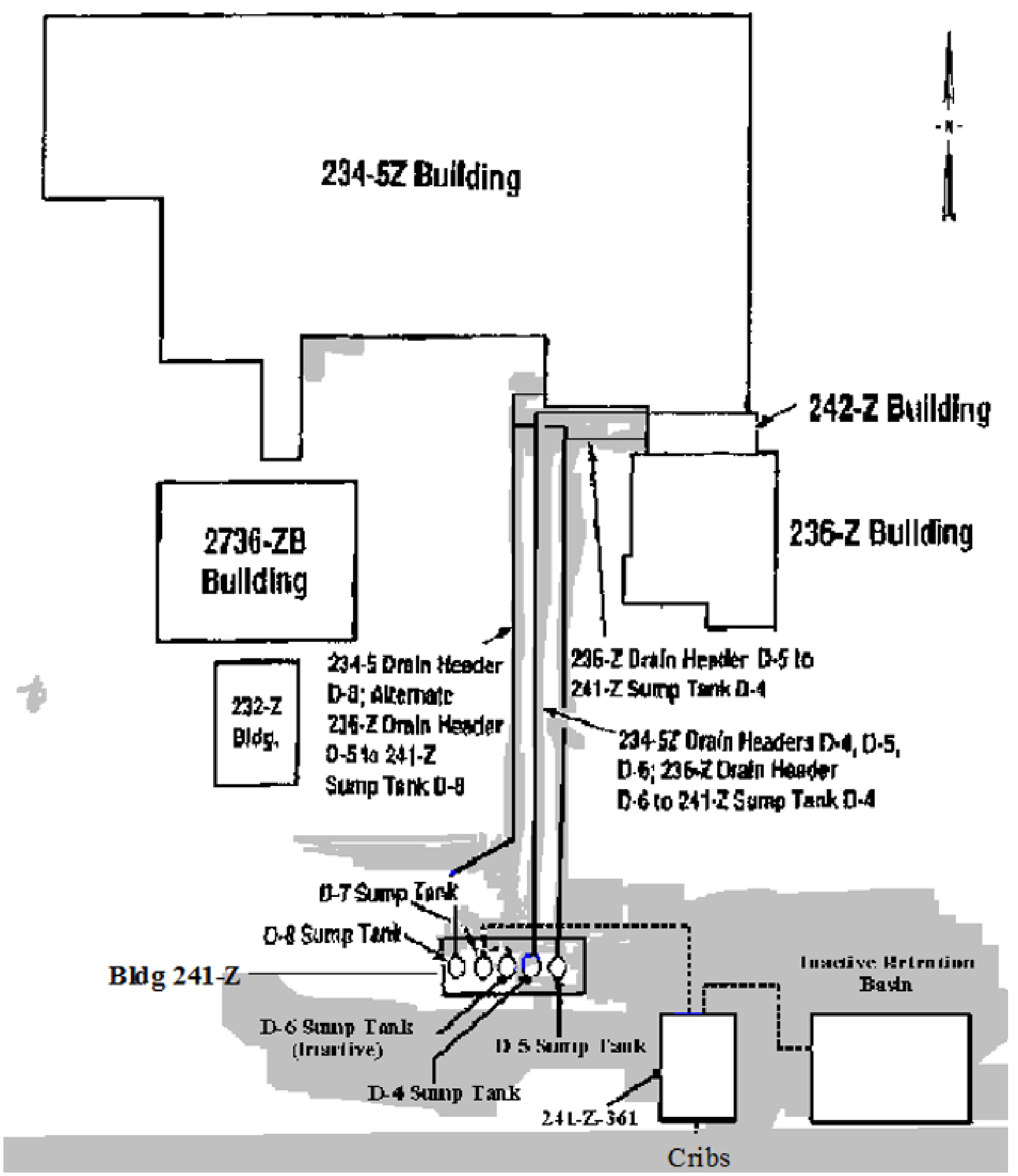

Figure 2-3. PFP Drain System (Historical Configuration)

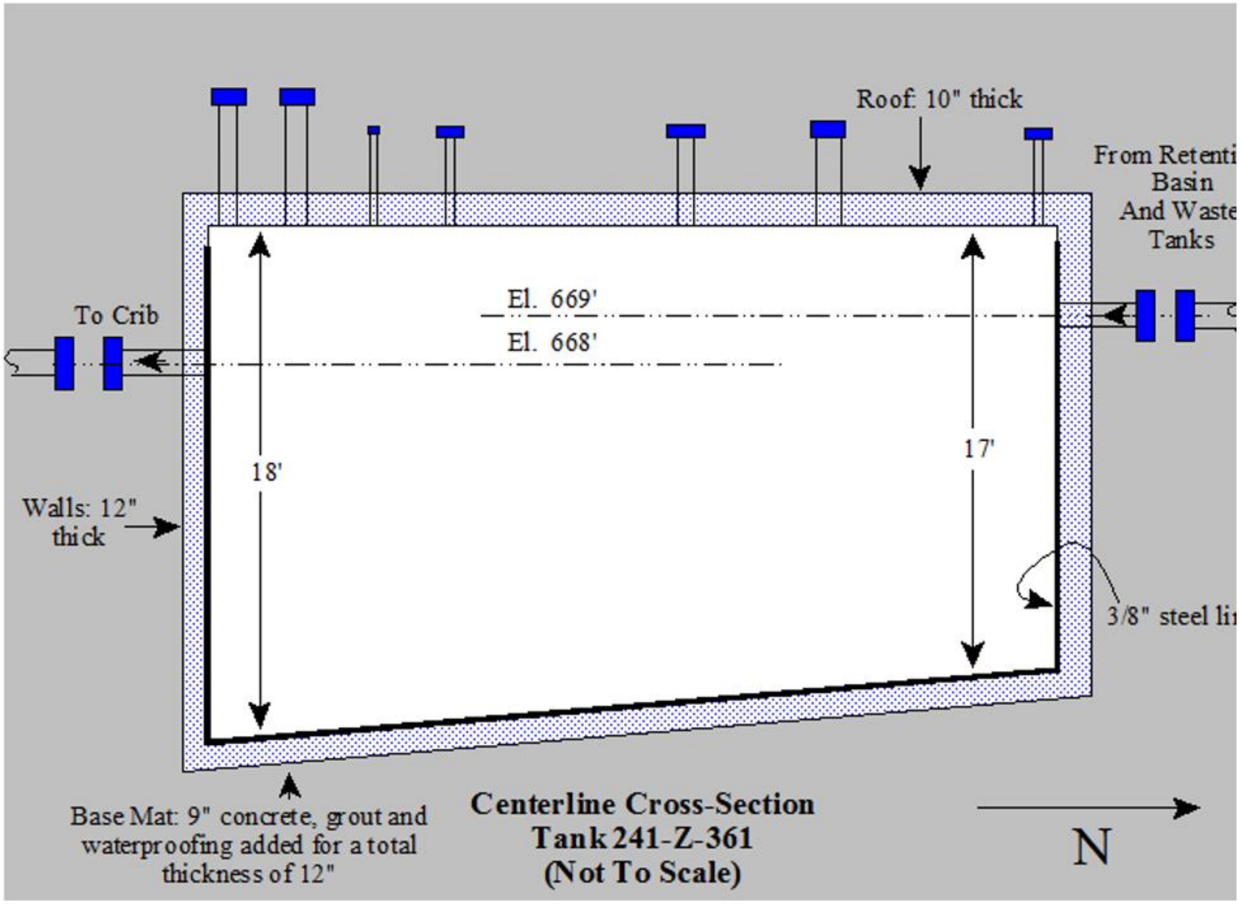

Figure 2-4. Section View of Tank 241-Z-361

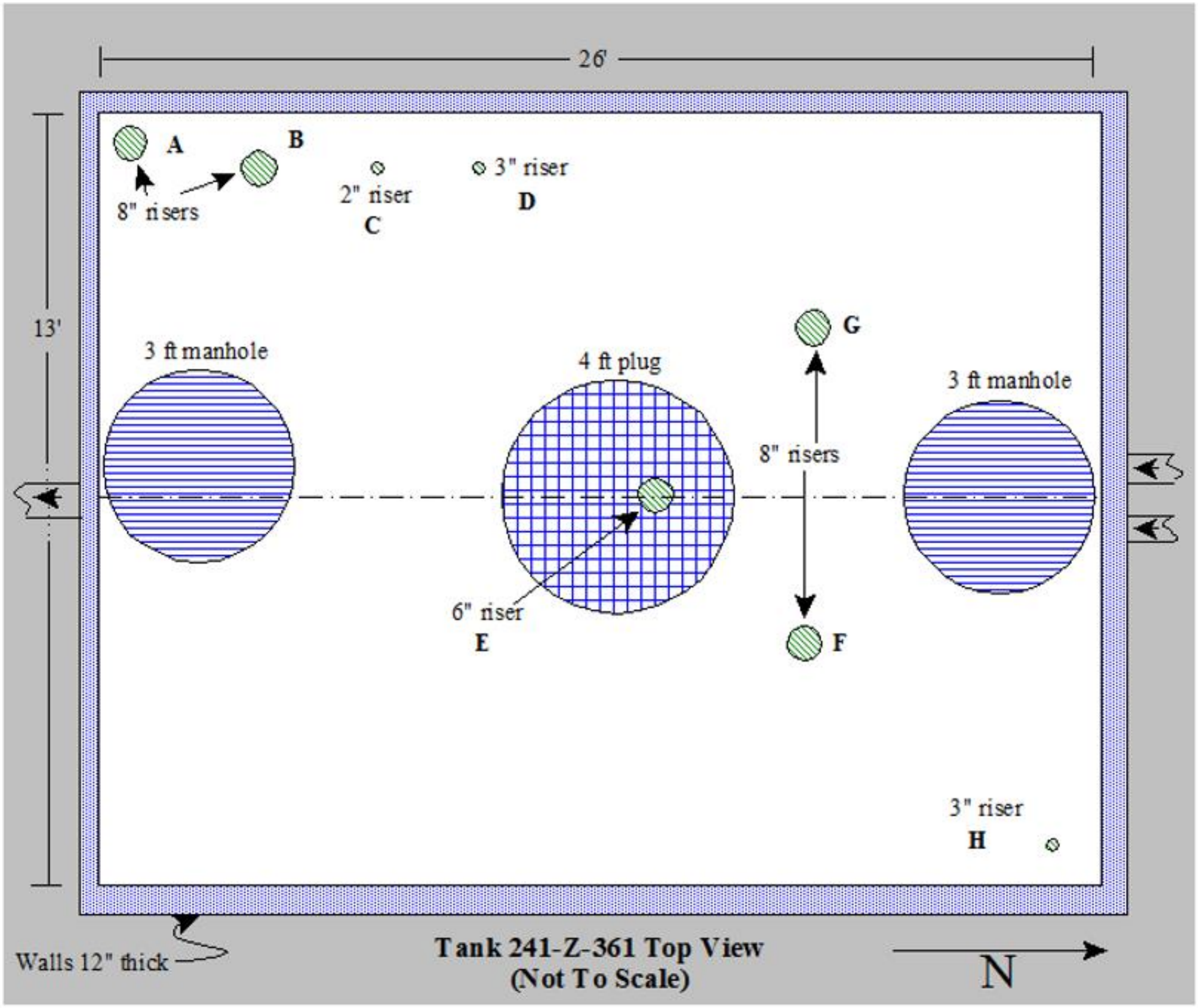

Figure 2-5. Top View of Tank 241-Z-361

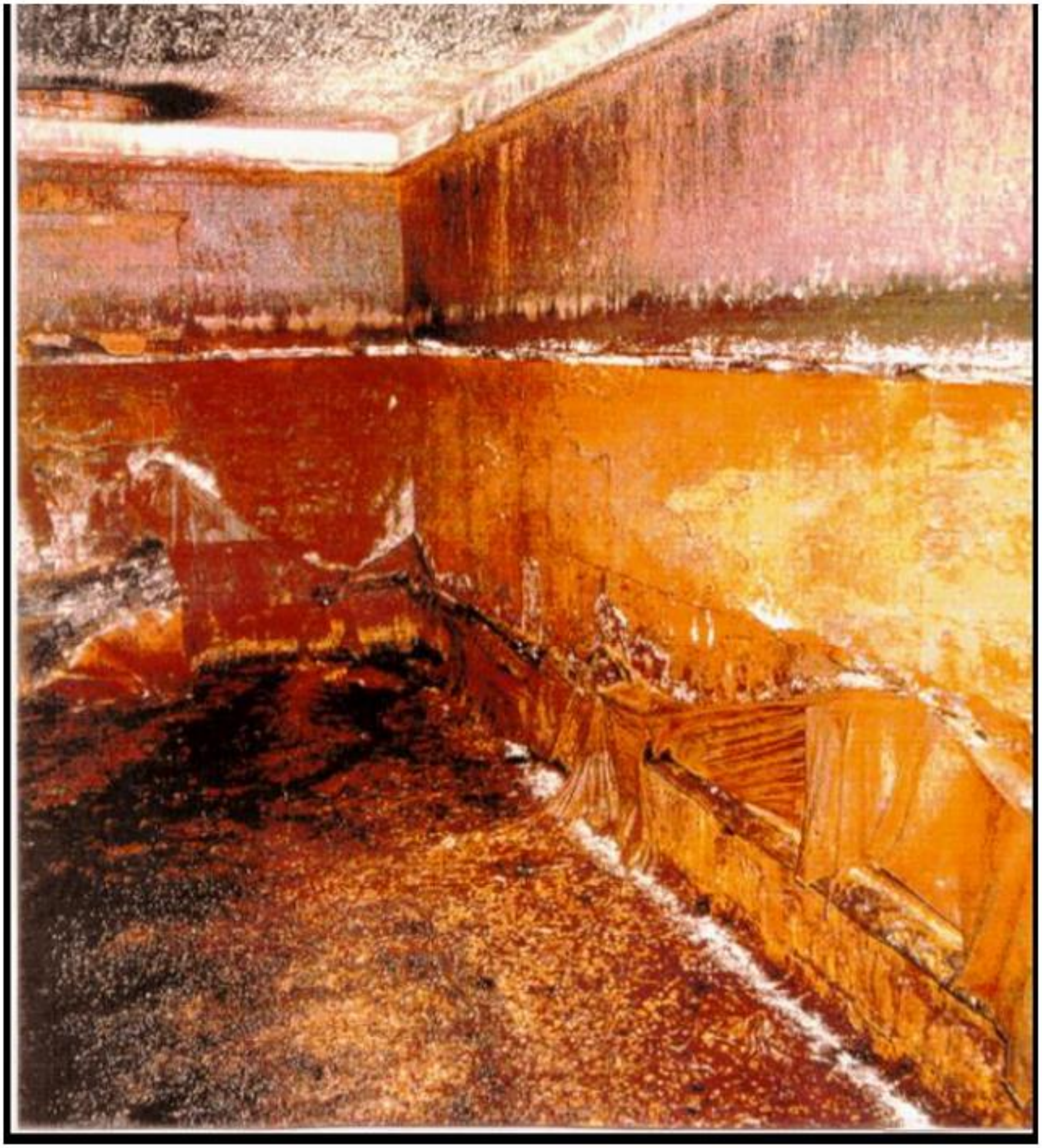

Figure 2-6. Tank 241-Z-361 Interior

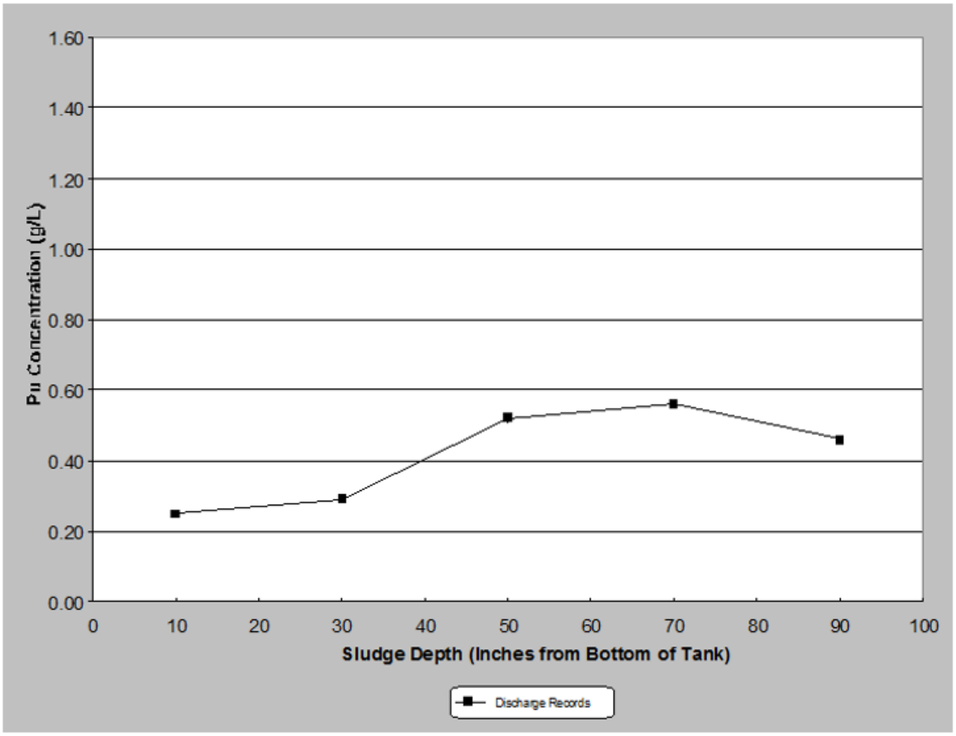

Figure 2-7. Predicted Plutonium Concentration Versus Depth Based on Discharge Records

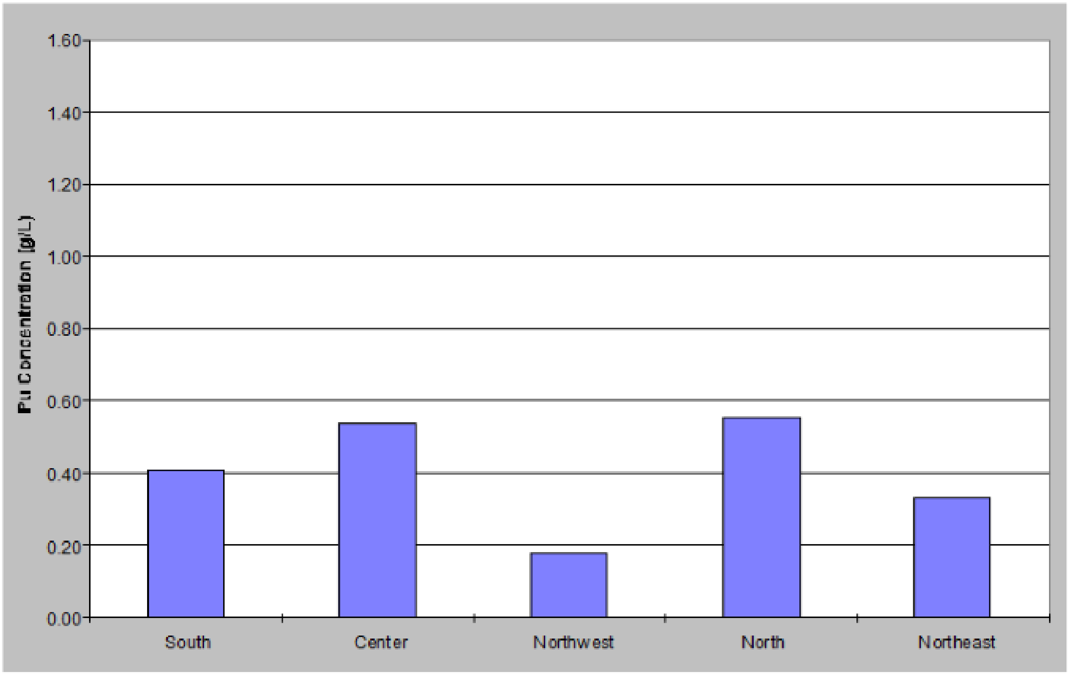

Figure 2-8. Average Plutonium Concentration Versus Location (1977)

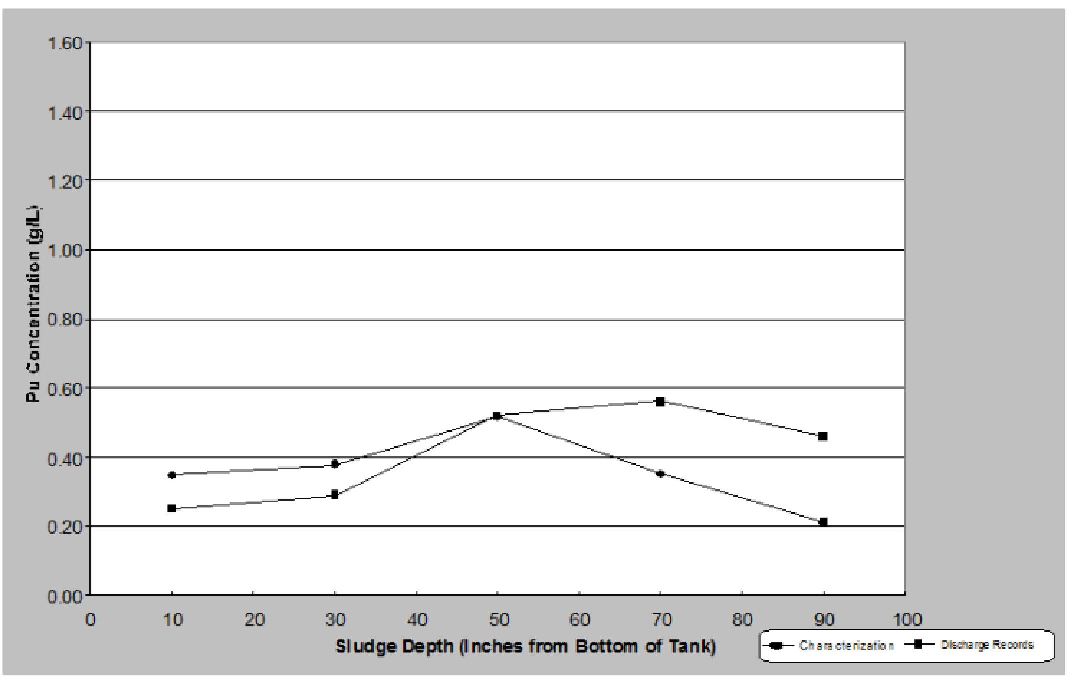

Figure 2-9. Average Plutonium Concentration Versus Depth

This page intentionally left blank.

3.0 Hazard and Accident Analyses

3.1 Introduction and Summary

3.1.1 Introduction

This chapter documents the hazard and accident analyses performed for the surveillance and maintenance of Tank 241-Z-361. The principal guidance documents used in the performance and preparation of the hazard and accident analyses were DOE-STD-3009-2014; DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*; DOE-STD-1186-2016, *Specific Administrative Controls*; and DOE-STD-1120-2016. Tank 241-Z-361 is a Hazard Category 2 nuclear facility and the rigor of this chapter is intended to meet the requirements and guidelines associated with a Hazard Category 2 nuclear facility.

Tank 241-Z-361 is an inactive, isolated, underground settling tank that presently contains approximately 75 m^3 (2,649 ft^3) of layered wet sludge contaminated with approximately 29 kg (63.9 lb) of total plutonium inventory. Tank 241-Z-361 is in a mode of long-term, continuing storage, surveillance, and maintenance while awaiting a planned tank remediation process.

The purpose of this chapter is to perform hazards and accident analyses to identify the SSCs and controls required for the safe surveillance and maintenance of Tank 241-Z-361. The hazard and accident analyses consist of hazards identification, facility hazard categorization, hazards evaluation, and quantitative accident analyses. The hazards identification results incorporate bounding estimates of hazardous material and energy quantities, forms, and locations. The facility hazard categorization establishes the hazard category of Tank 241-Z-361 in accordance with DOE-STD-1027-92. The hazards evaluation places the identified hazards within the context of the S&M activities associated with the tank and specifies controls based on the principles of defense-in-depth, worker safety, and environmental protection. The quantitative accident analyses take representative and unique deviations from the hazards evaluation, systematically analyze potential accident sequences and consequences, and identify any controls required to prevent or mitigate the accidents.

3.1.2 Summary

The safety analysis documented in this chapter is a comprehensive analysis of the potential upsets that could occur at Tank 241-Z-361 resulting in significant consequences. The accidents analyzed represent bounding scenarios that cover less significant upsets. As a result of these analyses, Technical Safety Requirement (TSR) level controls have been identified to prevent, and in some cases mitigate, the consequences of these accidents, reducing them to acceptable Risk Bins.

3.2 Requirements

The hazard and accident analyses in this chapter are prepared to comply with DOE-HDBK-3010-94; 10 CFR 830, "Nuclear Safety Management, Subpart B, Safety Basis Requirements"; and DOE-STD-3009-2014, the acceptable methodology defined in 10 CFR 830,

Table 2, for preparing a documented safety analysis. A facility hazard categorization was performed using DOE-STD-1027-92. In addition, general guidance is provided by *Guidelines for Hazard Evaluation Procedures* (AIChE 1992), issued by the Center for Chemical Process Safety of the American Institute of Chemical Engineers.

3.3 Hazards Analysis

3.3.1 Hazards Analysis Methodology

3.3.1.1 Hazard Identification Methodology

The hazard identification methodology used for the hazards analysis consisted of determining the presence of hazardous materials and energy sources.

The hazardous materials, which include radioactive and non-radioactive toxic materials, were identified for Tank 241-Z-361 from several sources: previously conducted hazards analyses, a facility walkdown, radioactive and hazardous material inventory reports, the Tank 241-Z-361 operating history, and existing and past facility safety documentation, including the final revision of the JCO from the 1997 USQ. Existing and past facility safety documentation provides an indication of areas of concern and ensures that hazards remaining from past operations are identified.

While previous hazards analyses had been conducted for the tank, a new hazards analysis (CP-58851, *2015 Tank 241-Z-361 Hazards Analysis*) was performed in 2015 using the current methodology of PRC-STD-NS-8739 and PRC-PRO-NS-700, *Safety Basis Development*. This hazards analysis focused on the anticipated operations involved with the long term S&M activities associated with the tank. The JCO sludge characterization activities involving push mode core sampling, the tank bridge, and OTC and OTC weather enclosure, were not analyzed in this hazards analysis and were removed from the DSA. These activities were driven and authorized by the JCO and once completed, the bridge was dismantled and the OTC and OTC weather enclosure were removed. Should another sludge characterization effort be needed in the future, a hazards analysis shall be conducted specific to those activities.

The tank's hazards identification process was performed by a multi-disciplinary team using a "checklist" methodology where a specific list of items is assessed to identify known types of hazards. Personnel from the PFP organization were involved in this hazards analysis to provide the history and current status of the tank and to aid in identifying the scope of the anticipated S&M activities and the hazards associated with those activities. The objective was to systematically and comprehensively identify the natural and man-made hazards, with respect to form, type, location, and quantity, associated with the facility, and as specified in DOE-STD-3009-2014.

As part of completing the hazard identification process, standard industrial hazards were identified, documented, and then screened from further evaluation in the safety basis development effort. Likewise, insignificant hazards from a DSA development perspective were also screened from further evaluation. These insignificant hazards from a DSA development perspective include localized spread of contamination, external skin contamination, minor radiological uptake, and occupational levels of radiation exposure addressed by the radiation protection program. The multi-disciplinary team also identified the safety management programs that exist to mitigate these types of hazards.

3.3.1.2 Hazard Evaluation Methodology

The Tank 241-Z-361 hazards evaluation was a structured and systematic examination of the hazardous conditions identified during the hazard identification process. A multi-disciplinary team of individuals, including safety analysts, facility personnel (operations and engineering) and subject matter experts (SMEs)(e.g., radiation protection, fire protection, industrial safety/hygiene, and environmental SMEs) performed the hazards evaluation using a table to record the identified hazard, the material at risk (MAR), the causes of the hazard, potential accidents that could result from the presence of each hazard, the frequency category, and the unmitigated consequence category to the maximally exposed offsite individual (MOI), onsite co-located worker (CW), facility worker, and the environment. The method of detection and safety function as well as candidate engineering and administrative controls were also identified for each hazard based on preventing or mitigating the consequences.

The qualitative assessment of the frequency and consequences for each hazardous condition took into consideration the impact of passive SSCs listed in the hazard analysis but not the impact of planned controls.

The consequence of each hazardous condition was ranked by group consensus using Table 3-1.

Table 3-1. Consequence Thresholds Used in the Hazards Analysis

Consequence Level	Public[1,4]	Co-located Worker[2,4]	Facility Worker[3]
High	≥ 25 rem TED or ≥ PAC[5]-2	≥ 100 rem TED or ≥ PAC-3	Prompt death, serious injury, or significant radiological and chemical exposure
Moderate	≥ 5 rem TED or ≥ PAC-1	≥ 25 rem TED or ≥ PAC-2	No distinguishable threshold
Low	< 5 rem TED or < PAC-1	< 25 rem TED or < PAC-2	No distinguishable threshold

Table 3-1. Consequence Thresholds Used in the Hazards Analysis

Consequence Level	Public[1,4]	Co-located Worker[2,4]	Facility Worker[3]

Notes:

[1] MOI – A hypothetical individual defined to allow dose or dosage comparison with numerical criteria for the public. This individual is an adult typically located at the point of maximum exposure on the Department of Energy (DOE) site boundary nearest to the facility in question (ground level release), or may be located at some farther distance where an elevated or buoyant radioactive plume is expected to cause the highest exposure (airborne release) – see DOE-STD-3009-2014 Section 3.2.4.2. The MOI used here is not the same as the Maximally Exposed Individual or the Representative Person used in DOE Order 458.1 for demonstrating compliance with DOE public dose limits and constraints.

[2] A co-located worker at a distance of 100 (328 ft) meters from a facility (building perimeter) or estimated release point.

[3] A worker within the facility boundary and located less than 100 (328 ft) meters from the release point.

[4] Although quantitative thresholds are provided for the MOI and co-located worker consequences, the consequences may be estimated using qualitative and/or semi-quantitative techniques.

[5] DOE's Protective Action Criteria are defined by Advanced Technologies and Laboratories International, Inc. in "Protective Action Criteria (PAC): Chemicals with AEGLs, ERPGs, & TEELs," Rev 27, February 2012. This is available at energy.gov/ehss/protective-action-criteria-pac-aegls-erpgs-teels-rev-29-chemicals-concern-may-2016.

The frequencies were obtained by team consensus and categorized using Table 3-2.

Table 3-2. Frequency Categories used in the Hazards Analysis

Estimated Annual Frequency	Description: Based on the initiating event(s) postulated
Anticipated (A) 1E-02/yr < to < 1E+00/yr	The hazardous condition has occurred or is likely to occur during the lifetime of the facility.
Unlikely (U) 1E-04/yr < to < 1E-02/yr	The hazardous condition is foreseeable, but unlikely to occur during the lifetime of the facility.
Extremely Unlikely (EU) 1E-06/yr < to < 1E-04yr	The hazardous condition is perhaps possible, but extremely unlikely to occur during the lifetime of the facility.
Beyond Extremely Unlikely (BEU) < 1E-06/yr	The hazardous condition is considered too improbable to warrant further consideration.

The risk class for each of the hazards was then determined from the unmitigated consequences and frequencies using Table 3-3.

Table 3-3. Risk Bin Values

	Beyond Extremely Unlikely Below 10E-06/yr	Extremely Unlikely 10E-04 – 10E-06/yr	Unlikely 10E-02 – 10E-04/yr	Anticipated Above 10E-02/yr
High Consequence	III	II	I	I
Moderate Consequence	IV	III	II	II
Low Consequence	IV	IV	III	III

3.3.2 Hazard Analysis Results

The results of the hazards analysis, which consisted of identifying and evaluating hazards related to the Tank's condition and anticipated S&M activities, are summarized below. The following sections provide the radiological and hazardous inventories, facility categorization and an evaluation of the potential hazards and hazardous energies associated with the Tank. The hazards are grouped into categories based on accident phenomenology and consequence severity.

3.3.2.1 Summary of Hazards Inventory

The Tank 241-Z-361 hazards inventory is a result of the sludge remaining inside the tank from past PFP processes. The sludge contains a nuclear fissile material hazard inventory and a hazardous waste inventory. The tank headspace atmosphere does not contain flammable gases.

3.3.2.1.1 Radiological Inventory

The most recent characterization data was obtained from tank sludge core samples taken in 1999 to fulfill the JCO objectives. Based on this characterization data, Tank 241-Z-361 is estimated to contain about 29 kg (63.9 lb) of fuels-grade plutonium (HNF-2024). The composition of this fuels-grade plutonium isotopic distribution is provided in Table 3-4 below (HNF-15500). The mass-weighted average is appropriate because the Tank was part of the low-salt waste disposal path from all PFP processes, including the incinerator (232-Z), the Plutonium Reclamation Facility (236-Z), and the Waste Treatment Facility (242-Z). The use of the >10% ^{240}Pu isotopic ratio conservatively assumes that all this material has the higher hazard potential of the latter N-Reactor fuels-grade production runs rather than the earlier weapons-grade production runs (HNF-15500).

Table 3-4. >10% ^{240}Pu Composition

Isotope	Normalized Mass Fractions
^{238}Pu	2.05E-03
^{239}Pu	7.94E-01
^{240}Pu	1.59E-01

Table 3-4. >10% ^{240}Pu Composition

Isotope	Normalized Mass Fractions
^{241}Pu	1.37E-02
^{242}Pu	6.54E-03
^{241}Am	2.41E-02
Total	1.00E+00

3.3.2.1.2 Chemical Inventory

Section 2.3.1.2 provides details on the chemical inventory of Tank 241-Z-361. In summary, the tank contains several hazardous waste constituents that may exceed regulatory thresholds. The tank sludge also contains PCBs. Several volatile organic compounds have been detected in the dome space of the tank, however the ranges of these compounds are below OSHA permissible exposure limits. The carbon dioxide content of the tank exceeds OSHA limits and the nitrous oxide content exceeds NIOSH limits. A qualitative assessment of the adequacy of controls concluded that the existing Safety Management Programs (SMPs) are adequate to protect all receptors and the environment and that no additional TSR controls are warranted.

3.3.2.2 Facility Hazard Categorization

A preliminary hazard categorization of Tank 241-Z-361 was performed to evaluate the types of safety analysis appropriate for this facility. HNF-2024, Appendix A documents an initial hazard categorization of this tank per DOE-STD-1027-92. The initial hazard categorization concluded that Tank 241-Z-361 should be designated Hazard Category 2. Subsequent characterization activities have been performed that show the plutonium concentration in the tank is less than the upper bound analyzed in HNF-2024, Appendix A, however the plutonium inventory remains consistent with a Hazard Category 2 ranking. Therefore, the final hazard category of Tank 241-Z-361 is Hazard Category 2.

3.3.2.3 Facility Hazards Evaluation

The hazards identified during the hazards analysis have been grouped into categories based on accident phenomenology and consequence severity. These hazard categories are discussed and evaluated in the sections below.

3.3.2.3.1 Tank Structural Failure

These are events that result in collapse of the tank roof or failure of the risers in the tank roof that cause a significant release of radioactive aerosols to the atmosphere and possibly gross contamination of workers. The collapse can range from the entire tank roof to failure of just a riser. Several events in this category have the potential to produce High consequences to the facility worker.

During the interim period before remediation, postulated causes for failing the tank roof or risers include the following:

- Putting an excess load (people or equipment) on the tank.
- Inadvertently driving a vehicle/crane onto or too close to the tank.
- Various load drop events.
- Application of excessive lateral load or torque during riser entry activities.
- Collapse of degraded riser due to weight of installed Y-adapter and breather filter.
- Pull out of riser with crane or winch because of failure to disconnect rigging before withdrawing rigging.
- Large spills or leaks caused by breaking nearby water lines during excavation activities that cause the tank to collapse.
- Natural phenomenon: seismic event, heavy snow or ash loading.

This hazard is carried forward into a bounding tank collapse accident analysis in Section 3.4.

3.3.2.3.2 Tank Pool Fire

These are events that result in a fire involving the tank contents that cause a significant release of radioactive aerosols to the atmosphere and possibly gross contamination of workers. The events in this category have the potential to produce High consequences to the facility worker.

The following activities are postulated causes for a fire involving the tank contents:

- Spray release of crane, truck, or other vehicle hydraulic fluid with an ignition source that breaches the tank.
- Vehicle driven on top of Tank 241-Z-361 causes the tank to collapse and breaches the vehicle's fuel tank. The fuel ignites and burns the sludge in the tank.

This hazard is carried forward into a bounding tank pool fire accident analysis in Section 3.4.

3.3.2.3.3 Flammable Gas

These are events that result in potential ignition of flammable gas in the tank head space causing damage to the tank roof and a release of radioactive aerosols to the atmosphere.

The tank was opened after being isolated for more than twenty years and the vapor space was sampled and tested for flammable gas. The vapor space was found to have only minute traces of flammable gases (less than 25% of the LFL). Since the tank maintained itself less than flammable after more than ten years in a "sealed" condition (though likely not airtight as cracks in the tank have been observed), the addition of the HEPA filtered passive ventilation path was not considered important for preventing a flammable tank atmosphere from forming; however, a passive, filtered ventilation path was installed to ensure the tank is at atmospheric pressure. No significant increases in the concentration of flammable vapor, such as that associated with a GRE, were reported during monitoring performed while conducting push mode core sampling of Tank 241-Z-361, which is a local waste disturbing activity.

Originally, Tank 241-Z-361 was conservatively designated as a tank that could have a GRE during waste disturbing activities – Flammable Gas Category 3. However, the evidence gained during performance of local waste disturbing activities showed no release of flammable gas

(HNF-2024). As a result of this new information gained, the tank is designated as non GRE. Globally waste disturbing activities are not planned during this period, and were not evaluated as part of this DSA.

3.3.2.3.4 Minor Releases

These are events that result in minor releases of radioactive aerosols with no damage to the basic tank structure. The events in this category produce low consequences. This includes unfiltered releases of contamination because of wind effects or atmospheric pressure changes when opening risers, as well as minor contamination events when withdrawing equipment from the tank.

3.3.2.3.5 Criticality

Tank characterization activities over a 20-year period and criticality analysis confirm the tank is a limited control facility. The form and distribution precludes an inadvertent criticality. There is no evidence of a time related phenomena that would alter these conclusions. *CSER 14-002: Criticality Safety Evaluation Report for Underground Settling Tank 241-Z-361* (CHPRC-02229) assumes that no additional fissile material will be added to the tank and that no intrusive operations are permitted that would significantly alter the fissile distribution in the tank. As such, the Criticality SMP provides adequate criticality controls.

3.3.2.3.6 Organic or Nitrate Reactions

These are events postulated to result in an ignition of organic or nitrate compounds potentially contained in the tank with subsequent release of radioactive aerosols. For an organic or nitrate reaction to occur, the waste must be dry and ignited by an energetic heat source. Postulated initiators are highly unlikely and include lightning strike and vehicle impact into riser resulting in a spill of burning fuel into the tank. The sampling and chemical analysis of the solid waste in the tank revealed only minute amounts of organic and nitrates in the tank. The tank also has a large amount of water present in the sludge. Based on these analyses, no tank hazards were postulated on the basis of organic or nitrate reactions.

3.3.2.3.7 Industrial or Contamination Hazards

These are events involving normal industrial hazards or small quantities of radioactive contamination. These events include small spills of radioactive material during tank S&M activities as well as fires involving small amounts of contaminated waste. Localized spread of contamination, external skin contamination, minor radiological uptakes, and occupational levels of radiation exposure resulting from these events are considered insignificant from a DSA development perspective and are addressed by 10 CFR 835. Potential causes for these events include improperly used or failed equipment and ignition of combustible materials. These events are considered standard industrial hazards.

3.3.2.3.8 Leak to Soil

These are potential leaks to the soil column caused by general tank degradation. Also, events such as water line breaks that result in localized flooding above the tank and intrusion of water into the tank exacerbating a tank leakage condition. Leaks to the soil column are low consequence events since the release stays confined to the soil. Large spills of water on top of the tank may overload the tank roof causing a roof collapse. The hazards and consequences of a tank collapse are evaluated in Section 3.3.2.3.1.

3.3.2.3.9 Pressurized Release

These are events that result in pressurized releases from the tank. The events in this category have the potential to produce low consequences due to worker injury (caused by ejected blind flange) or unfiltered release of plutonium particulate from the tank. A pressurized release event would be a concern from a direct worker injury and inhalation dose hazard standpoint. When the tank was opened after twenty years of isolation, no pressurization of the tank was observed. During the interim period prior to remediation, an internal pressurized release from the tank is not credible because of the continuous vent path established through a riser/HEPA filter arrangement. The remaining sources of pressurized releases are related to maintenance activities and are protected by the SMPs.

3.3.2.3.10 Tank Pressurization Evaluation

Small cracks or holes in Tank 241-Z-361 would keep the Tank from significantly pressurizing and allow atmospheric breathing. The qualitative videograph taken of the Tank in 1999 confirms such cracks. However, the existence of relief paths for the Tank could not be assured before Tank 241-Z-361 was opened during Phase I of the JCO. HNF-2024, Appendix E was prepared to evaluate the potential for tank pressurization and the resulting hydrogen concentration. Furthermore, Appendix E evaluates the expected flow rate as the tank is vented from this pressurized condition. This appendix formed the basis for developing the controls needed to safely vent Tank 241-Z-361 during Phase I. As a result of JCO Phase I activities, the tank has a continuous vent path, and it, therefore, cannot be pressurized. The remaining potential sources of pressurized releases are associated with small volumes of pressurized gas that might be used for HEPA filter testing and maintenance which are protected by the SMPs.

3.3.2.3.11 Standard Industrial Hazards

DOE-STD-3009-2014 defines a standard industrial hazard (SIH) as “hazards that are routinely encountered in general industry and construction” and “those in which national consensus codes and/or standards (e.g., Occupational Safety and Health Administration (OSHA) regulation) defines and regulates appropriate worker safety practices.”

DOE-STD-3009-2014 requires analysis of worker safety, but it also notes, “The DSA is not intended to deal extensively with chemicals that can be safely handled by implementation of a hazardous material protection program.” Based on discussion in Section 3.3.2.1.2, there are no chemical accidents identified that require analysis.

As part of completing the hazard identification process, these SIH are first identified, documented, and then screened from further evaluation in the safety basis development effort. Likewise, insignificant hazards from a DSA development perspective may be screened from further evaluation. These insignificant hazards from a DSA development perspective include localized spread of contamination, external skin contamination, minor radiological uptake, and occupational levels of radiation exposure addressed by 10 CFR 835.

3.3.2.4 Summary

Tank 241-Z-361 is in an S&M mode. Former concerns have been eliminated through tank characterization efforts that were associated with reactions of a presumed organic layer and buildup of flammable gases. Tank structural failure provides a mechanism to energetically release some of the tank contents as well as introduce a fire into the tank that burns the tank sludge. Table 3-5 provides the bounding accident scenarios for the hazards that were not screened out during the preliminary hazards analysis (PHA).

Table 3-5. Accident Scenarios and Related Hazard IDs

Accident Scenario	Accident Type	Scenario Description	PHA Event Identification
Tank Collapse (Section 3.4.1)	Spill	Collapse of the tank roof due to either an overload or seismic event that results in the concrete roof and the soil overburden dropping into the tank.	Z361-1-16, Z361-1-18, Z361-Z-20, Z361-1-27, Z361-1-30, Z361-1-51, Z361-1-95.
Tank Pool Fire (Section 3.4.2)	Fire	Collapse of the tank roof due to vehicle overloading that causes a rupture of the vehicle's fuel tank. The fuel spreads across the top layer of sludge, ignites, and burns.	Z361-1-38, Z361-1-69

3.4 Accident Analysis

The potential dose consequences of the Tank 241-Z-361 accidents selected for analysis are determined using RADIDOSE Version 3.0, a dose consequence spreadsheet for the Hanford Site.

The following information applies to both selected accident scenarios.

Releases are modeled as ground-level, point releases with no plume or building wake effects.

Leak Path Factor (LPF) and Damage Ratio (DR) values of 1.0 are used.

Airborne Release Fractions (ARFs) and Respirable Fractions (RFs) were developed using guidance from DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.

The dose to the CW is evaluated at 100 m (328 ft) from the Tank 241-Z-361. The nearest site boundary, 12,500 m (7.8 mi) to the west of the Tank 241-Z-361 (distance taken from HMAPS, part of the Hanford Geographic Information System), was used as the location for the MOI receptor.

The atmospheric dispersion factor, χ/Q, accounts for the effects of atmospheric dispersion of material released under postulated accident conditions at a specified receptor location. It is defined as the concentration in air per unit release rate of the material from an upwind source at a particular receptor location. The value of χ/Q is a function of the type of release (elevated, buoyant, ground-level, etc.), release duration, wind speed, atmospheric stability class, and distance from the source (only centerline or under centerline, ground-level values are considered). The default RADIDOSE χ/Q value of 3.28E-02 s/m^3 is used for a ground-level, no-building-wake release evaluation at the 100 m (328 ft) CW receptor location; this is due to there no longer being sufficient residual structure to create building wake influences.

The material form is modeled as soluble; a soluble material produces a higher dose for the CW, the limiting receptor for the 200 Area facilities. Inhalation of soluble aerosols produces higher doses than inhalation of oxide for transuranic (TRU) material.

The consequence analysis combines the results of the source term, atmospheric dispersion, and International Commission on Radiological Protection (ICRP) 68 (onsite) and 72 (offsite) reference man-dose models to estimate radiological consequences to onsite (CW) and offsite (MOI) individuals.

Receptor doses are reported as Total Effective Dose (TED).

Copies of the output sheets from RADIDOSE calculations for the applicable accident analyses are given in Appendix B. The dose consequences to the CW and MOI receptors from the RADIDOSE sheets are summarized in each accident analysis description subsection.

3.4.1 Tank Collapse

The 241-Z-361 Tank Collapse accident analyzes the collapse of the tank roof due to either an overload or seismic event that results in the concrete roof and the soil overburden dropping into the tank. The tank is constructed of reinforced concrete and is 7.93 m (26 ft) long and 3.96 m (13 ft) wide and varies in depth between 5.2 m (17 ft) at the north end and 5.49 m (18 ft) at the south end. The roof is 25.4 cm (10 in.) thick and an additional 4 in. of concrete has been applied in sealing the tank. There is approximately 0.61 m (2 ft) of dirt on top of the tank. The waste is approximately 2.39 m (94 in.) deep. The waste is wet sludge, which varies in solid content, but on average contains about 30 percent solids. The average plutonium content is 0.39 g/L. While data averaged from past measurements yields a 99 percent confidence plutonium density of 0.59 g/L, the highest 99 percent confidence measurement is 0.61 g/L. The accident analyses conservatively use the 0.61 g/L plutonium value.

The sludge is expected to stay a wet sludge based on information provided in HNF-8735. Further, HNF-8735 states:

> The tank has not changed significantly in level since 1975. The level of the sludge surface, and consequently the apparent depth of the sludge in the tank, is very similar in the two sets of photographs. The level is estimated by comparing the relative distance from the sludge surface to the roof of the tank in both photographs. This observation suggests that the level of waste in the tank has not changed substantially over the years between 1975 and 1999.

This report further states:

> The video record made in 1999 was compared to the photomosaic of the tank interior taken in 1974 or 1975, after removal of the supernatant liquid (RHO-ST-44). These two records indicate that residual free liquid in the tank was confined largely to an area in the

> extreme south end of the tank and that little liquid was apparent at the sludge surface elsewhere in the tank. Free liquid also is visible in the 1999 video in disturbed areas immediately surrounding the dry wells in Risers F and G and in the north manhole, as well as in cracks in the sludge surface in the northern portion of the tank.

Furthermore, the sludge has been determined to be about 70 percent water.

Between the 1975 observation and 1985, the tank remained passively ventilated. Between 1975 and its reopening in 1998, the tank was "sealed," although the tank atmosphere constituents measured in 1998 suggest that the tank was still breathing due to barometric pressure changes even during this period (e.g., the lack of hydrogen). Since 1998, the tank has been passively ventilated through a HEPA filter that precludes the possibility of pressure buildup. Because the tank has been quiescent for more than 25 years, and there is a lack of any appreciable drying mechanism (i.e., heat), the tank is evaluated for unmitigated accident analysis purposes as a wet sludge.

The entire roof is assumed to fall into the tank and impact the waste. The frequency of this event is "anticipated" due to the structural uncertainty of the tank.

3.4.1.1 Source Term Analysis

The source term resulting from the tank roof collapse onto the wet sludge is determined using the five factor formula from DOE-HDBK-3010-94:

$$Q = (\mathrm{MAR})(\mathrm{DR})(\mathrm{ARF})(\mathrm{RF})(\mathrm{LPF}) \qquad \textbf{Eq. 3-1}$$

where:

Q	=	source term released (g)
MAR	=	material at risk (g)
DR	=	damage ratio
RF	=	respirable fraction
ARF	=	airborne release fraction
LPF	=	leak path factor

This accident source term assumes a solid (tank roof) impacts a liquid (tank waste). The data in Bogen (1999) indicates the waste has liquid film on the surface. While DOE-HDBK-3010-94 does not provide data on the release from the impact of a solid onto a liquid, it does provide experimental data on the release from splashing of a liquid impacting a solid. From this data, Owczarski and Mishima (1996), *Airborne Release/Respirable Fractions for Dome Collapse in HLW Tanks,* derived a method for applying correlations for a liquid spill to an impact of a solid onto a liquid.

Section 3.2.3.1 of DOE-HDBK-3010-94 provides the following equation for the ARF of a liquid spilling onto a hard surface:

$$\mathrm{ARF} = (3)8.9\text{E-}10(\mathrm{Arch})^{0.55} \qquad \textbf{Eq. 3-2}$$

where:

$$\text{Arch} = \text{Archimedes Number} = (\text{density}_{air})^2 * (\text{spill height})^3 * g/(\text{solution viscosity})^2 \qquad \textbf{Eq. 3-3}$$

where:

density_{air} is in g/cc, spill height is in cm, solution viscosity is in poise, and g is a gravitational constant, 981 cm/s^2

The factor of 3 is applied in order to determine a bounding ARF for low-density aqueous solutions (DOE-HDBK-3010-94).

To find the ARF for a solid impacting a liquid, Owczarski and Mishima (1996) analyzed the inverse reaction of a liquid impacting a solid in the following text:

"To estimate the amount of liquid that is subject to aerosolization a semi-empirical model was devised. In the liquid spill experiments the liquid impacting the floor almost instantly produced a puddle on the order of one mm deep. Probably most of the aerosolization process occurred during this rapid spread. We can look at the object falling into the liquid similarly. The initial one mm of the liquid encountering the falling solid is rapidly accelerated around the object. This sheared layer would encounter like forces and receive some of the impact energy of the impacting object. This energy would result in the formation of liquid droplets."

RPP-12395, *Offsite Radiological Consequence Analysis for the Bounding Tank Failure Due to Excessive Loads Accident*, conservatively assumes a value of 3 mm (0.12 in.) for the sludge impacted as WHC-SD-WM-CN-051 states that is the thickness of a film of tank liquid if allowed to spread out on a flat surface. To determine the ARF of a solid impacting a liquid, the spill height in Equation 3-3 is determined by finding the velocity at which the solid impacts the 3 mm (0.12 in.) of liquid and the energy lost at impact. The impact velocity, V_1, is slowed to V_2 at 3 mm (0.12 in.) depth. The energy (with velocity V_{fl}) of the 3 mm (0.12 in.) fluid layer is some function of the average velocity ($V_{av} = 0.5[V_1 + V_2]$). Owczarski and Mishima (1996) assume the relationship is a simple multiplier α, where $V_{fl} = \alpha V_{av}$. From the set of liquid spill data examined, Owczarski and Mishima (1996) calculated the best fit for Equation 3-3 if $\alpha = 1.34$ and the actual impact velocity (V_1) is used for V_{av}.

To use this model for large solids impacting a liquid pool, a corrected fall height must be obtained by using $H = 0.5V_{fl}^2/g$. This height (H) is then used as the spill height in Equation 3-3.

The maximum tank depth is 5.49 m (18 ft) and the depth of the waste is 2.39 m (94 in.). The maximum distance the roof can drop is therefore 3.10 m (310 cm).

The impact velocity is:

$$V_1 = (2gh)^{1/2}$$
$$V_1 = (2 * 9.81\ \text{m/s}^2 * 3.10\ \text{m})^{1/2}$$
$$V_1 = 7.80\ \text{m/s}$$

The fluid velocity is:

$$V_{fl} = (1.34)(V_1) = 10.45\ \text{m/s}$$

The corrected height is then:

$$H = 0.5V_{fl}^2/g$$
$$H = 0.5(10.45\ m/s)^2/9.81\ m/s^2$$
$$H = 5.57\ m$$

A typical viscosity for tank supernate is 0.1 poise (RPP-5667, *Stochastic Consequence Analysis for Waste Leaks*). Therefore, Equation 3-3 may be solved by the following:

$$Arch = (1.187E\text{-}03\ g/cm^3)^2(557\ cm)^3 * (981\ cm/s^2)/(0.10\ poise)^2$$
$$Arch = 2.38E{+}7$$

Equation 3-2 is then:

$$ARF = (3)(8.9E\text{-}10)(2.38E{+}7)^{0.55} = 3.05E\text{-}5$$

RPP-12395 indicates the release fraction should be applied to a layer of liquid 3 mm (0.12 in.) thick. The volume of the waste in the tank that is involved in the release is therefore:

$$\text{Volume of release affected} = (3.96\ m)(7.93\ m)(0.003\ m) = 0.0942\ m^3 = 94.2\ L$$

The MAR for the quantity of plutonium is:

$$MAR = (94.2\ L)(0.61\ g/L) = 57.5\ g$$

The RF can approach 1.0 for aqueous solutions (DOE-HDBK-3010-94) so an RF of 1.0 will be assumed for this analysis. No leak path factor is assumed, and therefore a value of 1.0 is used.

The parameters for this calculation are therefore:

MAR	=	57.5g
DR	=	1.0
RF	=	1.0
ARF	=	3.0E-5
LPF	=	1.0

The source term from collapse of the tank roof onto the wet sludge is determined by Equation 3-1:

$$Q = (57.5g)(1.0)(1.0)(3.05E\text{-}5)(1.0) = 1.75E\text{-}3\ g$$

3.4.1.2 Consequence Analysis

The dose consequences to the CW and MOI for the unmitigated case of a ground-level release were calculated using the RADIDOSE spreadsheet. The source term parameters discussed in the previous section, distances associated with each receptor (CW – 100 m [328 ft] and MOI – 12,500 m [7.8 mi]) that determine the dispersion factors (χ/Q), dose conversion factors (DCFs) derived from ICRP 68 and ICRP 72, and a default breathing rate were used. The resulting dose consequences to the target receptors, and associated Risk Bins are presented in Table 3-6.

Table 3-6. Tank Collapse Consequences & Risk Bins

Location	CW TED (rem)	CW Risk Bin	MOI TED (rem)	MOI Risk Bin
Tank 241-Z-361	4.88E-01	III	4.30E-04	III

The following conservatisms were used in this analysis:

- The event initiator (whether an overload or seismic event) is assumed to catastrophically fail the Tank 241-Z-361 roof.
- The frequency of this event is considered Anticipated.
- A leak path factor of 1.0 is assumed.

The TED for the CW is significantly less than 25 rem, which corresponds to a Low consequence class. The TED for the MOI is significantly less than 5 rem, which also corresponds to a Low consequence class. With a frequency of Anticipated and Low consequence, the Risk Bins for both receptors are III.

No mitigated condition is considered because the unmitigated accident is a Risk Bin III/III event.

3.4.1.3 Comparison to the Evaluation Guideline

Offsite doses are compared to an evaluation guideline (EG). The EG is 25 rem total effective dose (TED). The dose estimates to be compared to it are the unmitigated doses received by the MOI at the site boundary for an exposure duration of two hours. The nominal exposure duration of two hours may be extended to eight hours if those release scenarios are especially slow to develop (DOE-STD-5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*).

The unmitigated dose from the tank collapse onto wet sludge does not challenge the EG of 25 rem. Therefore, safety class (SC) SSCs do not need to be considered for the MOI.

3.4.1.4 Summary of Safety SSCs and TSR Controls

The CW and MOI low dose consequences and anticipated frequency result in a Risk Bin III event. As such, Safety Class and Safety Significant SSCs are not required. The following hazard controls are established to reduce the risk of the event and protect accident assumptions, as well as provide protection to the facility worker and environment.

- <u>Defense in Depth Administrative Control (AC)</u>: The Vehicle Access AC reduces the frequency of this event, reducing the risk to the facility worker, by preventing an overload of the tank due a vehicle overload or heavy load drop. This control includes physical barriers to create spatial separation between the tank and adjacent traffic, vehicle access and speed limit controls, critical lift limits, and tank loading restrictions.
- <u>Defense in Depth Specific Administrative Control (SAC)</u>: The Material Management SAC reduces the frequency of the event by isolating the tank and restricting the

introduction of material and performs a mitigating function by protecting the source strength and criticality assumptions of the tank.

- <u>Defense in Depth AC:</u> The Excavation and Sampling AC reduces the frequency of the event by preventing intrusive sampling activities and aggressive excavation activities that could compromise the structural integrity of the tank.
- <u>Defense in Depth AC:</u> The SMP AC ensures that SMPs are established, implemented and maintained. Implementation of SMPs reduces the probability of an event occurring as well as mitigates the consequences of an event through applicable, established programs.

Table 3-7. Summary of a Tank Collapse

<table>
<tr><td colspan="6">Accident Title: Tank 241-Z-361 Collapse</td></tr>
<tr><td colspan="5">Accident Type: Spill</td><td rowspan="2">Initiators: Tank overloading; heavy load drop impact; seismic event
Energy sources: Vehicle operations; crane operations; excavation operations</td></tr>
<tr><td colspan="5">Location: Tank 241-Z-361
Activities: S&M activities; adjacent facility activities</td></tr>
<tr><td colspan="6">Hazards: Tank 241-Z-361 sludge contents; standard industrial hazards</td></tr>
<tr><th>Scenario</th><th>Freq</th><th>Consequence (rem TED and level)</th><th>Risk Bin</th><th>Control Designation</th><th>Controls</th></tr>
<tr><td rowspan="4">Collapse of the tank roof due to an overload, heavy load drop or seismic event that results in the concrete roof and the soil overburden dropping into the tank.</td><td rowspan="4">A*</td><td rowspan="4"><u>Unmitigated</u>
CW: 4.88E-01 (Low)
MOI: 4.30E-04 (Low)</td><td rowspan="4">
III
III</td><td>TSR AC (P)</td><td>Vehicle Access
Physical barriers, vehicle access limit, vehicle speed limit, critical lift limit, loading restriction</td></tr>
<tr><td>TSR SAC (M)</td><td>Material Management
Tank isolation, inventory control</td></tr>
<tr><td>TSR AC (P)</td><td>Excavation & Sampling
Sampling limit, excavation limit</td></tr>
<tr><td>TSR AC (P&M)</td><td>SMP
Hazardous Material Protection (P), Operational Safety (P)
Management, organization, and institutional safety (P)
Emergency preparedness (M)</td></tr>
</table>

Table 3-7. Summary of a Tank Collapse

*The unmitigated frequency for this accident is conservatively assumed to be anticipated (seismic events have been determined unlikely for the Hanford Site) as both operational activities and NPH are bounded by this accident.

A	=	Anticipated
AC	=	Administrative Control
CW	=	co-located worker
M	=	mitigative
MOI	=	maximally exposed offsite individual
NPH	=	natural phenomenon hazard
P	=	preventive
SMP	=	Safety Management Programs
TED	=	total effective dose
TSR	=	technical safety requirement
U	=	Unlikely

3.4.2 Tank Pool Fire

This accident analyzes a vehicle driving on top of the tank causing a failure of the tank roof. Heavy equipment with large fuel capacities is expected to be used during PFP demolition activities which will occur in the vicinity of the tank. As such, a large vehicle, i.e. a large excavator, containing 1,249 L (330 gal) of fuel is assumed in this event. The roof and vehicle collapse into the tank. Vehicle fuel is spilled into the tank when the vehicle fuel tank ruptures. The roof, soil overburden, and vehicle are assumed to sink into the sludge upon impact, which is 70 percent water, nearly 2.44 m (8 ft) deep. The impact of the vehicle and roof debris breaks up the crusted sludge layer on top of the wet sludge which sinks into the wet sludge as well. The ruptured roof punctures the vehicle's fuel tank during the collapse and the fuel spreads across the surface of the sludge. A spark is created during the collapse and the fuel ignites. The vehicle is assumed to have a full tank, 1,249 L (330 gal) of gasoline, and all of the fuel burns the sludge beneath it until all of the fuel is burned up.

The tank is constructed of reinforced concrete and is 7.93 m (26 ft) long and 3.96 m (13 ft) wide and varies in depth between 5.2 m (17 ft) at the north end and 5.49 m (18 ft) at the south end. The roof is 25.4 cm (10 in.) thick and an additional 10.2 cm (4 in.) of concrete has been applied in sealing the tank. There is approximately 0.61 m (2 ft) of dirt on top of the tank. The waste is approximately 2.39 m (94 in.) deep. The waste is wet sludge, which varies in solid content, but on average contains about 30 percent solids. The accident analysis conservatively assumes a plutonium content of 0.61 g/L.

3.4.2.1 Source Term Analysis

The vehicle accident consists of two different contributors to the consequences. First, the collapse of the tank roof from the weight of the vehicle and the resulting impact on the sludge releases aerosols. Second, the burning fuel from the ruptured vehicle tank spreads across the waste surface forming a large pool. The burning fuel causes additional aerosols to be generated from the boiloff. The consequence of the tank pool fire is, therefore, modeled as the sum of two contributors. The source term analysis for the tank collapse is covered in Section 3.4.1.1. This section will provide the analysis of the pool fire aspect and then add the source term from the tank collapse for a conservative total source term for this event.

It is assumed that the fuel tank of the excavator was 100 percent full at the time of the event and that all of the fuel enters the tank and spreads across the tank sludge. It is also assumed that there is sufficient oxygen for all of the fuel to burn. The ARF is assigned a value of 2.0E-03 on the basis of release fractions for boiling liquids as recommended by DOE-HDBK-3010-94. The RF and LPF are assigned a bounding value of 1.0.

Aerosolization of the tank waste could occur by evaporating water from the pool fire or by entrainment caused by airflow. While the pool fire would result in a fire plume that would induce air circulation in the headspace, air velocities near the surface of the waste outside the burning pool are judged to be too low to cause appreciable waste entrainment. Therefore, entrainment of waste caused by airflow at the surface of the waste is not assumed (RPP-12683, *Offsite Radiological Consequence Analysis for the Bounding Aircraft Crash Accident*).

The source term resulting from the pool fire is determined by Equation 3-1:

$$Q = (MAR)(DR)(ARF)(RF)(LPF)$$

where:

Q	=	source term released (g)
MAR	=	material at risk (g)
DR	=	damage ratio
RF	=	respirable fraction
ARF	=	airborne release fraction
LPF	=	leak path factor

In order to determine the MAR, the mass of liquid at risk is computed as the mass of water that could be evaporated by heat transferred from the flame to the inflamed surface. The following assumptions are made to calculate the MAR:

- The fuel that burns is 1,249 L (330 gal) of gasoline (920.9 kg).
- A flame heat transfer rate of 57 kW/m^2 is used (an average of values for the burning of rubber gloves and burning kerosene [Ayer et. al., 1988, *Nuclear Fuel Cycle Facility Accident Analysis Handbook*]). This rate takes into consideration both the vehicle fuel and potential organic waste constituents.
- The average specific burning rate is 1.2 kg/m^2/min (Jordan and Lindner 1983, "The Behavior of Burning Kerosene, Aerosol Formation and Consequences").
- The latent heat of water is 2.26 MJ/kg (Himmelblau 1974, *Basic Principles and Calculations in Chemical Engineering).*
- The plutonium density of the sludge is 0.61 g/L (the 99% confidence value is used in this analysis).

The mass of water evaporated per mass of fuel burned is:

$$(57\ \text{kJ/sec m}^2)*(60\ \text{sec/min})*(\text{m}^2\ \text{min}/1.2\ \text{kg fuel})*(1\ \text{kg}\ H_2O/2{,}260\ \text{kJ})$$
$$=1.26\ \text{kg}\ H_2O/\text{kg fuel}$$

The mass of water vaporized is:

$$920.9\ \text{kg fuel} * 1.26\ \text{kg}\ H_2O/\text{kg fuel} = 1{,}160.3\ \text{kg}\ H_2O$$

The MAR in the water vaporized is:

$$1{,}160.3\ \text{kg}\ H_2O * 0.00061\ \text{kg/L Pu} * 1.0\ \text{L}/1.0\ \text{kg}\ H_20 = 0.708\ \text{kg Pu}$$

The quantity of respirable material released to the environment based on the mass of water vaporized is provided by Equation 3-1:

$$Q = (MAR)(DR)(ARF)(RF)(LPF)$$

where:

MAR	=	708 g Pu
DR	=	1.0
ARF	=	2.0E-03
RF	=	1.0
LPF	=	1.0

The source term from the pool fire is:

$$Q = (708 \text{ g Pu})(1.0)(2.0\text{E-}03)(1.0)(1.0)$$
$$Q = 1.42 \text{ g}$$

Combined Source Term

The source term from the tank collapse scenario is 1.73E-3 g, which is negligible compared to the source term of the fire, 1.42 g, therefore the total source term is 1.42 g.

3.4.2.2 Consequence Analysis

The dose consequences to the CW and MOI for each unmitigated event were calculated using the RADIDOSE spreadsheet. The default source term parameters, distances associated with each receptor (CW – 100 m [328 ft] and MOI – 12,500 m [7.8 mi]) that determine the dispersion factors (χ/Q), dose conversion factors (DCFs) derived from ICRP 68 and ICRP 72, and breathing rate were used.

For the pool fire dose consequences, a material solubility class 2 (compounds are generally soluble) was used rather than the default class 3 (insoluble) typically used for fires, due to the guidance provide in Appendix A of HNF-26181, *User's Guide and Model Description for RADIDOSE Version 3.0*, Revision 1. Appendix A recommends a moderate solubility (class 2) be assumed for inhalation of plutonium oxides from Pu in a water environment like K Basin. Since the MAR at risk is sludge composed of 70 percent water, this recommendation is applied.

A pool diameter of 6.32 m (20.7 ft) was used to provide a pool area of 31.4 m^2 (338 ft^2), the approximate area of the tank. The fire heat rate was conservatively assumed to be 0.5 MW, a small fraction of the heat produced by the fire. A large heat release results in a very buoyant plume and small value of χ/Q.

The resulting dose consequences to the target receptors are presented in Table 3-8.

Table 3-8. Tank Pool Fire Dose Consequences

Event	CW TED (rem)	MOI TED (rem)
Physical Impact	4.88E-01	4.30E-04
Fire	1.38E+01	2.15E-01
Total	1.43E+01	2.15E-01

Table 3-9 provides the associated Risk Bins for the total radiological dose consequences of the unmitigated tank pool fire event.

Table 3-9. Tank Pool Fire Consequences and Risk Bins

Event	CW TED (rem)	CW Risk Bin	MOI TED (rem)	MOI Risk Bin
Tank Pool Fire	1.43E+01	III	2.15E-01	III

The following conservatisms were used in this analysis:

- 100 percent of the fuel is assumed to burn.
- The frequency of this event is considered Unlikely. Based on the probability of initial fuel ignition provided by RPP-13261, *Analysis of Vehicle Fuel Release Resulting in Waste Tank Fire*, the probability of a fire is 0.4 percent or 4.0E-03, supporting a frequency of Unlikely.
- A leak path factor of 1.0 is assumed.
- The source term from the tank collapse was added to the source term of the fire to account for both event contributors.

The TED for the CW is less than 25 rem, which corresponds to a Low consequence class. The TED for the MOI is less than 5 rem, which also corresponds to a "low" consequence class. The frequency of the event is "unlikely." As such, the Risk Bins for both the CW and MOI are Risk Bin III.

3.4.2.3 Comparison to the Evaluation Guideline

Offsite doses are compared to an evaluation guideline (EG). The EG is 25 rem total effective dose (TED). The dose estimates to be compared to it are the unmitigated doses received by the MOI at the site boundary for an exposure duration of two hours. The nominal exposure duration of two hours may be extended to eight hours if those release scenarios are especially slow to develop (DOE-STD-5506-2007).

The dose from the tank pool fire does not challenge the EG of 25 rem. Therefore, Safety Class SSCs do not need to be considered for the MOI.

3.4.2.4 Summary of Safety SSCs and TSR Controls

The CW and MOI Low consequences and Unlikely frequency result in a Risk Bin III event. As such, Safety Class and Safety Significant SSCs are not required. The following TSR controls are established to reduce the risk of the event and protect accident assumptions, as well as provide protection to the facility worker and environment.

- <u>Defense in Depth AC:</u> The Vehicle Access AC provides a preventative function for this accident scenario. The AC reduces the frequency of this event by preventing an overload of the tank due to a vehicle or heavy equipment. The elements of this control that reduce the probability of this event include physical barriers to create spatial separation between the tank and adjacent traffic, vehicle access and speed limit controls, and tank loading restrictions.

- Defense in Depth SAC: The Material Management SAC implements tank isolation and material restriction elements that provide a mitigative function by protecting the source strength and criticality assumptions of the tank.
- Defense in Depth AC: The Excavation and Sampling AC reduces the frequency of the event by preventing intrusive sampling activities and aggressive excavation activities that could compromise the structural integrity of the tank.
- Defense in Depth AC: The SMP AC ensures that SMPs are established, implemented and maintained. Implementation of SMPs reduces the probability of an event occurring as well as mitigates the consequences of an event through applicable, established programs.

Table 3-10. Summary of a Tank Pool Fire

<table>
<tr><td colspan="6">Accident Title: Tank 241-Z-361 Pool Fire</td></tr>
<tr><td colspan="5">Accident Type: Fire</td><td rowspan="2">Initiators: Tank overloading with vehicle; ruptured fuel tank, spark
Energy sources: Vehicle fuel</td></tr>
<tr><td colspan="5">Location: Tank 241-Z-361
Activities: S&M activities</td></tr>
<tr><td colspan="6">Hazards: Tank 241-Z-361 sludge contents; fire</td></tr>
<tr><th>Scenario</th><th>Freq</th><th>Consequence (rem and level)</th><th>Risk Bin</th><th>Control Designation</th><th>Controls</th></tr>
<tr><td rowspan="4">Collapse of the tank roof due to a vehicle overload ruptures the vehicle's fuel tank and ignites the fuel as it spreads across the top layer of the sludge.</td><td rowspan="4">U</td><td rowspan="4"><u>Unmitigated</u>
CW: 1.43E+01 (Low)
MOI: 2.15E-01 (Low)</td><td rowspan="4">
III
III</td><td>TSR AC (P)</td><td>Vehicle Access
Physical barriers, vehicle access limit, vehicle speed limit, vehicle fuel limit, loading restriction</td></tr>
<tr><td>TSR SAC (M)</td><td>Material Management
Inventory control</td></tr>
<tr><td>TSR AC (P)</td><td>Excavation & Sampling
Sampling limit, excavation limit</td></tr>
<tr><td>TSR AC (P & M)</td><td>SMP
Hazardous Material Protection (P), Management, organization, and institutional safety (P)
Emergency preparedness (M)</td></tr>
</table>

AC = Administrative Control
CW = co-located worker
M = mitigative
MOI = maximally exposed offsite individual
P = preventive
SMP = Safety Management Programs
TSR = technical safety requirement
U = Unlikely

3.4.3 Beyond Design Basis Earthquake (BDBE)

It is possible that over long periods of time the sludge in Tank 241-Z-361 could dry out. This is not an expected condition of the tank, however is considered a bounding analysis. The release is analyzed assuming the concrete tank roof and soil overburden impact the dried waste which is hard and brittle. Then fuel from heavy machinery spills into Tank 241-Z-361 and results in a pool fire.

This event is analyzed as an unmitigated event only as beyond design basis accidents (BDBAs) are not required to be analyzed to the same level of detail as DBAs. The requirement is that an evaluation be performed that simply provides insight into the magnitude of consequences of BDBAs (i.e., provide perspective on potential facility vulnerabilities). This insight from BDBA analysis has the potential for identifying additional facility features that could prevent or reduce severe BDBA consequences (DOE-STD-3009-2014).

3.4.3.1 Source Term Analysis

The source term resulting from the tank fire is determined using the five factor formula from DOE-HDBK-3010-94, which is determined by Equation 3-1.

$$Q = (MAR)(DR)(ARF)(RF)(LPF)$$

where:

Q	=	source term released (g)
MAR	=	material at risk (g)
DR	=	damage ratio
RF	=	respirable fraction
ARF	=	airborne release fraction
LPF	=	leak path factor

The MAR for the roof collapse portion of the event is the amount of radioactive material in the tank minus the MAR involved in the pool fire. The MAR is found by multiplying the plutonium density of the waste (0.61 g/L) by the waste volume and subtracting the MAR for the pool fire:

$$\begin{aligned} MAR &= (0.61\ g/L)(3.96\ m)(7.93\ m)(2.39\ m)(1000\ L/m^3) - 540.5\ g \\ &= 45.2\ kg \end{aligned}$$

The plutonium density of the waste used for the MAR is the 99 percent confidence interval, which is why the total MAR of the tank in this equation is significantly higher than the inventory specified in Chapter 2.

The respirable fraction (RF) for powder formed from impact on brittle solid is given in WHC-SD-WM-CN-051, *The Effects of Load Drop, Uniform Load and Concentrated Loads on Waste Tanks*, by the expression:

$$RF = 2 \text{ x } 10^{-4}\ (E/V) \qquad \textbf{Eq. 3-4}$$

Where:

E	=	the energy of the dropping objects (J)

V = the volume of the waste impacted (cm^3)

The energy of the dropping object in joules is given by:

$$E = mgh \qquad \textbf{Eq. 3-5}$$

where:

m = mass of dropping object (kg)
h = distance object drops (m)
g = gravitational acceleration (9.81 m/s^2)

The total mass dropped is the mass of the concrete roof plus the mass of the dirt. The concrete ceiling is 25.4 cm (10 in.) thick. An additional 4 in. of concrete has been added in sealing the tank. The total concrete thickness is therefore 0.36 m (14 in.). The density of the concrete is assumed to be 2.2 g/cm^3 (WHC-SD-WM-CN-051). The width of the roof is assumed to be 7.93 m (26 ft) by 3.96 m (13 ft). The mass of the concrete is:

$$M_{concrete} = \text{density x volume}$$
$$= (2.2\ g/cm^3)\ (3.96\ m)\ (7.93\ m)\ (0.36\ m)\ (10^6\ cm^3/m^3)\ (0.001\ kg/g)$$
$$= 2.49E{+}04\ kg$$

The mass of the dirt above the concrete is given by a similar expression except the depth of the dirt is 0.61 m (2 ft) and the density of the dirt is assumed to be 1.84 g/cm^3 (WHC-SD-WM-CN-051). The mass of the soil is:

$$M_{soil} = (1.84\ g/cm^3)\ (3.96\ m)\ (7.93\ m)\ (0.61\ m)\ (10^6\ cm^3/m^3)\ (0.001\ kg/g)$$
$$= 3.52E{+}04\ kg$$

The total mass is the mass of the concrete plus the mass of the soil:

$$M_{total} = 2.49E{+}04\ kg + 3.52E{+}04\ kg = 6.01E{+}04\ kg$$

The tank maximum depth is 5.49 m (18 ft) and the depth of the waste is 2.39 m (94 in.). The maximum distance the concrete and dirt can drop is therefore 5.49 m – 2.39 m = 3.10 m. Therefore, Equation 3-5 is:

$$E = mgh = (6.01E{+}04\ kg)\ (9.81\ m/s^2)\ (3.10\ m) = 1.83E{+}06\ J$$

Assuming the waste is uniformly 2.39 m thick, the volume of the waste is:

$$V = (2.39\ m)\ (3.96\ m)\ (7.93\ m)\ (10^6\ cm^3/m^3) = 7.51E{+}07\ cm^3$$

The RF in Equation 3-4 is therefore:

$$RF = 2 \text{ x } 10^{-4}\ (E/V) = (2.0E\text{-}04)\ (1.83E{+}06\ J)/(7.5E{+}07\ cm^3)$$
$$= 4.87E\text{-}06$$

The impact is assumed to create a respirable powder. The majority of this powder will be trapped by the debris but the impact will create a puff that could push a fraction of this respirable powder out of the tank. The bounding ARF for venting of pressurized powder is given in Section 4.4.2.3.1 of DOE-HDBK-3010-94 and is 0.1. The ARF is therefore:

ARF = 0.1

The impact is assumed to affect all of the MAR, therefore a DR of 1.0 is assumed. Though it is likely that the collapse of the concrete roof and soil overburden would trap particles, an LPF of 1.0 is conservatively applied.

The parameters for this calculation are therefore:

MAR = 4.52E+04 g
DR = 1.0
RF = 4.87E-06
ARF = 0.1
LPF = 1.0

The source term from collapse of the tank roof onto the dried sludge is:

$$Q = (4.52E{+}04\ g)(1.0)(4.87E{-}06)(0.1)(1.0)$$
$$| = 2.20E{-}02\ g$$

The MAR for the pool fire is the amount of radioactive material that is involved with the diesel fuel pool fire in the tank. The MAR for the pool fire is found by calculating the volume of material involved in the fire and then multiplying by the plutonium density of the waste (0.61 g/L). The plutonium density of the waste used for the MAR is the 99 percent confidence interval, which is why the total MAR of the tank in this equation is significantly higher than the inventory specified in Chapter 2.

The areal volume of the spilled diesel fuel pool is:

$$1{,}249\ L\ /\ (3.96\ m \times 7.93\ m) = 39.8\ L/m^2$$

The density of diesel fuel is 0.832 kg/L; therefore, the areal density of the spilled diesel fuel pool is:

$$39.8\ L/m^2 \times 0.832\ kg/L = 33.1\ kg/m^2$$

Per *The SFPE Handbook of Fire Protection Engineering*, the burn rate of diesel fuel is 0.039 kg/m^2/s. Therefore, the total burn time of the spilled diesel fuel pool in the Tank 241-Z-361 is:

$$(33.1\ kg/m^2)\ /\ (0.039\ kg/m^2/s) = 848.7\ s$$

Takeuchi, T., Tsuruda, T., Isizuka, S. and Hirano, T., "Burning Characteristics of a Combustible Liquid Soaked in Porous Beds" determined the affected depth of a bed of glass beads saturated with methanol. This is known as the "dry region boundary," as only the vaporized liquid fuel burns, not the fuel itself. As the burn time extends, the dry region boundary progresses deeper into the substrate into which the liquid fuel is soaked; there is some indication that the rate of progression is greater as particle size decreases.

In the Takeuchi, et. al., paper, the largest size of glass beads used as a substrate was 0.2 mm. At 600 seconds, the dry region boundary was 20 mm below the surface of the bead-particle bed. Scaling from these results to the burn time of the Tank 241-Z-361 determined above gives:

$$848.7 \text{ s} / 600 \text{ s} = 1.41, \text{and}$$

$$1.41 \text{ x } 20\text{mm} = 28.2 \text{ mm}$$

This distance of 28.2 mm (1.11 in.) is conservative because the diesel fuel would not be able permeate as easily through the dried waste as it would through glass beads.

The total MAR for this scenario is:

$$(3.96 \text{ m}) \text{ x } (7.93 \text{ m}) \text{ x } (0.0282 \text{ m}) = 0.886 \text{ m}^3$$

$$0.886 \text{ m}^3 = 886 \text{ L}$$

$$(886 \text{ L}) \text{ x } (0.61 \text{ g/L}) = 540.5 \text{ g}$$

The ARF and RF bounding values of 5.0E-03 and 0.4, respectively, are selected from DOE-HDBK-3010-94 using the thermal stress of an aqueous solution or air-dried salts under gasoline fire on a porous or otherwise absorbing (i.e., cracks, depressions) surface.

A DR of 1.0 is assumed. Though it is likely that the collapse of the concrete roof and soil overburden would trap particles, an LPF of 1.0 is conservatively applied.

The parameters for the pool fire calculation are therefore:

MAR	=	540.5 g
DR	=	1.0
ARF	=	5.0E-03
RF	=	0.4
LPF	=	1.0

The source term for the pool fire is:

$$Q = (540.5 \text{ g})(1.0)(5.0\text{E-}03)(0.4)(1.0)$$
$$| = 1.08 \text{ g}$$

3.4.3.2 Consequence Analysis

The dose consequences to the CW and MOI for the unmitigated case of a ground-level release and fire were calculated using the RADIDOSE spreadsheet. The default source term parameters, distances associated with each receptor (CW – 100 m [328 ft] and MOI – 12,500 m [7.8 mi]) that determine the dispersion factors (χ/Q), dose conversion factors (DCFs) derived from ICRP 68 and ICRP 72, solubility class, and default breathing rate were used.

A pool diameter of 6.32 m (20.7 ft) was used to provide a pool area of 31.4 m^2 (338 ft^2), the approximate area of the tank. The fire heat rate was conservatively assumed to be 0.5 MW, a small fraction of the heat produced by the fire. A large heat release results in a very buoyant plume and small value of χ/Q.

The resulting dose consequences to the target receptors are presented in Table 3-11.

Table 3-11. Beyond Design Basis Earthquake Event Dose Consequences

Event	CW TED (rem)	MOI TED (rem)
Physical Impact	6.13E+00	5.40E-03
Fire	1.06E+01	1.64E-01
Total	1.67E+01	1.69E-01

Table 3-12 provides the associated Risk Bins for the total radiological dose consequences of the unmitigated event.

Table 3-12. Beyond Design Basis Earthquake Event Consequences and Risk Bins

Location	CW TED (rem)	CW Risk Bin	MOI TED (rem)	MOI Risk Bin
Tank 241-Z-361	1.67E+01	BDBE	1.69E-01	BDBE

The following conservatisms were used in this analysis:

- The earthquake is assumed to catastrophically fail the Tank 241-Z-361 roof.
- No credit is taken for the fact that the suspended material is not released at ground level but at approximately 4.57 m (15 ft) below grade. Suspended material below grade in a relatively small opening (3.96 m [13 ft] by 7.93 m [26 ft]) does not transport as efficiently as suspended material at ground level.
- A leak path factor of 1.0 is assumed; no credit is taken for the 35.6 cm (14 in.) of concrete comprising the tank roof and 0.61 m (2 ft) of soil resting on the tank roof which would trap many of the suspended particles.
- 100 percent of the fuel is assumed to burn.
- The sludge inside the tank is assumed to have dried.
- The tank collapse was added to the fire to account for both event contributors.

This is a Beyond Design Basis Earthquake (BDBE). The unmitigated frequency of occurrence for natural phenomenon hazard (NPH) events cannot be reduced. There are no SC SSCs, safety significant (SS) SSCs or other safety controls required because this is a BDBE.

3.5 Margin of Safety

This section addresses margins of safety to facilitate USQ evaluations for changes affecting Tank 241-Z-361. Based on the guidance in DOE G 424.1-1B, Appendix A, and PRC-PRO-NS-062, *Unreviewed Safety Question Process*, the safety basis was reviewed to determine if there were instances of DOE-defined functional requirements for equipment that would provide a basis for the identification of margins of safety. There is no explicit margin of safety identified in this DSA. Margin of safety must be an explicit function between a design or assumed failure point and its associated safety limit. This DSA does not contain safety limits nor does it have Safety Class SSCs that if failed, would result in a potential release greater than 25 rem to the MOI. As such, there are no explicit or implicit margins of safety associated with Tank 241-Z-361. The margin of safety question in USQ evaluations performed against this DSA shall be answered "No."

4.0 Hazard Controls

This chapter identifies the facility features and controls required for Tank 241-Z-361. It provides details about facility equipment and features that are necessary to satisfy the current risk evaluation guidelines, provide defense in depth, and contribute to worker safety. The controls presented here are based on the results of the hazard analysis (CP-58851) and accident analysis for the Tank, as described in Chapter 3.0.

4.1 Safety Structures, Systems, and Components

There are no Safety Class or Safety Significant SSCs identified for Tank 241-Z-361. Any accident scenario with a Risk Bin value greater than III requires consideration of Safety Class or Safety Significant Structures, Systems, or Components (SSCs) to reduce the Risk Bin value to III or less (DOE-STD-3009-2014). Safety Class SSCs are identified to reduce risk to the MOI and Safety Significant SSCs are identified to reduce the risk to the CW. SSCs are evaluated for defense in depth status if they are below the criteria for Safety Class and Safety Significant SSCs discussed above. The accidents analyzed in Chapter 3 result in Risk Bin III values to the CW and MOI and therefore do not require Safety Class or Safety Significant SSCs.

Table 4-1 presents the potential consequences for the unmitigated accident scenarios.

Table 4-1. Tank 241-Z-361 Unmitigated Accident Scenario Summary

Scenario	Frequency	CW TED (rem)	MOI TED (rem)	CW/MOI Risk Bins
Tank Collapse	Anticipated	4.88E-01	4.30E-04	III/III
Tank Pool Fire	Unlikely	1.43E+01	2.15E-01	III/III
Beyond Design Basis Earthquake	BDBE	1.67E+01	1.69E-01	BDBE

4.2 Design Features

There are no Design Features identified for Tank 241-Z-361.

The tank structure was previously identified as a passive design feature and designated as Safety Significant in previous revisions of this DSA, however for conservatism, the LPF credited for this control has been removed from the accident analysis and the tank structure has been re-designated as defense in depth.

PRC-PRO-NS-700 provides requirements for credited passive design features which include a documented basis demonstrating that the passive design feature will perform its safety function and that in-service tests, inspections or surveillances necessary to ensure that a passive design feature continues to provide the defined degree of hazard controls that have been identified. Results of the videograph conducted in 1999 showed qualitative evidence that the tank's structural integrity had degraded since the load testing performed during the JCO activities. The tank's structure is expected to continue to deteriorate as it ages. Surveillances of the tank structure have been, and will continue to be performed, however they do not ensure that the hazard controls performed by the tank's confinement structure remain in place; rather, these surveillances would provide indication of a tank collapse after it occurred.

4.3 Defense in Depth

The Tank 241-Z-361 structure, including the tank roof, walls, and passive ventilation, is a passive SSC that provides confinement of radioactive and hazardous materials. Though the tank structure is not credited in the accident analysis for providing a preventive or mitigative function, the tank structure prevents release of the tank contents and provides shielding for worker protection during normal operations and accidents. Accordingly, the tank structural boundary is designated defense in depth. This designation of defense in depth is consistent with criteria provided in PRC-PRO-NS-700.

Changes to defense in depth equipment are considered significant modifications. The USQ process required by 10 CFR 830 ensures that changes are appropriately analyzed and controlled so they do not adversely affect safe operation.

Table 4-2. Defense in Depth Equipment

Element	Boundary definitions and passive functions
Tank 241-Z-361 (including the tank roof, walls, and passive ventilation)	**Boundary**: The physical boundary includes the tank roof, walls, and passive ventilation. **Passive function***: Confinement – The facility structures provide a degree of confinement of the MAR within the facility during normal operations and some accident conditions.

Notes:
*Not credited in accident analyses

4.4 Specific Administrative Controls

4.4.1 Material Management (SAC 5.6.1)

This Directive Action SAC provides controls to ensure that the radioactive inventories assumed in the accident analysis will not be exceeded, which would place the facility in a formally unanalyzed space. This SAC also provides controls to ensure that the interior of Tank 241-Z-361 remains disconnected from piped systems and isolated from potential sources of liquid.

4.4.1.1 Safety Function

This SAC ensures that the introduction of outside radiological waste material anywhere at the Tank 241-Z-361 is prohibited. The radiological inventory shall only decrease or remain constant.

4.4.1.2 Functional Requirements

The Material Management control is the initial underlying assumption for the accident analyses performed in Section 3.4. The MAR limit protects accident assumptions and ensures that the consequences are not invalidated, thereby placing the facility in unanalyzed space.

4.4.1.3 SAC Evaluation

Prohibiting the addition of radiological material to the Tank 241-Z-361 inventory (SAC 5.6.1 a) and ensuring that Tank 241-Z-361 remains disconnected and isolated from all historical piped systems (SAC 5.6.1 b) protects accident assumptions as documented in Chapter 3.0. The USQ process and implementing procedures adequately protect this SAC element.

4.4.1.4 TSR Requirements

This control has been written as a Directive Action (DA) SAC in the TSRs.

4.5 Administrative Controls

To ensure that assumptions of this DSA are maintained and to ensure continued safe management of the facility, the following ACs are provided. These ACs are not classified as Specific Administrative Controls (SACs) because none meet the criteria described in DOE-STD-1186-2016, Section 2.1, "Identification of SACs." That is, the ACs are not controls *needed* to prevent or mitigate an accident scenario and the safety function would not be Safety Class or Safety Significant if the function were provided by an SSC. The accidents analyzed in Chapter 3 result in Risk Bin III values to the CW and MOI which generally do not require protection by SACs.

4.5.1 Nuclear Criticality Safety (AC 5.7.1)

This AC establishes a Criticality Safety Program and provides measures that ensure Criticality Safety Program key elements are in place to prevent an accidental criticality at Tank 241-Z-361.

4.5.2 Vehicle Access Control (AC 5.7.2)

This AC defines measures, restrictions, and actions to prevent or minimize the occurrence of vehicle or other heavy equipment impact related accidents at Tank 241-Z-361.

4.5.3 Excavation & Sampling (AC 5.7.3)

This AC defines the measures, restrictions, and actions to prevent the occurrence of a Tank 241-Z-361 leak.

4.5.4 Safety Management Programs (AC 5.5.1)

This AC performs both a preventive and mitigative function by ensuring that SMP applicability is established, implemented, and maintained. Many SMPs serve preventive functions such as the Operational Safety SMP which implements Fire Protection and Hoisting & Rigging requirements. Other SMPs serve primarily mitigative functions, such as the Emergency Preparedness Program. Some SMPs serve as both, such as the Radiation Protection Program. By ensuring that these programs are established and maintained, overall risk is reduced.

5.0 Derivation of Technical Safety Requirements

5.1 Introduction

The TSR Document, HNF-20504, constitutes an agreement between DOE and CHPRC regarding safe stewardship of Tank 241-Z-361. The TSRs were derived from the analysis in the DSA as described in this chapter, building on the control functions that were determined to be essential in Chapter 3, Hazard and Accident Analyses, and Chapter 4, Safety Structures, Systems, and Components (SSCs). In addition to those TSRs that are explicitly derived from Chapter 3 and Chapter 4, other mandatory Safety Management Programs (SMPs) are included in the TSRs to ensure the safe operation of Tank 241-Z-361.

The TSRs consist primarily of the following:

- Limiting Condition of Operations (LCOs) necessary to maintain the operations within the safety analysis basis.
- ACs for administrative requirements necessary to control operation of the facility including commitments to SMPs and SACs.
- Requirements for passive Design Features (DFs).

5.2 Requirements

This chapter of the DSA provides information necessary to support the safety basis requirements for the derivation of the TSRs in 10 CFR 830. The information in this chapter demonstrates how the selected TSRs comply with 10 CFR 830.205. Further guidance can be found in DOE G 423.1-1B, *Implementation Guide for Use in Developing Technical Safety Requirements*.

5.3 TSR Coverage

This chapter describes the type of TSR coverage to be implemented for each control that is carried over to the separate TSR document. It summarizes all identified SC and SS SSCs, SACs, and programmatic ACs to be covered in the TSR document. Chapter 4 discusses the safety class and safety-significant SSCs and SACs that were identified in the Hazard Analysis (HA) and Accident Analysis (AA) in Chapter 3.

Table 5-1. TSR Coverage

TSR	Control	Relevant Hazard/Accident	Safety Limits, Limiting Control Settings, LCO, Surveillance Requirements, or Design Features
SAC 5.6.1	Material Management	Tank Collapse and Pool Fire	N/A
AC 5.5.1	Safety Management Programs	Tank Collapse and Pool Fire	N/A

Table 5-1. TSR Coverage

TSR	Control	Relevant Hazard/Accident	Safety Limits, Limiting Control Settings, LCO, Surveillance Requirements, or Design Features
AC 5.7.1	Nuclear Criticality Safety	Criticality	N/A
AC 5.7.2	Vehicle Access Control	Tank Collapse and Pool Fire	N/A
AC 5.7.3	Excavation & Sampling	Tank Collapse and Pool Fire	N/A

5.4 Derivation of Facility Modes

Facility modes are used to describe the applicability of LCOs and some SACs and ACs. This section describes, based on hazard analysis and accident analysis, where different facility modes are appropriately distinguished to facilitate application of identified LCOs and SACs or ACs.

As such, S&M mode has been established. During this mode, open waste containers are not present. Intrusive operations are not occurring.

5.4.1 S&M Mode

The S&M mode and activities authorized for performance in the S&M mode are characterized by the following:

- Activities needed to maintain S&M mode may be conducted.
- The facility or facility zone must be in a safe configuration to achieve S&M mode.
- Activities that could introduce an operational accident may not be performed in the facility or facility zone except as required to restore operability in the facility or facility zones. This prohibition does not preclude entry into the S&M mode to perform maintenance on systems addressed by LCO or TSR SAC or AC.

Waste generated during authorized activities may be managed in accordance with Site Radiological Control practices

5.5 TSR Derivation

5.5.1 Limiting Conditions for Operations and Surveillance Requirements

Chapter 3 does not currently identify any TSR LCOs requiring coverage in the TSRs.

5.5.2 Administrative Controls

5.5.2.1 Material Management (SAC 5.6.1)

SAC 5.6.1 is established, implemented, and maintained to ensure that the initial MAR (source inventory) conditions assumed in the Tank 241-Z-361 Accident Analyses will not be exceeded, as described in Section 1.7 of DOE-STD-1186-2016.

During the current Tank 241-Z-361 S&M life cycle phase, planned activities will consist primarily of S&M. The scope of work includes S&M activities that maintain confinement of hazardous wastes and protect the worker. This work scope includes activities for surveillance of the facility, preventative maintenance of selected equipment, and incidental storage of necessary supplies and equipment. The work scope also includes characterization, sampling, and neutron or gamma logging, asbestos abatement actions, replacement, or upgrades of postings and barriers, container management, demand repairs to SSCs, spill response, and response or investigation of non-typical surveillance reports. All of these activities center on the Tank 241-Z-361 existing inventory and do not include or authorize the introduction of any external source inventory.

5.6 Design Features

There are no credited Design Features for Tank 241-Z-361.

5.7 Step-Out Criteria

No specific step-out criteria are defined for the planned S&M activities for Tank 241-Z-361. This DSA is applicable until Tank remediation activities are planned, at which time the DSA shall be revised to allow such activities by providing the applicable controls.

This page is intentionally left blank.

6.0 Prevention of Inadvertent Criticality

6.1 Introduction

This chapter describes the CHPRC Criticality Safety Program (CSP) as specified by DOE-STD-3009-2014, Chapter 6, "Prevention of Inadvertent Criticality."

6.2 Governing Documents

The CHPRC CSP is described in PRC-NS-00004, *CH2M HILL Plateau Remediation Company Criticality Safety Program Description Document*. A summary of the CSP, including specific key attributes (KA), is provided in Chapter 6 of HNF-11724. All KAs have been implemented for Tank 241-Z-361 except for KA 6-6, "criticality alarm systems." Criticality alarm systems are not required in Limited Control Facilities. The Criticality Safety Program is implemented in HNF-7098, *Criticality Safety Program*, at the site level, and in PRC-PRO-NS-52334, *Criticality Safety*, for Tank 241-Z-361 at the project level. This Project procedure provides details that reinforce HNF-7098 and identifies approved exceptions that may apply to Tank 241-Z-361.

6.3 Criticality Safety Program

Tank 241-Z-361 is a Limited Control Facility per HNF-7098. A limited control facility is defined as a facility in which greater than half of a minimum critical mass is present, a criticality is documented to be incredible, and limits and controls are required to maintain incredibility. PRC-PRO-NS-52334 requires that all Criticality Safety Evaluation Reports demonstrate that a criticality is incredible to allow operation as a limited control facility. Specifically, criticality incredibility has been shown for limited activities in Tank 241-Z-361, including sampling, filter change out, radiation surveys, characterization of tank contents by nondestructive analysis, performing structural evaluations as documented in CHPRC-02229. TSR 5.7.1 "Nuclear Criticality Safety" ensures that a criticality safety program exists at Tank 241-Z-361. This makes certain that future activities are analyzed with respect to criticality safety requirements.

6.4 Supporting Safety Management Programs

Implementation of the CSP at the Tank 241-Z-361 is supported by several Safety Management Programs and processes.

CRD O 422.1, *Conduct of Operations*, is implemented at CHPRC through the specifications noted in Section 11.3 of HNF 11724. Each nuclear facility is required to establish an implementing matrix that addresses each of the guideline requirements from CRD O 422.1. These guidelines support mission success and promote worker, public, and environmental protection. It was stated in CRD O 422.1 that a Conduct of Operations Program supports ISMS by providing techniques and practices to implement the Core Functions of 'Develop and Implement Hazard Controls' and 'Perform Work Within Controls.' It is stated in Section 1.2.3 of HNF-7098 that the CHPRC Criticality Safety Program applies the principles of ISMS in developing, authorizing, and implementing criticality safety documents.

The Quality Assurance (QA) Program SMP is presented in Section 14 of HNF-11724. The QA Program establishes requirements for several activities as discussed in Section 14 of HNF-11724: work process, design, procurement, inspection and testing for acceptance, and assessments (management and independent). Section 1.4 of HNF-7098 assigns responsibilities to several groups within CHPRC. In particular, Section 1.4.9 assigns the Quality Assurance Program responsibility to verify equipment design features and installations essential to criticality safety, as requested by the CSR or criticality safety engineer, and to verify compliance with other criticality safety limits, upon request.

The QA Program also establishes the provisions for CHPRC configuration management as noted in Section 17.4.2 of HNF-11724. Engineering configuration control requirements were stated to be further described in engineering implementing procedures. Section 6.3 of HNF-7098 acknowledges one such procedure, PRC-PRO-EN-20050, *Engineering Configuration Management*, in specifying safety significant safety features on a safety equipment list.

The provisions of the Initial Testing, In-Service Surveillance, and Maintenance SMP are applicable to facility systems or equipment that provide a preventive and/or mitigative function as noted in the DSA hazard evaluation. Section 10 of HNF-11724 presents six key attributes of the CHPRC initial testing, in service surveillance, and maintenance program that support the implementation of criticality safety limits and controls. Initial testing and subsequent surveillance and maintenance are specifically discussed for fixed neutron absorber systems and criticality accident alarm systems in HNF-7098. In addition, all other active, safety significant, engineered safety features, as detailed on the safety equipment list, must have operability conditions and surveillance specifications in the TSRs.

It is noted in Section 12.4 of HNF-11724 that CHPRC Training Program develops, implements, and manages a program that includes identification of known requirements, definition of training standards, implementation of program training classes, certification/qualification of required skills, and verification of ongoing job qualifications. Section 1.4.10 of HNF-7098 assigns the Training Program responsibility to provide a formal criticality safety training program for certified fissionable material handlers, qualified fissionable material operators, supervisors, CSRs, and support personnel as described in Section 3 of that document.

7.0 Safety Management Programs

7.1 Radiation Protection

The Radiation Protection Program implements applicable regulatory (10 CFR 835 Occupational Radiation Protection) and other contractual requirements. The program is based on functional or operational organizations implementing the necessary requirements. The Radiological Control Program is described in Chapter 7.0 of HNF-11724. No exceptions are taken to the key attributes as described in HNF-11724.

7.2 Fire Protection

The Fire Protection SMP ensures that sufficient fire protection is provided to protect the health and safety of employees and the health and welfare of the public in the event of a fire, to prevent unacceptable delays in vital DOE Programs, and to prevent exceeding specific dollar-loss values should a fire occur.

Activities authorized by this DSA will be performed consistent with the requirements of the site Fire Protection Program. The Fire Protection Program is described in Chapter 11.4 of HNF-11724. The KA pertaining to fire protection, as described in HNF-11724 apply except for KA 11-5. There are no safety basis requirements for the deactivated facility fire suppression system. NFPA inspection, testing, and maintenance requirements are not applicable to this deactivated system.

7.3 Maintenance

The Tank 241-Z-361 Facility is currently in S&M mode, with limited access. The facility access is controlled by approved procedures of the Central Plateau Risk Management (CPRM) Project. Surveillances are performed in compliance with pre-approved procedures. Where applicable, changes in facility conditions are checked as compliant, noted for repair or the data collected for trending and further evaluation. The scope of activities to be performed is summarized in Section 2.5. The Initial Testing, In-service Surveillance, and Maintenance Program is found in Chapter 10.0 of HNF-11724. No exceptions are taken to the KA as described in HNF-11724.

7.4 Procedures

The procedure development program employs a graded approach to ensure that work processes are controlled by approved instructions, procedures, design documents, technical standards, or other hazard controls adopted to meet regulatory or contractual requirements appropriate to the specific tasks to be performed. A description of the procedures development and training programs may be found in HNF-11724, Chapter 12.0. No exceptions are taken of the KA as described in HNF-11724.

7.5 Training

The training program provides employees, who are required to perform specified job requirements, with the training necessary to become qualified and maintain qualification. A description of the procedures development and training programs may be found in HNF-11724, Chapter 12.0. No exceptions are taken of the KA as described in HNF-11724.

7.6 Conduct of Operations

Conduct of Operations provides a formal and disciplined method for safely performing work and operating site facilities. Conduct of Operations is based on the concept that workers are provided with adequate knowledge of requirements, and are disciplined in observing these requirements. It is founded on training, qualification, and use of procedures. It promotes implementation of a set of standards that establishes safe operations. Provisions of the program specify that appropriately trained personnel using approved, adequate, and controlled procedures perform work; that this work is properly supervised; that prior approval is obtained for the work; and that accountability exists for work performance.

No exceptions are taken to the KA as described in HNF-11724.

7.7 Quality Assurance

CHPRC implements a Quality Assurance (QA) Program meeting the requirements of 10 CFR 830, Subpart A, "Quality Assurance Requirements," in accordance with PRC-MP-QA-599, *Quality Assurance Program*. The QA Program is described in Chapter 14.0 in HNF-11724. No exceptions are taken to the KA as described in HNF-11724.

7.8 Emergency Preparedness

CHRPS implements the DOE Emergency Management Plan through its Emergency Preparedness Program. The implementing organization prepares and maintains hazard assessments and response plans for applicable facilities. Facility staff is trained and practice drills are used to ensure a timely and effective response should an emergency occur. While the CPRM Project will perform drills annually, they will not be performed for every facility annually. The Emergency Preparedness Program is described in Chapter 15.0 of HNF-11724. No exceptions are taken to the KA as described in HNF-11724.

7.9 Radiological and Hazardous Waste Management

The Radioactive and Hazardous Waste Management Program is found in Chapter 9.0 of HNF-11724. No exceptions are taken to the KA as described in HNF-11724.

7.10 Hazardous Material Protection

The Hazardous Material Control Program is found in Chapter 8.0 of HNF-11724. No exceptions are taken to the key attributes as described in HNF-11724.

7.11 Management, Organization, and Institutional Safety Provisions

The details of management, organization, and institutional safety policies are summarized in Chapter 17 of HNF-11724. No exceptions are taken to the key attributes as described in HNF-11724.

This page intentionally left blank.

8.0 References

10 CFR 830, "Nuclear Safety Management," *Code of Federal Regulations,* as amended.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*, as amended.

97-TPD-193, 1997, "Contract No. DE-AC06-96RL 13200 - Unreviewed Safety Questions (USQ) Regarding Plutonium Finishing Plant (PFP) Tank 241-Z-361" (letter to H. J. Hatch, Fluor Daniel Hanford, Inc., from L. J. Olguin), U.S. Department of Energy, Richland Operations Office, Richland, Washington, October 15.

CO-98-099, 1998, *Engineering Load Evaluation of the Riser on Tank 241-Z-361*, Fluor Daniel Northwest, Inc., Richland, Washington.

CO-99-BWHC-010, 1998, *Tank 241-Z-361 Dome Load Test Results Summary*, Fluor Daniel Northwest, Inc., Richland, Washington.

CO-2000-BWHC-307, 2000, "Transmittal of Letter Report, Contract 5204, Release 55" (letter to B. K. Hampton, from D. P. Hughes), Fluor Federal Services, Richland, Washington, May 1.

CP-58851, *2015 Tank 241-Z-361 Hazards Analysis,* Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington

CHPRC-02229, 2015, *CSER 14-002: Criticality Safety Evaluation Report for Underground Settling Tank 241-Z-361*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

DiNenno, Philip J & National Fire Protection Association & Society of Fire Protection Engineers, 1988, *SFPE Handbook of Fire Protection Engineering*, First Edition, National Fire Protection Association, Boston, Massachusetts, Society of Fire Protection Engineers, Quincy, Massachusetts.

DOE G 423.1-1B, Implementation Guide for Use in Developing Technical Safety Requirements, 2015, U.S. Department of Energy, Washington, D.C.

DOE G 424.1-1B, Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements, 2010, U.S. Department of Energy, Washington, D.C.

DOE-HDBK-3010-94, 2013, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, Change Notice No. 1, Washington, D.C.

DOE-STD-1027-92, 1992, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* Change Notice No. 1, DOE Technical Standard, U.S. Department of Energy, Washington, D.C.

DOE-STD-1120-2016, 2016, *Integration of Environment, Safety, and Health into Facility Disposition Activities,* U.S. Department of Energy, Washington, D.C.

DOE-STD-1186-2016, 2016, *Specific Administrative Controls,* U.S. Department of Energy, Washington, D.C.

DOE-STD-3009-2014, 2014, *Preparation of Nonreactor Nuclear Facility Documented Safety Analyses*, U.S. Department of Energy, Washington, D.C.

DOE-STD-5506-2007, 2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, U.S. Department of Energy, Washington, D.C.

FDNW, 1997, *Structural Integrity Assessment for PFP Tank 241-Z-361*, Fluor Daniel Northwest, Inc., Richland, Washington.

FH-0002791, 2000, "Submittal of Documentation in Fulfillment of TPA Milestone M-15-37B" (letter to P. M. Knollmeyer, U.S. Department of Energy, Richland Operations Office from G. W. Jackson), Fluor Hanford, Inc., Richland, Washington, June 15.

HNF-1989, 1998, *Tank 241-Z-361 Process and Characterization History*, Rev. 1, B&W Hanford Company, Richland, Washington.

HNF-2024, 1999, *Justification for Continued Operation for Tank 241-Z-361*, Rev. 2, Fluor Daniel Hanford, Inc., Richland, Washington.

HNF-7098, 2016, *Criticality Safety Program*, Rev. 26, CH2M HILL Plateau Remediation Company, Richland, Washington.

HNF-8735, 2002, *241-Z-361 Tank Characterization Report*, Rev. 0A, Fluor Hanford, Inc., Richland, Washington.

HNF-11724, 2016, *CH2M HILL Plateau Remediation Company Safety Management Programs*, Rev. 13, CH2M HILL Plateau Remediation Company, Richland, Washington.

HNF-15500, 2016, *PFP Deactivation and Decommissioning Documented Safety Analysis*, Rev. 14, CH2M HILL Plateau Remediation Company F, Richland, Washington.

HNF-20504, 2017, *Tank 241-Z-361 Technical Safety Requirements*, Rev. 4, CH2M HILL Plateau Remediation Company, Richland, Washington.

HNF-24256, 2014, *Addendum to Tank 241-Z-361 Quantitative Evaluation to Identify Indications of Imminent Tank Failure*, Rev. 0-B, CH2M HILL Plateau Remediation Company, Richland, Washington.

HNF-26181, 2010, *User's Guide and Model Description for RADIDOSE Version 3.0*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

HNF-IP-0263-PFP, 1998, *Building Emergency Plan for Plutonium Finishing Plant Complex*, Rev. 5, B&W Hanford Company, Richland, Washington.

Owczarski and Mishima, 1996, *Airborne Release/Respirable Fractions for Dome Collapse in HLW Tanks*, Rev. 1, Westinghouse Hanford Company, Richland, Washington

PRC-NS-00004, 2016, *CH2M HILL Plateau Remediation Company Criticality Safety Program Description Document*, Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington.

PRC-PRO-NS-062, 2016, *Unreviewed Safety Question Process*, Rev. 3, CH2M HILL Plateau Remediation Company, Richland, Washington.

PRC-PRO-NS-52334, 2016, *Criticality Safety*, Rev. 15, CH2M HILL Plateau Remediation Company, Richland, Washington.

PRC-PRO-NS-700, 2017, *Safety Basis Development*, Rev. 1, Chg. 4, CH2M HILL Plateau Remediation Company, Richland, Washington.

PRC-STD-NS-8739, 2016, *CHPRC Safety Analysis and Risk Assessment Handbook (SARAH)*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.

RPP-12395, 2003, *Offsite Radiological Consequence Analysis for the Bounding Tank Failure Due to Excessive Loads Accident*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-12683, 2009, *Offsite Radiological Consequence Analysis for the Bounding Aircraft Crash Accident*, Rev. 2, Washington River Protection Solutions LLC, Richland, Washington.

RPP-13261, 2003, *Analysis of Vehicle Fuel Release Resulting in Waste Tank Fire*, Rev. 2, CH2M HILL Hanford Group, Inc., Richland, Washington.

RPP-5667, 2000, *Stochastic Consequence Analysis for Waste Leaks*, Rev. 0, Fluor Federal Services, Richland, Washington.

RHO-ST-44, 1982, *216-Z-12 Transuranic Crib Characterization: Operational History and Distribution of Plutonium and Americium*, Rockwell Hanford Operations, Richland, Washington.

Supplemental ECN 662390, 2001, *Tank 241-Z-361, Addendum to Plutonium Finishing Plant Final Safety Analysis Report*, Addendum to HNF-SD-SAR-021, Rev. 1, Fluor Hanford, Inc., Richland, Washington.

Takeuchi, T., Tsuruda, T., Isizuka, S. and Hirano, T., 1991. "Burning Characteristics of a Combustible Liquid Soaked in Porous Beds." *Fire Safety Science – Proceedings of the Third International Symposium*, International Association for Fire Safety Science, London, England.

WHC-SD-WM-CN-051, 1996, *The Effects of Load Drop, Uniform Load and Concentrated Loads on Waste Tanks*, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

This page intentionally left blank.

Appendix A

Tank 241-Z-361 Structural Evaluation

Appendix A
Tank 241-Z-361 Structural Evaluation

Note: The contents of this Appendix were originally issued as Letter Report "In-Tank Video of Tank 241-Z-361: Structural Review," Fluor Federal Services, 5/1/2000 and published as Appendix B to Supplemental ECN 662390 Addendum to HNF-SD-CP-SAR-021, Rev. 1. The following Appendix contents have been imported directly from the Appendix B text in the PFP FSAR Addendum.

Contents

Figures

ORIGINAL

LETTER REPORT

IN-TANK VIDEO OF TANK 241-Z-361: STRUCTURAL REVIEW

Prepared by

FLUOR FEDERAL SERVICES, INC.

April 2000

Prepared for

FLUOR HANFORD

Contract 5204, Release 55

John T. Baxter, Technical Author — Date 4/25/2000

Larry J. Julyk, Reviewer
CH2M HILL Hanford Group, Inc. — Date 4/25/00

Mian A. Haq, Structural Engineering Lead — Date 5/01/00

Dennis P. Hughes, Area Manager — Date 5/1/00

A.1 Introduction

Tank 241-Z-361 is an inactive underground settling tank located within the protected area of the Plutonium Finishing Plant (PFP). It is buried approximately 240 feet south of Building 236-Z. Concerns regarding the structural integrity of the tank were raised during a chemical hazard assessment at PFP in 1997. The Department of Energy declared an unreviewed safety question (USQ) existed for Tank 241-Z-361 on October 15, 1997 (Wagoner, 1997) based on the discovery that potential hazards associated with the tank had not been included in the PFP authorization basis. One of the concerns was the lack of a current structural evaluation for the tank and limited knowledge of the in-situ condition of the tank concrete structure with respect to corrosion.

The PFP organization recommended imposition of interim operational restrictions when the USQ was issued. These operational restrictions have been superseded by controls approved in a justification for continuing operations (JCO). The JCO has evolved as more information about the tank has been acquired through a time-phased tank characterization plan. The current version of the JCO (HNF-2024) includes a set of administrative controls (Dome Loading Controls) to control access to the area around and immediately above the tank to protect the structural integrity of the tank.

Current dome loading controls are based on a series of structural analyses described in detail in the JCO, and a set of assumptions on the in-situ structural condition of the tank concrete structure. One important assumption is that the reinforcing steel on the inside tank walls is 50 percent degraded in the lower half of the sidewalls. Structural characterization efforts to date include elevations surveys, ground penetrating radar scans, load testing of the tank top, back calculations of margins from known historical loads on the tank roof, and new videotape scans of the interior of the tank.

The purpose of this report is to document a qualitative review of an In-Tank Video dated.

May 12, 1999 of the inside of Tank 241-Z-361. This review compares the interior appearance of the tank with the analysis assumptions on tank in-situ condition that are an important element of the bases for current access and dome loading controls. Based on this comparison, an evaluation is provided on the advisability of relaxing or maintaining current access and dome loading controls specified in the JCO. A preliminary assessment is furnished on the current general structural condition of the tank and likelihood of imminent failure.

A.2 Summary

Viewing of the 241-Z-361 In-Tank Video revealed new information about the current in-situ structural condition of Tank 241-Z-361. Widespread surface etching of the underside of the tank roof was observed that has reduced the concrete cover of the bottom reinforcing bars, which could reduce the bond strength between the bottom bars and the surrounding concrete. Several of the bottom bars show indications of corrosion as evidenced by rust like discoloration marks on the underside of the concrete and splitting cracks which have not yet progressed to spalling of the concrete cover. Thus, the roof load capacity has been reduced from the original design values.

The condition of the vertical sidewalls does not appear to be markedly different than shown in previous photos taken in 1985 at the time of tank closure. The 3/8-inch thick carbon-steel liner was dissolved below the maximum liquid level leaving only the upper steel panels above the liquid level remaining. However, much of the waterproofing material originally installed between the liner and the concrete remains in place. A limited number of small areas of the sidewall concrete were visible in the video where both the liner and the waterproofing had been removed. Exposed aggregate was observed at some of these locations, potentially reducing the concrete wall structural capacity. These areas were around two feet in lateral extent. Because of the limited visual access, the probable areal extent of this kind of degradation cannot be estimated accurately. This partially confirms the current concept that the tank lower sidewalls may have significantly reduced strength. All indications are that the tank roof and sidewalls have reduced structural capacity, which is consistent with the current JCO structural analyses.

A.3 Recommendations

Current access and dome loading restrictions specified in HNF-2024, Rev. 2 should be retained. Although no specific conditions were observed that indicate imminent probable failure of the tank, considerable uncertainty in the in-situ structural condition of Tank 241-Z-361 remains. Clear indications of damage (large cracks and widespread etching on the underside of the concrete) were observed in the roof structure. Some evidence of etching of the inside surface of the tank concrete sidewalls was observed also where the concrete was exposed to view. However, much of the sidewall concrete inner surface is obscured from direct viewing because the waterproofing material originally installed between the steel liner and the concrete remains in place, although damaged.

A.4 Report of Structural Review of Z-361 In-Tank Video

The In-Tank Video dated May 12, 1999 of Tank 241-Z-361, was reviewed on April 11, 2000 at the Fluor Federal Services, Inc., office in Richland, Washington. Prior to reviewing the videotape, the current Justification for Continued Operation (HNF-2024) was reviewed. Frame shots taken from the videotape are included in this report to illustrate comments on the current condition of the tank. Only the roof and sidewalls of the interior of the tank were visible. The bottom floor area was obscured by the layer of waste material remaining in the tank. The video camera was placed into the tank through Riser E (see Figure 2.1-2 of HNF-2024) that is near the center of the tank. The zero-degree pan angle points approximately in the direction of the southwest corner of the tank. The pan angle increases as the camera rotates clockwise from the zero orientation.

A.4.1 Roof Condition

The In-Tank Video provides visual information on the tank roof condition that has not been available from prior reviews. Local damage to the roof structure around Riser F is shown in Figure A-1 with dry well installed. The actual mechanism causing the observed spalling is unknown. There are several features in the image worthy of comment.

Figure A-1. Tank 241-Z-361 Roof Local Damage at Riser F – Toward Northeast Corner

The general undisturbed roof surface has an appearance similar to an exposed aggregate slab finish. This is attributed to the tank atmosphere etching the cement paste off the lower surface of the slab during past operations. Two of the roof reinforcing bars are visible near the spalled surface on each side of the dry well. Based on the tank drawings (H-2-16024), these reinforcing bars are 1-1/8-inch square bars spaced 12 inches on center. The design drawings show that these bars had ¾-inch cover as-designed. Specification of 3/4 inches of cover implies that the maximum aggregate size was also 3/4 inch. The physical size of the bar can be used to estimate the remaining cover on the roof slab bottom bars. It is estimated that about one-quarter, but less than one-half the cover cement paste has been removed by this etching process. Similar exposed aggregate is seen on the entire lower surface of the tank roof as shown in Figures A-2a, A-2b, and A-2c.

Figure A-2a. Tank 241-Z-361 Roof Damage – Near Southeast Corner

Figure A-2b. Tank 241-Z-361 Roof Damage – Near Center of West Wall

Figure A-2c. Tank 241-Z-361 Roof Damage – Near Center of East Wall

Cracking indications are shown in Figures A-2a, A-2b, and A-2c also, all of which show the underside condition of the tank roof. All of these pictures show the initiation of spalling of the slab underside surface, probably immediately below the 1-1/8-inch square bottom bars in the roof slab. The corrosion has progressed far enough to cause splitting, but not spalling of the concrete cover. There were many indications of rust-like discolorations observed on the underside of the roof at intervals consistent with the bottom bar spacing; suggesting widespread corrosion of the bottom rebar of the concrete roof structure. This could lead to additional splitting and spalling of the concrete, reducing the load carrying capacity of the roof structure.

A.4.2 Sidewall Condition

Figure A-3a shows a view of the inner tank wall in the lower part of the tank. The inner steel plate (3/8 inch) liner was dissolved or removed over most of the area exposed to the tank liquid contents. Two shelf angles and the upper portion of the liner remain intact and obscure direct observation of the inner concrete wall surface near the top of the tank. Although the liner plate is gone from the middle and lower elevations of the tank sidewalls, the waterproofing system (a mastic material with reinforcing fabric) remains partially in place on most of the wall area available for visual inspection. The remaining waterproofing material precludes direct visual examination of the current condition of the concrete inner wall in these areas. Figure A-3a shows an area where the concrete does not appear to have been much affected by the tank liquids. Two locations were observed in the videotape where the waterproofing system had completely failed.

Figure A-3a. Tank 241-Z-361 Wall Damage – Bottom Near Northeast Corner.

Figure A-3b. Tank 241-Z-361 Wall Damage – Near Center of East Wall. Adjacent to Remaining

At these locations, the tank liquid content has removed the cement paste around the aggregate rocks at the inner surface of the wall. Figure A-3b is an example of this etching of the sidewall as seen by the exposed aggregate. The images do not allow an estimation of the distance that this effect may extend into the wall thickness but is an indication of potential loss in wall structural capacity. Because of the limited visual access, the probable areal extent of this kind of degradation cannot be estimated accurately. These observations partially confirm the current concept that the tank lower sidewalls may have significantly reduced strength. All indications are that the tank roof and sidewalls have reduced structural capacity, which is consistent with the current JCO structural analyses.

A.5 References

HNF-2024, 1999, *Justification for Continued Operation for Tank 241-Z-361*, Rev. 2, Fluor Daniel Hanford, Inc., Richland, Washington.

In-Tank Video of Tank 241-Z-361 dated May 12, 1999.

Wagoner, J. D., 1997, *Contract No. DE-AC06-96RL13200 – Unreviewed Safety Question (USQ) Regarding Plutonium Finishing Plant (PFP) Tank 241-Z-361*, DOE-RL Letter 97-TPD-193, October 15, 1997.

H-2-16024, 1993, Waste Disposal Facilities 241-Z-361 Settling Tank, Rev. 5, General Electric Company, Hanford Works, Richland, Washington.

This page intentionally left blank.

Appendix B

RADIDOSE Calculations

Appendix B
RADIDOSE Calculations

RADIDOSE Version 3.0 (5-18-2005)			
Input Parameter	**User Input**	**Default**	**Description (based on user input)**
Facility/Material (1-14):	2		Plutonium Finishing Plant: > 10% Pu-240
Form of Material (1-10):	8		Aqueous Waste or Plutonium Solutions
Accident Type (1-6):	5		Spill
Quantity at Risk (MAR):	5.75E+01		gram
Damage Ratio:		1	
Airborne Release Fraction:	3.05E-05		ARF
Respirable Fraction:		1	RF from SARAH Table 3-4 (ARF page)
Leak Path Factor:		1	LPF (applies to particulate only)
HEPA Filter Factor:	1		DF = 1 (applies to particulate only)
Collocated Worker Dose Factor:		3	ICRP 68, 5 µm AMAD
Onsite & Offsite Public Dose Factor:		7	ICRP 72 for Adult
Material Solubility Class:		2	compounds are generally soluble
Hanford Processing Area (1-4):		2	200 Area
Distance or X/Q for Collocated Worker:		100	meters
Distance or X/Q for Onsite Public:		4,210	meters
Distance or X/Q for Offsite Public:		12,500	meters
Emission Source Type (1-4):	1		Point source at ground level
Release Duration (0 to 8760 h):		0.5	hours
Description of Accident Scenario:			Edit using function key F2. Carriage returns are not allowed.
Tank 241-Z-361 collapse involving wet sludge			

Plutonium Finishing Plant: > 10% Pu-240 – New composition (2004)				
Aqueous Waste or Plutonium Solutions				
Point Source At Ground Level				**200 Area**
Total Respirable Release:	1.75E-03	gram		
Dose Factors:	ICRP 68, 5µm	ICRP 72 for Adult		Release Duration 0.5 h
Receptor:	**Collocated Worker**	**Onsite Public**	**Offsite Public**	
Distance:	100 m	4,210 m	12,500 m	
X/Q:	3.28E-02	7.77E-05	1.89E-05	s/m3
Breathing Rate:	3.35E-04	3.29E-04	3.29E-04	m3/s
Unit DCF:	2.53E+07	3.94E+07	3.94E+07	rem/gram
Total Dose:	**4.88E-01**	**1.76E-03**	**4.30E-04**	**rem**
Consequence:	Low	na	Low	

B-1. Tank Collapse Involving Wet Sludge

RADIDOSE Version 3.0 (5-18-2005)			
Input Parameter	**User Input**	**Default**	**Description (based on user input)**
Facility/Material (1-14):	2		Plutonium Finishing Plant: > 10% Pu-240
Form of Material (1-10):	8		Aqueous Waste or Plutonium Solutions
Accident Type (1-6):	1		Fire
Quantity at Risk (MAR):	7.08E+02		gram
Damage Ratio:		1	
Airborne Release Fraction:		2.00E-03	ARF from SARAH Table 3-4 (ARF page)
Respirable Fraction:		1	RF from SARAH Table 3-4 (ARF page)
Leak Path Factor:		1	LPF (applies to particulate only)
HEPA Filter Factor:		1	DF = 1 (applies to particulate only)
Collocated Worker Dose Factor:		3	ICRP 68, 5 μm AMAD
Onsite & Offsite Public Dose Factor:		7	ICRP 72 for Adult
Material Solubility Class:	2		compounds are generally soluble
Hanford Processing Area (1-4):		2	200 Area
Distance or X/Q for Collocated Worker:		100	meters
Distance or X/Q for Onsite Public:		4,210	meters
Distance or X/Q for Offsite Public:		12,500	meters
Emission Source Type (1-4):	4		Ground level fire
Thermal Power (0.5 to 1000 MW):		0.5	MW (at 0.02 W/m²)
Pool Fire Diameter (1 to 20 m):	6.32		meters (Area = 31.4 m²)
Description of Accident Scenario:		Edit using function key F2. Carriage returns are not allowed.	
Tank 241-Z-361 Pool Fire involving wet sludge			

Plutonium Finishing Plant: > 10% Pu-240 – New composition (2004)				
Aqueous Waste or Plutonium Solutions				
Ground Level Fire – 0.5 MW – 6.3 m Diameter				**200 Area**
Total Respirable Release:	1.42E+00	gram		
Dose Factors:	ICRP 68, 5μm	ICRP 72 for Adult		Release
Receptor:	**Collocated Worker**	**Onsite Public**	**Offsite Public**	Duration 1 h
Distance:	100 m	4,210 m	12,500 m	
X/Q:	1.15E-03	3.86E-05	1.17E-05	s/m3
Breathing Rate:	3.35E-04	3.29E-04	3.29E-04	m3/s
Unit DCF:	2.53E+07	3.94E+07	3.94E+07	rem/gram
Total Dose:	**1.38E+01**	**7.08E-01**	**2.15E-01**	**rem**
Consequence:	Low	na	Low	

B-2. Tank Pool Fire Involving Wet Sludge

RADIDOSE Version 3.0 (5-18-2005)			
Input Parameter	**User Input**	**Default**	**Description (based on user input)**
Facility/Material (1-14):	2		Plutonium Finishing Plant: > 10% Pu-240
Form of Material (1-10):	8		Aqueous Waste or Plutonium Solutions
Accident Type (1-6):		1	Fire
Quantity at Risk (MAR):	5.41E+02		gram
Damage Ratio:		1	
Airborne Release Fraction:	5.00E-03		ARF
Respirable Fraction:	0.4		RF
Leak Path Factor:		1	LPF (applies to particulate only)
HEPA Filter Factor:	1		DF = 1 (applies to particulate only)
Collocated Worker Dose Factor:		3	ICRP 68, 5 µm AMAD
Onsite & Offsite Public Dose Factor:		7	ICRP 72 for Adult
Material Solubility Class:	2		compounds are generally soluble
Hanford Processing Area (1-4):		2	200 Area
Distance or X/Q for Collocated Worker:		100	meters
Distance or X/Q for Onsite Public:		4,210	meters
Distance or X/Q for Offsite Public:		12,500	meters
Emission Source Type (1-4):	4		Ground level fire
Thermal Power (0.5 to 1000 MW):		0.5	MW (at 0.02 W/m²)
Pool Fire Diameter (1 to 20 m):	6.32		meters (Area = 31.4 m²)
Description of Accident Scenario:		Edit using function key F2. Carriage returns are not allowed.	
BDBE Seismic Event - Tank 241-Z-361 MAR as air-dried salt; pool fire; DR = 1.0			

Plutonium Finishing Plant: > 10% Pu-240 -- New composition (2004)				
Aqueous Waste or Plutonium Solutions				
Ground Level Fire -- 0.5 MW -- 6.3 m Diameter				**200 Area**
Total Respirable Release:	1.08E+00 gram			
Dose Factors:	ICRP 68, 5µm	ICRP 72 for Adult		Release
Receptor:	**Collocated Worker**	**Onsite Public**	**Offsite Public**	Duration 1 h
Distance:	100 m	4,210 m	12,500 m	
X/Q:	1.15E-03	3.86E-05	1.17E-05	s/m3
Breathing Rate:	3.35E-04	3.29E-04	3.29E-04	m3/s
Unit DCF:	2.53E+07	3.94E+07	3.94E+07	rem/gram
Total Dose:	**1.06E+01**	**5.40E-01**	**1.64E-01**	**rem**
Consequence:	Low	na	Low	

B-3. BDBE Involving Dried Sludge Pool Fire

RADIDOSE Version 3.0 (5-18-2005)			
Input Parameter	User Input	Default	Description (based on user input)
Facility/Material (1-14):	2		Plutonium Finishing Plant: > 10% Pu-240
Form of Material (1-10):	7		Pu Oxide and Other Powders
Accident Type (1-6):	2		External Impact
Quantity at Risk (MAR):	4.52E+04		gram
Damage Ratio:		1	
Airborne Release Fraction:	1.00E-01		ARF
Respirable Fraction:	4.87E-06		RF
Leak Path Factor:		1	LPF (applies to particulate only)
HEPA Filter Factor:	1		DF = 1 (applies to particulate only)
Collocated Worker Dose Factor:		3	ICRP 68, 5 µm AMAD
Onsite & Offsite Public Dose Factor:		7	ICRP 72 for Adult
Material Solubility Class:	2		compounds are generally soluble
Hanford Processing Area (1-4):		2	200 Area
Distance or X/Q for Collocated Worker:		100	meters
Distance or X/Q for Onsite Public:		4,210	meters
Distance or X/Q for Offsite Public:		12,500	meters
Emission Source Type (1-4):	1		Point source at ground level
Release Duration (0 to 8760 h):		0.5	hours

Description of Accident Scenario: Edit using function key F2. Carriage returns are not allowed.

BDBE Seismic Event - Tank 241-Z-361 MAR impact; DR = 1.0

Plutonium Finishing Plant: > 10% Pu-240 – New composition (2004)				
Pu Oxide and Other Powders				
Point Source At Ground Level				200 Area
Total Respirable Release:	2.20E-02	gram		
Dose Factors:	ICRP 68, 5µm	ICRP 72 for Adult		Release Duration 0.5 h
Receptor:	**Collocated Worker**	**Onsite Public**	**Offsite Public**	
Distance:	100 m	4,210 m	12,500 m	
X/Q:	3.28E-02	7.77E-05	1.89E-05	s/m3
Breathing Rate:	3.35E-04	3.29E-04	3.29E-04	m3/s
Unit DCF:	2.53E+07	3.94E+07	3.94E+07	rem/gram
Total Dose:	**6.13E+00**	**2.22E-02**	**5.40E-03**	**rem**
Consequence:	Low	na	Low	

B-4. BDBE Involving Dried Sludge Impact

This page is intentionally left blank.