U.S. Department of Energy
Office of River Protection
P.O. Box 450, MSIN H6-60
Richland, Washington 99352

12-WTP-0395

DEC 31 2012

The Honorable Peter S. Winokur
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, NW, Suite 700
Washington, D.C. 200004-2901

Dear Mr. Chairman:

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.5.3.1

This letter provides the deliverable responsive to Commitment 5.5.3.1 of the U.S. Department of Energy, Office of River Protection, Waste Treatment and Immobilization Plant (ORP-WTP) plan to address WTP Vessels Mixing Issues, IP for DNFSB 2010-2.

An attachment provides the initial gap analysis between WTP Waste Feed Acceptance Criteria (WAC) and tank farm sampling and transfer capability. The initial gap analysis includes a definition of the initial WAC; determination of physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems, given the uncertainty associated with tank farm characterization data; a determination of the capability of staging tank sampling system; and identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.

Large-Scale Integrated Mixing System Expert Review Team review comments and resolution are also included in the attachment.

If you have any questions, please contact me at (509) 376-8830, or your staff may contact Ben Harp, WTP Start-up and Commissioning Integration Manager at (509) 376-1462.

Sincerely,

Stan Charboneau for

Scott L. Samuelson, Manager
Office of River Protection

WTP:WRW

Attachment

cc w/attachments: See page 2

cc w/attachments:

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W. W. Gay, BNI
F. M. Russo, BNI
D. McDonald, Ecology
D. G. Huizenga, EM-1
T. P. Mustin, EM-1
M. B. Moury, EM-1
K. G. Picha, EM-1
C. S. Trummell, EM-1
A. C. Williams, EM-2.1
J. A. Landmesser, EM-41
A. P. Bione, EM-41
J. A. Landmesser, EM-41
T. N. Lapointe, EM-41
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M. D. Johnson, WRPS
S. A. Saunders, WRPS
R. G. Skwarek, WRPS
M. G. Thien, WRPS
BNI Correspondence
WRPS Correspondence

ATTACHMENT
to
12-WTP-0395

TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD (DNFSB) RECOMMENDATION 2010-2 IMPLEMENTATION PLAN (IP) DELIVERABLE 5.5.3.1

(Total No. of Pages, not including cover sheet: 296

- WRPS-1205551-OS, One System – Washington River Protection Solutions LLC Transmittal of Defense Nuclear Facilities Safety Board Recommendation 2010-2 Implementation Plan Requirements for Commitment 5.5.3.1, dated December 27, 2012 (3 pages, Pages 1 through 3)

- WRPS-1205239-OS, One System Technical Team Response to Review of One System Initial Gap Analysis Between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability (ERT-21), dated November 30, 2012 (164 pages, Pages 4 through 167)

- ERT-21 Initial gap Analysis – Large-Scale Integrated Mixing System Expert Review Team (1 page, Page 168)

- RPP-RPT-53343, 24590-WTP-RPT-MGT-12-022, Revision 0 – One System Initial Gap Analysis Between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1 (125 pages, Pages 169 through 296)

washington river protection solutions | PO Box 850 Richland, WA 99352

December 27, 2012 WRPS-1205551-OS

Ms. S. E. Bechtol, Contracting Officer
U.S. Department of Energy
Office of River Protection
Post Office Box 450
Richland, Washington 99352-0450

Dear Ms. Bechtol:

CONTRACT NUMBER DE-AC27-08RV14800 – ONE SYSTEM - WASHINGTON RIVER PROTECTION SOLUTIONS LLC TRANSMITTAL OF DEFENSE NUCLEAR FACILITIES SAFETY BOARD RECOMMENDATION 2010-2 IMPLEMENTATION PLAN REQUIREMENTS FOR COMMITMENT 5.5.3.1

Washington River Protection Solutions (WRPS) transmits the enclosed documents to support the U.S. Department of Energy, Office of River Protection (ORP) transmittal of the commitment requirements to the Defense Nuclear Facilities Safety Board (DNFSB). In accordance with the WRPS 2010-2 Commitment Document Review Plan, we have completed the document associated with DNFSB Recommendation Commitment 5.5.3.1 and are providing the appropriate documents to ORP. Please note that this is a joint document which involved the participation of both WRPS and Bechtel National, Inc. (BNI) in the development review and approval process, and is therefore being issued with both a WRPS and BNI document numbers. Support documents include the following:

- RPP-RPT-533343, 24590-WTP-RPT-MGT-12-022, Rev. 0, "One System Initial Gap Analysis between Waste Treatment Plant Acceptance Criteria and Tank Farm Sampling and Transfer Capability2010-2 Implementation Plan Commitment 5.5.3.1" (Enclosure 1)

- WRPS-1205239-OS, WRPS Large-Scale Integrated Mixing System Expert Review Team (ERT) Comment Response Letter to L. M. Peurrung, ERT Chair. Letter also includes ERT comment dispositions and draft document with ERT review comment incorporations (Enclosure 2)

- ERT Comment Response Concurrence Letter (Enclosure 3)

If you have any questions concerning this matter, please contact Mr. M. G. Thien at 372-3665 or Mr. S. A. Saunders at 372-9939.

(Signature Attached)

R. J. Skwarek, Project Manager
One System Integrated Project Team

(Signature Attached)

C. A. Simpson
Contracts Manager

MGT:MES

Enclosures:
1. RPP-RPT-533343, 24590_WTP-RPT-MGT-12-022, Rev. 0, "One System Initial Gap Analysis between Waste Treatment Plant Acceptance Criteria and Tank Farm Sampling and Transfer Capability2010-2 Implementation Plan Commitment 5.5.3.1" (128 pages)

2. Letter, R. J. Skwarek, WRPS, to L. M. Peurrung, PNL, "One System Technical Team Response to Review of One System Initial Gap Analysis between Waste Treatment Plant Acceptance Criteria and Tank Farm Sampling and Transfer Capability (ERT-21)," WRPS-1205239-OS, dated November 30, 2012 (164 pages)

3. ERT Comment Response Concurrence Letter, dated December 6, 2012 (1 page)

cc: ORP Correspondence Control
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B. J. Harp, ORP
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P. J. Keuhlen, WTP
F. Russo, WTP

FROM THE DESK OF

Raymond J. Skwarek
Manager, One System IPT

Date: November 30, 2012 WRPS-1205239-OS

To: L. M. Peurrung, Chair
Large-Scale Integrated Mixing System Expert Review Team

Subject: ONE SYSTEM TECHNICAL TEAM RESPONSE TO REVIEW OF ONE SYSTEM INITIAL GAP ANALYSIS BETWEEN WASTE TREATMENT PLANT WASTE ACCEPTANCE CRITERIA AND TANK FARM SAMPLING AND TRANSFER CAPABILITY (ERT-21)

The One System Technical team appreciates the Large-Scale Integrated Mixing System Expert Review Team (ERT) review (Enclosure 1) of the subject document. We also appreciate the opportunity the One System Technical team had to address the ERT questions prior to issuing the ERT formal review letter. This helped put this phase of initial gap analysis in the proper perspective which we believe you have appropriately characterized in your review letter, *"... the ten gaps identified likely are justifiably One System's top ten issues to resolve with respect to meeting the waste acceptance criteria. The question is whether the approximations cause a gap to be omitted – whether there might be numbers eleven, twelve or thirteen – depending on the assumed values of waste parameters and associated uncertainties."* We have modified the draft report to clarify this perspective.

This response letter addresses the three specific recommendations identified by the ERT, followed by the One System response.

1. *"The ERT recommends that the authors include a sensitivity analysis on other acceptance criteria near failure with respect to the estimated relative standard deviations to determine if the gap analysis is complete. The ERT also suggests that the document more clearly acknowledge the level of uncertainty in some of its uncertainty estimates."*

The One System Technical team acknowledges that the majority of sampling percent relative standard deviations (%RSD) are based on qualitative assessment and that the total number of gaps may vary depending on the assumed values of waste parameters and associated uncertainties. We agree with your recommendation that a sensitivity analysis is an appropriate method to test the impact of sampling %RSD on the gap conclusion. The gap analysis report has been modified to include a sensitivity analysis for the sample size calculation by varying the sampling %RSD.

2. *"The spatially and temporally varying solids concentrations in the feed tank introduce other biases, as would particle settling in the transfer line. Bias may also vary from feed to feed. The ERT recommends that the document explain how these biases are addressed."*

The One System Technical team agrees with your assessment of potential biases in the waste feed delivery process. The gap analysis report has been modified to discuss qualitatively the source of process driven biases and explain how these potential biases could impact the waste acceptance decision.

3. *"The ERT observes that many parameters are based on the River Protection Project System Plan Rev. 6. The system plan is the technical basis for the flowsheet for treating Hanford tank waste, but it does include a number of assumptions. The ERT recommends that the authors evaluate any potential impact of those assumptions on the validity of the document's conclusions."*

The One System Technical team agrees that the System Plan, Rev. 6 includes a number of assumptions. The authors have evaluated potential impact of these assumptions and included the System Plan, Rev. 6 as an assumption in the document.

In addition to the specific responses highlighted above, the One System Technical team has reviewed the ERT document suggestions provided on a separate document review record and modified the DNFSB commitment document. The updated draft document (Enclosure 2) incorporating comments received from all reviewers, and the disposition of the ERT individual review comments (Enclosure 3) are included for your information.

Please feel free to contact me at 372-9117, or Mike Thien at 372-3665 if you have any further questions regarding our response to the ERT review.

Sincerely,

R Skwarek

R. J. Skwarek, Project Manager
One System Integrated Project Team

MGT:MES

Enclosure(s):
1. ERT-21 Review Letter (3 pages)
2. RPP-RPT-53343, Draft B, "One System Initial Gap Analysis between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1" (123 pages)
3. LSIMS ERT Document Review Record (32 pages)

cc:

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WRPS-1205239

Enclosure 1

Large-Scale Integrated Mixing System Expert Review Team

(L. Peurrung, Chair; R. Calabrese, R. Grenville, E. Hansen, R. Hemrajani)

To: Tom Fletcher, Tank Farms Federal Project Director; Michael D. Johnson, WRPS President and Project Manager, Tank Operations Contract

Cc: Ray Skwarek, One System IPT Manager; Rick Kacich, One System IPT Deputy Manager; Mike Thien, WRPS; ERT Members

Subject: *One System Initial Gap Analysis Between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1* (ERT-21 Initial Gap Analysis)

Date: October 11, 2012

The Large-Scale Integrated Mixing System Expert Review Team (ERT) was asked to review "One System Initial Gap Analysis Between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1" (RPP-RPT-53343, 24590-WTP-RPT-MGT-12-022, Revision Draft). This document is meant to satisfy Commitment 5.5.3.1 for an "Initial gap analysis between WTP WAC and Tank Farm sampling and transfer capability". Per the IP, the deliverable for Commitment 5.5.3.1 will include:

- A definition of the initial WAC.
- A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems given the uncertainty associated with tank farm characterization data.
- A determination of the capability of staging tank sampling system.
- Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.

The lines of inquiry for ERT-21 Initial Gap Analysis were:

- Does the document adequately address each of the areas in the deliverable description?
- Is the methodology valid? Will it lead to a reasonably accurate and complete picture of the current gaps between the WAC and tank farm capability?

The ERT concurs with the general methodology used in the Initial Gap Analysis – the collection of the relevant limits on parameters identified to date, the estimation of tank farm waste feed delivery performance and waste feed characteristics, the estimation of uncertainties in sampling

and analysis, and the use of the information in the system plan (as available) to forecast the waste delivery profile. This approach results in the list of ten issues (gaps) identified in the document that need to be resolved before feed delivery can proceed. The document makes a reasonable case for the validity of these ten gaps even though the analysis is based on figures that often are estimated. For example, the capabilities of the waste feed delivery and sampling systems are still being evaluated through testing, making predictions of performance (e.g., with respect to maximum particle size transferred, batch-to-batch consistency, or sampler bias and precision) rather preliminary. Almost all of the sampling relative standard deviations in Table 4-3 are based on qualitative assessment – they are virtually order-of-magnitude estimates. Even so, the ten gaps identified likely are justifiably OneSystem's top ten issues to resolve with respect to meeting the waste acceptance criteria. The question is whether the approximations cause a gap to be omitted – whether there might be numbers eleven, twelve or thirteen – depending on the assumed values of waste parameters and associated uncertainties. The ERT recommends that the authors include a sensitivity analysis on other acceptance criteria near failure with respect to the estimated relative standard deviations to determine if the gap analysis is complete. The ERT also suggests that the document more clearly acknowledge the level of uncertainy in some of its uncertainty estimates.

The document points out certain known biases with respect to particle size and density associated with mixing, transfer, and sampling. The ERT observes that how these biases are incorporated into uncertainty estimates and gap analysis is unclear. The reference cited in Table 4-2 of the document (PL Smith, *A Primer for Sampling Solids, Liquids and Gases – Based on the Seven Sampling Errors of Pierre Gy)* notes (on page 20) that "Grab sampling does not follow the principle of correct sampling since certain parts of the lot have no chance of being in the sample. Thus our estimate of the amount of the constituent of interest may be biased, and we cannot calculate a statistical error for it." The spatially and temporally varying solids concentrations in the feed tank introduce other biases, as would particle settling in the transfer line. Bias may also vary from feed to feed. The ERT recommends that the document explain how these biases are addressed.

The ERT observes that many parameters are based on the River Protection Project System Plan Rev. 6. The system plan is the technical basis for the flowsheet for treating Hanford tank waste, but it does include a number of assumptions. The ERT recommends that the authors evaluate any potential impact of those assumptions on the validity of the document's conclusions.

Comments from individual ERT members are attached. The ERT hopes you find this review helpful, and we look forward to your response per the ERT Charter.

Review Participants:

October 1, 2012: Loni Peurrung, Rich Calabrese, Erich Hansen, Ramesh Hemrajani, Mike Thien, Chi Leung

October 4, 2012: Loni Peurrung, Rich Calabrese, Erich Hansen, Ramesh Hemrajani

WRPS-1205239

Enclosure 2

RPP-RPT-53343
24590-WTP-RPT-MGT-12-022
Revision Draft B

One System Initial Gap Analysis between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1

C. L. Leung
URS Corporation

E. J. Slaathaug
Bechtel National Incorporated

C. Seidel
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Washington River Protection Solutions, LLC

Date Published
XXXXXX 2012

Prepared for the U.S. Department of Energy
Office of River Protection

Contract No. DE-AC27-08RV14800

EXECUTIVE SUMMARY

This report documents an initial gap analysis between the Hanford Tank Farm Waste Feed Delivery (WFD) system capabilities and the Hanford Tank Waste Treatment and Immobilization Plant (WTP) Waste Acceptance Criteria (WAC). It satisfies the deliverable requirements for Commitment 5.5.3.1 as delineated in the Implementation Plan (IP) for Defense Nuclear Facility Safety Board (DNFSB) Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*.

The purpose of this initial gap analysis is to determine if the expected range of waste properties for waste transferred to WTP exceeds the WAC and if the staging tank sampling systems can detect physical properties that exceed the WAC. It is part of a phased approach to address the underlying safety issue raised in the DNFSB Recommendation 2010-2, specifically Sub-Recommendation 5. The scope of this initial gap analysis is focused on the High Level Waste (HLW) feed because it contains the potentially large and fast settling solids that result in the safety concerns identified in the DNFSB Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant.* Information from this initial gap analysis can provide insights into the types of testing and potential controls that may be necessary to assure waste delivered to WTP conforms to the WAC.

The initial gap analysis process starts with defining the requirements (i.e., initial WAC) for the comparison of Tank Farm WFD system capabilities. Uncertainties in each step of the waste transfer process are estimated and propagated using the Root Sum Square (RSS) method to determine the total feed uncertainty. The total feed uncertainty would then be applied to the expected pre-transfer sample value and compared to the corresponding WAC action limit. This comparison is expressed in terms of number of samples required to meet the minimum Confidence Level (CL) of either 90% or 95% for the WAC parameter. The comparison of feed against the WAC parameters is referred to as the feed "screening" process in this report. This feed screening is repeated for each WAC parameter selected for the gap analysis. Since the pre-transfer sample provides the basis for the waste acceptance decision, a gap would be identified if the total number of pre-transfer samples exceeds 10, which is the baseline number in the WAC Data Quality Objective (DQO). Gaps identified through this screening process are preliminary and should not be used to draw conclusions regarding treatability of the waste or final acceptance decision. Possible options to address the gaps may be to take more samples or reduce the required Confidence Level.

A gap would also be identified in cases where there is insufficient information on the staged feed to allow a reasonable comparison against a particular WAC parameter, or a lack of established analytical techniques to support a waste acceptance decision.

Conclusions

An initial WAC has been defined to include the current HLW feed parameters from the WTP ICD-19. The list of parameters is consistent with the definition of Action Limits group in the WAC DQO, which applies to "…*those constituents deemed as impacting WTP receipt vessel design, ability to process waste through WTP unit operations, or WTP safety basis*…".

Collectively, this list of WAC parameters addresses the decision statement of: Does the staged feed meet the WTP WAC for transferring the feed to WTP?

A separate list of "potential new nuclear safety parameters" is compiled from 24590-WTP-RPT-ENS-11-021 for comparison against the Tank Farm sampling and analytical capabilities. The selected parameters cover the physical properties of concerns for mixing and sampling (e.g., large, fast settling solids) in WTP as raised in the DNFSB Recommendation 2010-2.

There are seven (7) gaps identified between Tank Farm's sampling and/or analytical capability in meeting some of the initial WAC parameters. The seven identified gaps as listed by the affected WAC parameters are (see Section 6.0 for details):

- Critical velocity – PulseEcho development and field application uncertainties.
- Separable organics – Potential stratification of a separate organic layer that cannot be mixed or sampled using current method (i.e., waste feed certification flow loop).
- Polychlorinated biphenyls (PCB) – High analytical Relative Standard Deviation (%RSD).
- $U_{fissile}$ to U_{total} ratio – Feed concentration close to the action limit driving a high number of required pre-transfer samples greater than ten (10) for some feed batches given the current feed strategy in System Plan 6.
- Hydrogen Generation Rate (HGR) – Lack of established hot cell procedures to measure generation rate compounded by high uncertainties in analytical technique (static vs. flow through).
- Feed temperature – Design is not final for this direct field measurement and there is no defined process control strategy. Uncertainties of the final design (thermocouple "tree") may be high considering the transfer temperature could approach and may exceed action limit.
- Abrasivity – Lack of established hot cell procedures to measure abrasiveness of primary particles or agglomerates.

There are three (3) open items identified between Tank Farm's sampling and/or analytical capability in meeting some of the potential new nuclear safety parameters listed in 24590-WTP-RPT-ENS-11-021. These are binned separately from the gaps because the affected parameters are not part of the initial WAC. The three open items as listed by the affected parameters are (see Section 6.0 for details):

- Pu particle size – Trace quantity (PuO_2 in particular) drives a high uncertainty in Tank Farm's capability to detect its presence, even assuming perfect tank mixing and sampling.
- Average particle density of pre-leached solids – Likelihood of HLW feed exceeding the average particle density limit and the misalignment between Tank Farm planning basis (HTWOS) and WTP design basis (BOD).

- HLW feed particle size – Maximum size of particles that can be physically transferred to WTP (up to 9,525 μm) may exceed the design bases maximum. Large particles may also be bypassed (not sampled) due to size exceeding the sample port (needle) opening.

The results of this initial gap analysis are based on limited testing and design information. As the design and test programs for WTP and Tank Farm WFD system continue to mature, the identified gaps may change. Planned updates to ICD-19 and the WAC DQO would either confirm or support closure of the identified gaps.

While not definitive, this initial gap analysis provides a metric for flagging potential issues that can affect the waste acceptance decision. This report is only one of ten deliverables under Sub-recommendation 5 of the 2010-2 Implementation Plan. A separate final gap analysis report will be issued to document resolution or closure of the identified gaps using latest testing results and a revised WAC (IP Commitment 5.5.3.9).

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Terms

Bias is the difference in the long-term mean value of estimates of a quantity and the true, unknown value of the quantity.

Gap refers to a mismatch between Tank Farm WFD system capabilities and the initial WAC for WTP. It is expressed either quantitatively in terms of number of samples required to meet the specified waste acceptance action limit, or qualitatively in terms of uncertainties in the sampling and analytical capabilities.

Open Item refers to a mismatch between Tank Farm WFD system capabilities and the Potential New Nuclear Safety Parameters, rather than the initial WAC.

Potential New Nuclear Safety Parameters refers to the list of parameters in the DNFSB 2010-2 IP Commitment 5.7.3.4 deliverable 24590-WTP-RPT-ENS-11-021, Rev. 0. This list as defined for initial gap analysis is separate from the initial WAC parameters.

Uncertainty refers to the lack of knowledge of the true value of a quantity. Uncertainty can be systematic or random.

Variation or Variability refers to differences in the true value of a quantity over time and/or space and is distinct from uncertainty.

Waste Acceptance Criteria (or initial WAC) refers to the High Level Waste (HLW) feed parameters established in the WTP Interface Control Document (24590-WTP-ICD-MG-01-019, Rev. 5) as defined for this initial gap analysis.

ABBREVIATIONS AND ACRONYMS

AEA	Alpha Energy Analysis
ALARA	As Low As Reasonably Achievable
ASTM	American Society for Testing and Materials
BNI	Bechtel National Incorporated
BOD	Bases of Design
CFD	Computational Fluid Dynamic
CL	Confidence Level
CSER	Criticality Safety Evaluation Report
CSL	Criticality Safety Limit
CV	Critical Velocity
DE	Delimitation Error
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
DST	Double-Shell Tank
DWP	Dangerous Waste Permit
EE	Extraction Error
ERT	Expert Review Team
FE	Fundamental Error
FEP	Feed Evaporator Process System
GC/TCD	Gas Chromatography/Thermal Conductivity Detector
GEA	Gamma Emission Analyzer
GSE	Grouping and Segregation Error
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HGR	Hydrogen Generation Rate
HLW	High-Level Waste
HTWOS	Hanford Tank Waste Operations Simulator
ICD	Interface Control Document
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectrophotometry
ICP-MS	Inductively Coupled Plasma – Mass Spectrometer
IWFDP	Integrated Waste Feed Delivery Plan
IP	Implementation Plan
LAW	Low-Activity Waste
LSIT	Large Scale Integrated Testing
%RSD	Percent Relative Standard Deviation
PCB	Polychlorinated biphenyls
PDSA	Preliminary Documented Safety Analysis
PE	Preparation Error
PIER	Project Issue Evaluation Report
PJM	Pulse Jet Mixer
PNNL	Pacific Northwest National Laboratory
QC	Quality Control
RPD	Relative Percent Difference

RPP	River Protection Project
RDQO	Regulatory Data Quality Objectives
RSS	Root Sum Square
SD	Standard Deviation
SEM	Scanning Electron Microscopy
SME	Subject Matter Expert
SRD	Safety Requirements Document
SpG	Specific Gravity
SRNL	Savannah River National Laboratory
SS	Stainless Steel
SSMD	Small-Scale Mixing Demonstration
SST	Single-Shell Tank
SVOC	Semi-Volatile Organic Compounds
TBD	To Be Determined
TFC	Tank Farm Contractor
TIC/TOC	Total Inorganic Carbon/Total Organic Carbon
TGA/DSC	Thermo-Gravimetric Analysis/Differential Scanning Calorimetry
TWINS	Tank Waste Information Network System
UFP	Ultra-filtration Process System
VOC	Volatile Organic Compounds
WAC	Waste Acceptance Criteria
WFD	Waste Feed Delivery
WRPS	Washington River Protection Solutions
WSCF	Waste Sampling and Characterization Facility
WTP	Hanford Tank Waste Treatment and Immobilization Plant

Units

Ci	Curies
cP	centipoise
ft	foot
g	gram
gal	gallon
gpm	gallons per minute
hp	horsepower
J	Joule
kg	kilogram
L	liter
mL	milliliter
Mohs	hardness scale
min	minute
Pa	Pascal
ppm	parts per million
psi	pounds per square inch
psig	pounds per square inch gauge
s	second
Sv	Sievert
µm	microns
wt%	weight percent

1.0 INTRODUCTION

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being constructed to process radioactive waste stored in 177 underground storage tanks at the Hanford Tank Farm. The stored waste will be staged and segregated into two main feed streams for transfer to WTP, a Low-Activity Waste (LAW) feed stream and a High-Level Waste (HLW) feed stream. Both feed streams must demonstrate compliance to the WAC prior to transfer to WTP. The current WAC was developed from design, safety, regulatory, and contractual sources to provide an interface control for ensuring safe and efficient operations of WTP.

Of the two feed streams to WTP, the HLW feed, which contains a wide range of undissolved solids in slurry of varying physical and rheological properties, represents a unique challenge to both the Tank Farm and WTP in areas of mixing, sampling, and transferring operations. Characterization data on the type, size, quantities, distribution, and properties (e.g., density, abrasiveness, etc.) of the wide range of undissolved solids in the HLW stream is very limited and the Tank Farm's ability to properly sample and analyze them to ensure WAC compliance is uncertain. Because of potential downstream safety impact at WTP, these "problematic" solids in the HLW are the focus driving many of the ongoing test programs being conducted by the Tank Farm and WTP Contractors. Settling and accumulation of solids from the HLW feed in particular is a safety concern expressed by the Defense Nuclear Facilities Safety Board (DNFSB) in Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*.

The Department of Energy (DOE) issued an Implementation Plan in November, 2011 (Chu, 2011) in response to Recommendation 2010-2. The Implementation Plan (IP) contains seven (7) sub-recommendations to address safety issues. Sub-recommendation 5 addresses representative samples from waste feed tanks. It delineates ten (10) separate Commitments, 5.5.3.1 through 5.5.3.10. This report satisfies the deliverable for Commitment 5.5.3.1 for an "*Initial gap analysis between WTP WAC and Tank Farm sampling and transfer capability*."

As stated in the IP, the deliverable for Commitment 5.5.3.1 includes:

- A definition of the initial WAC.
- A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems, given the uncertainty associated with tank farm characterization data.
- A determination of the capability of staging tank sampling system.
- Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.
- Expert Review Team (ERT) review comments and resolution will be included with the deliverable transmittal.

The first four bullets above define the general scope of the initial gap analysis. The ERT review has been conducted as an integral part of the approval and release process for this report. Table

1-1 provides a deliverable compliance matrix linking sections in this report to applicable scoping statements in the IP.

Table 1-1. Deliverable Compliance Matrix.

2010-2 IP Section	Excerpts	Addressed in Section(s)
5.5.2	Initial Phase Defi**n**e initial requirements for tank waste feed that is transferred between the Hanford tank farms and WTP, referred to as the WAC. This includes requirements to obtain representative samples. This initial set of requirements will be based on current information (Commitment 5.5.3.1).	3.1; Table 3-1
5.5.2	Initial Phase Determine the range of physical properties that can be sampled and characterized based on existing information on tank farm sampling systems (Commitment 5.5.3.1).	4.2.5
5.5.2	Initial Phase Perform an initial gap analysis to determine if the expected range of waste properties for waste transferred to WTP exceeds the WAC and if the staging tank sampling systems can detect physical properties important for the WAC and identify waste that may not meet the WAC (Commitment 5.5.3.1).	6.0
5.5.2	An assessment of the capability of the tank farm staging tank sampling systems to obtain samples that can be used to assess the range of physical properties identified in the initial WAC will be performed. This assessment will include an estimate of waste properties that can be measured and those that cannot be measured based on sampling system limitations.	6.0
5.5.2	An initial gap analysis is being performed to determine if the expected range of waste properties for waste transferred to WTP exceeds the initial WAC and if the staging tank sampling systems can detect physical properties that exceed the WAC. Information from this initial gap analysis will be used to define requirements for testing being planned by WRPS for evaluating tank waste feed staging, sampling, and transfer systems and BNI for pulse jet mixer (PJM) mixed vessel mixing, sampling, transfer, and PJM control testing. The results may provide insight into the types of potential controls that may be necessary to assure waste delivered to WTP conforms to the WAC.	6.0, 7.0
5.5.3	Commitment 5.5.3.1: Complete an initial gap analysis between Tank Farm sampling system capabilities, uncertainties, and waste projected to be transferred to WTP. This report will include:	
	A definition of the initial WAC.	3.1; Table 3-1
	A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems given the uncertainty associated with tank farm characterization data.	4.0, 6.0
	A determine of the capability of staging tank sampling system.	4.0; Table 4-2
	Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.	4.0; Table 4-3, 5.1

1.1 PURPOSE

The purpose of this initial gap analysis is to *"determine if the expected range of waste properties for waste transferred to WTP exceeds the initial WAC and if the staging tank sampling systems can detect physical properties that exceed the WAC"* (Chu, 2011). This report documents the identified gaps and associated evaluations to provide a starting point for tracking these gaps through resolution. Information from this report may be used as appropriate to define test requirements being planned by the Tank Farm Contractor, Washington River Protection Solutions, LLC (WRPS), and the WTP Contractor, Bechtel National Inc. (BNI). A separate final gap analysis report will be issued to document resolution or closure of the identified gaps (IP Commitment 5.5.3.9).

1.2 SCOPE

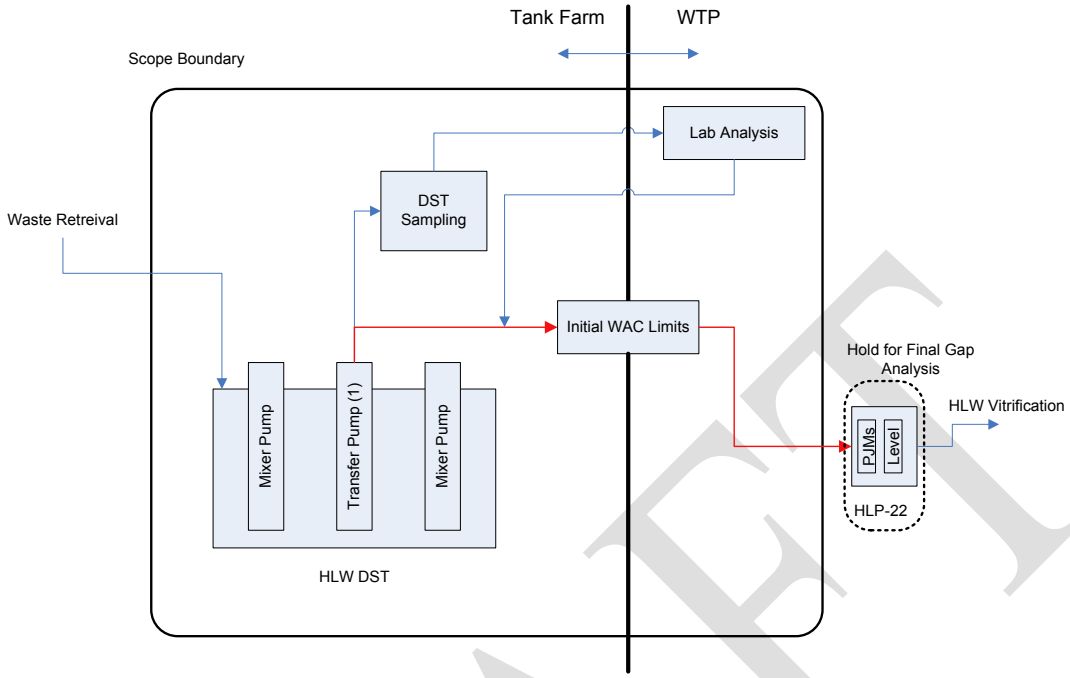
The scope of this report includes the assessment of gaps between the expected waste transferred to WTP, specifically HLW feed, and the corresponding acceptance limits in the "initial WAC". This document focuses on HLW feed because it contains the potentially large and fast settling solids that result in the safety concerns identified in the DNFSB Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*. The term "initial WAC" as defined in the context of this initial gap analysis report is limited to the current HLW feed parameters in 24590-WTP-ICD-MG-01-019, *ICD-19 – Interface Control Document for Waste Feed*. This document does not propose or set new WAC parameters for WTP.

The scope of this report also include the screening of other potential new nuclear safety related parameters as listed in the 2010-2 IP deliverable for Commitment 5.7.3.4 (24590-WTP-RPT-ENS-11-021, *Key Inputs, Assumptions, Safety Margin Uncertainties, and Nuclear Safety Parameters Required to be Included in the Waste Acceptance Criteria, 2010-2 Implementation Plan Commitment 5.7.3.4*). The parameters from this input document are screened following the same approach as the initial WAC parameters (i.e., ICD-19), but the results are binned and tracked separately as gap analysis "Open Items" because they do not fit the definition of a gap in the context of this report, which is always benchmarked to a WAC parameter (see Section 2.1).

In general, the scope of this initial gap analysis traces the sample flow path from the Double-Shell Tank (DST) at the Tank Farm to the HLW receipt vessel (HLP-22) at WTP, accounting for transfer equipment capability and uncertainties along the way that can impact the waste acceptance decision (see Figure 1-1. Initial Gap Analysis Scope Boundary). The actual HLW feed batch starts "as staged" in the DST to account for uncertainties and variability from waste retrieval. This is followed by the mixer pumps and Isolok™ Sampler[1] performance to address tank sampling capability, and is then followed by the transfer pump and in-line PulseEcho system to assess transfer limitations and solids settling detection. Finally, the laboratory sample analysis (off-line) evaluates analytical precision and techniques required to demonstrate WAC compliance.

[1] Isolok™ is a registered trademark of the Sentry Equipment Corporation, Yorkville, Illinois.

Figure 1-1. Initial Gap Analysis Scope Boundary.



Waste retrieval operations upstream of the feed DST and post-receipt treatment downstream of HLP-22 at WTP are outside this scope. Other programmatic or production related issues not covered by the initial WAC are not evaluated in this initial effort. There is insufficient testing data available to assess potential gaps between the current WAC and the WTP mixing and sampling capabilities in the receipt vessel (HLP-22). Planned testing such as the Large Scale Integrated Testing (LSIT) will be used to update the WAC and any potential gaps assessed during the final gap analysis (see Figure 2-2).

The scope of this initial gap analysis applies to the identification of gaps based on the latest information available (as of June 30, 2012). It does not resolve the gaps or initiate the work required to resolve the gaps. The results and conclusions are considered preliminary, since the supporting bases and assumptions are evolving and will likely change as the testing programs and design for WTP continues to mature. See Section 2.2 for more discussion on how this initial gap analysis serves as a starting point for the final gap analysis and the logic ties to other activities as required to fully implement the IP, Sub-recommendation 5.

1.3 REPORT ORGANIZATION

Information in this report is organized to follow the general work flow for the initial gap analysis. First define the requirements, then evaluate current capabilities and uncertainties, and finally use the collected information to perform a gap analysis between requirements and capabilities. Table 1-2 lists the major sections of the report and provides a brief description of each. Collectively these sections addressed the deliverable requirements in the IP, Commitment 5.5.3.1.

Table 1-2. Report Organization.

Section	Title	Content
1.0	Introduction	General introduction and background. Describes problem and driver for this initial gap analysis. Delineates scope and scope boundary.
2.0	Gap Analysis Process	Describes the overall approach for the initial gap analysis, including the methodology and use of the HTWOS model. Discusses application and limitation of the information. Highlights key inputs and assumptions used.
3.0	Define Waste Feed Parameters	General overview of the current WAC parameters as defined in ICD-19. Discusses rationale for the selection of specific WAC and potential new nuclear safety parameters for use in the initial gap analysis.
4.0	Assessment of Current Tank Farm Capabilities	Steps through the sample flow path. Compiles latest information and subject matter expert inputs. Summarizes latest equipment design and testing results on tank mixing and sampling capabilities. Discusses the development of sampling and analytical %RSD. Describes the construction of the sample size graphs.
5.0	Assessment of Current WTP Capabilities	Summarizes laboratory capability (222-S) in support of the initial gap analysis. This section serves as a place holder for the discussion and benchmarking of WTP testing results to be included in the final gap analysis.
6.0	Gap Analysis	Describes the HLW feed screening process. Presents and discuss the sample size graphs for selected WAC parameters. Evaluate gaps and open items in the areas of sampling and analytical capabilities.
7.0	Conclusions	Summarizes the gap analysis results. Draw conclusions on gaps and open items. Provide suggested path forward.
8.0	References	Lists references used throughout the report.

2.0 GAP ANALYSIS PROCESS

2.1 APPROACH

The approach for the initial gap analysis is mainly based on a staged feed "screening" process that is traceable to the initial Data Quality Objectives (DQO) effort (24590-WTP-RPT-MGT-11-014). This feed screening process is tailored to address deliverable requirements in the IP Commitment 5.5.3.1. As such sampling and analytical capabilities will be the primary focus. A gap, as defined in this report, is always benchmarked to a WAC parameter (i.e., no WAC parameter, no gap). It addresses the Tank Farm's capabilities to meet each WAC parameter at the specified action limit. Operational, production, or optimization issues not related to waste acceptance will not be identified as gaps in this context.

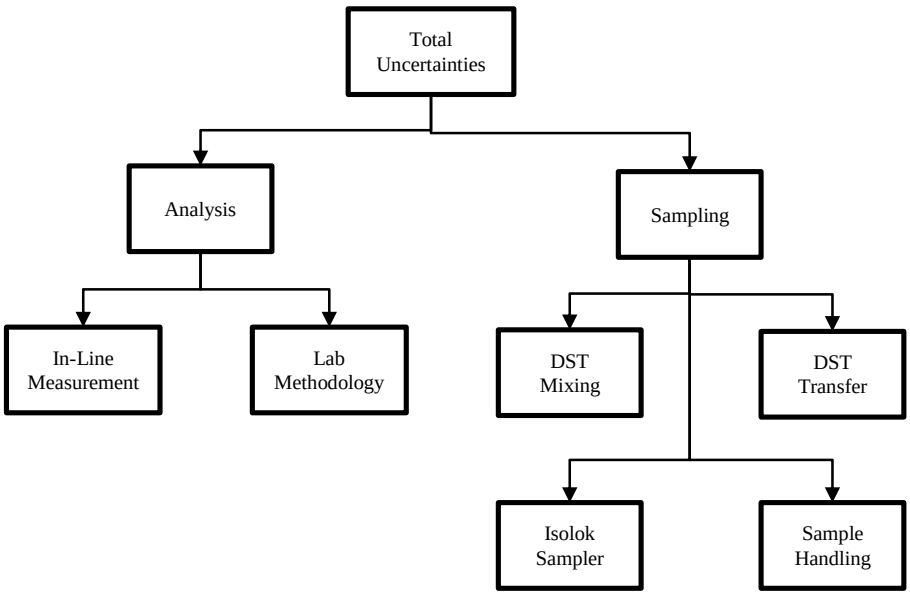
The approach uses a statistical hypothesis testing method to identify gaps in terms of error tolerance in the waste acceptance decision process (see Section 7, Error Tolerance, in 24590-WTP-RPT-MGT-11-014, *Initial Data Quality Objectives for WTP Feed Acceptance Criteria*). Uncertainties in each step of the waste transfer process are estimated and then

propagated, using the RSS method, to determine the total uncertainty. The total uncertainty would then be applied to the expected pre-transfer value and compared to the corresponding WAC action limit. This comparison is expressed in terms of number of samples required to meet the minimum Confidence Level (CL) of either 90% or 95% for the WAC parameter. The comparison of feed against the WAC parameters is referred to as the feed "screening" process in this report. This feed screening is repeated for each WAC parameter selected for the gap analysis. A gap would be identified if the total number of samples exceeds 10, which is the recommended baseline number in the WAC DQO (24590-WTP-RPT-MGT-11-014). A gap would also be identified in cases where there is insufficient information on the staged feed to allow a reasonable comparison against a particular WAC parameter.

The first step in the feed screening process is to decompose the transfer process into discrete elements to account for the associated uncertainties. For the initial gap analysis, the sampling and analytical capabilities are the two main elements contributing to the total uncertainty. These two elements are further decomposed into sub-components as shown in Figure 2-1.

Uncertainty in general is quantified by use of a %RSD value. These %RSDs are determined qualitatively by Subject Matter Experts (SME) for each of the uncertainty sub-components under the sampling and analytical capabilities. Sampling and analytical %RSDs are referenced from published test report(s), studies, standards, and lab procedures when available (as of June 30, 2012). As a starting point to track resolution of gaps, the absolute value of these initial %RSDs is not critical provided that the supporting bases and assumptions are well documented. These %RSD values may be validated and updated as more test results are obtained and the design of the associated equipment (e.g., Isolok™ Sampler, PulseEcho System, etc.) are finalized.

Figure 2-1. Elements of Feed Uncertainties.



The next step in the feed screening process is to develop a staged feed delivery profile. Most of the WAC parameters with action limits are tracked in the Hanford Tank Waste Operations Simulator (HTWOS) model. The HTWOS model is used to develop an operating scenario for the System Plan Baseline Case (ORP-11242, 2011, *River Protection Project System Plan*). The validated output from the HTWOS model represents the best available "as-delivered" feed information for use in support of this initial gap analysis. It is important to note HTWOS estimates of as-delivered feed are traceable back to historical information and tank waste sample analysis (i.e., Best Basis Inventory or BBI). BBI data is subject to uncertainties associated with the collection and analysis of tank waste. These uncertainties have not been quantified and their impact of upon the HTWOS results and the associated feed delivery profile is unknown. The assessment of error and uncertainty inherent to the HTWOS-derived feed delivery profile is beyond the scope of this gap analysis. None-the-less, feed delivery profile derived from HTWOS modeling represents the best tank waste characterization data available to date and provides a necessary enabling assumption for the analysis presented in this report.

The final step in the feed screening process is to calculate the number of samples based on the expected feed delivery profile, the total uncertainties, and the WAC parameter action limit. The calculation and construction of the sample size graphs is similar to the ones in the initial WAC DQO (24590-WTP-RPT-MGT-11-014) except for the incorporation of updated sampling and analytical %RSDs (see Section 6.0). Any WAC parameter requiring more than 10 samples (gap criterion) is flagged as a gap, recognizing that the number of required samples is only part of the WAC DQO waste acceptance decision process. The total number of samples greater than 10 provides a general magnitude of the gap. A gap is also identified if there is insufficient knowledge on the staged feed profile to support the feed screening process.

Physical properties that are not simulated in HTWOS are assessed qualitatively by SMEs using a conservative approach. For example, for feed screening purposes, the most challenging particle size and density distribution relative to mixing and transferring operations is used even though the probability and impact of such transfer(s) to WTP is unknown at this time. A qualitative approach is the only viable option for some staged waste properties due to a lack of reliable characterization data or analytical method.

Gaps identified through this screening process are preliminary and should not be used to draw conclusions regarding treatability of the waste or final acceptance decision. Possible options to address the gaps may be to take more samples, or reduce the required Confidence Level. The final acceptance decision in accordance with the WAC DQO decision statement is:

"Determine whether the staged feed meets the WTP WAC and can be accepted by WTP, requires a change to the feed to meet the WAC, requires sending the feed to an alternative treatment, requires a change to the WAC, or requires continued storage of the feed."

The screening process serves to highlight areas of uncertainties relative to each WAC parameter that may be used to define test requirements or develop appropriate mitigation strategy. Gaps may be mitigated by revising the waste staging strategy through the system planning effort, reducing the sampling or analytical %RSDs through testing and equipment design, or refining

the WAC requirement. The final gap analysis will incorporate results of any mitigation strategy implemented as a part of the 2010-2 IP, Sub-recommendation 5.

The initial gap analysis is a collaborative effort between the Tank Farm and WTP Contractors (WRPS and BNI respectively). Support from SMEs in the 222-S Laboratory and Tank Farm Characterization group are used to develop sampling and analytical %RSDs. This report also incorporates the feedback and input from the Expert Review Team (ERT) as a part of the document approval and release process.

2.2 KEY INPUTS AND ASSUMPTIONS

The initial gap analysis is a part of an integrated plan to address the technical and safety issues identified in Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*. Coordinated efforts are being pursued by WRPS and BNI in accordance with the Implementation Plan (Chu, 2011). Sub-recommendation 5 of the IP delineates the role of the initial gap analysis relative to the final gap analysis and other supporting deliverables. The required inputs, outputs, and logic ties for the initial gap analysis are depicted in Figure 2-2.

As shown in Figure 2-2, there are four (4) key inputs to the initial gap analysis: (a) the WTP Interface Control Document (24590-WTP-ICD-MG-01-019, *ICD-19 – Interface Control Document for Waste Feed*); (b) the WAC Data Quality Objectives (WAC DQO) (*24590-WTP-RPT-MGT-11-014, Initial Data Quality Objectives for WTP Feed Acceptance Criteria*); (c) the deliverable for Commitment 5.5.3.2 (RPP-RPT-51652, *One System Evaluation of Waste Transferred to the Waste Treatment Plant*); and (d) the deliverable for Commitment 5.7.3.4 (24590-WP-RPT-ENS-11-021, *Key Inputs, Assumptions, Safety Margin Uncertainties, and Nuclear Safety Parameters Required to be Included in the Waste Acceptance Criteria, 2010-2 Implementation Plan Commitment 5.7.3.4*).

a) The ICD-19 document identifies the WAC parameters and defines the associated action limits for waste feed acceptance.

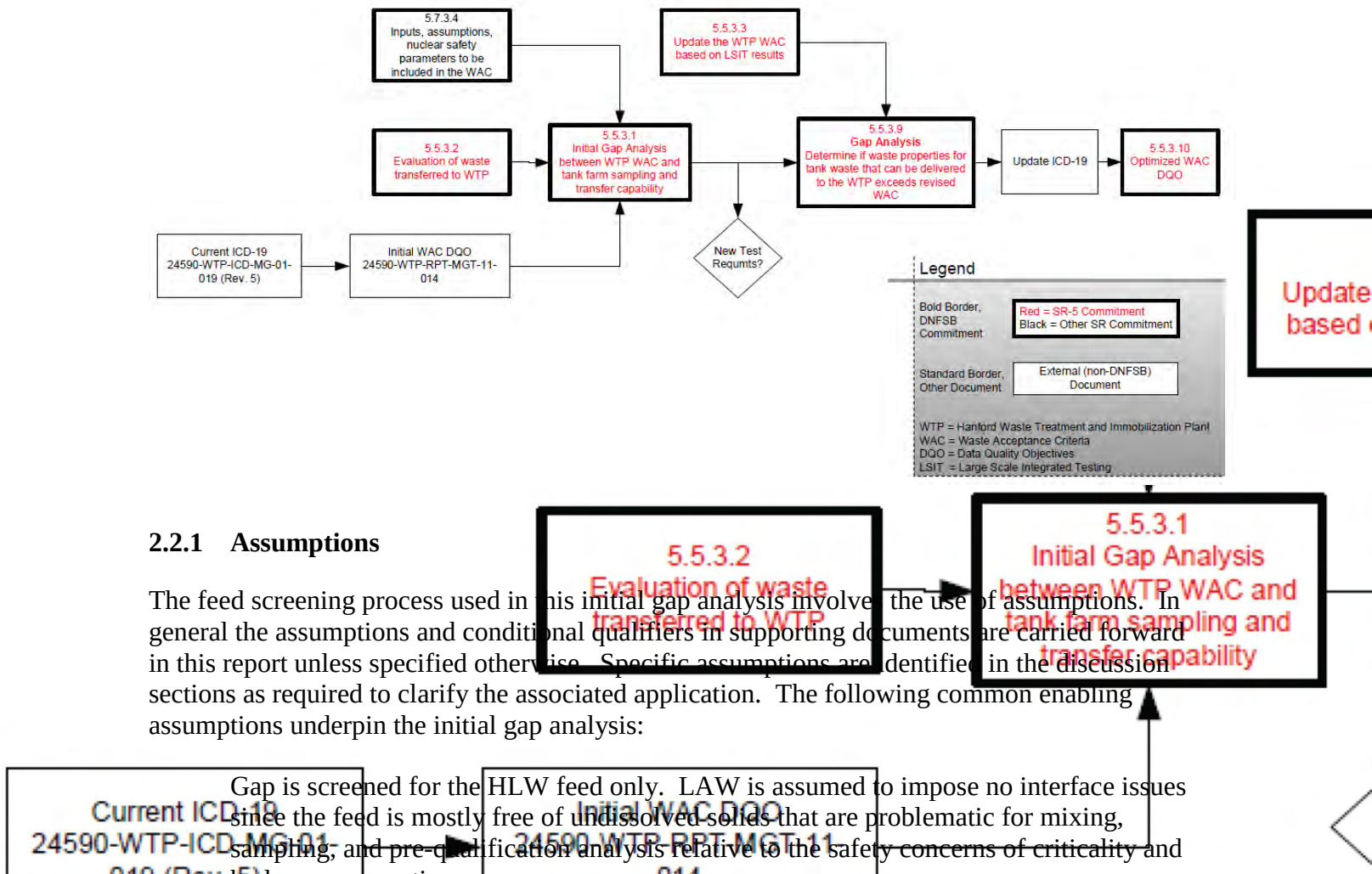
b) The WAC DQO document describes the type, quantity, and quality of the data required for the waste acceptance criteria in ICD-19. It defines a framework for the waste acceptance decision-making process.

c) The Commitment 5.5.3.2 deliverable provides a preliminary examination of the range of physical properties for waste that could be transferred to the WTP using current design concepts for waste retrieval, staging, and transfer. Selected particle size and density along with rheological properties are referenced from the 5.5.3.2 report (RPP-RPT-51652) as bounding values for the feed screening in this report.

d) The Commitment 5.7.3.4 deliverable (24590-WP-RPT-ENS-11-021) compiles a list of current WAC parameters and potential new nuclear safety parameters based on the latest nuclear safety analysis and assumptions. It provides the source of potential new nuclear safety parameters for the feed screening in this report. Gap analysis “open items” are screened against these potential new nuclear safety parameters in this report.

Output of the initial gap analysis may be used to define or confirm test requirements for Tank Farm and WTP. Results from the latest testing will be incorporated in a final gap analysis deliverable as a part of Commitment 5.5.3.9. Output of the final gap analysis will be used to update/optimize the WAC DQO.

Figure 2-2. Sub-recommendation 5 Logic Diagram.



2.2.1 Assumptions

The feed screening process used in this initial gap analysis involved the use of assumptions. In general the assumptions and conditional qualifiers in supporting documents are carried forward in this report unless specified otherwise. Specific assumptions are identified in the discussion sections as required to clarify the associated application. The following common enabling assumptions underpin the initial gap analysis:

Gap is screened for the HLW feed only. LAW is assumed to impose no interface issues since the feed is mostly free of undissolved solids that are problematic for mixing, sampling, and pre-qualification analysis relative to the safety concerns of criticality and hydrogen generation.

Simulant testing completed to date is assumed to be representative of actual waste behavior during mixing and transfer operations to WTP. Inherent uncertainties in simulant formulation and scale-up are not evaluated as gaps relative to Tank Farm's capability to meet the WAC.

Propagation of total waste acceptance uncertainties begins at the pre-transfer sample for the batch of HLW "as staged" in the DST. Characterization uncertainties with the individual source tank(s) and any blending effects from waste retrieval operations are assumed to be accounted for by sampling the actual "as-staged" feed to WTP.

- Worst case feed in terms of undissolved solids (size, density) is assumed for conservative estimate of gap. Worst case is defined as the solids that are difficult to keep suspended or mobilized by the baseline mixing and transfer systems in Tank Farm.
- The planning bases and assumptions in ORP-11242, 2011, *River Protection Project System Plan, Rev. 6* are applicable for the actual "as-staged" HLW feed campaigns to WTP.
- Sampling and analytical %RSDs for the WAC parameters are evaluated independently, even though some of the physical properties are related.

3.0 DEFINE WASTE FEED PARAMETERS

As per CCN 235230, the DNFSB has summarized its concerns relating to WTP's mixing and transfer systems, specifically that the PJMs lacked sufficient power to mix adequately and to transfer the most rapidly settling particles expected to be in the Tank Farm inventory. Three (3) significant safety issues were raised related to mixing using PJMs:

- Retention of fissile materials in vessel heels would present a criticality safety concern.
- There could be retention of flammable gas due to the presence of solids in vessel heels.
- The presence of a large solids inventory could have a detrimental effect on the vessel level instrumentation, which is required to control the PJMs.

Section 5.5.2 of the 2010-2 IP states that one of the sub-tasks for Deliverable 5.5.3.1 is to *"Define initial requirements for tank waste feed that is transferred between the Hanford tank farms and WTP, referred to as the WAC."* ICD-19 is the source document for the WAC for both the LAW and HLW feeds. ICD-19 states that the solids in the LAW feed will be *"delivered to the WTP after there has been sufficient settling time to ensure solids that settle faster than 0.03ft/min have settled below the transfer locations within the tank farms staging tank"* [Footnote 2 for Table 6 in ICD-19]. Therefore, the solids present in the delivered LAW feed will not be "rapidly settling particles," and thus will not have the same significant safety issues as the HLW solids that were raised by the DNFSB. Because of this, only the WAC for HLW feed will be evaluated further in this document.

The determination of parameters to use in this initial gap analysis is split into two groupings. The first grouping includes the currently defined WAC parameters for HLW from ICD-19. This grouping is labeled as the "Initial WAC" and is discussed in Section 3.1. The second grouping includes parameters defined as potential new nuclear safety parameters in the 2010-2 Deliverable 5.7.3.4 (24590-WTP-RPT-ENS-11-021) as well as any additional parameters identified in the WAC DQO (24590-WTP-RPT-MGT-11-014). In addition, this second grouping includes any foreseeable parameters that may need to be added based upon the proposed resolution to outstanding issues/items identified in ICD-19 and the WAC DQO. This grouping is labeled as the "Potential New Nuclear Safety Parameters" and is discussed in Section 3.2. Note that none of these "Potential New Nuclear Safety Parameters" is to be considered as HLW WAC.

3.1 INITIAL WASTE ACCEPTANCE CRITERIA (WAC)

For the WTP, the ICD-19 document (24590-WTP-ICD-MG-01-019) is the source document that provides the WAC for both the LAW and HLW feeds. This includes both physical and chemical parameters as well as transfer system requirements. These parameters are included in Tables 5 through 8 of ICD-19. However, some of the WAC criteria are included by reference in ICD-19. These references include:

- Specifications 7 and 8 from the WTP Contract
- WTP's Dangerous Waste Permit (DWP) - *Final Waste Treatment and Immobilization Plant Dangerous Waste Permit*)
- WTP's Safety Authorization Bases Documents (includes the *Preliminary Criticality Safety Evaluation Report for the WTP* (CSER), *Preliminary Documented Safety Analysis to Support Construction Authorization* (PDSA), *Safety Requirements Document* (SRD), etc.)

The report *Initial Data Quality Objectives for WTP Feed Acceptance Criteria* (WAC DQO - 24590-WTP-RPT-MGT-11-014) included an activity where the DQO team (consisting of BNI, WRPS, and DOE personnel) identified and categorized the WAC constituents into groups. The identification of these WAC constituents used the references listed above and also included the following:

- *Regulatory Data Quality Objectives Optimization Report* (RDQO - 24590-WTP-RPT-MGT-04-001)

- *IHLW Waste Form Compliance Plan for the Hanford Tank Waste Treatment and Immobilization Plant* (24590-HLW-PL-RT-07-0001)

These references are included by indirect reference by the "Environmental Permit Limits" entry in Table 8 of ICD-19. However, the overall purpose of the WAC DQO document is to establish the data quality requirements for WAC constituents to insure that the delivered feed meets the WTP WAC requirements. The WAC DQO document does not determine the WAC but summarizes the WAC from the above documents. As stated previously, ICD-19 is the source document for the WTP WAC.

Table 3-1 summarizes the initial WAC parameters for HLW feed that will be used in the initial gap analysis. Table A-1 in Appendix A provides the discussion and down selection of what HLW feed parameters are carried forward in this analysis. The "#" in Table 3-1 includes a "W" (except for Abrasivity – see footnote 2) to denote that these parameters are included in the WTP WAC when the parameters are referred to elsewhere in this document. As stated in Section 1.2, the focus of this gap analysis is on HLW feed; LAW feed is not addressed.

Table 3-1. Initial HLW Feed WAC Parameters for the Initial Gap Analysis.

#	Parameter	Value
W1	Solids Concentration	≤ 200 g/L

#	Parameter	Value
W2	Viscosity (delivered feed)	<1 Pa (yield stress) <10 cP (consistency viscosity)
W3	Slurry pH	≥ 12
W4	Bulk Density of Slurry	< 1.5 kg/L
W5	Critical Velocity	≤ 4 ft/s
W6	Ammonia Concentration	< 0.04M
W7	Separable Organics	No Visible Layer
W8	Polychlorinated Biphenyls (PCBs)	< 50 ppm
W9	HLW Feed Unit Dose	<270 Sv/g[1]
W10	Pu to Metals Loading Ratio	<6.20 g/kg
W11	U Fissile to U Total	<8.4 g/kg
W12	Pu Concentration of Liquids	<0.013g/L
W14	Hydrogen Generation Rate	2.1 E-06 gmole H_2/L/hr @ 150 ˚F
W15	Temperature	< 150˚F
W22	Sodium Concentration	0.1 to 10 M
W23	Total Organic Carbon (TOC)	< 10wt%
W24	Waste Feed Compatibility	Δ of +/- 20 ˚C
A1	Abrasivity	TBD

[1]The value provided is equivalent to the 2.9E5 Sv/L in Table 8 of ICD-19. The converted value (270 Sv/g) assumes 66% solids fraction (volume) and 1.63 g/mL density for the wet centrifuged solids as per the ICD-19 Table 8 footnote.
[2]Abrasivity replaces particle hardness and median particle size as the erosion parameter. The discussion for this replacement is provided in Appendix A.

A number of the parameters in Appendix A are not retained for gap analysis later in this document. The rationale for why a specific parameter was not retained is provided in Table A-1 of Appendix A. However, this does not indicate that the listed criteria is not part of the HLW feed WAC, just that the parameter is not analyzed further in this initial gap analysis.

3.2 POTENTIAL NEW NUCLEAR SAFETY PARAMETERS

The Defense Nuclear Facilities Safety Board (DNFSB) has expressed concerns related to the mixing and transfer systems in the WTP. In response, the DNFSB issued Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant* (DNFSB Recommendation 2010-2), which was accepted by the DOE in February of 2011. This recommendation addressed the need for the DOE to ensure that the WTP, in conjunction with the Tank Farm Contractor (TFC), will operate safely during its operating life by mitigating mixing and transfer risks relating to the accumulation of fissile materials, generation and accumulation of hydrogen, and PJM operation and controls. In response to the DNFSB recommendation, the

DOE issued an implementation plan (11-WTP-427) that provides commitments, responsibilities, and schedules for activities to address the DNFSB's recommendation. One of these commitments is 2010-2 Commitment 5.7.3.4 which is to:

> *Identify key inputs, assumptions, safety margin uncertainties, and nuclear safety parameters required to be included in the waste acceptance criteria.*

This commitment was met by the WTP in January of 2012 by issuing *Key Inputs, Assumptions, Safety Margin Uncertainties, and Nuclear Safety Parameters Required to be Included in the Waste Acceptance Criteria, 2010-2 Implementation Plan Commitment 5.7.3.4* (24590-WTP-RPT-ENS-11-021). The 5.7.3.4 report provides a source of potential new nuclear safety parameters for consideration in this initial gap analysis.

The intent of this subsection is to provide a listing of potential new parameters for HLW feed. (As stated in Section 1.2, the focus of this gap analysis is on HLW feed; LAW feed is not addressed.) This listing will use the "Potential New Nuclear Safety Parameters" from Section 4.4.2 of the 2010-2 Commitment 5.7.3.4 report as a starting point and will augment the list by considering any additional parameters in the WAC DQO document. In addition, the open items in ICD-19 and the WAC DQO are evaluated to determine if the closure of these items may impart new potential parameters to this listing. Note that none of these potential new parameters is to be considered as HLW WAC.

The summation of all the potential new nuclear safety parameters, along with the WAC parameters in Section 3.1, will serve as the basis for the initial gap analysis which will be used to document areas where additional technical development is required to address any gaps. These potential new nuclear safety parameters are <u>not</u> to be considered as part of the WTP WAC. The establishment of the WTP WAC is expected to be an iterative process with the initial gap analysis being only the first step. Following the completion of the WTP testing, the WTP WAC will be updated as necessary (2010-2 Commitment 5.5.3.3) and will be used as input to the final gap analysis (2010-2 Commitment 5.5.3.9). Commitment 5.5.3.3 will evaluate the list of potential new nuclear safety parameters and will have the potential for establishing other ones based on testing (such as LSIT) and ongoing process evaluations (such as erosion/corrosion) for possible inclusion in ICD-19. Following the final gap analysis, the updated WAC will be documented in a revision to ICD-19 that will be used as input to the WAC DQO, resulting in the Optimized WAC DQO (2010-2 Commitment 5.5.3.10).

Table 3-2 summarizes the potential new nuclear safety parameters for HLW feed that will be used in the initial gap analysis. Table A-2 in Appendix A provides the complete listing of the potential parameters evaluated for HLW feed. The listing in Appendix A includes the potential new nuclear safety parameters from the 2010-2 Commitment 5.7.3.4 document (denoted with an "N" in the parameter "#") that apply to HLW feed as well as any potential parameters from the WAC DQO and from the anticipated closure of ICD-19 and WAC DQO open items (denoted with an "A" in the parameter "#"). The "N" parameters in Table A-2 include the entire list of parameters from Section 4.4.2 of the 2010-2 Commitment 5.7.3.4 document that apply to HLW feed, but some of these parameters are duplicate of parameters already considered as HLW WAC (see Table 3-1). Where this occurs, it is so noted in the "Discussion" column and the reference to the applicable HLW WAC parameter is included. In addition, the number portions of

potential new nuclear safety parameters are the same as the parameter number from Section 4.4.2 of the 2010-2 Commitment 5.7.3.4 document. This provides an easy cross-reference for the parameters.

Table 3-2. Potential New Nuclear Safety Parameters for the Initial Gap Analysis.

#	Parameter	Value
N15	HLW Feed Particle Size	≤ 210μm
N18	Upper Bound Settled Layer Shear Strength	<200 Pa within 24 hours
N19	Pu Particle Size	TBD
N20	Average Particle Density of Pre-Leached Solids	≤ 2.18kg/L

3.2.1 ICD-19 Open Items

Appendix D of ICD-19 contains fifteen (15) open items, and a number of these items pertain to waste feed acceptance. The plans for closing these items are articulated in RPP-PLAN-53354, *One System Plan for Closing WTP Feed Acceptance Criteria Issues, Open Items and Actions*. These plans provide ties to existing activities (primarily other 2010-2 commitments) that are expected to address the issue or, if required, to initiate new activities addressing the items. These items have been reviewed for inclusion as "initial WAC" parameters, but the closure of these open items is not addressed further as a "gap" in this report. For the closure plan for the ICD-19 open items, see RPP-PLAN-53354.

Excerpts from the open items in ICD-19 that may result in new parameters are repeated below:

1. *ICD 19 needs to incorporate the Particle Size Density Distribution [PSDD] used in recent testing to form the acceptance window for solids.*

2. *The ICD needs to acknowledge that WTP does need to know the properties of particles/waste that are needed for mixing evaluations….*

3. *Determine if the limits of cohesiveness and agglomeration need to be incorporated into ICD 19, Table 8 (Waste Acceptance Criteria).*

4. *Determine if limits on yield stress and consistency need to be incorporated into ICD 19, Table 8 (Waste Acceptance Criteria).*

As stated previously, these items have been reviewed for inclusion as initial WAC parameters by the following:

- For items 1 and 2 above, a full PSDD is not currently defined as being required by the WTP. In Table 3-2, a maximum particle size and an average particle density are identified as potential new nuclear safety parameters (N15 and N20 respectively) as well as a particle size limit for Pu (N19). These are the currently defined parameters relating to particle size and density utilized by the WTP. Future testing may redefine these parameters and/or add other parameters relating to particle size or density, but it is speculation to assume what other parameters would be required. Therefore, no additional potential new nuclear safety parameters are proposed based upon these open items.

- For item 3, values for cohesiveness and agglomeration are not included as potential WAC parameters. However, the inclusion of a particle size limit (N15 in Table 3-2) accounts for agglomeration of particles and the slurry rheology limitation (W2 in Table 3-1), and the maximum settled sludge shear strength (N18 in Table 3-2) effectively incorporates cohesiveness. Cohesion of solids impacts the rheology and viscosity of a slurry (parameter W2), and cohesion is amplified when the solids are left undisturbed (parameter N18). Therefore, no additional potential new nuclear safety parameters are proposed based upon this open item.

- For item 4, a slurry rheology limit is included as W2 in Table 3-1.

Note that the ICD-19 open items have been addressed for inclusion as potential parameters, but this addressing does not constitute closure of the open item. The intent is to demonstrate that the open item was considered when the parameters to be included in this initial gap analysis were developed. As stated previously, see RPP-PLAN-53354 for the closure plan for the ICD-19 open items.

3.2.2 WAC DQO Open Items

Section 9.1 of the WAC DQO includes 15 open items that were expected to require further actions to close. Near term statuses for the WAC DQO open items are included in the WTP memo *"Update to WTP WAC DQO – One System"* (CCN 249897). The accompanying table in the WTP memo provides the expected closure plan/tie for the open items. These closure plans/ties include references to existing DNFSB 2010-2 commitments and/or internal WTP action tracking system (ATS) items. The items listed as "closed" in the WTP memo do not impact the WAC. Following the WTP memo, the report *One System Plan for Closing WTP Feed Acceptance Criteria Issues, Open Items and Actions* (RPP-PLAN-53354) provided further detail on the WAC DQO open items and their planned closure method.

As with the ICD-19 open items, a number of the WAC DQO open items pertain to waste feed acceptance. However, unlike the ICD-19 open items, the WAC DQO open items do not suggest the inclusion of additional WAC beyond those already included in the WAC DQO Tables 4-1 and 4-2. Therefore, the closure of these open items is not expected to result in additional WAC parameters. For the closure plan for the WAC DQO open items, see RPP-PLAN-53354.

4.0 ASSESSMENT OF CURRENT TANK FARM CAPABILITIES

This section provides an overview of the Tank Farm's capabilities and uncertainties relative to the staging and transferring of HLW feed to WTP. It summarizes the latest simulant testing completed to date (as of June 20, 2012) on tank mixing and sampling as supporting background for the uncertainties discussion. It discusses the possible sources of sampling and analytical uncertainties in sufficient details to provide input to the initial gap analysis in Section 6.0.

4.1 HLW FEED STAGING AND TRANSFER

This section provides an overview of the WFD process to set the framework for discussion of transfer equipment required to mix, sample and transfer HLW to WTP. Latest testing and assessments of these transfer equipment are compiled as applicable to support the gap analysis.

4.1.1 HLW Feed Delivery

The Integrated Waste Feed Delivery Plan (IWFDP) describes how the DST in the Tank Farm will be used to receive, stage, and deliver waste feed to WTP (RPP-40149-VOL 1, *Integrated Waste Feed Delivery Plan Volume 1 – Process Strategy*). As delineated in the IWFDP, the WFD logic for a typical HLW campaign is expected to proceed as follows:

1) A tank operating as a HLW feed tank is identified to receive staged waste, from one or more tanks operating as HLW feed staging tanks, for delivery to the HLW receipt tank in WTP. Waste compatibility and process control samples are taken prior to filling the HLW feed tank in order to generate a waste compatibility assessment and to assist in the development of the process control plan for the identified HLW feed tank.

2) After the feed is fully prepared, the HLW feed tank undergoes a prescribed hold time of thirty (30) days for mixing and sampling, and an additional 180 days for waste characterization, to confirm that the feed meets the waste acceptance criteria. Sampling of HLW is performed while the mixers pumps are in operation. A pre-transfer flush of inhibited water precedes the designated waste transfer – this preheats the transfer line and helps prevent solids precipitation during the waste transfer. The HLW feed campaign is then transferred to WTP HLW feed receipt tank, HLP-VSL-00022, in multiple batches, targeting up to 145 kgal per batch received.

3) The HLW feed tank is mixed prior to each HLW batch delivery to the WTP, and the transfer line will be flushed with inhibited water to clear it of any remaining waste following each HLW batch transfer. The received HLW feed may then be transferred by WTP to the Ultra-filtration Process System (UFP) system, depending on the specific gravity (SpG) and wt% solids in the waste, until the HLW feed receipt tank transfers out enough waste to receive another 145 kgal. This process is then repeated for each HLW campaign, with a goal of ensuring that the steps required for the next campaign of HLW batches to be transferred are completed prior to WTP requesting the feed.

4) The “pre-transfer” samples (vs. process control samples) to be taken in the HLW feed tank to confirm that the feed meets the waste acceptance criteria are the focus of this initial gap analysis. The quality requirements of these pre-transfer samples and the associated waste acceptance decision process are defined by the initial WAC DQO for the WTP WAC (24590-WTP-RPT-MGT-11-014). The initial WAC DQO provides the statistical hypothesis testing framework for calculating the required number of samples based on uncertainties in the sampling and analytical capabilities. While the ICD-19 and the initial WAC DQO do not represent all finalized requirements and includes action

items that need to be addressed, it does provide a starting point to begin identifying gaps in requirements and system capabilities (Chu, 2011).

The DST configuration and transfer equipment planned for HLW feed delivery to WTP are described in details in the 2010-2 IP Commitment 5.5.3.2 study (RPP-RPT-51652, *One System Evaluation of Waste Transferred to the Waste Treatment Plant*). In general, the DST configuration and transfer system infrastructures for HLW transfer include:

- Mixer Pumps (2)
- Transfer Pump (1)
- Primary and Secondary (annulus) Exhaust Ventilation
- Tank Instrumentation (temperature, level, pressure, and others)
- Transfer Lines (underground and aboveground[2])
- Equipment Pits
- Jumpers and Valves Assemblies

Traditional grab and core sampling methods are not sufficient to demonstrate compliance with the waste acceptance criteria for HLW slurry, which assumes the pre-transfer samples are representative of the staged feed and transferred material. Upgrades are being developed for a flow certification loop concept with a remote sampler (Isolok™ Sampler) to allow in-line sampling and a PulseEcho system for in-line detection of solids settling. New mixer pumps and transfer pump are also planned to complete the necessary DST upgrades in support of HLW feed delivery. The latest design configurations and operations of these equipment upgrades are described in more details in RPP-RPT-51652.

The WFD process involves primarily three (3) DST sub-functions: mixing, sampling, and transferring. The latest results of studies and testing of these systems are compiled in the following sections for use as input to the uncertainties discussion as applicable in Section 4.2. The PulseEcho detector development is discussed as a part of the sampling system. The laboratory analysis of the pre-transfer samples is an off-line interface function of the DST. The laboratory for waste acceptance analysis (assumed to be 222-S) is discussed as a part of the WTP capability in Section 5.0.

4.1.2 Tank Mixing System Benchmark

The HLW feed stream to WTP contains undissolved solids with a wide range of physical properties and settling characteristics. Adequate mixing in the DST is required to properly sample and characterize these solids to determine waste acceptance for transfer to WTP. Mixing in a DST configuration is a known project risk due to uncertainties in system performance with actual staged waste. A Small Scale Mixing Demonstration (SSMD) program is being implemented by the TFC to address DST mixing in four (4) progressive phases. Phases 1 and 2

[2] Aboveground transfer lines are considered temporary.

have been completed to date. Phase 3 (optimization) is in progress. Phase 4 (full-scale) is scheduled for completion between FY2013 – FY2017. A comprehensive review of mixing work done to date is documented in RPP-50557, *Tank Waste Mixing and Sampling Update*. The benchmark information in this report reflects the conclusions in RPP-50557 and the latest Phase 2 testing results as summarized in RPP-49740, *Small Scale Mixing Demonstration, Sampling & Batch Transfers Results Report*. Future results from Phase 3 and 4 demonstrations will be incorporated in the final gap analysis.

For the purpose of this initial gap analysis, mixing performance is graded relative to the control of sampling errors (see 4.2.1). Ideal mixing would mean tank content is being homogenously mixed or that batch to batch variations reduced or eliminated, and thus mixing performance correlates to Grouping and Segregation Error (GSE) and Long Range and Periodic Heterogeneity Errors (see Appendix C). The Phase 2 SSMD was mainly focused on determining the effects of process parameters on pre-transfer sample representativeness and the trend of batch transfers that characterizes tank mixing performance. The test concluded the following relative to these specific objectives among others (RPP-49740):

1. The batch transfer %RSD of the individual particulate components are below 30% at jet mixer nozzle velocity greater than 22 ft/s in the 43.2" tank and 28 ft/s in the larger 120" tank (Figure 4-1).

2. The total solids mass %RSD for the five batch transfers achieved the test objective of within 10% at a jet mixer nozzle velocity greater than 20 ft/s in the 43.2" tank and 30 ft/s in the larger 120" tank (Figure 4-2).

The above %RSD results are incorporated as appropriate for mixing and transfer uncertainties in Table 4-2.

Simulant used during Phase 2 SSMD was modeled on AY-102 waste in water (non-cohesive), which is conservative from the perspective of mixing and transferring of fast settling solids. Of particular interest for the gap analysis is the behavior of PuO_2, which was simulated using Bi_2O_3, due to a potential criticality concern specified in DNFSB 2010-2. As such, mixing and sampling performance (or uncertainties) is benchmarked using Bi_2O_3 data and trends when applicable.

Figure 4-1. Batch Transfer Trend
(Relative Standard Deviation for the 5 Batch Transfers).

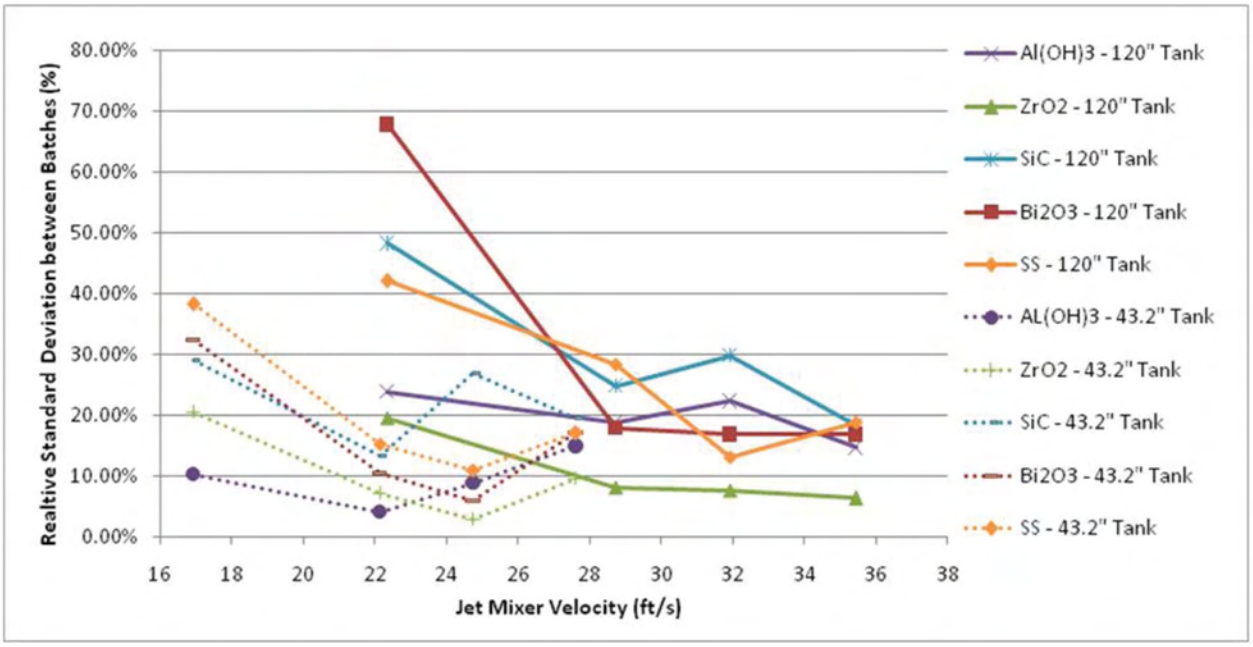
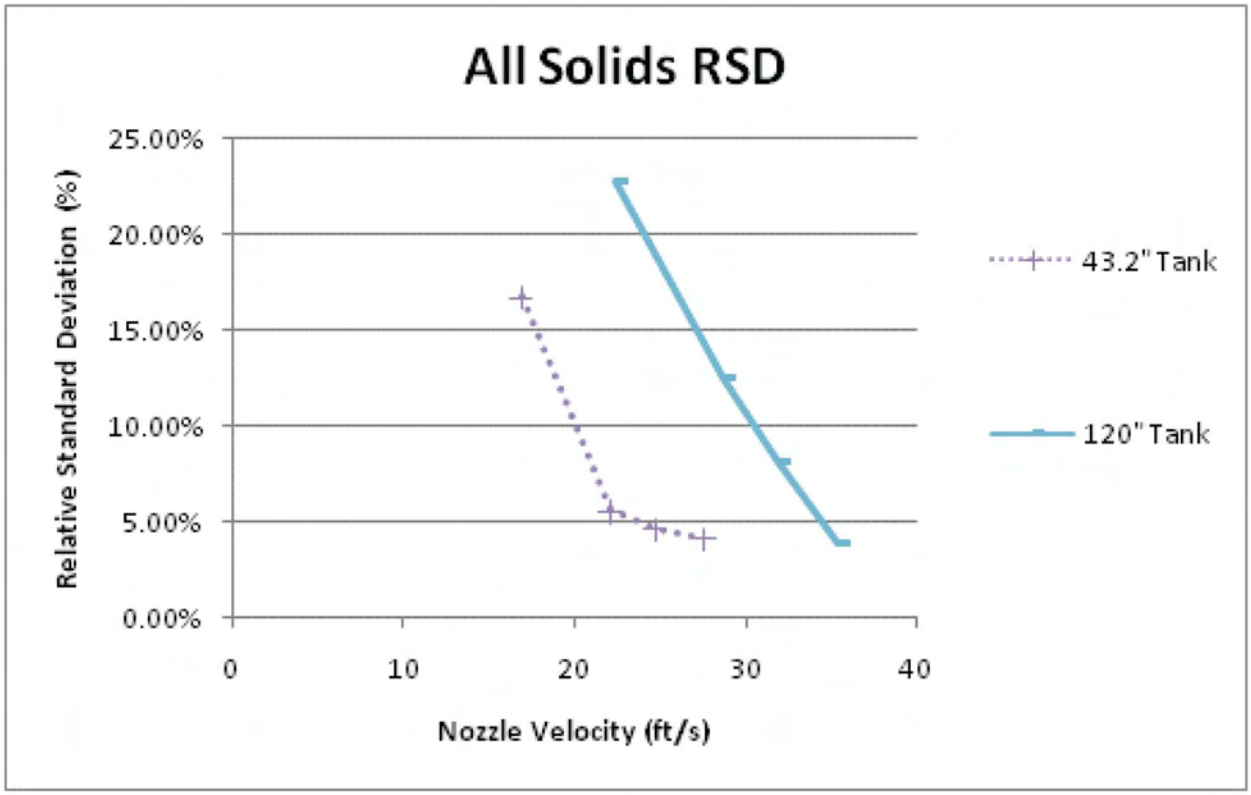


Figure 4-2. Total Solids Mass Trend
(Relative Standard Deviation for the 5 Batch Transfers).



Historical testing results dating back to April 2009 have provided incremental understanding in mixing performance. Results of the various testing, workshops, expert panel summits, and Computational Fluid Dynamic (CFD) studies are summarized in RPP-50557, Table 2-1. Collectively these results support the current understanding on DST mixing and effect on batch transfer as follow:

1. DST tanks are not homogeneously mixed.
2. Testing non-cohesive particles in water is conservative relative to fast settling solids.
3. More particulates are captured in the pre-transfer sample than subsequent transfer batches.
4. Pre-transfer sampling tends to overestimate fast settling particulates.
5. Batch-to-batch variability as indicated by bulk density is within 10%.

A separate technical analysis to look at the limits of performance of the baseline mixing system with respect to mobilization of large and heavy undissolved solids was discussed in RPP-RPT-51652. Conclusions of this study are consistent with the SSMD results to date, including that the higher density and viscosity (Non-Newtonian) is expected to increase the capability of the system for transferring rapidly settling particles. More transfer system-related results and conclusions are discussed in Section 4.1.4.

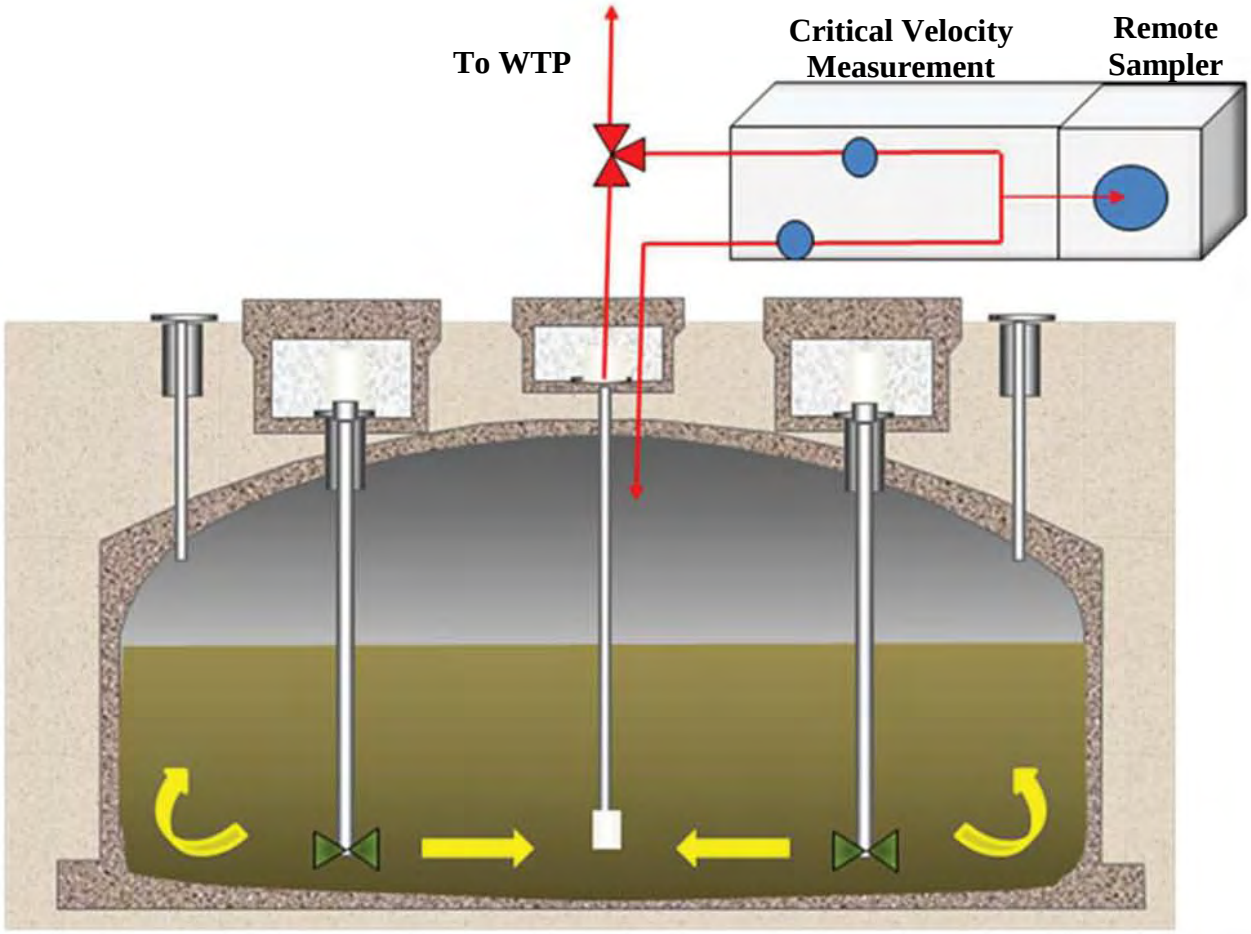
4.1.3 Tank Sampling System Benchmark

The pre-transfer sample provides the basis for the waste acceptance decision. The WTP WAC DQO assumes this sample is "representative" of the staged feed and transferred material (24590-WTP-RPT-MGT-11-014, Section 7.1, Assumptions 1 and 2). Initial SSMD testing has confirmed that there is variability and bias in the pre-transfer sample and between transferred batches due to mixing performance for undissolved solids (RPP-49740).

4.1.3.1 *Remote Sampling Demonstration*

Additional uncertainties and bias may be introduced by the physical sampling device. The current baseline sampling system for HLW slurry is the Isolok™ sampler. It is a remotely operated sampling system that is designed to take multiple grab samples from a recirculating flow loop (Figure 4-3). The concept is to extract in-line samples from the transfer pump discharge piping while the tank is being mixed by the two mixer pumps under transfer conditions that are close to the actual transfer. To conduct the required WAC analysis, approximately 300 mL of slurry containing at least 30 g of solids is recommended for each sample (24590-WTP-RPT-MGT-11-014).

Figure 4-3. Feed Certification Flow Loop and Remote Sampler System.[3]



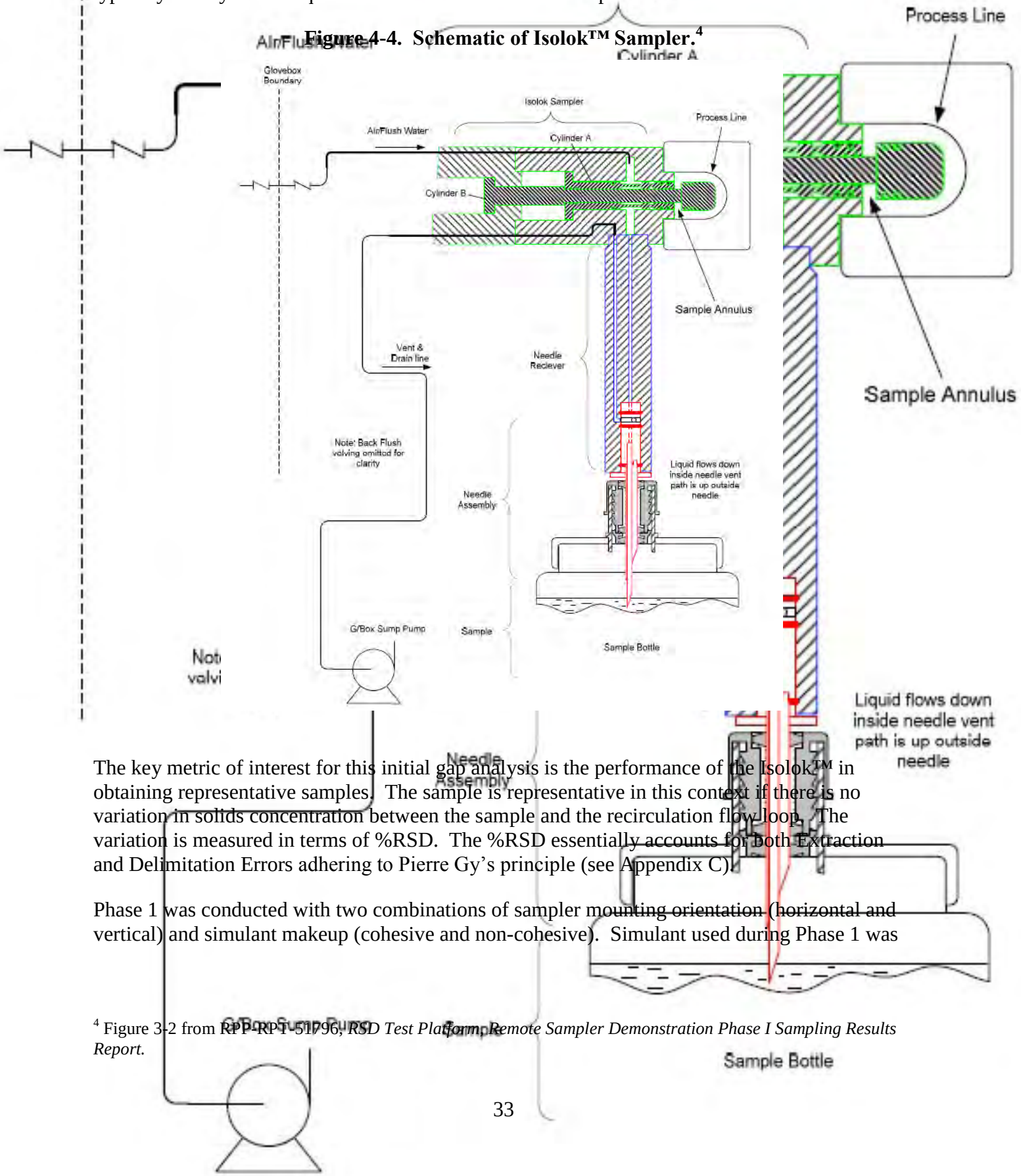
Although the Isolok™ system has similar applications at Hanford, including the 242-A Evaporator and WTP, there is little sampling experience with the HLW staged feed. Phase 1 of the Remote Sampling Demonstration program was initiated in 2011 to demonstrate the fundamental principles and capabilities of the Isolok™ sampling system. Sampling capability benchmark in this initial gap analysis is largely based on the Phase 1 results as documented in RPP-RPT-51796, *RSD Test Platform, Remote Sampler Demonstration Phase I Sampling Results Report*. There are additional mechanical handling demonstrations and optimizations planned for Phase 2. Results from the ongoing testing and development work will be reflected as appropriate in the final gap analysis.

The Isolok™ sampler was installed in a Remote Sampler Demonstration platform that recirculates contents in an agitated tank. The Isolok™ sampler tested is a full scale unit with the capacity to capture a fixed volume of liquid (~5.3 mL per extraction) from a 3" diameter transfer flow loop (Figure 4-4). The fixed volume of captured sample flows from a sample annulus to the

[3] Figure 3-2, RPP-RPT-51652, *Evaluation of Waste Transferred to the Waste Treatment Plant.*

sample bottle (~1L) via a needle assembly (i.e., 9-gauge needle inside a larger 6-gauge needle arrangement). This extraction process is repeated until the target sample volume is reached; typically ~57 cycles is required for a minimum 300 mL sample.

Figure 4-4. Schematic of Isolok™ Sampler.[4]



The key metric of interest for this initial gap analysis is the performance of the Isolok™ in obtaining representative samples. The sample is representative in this context if there is no variation in solids concentration between the sample and the recirculation flow loop. The variation is measured in terms of %RSD. The %RSD essentially accounts for both Extraction and Delimitation Errors adhering to Pierre Gy's principle (see Appendix C).

Phase 1 was conducted with two combinations of sampler mounting orientation (horizontal and vertical) and simulant makeup (cohesive and non-cohesive). Simulant used during Phase 1 was

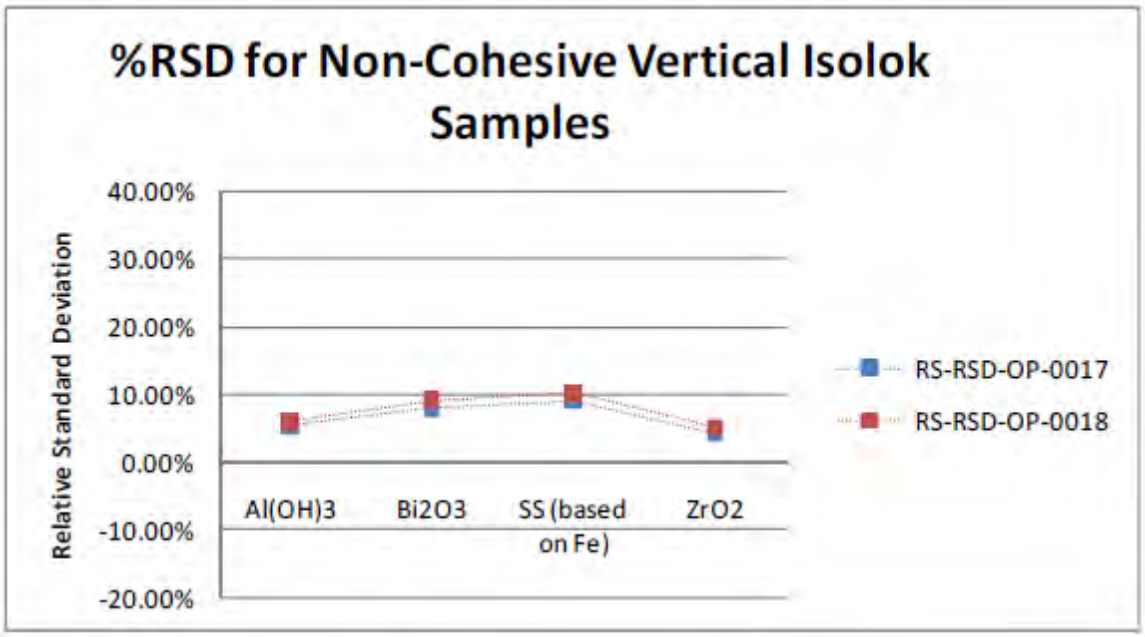
[4] Figure 3-2 from RPP-RPT-51796, *RSD Test Platform, Remote Sampler Demonstration Phase I Sampling Results Report.*

modeled on AY-102 waste. Similar to the SSMD, Bi_2O_3 (38 micron & 8.9 g/cc) is used as a surrogate for PuO_2 for the purpose of benchmarking sampler performance.

There were numerous observations and troubleshooting during Phase 1. However, a trend was established that supports the following general conclusions that are applicable to the initial gap analysis (RPP-RPT-51796):

1. Sample obtained by the Isolok™ was not representative (i.e., did not meet the established acceptance criteria consistently for all solids).
2. Variation of solids concentration between sample and recirculating flow loop is within %RSD of 10% for Bi_2O_3 (Figure 4-5).

Figure 4-5. %RSD for Non-Cohesive Vertical Isolok™ Sampler.



The mounting position of the Isolok™ was changed from horizontal to vertical as a result of troubleshooting, and now only the vertical orientation results are carried forward as benchmark. Reasons for the bias toward larger and heavier solids (Bi_2O_3 and Stainless Steel (SS)) are thought to be attributed to Isolok™ orientation. More testing will be conducted in Phase 2 to further investigate/optimize the %RSD trend observed in Phase 1.

4.1.3.2 *PulseEcho System*

Critical velocity (CV) is a term used to describe the slurry transfer velocity below which pipeline solid particulate deposition occurs. It can be estimated using correlations such as Oroskar and Turian or AD Thomas, but for HLW staged feed to WTP, critical velocity will be measured (24590-WTP-RPT-MGT-11-014).

The Pacific Northwest National Laboratory (PNNL) led the development effort for various ultrasonic instruments to detect CV. The work concluded with the recommendation of the PulseEcho system for field deployment. The PulseEcho system measures the signal amplitude modulation caused by particles within the fluid in the transfer piping to detect the onset of settling. The slurry flow velocity in the pipe is measured separately (e.g., Coriolis meter) to indicate the critical velocity corresponding to the onset of solids settling.

Testing to date of the PulseEcho system consists of various sensors and mounting configurations with different simulant combinations. More testing is underway but for the purpose of this initial gap analysis, the latest results and conclusions of PulseEcho performance are taken from Phase III (PNNL-19441, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments*) and Phase IV reports (PNNL-20350, *Hanford Tank Farms Waste Certification Flow Loop Phase IV: PulseEcho Sensor Evaluation*). Collectively, these two reports document the latest understanding on the capability of the PulseEcho system as applied for critical velocity detection in the waste certification flow loop configuration.

The PulseEcho system will be installed in the certification flow loop to be deployed at the DST for HLW staged feed (Figure 4-3). The system will detect the onset of solids settling in the 3" transfer pipe to WTP. Because the detection will be done "in-line" vs. off-line sample analysis, the uncertainties of interest for the gap analysis are mostly focused on the installed instrument accuracy/precision. The latest demonstrations conducted by PNNL have concluded the following, relative to accuracy/precision/range among others (PNNL-19441, PNNL-20350):

1. PulseEcho measurement of CV is accurate within ± 0.3 ft/s for all test runs in Newtonian[5] and Non-Newtonian[6] simulants.
2. PulseEcho equipped with a 5-MHz transducer can detect onset of settling for >50 μm particles in a full Schedule 40 pipe wall thickness.
3. Detection of CV for smaller (>20 μm) particles requires a 10-MHz transducer.
4. Detection of CV demonstrated with >2 wt% solids concentration in the transfer fluid.

Note that PulseEcho detection accuracy of CV was validated using experimental results, which is based on visual and camera inspection of flow regimes II and III (PNNL-19441). Flow regime II corresponds to focused axial motion. Flow regime III corresponds to a pulsating sliding bed as observed in two sections of clear spool pieces upstream and downstream of the PulseEcho. The accuracy has some inherent bias, depending on the tester, but it accounts for all instrument loop measurement uncertainties. For the field deployed PulseEcho, there will be no visual validation of measurement accuracy. Total measurement uncertainties of the instrument loop should account for the magnetic flow meter, Coriolis meter (if used), the data acquisition system, and possible environmental effect.

[5] Table 11-1, Critical Velocity Measurement for Newtonian Simulants – PNNL-19441.
[6] Table 11-2, Critical Velocity Measurement for Non-Newtonian Simulants – PNNL-19441.

4.1.4 Tank Transfer System Benchmark

Tank transfer system capability was evaluated as a part of the 2010-2 IP (Chu, 2011), Commitment 5.5.3.2. This commitment addresses the definition and determination of performance capabilities of the retrieval and transfer system. Report RPP-RPT-51652, *One System Evaluation of Waste Transferred to the Waste Treatment Plant*, was issued on June 26, 2012 as a deliverable for Commitment 5.5.3.2. This report provides the main source of input for this initial gap analysis relative to the transfer system benchmarks including:

1. Preliminary range of physical properties including particle size, particle density and rheology for waste anticipated to be delivered to WTP with the current feed staging and **t**ransfer concepts. Table 4-1 below summarizes the finding on bounding particle size and density that may be transferred to WTP:

Table 4-1. Particle Size and Density Combinations.[7]

Particle	Diameter (µm)	Density (g/mL)
Most dense primary particle (Pu)	100	19
Largest primary particle observed by Scanning Electron Microscopy (SEM) (gibbsite)	200	2.4
Largest particle hypothetically combined with highest density (Bi_2O_3) in AY-102	1,268	8.9
Agglomerate based on PSD limit (gibbsite)	1,441	1.6
Largest particle hypothetically combined with highest density (Ag_2O) in AZ-101	1,441	7.14
Largest agglomerate based on pump screen mesh (gibbsite)	9,525*	1.43

Notes: *9,525 µm = ⅜-inch.

2. Rheology studies concluded as stated in RPP-RPT-51652:

   The available rheology data were reviewed and separate plots were produced for each tank with data. For the sludge waste (i.e., containing undissolved solids), viscosity ranged from near 1 cP at 0.1-wt% solids to slightly more than 100 cP at 18-wt% solids. Yield stress data ranged from near 0.1 Pa at 1-wt% solids to near 80 Pa at 18-wt% solids. Yield stress data were fit with a power law function for various temperature ranges, and viscosity data were fit with an exponential function for various temperature ranges. These fits were then used to predict yield stress and viscosity at 10 wt% undissolved solids through interpolation or extrapolation. Except for one outlier (C-109), yield stress predictions at 10-wt% undissolved solids fell within a range of less than 0.01 to 12 Pa. The tank data suggest some feed batches would exceed a yield stress of 1 Pa. Similarly, viscosity predictions fell within a range (except for the same C-109 outlier) of 0.79 to 13.54 cP.

[7] Table ES-1, Particle Size and Density Combinations Used in Calculations, RPP-RPT-51652.

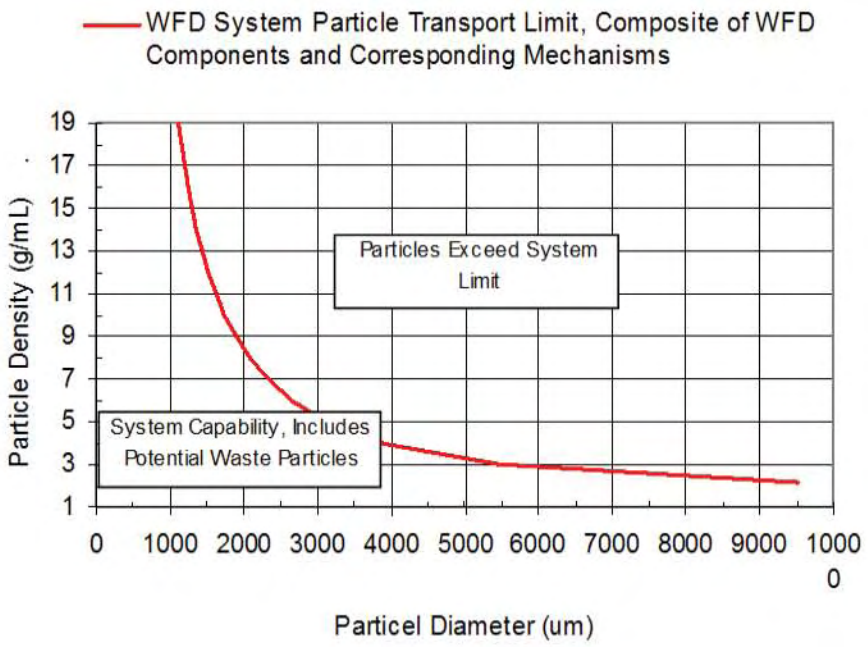
A literature review for the potential effects from waste mixing and blending suggests complicated relationships among particles sizes, solids fraction, particle and liquid densities, and repulsive and attractive forces. No good predictive tool exists for estimating yield stress and viscosity in mixed/blended wastes. Waste feed samples taken from the flow loop with the remote sampler will be tested for rheological properties. There will be about 600 mixed and blended HLW feed batches during WFD, and current data on blended waste is limited. It is likely that the ranges of yield stress and viscosity for all feed batches will be greater than the data ranges presented in this document (RPP-RPT-51652).

3. Transfer system capabilities based on particle size and density. Figure 4-6 below depicts a range of particle size and density that defines the system limitation. The WFD system transport limit capabilities are determined for waste properties established by characterization of the Hanford waste and the evaluated uncertainties of that characterization data. The line in Figure 4-6 corresponds to the WFD system limit for particle transport where particles are represented by size and density combinations. The WFD system is capable of delivering to the WTP the particles (as identified with size and density) that lie on or to the left of the line. The particles that lie to the right of the line exceed the WFD system capabilities. WFD system components analyzed for limits of performance with respect to UDS particle size and density include:

    - Jet mobilization and transport of particles to the transfer pump
    - Particle entrainment into the transfer pump
    - Particle motion in the vertical transfer pipeline
    - Particle transfer in the horizontal pipeline

    The potential limiting waste particles (maximum size and density) listed in Table 4-1 are to the left of the WFD system particle transport limit as denoted in Figure 4-6. Hence, it is concluded that the potential limiting waste particles from Table 4-1 do not exceed the limits of performance of the WFD system (see RPP-RPT-51652, Section 7.4 for more discussions).

Figure 4-6. Transfer System Particle Transport Limit. Representative Bounding Liquid (1.37 g/mL, 14 cP), Limiting Pipeline Length and Pressure, 0.99 miles, 400 psig.[8]



4.2 HLW FEED UNCERTAINTIES

Tank mixing and sampling capabilities in a DST for HLW staged feed to WTP are areas of known risks as discussed in various studies and reports, including the DNFSB Recommendation 2010-2. The risks are invariably linked to uncertainties in the HLW feed stream and the overriding question: *Does the staged feed meet the WTP WAC for transferring the feed to WTP?*

To properly address the fundamental question of waste acceptance compliance, it is necessary to understand the possible sources of uncertainties and relate them to each of the WAC parameters. Not all of the WAC parameters carry the same level of uncertainties. Parameters with largely liquid phase constituents would have fewer uncertainties (assuming the liquid constituents are miscible) because they are less sensitive to tank mixing performance, and therefore, the pre-transfer sample would be presumably more "representative" of the staged feed. Likewise parameters that target undissolved solids in terms of size/density distribution or other physical properties of the blended feed would have more uncertainties because of heavy dependence on tank mixing and sampler performance to ensure a representative or bounding pre-transfer sample.

[8] Figure ES-1, WFD System Particle Transport Limit. Representative Bounding Liquid (1.37 g/mL, 14 cP), Limiting Pipeline Length and Pressure, 0.99 miles, 400 psig, RPP-RPT-51652.

This section describes the different elements that make up the total feed uncertainties and summarizes the development of %RSD values for each of the major element. These %RSD values are then used in the feed screening process in Section 6.0.

4.2.1 Elements of Total Feed Uncertainties

The total feed uncertainties start with the characterization of source tanks that will be retrieved to produce the staged (or blended) feed. However, because of the interface control requirement to sample the staged HLW feed for WAC compliance prior to any tank transfer to WTP, the feed uncertainties for the purpose of this initial gap analysis starts at the pre-transfer sample taken at the staged HLW feed DST.

For normal operations (excluding abnormalities such as equipment failures or human errors), the two dominate sources of uncertainties in the waste acceptance decision are traceable to sampling and analytical errors. Sampling errors are affected by the tank mixing operations, the batch-to-batch transfer process (i.e., variation in tank composition over time as tank level decreases), the retrieval of pre-transfer sample using Isolok™, and the physical handling[9] of the pre-transfer sample. Analytical errors are associated with in-line measurements (i.e., no sample) and laboratory analysis that also include sample handling (see Figure 2-1. Elements of Feed Uncertainties). The total uncertainties can be approximated by propagating each of the sampling and analytical error sources using the RSS method[10].

$$Total\ uncertainties = \sqrt{sampling\ \ errors^2 + analytical\ errors^2}$$

4.2.1.1 *WAC DQO Process*

The accounting of sampling and analytical errors in the waste acceptance decision process has been addressed as a part of error tolerance discussion in the initial WAC DQO (24590-WTP-RPT-MGT-11-014). The WAC DQO process provides an evaluation of the probability of decision error based on an estimation of the mean, variance, and number of samples. The uncertainty evaluation is used to assess the accuracy and precision specified for sample collection and analysis, the level of decision error, and the number of samples required to meet a given decision error rate. The general framework of the waste acceptance decision process assumes that the staged feed does not meet the acceptance criteria. The collected sample data must clearly indicate the acceptance criteria are met in order to accept the staged feed.

The number of samples required to meet a given decision error rate is calculated from the standard deviation (SD) assuming a normal distribution. In general, the distribution of sample means approaches a normal distribution relatively quickly, as a function of sample size, in most cases where the original distribution is not too extreme. The validity of this condition (i.e., normal distribution) as an enabling assumption for this analysis will be assessed as additional characterization data for the "as-staged" waste is accumulated during operations. The

[9] Physical handling of sample refers to the manual handling of the sample during the retrieval and transport of sample bottles from the field to the lab.
[10] Mood, Graybill, and Boes, *Introduction to the Theory of Statistics*, 3rd Edition

uncertainties are shown as a %RSD, which is multiplied by the action limit to provide a conservative estimate of the SD for the sample size calculation. Details on the construction and interpretation of sample size graphs are discussed in the WAC DQO (24590-WTP-RPT-MGT-11-014), which is traceable to EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objective Process*, EPA QA/G-4. The initial gap analysis adheres to the same methodology and supporting assumptions in the WAC DQO process for calculating the number of samples, except for substituting with updated sampling and analytical %RSDs.

The following discussions on waste acceptance decision process are taken from the WAC DQO (24590-WTP-RPT-MGT-11-014). Refer to the source document for additional details.

The waste acceptance decision-making is accomplished using a statistical hypothesis testing framework. For most constituents, the requirement is that the constituent be below a specified action limit for the waste to be considered acceptable. Therefore, the null hypothesis (baseline condition) is the true (but unknown) mean value of the constituent and is greater than or equal to the action limit, i.e., the staged feed does not meet the acceptance criteria. A number of samples are taken, from which test statistics can be calculated to determine whether the null hypothesis can be rejected, i.e., whether there is substantial evidence to indicate that the constituent is below the action limit and the staged feed should be accepted. The decision reached using the test statistics is equivalent to comparing the calculated upper confidence limit on the mean value to the action limit. If the upper confidence limit is below the action limit, the null hypothesis is rejected, i.e., the staged feed is considered acceptable.

Specifying the significance level of the hypothesis test indicates the Type I error rate, which is the probability of rejecting the null hypothesis when in fact it is true (i.e., deciding the staged feed is acceptable to transfer when, in fact, it does not meet the acceptance criteria). In this hypothesis testing framework, the decision-making is impacted by the amount of data collected (number of samples), the variability in the data, the different error rates (which are generally based on acceptable risks), and what the "true" value of the constituent is. Unfortunately, one never knows what the true value of the constituent is, so the usual objective is to identify reasonable scenarios that can be evaluated in order to ultimately select the required number of samples.

4.2.1.2 *Mixing and Sampling Biases*

Generally, the WAC DQO process does not address the potential biases in the Tank Farm mixing and sampling systems. A bias is the difference between the measured "mean" and the "true" value of the constituents. It represents a consistent offset between the mean and true in one direction (non-random) and it is not the same as uncertainty. If the biases are known, then they may be applied toward the action limit (subtract or add) in the waste acceptance decision process. However, the system biases are never known in actual operations since the "true" value of constituents are never known. For example, during the pre-transfer sampling process, the various "true" values of solids concentrations in the staged feed tank may vary spatially and temporally, depending on mixer operations and other physical conditions (e.g., solids settling, solids accumulation, precipitation, etc.). The "true" values may also vary between the different feed campaigns. Mechanical equipment in the WFD system such as the transfer pumps and

Isolok™ Sampler often introduces other biases due to the physical design (size, capacity) and installation (location, orientation).

Biases introduced by the mixing and sampling systems can be measured in a laboratory setting when the "true" constituent is controlled and known. This information will be useful in optimizing the sampling system design and operations to minimize, but not completely eliminate, the effect of known biases. Testing completed to date shows the mixing system and the sampling system performance add positive bias to the fast settling solids concentration results. This bias suggests the true value will be less than the measured value and adds additional confidence that the acceptance limits will be met. The final gap analysis report will address how biases identified from the simulant testing are incorporated as appropriate in the sampling system design and waste acceptance decision.

In this report, the known biases from preliminary SSMD and Remote Sampler Demonstration testing are acknowledged, but they are not addressed in the statistical hypothesis testing framework (i.e., measured biases from testing were not added or subtracted to the action limit). This approach is consistent with the WAC DQO in that the actual waste acceptance decision can never fully quantify and account for the various biases introduced in the WFD process, even though they may exist. Confidence that mixing and sampling biases are conservative or inconsequential, from a waste acceptance perspective, will have to be demonstrated prior to final waste acceptance.

4.2.2 Estimate of Sampling Percent Relative Standard Deviation

This section describes the development of sampling %RSD estimate. Sampling uncertainty is quantified in terms of %RSD. The lower the %RSD translates, the more accurate and precise the result. It is composed of sampling errors from tank mixing, batch transfer, sampling equipment, and sample handling. Each type of sampling error can be traced to some aspects of the Pierre Gy's sampling theory, but no definitive correlations have been established given limited understanding on tank mixing and sampler performance on the staged HLW feed. Appendix C briefly describes the Pierre Gy's seven basic sampling errors and how aspects of each are applicable to the physical collection of HLW staged waste samples.

The initial WAC DQO uses an estimate based on the general target of the sampling demonstration program of "within 10%." Rather than using a sampling %RSD of 3.3%, corresponding to three RSDs, a slightly more conservative value of the sampling %RSD of 4% was used as the base case to calculate number of samples, with 10% and 20% as sensitivity checks. The 4%, 10%, and 20% sampling %RSDs were applied for all WAC parameters.

The initial gap analysis expands on the WAC DQO approach by assigning a %RSD to each of the four (4) sources of sampling errors (mixing, transfer, Isolok™, sample handling), which is propagated to determine the overall sampling %RSD. In other words, the sampling %RSD now varies as a function of specific sampling errors and WAC parameters. This way of systematic "accounting" of uncertainties will help document and highlight specific areas of weakness. Table 4-2 summarizes the assigned %RSD and the calculated sampling %RSD.

Given the early phase of the WFD project, most of the sampling %RSDs are ranked using an incremental scale (0 – 20) based on qualitative assessment. Selection of range is subjective at this point based on general alignment with the preliminary SSMD and Remote Sampler Demonstration results (Section 4.0), with the understanding that 20% may not be bounding for every parameter. Quantitative results from the SSMD and the Remote Sampler Demonstration were incorporated as applicable. RSDs that are based on testing are noted in ***(bold)*** and the appropriate source report cited in Table 4-2.

%RSD (0 – 20) Definition:

0 = Not applicable. This ranking is only for direct measured parameters (e.g., temperature, critical velocity).

1 = Minimum impact from sampling errors. This is a default ranking of most liquid phase analysis of WAC parameter where contribution from undissolved solids is negligible (e.g., pH). Also, this is a default minimum for co-precipitated fissile parameters (e.g., Pu to metal, $U_{fissile}$ to U_{total}) since the ratios are maintained independent of Isolok™ sampling uncertainties.

5 = Moderate impact from sampling errors. This is a default ranking for most slurry (liquid + solids) analysis of WAC parameters.

10 = Significant impact from sampling errors. This ranking is applicable for slurry sample analysis that targets undissolved solids.

20 = Extreme or unknown impact from sampling errors. Only applicable for slurry samples for WAC parameters that targets dense, fast settling, and sparse solids (i.e., PuO_2).

Table 4-2 lists the initial WAC parameters (ICD-19) and the potential new nuclear safety parameters as compiled from Section 3.0, Table 3-1 and Table 3-2 respectively. For each listed parameter, a sampling %RSD is assigned for the four (4) sources of sampling uncertainties. The associated rationale for selecting the 0 – 20 scale for each type of sampling error is given in the Bases and Assumptions column. The overall sampling %RSD is then used to calculate the number of samples in Section 6.0.

Following are discussions on the four (4) sampling uncertainties in Table 4-2:

Mixing – An estimate of uncertainties relative to how "representative" the pre-transfer sample is, compared to what is in the tank at the time of sampling event. It is a term used to assess mixing performance. Rotation of mixer nozzles during a batch transfer introduces periodic heterogeneity error (see Appendix C). The cyclic operation of the Isolok™ sampler helps minimize the effect from this type of error by compositing multiple samples (~5 mL) to make up the total sample volume.

Transfer – An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is transferred in subsequent batches. It is a term used to assess batch-to-batch variability over time. Variability of tank composition with decreasing tank level

introduces a non-periodic heterogeneity error. The less batch-to-batch variability, the lower the transfer %RSD value.

Isolok™ Sampler – An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the recirculation flow loop. It is a term used to assess sampler design. Physical configuration of the sampler design introduces delimitation (i.e., does not take full cross-section sample of the pipe) error. The larger the cross-section to full sample flow, the lower the sampler %RSD value.

Sample Handling – An estimate of uncertainties from physical preparation and handling of the pre-transfer sample from the time of sampling event to laboratory analysis. It is a term used to assess the integrity of the sample. Physical handling of the sample introduces preparation error (e.g., poor vapor seal, leaks, etc.). The better preservation of the sample, the lower the sample handling %RSD value.

Given the limited understanding of actual staged waste behavior under full scale operating conditions, all the assigned sampling %RSDs in Table 4-2, including those few that are based on preliminary SSMD testing, have inherent uncertainties. In other word, these are essentially best "ball park guesses" at this point. However as shown from the sensitivity analysis in Section 6.0, the absolute %RSD value does not affect the number of samples significantly for most parameters unless the expected feed composition approaches the action limit. These qualitative sampling %RSD values may be refined with additional testing and updated in the final gap analysis.

Table 4-2. Sampling %RSD

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
HLW WAC Parameters (ICD-19)							
Solids concentration (g/L)	< 200	5	***(10)***	5	5	13.2%	**Mixing**: Default minimum for slurry (liquid & solids) samples. Mixing effect offset by sampling over one complete pump rotation and by compositing multiple sub-samples pulled by the Isolok over time. **Transfer:** Set to be same as for bulk density sample. **Isolok:** Default minimum for solids sample. **Handling:** Higher uncertainties (relative to a pure supernatant matrix) to account for added complexity with handling sodium solution near or at saturation (e.g., precipitation of salt from liquid sample).
Na Molarity (moles/L)	< 10	1	1	1	5	5.3%	**Mixing:** Default minimum for liquid samples. **Transfer:** Liquid samples not as sensitive to variability over time compared to undissolved solids. **Isolok:** Liquid samples not as sensitive to physical configuration or bias of Isolok. **Handling:** Same as for solids concentration sample.

[11] Root-Sum-Square method of propagation of mixing, transfer, Isolok™, and sample handling %RSD.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Slurry rheology (at 25°C) – consistency viscosity (cP)	< 10	5	5	5	5	10%	**Mixing:** Default minimum for slurry (liquid & solids) samples. **Transfer:** Lower batch variability effect expected on rheological properties. **Isolok:** Same as for solids concentration sample. **Handling:** Same as for solids concentration sample.
Slurry rheology (at 25°C) - yield stress (Pa)	< 1	5	5	5	5	10%	**Mixing:** Default minimum for slurry (liquid & solids) samples. **Transfer:** Lower batch variability effect expected on rheological properties. **Isolok:** Default minimum for solids sample. **Handling:** Same as for solids concentration sample.
Slurry pH	≥ 12	1	1	1	1	2%	**Mixing:** Slurry pH assumed to be the same as liquid and therefore use default minimum for liquid. **Transfer:** Default min. for liquid. **Isolok:** Default min. for liquid samples. **Handling:** Default min. for liquid samples (not targeting any volatiles).
Slurry bulk density (kg/L)	< 1.5	5	***(10)***	5	5	13.2%	**Mixing:** Same as for the solids concentration sample. **Transfer:** Higher overall %RSD driven by batch-to-batch solids variations expected. Based on SSMD testing, relative batch trend of simulated HLW slurry bulk density was within 10% (ref. RPP-49740, Rev. 0). **Isolok:** Same as for the solids concentration sample. **Handling:** Same as for the solids concentration sample.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Critical velocity (ft/s)	≤ 4	10	10	0	0	14.1%	**Mixing:** RSD associated with this parameter will be driven largely by the analytical RSD for the instrument (i.e., PulseEcho). But mixing will change the recirculating flow loop composition in real time, which is detected by the Pulse-Echo, and as such mixing has the same impact as a physical sample. Default set higher than typical slurry samples since critical velocity detection is targeting larger, heavier, and difficult to suspend solids. **Transfer:** Same rationale as for mixing. **Isolok:** Default (n/a) for in-line measurement. **Handling:** Default (n/a) for in-line measurement.
Ammonia (M)	< 0.04	1	1	1	5	5.3%	**Mixing:** Default minimum for liquid samples. **Transfer:** Default minimum for liquid samples. **Isolok:** Default minimum for liquid samples. **Handling:** Higher RSD to account for effect of volatile components.
Separable organics (visual)	no visible layer	20	10	1	1	22.4%	**Mixing:** Higher mixing impact to account for potential stratification of separated organics (i.e., floating on liquid surface). **Transfer:** Higher batch variability due to the same stratification of separable organics (i.e., may be higher in subsequent batches than captured in the pre-transfer sample). **Isolok:** Default min. for liquid samples. **Handling:** Default min. for liquid samples assuming no volatiles and no loss of sample due to adhesion of organics to sample bottle.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
PCB (ppm)	< 50	5	10	5	1	12.3%	**Mixing:** Default min. for slurry samples assuming most PCBs are associated with solids. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Lower than typical slurry since PCB analysis are not sensitive to sodium precipitation or loss of volatile components.
TOC (wt%)	< 10	5	10	5	5	13.2%	**Mixing:** Targeting total liquid & solids and as such set to be the same as default min. for slurry samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration although the concern is less with precipitation but loss of volatiles.
HLW Feed unit dose (Sv/g)	< 270	5	10	5	1	12.3%	**Mixing:** Targeting the solid fraction of the sample and as such set to be the same as default min. for slurry samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Lower than for typical slurry sample since unit dose rate analysis is not sensitive to effect of precipitation or loss of volatiles.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Pu to metals ratio - solids (g/kg)	< 6.2	20	***(30)***	1	1	36.1%	**Mixing:** Highest overall RSD assumed to account for problematic particles (large, dense, fast settling) recognizing not all forms of Pu are large and dense. Further complicating the mixing factor is that Pu density is not the same as credited metals (i.e., the Pu/metal ratio is dependent on mixing). **Transfer:** Expect to have high batch variability due to problematic particles. Based on SSMD testing, all solids including Bi_2O_3 (surrogate for PuO_2) are below 30% RSD at jet mixer velocity greater than 28.7 f/s in the 120" tank (see Figure 4-1). **Isolok:** Default low RSD for this parameter since sampling is not expected to affect the co-precipitated Pu/metal ratio. **Handling:** Lower than for typical slurry sample since Pu to metal ratio is not sensitive to effect of precipitation or loss of volatiles.
Pu to metals ratio - liquid (g/kg)	< 6.2	1	1	1	1	2%	**Mixing:** Set as default for liquid samples since the analysis is targeting Pu concentration in the liquid fraction only. **Transfer:** Default min. for liquid samples. **Isolok:** Default min. for liquid samples. **Handling:** Default min. for liquid samples.
Pu concentration of liquids (g/L)	< 0.013	1	1	1	1	2%	**Mixing:** Set as default for liquid samples since the analysis is targeting Pu concentration in liquid only. **Transfer:** Default min. for liquid samples. **Isolok:** Default min. for liquid samples. **Handling:** Default min. for liquid samples.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
U fissile to U total (g/kg)	< 8.4	5	1	1	1	5.3%	**Mixing:** Default min. for slurry parameter. **Transfer**: Lower RSD expected than for typical slurry samples since the ratio will not change even if the batch concentration varies with time (i.e., ratio is maintained regardless of time or tank composition). **Isolok:** Default min. for fixed fissile ratio parameter (same as Pu to metal ratio).**Handling:** Lower than typical slurry samples since U/U total ratio is not sensitive to precipitation or loss of volatiles.
HGR (gmoles H_2/L/hr @ 150°F)	2.1 E-06	5	5	5	5	10%	**Mixing:** HGR sample is targeting both liquid and solids. Default RSD to default min. for solids samples. **Transfer:** Same as for solids concentrations sample. **Isolok:** Same as for solids concentration sample. **Handling:** HGR analysis is sensitive to loss of certain volatiles and as such set to be the same as the ammonia samples.
Temperature Change for	± 20	5	10	5	1	12.3%	**Mixing:** ASTM D5058-12 (supersedes D5058-90) stipulates mixing staged feed

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Waste Feed Compatibility (°C)		5	10	5	1	12.3%	(e.g., 10 mL) with the residual waste in feed receipt tanks (e.g., 10 mL) and therefore there are two independent samples required for this one analysis, one from tank farm and one from WTP. Assuming the same uncertainty for both samples, the mixing effect is combined statistically (Root Sum Square) together. Default both mixing RSD to be the same as solids concentration samples. **Transfer:** Assuming same transfer uncertainty, the transfer RSD is combined statistically. Default both transfer RSD to be the same as solids concentration samples. **Isolok:** Same as solids concentration samples. **Handling:** Default min. for liquid samples since compatibility analysis is not sensitive to precipitation or loss of volatiles.
						17.4%	

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Feed temperature (°F)	< 150	5	0	0	0	5%	**Mixing:** Although this is a direct measurement (no sampling), a default RSD is assigned to account for mixing impact on variability of temperature measurements in the DST that can complicate the acceptance decision process, which is undefined at this point (eg., use of average tank temperature, single maximum temperature, location of temperature measurement, etc). Set default to be same as for solids concentration samples because solids distribution in the tank affect temperature distribution. **Transfer:** Temperature will be monitored during transfer and as such this term is n/a. **Isolok:** No physical samples and as such this term is n/a. **Handling:** No physical samples and as such this term is n/a.
Abrasivity	TBD	5	10	5	1	12.3%	**Mixing:** Default min. for typical slurry samples since the analysis is targeting average particles hardness, not specific particles. **Transfer:** Same as for solids concentration samples. **Isolok:** Default min. for typical slurry samples. **Handling:** Default min. for liquid samples since average particle hardness is not sensitive to precipitation or sample loss.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases & Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Potential New Nuclear Safety Parameters (24590-WTP-RPT-ENS-11-021)							
Pu particle size (microns)	TBD	20	***(30)***	***(10)***	1	37.4%	**Mixing:** Default to be the same as for the Pu/metal samples due to the same constraints. **Transfer:** Same as for the Pu/metal samples. **Isolok:** A bounding RSD of 10% is referenced from preliminary remote sampler testing (based again on Bi_2O_3) (see Figure 4-5). RPP-RPT-51796, Rev. 0, Table 10-4). **Handling:** Same as for the Pu/metal samples.
Upper Bound Settled Layer Shear Strength within 24 hrs (Pa)	< 200	5	10	5	5	13.2%	**Mixing:** Same as for solids concentration samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration samples.
Average Particle Density of Pre-Leached Solids (kg/L)	≤ 2.18	5	10	5	5	13.2%	**Mixing:** Same as for solids concentration samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration samples.
HLW Feed Particle size (microns)	≤ 210	5	10	5	5	13.2%	**Mixing:** Same as for solids concentration samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration samples.

4.2.3 Estimate of Analytical Relative Standard Deviation

This section describes the development of analytical %RSD estimate. Analytical uncertainty is quantified in terms of %RSD. The lower the %RSD values, the more accurate and precise the result. It is composed of analytical errors from direct measurements in real time or laboratory sample analysis, but not both.

The analytical %RSDs are impacted mostly by techniques and equipment accuracies which, unlike the sampling %RSD, can be validated using established procedures and control charts. This report refers to analytical %RSDs that are traceable to 222-S control charts (shown in parentheses) or calculated using data from analysis where control charts are available. Control charts are created from actual repetitive measurement of control samples containing known quantities of analytes in a standard solution or other simple matrix. Control charts can be used to quantify analytical errors that occur from all steps in the laboratory analytical procedure, from sample preparations to the specific equipment used.

The analytical %RSDs are compiled for each of the WAC parameter in Table 4-3. Existing analytical %RSDs are taken directly from the initial WAC DQO while a few new %RSDs are based on subjective estimate. The only exception is the critical velocity %RSD (shown in **bold**) where the value is based on the latest PulseEcho demonstration (PNNL-19441, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments).*

Analytical capability, as expressed through the %RSD, is evaluated against the WAC parameters and the potential new nuclear safety parameters as defined in Sections 3.1 and 3.2 respectively. The %RSDs are to represent the overall uncertainty of the analytical method, not to be confused with the Quality Control (QC) acceptance criteria in % Recovery or Relative Percent Difference (RPD). Also note that the process qualification testing that requires up to 4 L of sample in support of WTP "process-ability" (e.g., filtration) is not assessed as a part of laboratory's capability since in general they do not impact WTP's acceptance of the staged waste.

A laboratory has not been selected for waste acceptance analysis of the pre-transfer samples. For the purpose of this initial gap analysis, all analysis for feed chemical, radiochemical, and physical properties required for waste acceptance is assumed to be provided by the 222-S Laboratory (Section 5.1). Most, not all, of the existing 222-S procedures have been vetted as a part of the WTP Waste Qualification Program. Gaps in analytical capability for WAC parameters have been identified as a part of a collaborative review effort by external subject matter experts (SCT-M0SRV00028-00-009-01-00002, *SRNL Phase 1 Assessment of the WAC/DQO and Unit Operations for the WTP Waste Qualification Program).* The results have been reviewed and captured as appropriate in the gap analysis (see Section 6.0).

Table 4-3. Analytical %RSD.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures & References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
HLW WAC Parameters (ICD-19)					
Solids concentration (g/L)	< 200	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-512-106: Total Suspended Solids. This procedure assumes the sample does not contain appreciable amounts of easily dissolved salts.
Na Molarity (moles/L)	< 10	0	(10)	10%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-505-174, Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Scientific iCAP 6500.
Slurry rheology (at 25°C) - consistency viscosity (cP)	< 10	0	(5)	5%	**Field Measurement:** Not applicable. **Lab Measurement:** ATS-LT-519-106; ATS-LT-519-108: viscosity range of approximately 1 to 10^6 mPa-s, or Centipose (cP).
Slurry rheology (at 25°C) - yield stress (Pa)	< 1	0	(5)	5%	**Field Measurement:** Not applicable. **Lab Measurement:** ATS-LT-519-106; ATS-LT-519-108: torque range of 0.05 micronewton-meters (µNm) to 200 millinewton-meters (mNm), with a torque resolution of <1 nNm and shear rate of 0.1 to 1100s^{-1}
Slurry pH [2]	≥ 12	0	(0.1)	0.1	**Field Measurement:** Not applicable. **Lab Measurement:** LA-212-106: pH Determination Of Aqueous Samples.

[1] Uncertainties shown in a parenthesis are based on or derived from use of control charts.
[2] Uncertainties for pH is defined in terms of absolute pH (12 +/- 0.1) and not as %RSD. Source of potential pH error is based on instrument measurement accuracy.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures & References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
Slurry bulk density (kg/L)	< 1.5	0	2	2%	**Field Measurement:** Not applicable. **Lab Measurement:** Process Chemistry Evaporator Support or LA-510-112:
Critical velocity (ft/s)	≤ 4	***(7.5)***	0	7.5%	**Field Measurement:** Empirically derived RSD based on +/- 0.3 ft/s variance between visual observation and Pulse-Echo detection of CV (PNNL-19441, Tables 11.1 and 11.2). **Lab Measurement:** Not applicable.
Ammonia (M)	< 0.04	0	(7)	7%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-533-101: Cation Analysis On Dionex Model DX-500; measures NH4 LA-544-112: Micro-distillation Separation of Ammonia For Ion Chromatographic Analysis. Note that the analysis is for ammonia in liquid, not vapor.
Separable organics (visual)	no visible layer	0	n/a	n/a	**Field Measurement:** Not applicable. **Lab Measurement:** Visual inspection of sample surface for oily/glassy substance.
PCB (ppm)	< 50	0	(50)	50%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-523-140. Polychlorinated Biphenyls (PCBs) By SW-846, Method 8082A, Using Gas Chromatography With Electron Detection.
TOC (wt%)	< 10	0	(5)	5%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-342-100: Determination of Carbon by Hot Persulfate Oxidation and Coulometric Detection. LA-344-104: Total Organic Carbon (TOC) Combustion Tube Change.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures & References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
HLW Feed unit dose (Sv/g)	< 270	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** Standard radiochemistry analysis performed for each isotope or a group of isotopes (GEA). The rad. analysis in Ci/L will be converted to Sv/g dose using public dose factor for individual isotope.
Pu to metals ratio - solids (g/kg)	< 6.2	0	(3.9)	3.9%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-943-129: Determination of Plutonium by Extraction and ICP-MS or LA-508-168: Calibration and Operation of the Ortec AEA System. LA-505-174, Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Scientific iCAP 6500.
Pu to metals ratio - liquid (g/kg)	< 6.2	0	(3.3)	3.3%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-943-129: Determination of Plutonium by Extraction and ICP-MS or LA-508-168: Calibration and Operation of the Ortec AEA System. LA-505-174, Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Scientific iCAP 6500.
Pu concentration of liquids (g/L)	< 0.013	0	(2.5)	2.5%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-943-129: Determination of Plutonium by Extraction and ICP-MS or LA-508-168: Calibration and Operation of the Ortec AEA System. LA-953-104: Determination of Plutonium and Americium by Extraction with TRU Resin.
U fissile to U total – solids (g/kg)	< 8.4	0	(10.8)	10.8%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-542-104: Co-Precipitation of Transuranics for Alpha Energy Analysis (AEA) Counting

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures & References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
U fissile to U total – liquid (g/kg)	< 8.4	0	(2.1)	2.1%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-542-104: Co-Precipitation of Transuranics for Alpha Energy Analysis (AEA) Counting
HGR (gmoles H_2/L/hr @ 150°F)	2.1 E-06	0	20	20%	**Field Measurement:** Not applicable. **Lab Measurement:** ATS-LT-523-163 222-S Laboratory Tracer Gas Analysis for Helium, Hydrogen and Methane Using Gas Chromatography/Thermal Conductivity Detector (GC/TCD). RSD is applicable for a "static" system and not a "flow-through" system. Flow through type technique is under development.
Temperature Change for Waste Feed Compatibility (°C)	± 20	0	1	1%	**Field Measurement:** Not applicable. **Lab Measurement:** ASTM D5058-12 (supersedes D5058-90) (mixing 10 mL staged feed w/ 10 mL of residual waste in feed receipt tanks). Based on Practice A of the standard and using thermocouples good to 0.1 °C precision, then a 1% RSD around the action limit is achievable. New lab procedure needs to be developed.
Feed temperature (°F)	< 150	1	0	1%	**Field Measurement:** Total RSD based on an assumed total instrument loop uncertainties of +/- 1.5°F from the action limit (or 1% RSD). Individual sensor accuracy for typical RTD is better than +/- 1% , but the bigger influence on tank temperature may be the signal transmission loop and location of the sensors. This RTD value is considered a place-holder only until a more thorough loop analysis is done based on a completed design and temperature control strategy for the HLW feed DST. **Lab Measurement:** Not applicable.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures & References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
Abrasivity	TBD	0	20	20%	**Field Measurement**: Not applicable. **Lab Measurement:** Final analytical technique to be determined. 222-S Lab is currently not equipped to perform ASTM G75-07 (Miller Number) or (SAR Number) testing in the hot cell.
Potential New Nuclear Safety Parameters (24590-WTP-RPT-ENS-11-021)					
Pu particle size (microns)	TBD	0	20	20%	**Field Measurement:** Not applicable. **Lab Measurement:** Scanning Electron Microscope w/ Energy Dispersive X-ray Analysis LT 161-100 PSEM Instrument, LT 161-102 FEI Instrument. Size calibration w/ NIST spheres and 40 microns grid. High %RSD driven by the inability to measure particles in 3D. The 2D measurement is around 1-2% RSD.
Upper Bound Settled Sludge Layer Shear Strength within 24 hrs (Pa)	< 200	0	20	20%	**Field Measurement:** Not applicable. **Lab Measurement:** A higher RSD is assumed due to unspecified conditions required to develop a more robust analytical procedure for settled sludge shear strength measurement.
Average Particle Density of Pre-Leached Solids (kg/L)	≤ 2.18	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** Process Chemistry Evaporator Support or LA-510-112:
HLW Feed Particle Size (microns)	≤ 210	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** Larger size particle will be analyzed using sieving procedure. Fines from sieving will be using Laser Scattering Particle Size Distribution Analyzer. LA-950/950V2. Instruction Manual CODE GZ0000079069B; GZ00000032875E. Test Plans LAB-PLN-10-00011 and LAB-PLN-11-00009.

4.2.4 Estimate of Waste Feed Delivery Profile

This section describes the process used to estimate the WFD profile, as well as how to use the information to calculate the number of samples and determine potential gaps.

4.2.4.1 *HTWOS & System Plan*

The Hanford Tank Waste Operations Simulator (HTWOS) is a dynamic event-simulation model that tracks waste as it moves through storage, retrieval, feed staging, and multiple treatment processes from the present day until the end of the River Protection Project (RPP) mission. It is a tool used to support WFD planning in accordance with the System Plan (ORP-11242, 2011, *River Protection Project System Plan*, Rev. 6).

The HTWOS model was used to perform a Baseline Case run to support the feed screening process. Baseline Case is a mission scenario in the System Plan (Rev. 6) that forms the technical basis for both the near-term baseline and the out-year planning estimate range. This run provides the most up to date projected compositional feed delivery profile from commissioning through the end of mission. It tracks most of the WAC parameters except for some of the physical properties (e.g., viscosity, particle size, abrasivity, etc.). It provides the expected values from which the sampling and analytical errors are applied to calculate number of samples as a quantitative measure of potential gap in the waste acceptance decision process. The Baseline Case for System Plan (Rev. 6) has already been run in support of feed screening in the IWFDP (RPP-40149-VOL2, *Integrated Waste Feed Delivery Plan Volume 2 – Campaign Plan)*. The same run was repeated with minor changes in output reporting for this initial gap analysis. Results are documented in SVF-2476, *WTP DQO Feed Screening with SP6 Data.xlsm*. The formatted data for HLW was copied and used as input for the numbers of samples calculation.

4.2.4.2 *Construction of Sample Size Graphs*

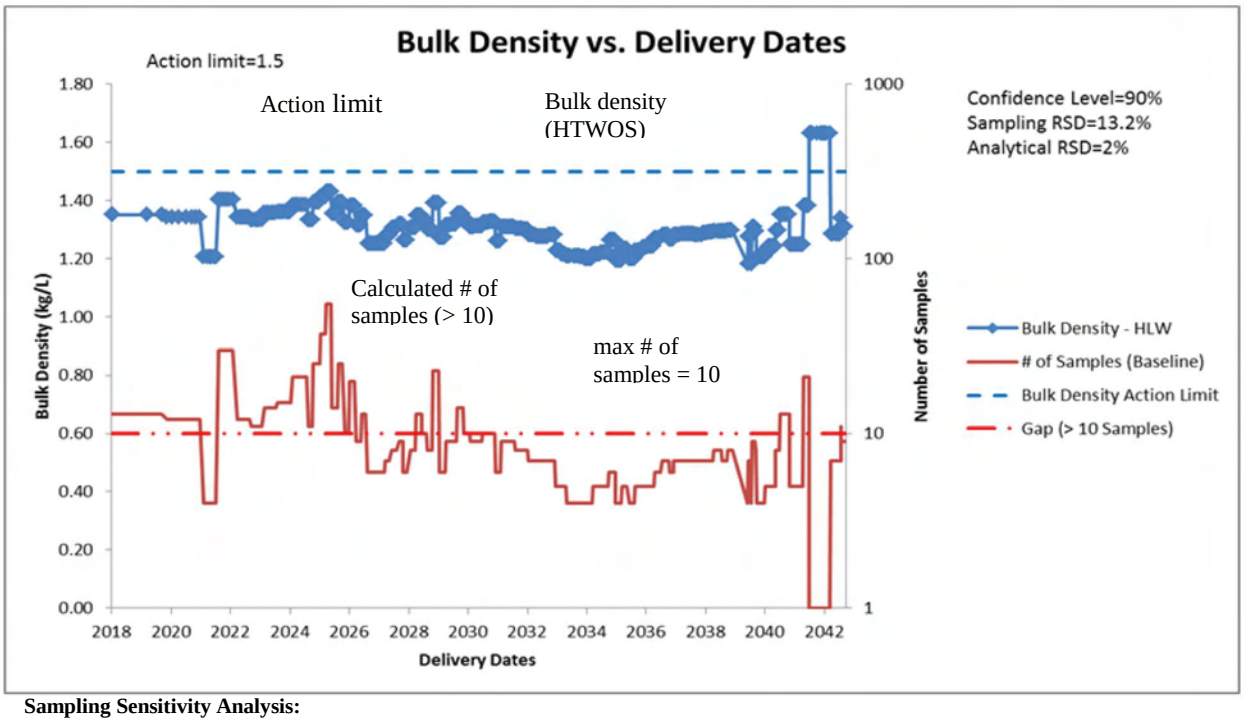
Gaps are evaluated on the statistical hypothesis testing based on the number of samples required to ensure compliance with the WAC action limit given a required confidence level. With the exception of the analyses for criticality safety limit (CSL) requirements (ratio of Pu to metal absorbers, $U_{fissile}$ to U_{total}, and Pu concentrations in liquids), all of the action limits are evaluated at a 90% confidence level. The CSL action limits are evaluated at a 95% confidence level (24590-WTP-RPT-MGT-11-014). If an excessive number of samples are required based on proximity of the project feed composition value to the waste acceptance action limit, then a gap is identified. The number of samples is set to 10 as a threshold for gap analysis purpose, with the understanding that, if necessary, more samples can be taken or the required Confidence Level can be decreased to resolve the gap. The ten samples limit was selected to be consistent with the approach in the WAC DQO (i.e., plan to take 10 samples regardless, but analyze only three).

The number of samples calculation adheres to the method as defined in the WAC DQO process. The equation is based on EPA/240/B-06/001, *Guidance on Systematic Planning Using the Data Quality Objectives Process*, Equation A-8 (see Appendix B). The numbers of samples calculated are plotted on the sample size graph generated for each of the WAC parameters (SVF-2548,

Sample Number Calculations for Initial Gap Analysis, 2010-2 Commitment 5.5.3.1.xlsm). These graphs are constructed to provide visual at-a-glance information (see Figure 4-7):

- Projected feed compositional data from HTWOS model run (SVF-2476) vs. delivery schedule dates
- Calculated number of sample corresponding to each feed compositional data point vs. delivery schedule dates
- Waste acceptance action limit
- Maximum number of sample (=10)
- Sensitivity results

Figure 4-7. Example Sample Size Graph.



Sampling Sensitivity Analysis:

Sampling	Max. # of Samples
4.0%	**7**
13.2%	**55**
50.0%	**745**

Sensitivity results (base case)

Details on the construction and interpretation of similar sample size graphs are provided in the WAC DQO (24590-WTP-RPT-MGT-11-014). In general, the graphs are intended to highlight instances where the maximum numbers of samples are exceeded (indicative of possible gap). The number of samples value varies as a function of the difference (delta) between the projected feed composition and the action limit. The number of samples will increase exponentially as the

delta gets smaller (or as the projected feed composition approaches the action limit). For a few rare instances when the feed exceeded the action limit, the number of samples is defaulted to 1 as an indication that the decision (reject) is no longer dependent on the number of samples. Interpretation of the sample size graphs are discussed as part of the gap analysis results in Section 6.0.

4.2.5 Evaluation of Waste Transferred to WTP

Not all the WAC parameters are tracked in the HTWOS. Parameters not currently modeled in HTWOS are qualitatively assessed for potential gaps by leveraging subject matter expertise and technical studies as applicable. For most of these parameters, there is not enough characterization data or reliable correlations to support a feed screening approach (number of samples). These parameters include:

- Critical velocity
- Slurry rheology (viscosity consistency & yield stress)
- Abrasivity
- Pu particle size
- HLW feed particle size
- Upper bound settled layer shear strength
- Feed temperature
- Waste feed compatibility in terms of temperature change
- Average particle density of pre-leached solids
- Separable organics
- PCBs

Most of the above are related to the physical properties of the "as-staged" HLW feed. As cited from the latest study of the expected waste to be transferred to WTP (RPP-RPT-51652), the incidental and intentional blending of the tank wastes affects rheological properties *"…through changes in various physicochemical characteristics such as pH, chemical composition of particles and salts, concentrations of particles and salts, particle size distribution and density and shape of particles."*, and that *"…it is difficult or impossible to draw deterministic conclusions on the effect of tank waste blending on rheology. In fact, it is case-by-case as noted from the examples of actual waste blending."* For the given reasons, the rheological and particle size parameters are screened using a more conservative approach based on the study results in RPP-RPT-51652 as applicable. Sampling and analytical uncertainties are applied to a bounding value or upper range that is assumed valid for all batches, instead of a nominal value for batch-to-batch, to determine if there is a potential gap in compliance. For example, if the largest solid particles that can be physically be transferred to WTP exceed the initial WAC for bounding particle size or range, then a gap is flagged regardless of the actual amount, distribution, or impact on WTP operations. These types of potential gaps (or open items) do not necessarily require mitigation but rather serves to highlight the need to develop additional understanding. A purely qualitative approach is used for screening the remaining parameters that have little supporting process information (e.g., separable organics, feed temperature, PCB, etc.). The qualitative screening of these parameters is discussed in Section 6.0.

5.0 ASSESSMENT OF CURRENT WTP CAPABILITIES

WTP capabilities in terms of PJM mixing, sampling, and heel management at the HLW Feed Receipt Vessel (HLP-VSL-00022) could drive potential changes to the initial WAC. Testing planned including the Large Scale Integrated Testing (LSIT) will be assessed for impact on the WTP WAC when data becomes available (2010-2 IP Commitment 5.5.3.3). Subsequent updates to the WTP WAC will be incorporated in the final gap analysis (2010-2 IP Commitment 5.5.3.9).

Until testing data is available for benchmarking against current or updated WAC parameters, this section is limited to a summary description on the laboratory capabilities to support the analytical %RSD discussion in Section 4.2.3.

5.1 LABORATORY ANALYTICAL CAPABILITY

This section discusses laboratory facilities and capabilities as a backdrop for the gap analysis. Information is excerpted in part or whole from the latest report on analytical laboratory capabilities (RPP-RPT-50014, *Qualitative Analysis of the Analytical Laboratory Capabilities Required to Support Hanford Tank Farm Closure)*. Gaps or issues concluded within the RPP-RPT-50014 report are not necessarily declared as gaps in this report if they deal with capacity (turn-around-time) or budget type constraints that are more in-line with production/programmatic issues, rather than the technical capability required for making waste acceptance decisions.

As of June 30, 2012, a laboratory had not been selected to handle the pre-transfer samples analysis required to confirm the WTP WAC. A qualitative gap analysis was performed on five candidate facilities, each with distinct capabilities to support the Hanford tank closure mission (RPP-RPT-50014). The five candidate laboratory facilities are the 222-S Laboratory on the Hanford site; PNNL in Richland, Washington; the Savannah River National Laboratory (SRNL) in Aiken, South Carolina; the Waste Sampling and Characterization Facility (WSCF) on the Hanford site; and the WTP-LAB that is being constructed on the Hanford site. All facilities except the WSCF can perform chemical and radiochemical characterization of tank waste, but only 222-S can currently perform analysis for volatile organic compounds (VOCs), semi-volatile compounds (SVOCs), and PCBs on site. At this time, certified radioactive material transportation packages are limited to the Hedgehog-II type, which makes shipping multi-liter samples off-site to SRNL currently impractical.

The 222-S Laboratory is a full-service, analytical facility that handles samples of low to high radioactivity for the purpose of organic, inorganic, and radiochemistry analyses. Originally constructed to support the REDOX reprocessing plant, the 222-S laboratory now supports the environmental clean-up mission at Hanford. The capability of the 222-S Laboratory is organized into four (4) major functional areas:

- Organic. This area contains the equipment to perform extractions and analysis for PCBs, VOCs, and SVOCs. Analytical equipment includes two GC-MS and two GC-Electron Capture Detector analyzers.

- Inorganic. Samples are prepared in room 1B before analysis by ICP-AES, ICP-MS, IC, or atomic absorption. Two of each type of analyzer are provided. Other analyses include TIC/TOC, TGA/DSC, specific gravity, solids concentration, pH, and hydroxide.
- Radiochemistry. The rooms on the first floor contain the equipment to perform various radionuclide separations. The radiochemical counting equipment is located in the basement and consists of GEA, Alpha Energy Analysis (AEA), LSC, and GPC analyzers.
- Process Chemistry. This area contains equipment for performing various physical characterizations of samples, including scanning electron and optical microscopy, laser-based particle size analysis, X-ray diffraction, and rheology. The area also includes hot cells for technology testing.

The analytical procedures used in 222-S are compliant with the Hanford Analytical Services Quality Assurance Requirements Document (HASQARD) and consistent with SW-846 methods for RCRA analyses. Modifications to the SW-846 methods are mainly associated with reduced sample sizes to reduce radiation dose rates and are declared to the regulator (Washington State Department of Ecology). The laboratory currently supports all of the tank farms operations outlined above by means of its analytical equipment, established analytical methods, and radiological facilities.

For the purpose of this initial gap analysis, the 222-S Laboratory is assumed to be the laboratory where the pre-transfer samples analysis for WTP WAC compliance will be performed and that the supporting analytical work are performed in compliance with NQA-1-1989 (Part II, Basic, and Part III, Supplementary Requirements), as applicable. Therefore, the analytical procedures and %RSD estimates in this report (Section 4.2.3) are traceable to 222-S. This assumption is consistent with the initial WAC DQO approach for WAC analyses.

6.0 GAP ANALYSIS

This section compares the capabilities and uncertainties compiled against the initial WAC parameters and the potential new nuclear safety parameters to assess potential gaps and open items. For those parameters that are tracked in HTWOS, the results of the comparison are presented in the form of sample size graphs. Observed gaps are summarized and likely sources of gaps discussed in Section 6.1. Parameters that are not tracked in HTWOS are addressed individually in Section 6.2.

6.1 HLW FEED SCREENING (HTWOS) AND GAPS

The screening of all the planned HLW feed campaigns (~600) against the current waste acceptance criteria action limits are presented by the use of sample size graphs. The sample size graphs are constructed using HTWOS run results generated for System Plan (Rev. 6) Baseline Case (SVF-2476_R0_*WTP DQO Feed Screening with SP6 Data.xlsm*) that provides the compositional data spanning the WFD schedule. The required number of samples used to decide whether the staged feed is acceptable for transfer to WTP is calculated and plotted for each compositional data point. The derivation of the associated equations used is provided in Appendix B. The complete spreadsheet calculation is documented in SVF-2548.

The sample size graphs shown (Figure 6-1 to Figure 6-13) follow a general format. The horizontal axis represents the delivery dates chronologically from hot commissioning (5/31/2018) through end of mission (2/18/2043). The left vertical axis represents the compositional data for the constituents of interest (e.g., bulk density in kg/L). The right axis represents the number of samples required, at the corresponding "mean" of the constituents of interest, for the specified confidence level and uncertainties (sampling + analytical) shown at the upper right corner of each graph. Note that some of the right axes for the number of samples are plotted in log scale (e.g. bulk density, $U_{fissile}$ to U_{total} – solids, and hydrogen generation rate). The corresponding waste acceptance action limit is plotted along with the maximum number of samples criterion (10) to provide a visual guide for at-a-glance comparison. For a few rare instances when the feed exceeded the action limit, the number of samples is defaulted to either 0 or 1 as an indication that the decision (reject) is no longer dependent on number of samples.

To illustrate how sensitive the number of samples is to the assigned sampling %RSD, which by large are qualitative "best guesses," a simple sensitivity test was performed by varying the assigned sampling %RSD value to bracket the Base Case between 2% and 50%. Result of this sampling sensitivity analysis is tabulated directly below the sample size graph for each constituent. An additional sensitive analysis was performed for the $U_{fissile}$ to U_{total} parameter to determine what effect the CL has on the number of samples.

Note that different constituents may require different sample sizes, based on the mean value of the constituents. However, since the analytical results for the different constituents are often

obtained from the same samples, the number of samples required will generally be driven by the constituent that requires the largest number of samples.

6.1.1 Results

Result from the use of HTWOS for feed screening is summarized in Table 6-1. Out of the thirteen WAC parameters screened using HTWOS model output, three of the thirteen (3 of 13) have periods when the number of samples exceeded ten. The rest require between one to four samples, which is in-line with the WAC DQO baseline. The three that exceeded 10 samples are the same ones evaluated previously as a part of the WAC DQO. These are $U_{fissile}$ to U_{total} ratio - liquid (Figure 6-8), $U_{fissile}$ to U_{total} ratio – solids (Figure 6-9), and bulk density (Figure 6-1). As summed up by the IWFDP (RPP-40149-VOL2), the quantity of samples required is primarily driven by the $U_{fissile}$ to U_{total} ratio and, to a lesser extent, the bulk density of the deliveries. Raising the action limit for the uranium ratio is under investigation, as it would have significant benefit in reducing the number samples required. For the bulk density measurement, the staging of feed near the limits and sampling error will need to be managed to minimize the number of samples. Finally, blending or dilution may be employed to resolve most out-of-tolerance feed conditions and has the potential to reduce the number of samples required.

Table 6-1. HTWOS Feed Screening Summary.

Reference	Parameter	Max. # of Samples (Base Case)	Gap? Y/N	Comment
Figure 6-1	Bulk Density	55	N	Sensitivity analysis based on adjusting down to a 4% sampling RSD dropped the max. # of samples to 7 indicating that this parameter may be mitigated by improving sampling performance alone.
Figure 6-2	Slurry pH	2	N	# of samples < 10. Relatively insensitive to sampling %RSD.
Figure 6-3	Total Organic Carbon (TOC)	1	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-4	Ammonia	1	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-5	Pu to Metals Ratio – Liquid	2	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-6	Pu to Metals Ratio – Solids	4	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-7	Pu Concentration of Liquid	2	N	# of samples < 10. Not sensitive to sampling %RSD.

Reference	Parameter	Max. # of Samples (Base Case)	Gap? Y/N	Comment
Figure 6-8	$U_{fissile}$ to U_{total} – Liquid	12	N	Sensitivity analysis based on adjusting down to a 4% sampling RSD, or by adjusting down to 90% CL, effectively dropped the max. # of samples to 6 and 8 respectively, indicating that this parameter may be mitigated by improving sampling performance or by relaxing the CL alone.
Figure 6-9	$U_{fissile}$ to U_{total} – Solids	247	**Y**	# of samples >> 10. This is the main driver for excessive # of samples compared to the other parameters. See Section 6.1.1.1.
Figure 6-10	Feed Unit Dose	2	N	# of samples < 10.
Figure 6-11	Hydrogen Generation Rate	2	**Y**	See Section 6.1.1.2.
Figure 6-12	Solids Concentration	2	N	# of samples < 10.
Figure 6-13	Sodium Molarity	2	N	# of samples < 10.

6.1.1.1 *$U_{fissile}$ to U_{total} – Solids*

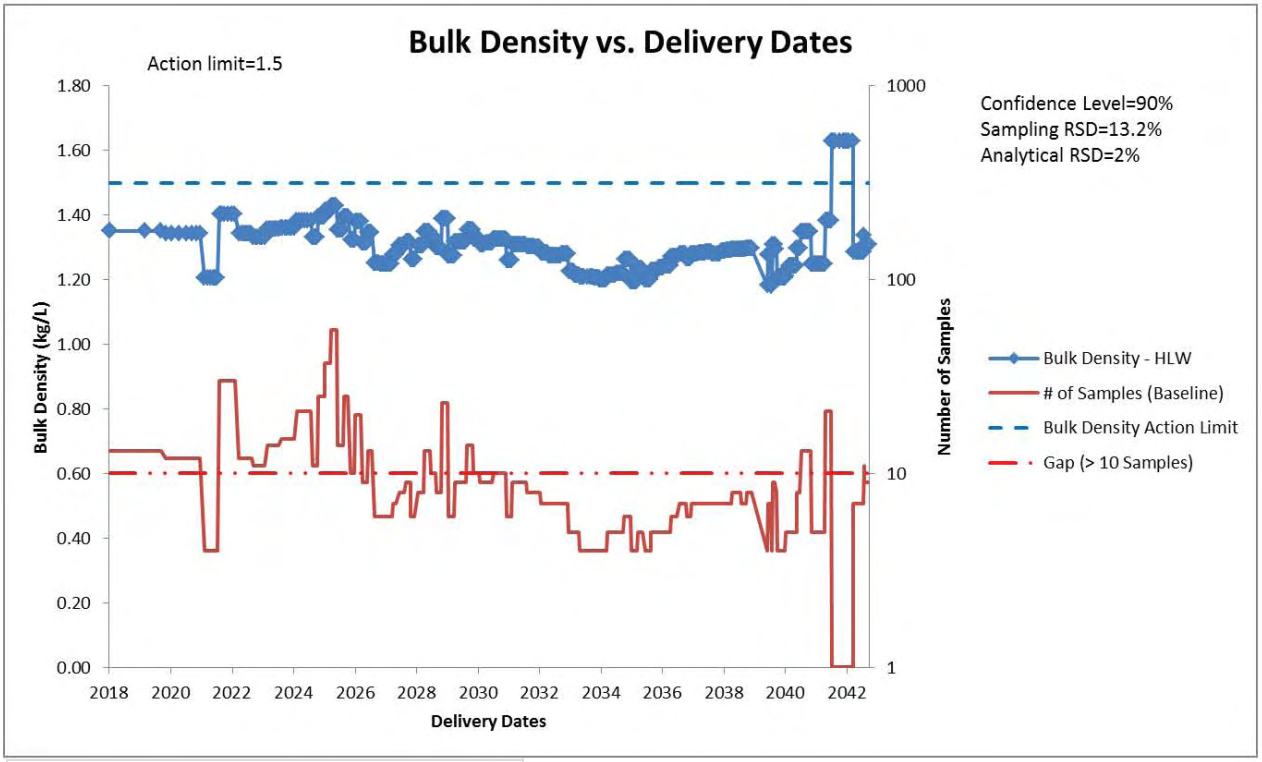
For those constituents that are tracked in HTWOS, the uncertainties introduced from sampling and analytical in most part, did not contribute to a gap. This is not surprising since most of the predicted mean values are sufficiently below the action limit. The sampling and analytical %RSD plays a minor role in general in driving the number of samples except when the mean approaches the action limit, as in the case for bulk density and the $U_{fissile}$ to U_{total} parameters. As a sensitivity check, the sampling %RSDs were set back to the original 4% as in the WAC DQO for these two constituents. The sensitivity results confirms that $U_{fissile}$ to U_{total} – solids is the only parameter driving the maximum number of required sample, and that improvement in the sampling uncertainties, i.e., capability, or reducing the CL from 95% to 90%, would not be sufficient in mitigating the gap.

6.1.1.2 *Hydrogen Generation Rate (HGR)*

One WAC parameter has an extreme sampling %RSD but didn't result in excessive number of samples. The Pu metal ratio to total solids parameter has the highest uncertainties in sampling (~38% RSD), but the feed quantity is orders of magnitude below the action limit, so the net effect on number of samples is still within an acceptable range (< 10). With the current Isolok™ testing underway to optimize the sampler performance, the overall sampling %RSD may be reduced further to provide additional margins of safety for this parameter. The high sampling uncertainties are not driving a gap for this parameter due to a higher error tolerance.

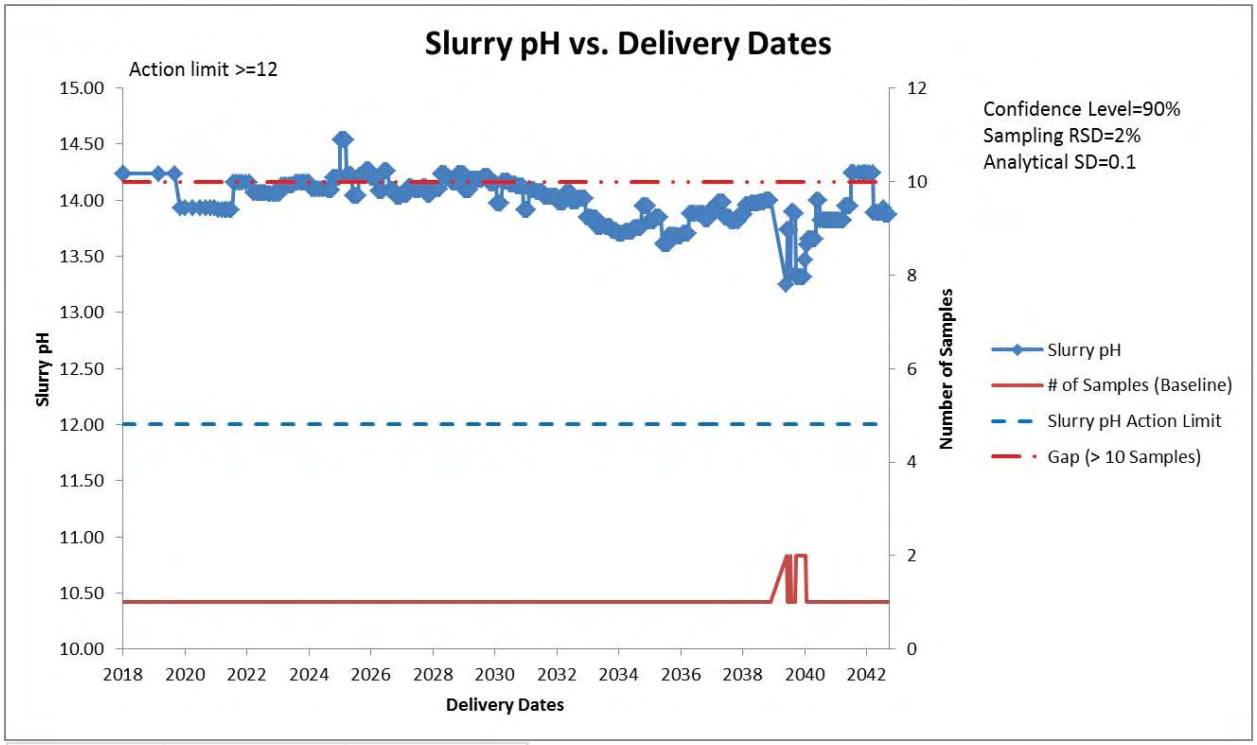
There are four (4) parameters that have high analytical %RSD (i.e. 20% or above). Three of these are not tracked in HTWOS (abrasivity, PCB, and Pu particles), and are therefore discussed separately in Section 6.2. The one parameter tracked in HTWOS, the Hydrogen Generation Rate (HGR), has a high analytical %RSD but the expected mean is still well below the action limit so the number of samples calculated did not trigger the gap. However, the high uncertainty for HGR measurement is due to the proposed use of an analytical technique (static conditions) being developed at 222-S in a hot cell environment. The original intent was for the HGR to be calculated using radiolysis correlations, but this is now required to be measured at a given temperature. There are some inherent advantages and disadvantages for static versus flow-through type measurement techniques (SCT-M0SRV00028-00-009-01-00002). The method to measure HGR is being developed by WTP using support from SRNL. Until the technique can be demonstrated to provide reliable HGR measurement, this parameter is flagged as a gap (see Table 6-1).

Figure 6-1. Bulk Density.



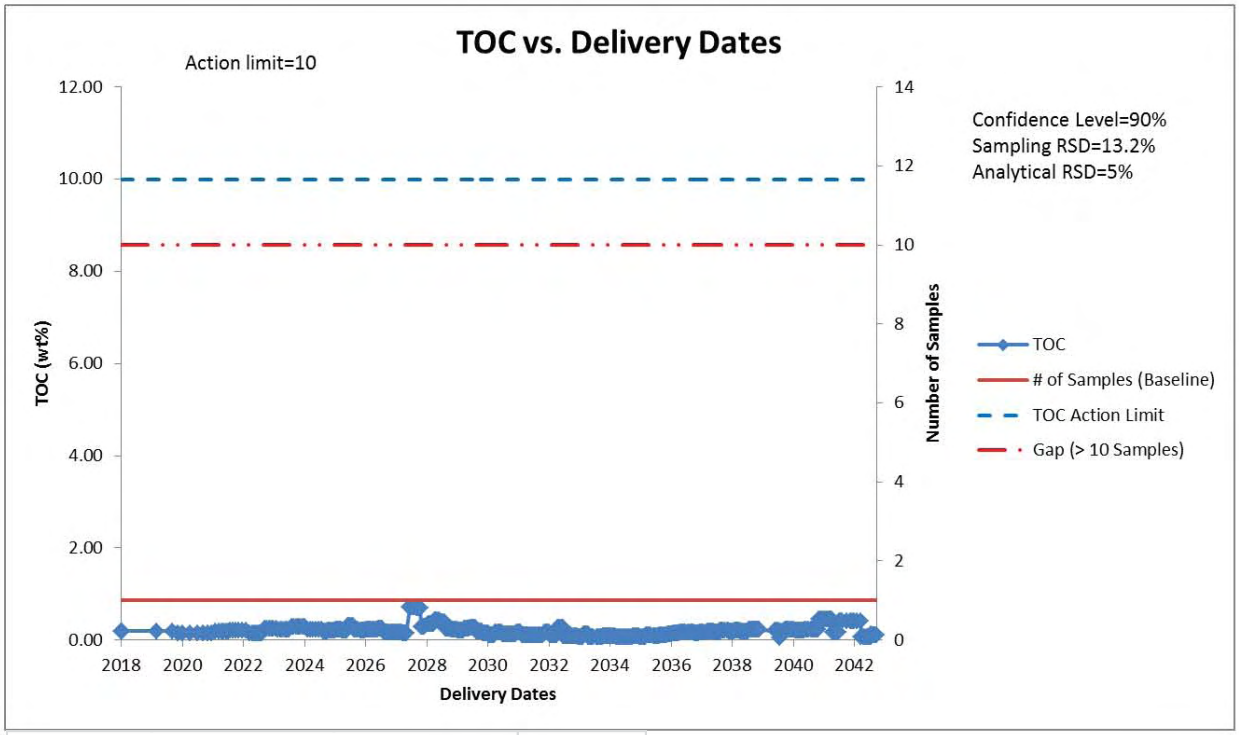
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	**7**	
13.2%	**55**	<< Base Case
50.0%	**745**	

Figure 6-2. Slurry pH.



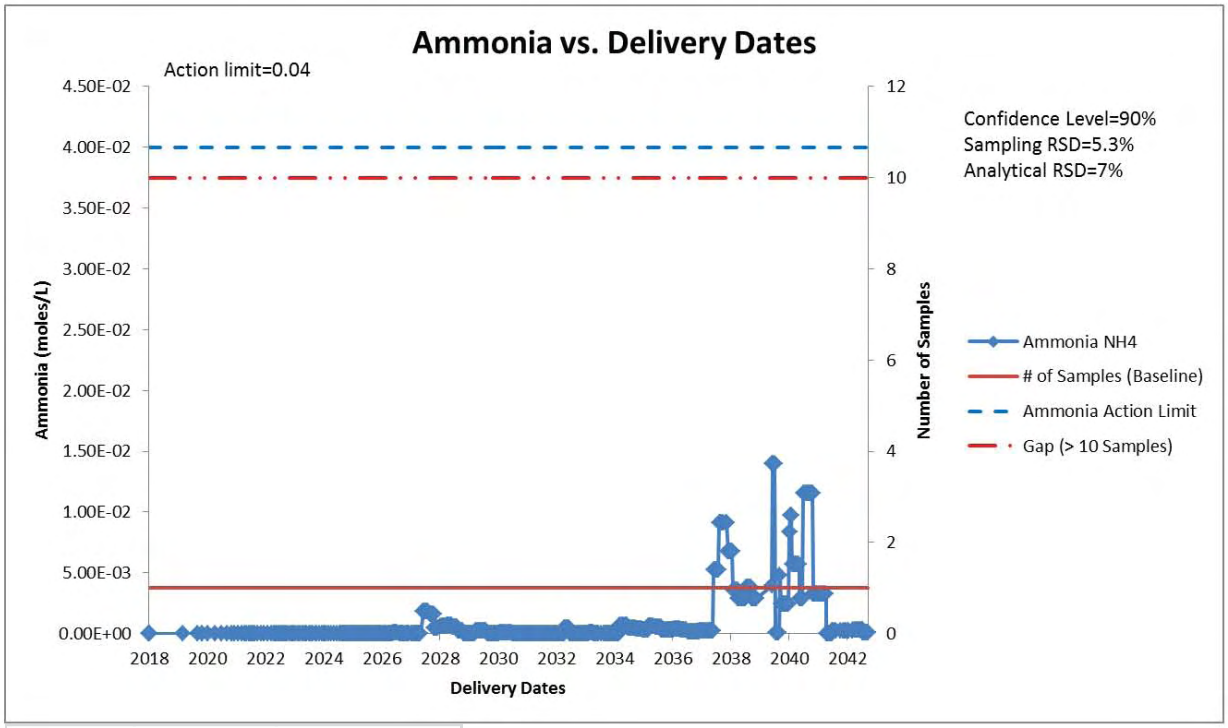
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
2.0%	**2**	**<< Base Case**
4.0%	2	
50.0%	154	

Figure 6-3. Total Organic Carbon (TOC).



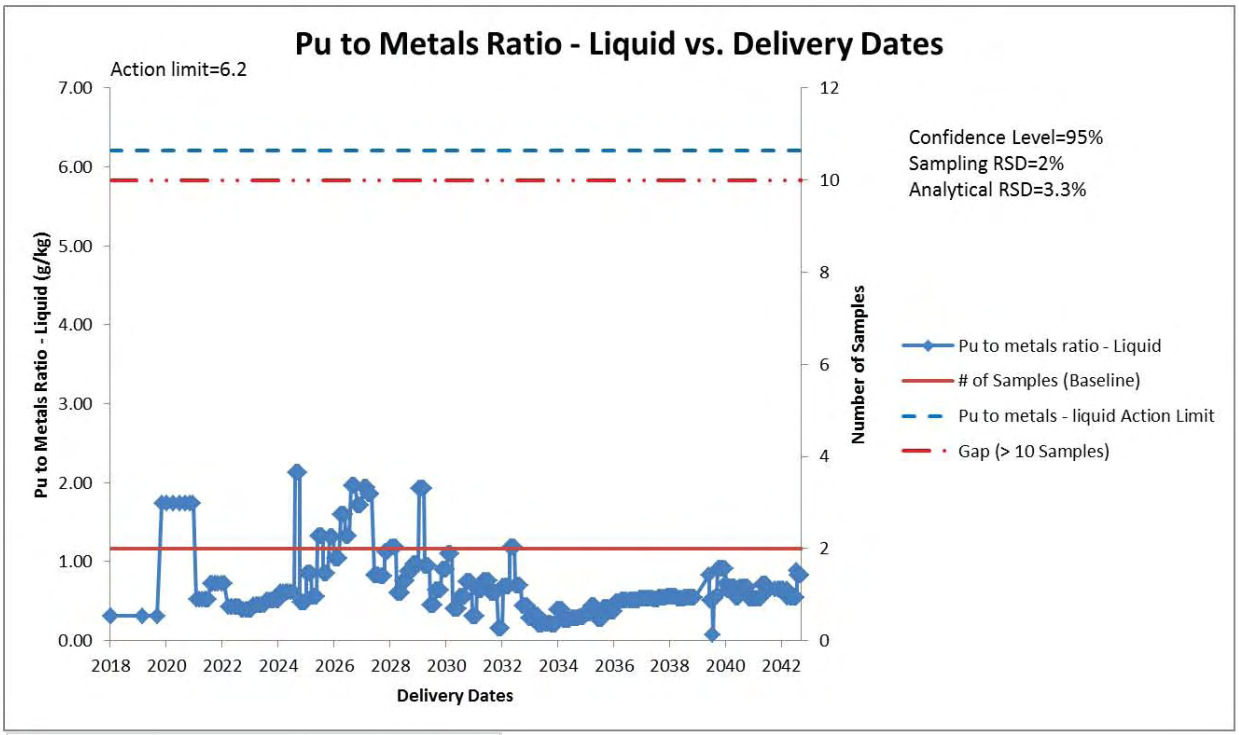
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	1	
13.2%	1	<< Base Case
50.0%	3	

Figure 6-4. Ammonia.



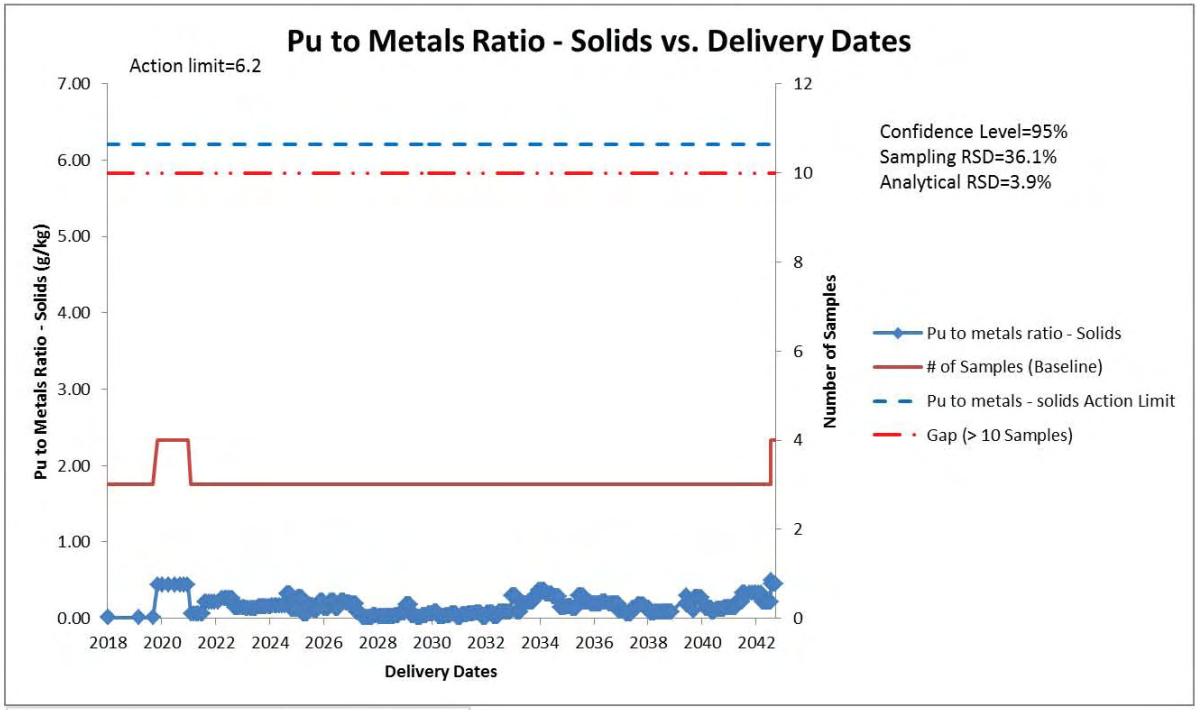
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	1	
5.3%	1	<< Base Case
50.0%	5	

Figure 6-5. Pu to Metals Ratio – Liquid.



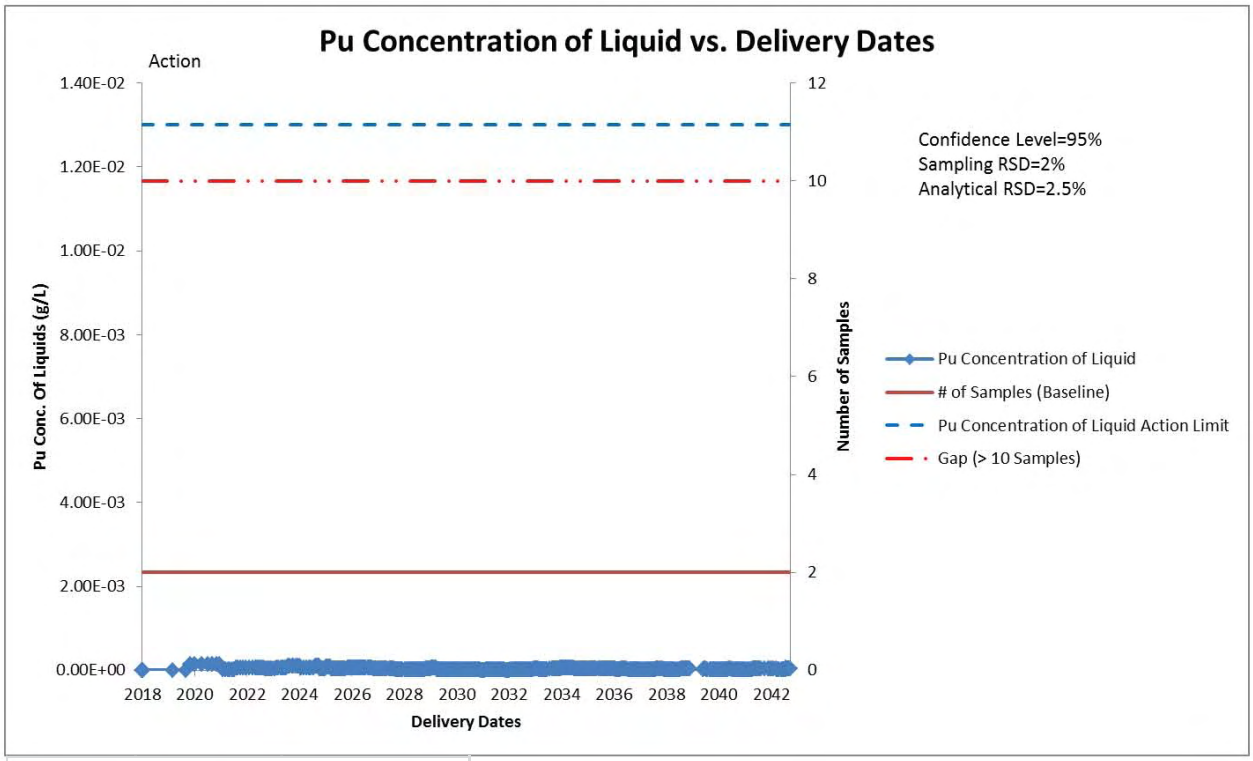
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
2.0%	2	<< Base Case
4.0%	2	
50.0%	8	

Figure 6-6. Pu to Metals Ratio – Solids.



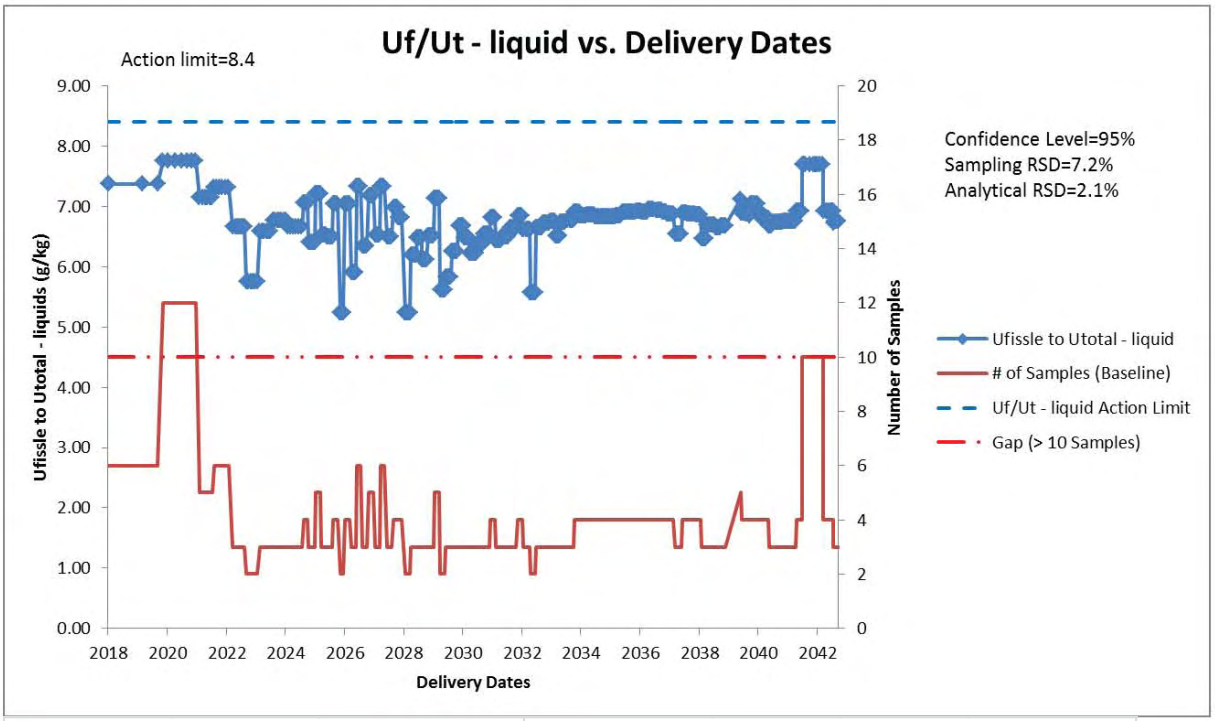
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	**2**	
36.1%	4	<< Base Case
50.0%	5	

Figure 6-7. Pu Concentration of Liquid.



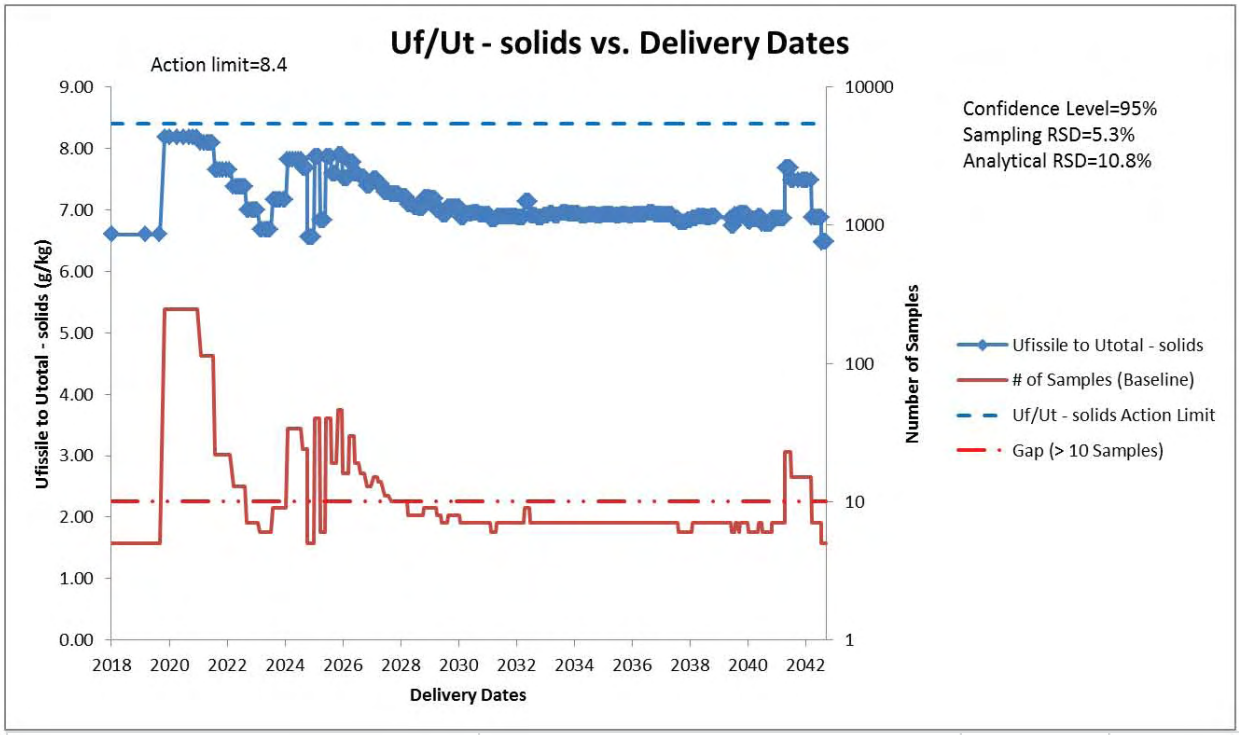
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
2.0%	2	<< Base Case
4.0%	2	
50.0%	5	

Figure 6-8. $U_{fissile}$ to U_{total} – Liquid.



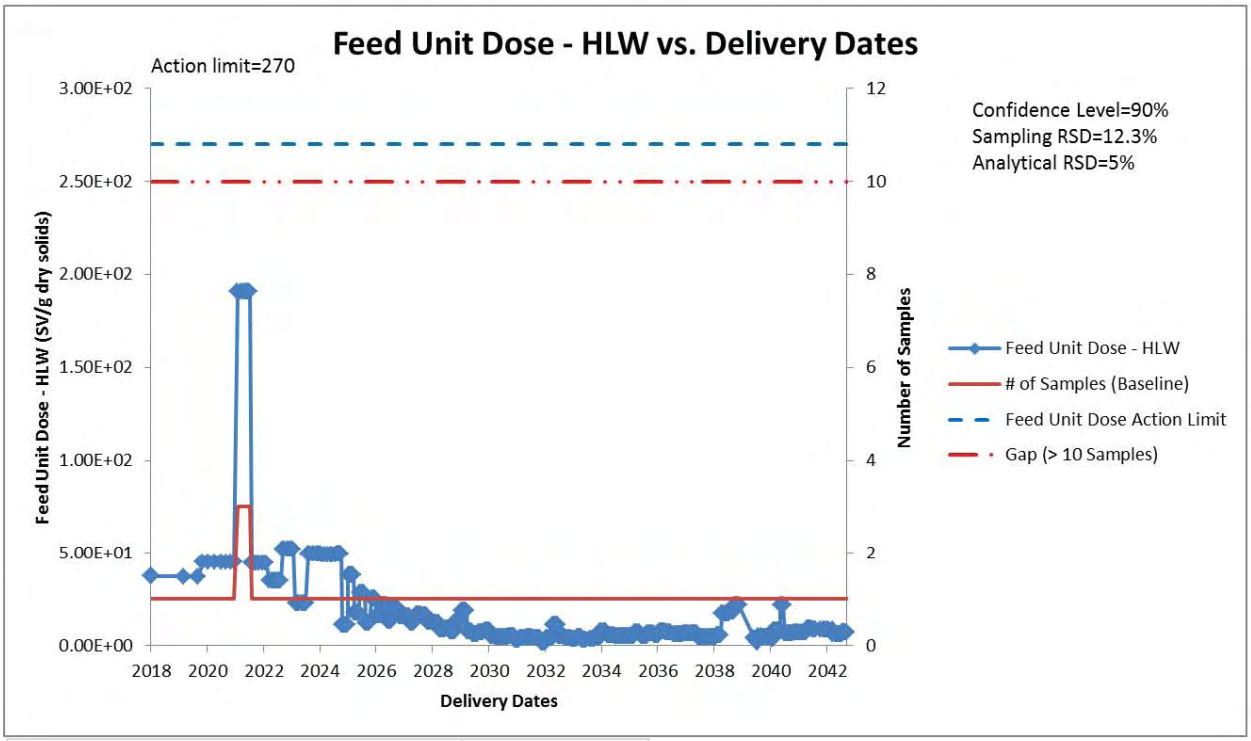
Sampling Sensitivity Analysis:			Confidence Level Sensitivity Analysis:		
Sampling	**Max. # of Samples**		**Confidence Level**	**Max. # of Samples**	
4.0%	6		90%	8	
7.2%	12		95%	12	<< Base Case
50.0%	458				

Figure 6-9. $U_{fissile}$ to U_{total} – Solids.



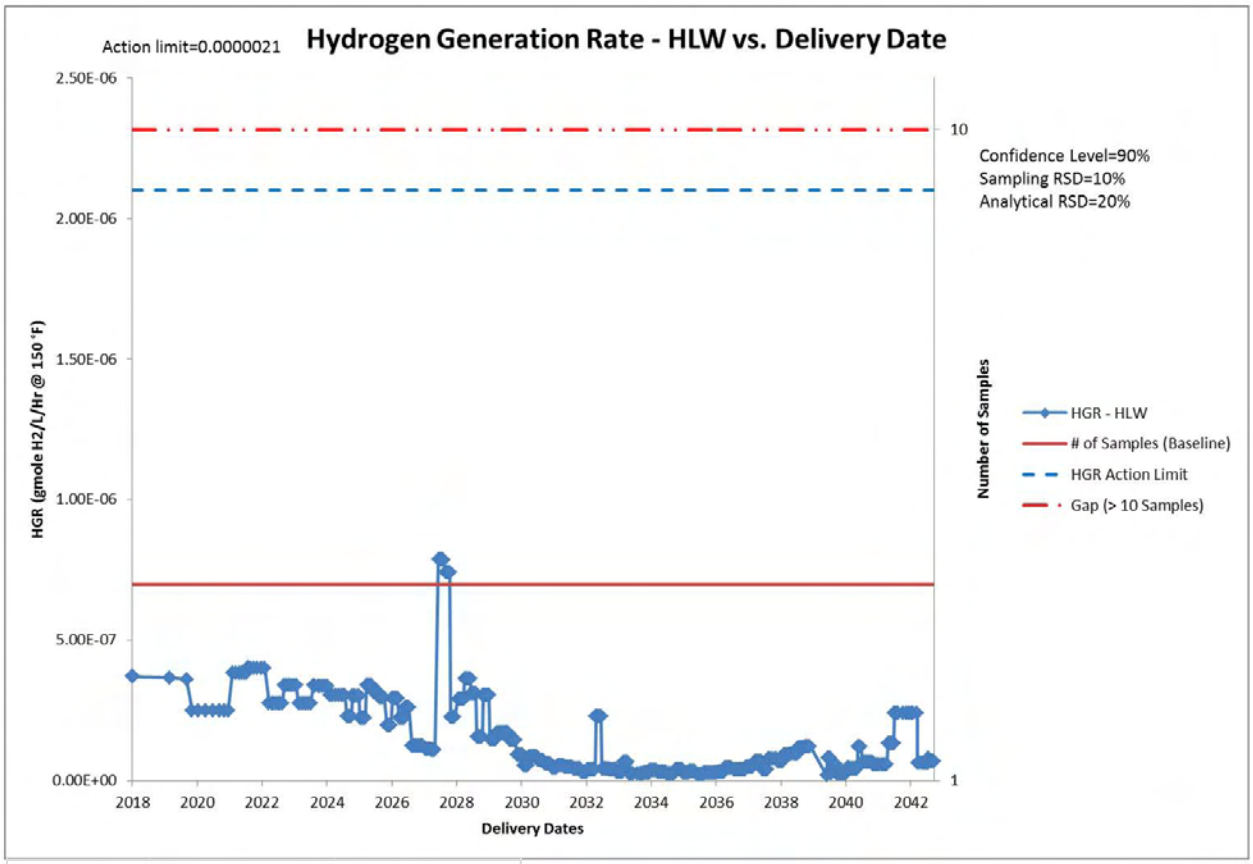
Sampling Sensitivity Analysis:		Confidence Level Sensitivity Analysis:		
Sampling	**Max. # of Samples**	**Confidence Level**	**Max. # of Samples**	
4.0%	227	90%	150	
5.3%	247	95%	247	<< Base Case
50.0%	4434			

Figure 6-10. Feed Unit Dose.



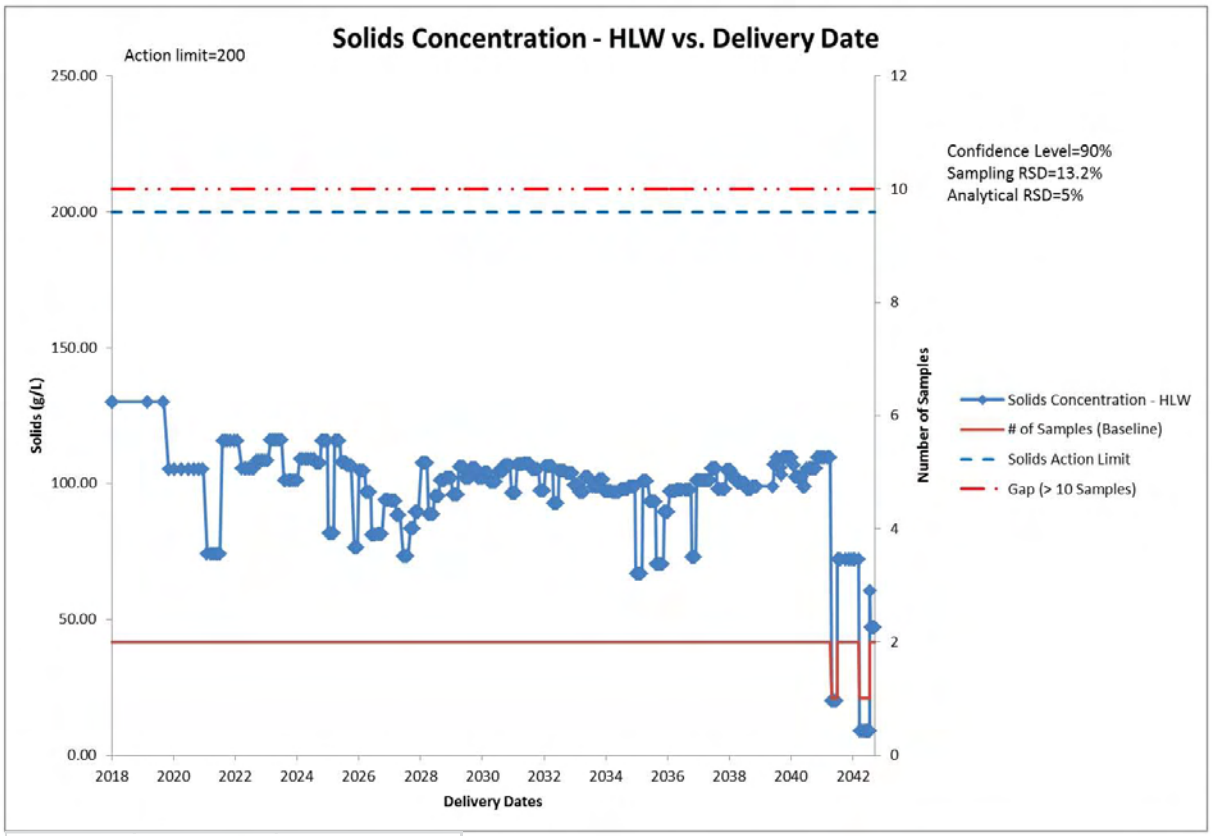
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
12.3%	3	<< Base Case
50.0%	21	

Figure 6-11. Hydrogen Generation Rate.



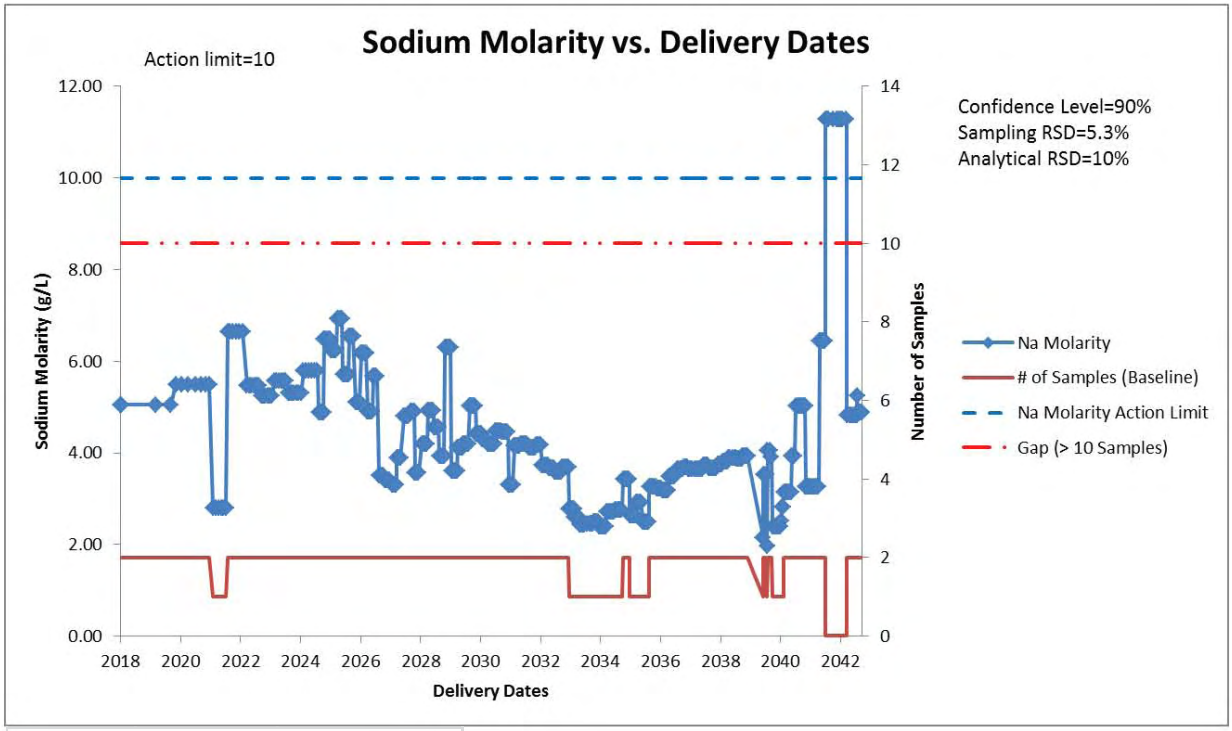
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
10.0%	2	<< Base Case
50.0%	6	

Figure 6-12. Solids Concentration.



Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
13.2%	2	<< Base Case
50.0%	15	

Figure 6-13. Sodium Molarity.



Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
5.3%	2	<< Base Case
50.0%	19	

6.2 HLW FEED SCREENING (NON-HTWOS) AND GAPS

Many of the physical properties on the list of WAC parameters (Table 3-1) and potential new nuclear safety parameters (Table 3-2) are not modeled in HTWOS. In lieu of using a compositional feed profile as a starting point, each of the parameters not modeled in HTWOS is discussed and potential gaps assessed in qualitative assumptions using available technical studies and current process information.

6.2.1 Abrasiveness

Gap: **Yes** – Based on a lack of proven analytical technique in a hot cell environment.

Abrasiveness is not currently screened as a waste acceptance parameter in the ICD-19 (24590-WTP-ICD-MG-01-019). However, this is related to a "known" gap in Tank Farm's ability to demonstrate compliance with particle hardness or size as reflected by ICD-19 Open Item #0015 (24590-WTP-ICD-MG-01-019, Appendix D) and, therefore, it is captured in this report for completeness and tracking purpose (see Appendix A).

The over-riding uncertainty driving this as a gap lies in analytical capability more so than sampling or the expected mean of the feed. If there is no reliable method to verify this parameter, then the ability to make the waste acceptance decision is in question.

A 20% RSD value was assigned qualitatively for the analytical capability (Table 4-3). This is essentially a "place holder" meant to flag this as an area of concern. There is no analytical procedure for this type of measurement in the 222-S Laboratory. This capability (or lack thereof) is also identified as a gap in SCT-M0SRV00028-00-009-01-00002, *SRNL Phase 1 Assessment of the WAC/DQO and Unit Operations for the WTP Waste Qualification Program*. A direct method of measuring abrasivity is under development by WTP and SRNL to implement a procedure based on ASTM G75-07[1] as modified for radioactive environment. This test method covers a laboratory procedure that can be used to develop data from which either the relative abrasivity of any slurry (Miller Number) or the response of different wearing materials to the abrasivity of different slurries (SAR Number). A Miller instrument could be put in a hot (shielded) cell. This parameter is flagged as a gap based on a current lack of analytical capability.

6.2.2 Critical Velocity

Gap: **Yes** – PulseEcho development and field application uncertainties.

Critical velocity (CV) is a term that describes the fluid transfer velocity below which pipeline solid particulate deposition occurs. It can be estimated using correlations such as Oroskar and

[1] ASTM G75-07, Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)

Turian or AD Thomas, but for HLW staged feed to WTP, critical velocity as a waste acceptance criterion will be measured (24590-WTP-RPT-MGT-11-014).

Based on the latest development effort by PNNL, the PulseEcho system provides accurate detection of solid settling for a 3", Schedule 40, transfer line (see Section 4.1.3.2). The current WFD configuration has the PulseEcho detector spool piece installed in the waste certification flow loop upstream of the Isolok™ Sampler. The PulseEcho system will detect solid settling during the sampling event for the pre-transfer sample, during which the transfer pump and the mixer pump(s) will be operated under conditions similar to the actual transfer to WTP (except that all flow is recirculated back into the feed tank).

CV applies to particle transport in liquid through a horizontal pipe. The WFD system's capability to transfer large-dense particulate was evaluated in RPP-RPT-51652. The evaluation identified limits of performance, including the mixer pumps and the vertical and horizontal legs of the transfer pipeline with respect to undissolved solids size and density. As summarized in Figure 4-6, the capability of the transfer system spans a wide range of particulate size and density, from large 9,525 µm 1.43 g/mL gibbsite agglomerate to postulated 100 µm 19 g/mL plutonium metal particle (RPP-RPT-51652).

Based on the preliminary testing that: a) PulseEcho type device can detect critical velocity within 0.3 ft/s; b) waste transfer system can deliver particulates that span a wide range of sizes and densities; and c) tendency for fast settling solids to be oversampled during the pre-transfer sampling event, that there is no gap expected in Tank Farm's capability to meet the CV waste acceptance criteria. However, a large part of this conclusion depends on how well the PulseEcho technology can be properly scaled for actual waste measurement and deployed in a field (vs. lab) application. For example, the accuracy of +/- 0.3 ft/s, validated through careful visual observations of solids settling, cannot be performed in a field application. A total instrument loop uncertainties calculation must be performed for the field as-installed configuration to ensure the accuracy/precision can be maintained. External background effects not easily replicated in a controlled test environment should also be considered (e.g., dirty pipe, electronic noise/interference, etc.). This capability must be demonstrated at the conclusion of ongoing development and design work to support closure of this gap in the final gap analysis. In addition, the sensitivity of this instrument to detect settling in a more dilute feed (i.e., < 2 wt% solids) with trace quantities of large, fast settling solids has not yet been demonstrated. Therefore, this parameter is flagged and tracked as a gap based on a need to validate PulseEcho's detection accuracy with a simulant more representative of actual waste (e.g., include a broader range of particle size and density) and a design configuration more prototypic of the field application.

6.2.3 HLW Feed Particle Size

Open Item: **Yes** – Based on the potential to transfer greater than 210 µm particles to WTP and unknown safety impact.

The current action limit for this parameter as defined in Table 3-2 is ≤ 210 µm. The range of particle size that can be transferred to WTP was evaluated in RPP-RPT-51652. As stated in

RPP-RPT-51652, what is of interest for particles that will be fed to WTP is the distribution of solid particle size, shape, and density in the waste slurry delivery batches. Because the plans for retrieval, mixing, and WFD of tank wastes to WTP are not complete, it is difficult to provide accurate, quantitative estimates of the distributions of particle size, shape, and density. However, expertise and experience provides for making some qualitative or semi-quantitative judgments.

It is believed that delivered particle size is limited by the transfer pump inlet screen (e.g., ⅜-inch or 9,525 μm) or transfer pump pipe openings and that typical particle shape is an agglomerate of roughly spherical shape (RPP-RPT-51652). Any rods or sharp edges might be broken and/or worn out as the solids are agitated during retrievals, transfers, and in preparation for feeding waste to WTP. Some break up of agglomerates might occur when slurry is cycled through the mixer pumps and transfer pumps, but these WFD operations by themselves are not likely to eliminate large agglomerates. Based on this assessment alone, the upper bound range of solid particles, including agglomerates that can be transferred to WTP exceeds the current 210 μm limit (Figure 4-6).

Analytical capability is not currently driving a gap for this parameter. The common approach to particle analysis is to determine large particles by sieving. The fines from the sieving analysis can be analyzed by laser diffraction. The 222-S Laboratory currently uses a Horiba Partica LA-950v2 as a primary instrument with an analytical range of 0.01 – 1,000 μm. Particle size can also be determined by automated imaging analysis using the SEM. This method allows the sorting of particles by chemical composition while determining the cross sectional area of each particle. The analytical range is about 0.5 – 3,000 μm.

Sampling capability is potentially driving a gap for this parameter. Based on Phase 1 remote sampler demonstration (Section 4.1.3.1), there is about a 10% bias (oversample) for the larger, dense solids [up to 128 μm stainless steel (SS)]. The bias from the sampler mounted in a vertical position represents an improvement over the same measurement with the sampler mounted in a horizontal position. The exact reason for the bias is being investigated in Phase 2 testing. This bias compounds the uncertainties from tank mixing and transfer relative to spatial and temporal fluctuations. The bias could also increase a pluggage potential at the sampler from larger particles. The inside diameter of the sampler needle assembly is about 0.135 inch (~3429 μm). Assuming the agglomerates retain the largest possible size (9,525 μm), they will likely bypass the sampler due to the physical constraint of the needle size (a source of "Extraction Error").

Until the impact of larger particles (up to 9,525 μm or 3/8 inch diameter) on the WTP design bases can be assessed for safety impacts, this parameter as screened is identified and tracked as a gap.

6.2.4 Average Particle Density of Pre-Leached Solids

Open Item: **Yes** – Based on the likelihood of HLW feed exceeding the average particle density limit and the misalignment between Tank Farm planning basis (i.e., HTWOS) and WTP design basis (i.e., BOD).

This parameter is referring to the average primary particle density (2.18 g/mL), not to be confused with slurry density. As discussed in Table A-2, this parameter is currently not fully covered by the CV parameter as described in the WTP Bases of Design (BOD), and therefore it is flagged for screening in this initial gap analysis. Average particle density is used in slurry transport related calculations in WTP.

Mineralogy and density data for primary particles are summarized in Table 4-4 in RPP-RPT-51652. Density values for the primary particles range from 1.8 g/mL (aluminum phosphates) to 19 g/mL (plutonium metal). A majority of the primary particles in the aluminum phases exceed the 2.18 g/mL limit (e.g., 2.4 g/mL for Gibbsite and 3.0 g/mL for Boehmite). Most of the primary particles identified in Table 4-4 in RPP-RPT-51652 exceed the 2.18 g/mL limit, with aluminum phase being the most frequently observed. However, there are many sources of uncertainties on this data as discussed in RPP-RPT-51652. The primary uncertainty is the lack of complete knowledge of the primary particles (minerals) that may appear in Hanford tank wastes. This lack of knowledge exists because there is limited mineralogy data for only 60 of 177 Single-Shell Tanks (SSTs) and DSTs. Uncertainties associated with sampling and analytical capabilities for this average density parameter are within the norm for undissolved solids in general (Table 4-2 and Table 4-3) and are not the main source of errors for this parameter.

Rather than a maximum density, this parameter is targeting the "average" density, which is dependent on the actual distribution of primary particles in the staged feed. Currently, there is insufficient data to track the distribution of primary particles/minerals in the HLW staged feed, but it has the potential for a given batch to exceed an average particle density of 2.18 g/mL. The current planning basis for all HLW feed campaigns in the HTWOS model uses a solids density of 3.0 g/mL. Lowering the density value in HTWOS could impact the overall mass balance.

Until the impact of exceeding this parameter on safe WTP processing is known, this parameter is being flagged as an open item for tracking purpose.

6.2.5 Pu Particle Size

Open Item: **Yes** – Based on trace quantity driving a high uncertainty in WFD's capability to detect its presence in the pre-transfer sample.

The current limit is To Be Determined (TBD) for this potential new nuclear safety parameter as defined in Table 3-2. It has been assessed with a high mixing and transfer uncertainties in Section 4.2.2 because of its settling characteristic and relative trace quantities expected in the staged feed (based on PuO_2 or as large, fast settling fissile). However, as shown in the feed screening process, the high uncertainties would not necessarily translate into a gap if the compositional mean is far below the action limit. As summarized in RPP-PLAN-53193, *One System Waste Feed Delivery Mixing and Sampling Program Solids Accumulation Test Plan*, the practical upper limit particle size for the PuO_2 and Pu metal in the transferable Hanford tank waste is 100 microns. The amount of PuO_2 and Pu metal in all of the tank waste is on the order of 10s of kilograms and is likely to be primarily PuO_2 because Pu metal fines are not thermodynamically stable in tank waste and may not have survived the extended storage time.

The sampling capability is not driving a gap for this parameter. Based on SSMD and Isolok™ demonstration completed to date, the dense particle, such as Pu oxide and metal, can be sufficiently mobilized and sampled. The analytical capability in terms of laboratory analysis is not driving a gap for this parameter. If sufficient PuO_2 is in the pre-transfer sample, then the standard laboratory technique (e.g., SEM) and procedures exist for its detection. Even with a high uncertainty (due to SEM's 2-D limitation), the expected mean should be below the action limit. However, the key for the analytical capability is the quantity of available PuO_2 in the pre-transfer sample.

The trace quantity of this constituent (in PuO_2 form) is driving a gap, rather than the sampling and analytical capabilities. Taking a deterministic approach, this report assumes that if sufficient quantities are available in the Tank Farm, then the total amount of Pu oxide and metal will eventually find its way to WTP. Assuming waste is homogenized and sampling is ideal (e.g., no EE/DE errors), even then the likelihood of capturing even a small fraction of these off-spec. solids in the current sample size (1 L bottle) is extremely remote. One can treat this as a FE problem (one of seven Gy's sampling errors) and try to quantify the sample size required; however, the common consensus is that it will be challenging to prove if these sparse particles are present in any given feed batches and to deduce any subsequent accumulation in HLP-22. This point was highlighted in a recent SSMD workshop (WRPS-1105293, *Small Scale Mixing Demonstration Optimization Workshop Meeting Minutes – Appendix M)*.

Until the full impact on Pu particle accumulation can be assessed, this parameter is flagged as an open item, not because of Tank Farm's sampling or analytical capabilities per se, but to highlight the inherent issue of meeting this potential new nuclear safety parameter due to the trace quantities of the source material (in PuO_2 form in particular).

6.2.6 HLW Slurry Rheology – Viscosity Consistency & Yield Stress

Gap: **No**.

This waste acceptance parameter targets the viscosity and yield stress of the staged HLW feed (<10 cP and <1 Pa respectively). The data gap on rheological properties of individual waste tank has been evaluated and documented in a number of technical reports, including RPP-RPT-51652 and the latest updates in RPP-52774, *Hanford Waste Rheology Reference Report*. However, there is little conclusive study on the effect of waste blending on rheology, which is applicable to the staged feed to WTP (vs. characterization of individual waste tank). A preliminary assessment of WFD operations effect on rheology was conducted in RPP-RPT-51652. It concluded that it is difficult or impossible to draw deterministic conclusions on the effect of tank waste blending, and that measurements on actual blended waste feed are likely needed. Therefore, rather than assessing gap relative to a mean value as compared to the action limit, this report focuses on the ability to sample and analyze this parameter.

Qualitatively, this parameter can be sampled and analyzed with reasonable accuracy (i.e., 10% and 5% RSD respectively). However, applying these uncertainties to the "predicted" range of viscosities and yield stress at 10% solids (RPP-RPT-51652, Table 6-4) would yield instances where the calculated number of samples is either below 10 or set at 0, because the feed exceeded

the action limit. By inspection there is only one batch that approaches the action limit for both yield stress and viscosity (T-111 2C Sludge @ 0.78 Pa and 6.7 cP). This implies that if the actual staged waste behaves as predicted, then the sampling and analysis should be able to verify waste acceptance within the maximum ten samples at 90% CL.

6.2.7 Upper Bound Settled Layer Shear Strength

Open Item: **No.**

This parameter targets the settled sludge layer shear strength as a function of time (< 200 Pa after 24 hours) in HLP-22. The latest data on settled sludge layer shear strength for actual waste testing (AZ-101, AY-102, etc.) is summarized in PNNL-20646, *Hanford Waste Physical and Rheological Properties: Data and Gaps*. However most of the shear strength data was collected for a DST with settling time that far exceeds the 24 hrs (most >100 days) of interest to WTP. One data point based on in-situ settling of AZ-101 waste is traceable to be the source of the 200 Pa action limit (PNNL-17707, *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels*, Table 2.1). However, a concern is raised in the same report indicating recent laboratory measurements on settled material from actual cladding waste composites showed unusually fast settling and high strengths, with settling occurring over a 3-hr period and the strength of the settled material ranging from 100 to 700 Pa and possibly higher. As acknowledged in the PNNL-20646 report, changes in shear strength in settled solids layers with an emphasis on shorter settling times and shear strength as a function of solids depth is not well quantified. It is being flagged as a data gap in the PNNL-20646 report.

The capability to sample and analyze this parameter is not driving a gap. Additional sample volume may be required to properly perform this analysis in the 222-S lab, but the capability exists to measure shear strength once the settling conditions can be defined and used to develop a procedure tailored to the vessel of concern. Transferring of slurry in general (i.e., not targeting any particular undissolved solids) should be within the capability of the waste feed transfer system (RPP-RPT-51652). Preliminary Isolok™ and SSMD results to date are not directly applicable to this type of static measurement of rheological property. The real risk is in complying with the acceptance limit given the limited understanding on the behavior of the actual waste (sludge) as staged and delivered to WTP, more so than Tank Farm's ability to sample, analyze, and transfer capabilities.

6.2.8 Separable Organics

Gap: **Yes –** Potential stratification of a separate organic layer that cannot be mixed or sampled using current method (i.e., waste feed certification flow loop).

This parameter targets separable organics, which is defined in ICD-19 (24590-WTP-ICD-MG-01-019) as *"Separable organics are organic compounds (carbon based molecules) that are present in the HLW or LAW waste streams transferred to the WTP and are present in concentrations beyond their saturation point for a particular batch inventory. The saturation point for a particular HLW or LAW waste is determined by blending the two wastes together at a*

minimum 8 wt% solids concentration and 10 molar sodium concentration then holding at 25 °C for 8 hrs. If the organic species separates as a solid or liquid under these conditions, the organic is deemed 'separable'." There is no quantified action limit other than "no" separable organics defined for this parameter.

The analytical capability is not driving a gap. The current approach is based on a visual inspection of the pre-transfer sample for any reflective/oily appearance on the liquid surface under the assumption that separable organics exist as a "visible" layer (24590-WTP-RPT-MGT-11-014).

There may be a potential gap for the sampling capability. Applying the same assumption that separable organics can be observed "visually" would mean some or all of the material is present as a layer at the liquid surface in the DST. If this hypothesis is true, then the pre-transfer sampling event may not be able to capture this stratified layer (i.e., the sampler take multiple grabs of HLW at the transfer pump discharge located near the bottom of the tank). A higher %RSD (15%) is assigned to the sampling uncertainties to highlight the potential for this stratified condition. Regardless of the expected mean concentration of separable organics, if it cannot be sampled, then it will not be verified as a part of waste acceptance. The likelihood of transferring stratified organic layer increases as the tank level decreases from subsequent batch transfer. Until the impact of transferring separable organics to WTP is determined and better quantified (i.e., the current action limit does not specify a deminimus concentration level in the feed), this parameter is flagged as a gap to highlight a condition that may require an alternate verification method.

6.2.9 Waste Feed Compatibility

Gap: **No.**

This parameter targets waste feed compatibility uses ASTM D5058-12 (supersedes D5058-90) method that looks for any temperature or rheology changes when mixing 10mL of staged feed with 10mL of residual feed in WTP receipt vessels. The rheology change (i.e., viscosity increase) is observed and not measured. ALARA concerns will most likely waive the viscosity observation from the ASTM method. The 222-S Laboratory currently does not have a procedure to perform the ASTM test; however, the technique (temperature change measurement) is reliable and accurate so analytical capability is not expected to drive a gap for this parameter. Sampling capability is also not expected to drive a gap since this is for the pre-transfer sample and not targeting any particular composition or physical properties. The overall sampling uncertainty is higher since there are two samples required for this one parameter (a staged feed sample from Tank Farm and a residual feed sample from WTP).

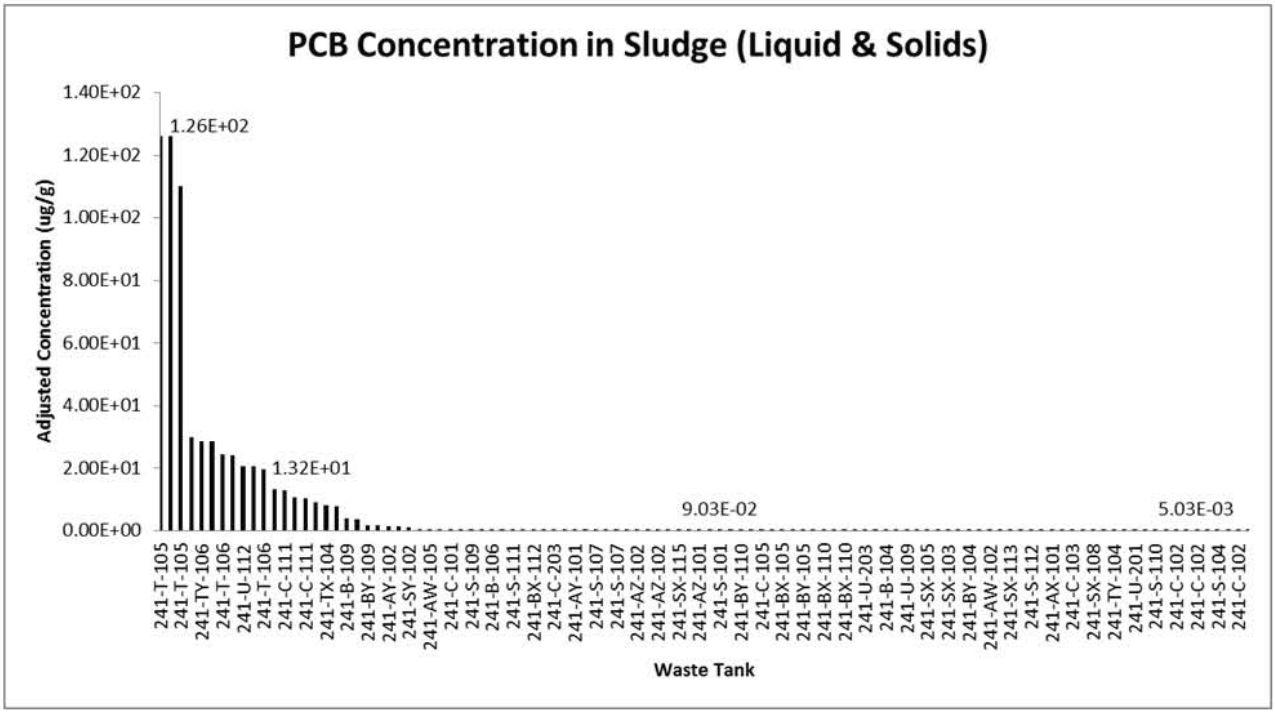
6.2.10 Polychlorinated biphenyl (PCB)

Gap: **Yes –** Based on high analytical %RSD.

This parameter targets total PCB (Aroclors) in the staged HLW feed. Total PCB is currently not tracked in HTWOS. The concentration is generally expected to be well below the limit of

< 50 ppm for most tanks. However, there are a few problem tanks that contain an elevated concentration of PCB in the sludge phase, as shown by querying the latest Best Basis Inventory (BBI) from the Tank Waste Information Network System (TWINS) database for PCB (Aroclors) concentrations that are based on actual sample results. Results are plotted in Figure 6-14, sorted by the highest adjusted concentration. The tank with the highest amount of PCB reported is T-105, a SST with an adjusted concentration of 126 µg/g. This is the only tank that exceeds the 50 ppm action limit.

Figure 6-14. BBI Inventory of Total PCB.[1]



The sampling capability is not driving a gap. PCB is expected to be mobilized and tracked along with the HLW sludge based on observed retrieval operations for C-103 and C-106. However, the analytical uncertainty is high (50 %RSD) for this type of organic analysis due to the relatively complex laboratory procedure requiring a series of distillation/extraction steps combined with a low target limit. In this case, the high analytical %RSD could be driving a gap since there is at least one tank with high PCB concentration and several other tanks with concentrations that approach the action limit. This parameter is flagged as a gap at this time to highlight a potential need to refine/improve the analytical capability to ensure WAC compliance.

6.2.11 Feed Temperature

Gap: **Yes** – Based on a current lack of waste tank temperature control strategy that addresses field measurement uncertainties.

[1] Tank Waste Information Network System, data compiled on 9/12/2012.

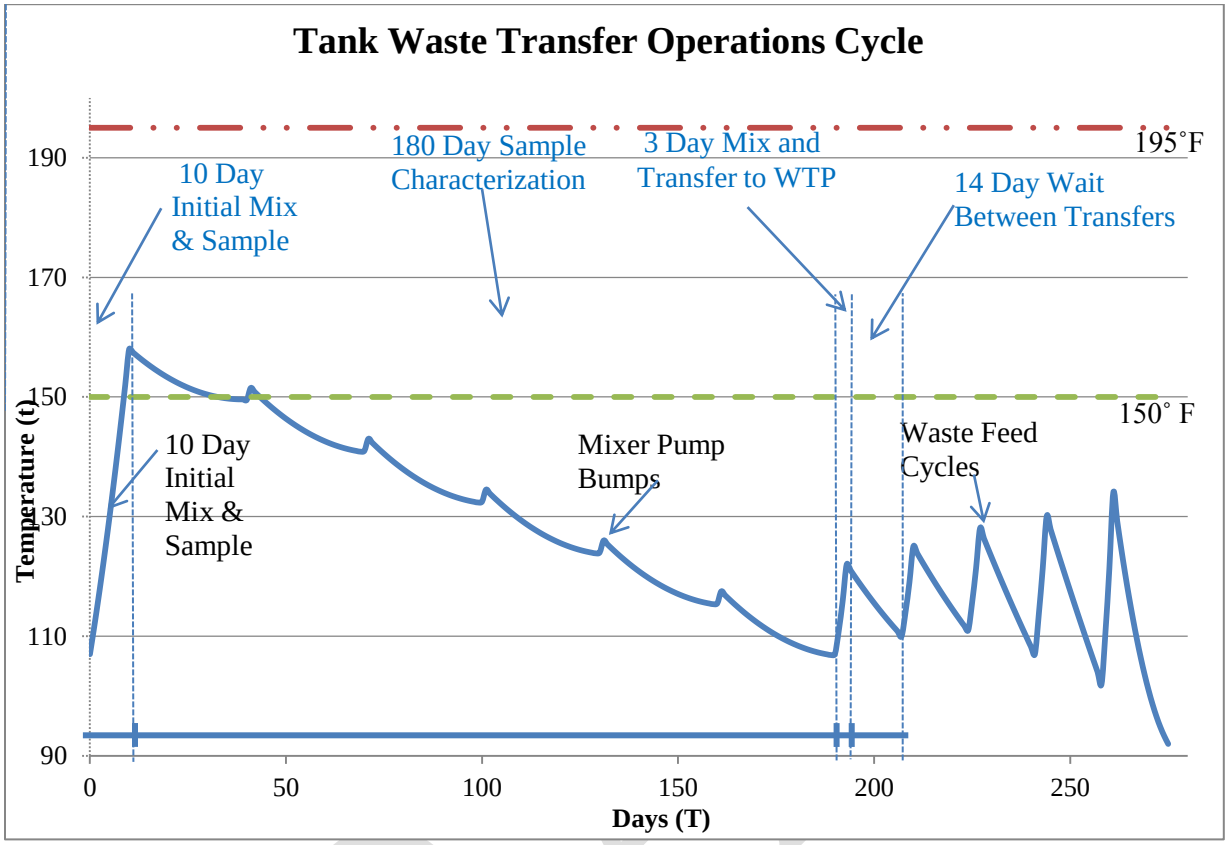
This parameter is a direct measurement (no sample) of tank waste temperature in real time. The action limit is defined as < 150 °F. This means the bulk temperature cannot exceed the limit at any time during transfers of waste to WTP.

There is no sampling requirement for this parameter, and therefore sampling capability is not driving a gap.

There may be a potential gap in the analytical (direct measurement) capability. The WFD design for tank temperature control is in-progress. The preliminary design for the AY-102 tank has a total of 98 temperature readings by thermocouple "trees" installed in different risers (RPP-RPT-53044, *Strategy and Technical Basis for Managing Flammable Gases During Tank 241-AY-102 Mixer Pump Testing*). Conceivably, the decision for starting or stopping a transfer will be based on more than one single temperature reading, perhaps an average or bulk temperatures. Temperature distribution in a DST is expected to vary with riser location, elevation, mixer pumps operation, ventilation rate, tank level changes, and other factors. While individual temperature measurement uncertainty is low, the propagation of multiple readings accounting for response time may be higher. The measurement uncertainties would be more significant as the actual tank temperature approaches the action limit. There are existing thermal hydraulic evaluations that predicted tank waste temperature during the transfer cycle (Figure 6-15). There may be times that the tank temperature will approach and at times exceed the limit (but not during transfer). There is a risk (albeit small) that the waste temperature can exceed the limit during a batch transfer to WTP. Therefore, the waste temperature control strategy must account for the total loop uncertainties and response time to protect the WAC limit during transfers to WTP. Alternative temperature measurement technologies should be evaluated as a contingency to ensure WAC compliance.

This parameter is flagged as a potential gap to track as a follow-up item to be addressed upon completion of the WFD design. Results are to be incorporated in the final gap analysis.

Figure 6-15. AY-102 Tank Waste Temperature Prediction.[1]



[1] Figure 3-9: Waste Transfer Operations Cycle for Temperature , RPP-RPT-49492, *702-AZ Thermal Hydraulic Evaluation Benchmark and Flammable Gas Analysis*

7.0 CONCLUSIONS

This report documents an initial gap analysis between Tank Farm sampling system capabilities, uncertainties, and waste projected to be transferred to WTP. An initial WAC with current parameters has been defined for HLW. Tank Farm's capability in meeting each WAC parameter was assessed in terms of sampling and analytical uncertainties. Staged feed delivery composition profile for HLW and available technical studies on expected waste transferred to WTP have been evaluated, incorporating the effects from sampling and analytical uncertainties.

Potential gaps and open items have been identified to highlight problem areas that can affect the waste acceptance decision. These gaps and open items are starting points for focusing development/ design/ characterization efforts on areas of high uncertainties. The list(s) of gaps and open items may grow or shrink as understanding on Tank Farm and WTP capabilities continues to mature. The goal is to track to closure efforts that will minimize, but not necessarily eliminate, uncertainties from the WTP waste acceptance decision.

Conclusions relative to specific WAC parameters and potential new nuclear safety parameters are summarized in Section 7.1. A path forward is suggested for handling the gaps and open items in Section 7.2.

7.1 CONCLUSIONS

As stated in DNFSB 2010-2 IP, Commitment 5.5.3.1 (Chu, 2011), this report includes the following deliverable elements and associated conclusions.

- *A definition of the initial WAC.*

The initial WAC as defined in the context of this initial gap analysis includes current HLW feed parameters from the ICD-19 including an abrasivity parameter as a proposed replacement for the nominal particle size and hardness parameters (see Table 3-1). The effort includes the evaluation of a list of potential new nuclear safety parameters from 2010-2 IP, Commitment 5.7.3.4 deliverable, 24590-WTP-RPT-ENS-11-021 (see Table 3-2).

- *A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems given the uncertainty associated with tank farm characterization data.*

The physical characteristics of waste (including feed temperature and compatibility) expected to be transferred to WTP have been evaluated using a combination of HTWOS feed screening and technical reports (mainly RPP-RPT-51652). Uncertainties have been assessed using a statistical hypothesis testing method consistent with the WAC DQO process (i.e., number of samples required to support the waste acceptance decision), and using a qualitative approach based on latest process understanding supplemented with available simulant testing data.

- *A determination of the capability of staging tank sampling system.*

The latest concept of the tank sampling system (Isolok™ remote sampler installed in a waste certification flow loop) was reviewed. The sampling system capability was broken down into elements of sampling errors traceable to aspects of Pierre Gy's sampling principle. Uncertainties in each element are quantified and propagated in terms of %RSD numbers to assess overall sampling capability.

- *Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC*

Analytical techniques applied to each WAC and potential new nuclear safety parameter were assessed. Analytical capability was broken down into direct measurement in the field (i.e., critical velocity and tank temperatures) and laboratory analysis. Uncertainties of analytical errors were assessed using %RSD and design information as applicable.

The majority of the WAC parameters did not trigger a gap. Of the thirteen (13) WAC parameters currently tracked in HTWOS, only one ($U_{fissile}/U_{total}$ – solids) is driving a gap based on the number of required samples greater than 10. The sensitivity results confirms that $U_{fissile}$ to U_{total} – solids is the only parameter driving the maximum number of required sample, and that improvement in the sampling uncertainties or reducing the Confidence Level from 95% to 90%, alone would not be sufficient in mitigating the gap.

In summary, there are seven (7) gaps identified between Tank Farm's sampling and/or analytical capability in meeting some of the initial WAC parameters. The seven identified gaps as listed by the affected WAC parameters are (see Section 6.0 for details):

- Critical velocity – PulseEcho development and field application uncertainties.
- Separable organics – Potential stratification of a separate organic layer that cannot be mixed or sampled using current method (i.e., waste feed certification flow loop).
- PCB – High analytical %RSD.
- $U_{fissile}$ to U_{total} ratio – Feed concentration close to the action limit driving a high number of required pre-transfer samples greater than ten (10) for some feed batches given the current feed strategy in System Plan 6.
- Hydrogen Generation Rate (HGR) – Lack of established hot cell procedures to measure generation rate compounded by high uncertainties in analytical technique (static vs. flow through).
- Feed temperature – Design is not final for this direct field measurement, and there is no defined process control strategy. Uncertainties of the final design (thermocouple "tree") may be high considering the transfer temperature could approach and may exceed action limit.
- Abrasivity – Lack of established hot cell procedures to measure abrasiveness of primary particles or agglomerates.

There are also three (3) open items identified between Tank Farm's sampling and/or analytical capability in meeting some of the potential new nuclear safety parameters listed in 24590-WTP-RPT-ENS-11-021. These are binned separately from the gaps because the affected parameters are not part of the initial WAC. The three open items as listed by the affected parameters are (see Section 6.0 for details):

- Pu particle size – Trace quantity (PuO_2 in particular) drives a high uncertainty in Tank Farm's capability to detect its presence, even assuming perfect tank mixing and sampling.
- Average particle density of pre-leached solids – Likelihood of HLW feed exceeding the average particle density limit and the misalignment between Tank Farm planning basis (HTWOS) and WTP design basis (BOD).
- HLW feed particle size – Maximum size of particles that can be physically transferred to WTP (up to 9,525 μm) may exceed the design bases maximum. Large particles may also be bypassed (not sampled) due to size exceeding the sample port (needle) opening.

The three Open Items associated with the new potential nuclear safety parameters are forward looking and should be validated first through the scheduled ICD-19 update effort.

7.2 PATH FORWARD

The role of this initial gap analysis is focused on the identification of gaps rather than mitigation. A separate mechanism is required to track and measure progress made to resolve the gaps. An actively managed database, such as the WTP PIER (24590-WTP-PIER-MGT-12-TBD), can be used to address these gaps as a collective technical issue to be resolved as an integral part of the ICD-19 update process. The PIER will drive the review of these gaps by the ICD-19 Team in the next review cycle in 2013. The ICD-19 Team may update the ICD-19 to include these gaps as open items or issue as appropriate. These Open Items and Issue and associated mitigations will then be tracked to closure by the One System team in a way that is consistent with the Interface Management Plan (24590-WTP-PL-MG-01-001, *Interface Management Plan).* Mitigations for these gaps and open items may include updates to test requirements and inputs to equipment design. Final disposition of gaps and open items will be updated and documented in a Final Gap Analysis report in accordance with the DNFSB 2010-2 IP schedule (Commitment 5.5.3.9).

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APPENDIX A. EVALUATION OF INITIAL WAC AND POTENTIAL NEW NUCLEAR SAFETY PARAMETERS

Table A-1. Initial WAC Parameters for HLW Feed.

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W1	Solids Concentration	≤ 200 g/L	Solids measured after holding the Tank Farm sample at 25°C for 8 hours. Basis of Design (Section 6.1.1) states that HLW feed will be between 3.8wt%-16wt% solids. This is assumed to be based on LAW limits (<3.8wt% solids) and estimated weight percent of 200 g/L solids in a 10M Na liquid. Solids concentration in WTP receipt vessel (HLP-22) will be controlled to meet more restrictive limitations (see Parameter N9 in Table A-2).	Y	Retained
W2	Viscosity (delivered feed)	<1 Pa (yield stress) <10 cP (consistency [plastic] viscosity)	HLP-22 vessel is a Newtonian vessel; therefore the yield stress cannot exceed 1Pa.	Y	Retained
W3	Slurry pH	≥ 12	Value in WAC-DQO (24590-WTP-RPT-MGT-11-014) listed at >7, but will be changed to reflected the more limiting value of ≥ 12 in the next revision.	Y	Retained
W4	Bulk Density of Slurry	< 1.5 kg/L	Bulk density of the as-delivered slurry.	Y	Retained
W5	Critical Velocity	≤ 4 ft/s	Based on a 3” transfer line and applicable to as-delivered HLW feed only.	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W6	Ammonia Concentration	< 0.04M	Value is under further consideration. An action in the WAC-DQO (24590-WTP-RPT-MGT-11-014) is to define the concentration limit as being free ammonia or dissolved ammonium.	Y	Retained
W7	Separable Organics	No Visible Layer[1]	Separable organics are not specifically addressed in the safety basis. Therefore, the limit is no separable organics in the feed. This analysis will be performed by visual observation of the Tank Farm sample.	Y	Retained
W8	Polychlorinated Biphenyls (PCBs)	< 50 ppm	Based on regulatory compliance.	Y	Retained
W9	HLW Feed Unit Dose	<2.9E5 Sv/L	Footnotes in Table 8 of ICD-19 state that this value is based on wet centrifuged solids and is derived from the HNF-IP-1266 value for Tank Farms controls. The value is converted to Sv/g value (270 Sv/g) by WTP assuming 66% solids fraction (volume) and 1.63 g/mL density for the wet centrifuged solids. Since the converted value is what is used by the WTP and since the values are essentially equivalent, the converted value (270 Sv/g) will be used in the initial gap analysis.	Y	Retained (see Discussion)
W10	Pu to Metals Loading Ratio	<6.20 g/kg	Definition of Pu and "metals" provided in Section 8.1 of the CSER (24590-WTP-CSER-ENS-08-0001). Applies to both the solid and the liquid phases.	Y	Retained
W11	U Fissile to U Total	<8.4 g/kg	Definition of U fissile and total provided in Section 8.1 of the CSER (24590-WTP-CSER-ENS-08-0001). Applies to both the solid and the liquid phases.	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W12	Pu Concentration of Liquids	<0.013g/L	Definition of Pu provided in Section 8.1 of the CSER (24590-WTP-CSER-ENS-08-0001).	Y	Retained
W13	Total Radioactivity in Material Fed to WTP per Year from External Sources	1.1E8 Ci/year	This parameter is included in Table 8 of ICD-19 (24590-WTP-ICD-MG-01-019). Assumed to be a maximum value.	N	Limit is a yearly limit and is not based on an individual source or sample.
W14	Hydrogen Generation Rate	2.1 E-06 gmole H_2/L/hr @ 150 ˚F	Value based on HLP-22 receiving feed at the bounding limits (10M Na and 200g/L solids). This does not account for the change to the acceptable concentrations in HLP-VSL-00022 due to mixing limitations (7M and 10wt% solids – see Parameters N9 and N10 in Table A-2). Assumed to be a maximum value.	Y	Retained
W15	Temperature	< 150˚F	Temperature is utilized in the HGR calculation (24590-WTP-M4C-V11T-00011). Note that the temperature determination is not sample based and will need to be monitored during any HLW feed transfer to the WTP. Note that the BNI reference in the ICD is superseded (by 24590-PTF-M4C-V11T-00015). 24590-PTF-M4C-V11T-00015 provides an evaluation that assesses if 150˚F is a reasonable temperature limit for HLW feed. However, the evaluation is based on TWINS data and does not account for retrieval operations except to say that the temperature should be lower than the TWINS temperature. With two 300-HP mixer pumps running, this may not be true.	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W16	Environmental Permit Limits (such as the Regulatory Data Quality Objectives (RDQO) report constituents and negotiated concentration limits)	N/A	The compositional analysis of the waste feed will be required as a waste acceptance requirement, but the RDQO (24590-WTP-RPT-MGT-04-001) and the IHLW Waste Form Compliance Plan (24590-HLW-PL-RT-07-0001) do not stipulate specific values for waste acceptance. However, they do list constituents of concern requiring analyses.	N[2]	WAC components are specified individually. No upper limit is prescribed for the remainder of the components.
W17	Specification 7 List of Constituents and Concentrations	Specification 7	These parameters include the liquid composition limits provided in Tables TS-7.1 and TS-7.2 of Specification 7 as well as the sodium molarity limits in the table in Section 7.2.2.1. Sodium limit in included separately in Parameter W21. Note that the bulk of components from these tables are listed in Table 4-2 of the WAC-DQO (24590-WTP-RPT-MGT-11-014) and are not considered "Action Limits" at this time. The compositional analysis of the waste feed will be required as a waste acceptance requirement, but the values do not stipulate waste acceptance criteria unless they are listed individually in ICD-19. Following the completion of the WTP testing, the WTP WAC will be updated as necessary (2010-2 Commitment 5.5.3.3) and will be used as input to the final gap analysis (2010-2 Commitment 5.5.3.9). Commitment 5.5.3.3 will establish any new WTP WAC parameters based on testing (such as LSIT) and ongoing process evaluations (such as erosion/corrosion). This may result in additional Specification 7 constituents having true concentration limits.	N[2]	WAC components are specified individually. No upper limit is prescribed for the remainder of the components.

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W18	Specification 8 List of Constituents and Concentrations	Specification 8	These parameters include the solid composition limits Tables TS-8.1, TS-8.2, and TS-8.3 in Specification 8. Table TS-8.4 in Specification 8 identifies a number of other components important to HLW glass production, but these values are not specification limits as per the WTP Contract. Note that the bulk of components from these tables are listed in Table 4-2 of the WAC-DQO (24590-WTP-RPT-MGT-11-014) and are not considered "Action Limits" at this time. The compositional analysis of the waste feed will be required as a waste acceptance requirement, but the values do not stipulate waste acceptance criteria unless they are listed individually in ICD-19. Following the completion of the WTP testing, the WTP WAC will be updated as necessary (2010-2 Commitment 5.5.3.3) and will be used as input to the final gap analysis (2010-2 Commitment 5.5.3.9). Commitment 5.5.3.3 will establish any new WTP WAC parameters based on testing (such as LSIT) and ongoing process evaluations (such as erosion/corrosion). This may result in additional Specification 8 constituents having true concentration limits.	N[2]	WAC components are specified individually. No upper limit is prescribed for the remainder of the components.

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W19	Mean Size Particle	≤ 11 µm	The 11µm mean particle size value, in conjunction with the particle hardness of 4.4 Mohs [Parameter W20], is used as the erosion design basis as per the *WTP Waste Particle Size and Hardness Characterization* report (24590-WTP-RPT-M-05-001). ICD-19 provides no additional definition of a particle size distribution. The WAC-DQO (24590-WTP-RPT-MGT-11-014) does not include mean particle size as a parameter and Open Item #15 in Appendix D of ICD-19 states that this value is not likely to be measured directly and will likely be replaced. Abrasivitiy is included in Table 4-2 of the WAC DQO as a potential replacement.	N	Abrasivitiy is included in Table 4-2 of the WAC-DQO as a potential replacement and the Abrasivity parameter is included in this table as Parameter A1.
W20	Arithmetic Average Particle Hardness	≤ 4.4 Mohs	The 11µm mean particle size value [Parameter W19], in conjunction with the particle hardness of 4.4 Mohs, is used as the erosion design basis as per the *WTP Waste Particle Size and Hardness Characterization* report (24590-WTP-RPT-M-05-001). The WAC-DQO (24590-WTP-RPT-MGT-11-014) does not include mean particle size as a parameter and Open Item #15 in Appendix D of ICD-19 states that this value is not likely to be measured directly and will likely be replaced. Abrasivitiy is included in Table 4-2 of the WAC DQO as a potential replacement.	N	Abrasivitiy is included in Table 4-2 of the WAC-DQO as a potential replacement and the Abrasivity parameter is included in this table as Parameter A1.
W21	Transfer System Design	90-140 gpm 400 psi 200 ˚F 500-550 ft Head	Equipment and transfer system design parameters are from ICD-19 Table 5. These are physical design limits and are not feed acceptance criteria.	N	Physical design criteria - not HLW feed specific WAC

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W22	Sodium Concentration	0.1 to 10 M	Sodium molarity as specified by the WTP Contract (Specification 7) and therefore carried as a WAC parameter. This parameter is not directly included in the tables in ICD-19. However, it is included by reference by Section 2.3.1 of ICD-19.	Y	Retained
W23	Total Organic Carbon (TOC)	< 10wt%	WTP Permit (WA7890008967) requirement. This parameter is not directly included in the tables in ICD-19. However, it is included by reference by Section 2.3.1 of ICD-19.	Y	Retained
W24	Waste Feed Compatibility	Δ of +/- 20 ˚C	Waste feed compatibility uses ASTM D5050-90 method that looks for any temperature or rheology changes when mixing 10mL of staged feed with 10mL of residual feed in WTP receipt vessels. The rheology change is observed and not measured. WTP Permit (WA7890008967) requirement. This parameter is not directly included in the tables in ICD-19. However, it is included by reference by Section 2.3.1 of ICD-19.	Y	Retained
A1	Abrasivity	TBD	HLP-VSL-00022 is to be designed to last 40 years. The vessel is mixed using high velocity jets and the vessel is located in a “black” cell (a cell in the facility that is inaccessible and therefore no maintenance can be performed on the vessel). Because of this, vessel erosion is a key concern to completing the WTP mission. ICD-19 (24590-WTP-ICD-MG-01-019) includes a value for average (arithmetic) particle hardness (≤ 4.4 Mohs - parameter W20). The WAC DQO (24590-WTP-RPT-MGT-11-014) does not include particle hardness as a parameter and Open Item #15 in Appendix D of ICD-19 states that this value is likely to be replaced. Abrasivitiy is included in Table 4-2 of the WAC DQO, but no limit is provided. Abrasivity is not included	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
			directly in ICD-19. The 11µm d_{50} particle size value [W19] in conjunction with the particle hardness of 4.4 Mohs [W20], is used as the erosion design basis as per the *WTP Waste Particle Size and Hardness Characterization* report (24590-WTP-RPT-M-05-001). The final decision on abrasivity (what it is and how it is measured) may ultimately require a limitation on the d_{50} particle size. This is not included in the potential particle size parameter [N15] and may impact the description of Parameter N15 if a d_{50} particle size is ultimately specified. The WTP needs to determine if particle hardness or abrasivity is a waste acceptance parameter, how the acceptance value will be set, and how it will be determined. In addition, the impact of vessel erosion extends beyond HLP-22 and may be impacted by process operations (solids concentration, washing, leaching).		

[1]A more detailed discussion on "separable organics" and "no visible layer" is provided following Table A-1.
[2]While these sources do not have WAC limits, the components included in the RDQO and Contract Specification 7 and 8 will be analyzed for using the same rigor and requirements included in the WAC DQO in terms of quality control, detection limits, analytical method guidelines, and data reporting as the parameters with limits.

Separable organics (Parameter W7) - Specification 8 of the WTP Contract states that "The HLW feed provided will not contain a visible separate organic layer." Therefore, the presence of separable organics is determined by visual observation. Appendix C of ICD-19 provides this definition of separable organics:

> *Separable organics are organic compounds (carbon based molecules) that are present in the HLW or LAW waste streams transferred to the WTP and are present in*

Separable organics are further defined in ICD-19 as:

> *...organic species that separates as a solid or liquid...*

Footnote #1 for Table 8 in ICD-19 states that:

> *The Contractor* [BNI] *shall propose a deminimus concentration level for separable organics that could be sent to the WTP without adversely affecting the WTP*

Standard 2, subpart (a)(3)(viii) of the WTP Contract states that:

> *The Contractor shall evaluate the effects of trace quantities (~25 ppm) of separable organics (tributyl phosphate and normal paraffin hydrocarbon) in the tank waste liquid feed to the WTP and the fate of the separable organics within the system. Each potentially affected unit operation (including ion exchange elution and evaporation) shall be examined for process, safety, and permitting implications. Based upon the results of these tests, the Contractor shall propose a deminimus concentration level for separable organics that could be sent to the WTP without adversely affecting the WTP*

This work is tied to Contract Deliverable 2.11, which, according to Table C.5-1.1 of the WTP Contract, has a due date of 12/31/2012. The deminimus WAC parameter value for separable organics will be defined following the completion of Contract Deliverable 2.11.

In addition, it should be noted that Table 3-1 lists the parameters and the values, but it does not necessarily dictate under what conditions an individual parameter is to be evaluated. For example, a temperature is not given for viscosity [W2] nor are any handling/preparation requirements (settling, sonication, etc.) provided. Further definition of these analysis conditions will need to be determined by the WTP prior to finalizing the WAC (2010-2 Commitment 5.5.3.3).

Table A-2. Evaluation for Potential New Parameters for HLW Feed Acceptance.

#	Parameter	In Table 3-1?	Discussion	New?	Value
N1	LAW feed slurry pH must be ≥ 12	No	Specific to LAW feed	No	NA
N2	LAW solids concentration must be ~3.8 wr% based on 5 M sodium supernate.	No	Specific to LAW feed	No	NA
N3	LAW slurry bulk density must be < 1.46 kg/L	No	Specific to LAW feed	No	NA
N4	LAW feed temperature must be ≥59 ˚F	No	Specific to LAW feed	No	NA
N5	LAW feed temperature must be < 120 ˚F	No	Specific to LAW feed	No	NA
N6	LAW allowable viscosity range of 1.1 cP to 26 cP	No	Specific to LAW feed	No	NA
N7	LAW feed hydrogen generation rate ≤ 3.7E-07 gmole H_2/L/Hr @ 120 ˚F	No	Specific to LAW feed	No	NA
N8	HLW transfer solids concentration must be ≤ 200 g/L	Yes	As per ICD-19, the solids concentration is determined after holding the sample at 25 ˚C for 8 hours. Included in Table 3-1 as Parameter W1.	No	NA
N9	HLW solids concentration of 10 grams unwashed solids/liter to a maximum of 107 g/L at 0.1 M Na to 144 g/L at 1M Na	No	The solids concentration is based on the resulting slurry in HLP-22 (the values are essentially based with a limitation of 10wt% solids). The delivered HLW feed slurry may exceed these values within the 200 g/L limit in ICD-19. The volume transferred from TFs will need to be controlled and pre-staging operations performed by WTP in order to not exceed these values.	No	NA
N10	HLW sodium content must be 0.1 to 7 M	No	The upper sodium concentration limit is based on the resulting slurry in HLP-22. The delivered HLW feed slurry may exceed this value within the 10M limit in ICD-19 The volume transferred from TFs will need to be controlled and pre-staging operations performed by WTP in order to not exceed the upper value. The lower limit of 0.1M is as per the WTP Contract, but is not considered a nuclear safety parameter.	No	NA

#	Parameter	In Table 3-1?	Discussion	New?	Value
N11	HLW slurry pH must be ~ 12	Yes	Included in Table 3-1 as Parameter W3.	No	NA
N12	HLW slurry density must be between 1 and 1.7 g/ml	Yes	Upper density value is based on density AT THE PUMP SUCTION. This value is based on the mixing capabilities in HLP-22 and with 10wt% solids in 7M sodium liquid. This is not the limit for the delivered HLW feed or a limit to the average density in the vessel. Since the wt% solids and molarity in HLP-22 is limited by the feed delivery conditions, this parameter is also limited by the feed delivery conditions. Included in Table 3-1 as Parameter	No	NA
N13	HLW feed temperature must be ≥59 ˚F	No	The lower temperature is stated in the vessel mixing assessment for HLP-22 (24590-WTP-RPT-ENG-08-021-08) and is based on the lower temperature of the black cells from the BOD. This lower temperature is not used directly in the mixing assessment for HLP-22 and is therefore not considered a potential new nuclear safety parameter.	No	NA
N14	HLW feed temperature must be < 150 ˚F	Yes	Included in Table 3-1 as Parameter W15.	No	NA
N15	HLW feed particle size ≤ 700µm	No	Table 8 of ICD-19 lists the mean particle size as ≤ 11µm with no particle size distribution provided. Section 6 of the BOD states that the expected maximum particle size for Tank Farm transfers is 700µm. The listed particle size range is based on RPP-9805 – the low end is the Mean 1% [0.7µm] and the high end is the 95/95 TL 99% (and is as stated in the BOD). However, the range is described as not being a limitation to feed delivery in the BOD. The feed delivery limitation is to be based on a critical velocity of ≤ 4ft/s in a 3" pipe as per the BOD (Parameter W5 in Table 3-1). Section 6 of the BOD also states that "The RPP-9805; 95% UL particle size distribution shall be used as the WTP computational design basis for pumping and line sizing of the as-received HLW feed solids." Appendix C of ICD-19 states that the particle size to be used in WTP critical velocity calculations is the d_{95} particle size. From RPP-9805, this size is 210µm. This particle, in conjunction with the bulk/average solids density [Parameter N20], and a 30% design margin, is used to calculate the required critical velocity of the WTP transfer pump. The ≤ 4 ft/s critical velocity value [Parameter W5] is not used directly in WTP transfer or mixing calculations, but is expected to protect the BOD assumptions. The 210µm size is set as the limit.	Yes	≤ 210µm

#	Parameter	In Table 3-1?	Discussion	New?	Value
N16	HL W feed hydrogen generation rate ≤ 2.1 E-06 gmole H_2/L/Hr @ 150 ˚F	Yes	Included in Table 3-1as Parameter W14.	No	NA
N17	Ammonia < 0.04M	Yes	Included in Table 3-1 as Parameter W6.	No	NA
N18	An average upper bound settled layer shear strength of up to 200 Pa can be expected within 24 hours.	No	Information taken from *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels* (PNNL-17707) and expected to bound the waste fed to the WTP. The vessel mixing assessment for HLP-22 (24590-WTP-RPT-ENG-08-021-08) states that ITS mixing will be employed within the 24 hours to mitigate the development of higher shear strengths. Mixing tests for HLP-22 using a 200 Pa settled simulant were deemed to be successful with no testing of higher shear strength simulants. Thus the <200P within 24 hours is set as the limit.	Yes	<200 Pa within 24 hours

#	Parameter	In Table 3-1?	Discussion	New?	Value
N19	The bounding PuO_2 particle is 10μm spherical equivalent diameter in HLP-22	No	A 10μm size for Pu oxide particles was used in determining the mixing capability of the HLP-22 vessel (24590-WTP-RPT-ENG-08-021-08). The size was based upon an early review of waste sample results that noted that Pu oxide particles sizes were bounded by a 10μm spherical equivalent diameter particle (CCN 211814). Since then, a more recent documentation states that there may be Pu material that exceeds the 10μm size (RPP-RPT-51652). This document also notes that Pu metal, which has a higher density than the oxide form of Pu, may also be present in the tank wastes. Mixing tests for HLP-22 using a surrogate 10μm PuO_2 particle were deemed to be successful with no testing of larger particles with similar densities. However, with more recent information suggesting a larger size may be present, the successfulness of the mixing tests comes into question. This evaluation is further complicated by the fact that the successful mixing of any PuO_2 particle has not been implemented as a WTP criticality control parameter in the CSER. The *2012 Plan for Updating the CSER* (24590-WTP-PL-ENS-11-0005) states for Item #3 in Table 5-1 that "*If this* [Research and Technology] *characterization concludes that the Pu particle sizes are large enough to be a concern, the issue may be raised with the ICD-19 interface committee. A potential outcome is that criticality controls on Pu particle size or Pu form could be needed*." This work has not been completed at this time. Therefore it has not been determined if any PuO_2 particle size is a required nuclear safety control parameter. Because of this, the control value for a Pu particle (as per the reference, a control on Pu form may also be implemented so PuO_2 not specified) will be listed as "TBD" at this time until it has been fully evaluated and addressed as outlined in 24590-WTP-PL-ENS-11-0005.	Yes	TBD

#	Parameter	In Table 3-1?	Discussion	New?	Value
N20	Average particle density of 2.9 for pre-leached solids and 3.8 for post-leached solids.	No	The 2.9kg/L value is based on mass average maximum density for the solid particles and is assumed to be applied to the staged HLW feed in Tank Farms (i.e, untreated solids). As per the BOD, this value is used for mixing and is described as not being a limitation to feed delivery. The particle density limitation is based on a critical velocity of 4ft/s in a 3" pipe (BOD Section 6.2.1). The BOD includes another particle density value of 2.18kg/L. This value is based on a mass average density for the solid particles (not a maximum) and is assumed to be applied to the staged HLW feed in Tank Farms (i.e., untreated solids). This value is used in the WTP for pump and line and is described as not being a limitation to feed delivery. As with the 2.9kg/L value, the overall particle density limitation is based on a critical velocity of 4ft/s in a 3" pipe (BOD Section 6.2.1). The value for the post-leached solids (3.8 kg/L) is not applicable to feed receipt in HLP-22 and is therefore not addressed. The BOD text clearly states that the feed specification criterion is critical velocity only (Parameter W5). However, the particles sizes and densities in the BOD are used as input to the WTP design and may be considered to be de facto requirements. Without a PSD, it cannot be determined by calculation if the average particle density results in a critical velocity that exceeds 4 ft/s. Therefore, all three parameters (Parameter W5, N15, and N20) are retained. For this parameter, the lesser value of 2.18kg/L is specified. This gives a considerable degree of margin above the bulk average solids density of 2.9 kg/L.	Yes	$\leq$ 2.18kg/L
N21	Thermal conductivity of the sludge is >0.6 W/m K	No	The derivation of this parameter is included in Appendix L of 24590-WTP-M4C-V11T-00011. This value is used to estimate the temperature rise in a settled solids layer. Derivation shows that this value is conservative and sufficiently bounding and the calculation states that the assumption for this value does not require verification.	No	NA
N22	The specific heat capacity of the sludge is > 2.4 kJ/kg °C	No	The derivation of this parameter is included in Appendix L of 24590-WTP-M4C-V11T-00011. This value is used to estimate the temperature rise in a settled solids layer. Derivation shows that this value is conservative and sufficiently bounding and the calculation states that the assumption for this value does not require verification.	No	NA

#	Parameter	In Table 3-1?	Discussion	New?	Value
N23	The settled non-convective layer in a vessel is 10% by volume	No	The WTP Design Criteria Database (DCD) lists this parameter as being an assumption to accident analysis reports 24590-PTF-Z0C-10-00002 and 24590-HLW-Z0C-W14T-00021 (note that the accident analysis report specific to HLW Vitrification (24590-HLW-Z0C-W14T-00021) does not apply to Pretreatment vessel HLP-VSL-00022). The analysis performed in 24590-PTF-Z0C-10-00002 has been replaced by a steam bump analysis performed in 24590-WTP-Z0C-W14T-00015. In the more recent document, the non-convective layer assumption is replaced by a settled sludge layer assumption of 70 wt% maximum (Assumption 6 in the reference). Based on discussions with experts in this field, this assumption is conservative and defendable. Also, from Table A-2 in 24590-WTP-Z0C-W14T-00015, the safety evaluation results in over 100 hours of margin between the time to the lower flammability limit for hydrogen and the time to boil. Therefore this parameter is deemed sufficiently bounding and is not considered a potential parameter for waste acceptance.	No	NA
N23	The heat capacity for the non-convective layer is 2,850 J/(kg-K)	No	The WTP DCD lists parameter as being an assumption to accident analysis reports 24590-PTF-Z0C-10-00002 and 24590-HLW-Z0C-W14T-00021 (note that the accident analysis report specific to HLW Vitrification (24590-HLW-Z0C-W14T-00021) does not apply to Pretreatment vessel HLP-VSL-00022). The analysis performed in 24590-PTF-Z0C-10-00002 has been replaced by a steam bump analysis performed in 24590-WTP-Z0C-W14T-00015. In the more recent document, the heat capacity assumption has been expanded to include both the liquid and solid portion of the slurry (Assumption 3 in the reference). However, the more recent calculation states that the dose consequences for this analysis are not affected by this assumption and therefore the heat capacity values are not considered potential parameters for waste acceptance.	No	NA

In addition, it should be noted that Table 3-2 lists the potential parameters and the values, but it does not necessarily dictate under what conditions an individual parameter is to be evaluated. For example, a temperature is not given for particle size and solids density nor is any handling/preparation requirement (holding time, sonication, etc.) provided. Further definition of these analysis conditions will need to be determined by the WTP prior to finalizing the WAC (2010-2 Commitment 5.5.3.3).

APPENDIX B. NUMBER OF SAMPLES EQUATIONS

Source of sample number formula: EPA/240/B-06/001 Guidance on Systematic Planning Using the Data Quality Objectives Process, Equation A-8.

Definitions:

$\alpha = Probability\ of\ Type\ I\ error = NORMSDIST(z_\alpha)$

$z_\alpha = NORMSINV(\alpha)$

$\beta = Probability\ of\ Type\ II\ error$

$n = number\ of\ samples$

$\sigma = Standard\ Deviation$

$AL = Action\ Limit$

$\mu = Mean$

$U = Fixed\ constant; the\ probability\ of\ accepting\ H_0\ when\ \mu = U\ is\ \beta$

$d = U - AL$

For pH:

$$H_0: \mu \leq AL$$

$$H_A: \mu > AL$$

$$n = \frac{(z_{1-\alpha} + z_{1-\beta})^2 \sigma^2}{d^2} + \frac{1}{2} z_{1-\alpha}^2$$

$$z_{1-\beta} = \sqrt{n - \frac{1}{2} z_{1-\alpha}^2} \frac{d^2}{\sigma^2} - z_{1-\alpha}$$

$$z_{1-\beta} = \sqrt{n - \frac{1}{2}\ NORMSINV\ 1-\alpha\ ^2\ \frac{U-AL}{\sigma}} - NORMSINV(1-\alpha)$$

For all other constituents:

$$H_0: \mu \geq AL$$

$$H_A: \mu < AL$$

Rejection region is all in "other" (lower) tail; replace 1-β with β, 1-α with α to reverse tails. Alternatively, deriving sample number formula for this case produces equivalent result.

$$n = \frac{(z_\alpha + z_\beta)^2 \sigma^2}{d^2} + \frac{1}{2} z_\alpha^2 = \frac{(z_{1-\alpha} + z_{1-\beta})^2 \sigma^2}{d^2} + \frac{1}{2} z_{1-\alpha}^2$$

$$z_\beta = \sqrt{n - \frac{1}{2} z_\alpha^2} \frac{d^2}{\sigma^2} - z_\alpha$$

$$z_\beta = \sqrt{n - \frac{1}{2} z_{1-\alpha}^2} \frac{U - AL}{\sigma} + z_{1-\alpha}$$

$$z_\beta = \sqrt{n - \frac{1}{2} NORMSINV(1-\alpha)^2} \frac{U - AL}{\sigma} + NORMSINV(1-\alpha)$$

APPENDIX C. SAMPLING ERRORS

This section briefly describes the Pierre Gy's seven basic sampling errors and how aspects of each are applicable to the physical collection of HLW staged waste samples. The impact from each type of error has been qualitatively assessed and factored in the estimate of sampling %RSDs. Since the DST sampling system design and testing is preliminary and evolving, the initial gap analysis helps to spot potential areas of concern such that mitigation can be incorporated in the design or tracked as an open item through final resolution. Table C-1 below itemized the types of basic errors and discuss in qualitative terms how they relates to the four types of sampling errors as defined for the HLW feed (i.e., mixing, transfer, Isolok™, and handling).

Table C-1. Sampling Errors.

Gy's Seven Basic Errors[1]	Description	Relates to
Fundamental Error (FE)	The constitution (or makeup) of the material causes it to be heterogeneous. Gy calls this the constitution heterogeneity (CH). It represents the differences between particles or molecules. The CH of solids is influenced by particle size, shape, density, chemical composition, and other physical properties.	This type of inherent error cannot be minimized as applied to DST sampling of wet slurry. Fundamental error exists even if the tank is perfectly mixed (homogenized) and the sampler system operates perfectly.
Grouping and Segregation Error (GSE)	Error due to the differences from one group of particles to another or from one part of the lot to another. Gy calls this the distribution heterogeneity (DH). It is caused by the combination of the CH, the spatial distribution of the constituents, and the shape of the lot. The sampling error resulting from grouping and segregation can be reduced by taking many small increments and compositing them to form the sample.	Short-range GSE is mostly covered by the analytical RSD for the pre-transfer sample. Long-range (large scale) GSE as applied to the DST sampling is covered as an integral part of the non-periodic and periodic heterogeneity of the DST.

[1] Patricia L. Smith, *A Primer for Sampling Solids, Liquids, and Gases – Based on the Seven Sampling Errors of Pierre Gy.*

Gy's Seven Basic Errors[1]	Description	Relates to
Long-range Non-periodic Heterogeneity Error	Processes often change over time, sometimes in short intervals and sometimes over a longer time span. This variation can be broken down roughly into random, nonrandom, and cyclic variation. Nonrandom variation is due to shifts or trends in the process. Because of this long-range fluctuation error, samples taken at different times will give different results.	**Transfer RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is transferred in subsequent batches. It is a term used to assess batch-to-batch variability over time. Variability of tank composition with decreasing tank level introduces a non-periodic heterogeneity error. Less batch-to-batch variability, the lower the transfer RSD value.
Long-range Periodic Heterogeneity Error	This periodic fluctuation error affects the variation in the process. The cause of the process cycle is not a sampling error, but a sampling error may be generated by variations in the cycle period, amplitude, and sampling frequency.	**Mixing RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the tank at the time of sampling event. It is a term used to assess mixing performance. Rotation of mixer nozzles during a batch transfer introduces periodic heterogeneity error. The cyclic operation of the Isolok™ sampler helps minimize the effect from this type of error by compositing multiple samples (~5 mL) to make up the total sample volume.
Delimitation Error (DE)	Error occurs when not every part of the lot has an equal chance of being in the sample, in other words, when the defined sample boundary is not correct.	**Isolok™ Sampler RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the recirculation flow loop. It is a term used to assess sampler design. Physical configuration of the sampler design introduces delimitation (i.e., does not take full cross-section sample of the pipe) error. The larger the cross-section to full sample flow, the lower the sampler RSD value.
Extraction Error (EE)	Error occurs if the sample that has been identified cannot be obtained. In other words, a delimitation error may be avoided by defining a correct boundary for the sample, but if it cannot actually be recovered, then an extraction error is incurred.	**Isolok™ Sampler RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the recirculation flow loop. It is a term used to assess sampler design. Physical configuration of the sampler design (e.g., size and shape of the sample annulus) introduces extraction error.

Gy's Seven Basic Errors[1]	Description	Relates to
Preparation Error (PE)	This error results from the incorrect preservation, handling, mixing, grinding, and subsampling that can result in loss, contamination, or altering of the sample such that it no longer is an accurate representation of the material being sampled.	**Sample Handling RSD**. An estimate of uncertainties from physical preparation and handling of the pre-transfer sample from the time of sampling event to laboratory analysis. It is a term used to assess the integrity of the sample. Physical handling of the sample introduces preparation error (e.g., poor vapor seal, leaks, etc.). Better preservation of the sample, the lower the sample handling RSD value.

WRPS-1205239

Enclosure 3

LSIMS ERT DOCUMENT REVIEW RECORD		
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Comment			Comments and Recommendations:	Resolution:
Number	Reviewer	Type*		
1	LMP	E	Do you really need Section 5? It doesn't factor into the Deliverable Compliance Matrix (Table 1-1). Information in Section 5 doesn't seem to be used later in the document. And the treatment of both mixing (5.1.2) and sampling (5.1.3) at WTP is completely superficial. (To say that "…solids stratification…may present a challenge for analysis of the sample and vessel contents" is a huge understatement. Remember Subrecommendation 4?) I'd avoid stirring the pot and just leave this section out.	Accept. Removed Section 5.1 on HLP-22 system description but retained the Laboratory capability section as background to support using 222-S procedures and control charts for the analytical RSDs.
2	LMP	**M**	**Section 2.2.1, Assumptions: There are a number of assumptions buried in the System Plan. I suggest this section also identify "the system plan rev 6" as an assumption.**	Accept. Added system plan rev 6 as a separate assumption in Section 2.2.1.
3	LMP	E	Table 3-2: Why is there no discussion of the basis for the slurry density limit in this table?	Limit is quoted from ICD-19 direct and no special interpretation/clarification required. Will state as such so there is not a "blank" space.
4	LMP	**M**	**I'm not sure the data in Figure 4-1 support the statement at the bottom of page 36 that the batches were "characterized by more consistency for the more populous, slower settling components…". Seems like ZrO_2 and Bi_2O_3 (<u>not</u> $Al(OH)_3$) have the smallest RSDs. Doesn't that make them the most consistent?**	Accept. Reworded to be consistent with the figure.
5	LMP	O/E	Page 38, Figure 4-1: Not a lot of rhyme and reason in evidence here. Legend not explained. Why is high velocity resulting in more inconsistency from batch to batch?	Replaced Figure 4-1 with one showing the component RSD vs. mixer jet velocity relationship showing the lowering of RSD in general with higher velocity.
6	LMP	O/E	The poor repeatability between the two VS4 curves in Figure 4-3 is telling. Note that you've changed the color scheme in the key compared to Figure 4-1, which is confusing.	Noted. Deleted Figure 4-3. Results not used to develop sampling uncertainties.

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			You may want to be more explicit in the figure that the bias being reported is a RMSD across several batches.	
7	LMP	E	Page 43: Is statement 3 ("within 10%") fair given that there's a bias of 20% or more? Is Figure 4-7 just the error bars on Figure 4-6? Don't connect data within these figures with lines, especially if the components are simply in alphabetical order.	Deleted Figure 4-6 (% relative difference results not used in the propagating sampling uncertainties).
8	LMP	O	Isn't the statement on page 46 that "It is likely that the range of yield stress and viscosity for all feed batches will be greater than the data ranges presented in this document" a problem?	Yes, but it also has a disclaimer about "no good predictive tool exists for estimating yield stress and viscosity in mixed/blended wastes".
9	LMP	**M**	**Figure 4-8 is inadequately described, i.e., is this just representing the capability of the transfer lines themselves or the pump suction, etc.?**	Added description for Figure 4-8 from the source report.
10	LMP	E	Red solid line on Figure 6-11 appears to be incorrect unless the number of samples is always 2 no matter what.	Number of samples is 2 given the analytical and sampling RSD at the specified Confidence Level (90%). See sensitivity results. This one is not sensitive to sampling/analytical uncertainties due to concentrations far below the action limit.
11	LMP	E	I find the discussion of average bulk solids density somewhat confusing. "A majority of the primary particles in the aluminum phases exceed the 2.18 g/mL limit," but it isn't clear what fraction of the bulk solids are aluminum phases or how big those majorities are.	Noted. Distribution of densities of primary particles is not given in the source report, other than a histogram of frequency of observation. Added a few qualifier to the discussion but also highlighted an alignment issue between the Tank Farm planning basis (HTWOS) and the WTP design basis (i.e., 3 g/mL vs 2.18 g/mL).
12	EKH	O/E	Cover page, title: This title should be a little more specific; the document seems to address only the HLW requirements and if so, it should be stated here.	Clarification of scope relative to focus on HLW is stated in Section 1.2. Title is consistent with 2010-2 Commitment 5.5.3.1 title.
13	EKH	O/E	Page i, Executive Summary, third paragraph: Make it clear here that this gap analysis is only looking at the HLW requirements.	Accept. Scope statement added to the second paragraph.
15	EKH	O/E	Page i, Executive Summary, fourth paragraph, fourth sentence, "… tank	Tank mixing's contribution to the overall sampling uncertainty is covered in

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			mixing…": Not sure this was covered as an uncertainty in this document, but it should be.	Section 4, Table 4-3, Sampling %RSD. Covered, agree that pH and other liquid aspects are within an RSD of 1%. As for the density/solids(includes all types)/rheology, not sure they can all be 5%. For example (this was discussed in a previous ERT review), lets say the measured density of slurry is 1.4, supernate is 1.3, and solids is 2.3, then the mass fraction of solids is 0.164. For an RSD of 5% on the density (1.45 or 1.33), the mass fraction of solids is 0.266 and 0.052 respectively, much greater than an RSD of 5%. If you have confidence that wt% is the limiting factor, then you are correct, but its error would be much less. These properties are connected. *Added an enabling assumption that the RSDs are evaluated independently for each constituents, eventhough some of the physical properties are related.*
15	EKH	O/E	Page ii, Table ES1, Row 9, Solids density: Have not seen evidence that this value can be calculated or measured to that stated in Table 4-4.	Noted.
16	EKH	E	Page iii, Conclusions, a), second paragraph, third sentence: Should read "… sufficient data to determine **the** ability to meet …".	Accept.

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17	EKH	**M**	**Page iii, Conclusions, b), first sentence: Ok, if the sampling system has a bias (this could be due to the process as well), how do you determine the error and is this bias consistent for all feed types? See page 20 of "A primer for Sampling Solids, Liquids and Gases …". This question goes back to how the tank is mixed, transferred and sampled. Bias make it very hard to properly use a sampling system that cannot be defensible.**	Noted. The sampler bias refers to results from preliminary testing, where we know the "true" value and the mean. Don't know beyond what was tested, but doubtful the bias will be consistent for "all" feed types. We will never know the process bias during actual operation because we won't know the "true" value of constituents in the tank and this "true" value will likely change from batch to batch as suggested. Added a section (4.2.1.2) to discuss general mixing and sampling biases and why they are not applied in the gap analysis (i.e., subtracted or added to the action limit). I'm not sure you can neglect bias if it is a factor that can impact compliance (or process) issues and these bias can be either systematic and/or the waste itself. As stated in the "Gy" primer, if there is bias, you can't calculate a statistical error (hence how do you proceed)!! I believe this is an WTP issue, given that they essentially have the same types of systematic (and waste) issues. *Neglect only in terms of the gap analysis for the waste acceptance decision process for actual operations since biases are a moving target with the "true". Added additional verbiage to Section 4.2.1.2 to acknowledge the existence of inherent biases and future plan to incorporate such biases in the design/waste acceptance decision.* Agree. An ideal sampling system should not exhibit any biases (no such system exists) *agree*. Biases observed from preliminary testing may be due in large part by improper sampler configuration (it could also be other systemic issues, such as the mixing). *agree* More testing is underway to understand the bias issue.

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18	EKH	**M**	**Page iii, Conclusions, b), fourth paragraph, first sentence: A: I would also include "average solids density," unless you can show me otherwise. The procedure you provided does not show how this value is obtained using physical measurements and/or equations that use the physical measurements to obtain the "average density of the solids".** **B: Also consider settled solids shear strength after 24 hours. Not sure if sufficient thought has been placed on settling up this measurement using the provided instruments in remote operations.**	A: The average solids density is determined by determination of the density of the solid in the sample. The solids are separated from the sample and then suspended in a fluid of known density (such as hexane). PLEASE PROVIDE ME THE PROCEDURE (OR WORK INSTRUCTIONS) and method used to determine the errors assocatied with using such measurements. I'm also very hard presssued that such volatile organic materials are permitted in the cells, given that they can't even use rheology oil standards! *The 2%RSD is achievable based on 222-S experience with doing similar analysis for supporting the Tank Farm Evaporator operations, however, details on specific techniques and quality control to achive the desired RSD is not published (largely through use of experienced personel and precision instrumentations) and therefore, we agree to adjust the %RSD from 2 – 5% to account for lack of documented "evidence". The fact is that this level of analytical precision, although achievable, may not be required for waste acceptance (e.g., this parameter is not in ICD-19 yet).* B: The requirement does not impose any specific conditions for the analysis aside from the 24 hrs. There are questions regarding how meaningful measuring settled solids shear strength in a sample vs. in the WTP vessel. It is unlikely this parameter will become a WAC but more for process control.
19	EKH	E	Page 12, Section 1.0, third paragraph, fifth sentence: Recommend "This report satisfies **the deliverables for** Commitment …".	Accept.
20	EKH	E	Page 12, Section 1.0, fourth paragraph, first	Accept.

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			sentence: Recommend "… for Commitment 5.5.3.1 include:" (delete "will").	
21	EKH	E	Page 13, Table 1-1, fourth row, Excerpts column: Recommend "… tank sampling **systems** to obtain …".	Accept.
22	EKH	O/E	Page 15, Section 1.2, first paragraph, first sentence, "… specifically HLW …": This should also be stated in the summary and title.	Stated in Executive Summary but not title. See Comment #12.
23	EKH	O/E	Page 16, Figure 1-1: 1) This figure seems to indicate that the WAC analysis will be performed by WTP. Based on this document and methods used for analyses, it seems that the tank farm is doing this. Which is correct? 2) What is the empty cylinder in the HLW DST for?	1) WAC analysis is WTP's responsibility under the Contract. Tank Farm is responsible for providing the samples for the WAC analysis. 2) The second mixer pump (fixed).
24	EKH	E	Page 16, Section 1.2, third paragraph, first sentence: Recommend "… at WTP are outside **this** scope."	Accept.
25	EKH	**M**	**Page 18, Section 2.1, second paragraph, third sentence: This question came up in a previous review. What is the basis for the "pre-transfer value" and why is it considered "true". Why isn't the sampler result compared to the tank contents, which is batched with known errors? If the pre-transfer sample is used as a basis (or 'true") to compare sampler performance, then what is the error in the pre-transfer sample given that the tank contents are known and how much of a variable is the pre-transfer sample if properties of the tank contents change? The question comes back to how does one treat a bias and how do you put any type of tolerance around this bias?**	Agree. Deleted the word "true" in reference to the pre-transfer sample. Since one never know the "true" value, a bias cannot be defined for the actual process. Uncertainties or tolerances can be defined for the mean value, but not around the bias, which is a moving target in the waste feed delivery process. As previously stated in other ERT reviews, hard for me to see how you can defend the pre-transfer sample (since it has no pedigree) as compared to what was batched into the vessel, since what was batched in the vessel is what will finally be transferred (given steady state conditions in the mixing vessel have been achieved), where as the initial transfer sample may not be representative to the tank contents. As stated earlier, if you don't know the errors associated with transfer sample, how can you compare results! *Agree that a best indicator of this total uncertainty is to compare the pre-transfer sample to what is batch into the feed tank, which*

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				encompasses the mixing, transfer, and sampling uncertainties. For the initial gap analysis, available simulant data (10% RSD for Bi2O3) from Phase 1 Remote Sampler Demo was applied. This RSD is between the sample and the recir flow loop but not what is batched into the tank. There may be additional testing data (perhaps integrated SSMD and Sampler testing) that can be used to refine the RSDs, which do not have a detrimental impact on most WAC parameters based on the sensitivity analysis.
26	EKH	E	Page 19, Section 2.1, fourth paragraph, second sentence: Recommend "These RSDs are **determined** by Subject Matter Experts …".	Accept.
27	EKH	E	Page 19, Figure 2-1: This is a little confusing. I would have expected two branches coming off total uncertainties, DST Mixing, and DST transfer; one being In-line measurements and the other being Isolok sampler, sample handling, and lab methodology.	DST mixing and DST transfer uncertainties are binned under Sampling to account for their potential impact (spatial and temporal respectively) on the pre-transfer samples. Everything is relative to the waste acceptance decision so focus is on the samples and analysis.
28	EKH	**M**	**Page 19, Section 2.1, fifth paragraph, last sentence: This validated output uses an average solids density of 3.0 g/cm^3. This is above the 2.9 g/cm^3 wac limit and definitely way above the 2.18 g/cm^3 average limit specified in Table 3-2. This would indicate you've got problems off the bat! Address this difference.**	Agree. As stated in Table 3-2, this parameter (2.18 g/ml) is not a "WAC" limit yet (i.e., not in ICD-19). However the apparent disconnect between the TOC planning basis (HTWOS) and the WTP design basis could have potential production impact. This is identified as an "Open Item" to reconcile the disconnect.
29	EKH	O/E	Page 20, Section 2.1, seventh paragraph, fourth sentence: Where is the data summarized?	If referring to the number of samples greater than 10, then this data is summarized in Section 6. Revised to include a reference to the calculation file SVF-2548. Also tabulated the max. number of samples calculated (base case) under each sample size graph, along with a min. (2%) and max. (50%) sensitivity case.

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30	EKH	O/E	Page 22, Section 2.2.1, second bullet, first sentence: Please state why the simulants that have been tested to date are bounding? In what manner?	This is an assumption to allow the use of preliminary SSMD and RSD testing results in compiling the sampling %RSD. Bounding in terms of representing mixing and sampling characteristics of large, fast settling solids in the HLW feed.
31	EKH	E	Page 22, Section 2.2.1, third bullet, first sentence: Recommend putting as staged in quotes.	Accept.
32	EKH	O/E	Page 22, Section 2.2.1, last bullet, "… 222-S Laboratory": This is not consistent with Figure 1-1.	Figure 1-1 is depicting scope and system interface boundary. WTP is responsible for the lab analysis wherever it may be (222-S or elsewhere).
33	EKH	O/E	Page 22, Section 3.1, first paragraph, second sentence, "… physical and chemical parameters …": Limits?	Use of parameters in this context implies limits, but not always.
34	EKH	E	Page 23, Section 3.1, third paragraph, second sentence: Change "… WTP/DQO document …" to "…**WAC**/DQO document …".	Accept. Note that Section 3.1 has been revised in entirety.
35	EKH	O/E	Page 23, Section 3.1, third paragraph, second sentence "… attempts …": The use of this word sounds like the task in incomplete.	Accept.
36	EKH	O/E	Page 24, Section 3.1.1, third numbered item: Ok, how would you go about measuring this property and what would be the limit?	Conditional statement. If it can't be measured, then it won't be controlled as a limit.
37	EKH	O/E	Page 24, Section 3.1.1, fourth numbered item, "… yield stress and consistency …": My preference is to use the Bingham Plastic yield stress and plastic viscosity. This terminology is very specific to the Bingham plastic model. Consistency has too many uses.	Yield stress and consistency is used in ICD-19.
38	EKH	**M**	**Page 24, Section 3.1.1, first bullet: A particle size distribution and "average" solids density is not a PSDD. This is not an adequate technical justification. Please provide additional information why this is sufficient (e.g., where would a PSDD be used and how would an "average density" suffice). As for PuO2, the procedure seems to be adequate, but you could be searching for the needle…….**	Noted. The open item (which is a DOE comment) states that WTP requires a PSDD, but this has not been determined by WTP as of yet. The parameters listed are what is "required" as of right now. LSIT testing may determine other needs, but currently, a full PSD or PSDD is not required. Revised bullet to clarify.

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39	EKH	O/E	Page 24, Section 3.1.1, second bullet: Interesting. Not sure if I agree that this properly quantifies cohesiveness and agglomeration properties. Other measurements not being performed, such as zeta potential, optical probes, and insitu PSD (lazentec) could further assist in this characterization, but I'm not sure what it would buy you. I can't think of what would even be the limiting values!	Noted. See above. Revised section to clarify.
40	EKH	E	Page 24, Section 3.1.1, second bullet, second sentence: Replace "range" with **distribution**.	Accept.
41	EKH	O/E	Page 27, Table 3-2, Row 1, Discussion column, first sentence: 1) What does TF mean? 2) Not clear on this statement. What does it mean to make a measurement after 8 hours at 25C?	TF is Tank Farms. Will clarify. Statement is from ICD-19. Holding at temperature for a time allows for precipitation. OK, sample has to be placed in an controlled environment**.** *Agree.*
42	EKH	E	Page 27, Table 3-2, Row 1, Discussion column, first paragraph, last sentence: Recommend "… 200 g/L solids in **a** 10M Na liquid."	Accept.
43	EKH	O/E	Page 27, Table 3-2, Row 6, Value column: This is a very low solids density.	Noted.
44	EKH	O/E	Page 30, Table 3-2, Row 23, Current WAC-DQO Parameter column: This is listed in Table 8 in ICD-19, as of now. May not be around in the future.	Noted. Revised Section 3 to address this comment.
45	EKH	O/E	Page 31, Table 3-2, Row 27, Discussion column, first sentence "… of Pu and "metals" provided …": Specify Table 4-1 in the reference; took too much effort to find this. This is applicable to others.	Accept.
46	EKH	E	Page 32, Section 3.2, second paragraph, "… Initial WAC values.": Replace "values" with **parameters**.	Accept.
47	EKH	O/E	Page 32, Table 3-3, Row 23: This seems to be defined elsewhere in this document and in ICD-19. May not be correct, but it is what it is.	Noted.
48	EKH	E	Page 32, Section 3.2, third paragraph:	Accept.

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			Should read "… of **these parameters** warrant further …".	
49	EKH	O/E	Page 33, Section 3.2, fifth paragraph, fourth sentence, "… if the densities result …": What densities? You're only measuring or determining the average solids density.	Accept.
50	EKH	E	Page 33, Section 3.2, seventh paragraph (Abrasivity), third sentence: Should read "… abrasivity is **a** waste …".	Accept.
51	EKH	O/E	Page 36, Section 4.1.2, first numbered item, "… consistency …": This word has been defined. Use something else such as RSD.	Accept.
52	EKH	O/E	Page 36, Section 4.1.2, first numbered item: This sentence is not clear (nor is the associated figure) in what you are trying to convey. Are you trying to state that the RSD of the individual particles given 5 batch transfers out of the tanks are provided in Figure 4-1 for the two different scales that have been tested? This needs to be reworded (as well as the figure) and will need to be reviewed.	Accept. Replaced Figure 4-1 with %RSD vs. jet mixer velocity (slightly less confusing to read).
53	EKH	O/E	Page 37, Section 4.1.2, second numbered item: Same issue as above; not clear at what your trying to get at. Text says density, figure states total solids. Is this for the 1st transfer, RSD of the 5 transfers, etc…..	Accept.
54	EKH	O/E	Page 37, Section 4.1.2, third numbered item: Ok, is the bias that of the pre-transfer sample as compared to what was batched in to the tanks or that of batches that were transferred out of the tank? Not clear.	Accept. Deleted third numbered item and Figure 4-3.
55	EKH	E	Page 37, Section 4.1.2, third paragraph, second sentence: Should read "… criticality concern **specified in** DNFSB 2010-2."	Accept.
56	EKH	O/E	Page 37, Section 4.1.2, second numbered item, "… conservative.": With respect to fast settling particles? Suspension? Specify.	Accept (added fast settling solids).
57	EKH	O/E	Page 37, Section 4.1.2, third numbered item: Could this be due to how the pump suction was configured, e.g., no cage was used.	Attributable to mixing and fast settling characteristic than physical configuration of pump suction. More solids at the bottom of the tank at the pump suction during the initial batch transfer than

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				subsequent batches, thus more solids in the pre-transfer samples. Not sure if I agree. In the present scaled testing, there is no cage around the pump suction, hence all particles are allowed free access to the suction. In reality, particles have to get into the suction cage and be in a velocity field that will draw the solids into the suction. Such has not been tested. This might be an over-estimate of what can actually be transferred, hence sampled. *Noted. More testing data may provide additional insights.*
58	EKH	O/E	Page 37, Section 4.1.2, fifth numbered item: This is quite large when you start to back out the mass fraction of UDS.	Noted.
59	EKH	O/E	Page 40, Section 4.1.2, fifth paragraph, second sentence, "… settling particles.": More uniformly between batches? Not clear.	Noted.
60	EKH	**M**	**Page 40, Section 4.1.3, first paragraph, first sentence: This must be stated in the Executive Summary; it's the basis in this document.**	Accept.
61	EKH	E	Page 40, Section 4.1.3, first paragraph, third sentence: Should read "**Initial** SSMD **testing** has …".	Accept.
62	EKH	O/E	Page 40, Section 4.1.3, first paragraph, third sentence, "… variability and bias …": See attached PDF, "page 20" discussing how you can place variability around a bias. Seems to very difficult from what I can tell.	Noted.
63	EKH	O/E	Page 41, Section 4.1.3.1, second paragraph, first sentence: I would also make it clear that there is little experience using this Isolok with fast settling (or heterogeneous) slurries. There is a lot of data out there showing it very effective for "homogenous" types of fluids.	Noted. Sentence applies to HLW staged feed, whatever it may be.
64	EKH	O/E	Page 41, Section 4.1.3.1, third paragraph, first sentence, "… mixed tank.": Not designed to provide a homogenized feed to the recirculation line.	Accept. Changed from "mixed" tank to "agitated" tank to avoid implication of homogenized feed.

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65	EKH	O/E/ **M**	Page 42, Section 4.1.3.1, fourth paragraph, second sentence, "… recirculation flow loop.": 1) Personally, there is a bias between the sampler and recirculation sample and that of the batched material. What is the bias between the sampler and batched contents? Is it worse or better than the recirculation sample? **2) What errors are associated with the recirculation loop sample (e.g,. have the uncertainties in the recirculation loop sample been quantified? Do you consistently obtain the same composition? How was this determined to be the "true" value for comparison between the Isolok?)**	In general, the uncertainties in the tank or batch is addressed by the "mixing" term in the overall sampling RSD. Then the uncertainties in the recirculation loop is addressed by the "transfer" term in the overall sampling RSD. Finally, the uncertainties/bias in the Isolok Sampler is covered by the "sampler" term. These uncertainties, along with a fourth term for sample handling are propagated to determine the overall sampling RSD. Most of the uncertainties for these uncertainty elements are based on qualitative "guesses" now since very little actual data is available. Additional sensitivity analysis suggests that for most of the WAC parameters, the sampling RSD uncertainties really don't matter that much because the expected composition is sufficiently below the action limit. Still have not addressed errors associated with the recirc sample. How good are those values? Same analytical errors for sure, but anything else? *Batch to batch variation is less than 30% for nozzle velocity greater than 30 ft/s (see Figure 4-1).*
66	EKH	O/E	Page 42, Section 4.1.3.1, fourth paragraph last sentence, "… Pierre Gy's principle …": Recommend hiring somebody who really understands (and has applied) this theory and how to apply it to this process. Given my read of the Patricia Smith book, there are problems with using a biased sample and a system which can be oscillatory.	Noted. Moved Table 4-2 to the Appendix due to its minor part in the gap analysis. Inclusion of Gy's sampling theory, which is not 100% applicable to wet slurry mixture per D. Greer (ex. WRPS statistician), is largely tailored to the targeted audience (DNFSB) who has used it to frame inquires on the sampler design. Gy's sampling theory is applicable to slurries. See the reference you provided in the document as well as the following: "Pierre Gy's Sampling Theory and Sampling Practice", Volume I

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				(Hetrogeneity and Sampling) & Volume II (Sampling Correctness and Sampling Practice), CRC Press, 1989. Clearly specify how Gy's sampling theory is not applicable to this case. *Gy's applicability is an opinion and not reflected in the report. We don't have sufficient understanding at this point or have enough empirical data to really make much of Gy's principles other than as a general categorization of possible source of sampling errors as applied to the DST sampling process. We recognize that this may be a source for scrunity from DNFSB, but it is a true reflection of where we are.*
67	EKH	O/E	Page 43, Figure 4-6: Make it clear in this figure that the RSD is between the isolok and recirculation sample. Same for the next figure.	Accept.
68	EKH	E	Page 45, Section 4.1.3.2, fourth paragraph, third sentence: Should read "… mostly focused on the **installed** instrument …".	Accept.
69	EKH	E	Page 46, Section 4.1.4, second numbered item, first paragraph, second sentence: Should read "… (i.e., **containing** un-dissolved solids) …".	Accept.
70	EKH	O/E	Page 46, Section 4.1.4, second numbered item, first paragraph, third sentence, "… 0.1 Pa …": It should have been reported as zero! Hard to believe an instrument can measure the Bingham Plastic yield stress of a 1 wt% UDS slurry having a viscosity of 1 cP!	Noted. Direct quote from the source document.
71	EKH	O/E	Page 46, Section 4.1.4, second numbered item, first paragraph, fifth sentence, "… or extrapolation.": I do not recommend extrapolation; errors can be very large.	Noted. Direct quote from the source document.
72	EKH	O/E	Page 46, Section 4.1.4, second numbered item, first paragraph, sixth sentence, "… less than 0.01 to …": See comment above; this should be zero.	Noted. Direct quote from the source document.
73	EKH	O/E	Page 46, Section 4.1.4, second numbered item, second paragraph, last sentence: Is this	Yes, it is based on 51652. Yes, dilution is a viable, but also not accepting the

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			based on 51652 or something else? If rheological data is outside the range, would the recommended path be dilution?	batch (continue storage), or changing the limit are also acceptable disposition per the WAC DQO.
74	EKH	O/E	Page 46, Section 4.1.4, third numbered item: This is not very clear. Please state how this curve was generated and what is the general conclusion? Seems you can transport anything, but it would help to know what was the average pipeline velocity.	Accept. Included additional descripton of the graph from the source report.
75	EKH	O/E	Page 46, Figure 4-8, Title: Not sure how important the length or pressure is, unless the method of calculation determines the velocity given these limitations and particle/density. Again, not clear.	Accept. Included additional descriptiontion of the graph from the source report. The evaluation considered the limitation of velocity and pressure drop in the transfer line (see report for detailed discussion).
76	EKH	O/E	Page 47, Section 4.2, second paragraph, third sentence, "… largely liquid phase constituents …": This is true if the liquids do not contain floating liquids are the liquids are immiscible.	Accept. Added "…(assuming the liquid constituents are miscible)…" as a qualifier.
77	EKH	O/E	Page 48, Section 4.2.1, second paragraph, first sentence, "… sampling …": There can also be systematic errors, e.g., the sampler is also dependent on what feed is provided and the environment from which it samples. Change the environmental conditions you can change its performance!	Accept. Changed to "…two dominate sources of uncertainties in the *waste acceptance decision* are traceable to sampling and analytical…".
78	EKH	O/E	Page 48, Section 4.2.1, second paragraph, first sentence, "… sampling and analytical errors.": I would also include sample handling (taking subsamples of the samples or putting samples together to make a larger sample) errors as a potential source of error, given what type of slurry you are processing.	Accept. Added sample handling under the Anaytical error sentence in this section rather than adding a separate uncertainty element just to be consistent with the roll up of uncertainties in this report.
79	EKH	O/E	Page 48, Section 4.2.1, second paragraph, second sentence, "… and the physical handling …": What does this mean? Is this sample handling?	Accept. It is not referring to the sub-sampling or sample handling inside the lab that is covered under the analytical uncertainties. Physical handling in this context refers to the manual handling of the sample during the retrieval and transport of the samples bottles from the field to the lab (e.g., breach of containment or seal resulting in a loss of sample or sample integrity). Added a

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				footnote to clarify.
80	EKH	**M**	**Page 48, Section 4.2.1.1, first paragraph, second sentence, "… mean, variance, and number of samples.": How is bias and its uncertainty taken into consideration?**	See disposition to Comment # 25. Bias from preliminary testing is discussed but not really quantified and used explicitly. Uncertainty is applied to the # of sample calculation, a statistical hypothesis testing for a given action limit.
81	EKH	O/E	Page 53, Section 4.2.2, %RSD items, #5, #10, #20: Where would you place organics, especially if they are in a distinct phase?	High %RSD for separable organics (20) due to potential stratification in the tank (gap). Between 5 and 10% for transfer and Isolok Sampler to be consistent with general sludge sampling (assuming it tracks with sludge).
82	EKH	**M**	**Page 54, Table 4-3, Solids concentration row, Sample Handling column: (How was this value determined and for what conditions? Given the types of slurries (from heterogeneous to homogenous), subsampling which is a sample handling uncertainty, can be an issue. This is especially true for the heterogeneous slurries. For slurries that have good suspension characteristics and are easy to mix, I would agree the 5% is an upper bound (could potentially be reduced). The only way to fully minimize the heterogeneous case is to consume the whole sample and this would not be permissible in many of the various analytical analyses. Also note that these types of subsampling operations will be occurring using manipulators (remote operations). I would expect sample handling for the heterogeneous case could be larger, but I can't place a value on it.**	Noted. Let's assume the sample delivered is representative of the material being delivered to WTP as feed. If this is true then the material must be supendable and the solids must have characterizations that allow suspension for the short period of time required to take a subsample (a few seconds). If necessary the material could be subsampled while it is being actively mixed. Not sure the assumption that the sample delievered is representative is something that can be said as of now, given the mixing/transfer/sampling systems as well as the simulants that are being used.. Again, what is the definition of representative (+/- 40%)? *Agree but the sampling uncertainties are addressed separately from analytical. It is a reasonable baseline assumption that the sample as recieived is "good" as a starting point.* The only question here is if the Isolok sampler is capable of delivering a representative sample to the laboratory. (It an integrated system, mixing, transfer and sampling, not just the sampler.) *Agree.*
83	EKH	O/E	Page 55, Table 4-3, Slurry viscosity consistency row, Bases & Assumptions	Noted.

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			column, last sentence: Rheology is a gross measurement as compared to solids analysis. In the heterogeneous cause, the fast/dense solids would settle out, typically before the measurement would start. Given the lower limit of 1 Pa for the non-Newtonian slurry, I would not expect handling issues such as air entrainment would be an issue, but settling could.	
84	EKH	O/E	Page 55, Table 4-3, Slurry bulk density row, Bases & Assumptions column, last sentence: Slurry density is less sensitive to solids variation as compared to wt%, but errors in density measurements can affect other calculations.	Noted.
85	EKH	E	Page 56, Table 4-3, Critical velocity row, Overall Sampling %RSD column: Replace 15% with **14.1%**.	Accept.
86	EKH	E	Page 56, Table 4-3, Ammonia row, Overall Sampling %RSD column: Replace 6% with **5.3%**.	Accept.
87	EKH	O/E	Page 56, Table 4-3, Separable organics row, Sampling Handling column: Is the sampling bottle selected such that the wetter materials do not interact (typically the organics would adhere to parts of the bottle) with the organics? If not, is this RSD appropriate?	Noted. The current RSD does not assume interaction of organics to bottle (or contact to the sampler surfaces). Could adjust up the RSD but the source driving a potential gap for this parameter is the question of wether the organics (separate phase) could be mixed and sampled in the first place. Added no loss of sample due to adhesion of organics to sample bottle as an assumption.
88	EKH	E	Page 56, Table 4-3, Separable organics row, Overall Sampling %RSD column: Replace 15% with **14.3%**.	Accept.
89	EKH	E	Page 57, Table 4-3, PCB row, Overall Sampling %RSD column: Replace 9% with **8.7%.**	Accept.
90	EKH	E	Page 57, Table 4-3, Feed unit dose row, Overall Sampling %RSD column: Replace 9% with **8.7%.**	Accept.
91	EKH	E	Page 58, Table 4-3, Pu to metals ratio –	Accept.

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			solids row, Overall Sampling %RSD column: Replace 38% with **37.4%**.	
92	EKH	O/E	Page 58, Table 4-3, Pu to metals ratio – solids row, Bases & Assumptions column, last sentence: How would this be different than solids concentration? Subsampling can be an issue. See comment on solids concentration.	Noted. Analysis is based on a ratio, which is fixed.
93	EKH	E	Page 59, Table 4-3, U fissile to U total row, Overall Sampling %RSD column: Replace 8% with **7.2%.**	Accept.
94	EKH	O/E	Page 59, Table 4-3, U fissile to U total row, Bases & Assumptions column, last sentence: How would this be different than solids concentration? Subsampling can be an issue. See comment on solids concentration.	Noted. Analysis is based on a ratio, which is fixed.
95	EKH	E	Page 59-60, Table 4-3, Temperature Change for Waste Feed Compatibility row, Overall Sampling %RSD column: Replace 9% with **8.7%**.	Accept.
96	EKH	O/E	Page 60, Table 4-3, Overall Sampling %RSD column, "13%": What is this for?	Propagation of two samples %RSD (8.7%) since two samples are required to verify this one parameter, one from tank farm and one from WTP.
97	EKH	E	Page 61,Table 4-3, Abrasivity row, Overall Sampling %RSD column: Replace 9% with **8.7%**.	Accept.
98	EKH	O/E	Page 61, Table 4-3, Abrasivity row, Bases & Assumptions column, last sentence: Depending on what type of measurement will be performed to determine this quantity, handling can be an issue. If the Miller test is used, most likely more than one sample will be used. As for the other method (PLM), it will make a difference, especially for heterogeneous slurries, greater that +/-1.	Noted.
99	EKH	E	Page 62, Table 4-3, Bounding PuO2 particle row, Overall Sampling %RSD column: Replace 38% with **37.4%**.	Accept.
100	EKH	O/E	Page 62, Table 4-3, Bounding PuO2 particle row, Bases & Assumptions column, last sentence: See previous comment on Pu solid. How is the sample going to be	Noted.

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			sub-sampled?	
101	EKH	E	Page 62, Table 4-3, Settled Sludge Layer row, Overall Sampling %RSD column: Replace 14% with **13.2%**.	Accept.
102	EKH	E	Page 62, Table 4-3, Average Bulk solids density row, Overall Sampling %RSD column: Replace 14% with **13.2%**.	Accept.
103	EKH	E	Page 62, Table 4-3, Particle size row, Overall Sampling %RSD column: Replace 14% with **13.2%**.	Accept.
104	EKH	O/E	Page 62, Table 4-3, Particle size row, Bases & Assumptions column, last sentence: See comment about solids concentration. Depending on where you subsample a sample can impact PSD, especially for heterogeneous slurries.	Noted.
105	EKH	O/E	Page 64, Table 4-4, Solids concentration row, Procedure & References column: Review of this procedure indicates that it can generate a bias, though it is unknown. Washing of slurries can be problematic in the sense you don't know if you washed out the dissolved salts (including interstitial) and you don't know if any of the undissolved salts are dissolved. Additionally this procedure states the method is good for a maximum UDS of 20 g/l (as where the limit is 200 g/l). Method needs to be revised to be able to determine this concentration. I believe SRNL has provided their method to WTP on how they perform solid analysis (soluble solids in the supernate, total solids in slurry, and calculation of UDS in slurry).	Noted. It would be the objective of the procedure to remove the interstitial liquid as that mass is not part of the solids mass. The procedure or analytical sample size is easily adjusted to increase the range of the procedure. The procedure does assume the sample does not contain approachable amounts of easily dissolved salts. It has been my understanding such material would not be present. State this in your table as part of your assessment. *Agree. Included the assumption that the sample does not contain appreciable amounts of easily dissolved salts. If such salts are present they will most likely be dissolved during the waste retrieval and mixing prior to staging the waste for delivery.* This is not defined. This is a method we would not use at SRS. The following recently ASTM procedure is a method that can be employed to determine the UDS, but no error is provided. ASTM C1752-11, "Standard guide for Measuring Physical and Rheological Properties of Radiaoctive Solutions, Slurries, and

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				Sludges". This standard was pushed by PNNL.
106	EKH	O/E	Page 64, Table 4-4, Slurry viscosity row, Procedure & References column: For the RV (as well as the VT) instruments, the tolerance on the torque (hence shear stress) measurement is 0.5% of full scale. What this means is given the maximum value of the torque sensor of the M5 head, the tolerance for any torque measurement is 0.005 the maximum, hence the accuracy of the measurement decreases when the measured torque decreases (see attached "Calibration Information Sheet"). Additionally, the range of the M5 head is between 0.049 to 4.9 Ncm, not zero as stated in the procedure (see spec sheets from "Instruction Manual Rotovisco RV30"). These errors, based on my experience can impact vane measurements more than they impact flow curve measurements. Not sure I would use the RV for very thin fluids (say less than 5 cP) with the MV1 sensor. I am not familiar with the Malvern specifications, but by design it is more sensitive.	Noted. As the program objective is to show that the slurry viscosity is less than 10cP the need for additional sensitivity for very thin fluids is not needed.
107	EKH	O/E	Page 64, Table 4-4, Slurry bulk density row, Procedure & References column: This method is good, as long as the fluids do not get too thick or are "cohesive" in nature. For the thin fluids that will be transported (less than 1 Pa BP yield stress), this method seems to be sufficient.	Agree and from the comment above we do not expect this to be a problem.
108	EKH	E	Page 65, Table 4-4, Critical velocity row, Overall Analytical %RSD column: Replace 8% with **7.5%**.	Accept.
109	EKH	O/E	Page 68, Table 4-4, Abrasivity row, Limit column: I assume these units are in Mohs?	The 4.4 is in Mohs, but the revised abrasivity parameter the limit is TBD.
110	EKH	O/E	Page 68, Table 4-4, Abrasivity row, Procedure & References column, last sentence: Ok, this method is available, but how do you go about calculating the average particle hardness and what errors would be associated with such a measurement?	Noted. Hardness will not be measured directly. OK, either remove the PLM method (since it seems you're not using it) or state the errors associated using such a method. *Removed the PLM method.*
111	EKH	O/E	Page 68, Table 4-4, Settled Sludge Layer	More detail on the objective of this test

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			Shear Strength row, Procedure & References column: I agree that the Malvern is more sensitive than the VT550, but it is not as flexible. Given a 1 Pa (or less) BP yield stress fluid that is allowed to settle for 24 hours, the settle layer may not be deep enough given the Malvern geometry (I do not have any specifics on this instrument) to permit a vane measurement. If this is the case, then the VT550 would have to be utilized, but it also has its own issues; see discussion above on VT550. If the VT550 is used, the errors could potentially be much larger due to the tolerance of the instrument, requiring the use of the larger vane, which requires additional sample. For example, the FL10 is the smallest vane (H=1.77 cm, D =0.7cm) and requires the smallest volume of settle solids. Using the lowest range on the torque scale of 0.049 Ncm, the measured yield stress would be 318 Pa, with a 50% error (or +/-156 Pa). Has the issue of settled bed depth been assessed on instrument utilization? Another potential error with the lab measurement is the settling of the slurry may not be the same as that in the actual process (scale).	are required to determine the correct solids depth and configuration of the equipment to collect the desired information. The vanes in the Malvern can be adjusted as well as the sample container to collect the required information. There are requirements that must be met for using the vane to measure settled sludge. See referenced ASTM above. If the objective is to completely cover the vanes such that they are completely covered by packed solids, than I have to ask how far above the vanes do the mass of solids have to extend to ensure equalization of the pressure during the solids settling. The vane is introduced into the bed of settled solids. The vane must satisfy distances from the walls/bottom and it is highly recommended that be submerged below the surface (for a specified depth). Surface measurements are permissible, but they typically lead to a lower yield stress. Also note that some people concentrate the slurry prior to settling, not sure if this is appropriate (people have different thoughts). The laboratory has not been directed to develop this procedure so the questions here have not been evaluated. So why metion this procedure, since this is still being evalulated**.** *Agree. Adjusted up the %RSD from 5 to 20 and revised the accompany note to explain that the higher RSD is due to unspecified conditions required to develop a more robust analytical procedure. As solids settle in a large tank after mixing they will segregate based on the rate of settling for each particle. It is reasonable to expect the shear strength will be variable throughout a column of*

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				settled solids. At this time, we have not designed a method for reproducing the conditions in the bottom of tank in the laboratory. Additional definition of the requested measurement on settled solids is required.
112	EKH	O/E	Page 68, Table 4-4, Solids density row, Procedures & References column: This procedure was not written to measure the density of the undissolved solids. Please provide the method that will be used to determine this value and its overall RSD? This is a very hard measurement to perform. It can be calculated using other physical properties, but this can also have a large RSD.	This work is currently being done by Test Plan. How can you assign an RSD if this has not been developed? An RSD of 2% for UDS density is highly questionable (SEE comment 18). Recommend you give any procedure or method that needs to be developed an RSD of 20 since there errors have not been quantified.. *Agree. See comment # 18.*
113	EKH	O/E	Page 68, Table 4-4, Particle size range row, Procedure & References column: Procedures need to be clear that supernate (or simulant supernate) must be used for sieving operations, other solutions could potentially dissolve particles and affect the PSD. Additionally, how does one integrate PSD using sieving and laser scattering methods? Based on testing of simulants (WTP – CFD testing), it was shown that sieving and laser data cannot be used to make an overall PSD (and this is supported by other researchers). What is the %RSD based on; the distribution and/or mean values?	The sieving is used for larger fractions. The LASER method is only used to characterize the finest fraction from the sieving. Question on integrating the two different methods to determine PSD is not addressed. I want to say that different methods typically can not be integrated! Hence how was the 5% RSD determined and is it based on the distribution and/or mean values? Questions not addressed. *Based on distribution. The two different methods will be presented separately (not integrated). The larger fraction will be categorized and reported as percentage greater than or less than certain size. The fine fraction will be reported as PSD.*
114	EKH	O/E	Page 70, Section 4.2.5, ninth bullet: Actually they use a density of 3 g/cm^3, based on SVF-2476. The raw data tab provides total volume, solids volume, and wt% solids per liter which then allows you to calculate the density of the solids. This must be an assumption, since without this data you can't calculate volume. Should it be a variable,	Agree. See disposition for comment #28.

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			yes, since all batches are not the same. As stated earlier, this density is outside the WAC.	
115	EKH	O/E	Page 71, Section 4.2.5, second paragraph, second sentence, "… it is difficult or impossible … waste blending.": Just a note, this is also consistent at SRS, no means to predict.	Noted.
116	EKH	O/E	Page 72, Section 5.0, first paragraph, first three sentences: Not spending any time in this section since it was stated in the text that what happens here is not part of the WAC; it's a processing issue from this point on.	Noted.
117	EKH	E	Page 72, Section 5.0, first paragraph, fourth sentence: Should read "… solids density, **rheology**], …".	Accept. Note that Section 5 has been revised in entirety (5.1 has been deleted).
118	EKH	O/E	Page 79, Section 6.1, third paragraph, first sentence, "… "true" value of the constituents.": If there is a bias (due to sampling and systemic), what is the "true" value?	Accept. Replaced "true" with mean. We won't know the true values in actual operations.
119	EKH	O/E	Page 87, Section 6.1, fourth paragraph, fourth sentence, "… and bulk density …": Ok, how can bulk density be an issue and not particle density? This does not make sense why this error is even less than that of the bulk!	Particle density is an issue. Bulk density is an "issue" from the standpoint of # of samples. Solution may be to take more samples, dilution or change the feed campaigns (system plan).
120	EKH	O/E	Page 91, Section 6.2.3, second paragraph, first sentence, "… (e.g., 3/8-inch or 9,525 µm) …": Based on recent discussion, they are ¼ inch openings. If this is true, have Mike provide you the reference where such an activity is occurring.	Noted. This report is based on a "snapshot" in time and the cutoff of information is 6/30/12. This report will be updated at least one more time during the final gap analysis (Commitment deliverable 5.5.3.9).
121	EKH	O/E	Page 91, Section 6.2.3, third paragraph: Three different methods. As stated earlier, it can become problematic when trying to compare PSD using these three methods.	Noted.
122	EKH	O/E	Page 92, Section 6.2.3, fourth paragraph, seventh sentence, "… 0.135 inch (~3429 µm)." See comment on new pump suction screen.	Noted.
123	EKH	O/E	Page 92, Section 6.2.4, second paragraph, last sentence: I have yet to see any	Noted. This work is currently being done by Test Plan.

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			procedure the determines this quantity. Please provide the procedure and the data that supports that the analytical RSD is +/-2%.	
124	EKH	O/E	Page 93, Section 6.2.5, second paragraph, third sentence, "… current sample size (1 L) is …": I thought samples sizes were 300 mL (see page 40). Is each sample 1 liter? If so, please correct page 40.	Accept. 300 mL in a 1L sample bottle is the minimum required. Added the work bottle to clarify.
125	EKH	O/E	Page 93, Section 6.2.5, third paragraph, first two sentences: This is based on that fact that a substantially larger mass basis for the Pu simulant was used and there was no cage around the suction to the scaled transfer pumps. This statement needs to be confirmed with a test where a more realistic concentration is used and where sampling can be obtained from a jet mixer tank.	Noted.
126	EKH	O/E	Page 94, Section 6.2.6, title, "… Consistency & Shear Stres": Do you mean yield stress?	Yes. Fixed.

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127	EKH	O/E	Page 96, Section 6.2.9, first paragraph, second sentence: What is observed and how can you tell if the limits (rheological) are not exceeded visually? What does the technician look for that states this observation is a go or no-go observation? Note that this operation occurs in a shield cell environment, hard to see things clearly.	Good question. Here's the verbiage from the permit: *Waste feed compatibility will be evaluated using the American Society for Testing and Materials Method (ASTM) D5058-90, Standard Test Methods for Compatibility of Screening Analysis of Waste (ASTM 2001). This evaluation provides three test methods to determine compatibility. Test method A, using a reduced sample volume, will be applied to the proposed DST system unit waste feed and the WTP feed receipt tank residual waste. This method prescribes the mixing of aliquots of the two waste streams and an evaluation of any temperature change of the mixture. The method also calls for a visual examination to determine whether viscosity has increased. These evaluations will be performed to test for potential incompatibilities that could adversely affect the management of the waste in the WTP.* Right now the only limit is on the temperature change. ALARA concerns will most likely waive the viscosity observation from the ASTM method. State this in this document. *Agree.*
128	EKH		The primary issue I have is how do you determine the RSD for the sampler system (e.g., mixing/transfer/sampler) that has a bias (see page 20) which can then be used in the overall RSD for a specific WAC value? Furthermore, is this basis consistent from feed to feed and what about the RSD? Most of the mixing/transfer/sampling processes that I've been involved with have slurries that are considered homogeneous slurries (e.g., have non-Newtonian properties or are viscous, good suspension characteristics, and	Bias, if known, can potentially be applied to the action limit to offset the bias. This was not done in the gap analysis. Only uncertainties around a calculated "mean" value based on HTWOS were used in the statistical hypothesis testing. Did not attempt to place a tolerance around a bias in the report. Agree that the terminology has not been

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			processed with mixing and transfer systems that were designed to handle such fluids), hence sampling has not been an issue, unlike for a heterogenous and oscillatory process (such as we have here). Based on page 20 (A Primer for Sampling Solids, Liquids, and Gases - Based on the Seven Sampling Errors of Pierre Gy), it's almost an impossibility to place a tolerance around a bias and to use this tolerance in determining the overall RSD (I'm not a statistician, but you may have tricks up your sleeve where such can be used and be defensible)?	used consistently and may be the source of confusion. Minimized the use of "bias" in the revised report. The data clearly shows you've got bias (and is inconsistent on top of that), hence not sure ignoring the issue makes it go away! Then the problem comes back to bias unless you can show that its inconsequential. *Agree. Added verbiage to Section 4.2.1.2.*
129	RKG		Tables 3-2 and 3-3 summarizing the Initial WAC parameters show the densest particle will be PuO2 with a particle size of 10 microns. Using the Poloski et al (2010) correlation I estimate that the minimum Transport (Critical) Velocity of this particle will be 3.9 ft / sec in a pipe of 3 inches diameter. This agrees well with the Critical Velocity parameter of less than or equal to 4 ft / sec.	Noted.
130	RKG		Then in Table 4-1 the "most dense primary particle" is Pu metal with a particle size of 100 microns. The minimum Transport Velocity of this particle will be 18.2 ft / sec in a 3 inch pipe.	Noted.
131	RKG		Similarly, for the "largest particle hypothetically combined with the highest density (Ag2O) the minimum Transport Velocity will be 9.8 ft / sec in a 3 inch pipe.	Noted.
132	RKG		I cannot reconcile what is discussed in Section 3 with Section 4. Have I missed something?	Section 3 is a discussion on the current WAC with the focus on establishing the "requirement" for the gap analysis. Section 4 provides latest data as input to developing uncertainties for tank farm mixing, sampling, and transfer system "capabilities". The gap analysis compares the requirements from Section 3 against the capabilities from Section 4 to determine if there are gaps.
133	RKG		How is a Yield Stress of less than 1 Pascal measured?	Refer to the Table 4-3 under the procedures and references column for

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				yield stress measurement.
134	RRH		General: While it is mentioned in the report that circulation loop is expected to receive cyclic concentration of solids, there is no discussion on the gap that may exist in sample analysis and contents of the DST. Due to rotating pump mixer jets it is expected that fast settling solids will enter the suction of the transfer pump when jets are directed towards the suction. On the other hand when jets are directed away, slow settling solids would enter the transfer pump suction. In addition, concentration of solids will cycle in the recirculation loop based on settling rate.	The "mixing" term under the overall sampling uncertainties in Table 4-2 is the attempt to account for the spatial uncertainties from mixer operation. This is a qualitative best "guess" at this time based on the particular WAC parameter with the greatest uncertainties or %RSD for parameters targeting specific undissolved solids (vs. the lowest uncertainties for liquid phase parameters such as pH).
135	RRH		General: While not in the scope of this report, there is no mention of design of mixing in SSTs and status of how successful the operation is expected to be for waste retrieval from SSTs to DST staging tanks.	Noted. Mixing and retrieval of SST won't directly impact the waste acceptance decision because the requirement is to sample the blended "as-staged" feed prior to transfer. The pre-transfer sample therefore provides the basis for the waste acceptance decision.
136	RRH		General: It has been briefly mentioned but not addressed that pre-transfer sample represents the material that was in the vessel at the beginning. As batches are transferred and liquid height decreases, the composition of material in the vessel is expected to change. This is likely to cause a bias. It is difficult to predict if fast settling particles will increase or decrease from batch to batch.	Noted. Based on preliminary SSMD testing the fast settling particles tends to decrease with tank level/batches.
137	RRH		General: The data obtained so far was from systems using transfer pump suction not surrounded by a screen cage. Since full scale system will be equipped with a cage, flow patterns are likely to be significantly modified. This should be considered as a potential gap and should be resolved by using a cage in future small scale testing.	Noted.
138	RRH		General: Since mixing jets are horizontal, it is possible that fast settling solids are suspended only at the vessel wall and do not get moved towards the transfer pump	Noted.

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			suction. Therefore they may accumulate in the vessel without being transferred. You may have observed this behavior in SSMD tests.	
139	RRH		The document provides valuable information on the initial WAC in Table 3-3. Only part which is confusing is with PuO2 particle size <10 microns in this table. Why then is 100 microns particle size considered in the gap analysis? These large and dense particles may not be suspended and/or may have higher than 4 ft/s critical velocity in the transfer line.	Noted. 10um is in the M-3 mixing and Basis Of Design. Larger sizes have been identified, but not addressed in mixing (will be with LSIT testing).
140	RRH		Table 3-2, Item 37: States value of mean particle size <11 microns. It is not clear the source of this number considering that Item 7 provides particle size range of 0.7-700 microns.	Noted. 11um is from ICD-19 and is used along with average particle hardness in the current erosion calculation. However, these parameters are exptected to be overtaken by “abrasivity” which is not clearly defined as of yet. Additional discussion is added.
141	RRH		Section 4.1.1, HLW Feed Delivery: It states that the feed tank will be operated with 30 days of hold time for mixing and sampling and 180 days for waste characterization before transfer. Why such long times?	Time is for waste characterization including process control testing to qualify the staged feed. This time will overlap with WTP processing in subsequent staged feed from a second DST.
142	RRH		Page 35, Section 4.1.1, HLW Feed Delivery, second paragraph: It states that batches will be targeted up to 120 kgal. However other documents have indicated 6.5 batches of size 145 kgal each. Why is there discrepancy?	Accept. Changed to 145 kgal to be consistent with ICD-19.
143	RRH		Page 36, Section 4.1.2: It is mentioned that SSMD program has 4 phases with 2 phases already completed. I assume the program described in RPP-PLAN-53193 (ERT-20) is the 3rd phase.	Most likely.
144	RRH		Figure 4-2 shows effect of nozzle velocity on RSD as expected--RSD decreases as nozzle velocity increases on both scales. However results plotted in Figures 4-1 and 4-3 are confusing. I suggest replotting these data as follows: • Chemicals on X-axis should be in the increasing order of settling velocity.	These figures are copied from the SSMD test report and can’t be replotted. Replaced original Figure 4-2 that better depicts the relationship between RSD and mixer jet velocity (now Figure 4-1). Deleted the original Figure 4-1.

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			• Prepare separate plots for small and large vessels. • Create a new plot showing RSD changes with number of batches.	
145	RRH		Page 45, under Table 4-1, middle of page: Yield stress range of 0.01-12 Pa is mentioned. It would be difficult to measure yield stress of 0.01 Pa.	Agree. The verbiage is taken from the source report (RPP-RPT-51652).
146	RRH		Page 41, Section 4.1.3.1: While compositing multiple samples of ~5ml size is a good strategy, just collecting 5ml samples seems to be very small and may create a bias in particle size trapped in the sample. Has there been any study to determine minimum size samples to avoid this bias.	Not sure but can do follow up outside of this comment dipsoition.
147	RRH		Page 45, Table 4-1: • It would help to add a column for estimated settling velocity of these particles to appreciate relative degree of suspension difficulty. • Recent discussions have indicated that the screen around suction of the transfer pump will have ¼" holes. Should the largest agglomerate size be changed based on this? • Since screens are like filters, they can build a layer of large particles and allow only much smaller size particles to go into the pump suction.	Noted. There is very little reliable settling velocity data for HLW. The suction screen size is based on the published source (RPP-RPT-51652) as input for this report. This information may be updated in the final gap analysis to reflect the final transfer pump design. Agree with the filtering effect of a partially blocked suction screen.
148	RRH		Page 45, first paragraph: It is mentioned that yield stress and viscosity will be predicted through interpolation and extrapolation. If extrapolation is used, it may cause large errors.	Noted.
149	RRH		Figure 4-8: Use of a combination of particle dia. and particle density may not be sufficient to characterize system capability and limit. Estimated settling velocity and critical velocity should also be included.	Noted. Again this is based on the work published in RPP-RPT-51652.
150	RRH		Section 4.2.1.2, Gy's Seven Basic Errors: While these concepts are impressive, they appear to be academic. Ideally robust sampling and analytical protocols should be	Noted. Moved the Gy's discussion to the back in Appendix C.

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			defined to minimize errors.	
151	RRH		Table 4-3: Sampling %RSD assigned numbers are not quantitative but hierarchy as defined in the report. Then using them to quantify overall sampling %RSD could become misleading.	Noted. Performed sensitivity anslysis to test the impact of these numbers on the number of samples calculation. Most parameters are by large not sensitive to the absolute value of these assigned numbers.
152	RRH		Table 4-4: • Page 63, Slurry Viscosity: It will be measured using a viscometer. I assume that this measurement technique involves full homogenization of slurry. • Page 67, Particle Size Range: Use of two different techniques for large particles and fines is likely to provide discontinuity in PSD. How would %RSD be established?	• The samples for Viscosity are analyzed as received, unless the laboratory is directed to treat the material prior to analysis. Any attempt to homogenize the solids would change the properties of the slurry. • The % RSD for particle size would be reported for each method independently. There would not be an RSD for the combined result. It is better to think as this a two separate tests.
153	RRH		Section 6.2.3, Particle Size Range, second paragraph: Breakup of agglomerates and rods is important. Since DSTs will be mixed for 30 days followed by 180 days of recirculation, large amount of particle attrition can be expected. Is there any data on attrition rates when HLW slurry is subjected to long term shear in the pump and mixer?	No.
154	RRH		Page 91, second paragraph: Since the sampler needle is 0.135" in size, there is no way 9,525 micron particles will be trapped in the sample. What is the mitigation action for this?	None to date. Mitigation may be part of the gap closure process.
155	RRH		Section 6.2.6, HLW Slurry Viscosity, first paragraph: Has any consideration been given to possible "Incompatibility" of two fluids that are blended? This phenomenon can potentially cause precipitation of solids, change in rheology and rise in temperature.	Yes. This is captured by the waste feed compatibility parameter using +/- 20 °C temperature change as an indicator of incompatibility (see Table 3-2).
156	RVC	O	General: As a member of the ERT it is fair for me to say that if I do not understand the	Noted. The statistical hypothesis testing approach based on the WAC DQO

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	DOCUMENT TITLE:	One System Initial Gap Analysis Between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1

			written word, then the same may be true of the general audience. The idea that the best criterion for identifying a gap is the number of samples is not obvious. This is particularly true since 7 of the 10 gaps are identified (Section 6.2) wihout any quantitative assessment. It was not until I reached pp. 69-70 that I got my first glimpse of how the number of samples was relevant, and the point was not driven home until Section 6.2.5 and there, only by example. In hindsight, it is easy to see why the number of samples is important for determining the bounding PuO_2 particle size, but this is not generally obvious in hindsight for many of the quantities under consideration. It needs to be made clear upfront why the number of samples is a universally accepted criterion and why a rigorous statistical analysis is the center piece when 7 of 10 gaps were identified without its use. If you claim that the data are forthcoming, then please discuss how realistic it is to expect definitive inputs for each of the "7 of 10" and others, in order to make the statistical approach more generally useful in the final gap analysis.	process is only truly relavent when we have actual sample results and need to make a go/no go decision. It is really not intended to be the center piece other than providing a platform to address various uncertainties that can affect the waste acceptance decision. The statistical hypothesis testing approach does not work for most of the physical properties since these are not simulated in HTWOS so there is not a calculated mean to apply the uncertainties. Since we really don't know much about the actual staged HLW feed, and probably will NOT know until we sample the feed (as concluded from the Meacham report RPP-RPT-51652), the only option is to based the initial gap on a speculation of general sampling and analytical capabilities. Mitigation of gaps may be to get "smarter" using addition waste characterization or testing and then update the assessment in the final gap analysis.
157	RVC	O	General: Is it obvious how the final gap analysis follows from the initial gap analysis, or should there be some upfront discussion of the evolutionary process? Are the methods expected to be exactly the same, with only the values of %RSD changing?	See Section 2.2 and Figure 2-2. The method can stay the same but the most change is expected to come from the WTP LSIT testing, which could facilitate changes to the WTP WAC (the requirement side). The tank farm capabilities side should only have evolutionary type updates to the RSDs from insights gained from SSMD, Isolok, and PulseEcho testing.
158	RVC	O	Table 4-3: Many of the entries for % RSD are admittedly bogus but, more importantly, unfounded. While the table contains known % RSD values > 20, the Definition Table on p. 53 implies that 20 is the highest expected value for unknown quantities. You even	Incorporated sensitivity test to vary the sampling RSD up to 50%. Added discussion in Section 4.2.2 on the use of sensitivity test to check for impact on feed screening and explained the "ballpark" nature at this point for many

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			include guesses for the non-HTWOS quantities of Section 6.2. Why should we believe that all unknown % RDS's are ≤ 20? What is the basis for such an optimistic expectation? If the inputed values are placeholders, why did I not see any discussion of "placeholder" until Section 6.2? You should clearly explain what the numbers in this table mean and how (if possible) accurate values will be evolved.	of the sampling %RSD.
159	RVC	O	Table 4-3: To the extent that estimated %RSD values depend on qualitative input from SMEs and others, there should be some discussion of uncertainty and bias.	Revised Section to include some discussion on uncertainty and bias in Section 4.
160	RVC	O	Pu/PuO_2 particles: In some places the largest particle is 10 μm and in other places it is 100 μm. This is confusing.	Deleted reference to the 10 micron limit for Pu/PuO_2. Now is just Pu size with a TBD limit.
161	RVC	O	Pages 36 and 41 & 44: Is Phase 2 complete or still in progrsss?	Phase 2 is complete.
162	RVC	O	Page 45, Pulse Echo: Do you expect that an evolved model of this instrument that can be suitably deployed in the field will be accurate to within 0.3 ft/s?	Accuracy is probably achievable. RAMI is another issue.
163	RVC	O	Page 46: Please clarify 1/4 vs. 3/8 inch screen size. What does it mean you have a yield stress of 0.01 Pa?	3/8" is the screen size used to limit the maximum particle size that can be physically transferred to WTP. 0.01Pa is a low range of yield stress possible cited from the source report RPT-RPT-51652.
164	RVC	O	Table 4-2: What is the relative contribution of the 7 sampling error sources? Can some be dismissed? Is there a need for the table with such discussion.	Very little is actually used to correlate to conceptually to support the delineation of %RSD among the mixing, transfer, and Isolok sampler uncertainties. Moved Table 4-2 to Appendix to limit its distraction.
165	RVC	O	Table 4-3: If I square the numbers in columns 3 to 6, add them, and take the square root, I do not get the number in column 7. Am I missing something?	Rounding of numbers. Does not make sense to be that precise with what amounts to "best guesses", but revised to remove rounding.
166	RVC	O	Section 5.1: The presented description of operating conditions in HLP-22 may be accurate and well documented based on the	Agree. Deleted Section 5.1.

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			current "written word", but I doubt that it is totally realistic given recent findings. There is little discussion of its validity or how expected changes will impact the gap analysis. This is your call, but I am not comfortable in stating an evolving story as fact. Do you run a similar risk with the DNFSB?	
167	RVC	O	Page 91: Do you believe that the Horiba Partica LA-950v2 can measure particles of size 0.01 to 1,000 μm with a level of uncertainty that is independent of particle size? Same question for SEM, p. 92, - 0.5 to 3,000 μm.	No. The SEM is also effected more by particle shape as only two dimensions of the particle can be viewed and there is a tendency to obscure the shortest axis.
168	RVC	O	Figure 6-17: It is not clear what the various horizontal lines mean.	The two horizontal dashed lines are temperature limits at 195 and 150 °F.
169	RVC	O	Appendix A: Equations without some explanation or references to guide the reader are not always useful.	Reference provided at the end of the equations (moved to up front).
170	EKH	E	The use of the word "consistency" should be referred to as that of a rheology property. Check your document in the use of this word (pp. 28, Figure 4-1, 4-2, pp 43)	*Accept. Changed to trend where it is not referring to a rheological property.*

ERT-21 Initial Gap Analysis

Large-Scale Integrated Mixing System Expert Review Team

(L. Peurrung, Chair; R. Calabrese, R. Grenville, E. Hansen, R. Hemrajani)

To: Ray Skwarek, One System IPT Manager

From: Loni Peurrung, Chair, Large-Scale Integrated Mixing System Expert Review Team

Subject: Concurrence on ***One System Initial Gap Analysis Between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1***, Revision Draft B (ERT-21)

Date: December 6, 2012

Dear Mr. Skwarek:

The Large-Scale Integrated Mixing System Expert Review Team (ERT) concurs with the WRPS disposition of ERT comments documented in ERT-21 as described in your response WRPS-1205239-OS dated November 30, 2012.

This letter closes review ERT-21.

DOCUMENT RELEASE FORM

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HANFORD RELEASE

One System Initial Gap Analysis between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1

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Abstract: This report documents an initial gap analysis between the Hanford Tank Farm Waste Feed Delivery (WFD) system capabilities and the Hanford Tank Waste Treatment and Immobilization Plant (WTP) Waste Acceptance Criteria (WAC). It satisfies the deliverable requirements for Commitment 5.5.3.1 as delineated in the Implementation Plan (IP) for Defense Nuclear Facility Safety Board (DNFSB) Recommendation 2010-2, Pulse Jet Mixing at the Waste Treatment and Immobilization Plant.

RPP-RPT-53343
24590-WTP-RPT-MGT-12-022
Revision 0

One System Initial Gap Analysis between Waste Treatment Plant Waste Acceptance Criteria and Tank Farm Sampling and Transfer Capability, 2010-2 Implementation Plan Commitment 5.5.3.1

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EXECUTIVE SUMMARY

This report documents an initial gap analysis between the Hanford Tank Farm Waste Feed Delivery (WFD) system capabilities and the Hanford Tank Waste Treatment and Immobilization Plant (WTP) Waste Acceptance Criteria (WAC). It satisfies the deliverable requirements for Commitment 5.5.3.1 as delineated in the Implementation Plan (IP) for Defense Nuclear Facility Safety Board (DNFSB) Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*.

The purpose of this initial gap analysis is to determine if the expected range of waste properties for waste transferred to WTP exceeds the WAC and if the staging tank sampling systems can detect physical properties that exceed the WAC. It is part of a phased approach to address the underlying safety issue raised in the DNFSB Recommendation 2010-2, specifically Sub-Recommendation 5. The scope of this initial gap analysis is focused on the High-Level Waste (HLW) feed because it contains the potentially large and fast settling solids that result in the safety concerns identified in the DNFSB Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*. Information from this initial gap analysis can provide insights into the types of testing and potential controls that may be necessary to assure waste delivered to WTP conforms to the WAC.

The initial gap analysis presented in this report starts with defining the requirements (i.e., initial WAC) for comparison against tank farm WFD system capabilities. Uncertainties in each step of the waste transfer process are estimated and propagated using the Root Sum Square (RSS) method to determine the total feed uncertainty. Some uncertainties (e.g. those associated with mixing) are based on results from preliminary tests while others are based on expert judgment.

The total feed uncertainty is applied to the expected pre-transfer sample value and compared to the corresponding WAC action limit. This comparison is expressed in terms of number of samples required to meet the minimum Confidence Level (CL) of either 90% or 95% for the WAC parameter. The comparison of feed against the WAC parameters is referred to as the feed "screening" process in this report. The feed screening is repeated for each WAC parameter selected for the gap analysis.

The fundamental premise underlying the methodology used to perform this initial gap analysis is that waste properties relevant to the waste acceptance criteria have a normal or Gaussian distribution. This was the approach followed for the Initial WAC DQO (24590-WTP-RPT-MGT-11-014) to calculate the number of required samples from the standard deviation (SD), assuming normally distributed waste properties. It is recognized that many, if not all, of the waste properties are not in fact normally distributed across all tank farms waste. However, that was the assumption underlying the Initial WAC DQO, and since the Initial WAC DQO is the only available point of reference for the required number of samples to achieve the requisite confidence in waste acceptance decisions, the same methodology was adopted for the Initial Gap Analysis. This is understood to be a basic weakness of the current process but it provides a starting point for identifying gaps between waste acceptance criteria and tank farm capabilities. There is a plan to re-evaluate and revise the methodology (with its assumption of normally distributed waste properties and its evaluation of uncertainties in terms of percent

relative standard deviations propagated using the RSS technique) for future updates to the Initial WAC DQO starting in 2013 after the next revision of ICD-19 (24590-WTP-ICD-MG-01-019).

Since each pre-transfer sample provides the basis for a waste acceptance decision, a gap is identified in this report if the total number of pre-transfer samples exceeds 10, which is the baseline number in the WAC Data Quality Objective (DQO). Gaps identified through this screening process are preliminary and should not be used to draw conclusions regarding treatability of the waste or a final acceptance decision.

A gap would also be identified in cases where there is insufficient information on the staged feed to allow a reasonable comparison against a particular WAC parameter, or a lack of established analytical techniques to support a waste acceptance decision.

Conclusions

An initial WAC has been defined to include the current HLW feed parameters from 24590-WTP-ICD-MG-01-019, *ICD 19 – Interface Control Document for Waste Feed* (herein referred to as ICD 19). The list of parameters is consistent with the definition of Action Limits in 24590-WTP-RPT-MGT-11-014, *Initial Data Quality Objectives for WTP Feed Acceptance Criteria*, also known as the WAC DQO document, which applies to "…*those constituents deemed as impacting WTP receipt vessel design, ability to process waste through WTP unit operations, or WTP safety basis*…". Collectively, this list of WAC parameters addresses the decision statement of: Does the staged feed meet the WTP WAC for transferring the feed to WTP?

A separate list of "potential new nuclear safety parameters" is compiled from 24590-WTP-RPT-ENS-11-021, *Key Inputs, Assumptions, Safety Margin Uncertainties, and Nuclear Safety Parameters Required to be Included in the Waste Acceptance Criteria, 2010-2 Implementation Plan Commitment 5.7.3.4,* for comparison against the tank farm sampling and analytical capabilities. The selected parameters cover the physical properties of concerns for mixing and sampling in WTP as raised in the DNFSB Recommendation 2010-2. These parameters are not to be interpreted as WAC since they are not included in ICD 19.

There are seven (7) gaps identified between the tank farm's sampling and/or analytical capability in meeting some of the initial WAC parameters. The gaps should be considered initial given they are derived using preliminary quantitative data (e.g. from preliminary mixing tests), qualitative assessments and assumptions (e.g. waste properties are normally distributed) that will be re-evaluated and revised as the WAC DQO evolve. Furthermore, development of waste feed qualification techniques to measure hydrogen generation rate and abrasivity are at early stages. Nonetheless, the initial seven identified gaps as listed by the affected WAC parameters are (see Section 6.0 for details):

- Critical velocity – PulseEcho development and field application uncertainties.
- Separable organics – Potential stratification of a separate organic layer that cannot be mixed or sampled using the current method (i.e., waste feed certification flow loop).

- Polychlorinated biphenyls (PCB) – High analytical percent Relative Standard Deviation (%RSD).
- $U_{fissile}$ to U_{total} ratio – Feed concentration close to the action limit, driving a high number of required pre-transfer samples greater than ten (10) for some feed batches given the current feed strategy in ORP-11242, *River Protection Project System Plan* (also referred to as the System Plan Baseline Case).
- Hydrogen Generation Rate (HGR) – Lack of established hot cell procedures to measure generation rate compounded by high uncertainties in analytical technique (static vs. flow through).
- Feed temperature – Design is not final for this direct field measurement, and there is no defined process control strategy. Uncertainties of the final design (thermocouple "tree") may be high, considering the transfer temperature could approach and may exceed action limit.
- Abrasivity – Lack of established hot cell procedures to measure abrasiveness of primary particles or agglomerates.

There are two (2) open items identified between the tank farm's sampling and/or analytical capability in meeting some of the potential new nuclear safety parameters listed in 24590-WTP-RPT-ENS-11-021. These are binned separately from the gaps because the affected parameters are not part of the initial WAC. The two open items as listed by the affected parameters are (see Section 6.0 for details):

- Average particle density of pre-leached solids – Likelihood of HLW feed exceeding the average particle density limit and the misalignment between tank farm planning basis (HTWOS) and WTP design basis (BOD).
- HLW feed particle size – Maximum size of particles that can be physically transferred to WTP (up to 9,525 µm) may exceed the design bases maximum. Large particles may also be bypassed (not sampled) due to size exceeding the sample port (needle) opening.

A potential new nuclear safety parameter listed in 24590-WTP-RPT-ENS-11-021, Parameter N19 in Table A-2, attempts to address the existence of discrete plutonium oxide particles in the waste. However, since the required criticality safety analysis has not been completed, no specific control parameters are available for assessment in this gap analysis. Once this criticality safety analysis for discrete fissile particles is completed (see 24590-WTP-PL-ENS-11-0005, *2012 Plan for Updating the CSER*) and if additional WAC parameters are required to ensure the safety of the WTP facilities, then these additional parameters will be evaluated for gaps.

The results of this initial gap analysis are based on limited testing and design information. As the design and test programs for WTP and the tank farm WFD system continue to mature, the identified gaps may change. Planned updates to ICD 19 and the WAC DQO would either confirm or support closure of the identified gaps.

While not definitive, this initial gap analysis provides a metric for flagging potential issues that can affect the waste acceptance decision. This report is only one of ten deliverables under Sub-recommendation 5 of the 2010-2 Implementation Plan. A separate final gap analysis report will be issued to document resolution or closure of the identified gaps using latest testing results and a revised WAC (IP Commitment 5.5.3.9).

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Terms

Bias is the difference in the long-term mean value of estimates of a quantity and the true, unknown value of the quantity.

Gap refers to a mismatch between the tank farm WFD system capabilities and the initial WAC for WTP. It is expressed either quantitatively in terms of number of samples required to meet the specified waste acceptance action limit, or qualitatively in terms of uncertainties in the sampling and analytical capabilities.

Open Item refers to a mismatch between the tank farm WFD system capabilities and the Potential New Nuclear Safety Parameters, rather than the initial WAC.

Potential New Nuclear Safety Parameters refers to the list of parameters in the DNFSB 2010-2 IP Commitment 5.7.3.4 deliverable 24590-WTP-RPT-ENS-11-021. This list as defined for initial gap analysis is separate from the initial WAC parameters.

Uncertainty refers to the lack of knowledge of the true value of a quantity. Uncertainty can be systematic or random.

Variation or Variability refers to differences in the true value of a quantity over time and/or space and is distinct from uncertainty.

Waste Acceptance Criteria (or initial WAC) refers to the High Level Waste (HLW) feed parameters established in the WTP Interface Control Document (24590-WTP-ICD-MG-01-019) as defined for this initial gap analysis.

ABBREVIATIONS AND ACRONYMS

AEA	Alpha Energy Analysis
ALARA	As Low As Reasonably Achievable
ASTM	American Society for Testing and Materials
ATS	Action Tracking System
BBI	Best Basis Inventory
BNI	Bechtel National Incorporated
BOD	Bases of Design
CFD	Computational Fluid Dynamic
CL	Confidence Level
CSER	Criticality Safety Evaluation Report
CSL	Criticality Safety Limit
CV	Critical Velocity
DE	Delimitation Error
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DQO	Data Quality Objectives
DST	Double-Shell Tank
DWP	Dangerous Waste Permit
EE	Extraction Error
ERT	Expert Review Team
FE	Fundamental Error
GC-MS	Gas Chromatography – Mass Spectrometry
GC/TCD	Gas Chromatography/Thermal Conductivity Detector
GEA	Gamma Emission Analyzer
GPC	Gel Permeation Chromatography
GSE	Grouping and Segregation Error
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HGR	Hydrogen Generation Rate
HLW	High-Level Waste
HTWOS	Hanford Tank Waste Operations Simulator
IC	Ion Chromatography
ICD	Interface Control Document
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectrophotometry
ICP-MS	Inductively Coupled Plasma – Mass Spectrometer
IWFDP	Integrated Waste Feed Delivery Plan
IP	Implementation Plan
LAW	Low-Activity Waste
LSC	Liquid Scintillation Counting
LSIT	Large Scale Integrated Testing
%RSD	Percent Relative Standard Deviation
PCB	Polychlorinated biphenyls
PDSA	Preliminary Documented Safety Analysis
PE	Preparation Error

pH	Potential of Hydrogen
PIER	Project Issue Evaluation Report
PJM	Pulse Jet Mixer
PNNL	Pacific Northwest National Laboratory
QC	Quality Control
RPD	Relative Percent Difference
RPP	River Protection Project
RDQO	Regulatory Data Quality Objectives
RSS	Root Sum Square
SD	Standard Deviation
SEM	Scanning Electron Microscopy
SRD	Safety Requirements Document
SpG	Specific Gravity
SRNL	Savannah River National Laboratory
SS	Stainless Steel
SSMD	Small-Scale Mixing Demonstration
SST	Single-Shell Tank
SVOC	Semi-Volatile Organic Compounds
TBD	To Be Determined
TFC	Tank Farm Contractor
TIC/TOC	Total Inorganic Carbon/Total Organic Carbon
TGA/DSC	Thermo-Gravimetric Analysis/Differential Scanning Calorimetry
TWINS	Tank Waste Information Network System
UFP	Ultra-filtration Process System
VOC	Volatile Organic Compounds
WAC	Waste Acceptance Criteria
WFD	Waste Feed Delivery
WRPS	Washington River Protection Solutions
WSCF	Waste Sampling and Characterization Facility
WTP	Hanford Tank Waste Treatment and Immobilization Plant

Units

Ci	Curies
cP	centipoise
ft	foot
g	gram
gal	gallon
gpm	gallons per minute
hp	horsepower
J	Joule
kg	kilogram
L	liter
mL	milliliter
Mohs	hardness scale
min	minute
Pa	Pascal
ppm	parts per million
psi	pounds per square inch
psig	pounds per square inch gauge
s	second
Sv	Sievert
µm	microns
wt%	weight percent

1.0 INTRODUCTION

The Hanford Tank Waste Treatment and Immobilization Plant (WTP) is being constructed to process radioactive waste stored in 177 underground storage tanks at the Hanford Tank Farm. The stored waste will be staged and segregated into two main feed streams for transfer to WTP, a Low-Activity Waste (LAW) feed stream and a High-Level Waste (HLW) feed stream. Both feed streams must demonstrate compliance to the WAC prior to transfer to WTP. The current WAC was developed from design, safety, regulatory, and contractual sources to provide an interface control for ensuring safe and efficient operations of WTP.

Of the two feed streams to WTP, the HLW feed, which contains a wide range of undissolved solids in slurry of varying physical and rheological properties, represents a unique challenge to both the tank farm and WTP in areas of mixing, sampling, and transferring operations. Characterization data on the type, size, quantities, distribution, and properties (e.g., density, abrasiveness, etc.) of the wide range of undissolved solids in the HLW stream is very limited and the tank farm's ability to properly sample and analyze them to ensure WAC compliance is uncertain. Because of potential downstream safety impact at WTP, these "problematic" solids in the HLW are the focus driving many of the ongoing test programs being conducted by the TFC (Tank Farm Contractor) and the WTP Contractor. Settling and accumulation of solids from the HLW feed in particular is a safety concern expressed by the Defense Nuclear Facilities Safety Board (DNFSB) in Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*.

The Department of Energy (DOE) issued an Implementation Plan in November, 2011 (Chu, 2011) in response to Recommendation 2010-2. The Implementation Plan (IP) contains seven (7) sub-recommendations to address safety issues. Sub-recommendation 5 addresses representative samples from waste feed tanks. It delineates ten (10) separate Commitments, 5.5.3.1 through 5.5.3.10. This report satisfies the deliverable for Commitment 5.5.3.1 for an "*Initial gap analysis between WTP WAC and Tank Farm sampling and transfer capability.*"

As stated in the IP, the deliverable for Commitment 5.5.3.1 includes:

- A definition of the initial WAC.
- A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems, given the uncertainty associated with tank farm characterization data.
- A determination of the capability of staging tank sampling system.
- Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.
- Expert Review Team (ERT) review comments and resolution will be included with the deliverable transmittal.

The first four bullets above define the general scope of the initial gap analysis. The ERT review has been conducted as an integral part of the approval and release process for this report. Table 1-1 provides a deliverable compliance matrix linking sections in this report to applicable scoping statements in the IP.

Table 1-1. Deliverable Compliance Matrix.

2010-2 IP Section	Excerpts	Addressed in Section(s)
5.5.2	Initial Phase Define initial requirements for tank waste feed that is transferred between the Hanford tank farms and WTP, referred to as the WAC. This includes requirements to obtain representative samples. This initial set of requirements will be based on current information (Commitment 5.5.3.1).	3.1; Table 3-1
5.5.2	Initial Phase Determine the range of physical properties that can be sampled and characterized based on existing information on tank farm sampling systems (Commitment 5.5.3.1).	4.2.5
5.5.2	Initial Phase Perform an initial gap analysis to determine if the expected range of waste properties for waste transferred to WTP exceeds the WAC and if the staging tank sampling systems can detect physical properties important for the WAC and identify waste that may not meet the WAC (Commitment 5.5.3.1).	6.0
5.5.2	An assessment of the capability of the tank farm staging tank sampling systems to obtain samples that can be used to assess the range of physical properties identified in the initial WAC will be performed. This assessment will include an estimate of waste properties that can be measured and those that cannot be measured based on sampling system limitations.	6.0
5.5.2	An initial gap analysis is being performed to determine if the expected range of waste properties for waste transferred to WTP exceeds the initial WAC and if the staging tank sampling systems can detect physical properties that exceed the WAC. Information from this initial gap analysis will be used to define requirements for testing being planned by WRPS for evaluating tank waste feed staging, sampling, and transfer systems and BNI for pulse jet mixer (PJM) mixed vessel mixing, sampling, transfer, and PJM control testing. The results may provide insight into the types of potential controls that may be necessary to assure waste delivered to WTP conforms to the WAC.	6.0, 7.0
5.5.3	Commitment 5.5.3.1: Complete an initial gap analysis between Tank Farm sampling system capabilities, uncertainties, and waste projected to be transferred to WTP. This report will include:	
	A definition of the initial WAC.	3.1; Table 3-1
	A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems given the uncertainty associated with tank farm characterization data.	4.0, 6.0
	A determine of the capability of staging tank sampling system.	4.0; Table 4-2
	Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.	4.0; Table 4-3, 5.1

1.1 PURPOSE

The purpose of this initial gap analysis is to *"determine if the expected range of waste properties for waste transferred to WTP exceeds the initial WAC and if the staging tank sampling systems can detect physical properties that exceed the WAC"* (Chu, 2011). This report documents the identified gaps and associated evaluations to provide a starting point for tracking these gaps through resolution. Information from this report may be used as appropriate to define test requirements being planned by the TFC, Washington River Protection Solutions, LLC (WRPS), and the WTP Contractor, Bechtel National Inc. (BNI). A separate final gap analysis report will be issued to document resolution or closure of the identified gaps (IP Commitment 5.5.3.9).

1.2 SCOPE

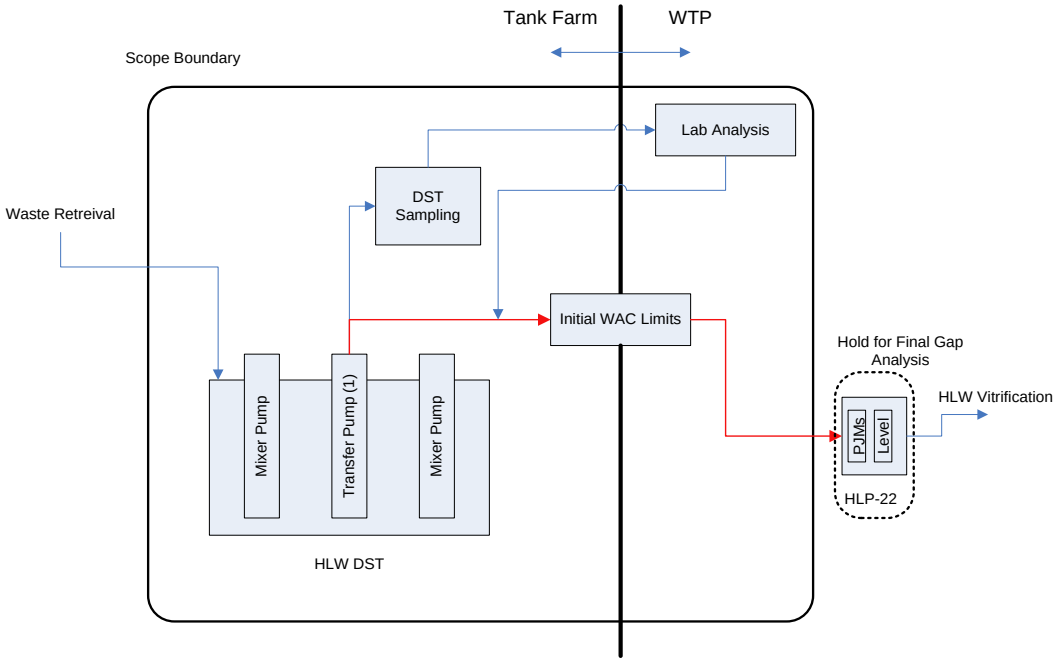
The scope of this report includes the assessment of gaps between the expected waste transferred to WTP, specifically HLW feed, and the corresponding acceptance limits in the "initial WAC." This document focuses on HLW feed because it contains the potentially large and fast settling solids that result in the safety concerns identified in the DNFSB Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*. The term "initial WAC" as defined in the context of this initial gap analysis report is limited to the current HLW feed parameters inthe ICD 19 document (24590-WTP-ICD-MG-01-019). This document does not propose or set new WAC parameters for WTP.

The scope of this report also include the screening of other potential new nuclear safety related parameters as listed in the 2010-2 IP deliverable for Commitment 5.7.3.4 (24590-WTP-RPT-ENS-11-021). The parameters from this input document are screened following the same approach as the initial WAC parameters (i.e., ICD 19), but the results are binned and tracked separately as gap analysis "Open Items" because they do not fit the definition of a gap in the context of this report, which is always benchmarked to a WAC parameter (see Section 2.1).

In general, the scope of this initial gap analysis traces the sample flow path from the Double-Shell Tank (DST) at the tank farm to the HLW receipt vessel (HLP-22) at WTP, accounting for transfer equipment capability and uncertainties along the way that can impact the waste acceptance decision (see Figure 1-1. Initial Gap Analysis Scope Boundary). The actual HLW feed batch starts "as staged" in the DST. This is followed by the mixer pumps and Isolok™ Sampler[1] performance to address tank sampling capability, and is then followed by the transfer pump and in-line PulseEcho system to assess transfer limitations and solids settling detection. Finally, the laboratory sample analysis (off-line) evaluates analytical precision and techniques required to demonstrate WAC compliance.

[1] Isolok™ is a registered trademark of the Sentry Equipment Corporation, Yorkville, Illinois.

Figure 1-1. Initial Gap Analysis Scope Boundary.



Waste retrieval operations upstream of the feed DST and post-receipt treatment downstream of HLP-22 at WTP are outside this scope. Other programmatic or production related issues not covered by the initial WAC are not evaluated in this initial effort. There is insufficient testing data available to assess potential gaps between the current WAC and the WTP mixing and sampling capabilities in the receipt vessel (HLP-22). Planned testing such as the Large Scale Integrated Testing (LSIT) will be used to update the WAC and any potential gaps assessed during the final gap analysis (see Figure 2-2).

The scope of this initial gap analysis applies to the identification of gaps based on the latest information available (as of June 30, 2012). It does not resolve the gaps or initiate the work required to resolve the gaps. The results and conclusions are considered preliminary, since the supporting bases and assumptions are evolving and will likely change as the testing programs and design for WTP continues to mature. See Section 2.2 for more discussion on how this initial gap analysis serves as a starting point for the final gap analysis and the logic ties to other activities as required to fully implement the IP, Sub-recommendation 5.

1.3 REPORT ORGANIZATION

Information in this report is organized to follow the general work flow for the initial gap analysis. First define the requirements, then evaluate current capabilities and uncertainties, and finally use the collected information to perform a gap analysis between requirements and capabilities. Table 1-2 lists the major sections of the report and provides a brief description of each. Collectively these sections addressed the deliverable requirements in the IP, Commitment 5.5.3.1.

Table 1-2. Report Organization.

Section	Title	Content
1.0	Introduction	General introduction and background. Describes problem and driver for this initial gap analysis. Delineates scope and scope boundary.
2.0	Gap Analysis Process	Describes the overall approach for the initial gap analysis, including the methodology and use of the Hanford Tank Waste Operations Simulator (HTWOS) model. Discusses application and limitation of the information. Highlights key inputs and assumptions used.
3.0	Define Waste Feed Parameters	General overview of the current WAC parameters as defined in ICD 19. Discusses rationale for the selection of specific WAC and potential new nuclear safety parameters for use in the initial gap analysis.
4.0	Assessment of Current Tank Farm Capabilities	Steps through the sample flow path. Compiles latest information. Summarizes latest equipment design and testing results on tank mixing and sampling capabilities. Discusses the development of sampling and analytical %RSD. Describes the construction of the sample size graphs.
5.0	Assessment of Current WTP Capabilities	Summarizes laboratory capability (222-S) in support of the initial gap analysis. This section serves as a place holder for the discussion and benchmarking of WTP testing results to be included in the final gap analysis.
6.0	Gap Analysis	Describes the HLW feed screening process. Presents and discuss the sample size graphs for selected WAC parameters. Evaluate gaps and open items in the areas of sampling and analytical capabilities.
7.0	Conclusions	Summarizes the gap analysis results. Draw conclusions on gaps and open items. Provide suggested path forward.
8.0	References	Lists references used throughout the report.

2.0 GAP ANALYSIS PROCESS

2.1 APPROACH

The approach for the initial gap analysis is mainly based on a staged feed "screening" process that is traceable to the initial Data Quality Objectives (DQO) effort (24590-WTP-RPT-MGT-11-014). This feed screening process is tailored to address deliverable requirements in the IP Commitment 5.5.3.1. As such sampling and analytical capabilities will be the primary focus. A gap, as defined in this report, is always benchmarked to a WAC parameter (i.e., no WAC parameter, no gap). It addresses the tank farm's capabilities to meet each WAC parameter at the specified action limit. Operational, production, or optimization issues not related to waste acceptance will not be identified as gaps in this context.

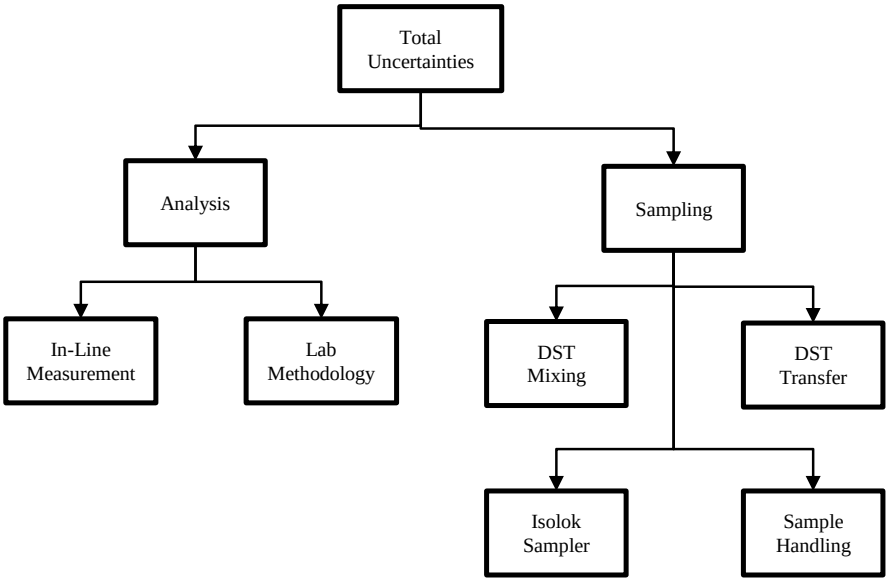
The approach uses a statistical hypothesis testing method to identify gaps in terms of error tolerance in the waste acceptance decision process (see Section 7, Error Tolerance, in 24590-WTP-RPT-MGT-11-014. Uncertainties in each step of the waste transfer process are estimated and then propagated, using the RSS method, to determine the total uncertainty associated with quantification of the WAC parameter. The total uncertainty would then be

applied to the expected pre-transfer value and compared to the corresponding WAC action limit. This comparison is expressed in terms of number of samples required to meet the minimum CL of either 90% or 95% for the WAC parameter. The comparison of feed against the WAC parameters is referred to as the feed "screening" process in this report. This feed screening is repeated for each WAC parameter selected for the gap analysis. A gap would be identified if the total number of samples exceeds 10, which is the recommended baseline number in the WAC DQO (24590-WTP-RPT-MGT-11-014). A gap would also be identified in cases where there is insufficient information on the staged feed to allow a reasonable comparison against a particular WAC parameter.

The first step in the feed screening process is to decompose the transfer process into discrete elements to account for the associated uncertainties. For the initial gap analysis, the sampling and analytical capabilities are the two main elements contributing to the quantification of the total uncertainty associated with the WAC parameter. These two elements are further decomposed into sub-components as shown in Figure 2-1. These uncertainties are not all-inclusive and are subject to other uncertainties not explicitly considered in the initial gap analysis. For example, the uncertainty associated with DST mixing is quantified from preliminary tests, the results of which contain some uncertainty with respect to scaling, for example

WAC uncertainty, in general, is quantified by use of %RSD values. These %RSDs are determined qualitatively for each of the uncertainty sub-components under the sampling and analytical capabilities. Sampling and analytical %RSDs are referenced from published test report(s), studies, standards, and lab procedures when available (as of June 30, 2012). As a starting point to track resolution of gaps, the absolute value of these initial %RSDs is not critical provided that the supporting bases and assumptions are well documented. These initial %RSD values will be validated and updated as more test results are obtained and the design of the associated equipment (e.g., Isolok™ Sampler, PulseEcho System, etc.) is finalized.

Figure 2-1. Elements of Feed Uncertainties.



The next step in the feed screening process is to develop a staged feed delivery profile. Most of the WAC parameters with action limits are tracked in the HTWOS model. The HTWOS model is used to develop an operating scenario for the System Plan Baseline Case (ORP-11242). The validated output from the HTWOS model represents the best available "as-delivered" feed information for use in support of this initial gap analysis. It is important to note HTWOS estimates of as-delivered feed are traceable back to historical information and tank waste sample analysis (i.e., Best Basis Inventory or BBI). BBI data is subject to uncertainties associated with the collection and analysis of tank waste samples, Hanford Defense Waste modeling, and engineering calculations. These uncertainties have not been quantified and their impact of upon the HTWOS results and the associated feed delivery profile is unknown. An HTWOS sensitivity study performed and documented in RPP-RPT-51819 *Hanford Tank Waste Operations Simulator (HTWOS) Sensitivity Study* is noteworthy but the assessment of error and uncertainty inherent to the HTWOS-derived feed delivery profile is beyond the scope of this initial gap analysis. Nonetheless, the feed delivery profile derived from HTWOS modeling represents the best tank waste characterization data available and provides a necessary enabling assumption for the analysis presented in this report.

The final step in the feed screening process is to calculate the number of samples based on the expected feed delivery profile, the total uncertainties, and the WAC parameter action limit. The fundamental premise underlying the methodology used to perform this initial gap analysis is that waste properties relevant to the waste acceptance criteria have a normal or Gaussian distribution. This was the approach followed for the Initial WAC DQO (24590-WTP-RPT-MGT-11-014) to calculate the number of required samples from the standard deviation (SD), assuming normally distributed waste properties. It is recognized that many, if not all, of the waste properties are not in fact normally distributed across all tank farms waste. However, that was the assumption underlying the Initial WAC DQO, and since the Initial WAC DQO is the only available point of reference for the required number of samples to achieve the requisite

confidence in waste acceptance decisions, the same methodology was adopted for the Initial Gap Analysis. This is understood to be a basic weakness of the current process but it provides a starting point for identifying gaps between waste acceptance criteria and tank farm capabilities. There is a plan to re-evaluate and revise the methodology (with its assumption of normally distributed waste properties and its evaluation of uncertainties in terms of percent relative standard deviations propagated using the RSS technique) for future updates to the Initial WAC DQO starting in 2013 after the next revision of ICD-19 (24590-WTP-ICD-MG-01-019)..

As stated, the calculation and construction of the sample size graphs is similar to the ones in the initial WAC DQO (24590-WTP-RPT-MGT-11-014) except for the incorporation of updated sampling and analytical %RSDs (see Section 6.0). Any WAC parameter requiring more than 10 samples (gap criterion) is flagged as a gap, recognizing that the number of required samples is only part of the WAC DQO waste acceptance decision process. The total number of samples greater than 10 provides a general magnitude of the gap. A gap is also identified if there is insufficient knowledge on the staged feed profile to support the feed screening process.

Physical properties that are not simulated in HTWOS are assessed qualitatively. For example, for purposes of this initial feed screening, the most challenging particle size and density distribution relative to mixing and transferring operations is use. The authors acknowledge, however, that the probability and impact of such transfer(s) to WTP and uncertainties associated with the most challenging parameter values are unknown at this time, but will be evaluated as the WAC DQO evolves. A qualitative approach is the only viable option for some staged waste properties due to a lack of reliable characterization data or analytical method.

Gaps identified through this screening process are preliminary and should not be used to draw conclusions regarding treatability of the waste or final acceptance decision. The final acceptance decision in accordance with the WAC DQO decision statement is:

> *Determine whether the staged feed meets the WTP WAC and can be accepted by WTP, requires a change to the feed to meet the WAC, requires sending the feed to an alternative treatment, requires a change to the WAC, or requires continued storage of the feed.*

The screening process serves to highlight areas of uncertainties relative to each WAC parameter that may be used to define test requirements or develop appropriate mitigation strategy. Gaps may be mitigated by revising the waste staging strategy through the system planning effort, reducing the sampling or analytical %RSDs through testing and equipment design, or refining the WAC requirement. The final gap analysis will incorporate results of any mitigation strategy implemented as a part of the 2010-2 IP, Sub-recommendation 5.

The initial gap analysis is a collaborative effort between the TFC and the WTP Contractor (WRPS and BNI respectively). The authors associated with the 222-S Laboratory and Tank Farm Characterization group are used to develop sampling and analytical %RSDs. This report also incorporates the feedback and input from the Expert Review Team (ERT) as a part of the document approval and release process.

2.2 KEY INPUTS AND ASSUMPTIONS

The initial gap analysis is a part of an integrated plan to address the technical and safety issues identified in Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant*. Coordinated efforts are being pursued by WRPS and BNI in accordance with the Implementation Plan (Chu, 2011). Sub-recommendation 5 of the IP delineates the role of the initial gap analysis relative to the final gap analysis and other supporting deliverables. The required inputs, outputs, and logic ties for the initial gap analysis are depicted in Figure 2-2.

As shown in Figure 2-2, there are four (4) key inputs to the initial gap analysis: (a) the WTP Interface Control Document (24590-WTP-ICD-MG-01-019, *ICD 19 – Interface Control Document for Waste Feed*); (b) the WAC Data Quality Objectives (WAC DQO) (*24590-WTP-RPT-MGT-11-014, Initial Data Quality Objectives for WTP Feed Acceptance Criteria*); (c) the deliverable for Commitment 5.5.3.2 (RPP-RPT-51652, *One System Evaluation of Waste Transferred to the Waste Treatment Plant*); and (d) the deliverable for Commitment 5.7.3.4 (24590-WP-RPT-ENS-11-021, *Key Inputs, Assumptions, Safety Margin Uncertainties, and Nuclear Safety Parameters Required to be Included in the Waste Acceptance Criteria, 2010-2 Implementation Plan Commitment 5.7.3.4*).

a) The ICD 19 document identifies the WAC parameters and defines the associated action limits for waste feed acceptance.

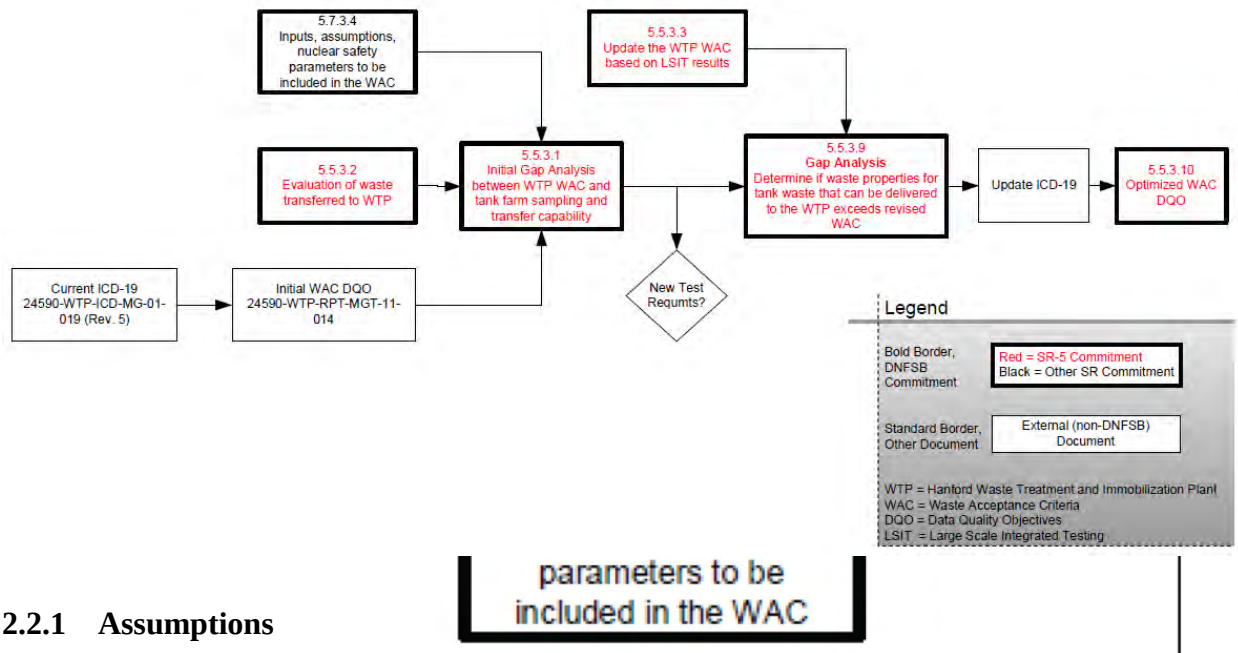
b) The WAC DQO document describes the type, quantity, and quality of the data required for the waste acceptance criteria in ICD 19. It defines a framework for the waste acceptance decision-making process.

c) The Commitment 5.5.3.2 deliverable provides a preliminary examination of the range of physical properties for waste that could be transferred to the WTP using current design concepts for waste retrieval, staging, and transfer. Selected particle size and density along with rheological properties are referenced from the 5.5.3.2 report (RPP-RPT-51652) as bounding values for the feed screening in this report.

d) The Commitment 5.7.3.4 deliverable (24590-WP-RPT-ENS-11-021) compiles a list of current WAC parameters and potential new nuclear safety parameters. It provides the source of potential new nuclear safety parameters for the feed screening in this report. Gap analysis "open items" are screened against these potential new nuclear safety parameters in this report.

Output of the initial gap analysis may be used to define or confirm test requirements for the tank farm and WTP. Results from the latest testing will be incorporated in a final gap analysis deliverable as a part of Commitment 5.5.3.9. Output of the final gap analysis will be used to update/optimize the WAC DQO.

Figure 2-2. Sub-recommendation 5 Logic Diagram.



2.2.1 Assumptions

The feed screening process used in this initial gap analysis involves the use of assumptions. In general the assumptions and conditional qualifiers in supporting documents are carried forward in this report unless specified otherwise. Specific assumptions are identified in the discussion sections as required to clarify the associated application. The following common enabling assumptions underpin the initial gap analysis:

Gap is screened for the HLW feed only. LAW is assumed to impose no interface issues since the feed is mostly free of undissolved solids that are problematic for mixing, sampling, and pre-qualification analysis relative to the safety concerns of criticality and hydrogen generation.

The representativeness of the simulant testing completed to date to actual waste behavior during mixing and transfer operations to WTP is an unverified assumption. Inherent uncertainties in simulant formulation and scale-up are not evaluated as part of the gap analysis relative to the tank farm's capability to meet the WAC. Preliminary test results are considered valid for initial analysis.

Propagation of total waste acceptance uncertainties begins at the pre-transfer sample for the batch of HLW "as staged" in the DST. Characterization uncertainties with the individual source tank(s) and any blending effects from waste retrieval operations are assumed to be accounted for by sampling the actual "as-staged" feed to WTP.

Worst case feed in terms of undissolved solids (size, density) is assumed for conservative estimate of gap. Worst case is defined as the solids that are difficult to keep suspended or mobilized by the baseline mixing and transfer systems in the tank farm.

- The planning bases and assumptions (e.g. results from HTWOS) in ORP-11242 are assumed the best available for the actual "as-staged" HLW feed campaigns to WTP. The bases and assumptions in ORP-11242 have inherent uncertainties associated with them, but are widely considered the standard for tank farm planning purposes. The uncertainties have not been carried forward into the analysis performed to complete this report.
- Sampling and analytical %RSDs for the WAC parameters are evaluated independently, even though some of the physical properties are related.
- The fundamental premise underlying the methodology used to perform this initial gap analysis is that waste properties relevant to the waste acceptance criteria have a normal or Gaussian distribution. This was the approach followed for the Initial WAC DQO (24590-WTP-RPT-MGT-11-014) to calculate the number of required samples from the standard deviation (SD), assuming normally distributed waste properties. It is recognized that many, if not all, of the waste properties are not in fact normally distributed across all tank farms waste. However, that was the assumption underlying the Initial WAC DQO, and since the Initial WAC DQO is the only available point of reference for the required number of samples to achieve the requisite confidence in waste acceptance decisions, the same methodology was adopted for the Initial Gap Analysis. This is understood to be a basic weakness of the current process but it provides a starting point for identifying gaps between waste acceptance criteria and tank farm capabilities. There is a plan to re-evaluate and revise the methodology (with its assumption of normally distributed waste properties and its evaluation of uncertainties in terms of percent relative standard deviations propagated using the RSS technique) for future updates to the Initial WAC DQO starting in 2013 after the next revision of ICD-19 (24590-WTP-ICD-MG-01-019).

3.0 DEFINE WASTE FEED PARAMETERS

As per CCN 235230, the DNFSB has summarized its concerns relating to WTP's mixing and transfer systems, specifically that the PJMs lacked sufficient power to mix adequately and to transfer the most rapidly settling particles expected to be in the Tank Farm inventory. Three (3) significant safety issues were raised related to mixing using PJMs:

- Retention of fissile materials in vessel heels would present a criticality safety concern.
- There could be retention of flammable gas due to the presence of solids in vessel heels.
- The presence of a large solids inventory could have a detrimental effect on the vessel level instrumentation, which is required to control the PJMs.

Section 5.5.2 of the 2010-2 IP states that one of the sub-tasks for Deliverable 5.5.3.1 is to *"Define initial requirements for tank waste feed that is transferred between the Hanford tank farms and WTP, referred to as the WAC."* ICD 19 is the source document for the WAC for both the LAW and HLW feeds. ICD 19 states that the solids in the LAW feed will be *"delivered to the WTP after there has been sufficient settling time to ensure solids that settle faster than*

0.03ft/min have settled below the transfer locations within the tank farms staging tank" [Footnote 2 for Table 6 in ICD 19]. Therefore, the solids present in the delivered LAW feed will not be "rapidly settling particles," and thus will not have the same significant safety issues as the HLW solids that were raised by the DNFSB. Because of this, only the WAC for HLW feed will be evaluated further in this document.

The determination of parameters to use in this initial gap analysis is split into two groupings. The first grouping includes the currently defined WAC parameters for HLW from ICD 19. This grouping is labeled as the "Initial WAC" and is discussed in Section 3.1. The second grouping includes parameters defined as potential new nuclear safety parameters in the 2010-2 Deliverable 5.7.3.4 (24590-WTP-RPT-ENS-11-021) as well as any additional parameters identified in the WAC DQO (24590-WTP-RPT-MGT-11-014). Those parameters identified from 24590-WTP-RPT-ENS-11-021 are subject to change as information emerging, since the report was issued, is considered. In addition, this second grouping includes any foreseeable parameters that may need to be added based upon the proposed resolution to outstanding issues/items identified in ICD 19 and the WAC DQO. This grouping is labeled as the "Potential New Nuclear Safety Parameters" and is discussed in Section 3.2. Note that none of these "Potential New Nuclear Safety Parameters" is to be considered as HLW WAC.

3.1 INITIAL WASTE ACCEPTANCE CRITERIA (WAC)

For the WTP, the ICD 19 document is the source document that provides the WAC for both the LAW and HLW feeds. This includes both physical and chemical parameters as well as transfer system requirements. These parameters are included in Tables 5 through 8 of ICD 19. However, some of the WAC criteria are included by reference in ICD 19. These references include:

- Specifications 7 and 8 from the WTP Contract
- WTP's Dangerous Waste Permit (DWP) - *Final Waste Treatment and Immobilization Plant Dangerous Waste Permit*
- WTP's Safety Authorization Bases Documents (includes the *Preliminary Criticality Safety Evaluation Report for the WTP* (CSER), *Preliminary Documented Safety Analysis to Support Construction Authorization* (PDSA), *Safety Requirements Document* (SRD), etc.).

The WAC DQO (24590-WTP-RPT-MGT-11-014) included an activity where the DQO team (consisting of BNI, WRPS, and DOE personnel) identified and categorized the WAC constituents into groups. The identification of these WAC constituents used the references listed above and also included the following:

- 24590-WTP-RPT-MGT-04-001, *Regulatory Data Quality Objectives Optimization Report* (RDQO)
- 24590-HLW-PL-RT-07-0001, *IHLW Waste Form Compliance Plan for the Hanford Tank Waste Treatment and Immobilization Plant*

These references are included by indirect reference by the "Environmental Permit Limits" entry in Table 8 of ICD 19. However, the overall purpose of the WAC DQO document is to establish the data quality requirements for WAC constituents to insure that the delivered feed meets the WTP WAC requirements. The WAC DQO document does not determine the WAC but summarizes the WAC from the above documents. As stated previously, ICD 19 is the source document for the WTP WAC.

Table 3-1 summarizes the initial WAC parameters for HLW feed that will be used in the initial gap analysis. Table A-1 in Appendix A provides the discussion and down selection of what HLW feed parameters are carried forward in this analysis. The "#" in Table 3-1 includes a "W" (except for Abrasivity – see footnote 2) to denote that these parameters are included in the WTP WAC when the parameters are referred to elsewhere in this document. As stated in Section 1.2, the focus of this gap analysis is on HLW feed; LAW feed is not addressed.

Table 3-1. Initial HLW Feed WAC Parameters for the Initial Gap Analysis.

#	Parameter	Value
W1	Solids Concentration	≤ 200 g/L
W2	Viscosity (delivered feed)	<1 Pa (yield stress) <10 cP (consistency viscosity)
W3	Slurry pH	≥ 12
W4	Bulk Density of Slurry	< 1.5 kg/L
W5	Critical Velocity	≤ 4 ft/s
W6	Ammonia Concentration	< 0.04M
W7	Separable Organics	No Visible Layer
W8	Polychlorinated Biphenyls (PCBs)	< 50 ppm
W9	HLW Feed Unit Dose	<270 Sv/g[1]
W10	Pu to Metals Loading Ratio	<6.20 g/kg
W11	U Fissile to U Total	<8.4 g/kg
W12	Pu Concentration of Liquids	<0.013g/L
W14	Hydrogen Generation Rate	2.1 E-06 gmole H_2/L/hr @ 150 ˚F
W15	Temperature	< 150˚F
W22	Sodium Concentration	0.1 to 10 M
W23	Total Organic Carbon (TOC)	< 10wt%
W24	Waste Feed Compatibility	Δ of +/- 20 ˚C
A1	Abrasivity	TBD

[1]The value provided is equivalent to the 2.9E5 Sv/L in Table 8 of ICD 19. The converted value (270 Sv/g) assumes 66% solids fraction (volume) and 1.63 g/mL density for the wet centrifuged solids as per the ICD 19 Table 8 footnote.
[2]Abrasivity replaces particle hardness and median particle size as the erosion parameter. The discussion for this replacement is provided in Appendix A.

A number of the parameters in Appendix A are not retained for gap analysis later in this document. The rationale for why a specific parameter was not retained is provided in Table A-1

of Appendix A. However, this does not indicate that the listed criteria is not part of the HLW feed WAC, just that the parameter is not analyzed further in this initial gap analysis.

3.2 POTENTIAL NEW NUCLEAR SAFETY PARAMETERS

The Defense Nuclear Facilities Safety Board (DNFSB) has expressed concerns related to the mixing and transfer systems in the WTP. In response, the DNFSB issued Recommendation 2010-2, *Pulse Jet Mixing at the Waste Treatment and Immobilization Plant* (DNFSB Recommendation 2010-2), which was accepted by the DOE in February 2011. This recommendation addressed the need for the DOE to ensure that the WTP, in conjunction with the TFC, will operate safely during its operating life by mitigating mixing and transfer risks relating to the accumulation of fissile materials, generation and accumulation of hydrogen, and PJM operation and controls. In response to the DNFSB recommendation, the DOE issued an implementation plan (11-WTP-427) that provides commitments, responsibilities, and schedules for activities to address the DNFSB's recommendation. One of these commitments is 2010-2 Commitment 5.7.3.4 which is to:

> *Identify key inputs, assumptions, safety margin uncertainties, and nuclear safety parameters required to be included in the waste acceptance criteria.*

Subject to annual updates, this commitment was initially met by the WTP in January 2012 by issuing report 24590-WTP-RPT-ENS-11-021. This report provides a source of potential new nuclear safety parameters for consideration in this initial gap analysis.

The intent of this subsection is to provide a listing of potential new parameters for HLW feed. (As stated in Section 1.2, the focus of this gap analysis is on HLW feed; LAW feed is not addressed.) This listing will use the "Potential New Nuclear Safety Parameters" from Section 4.4.2 of the 2010-2 Commitment 5.7.3.4 report (24590-WTP-RPT-ENS-11-021) as a starting point and will augment the list by considering any additional parameters in the WAC DQO document. In addition, the open items in ICD 19 and the WAC DQO are evaluated to determine if the closure of these items may impart new potential parameters to this listing. Note that none of these potential new parameters is to be considered as HLW WAC.

The summation of all the current potential new nuclear safety parameters, along with the WAC parameters in Section 3.1, will serve as the basis for the initial gap analysis which will be used to document areas where additional technical development is required to address any gaps. These potential new nuclear safety parameters are <u>not</u> to be considered as part of the WTP WAC. They are considered in this Initial Gap Analysis to provide the WTP and TOC program managers with information needed for long term decision making. Following the completion of the WTP and TOC testing, the WTP WAC will be updated as necessary (2010-2 Commitment 5.5.3.3) and will be used as input to the final gap analysis (2010-2 Commitment 5.5.3.9). Commitment 5.5.3.3 will evaluate the list of potential new nuclear safety parameters then existing and will have the potential for establishing other ones based on testing (such as LSIT) and ongoing process evaluations (such as erosion/corrosion) for possible inclusion in ICD 19. Following the final gap analysis, the updated WAC will be documented in a revision to ICD 19 that will be used as input to the WAC DQO, resulting in the Optimized WAC DQO (2010-2 Commitment 5.5.3.10).

Table 3-2 summarizes the potential new nuclear safety parameters for HLW feed that will be used in the initial gap analysis. Table A-2 in Appendix A provides the complete listing of the potential parameters evaluated for HLW feed. The listing in Appendix A includes the potential new nuclear safety parameters from the 2010-2 Commitment 5.7.3.4 document (denoted with an "N" in the parameter "#") that apply to HLW feed as well as any potential parameters from the WAC DQO and from the anticipated closure of ICD 19 and WAC DQO open items (denoted with an "A" in the parameter "#"). The "N" parameters in Table A-2 include the entire list of parameters from Section 4.4.2 of the 2010-2 Commitment 5.7.3.4 document that apply to HLW feed, but some of these parameters are duplicate of parameters already considered as HLW WAC (see Table 3-1). Where this occurs, it is so noted in the "Discussion" column in Table A-2 and the reference to the applicable HLW WAC parameter is included. In addition, the number portions of potential new nuclear safety parameters are the same as the parameter number from Section 4.4.2 of the 2010-2 Commitment 5.7.3.4 document. This provides an easy cross-reference for the parameters.

A potential new nuclear safety parameter listed in 24590-WTP-RPT-ENS-11-021, Parameter N19 in Table A-2, addresses discrete fissile (e.g., plutonium oxide) particles. However, since the required criticality safety analysis has not been completed, no specific control parameters are available for assessment in this gap analysis. Once this criticality safety analysis is completed (see planning document 24590-WTP-PL-ENS-11-0005) and if additional WAC parameters are required to ensure the safety of the WTP facilities, then these additional parameters will be evaluated for gaps.

Table 3-2. Potential New Nuclear Safety Parameters for the Initial Gap Analysis.

#	Parameter	Value
N15	HLW Feed Particle Size	≤ 210μm
N18	Upper Bound Settled Layer Shear Strength	<200 Pa within 24 hours
N20	Average Particle Density of Pre-Leached Solids	≤ 2.18kg/L

3.2.1 ICD 19 Open Items

Appendix D of ICD 19 contains fifteen (15) open items, and a number of these items pertain to waste feed acceptance. The plans for closing these items are articulated in RPP-PLAN-53354, *One System Plan for Closing WTP Feed Acceptance Criteria Issues, Open Items and Actions*. These plans provide ties to existing activities (primarily other 2010-2 commitments) that are expected to address the issue or, if required, to initiate new activities addressing the items. These items have been reviewed for inclusion as "initial WAC" parameters, but the closure of these open items is not addressed further as a "gap" in this report. For the closure plan for the ICD 19 open items, see RPP-PLAN-53354.

Excerpts from the open items in ICD 19 that may result in new parameters are repeated below:

1. *ICD 19 needs to incorporate the Particle Size Density Distribution [PSDD] used in recent testing to form the acceptance window for solids.*

2. *The ICD needs to acknowledge that WTP does need to know the properties of particles/waste that are needed for mixing evaluations….*

3. *Determine if limits on yield stress and consistency need to be incorporated into ICD 19, Table 8 (Waste Acceptance Criteria).*

As stated previously, these items have been reviewed for inclusion as initial WAC parameters by the following:

- For items 1 and 2 above, a full PSDD is not currently defined as being required by the WTP. In Table 3-2, a maximum particle size and an average particle density are identified as potential new nuclear safety parameters (N15 and N20 respectively). These are the currently defined parameters relating to particle size and density utilized by the WTP. Future testing may redefine these parameters and/or add other parameters relating to particle size or density, but it is speculation to assume what other parameters would be required. Therefore, no additional potential new nuclear safety parameters are proposed based upon these open items.

- For item 3, a slurry rheology limit is included as W2 in Table 3-1.

Note that the ICD 19 open items have been addressed for inclusion as potential parameters, but this addressing does not constitute closure of the open item. The intent is to demonstrate that the open item was considered when the parameters to be included in this initial gap analysis were developed. As stated previously, see RPP-PLAN-53354 for the closure plan for the ICD 19 open items.

3.2.2 WAC DQO Open Items

Section 9.1 of the WAC DQO includes 15 open items that were expected to require further actions to close. Near term statuses for the WAC DQO open items are included in the WTP memorandum CCN 249897, "Update to WTP WAC DQO – One System.". The accompanying table in the WTP memo provides the expected closure plan/tie for the open items. These closure plans/ties include references to existing DNFSB 2010-2 commitments and/or internal WTP action tracking system (ATS) items. The items listed as "closed" in the WTP memo do not impact the WAC. Following the WTP memo, the report RPP-PLAN-53354 provided further detail on the WAC DQO open items and their planned closure method.

As with the ICD 19 open items, a number of the WAC DQO open items pertain to waste feed acceptance. However, unlike the ICD 19 open items, the WAC DQO open items do not suggest the inclusion of additional WAC beyond those already included in the WAC DQO Tables 4-1 and 4-2. Therefore, the closure of these open items is not expected to result in additional WAC parameters. For the closure plan for the WAC DQO open items, see RPP-PLAN-53354.

4.0 ASSESSMENT OF CURRENT TANK FARM CAPABILITIES

This section provides an overview of the tank farm's capabilities and WAC quantification uncertainties relative to the staging and transferring of HLW feed to WTP. It summarizes the latest simulant testing completed to date (as of June 20, 2012) on tank mixing and sampling as supporting background for the uncertainties discussion. It discusses the possible sources of WAC quantification sampling and analytical uncertainties in sufficient details to provide input to the initial gap analysis in Section 6.0.

4.1 HLW FEED STAGING AND TRANSFER

This section provides an overview of the WFD process to set the framework for discussion of transfer equipment required to mix, sample and transfer HLW to WTP. Latest testing and assessments of these transfer equipment are compiled as applicable to support the gap analysis.

4.1.1 HLW Feed Delivery

The Integrated Waste Feed Delivery Plan (IWFDP) describes how the DST in the tank farm will be used to receive, stage, and deliver waste feed to WTP (RPP-40149-VOL 1, *Integrated Waste Feed Delivery Plan Volume 1 – Process Strategy*). As delineated in the IWFDP, the WFD logic for a typical HLW campaign is expected to proceed as follows:

1) A tank operating as a HLW feed tank is identified to receive staged waste, from one or more tanks operating as HLW feed staging tanks, for delivery to the HLW receipt tank in WTP. Waste compatibility and process control samples are taken prior to filling the HLW feed tank in order to generate a waste compatibility assessment and to assist in the development of the process control plan for the identified HLW feed tank.

2) After the feed is fully prepared, the HLW feed tank undergoes a prescribed hold time of thirty (30) days for mixing and sampling, and an additional 180 days for waste characterization, to confirm that the feed meets the waste acceptance criteria. Sampling of HLW is performed while the mixers pumps are in operation. A pre-transfer flush of inhibited water precedes the designated waste transfer – this preheats the transfer line and helps prevent solids precipitation during the waste transfer. The HLW feed campaign is then transferred to WTP HLW feed receipt tank, HLP-VSL-00022, in multiple batches, targeting up to 145 kgal per batch received.

3) The HLW feed tank is mixed prior to each HLW batch delivery to the WTP, and the transfer line will be flushed with inhibited water to clear it of any remaining waste following each HLW batch transfer. The received HLW feed may then be transferred by WTP to the Ultra-filtration Process System (UFP) system, depending on the specific gravity (SpG) and wt% solids in the waste, until the HLW feed receipt tank transfers out enough waste to receive another 145 kgal. This process is then repeated for each HLW campaign, with a goal of ensuring that the steps required for the next campaign of HLW batches to be transferred are completed prior to WTP requesting the feed.

4) The "pre-transfer" samples (vs. process control samples) to be taken in the HLW feed tank to confirm that the feed meets the waste acceptance criteria are the focus of this initial gap analysis. The quality requirements of these pre-transfer samples and the associated waste acceptance decision process are defined by the initial WAC DQO (24590-WTP-RPT-MGT-11-014) for the WTP WAC. The initial WAC DQO provides the statistical hypothesis testing framework for calculating the required number of samples based on uncertainties in the sampling and analytical capabilities. While the ICD 19 and the initial WAC DQO do not represent all finalized requirements and includes action items that need to be addressed, it does provide a starting point to begin identifying gaps in requirements and system capabilities (Chu, 2011).

The DST configuration and transfer equipment planned for HLW feed delivery to WTP are described in details in the 2010-2 IP Commitment 5.5.3.2 study (RPP-RPT-51652). In general, the DST configuration and transfer system infrastructures for HLW transfer include:

- Mixer Pumps (2)
- Transfer Pump (1)
- Primary and Secondary (annulus) Exhaust Ventilation
- Tank Instrumentation (temperature, level, pressure, and others)
- Transfer Lines (underground and aboveground[2])
- Equipment Pits
- Jumpers and Valves Assemblies

Traditional grab and core sampling methods are not sufficient to demonstrate compliance with the waste acceptance criteria for HLW slurry, which assumes the pre-transfer samples are representative of the staged feed and transferred material. Upgrades are being developed for a flow certification loop concept with a remote sampler (Isolok™ Sampler) to allow in-line sampling and a PulseEcho system for in-line detection of solids settling. New mixer pumps and transfer pump are also planned to complete the necessary DST upgrades in support of HLW feed delivery. The latest design configurations and operations of these equipment upgrades are described in more details in RPP-RPT-51652.

The WFD process involves primarily three (3) DST sub-functions: mixing, sampling, and transferring. The latest results of studies and testing of these systems are compiled in the following sections for use as input to the uncertainties discussion as applicable in Section 4.2. The PulseEcho detector development is discussed as a part of the sampling system. The laboratory analysis of the pre-transfer samples is an off-line interface function of the DST. The laboratory for waste acceptance analysis (assumed to be 222-S) is discussed as a part of the WTP capability in Section 5.0.

[2] Aboveground transfer lines are considered temporary.

4.1.2 Tank Mixing System Benchmark

The HLW feed stream to WTP contains undissolved solids with a wide range of physical properties and settling characteristics. Adequate mixing in the DST is required to properly sample and characterize these solids to determine waste acceptance for transfer to WTP. Mixing in a DST configuration is a known project risk due to uncertainties in system performance with actual staged waste. A Small Scale Mixing Demonstration (SSMD) program is being implemented by the TFC to address DST mixing in four (4) progressive phases. Phases 1 and 2 have been completed to date. Phase 3 (optimization) is in progress. Phase 4 (full-scale) is scheduled for completion between FY2013 – FY2017. A comprehensive review of mixing work done to date is documented in RPP-50557, *Tank Waste Mixing and Sampling Update*. The benchmark information in this report reflects the conclusions in RPP-50557 and the latest Phase 2 testing results as summarized in RPP-49740, *Small Scale Mixing Demonstration, Sampling & Batch Transfers Results Report*. Future results from Phase 3 and 4 demonstrations will be incorporated in the final gap analysis.

For the purpose of this initial gap analysis, mixing performance is graded relative to the control of sampling errors (see 4.2.1). Ideal mixing would mean tank content is being homogenously mixed or that batch to batch variations reduced or eliminated, and thus mixing performance correlates to Grouping and Segregation Error (GSE) and Long Range and Periodic Heterogeneity Errors (see 0). The Phase 2 SSMD was mainly focused on determining the effects of process parameters on pre-transfer sample representativeness and the trend of batch transfers that characterizes tank mixing performance. The test concluded the following relative to these specific objectives among others (RPP-49740):

1. The batch transfer %RSD of the individual particulate components are below 30% at jet mixer nozzle velocity greater than 22 ft/s in the 43.2” tank and 28 ft/s in the larger 120” tank.

2. The total solids mass %RSD for the five batch transfers achieved the test objective of within 10% at a jet mixer nozzle velocity greater than 20 ft/s in the 43.2” tank and 30 ft/s in the larger 120” tank.

The above %RSD results are incorporated based on preliminary mixing and transfer uncertainties in Table 4-2. These uncertainties will be refined as additional information regarding mixing and transfer from the SSMD program are available.

Simulant used during Phase 2 SSMD was modeled on waste in tank AY-102 in water (non-cohesive), which is considered conservative from the perspective of mixing and transferring of fast settling solids (RPP-49740).

Historical testing results dating back to April 2009 have provided incremental understanding in mixing performance. Results of the various testing, workshops, expert panel summits, and Computational Fluid Dynamic (CFD) studies are summarized in RPP-50557, Table 2-1. Collectively these results support the current understanding on DST mixing and effect on batch transfer as follow:

1. DST tanks are not homogeneously mixed.
2. Testing non-cohesive particles in water is conservative relative to fast settling solids.
3. More particulates are captured in the pre-transfer sample than subsequent transfer batches.
4. Pre-transfer sampling tends to overestimate fast settling particulates.
5. Batch-to-batch variability as indicated by bulk density is within 10%.

A separate technical analysis to look at the limits of performance of the baseline mixing system with respect to mobilization of large and heavy undissolved solids was discussed in RPP-RPT-51652. Conclusions of this study are consistent with the SSMD results to date, including that the higher density and viscosity (Non-Newtonian) is expected to increase the capability of the system for transferring rapidly settling particles. More transfer system-related results and conclusions are discussed in Section 4.1.4.

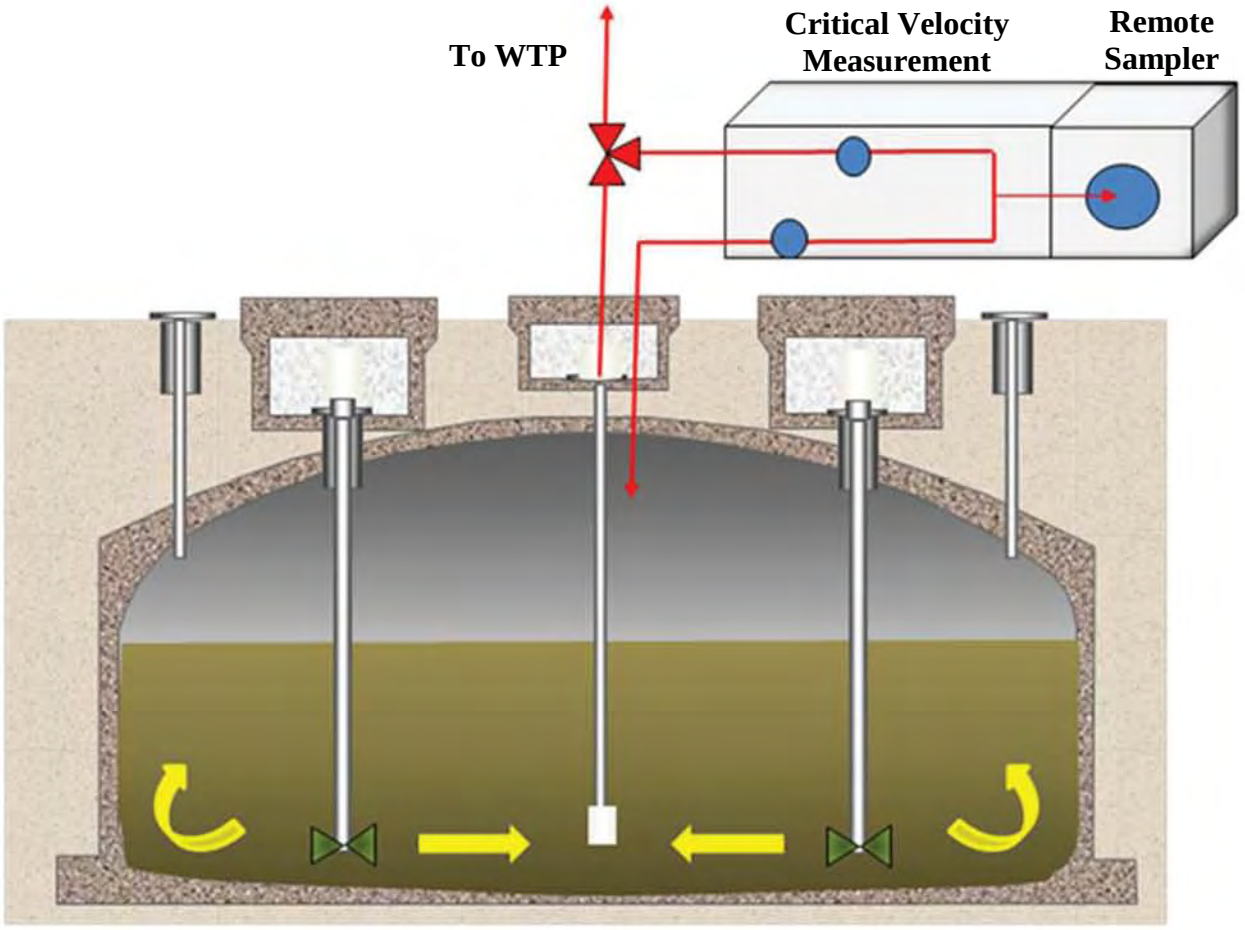
4.1.3 Tank Sampling System Benchmark

The pre-transfer sample provides the basis for the waste acceptance decision. The WTP WAC DQO assumes this sample is "representative" of the staged feed and transferred material (24590-WTP-RPT-MGT-11-014, Section 7.1, Assumptions 1 and 2). Initial SSMD testing has confirmed that there is variability and bias in the pre-transfer sample and between transferred batches due to mixing performance for undissolved solids (RPP-49740).

4.1.3.1 *Remote Sampling Demonstration*

Additional uncertainties and bias may be introduced by the physical sampling device. The current baseline sampling system for HLW slurry is the Isolok™ sampler. It is a remotely operated sampling system that is designed to take multiple grab samples from a recirculating flow loop (Figure 4-1). The concept is to extract in-line samples from the transfer pump discharge piping while the tank is being mixed by the two mixer pumps under transfer conditions that are close to the actual transfer. To conduct the required WAC analysis, approximately 300 mL of slurry containing at least 30 g of solids is recommended for each sample (24590-WTP-RPT-MGT-11-014).

Figure 4-1. Feed Certification Flow Loop and Remote Sampler System.[3]



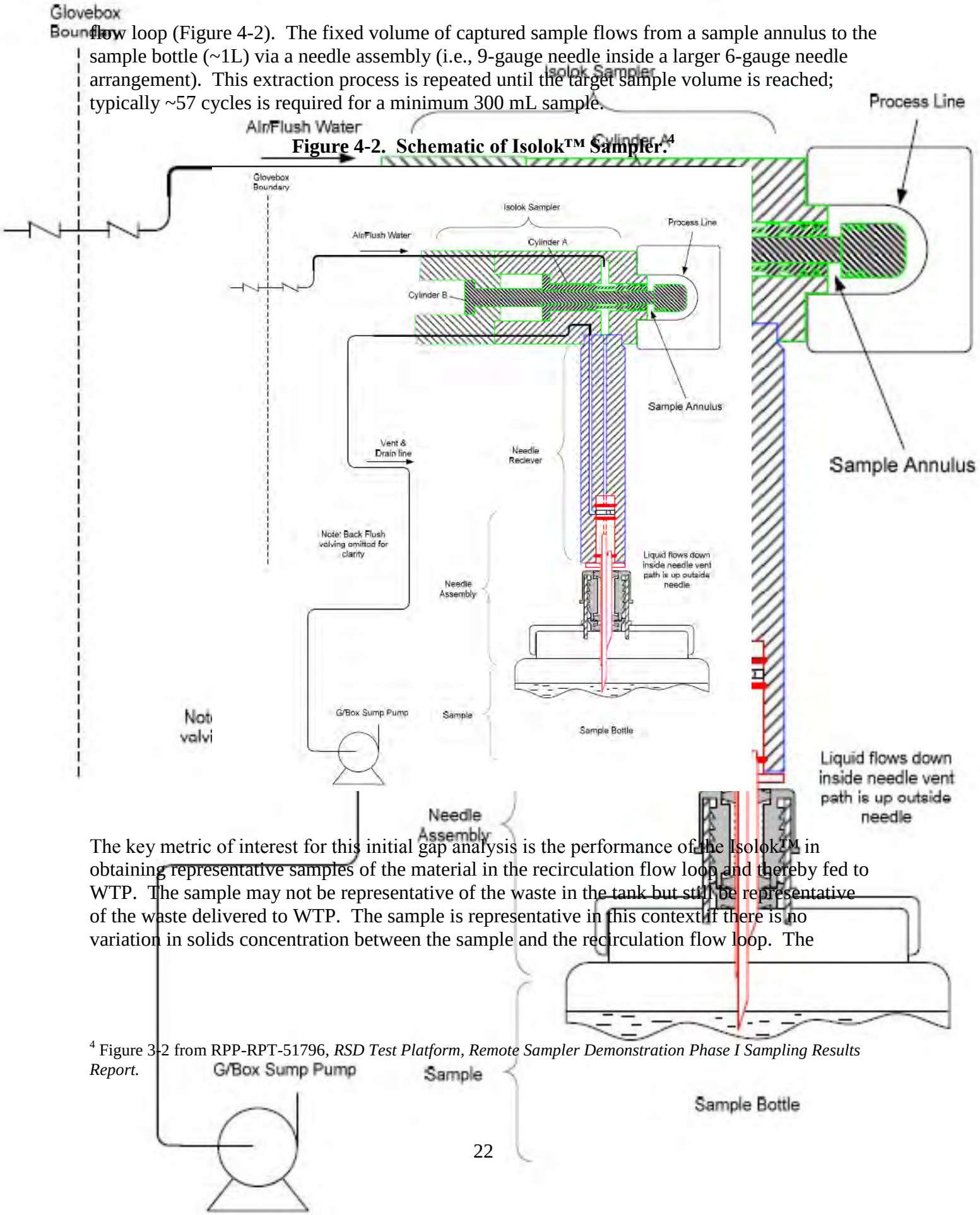
Although the Isolok™ system has similar applications at Hanford, including the 242-A Evaporator and WTP, there is little sampling experience with the HLW staged feed. Phase 1 of the Remote Sampling Demonstration program was initiated in 2011 to demonstrate the fundamental principles and capabilities of the Isolok™ sampling system. Sampling capability benchmark in this initial gap analysis is largely based on the Phase 1 results as documented in RPP-RPT-51796, *RSD Test Platform, Remote Sampler Demonstration Phase I Sampling Results Report*. There are additional mechanical handling demonstrations and optimizations planned for Phase 2. Results from the ongoing testing and development work will be reflected as appropriate in the final gap analysis.

The Isolok™ sampler was installed in a Remote Sampler Demonstration platform that recirculates contents in an agitated tank. The Isolok™ sampler tested is a full scale unit with the capacity to capture a fixed volume of liquid (~5.3 mL per extraction) from a 3" diameter transfer

[3] Figure 3-2, RPP-RPT-51652, *Evaluation of Waste Transferred to the Waste Treatment Plant.*

flow loop (Figure 4-2). The fixed volume of captured sample flows from a sample annulus to the sample bottle (~1L) via a needle assembly (i.e., 9-gauge needle inside a larger 6-gauge needle arrangement). This extraction process is repeated until the target sample volume is reached; typically ~57 cycles is required for a minimum 300 mL sample.

Figure 4-2. Schematic of Isolok™ Sampler.[4]



The key metric of interest for this initial gap analysis is the performance of the Isolok™ in obtaining representative samples of the material in the recirculation flow loop and thereby fed to WTP. The sample may not be representative of the waste in the tank but still be representative of the waste delivered to WTP. The sample is representative in this context if there is no variation in solids concentration between the sample and the recirculation flow loop. The

[4] Figure 3-2 from RPP-RPT-51796, *RSD Test Platform, Remote Sampler Demonstration Phase I Sampling Results Report.*

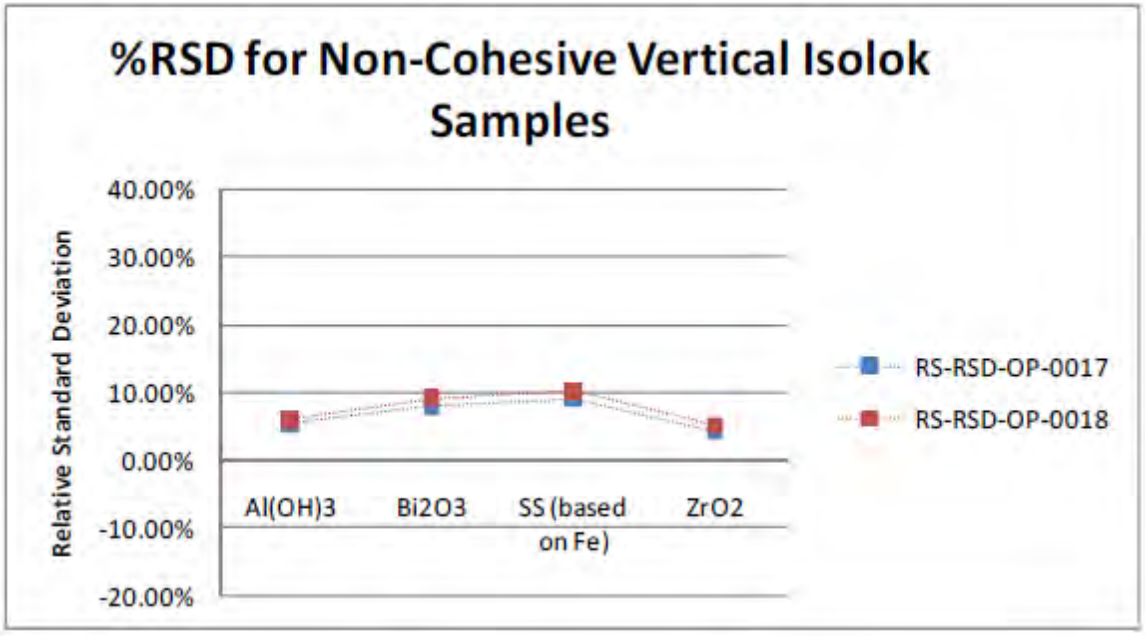
variation is measured in terms of %RSD. The %RSD essentially accounts for both Extraction (EE) and Delimitation Errors (DEs) adhering to Pierre Gy's principle (see 0).

Phase 1 was conducted with two combinations of sampler mounting orientation (horizontal and vertical) and simulant makeup (cohesive and non-cohesive). Simulant used during Phase 1 was modeled on the waste in tank AY-102.

There were numerous observations and troubleshooting during Phase 1. However, a trend was established that supports the following general indicative conclusions that are applicable to the initial gap analysis (RPP-RPT-51796):

1. Sample obtained by the Isolok™ was not representative (i.e., did not meet the established acceptance criteria consistently for all solids).
2. Variation of solids concentration between sample and recirculating flow loop is within %RSD of 10% for Bi_2O_3 (Figure 4-3).

Figure 4-3. %RSD for Non-Cohesive Vertical Isolok™ Sampler.



The mounting position of the Isolok™ was changed from horizontal to vertical as a result of troubleshooting, and now only the vertical orientation results are carried forward as benchmark. Reasons for the indicative bias toward larger and heavier solids (Bi_2O_3 and Stainless Steel (SS)) are thought to be attributed to Isolok™ orientation. More testing will be conducted in Phase 2 to further investigate/optimize the %RSD trend observed in Phase 1.

4.13.2 *PulseEcho System*

Critical velocity (CV) is a term used to describe the slurry transfer velocity below which pipeline solid particulate deposition occurs. It can be estimated using correlations such as Oroskar and

Turian or AD Thomas, but for HLW staged feed to WTP, CV will be measured (24590-WTP-RPT-MGT-11-014).

The Pacific Northwest National Laboratory (PNNL) led the development effort for various ultrasonic instruments to detect CV. The work concluded with the recommendation of the PulseEcho system for field deployment. The PulseEcho system measures the signal amplitude modulation caused by particles within the fluid in the transfer piping to detect the onset of settling. The slurry flow velocity in the pipe is measured separately (e.g., Coriolis meter) to indicate the CV corresponding to the onset of solids settling.

Testing to date of the PulseEcho system consists of various sensors and mounting configurations with different simulant combinations. More testing is underway but for the purpose of this initial gap analysis, the latest results and conclusions of PulseEcho performance are taken from Phase III (PNNL-19441, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments*) and Phase IV reports (PNNL-20350, *Hanford Tank Farms Waste Certification Flow Loop Phase IV: PulseEcho Sensor Evaluation*). Collectively, these two reports document the latest understanding on the capability of the PulseEcho system as applied for CV detection in the waste certification flow loop configuration.

The PulseEcho system will be installed in the certification flow loop to be deployed at the DST for HLW staged feed (Figure 4-1). The system will detect the onset of solids settling in the 3" transfer pipe to WTP. Because the detection will be done "in-line" vs. off-line sample analysis, the uncertainties of interest for the gap analysis are mostly focused on the installed instrument accuracy/precision. The latest demonstrations conducted by PNNL have concluded the following, relative to accuracy/precision/range among others (PNNL-19441, PNNL-20350):

1. PulseEcho measurement of CV is accurate within ± 0.3 ft/s for all test runs in Newtonian[5] and Non-Newtonian[6] simulants.
2. PulseEcho equipped with a 5-MHz transducer can detect onset of settling for >50 μm particles in a full Schedule 40 pipe wall thickness.
3. Detection of CV for smaller (>20 μm) particles requires a 10-MHz transducer.
4. Detection of CV tested and demonstrated with >2 wt% solids concentration in the transfer fluid.

Note that PulseEcho detection accuracy of CV was validated using experimental results, which is based on visual and camera inspection of flow regimes II and III (PNNL-19441). Flow regime II corresponds to focused axial motion. Flow regime III corresponds to a pulsating sliding bed as observed in two sections of clear spool pieces upstream and downstream of the PulseEcho. The accuracy has some inherent bias, depending on the tester, but it accounts for all instrument loop measurement uncertainties. A performance verification procedure is completed before each PulseEcho device is deployed in the field. Total measurement uncertainties of the instrument

[5] Table 11-1, Critical Velocity Measurement for Newtonian Simulants – PNNL-19441.
[6] Table 11-2, Critical Velocity Measurement for Non-Newtonian Simulants – PNNL-19441.

loop should account for the magnetic flow meter, Coriolis meter (if used), the data acquisition system, and possible environmental effect.

4.1.4 Tank Transfer System Benchmark

Tank transfer system capability was evaluated as a part of the 2010-2 IP (Chu, 2011), Commitment 5.5.3.2. This commitment addresses the definition and determination of performance capabilities of the retrieval and transfer system. Report RPP-RPT-51652 was issued on June 26, 2012 as a deliverable for Commitment 5.5.3.2. This report provides the main source of input for this initial gap analysis relative to the transfer system benchmarks including:

1. Preliminary range of physical properties including particle size, particle density and rheology for waste anticipated to be delivered to WTP with the current feed staging and **t**ransfer concepts. Table 4-1 below summarizes the finding on bounding particle size and density that may be transferred to WTP:

Table 4-1. Particle Size and Density Combinations.[7]

Particle	Diameter (µm)	Density (g/mL)
Most dense primary particle (Pu)	100	19
Largest primary particle observed by Scanning Electron Microscopy (SEM) (gibbsite)	200	2.4
Largest particle hypothetically combined with highest density (Bi_2O_3) in AY-102	1,268	8.9
Agglomerate based on PSD limit (gibbsite)	1,441	1.6
Largest particle hypothetically combined with highest density (Ag_2O) in AZ-101	1,441	7.14
Largest agglomerate based on pump screen mesh (gibbsite)	9,525*	1.43

Notes: *9,525 µm = ⅜-inch.

2. Rheology studies concluded as stated in RPP-RPT-51652:

   The available rheology data were reviewed and separate plots were produced for each tank with data. For the sludge waste (i.e., containing undissolved solids), viscosity ranged from near 1 cP at 0.1-wt% solids to slightly more than 100 cP at 18-wt% solids. Yield stress data ranged from near 0.1 Pa at 1-wt% solids to near 80 Pa at 18-wt% solids. Yield stress data were fit with a power law function for various temperature ranges, and viscosity data were fit with an exponential function for various temperature ranges. These fits were then used to predict yield stress and viscosity at 10 wt% undissolved solids through interpolation or extrapolation. Except for one outlier (C-109), yield stress predictions at 10-wt% undissolved solids fell within a range of less than 0.01 to 12 Pa. The tank data suggest some feed batches would exceed a yield stress of 1 Pa. Similarly,

[7] Table ES-1, Particle Size and Density Combinations Used in Calculations, RPP-RPT-51652.

viscosity predictions fell within a range (except for the same C-109 outlier) of 0.79 to 13.54 cP.

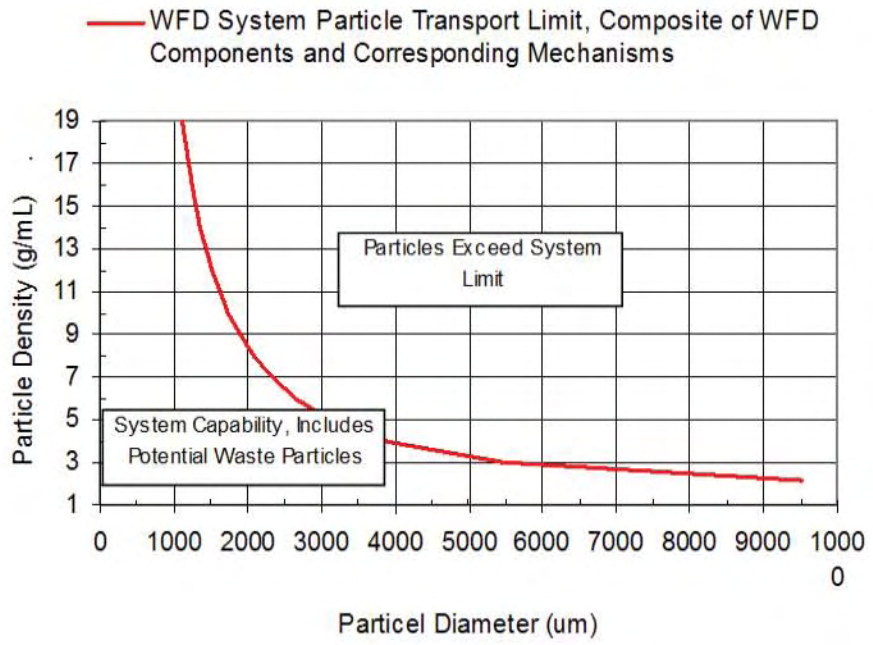
A literature review for the potential effects from waste mixing and blending suggests complicated relationships among particles sizes, solids fraction, particle and liquid densities, and repulsive and attractive forces. No good predictive tool exists for estimating yield stress and viscosity in mixed/blended wastes and prediction of these properties is not attempted in HTWOS. Waste feed samples taken from the flow loop with the remote sampler will be tested for rheological properties. There will be about 600 mixed and blended HLW feed batches during WFD, and current data on blended waste is limited. It is likely that the ranges of yield stress and viscosity for all feed batches will be greater than the data ranges presented in this document (RPP-RPT-51652).

3. Transfer system capabilities based on particle size and density. Figure 4-4 below depicts a range of particle size and density that defines the system limitation. The WFD system transport limit capabilities are determined for waste properties established by characterization of the Hanford waste and the evaluated uncertainties of that characterization data. The line in Figure 4-4 corresponds to the WFD system limit for particle transport where particles are represented by size and density combinations. The WFD system is capable of delivering to the WTP the particles (as identified with size and density) that lie on or to the left of the line. The particles that lie to the right of the line exceed the WFD system capabilities. WFD system components analyzed for limits of performance with respect to UDS particle size and density include:

    - Jet mobilization and transport of particles to the transfer pump
    - Particle entrainment into the transfer pump
    - Particle motion in the vertical transfer pipeline
    - Particle transfer in the horizontal pipeline

    The potential limiting waste particles (maximum size and density) listed in Table 4-1 are to the left of the WFD system particle transport limit as denoted in Figure 4-4. Hence, it is concluded that the potential limiting waste particles from Table 4-1 do not exceed the limits of performance of the WFD system (see RPP-RPT-51652, Section 7.4 for more discussions).

Figure 4-4. Transfer System Particle Transport Limit. Representative Bounding Liquid (1.37 g/mL, 14 cP), Limiting Pipeline Length and Pressure, 0.99 miles, 400 psig.[8]



4.2 HLW FEED UNCERTAINTIES

Tank mixing and sampling capabilities in a DST for HLW staged feed to WTP are areas of known risks as discussed in various studies and reports, including the DNFSB Recommendation 2010-2. The risks are invariably linked to uncertainties in the HLW feed stream and the overriding question: *Does the staged feed meet the WTP WAC for transferring the feed to WTP?*

To properly address the fundamental question of waste acceptance compliance, it is necessary to understand the possible sources of uncertainties and relate them to each of the WAC parameters. Not all of the WAC parameters carry the same level of uncertainties. Parameters with largely liquid phase constituents would have fewer uncertainties (assuming the liquid constituents are miscible) because they are less sensitive to tank mixing performance, and therefore, the pre-transfer sample would be presumably more "representative" of the staged feed. Likewise parameters that target undissolved solids in terms of size/density distribution or other physical properties of the blended feed would have more uncertainties because of heavy dependence on tank mixing and sampler performance to ensure a representative or bounding pre-transfer sample.

[8] Figure ES-1, WFD System Particle Transport Limit. Representative Bounding Liquid (1.37 g/mL, 14 cP), Limiting Pipeline Length and Pressure, 0.99 miles, 400 psig, RPP-RPT-51652.

This section describes the different elements that make up the total feed uncertainties and summarizes the development of %RSD values for each of the major element. These %RSD values are then used in the feed screening process in Section 6.0.

4.2.1 Elements of Total Feed Uncertainties

The total feed uncertainties start with the characterization of source tanks that will be retrieved to produce the staged (or blended) feed. However, because of the interface control requirement to sample the staged HLW feed for WAC compliance prior to any tank transfer to WTP, the feed uncertainties for the purpose of this initial gap analysis starts at the pre-transfer sample taken at the staged HLW feed DST.

For normal operations (excluding abnormalities such as equipment failures or human errors), the two dominant sources of uncertainties considered for this Initial Gap Analysis are traceable to sampling and analytical errors. There are other uncertainties (e.g. associated with the results from preliminary tests) described in Section 2 that this Initial Gap Analysis does not address. Sampling errors are affected by the tank mixing operations, the batch-to-batch transfer process (i.e., variation in tank composition over time as tank level decreases), the retrieval of pre-transfer sample using Isolok™, and the physical handling[9] of the pre-transfer sample. Analytical errors are associated with in-line measurements (i.e., no sample) and laboratory analysis that also include sample handling (see Figure 2-1. Elements of Feed Uncertainties). The total uncertainties can be approximated by propagating each of the sampling and analytical error sources using the RSS method[10].

$$Total\ uncertainties = \sqrt{sampling\ \ errors^2 + analytical\ errors^2}$$

4.2.1.1 *WAC DQO Process*

The accounting of sampling and analytical errors in the waste acceptance decision process has been addressed as a part of error tolerance discussion in the initial WAC DQO (24590-WTP-RPT-MGT-11-014). The WAC DQO process provides an evaluation of the probability of decision error based on an estimation of the mean, variance, and number of samples. The uncertainty evaluation is used to assess the accuracy and precision specified for sample collection and analysis, the level of decision error, and the number of samples required to meet a given decision error rate. The general framework of the waste acceptance decision process assumes that the staged feed does not meet the acceptance criteria. The collected sample data must clearly indicate the acceptance criteria are met in order to accept the staged feed.

The number of samples required to meet a given decision error rate is calculated from the SD assuming a normal distribution. In general, the distribution of sample means approaches a normal distribution relatively quickly, as a function of sample size, in most cases where the

[9] Physical handling of sample refers to the manual handling of the sample during the retrieval and transport of sample bottles from the field to the lab.
[10] Mood, Graybill, and Boes, *Introduction to the Theory of Statistics*, 3rd Edition

original distribution is not too extreme. The validity of this condition (i.e., normal distribution) as an enabling assumption will be re-evaluated and revised (as needed) as the WAC DQO evolves. The uncertainties are shown as a %RSD, which is multiplied by the action limit to provide a conservative estimate of the SD for the sample size calculation. Details on the construction and interpretation of sample size graphs are discussed in the WAC DQO (24590-WTP-RPT-MGT-11-014). The initial gap analysis adheres to the same methodology and supporting assumptions in the WAC DQO process for calculating the number of samples, except for substituting with updated sampling and analytical %RSDs.

The following discussions on waste acceptance decision process are taken from the WAC DQO (24590-WTP-RPT-MGT-11-014). Refer to the source document for additional details.

The waste acceptance decision-making is accomplished using a statistical hypothesis testing framework. For most constituents, the requirement is that the constituent be below a specified action limit for the waste to be considered acceptable. Therefore, the null hypothesis (baseline condition) is the true (but unknown) mean value of the constituent and is greater than or equal to the action limit, i.e., the staged feed does not meet the acceptance criteria. A number of samples are taken, from which test statistics can be calculated to determine whether the null hypothesis can be rejected, i.e., whether there is substantial evidence to indicate that the constituent is below the action limit and the staged feed should be accepted. The decision reached using the test statistics is equivalent to comparing the calculated upper confidence limit on the mean value to the action limit. If the upper confidence limit is below the action limit, the null hypothesis is rejected, i.e., the staged feed is considered acceptable.

Specifying the significance level of the hypothesis test indicates the Type I error rate, which is the probability of rejecting the null hypothesis when in fact it is true (i.e., deciding the staged feed is acceptable to transfer when, in fact, it does not meet the acceptance criteria). In this hypothesis testing framework, the decision-making is impacted by the amount of data collected (number of samples), the variability in the data, the different error rates (which are generally based on acceptable risks), and what the "true" value of the constituent is. Unfortunately, one never knows what the true value of the constituent is, so the usual objective is to identify reasonable scenarios that can be evaluated in order to ultimately select the required number of samples.

4.2.1.2 *Mixing and Sampling Biases*

Generally, the WAC DQO process does not address the potential biases in the tank farm mixing and sampling systems. A bias is the difference between the measured "mean" and the "true" value of the constituents. It represents a consistent offset between the mean and true in one direction (non-random), and it is not the same as uncertainty. If the biases are known, then they may be applied toward the action limit (subtract or add) in the waste acceptance decision process. However, the biases of the system are never known in actual operations since the "true" value of constituents are never known. For example, during the pre-transfer sampling process, the various "true" values of solids concentrations in the staged feed tank may vary spatially and temporally, depending on mixer operations and other physical conditions (e.g., solids settling, solids accumulation, precipitation, etc.). The "true" values may also vary between the different feed campaigns. Mechanical equipment in the WFD system such as the transfer pumps and

Isolok™ Sampler often introduces other biases due to the physical design (size, capacity) and installation (location, orientation).

Biases introduced by the mixing and sampling systems can be measured in a laboratory setting when the "true" constituent is controlled and known. This information will be useful in optimizing the sampling system design and operations to minimize, but not completely eliminate, the effect of known biases. Preliminary testing completed to date indicates the mixing system and the sampling system performance may add positive bias to the fast settling solids concentration results. The final gap analysis report will address how biases identified from the simulant testing are incorporated as appropriate in the sampling system design and waste acceptance decision.

In this report, the known biases from preliminary SSMD and Remote Sampler Demonstration testing are acknowledged, but they are not addressed in the statistical hypothesis testing framework (i.e., measured biases from testing were not added or subtracted to the action limit). This approach is consistent with the WAC DQO in that the actual waste acceptance decision can never fully quantify and account for the various biases introduced in the WFD process, even though they may exist. Confidence that mixing and sampling biases are conservative or inconsequential, from a waste acceptance perspective, will have to be demonstrated prior to final waste acceptance.

4.2.2 Estimate of Sampling Percent Relative Standard Deviation

This section describes the development of sampling %RSD estimates using the assumptions described in Section 2.0. Sampling uncertainty is quantified in terms of %RSD. The lower the %RSD translates, the more accurate and precise the result. It is composed of sampling errors from tank mixing, batch transfer, sampling equipment, and sample handling. Each type of sampling error can be traced to some aspects of the Pierre Gy's sampling theory, but no definitive correlations have been established given limited understanding on tank mixing and sampler performance on the staged HLW feed. 0 briefly describes the Pierre Gy's seven basic sampling errors and how aspects of each are applicable to the physical collection of HLW staged waste samples.

The initial WAC DQO uses an estimate based on the general target of the sampling demonstration program of "within 10%." Rather than using a sampling %RSD of 3.3%, corresponding to three RSDs, a slightly more conservative value of the sampling %RSD of 4% was used as the base case to calculate number of samples, with 10% and 20% as sensitivity checks. The 4%, 10%, and 20% sampling %RSDs were applied for all WAC parameters.

The initial gap analysis expands on the WAC DQO approach by assigning a %RSD to each of the four (4) sources of sampling errors (mixing, transfer, Isolok™, sample handling), which is propagated to determine the overall sampling %RSD. In other words, the sampling %RSD now varies as a function of specific sampling errors and WAC parameters. This way of systematic "accounting" of uncertainties will help document and highlight specific areas of weakness. Table 4-2 summarizes the assigned %RSD and the calculated sampling %RSD.

Given the early phase of the WFD project, most of the sampling %RSDs are ranked using an incremental scale (0–20) based on qualitative assessment. Selection of range is subjective at this point based on general alignment with the preliminary SSMD and Remote Sampler Demonstration results (Section 4.0), with the understanding that 20% may not be bounding for every parameter. Certain quantitative results from the SSMD and the Remote Sampler Demonstration were incorporated into the analysis. It is acknowledged that the results are from preliminary tests and will need to be updated as new information arises. RSDs that are based on preliminary testing are noted in ***(bold)*** and the appropriate source report cited in Table 4-2.

%RSD (0 – 20) Definition:

0 = Not applicable. This ranking is only for direct measured parameters (e.g., temperature, CV).

1 = Minimum impact from sampling errors. This is a default ranking of most liquid phase analysis of WAC parameter where contribution from undissolved solids is negligible (e.g., pH). Also, this is a default minimum for co-precipitated fissile parameters (e.g., Pu to metal, $U_{fissile}$ to U_{total}) for the sampler since the ratios are maintained independent of Isolok™ sampling uncertainties.

5 = Moderate impact from sampling errors. This is a default ranking for most slurry (liquid + solids) analysis of WAC parameters.

10 = Significant impact from sampling errors. This ranking is applicable for slurry sample analysis that targets undissolved solids.

20 = Extreme or unknown impact from sampling errors. .

Table 4-2 lists the initial WAC parameters (ICD 19) and the potential new nuclear safety parameters as compiled from Section 3.0, Table 3-1 and Table 3-2 respectively. For each listed parameter, a sampling %RSD is assigned for the four (4) sources of sampling uncertainties. The associated rationale for selecting the 0 – 20 scale for each type of sampling error is given in the Bases and Assumptions column. The overall sampling %RSD is then used to calculate the number of samples in Section 6.0.

The reader should refer to Section 2.0 for the assumptions underlying quantification of the four (4) sampling uncertainties presented in Table 4-2 and discussed below:

Mixing – An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the tank at the time of sampling event. It is a term used to assess mixing performance. Rotation of mixer nozzles during a batch transfer introduces periodic heterogeneity error (see 0). The cyclic operation of the Isolok™ sampler helps minimize the effect from this type of error by compositing multiple samples (~5 mL) to make up the total sample volume.

Transfer – An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is transferred in subsequent batches. It is a term used to assess batch-to-batch variability over time. Variability of tank composition with decreasing tank level

introduces a non-periodic heterogeneity error. The less batch-to-batch variability, the lower the transfer %RSD value.

Isolok™ Sampler – An estimate of uncertainties relative physical and chemical differences between the pre-transfer sample and what is in the recirculation flow loop. It is a term used to assess sampler design. Physical configuration of the sampler design introduces delimitation (i.e., does not take full cross-section sample of the pipe) error. The larger the cross-section to full sample flow, the lower the sampler %RSD value.

Sample Handling – An estimate of uncertainties from physical preparation and handling of the pre-transfer sample from the time of sampling event to laboratory analysis. It is a term used to assess the integrity of the sample. Physical handling of the sample introduces preparation error (e.g., poor vapor seal, leaks, etc.). The better preservation of the sample, the lower the sample handling %RSD value.

Given the limited understanding of actual staged waste behavior under full scale operating conditions, all the assigned sampling %RSDs in Table 4-2, including those few that are based on preliminary SSMD testing, have inherent uncertainties. In other words, these are essentially best "ball park guesses" at this point. However, as shown from the limited sensitivity test in Section 6.0, and not considering the impact of the assumptions described in Section 2.0, the absolute %RSD value does not affect the number of samples significantly for most parameters unless the expected feed composition approaches the action limit. These qualitative sampling %RSD values may be refined with additional testing and updated in the final gap analysis.

Table 4-2. Sampling %RSD

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
HLW WAC Parameters (ICD 19)							
Solids concentration (g/L)	< 200	5	***(10)***	5	5	13.2%	**Mixing**: Default minimum for slurry (liquid and solids) samples. Mixing effect offset by sampling over one complete pump rotation and by compositing multiple sub-samples pulled by the Isolok over time. **Transfer:** Set to be same as for bulk density sample. **Isolok:** Default minimum for solids sample. **Handling:** Higher uncertainties (relative to a pure supernatant matrix) to account for added complexity with handling sodium solution near or at saturation (e.g., precipitation of salt from liquid sample).
Na Molarity (moles/L)	< 10	1	1	1	5	5.3%	**Mixing:** Default minimum for liquid samples. **Transfer:** Liquid samples not as sensitive to variability over time compared to undissolved solids. **Isolok:** Liquid samples not as sensitive to physical configuration or bias of Isolok. **Handling:** Same as for solids concentration sample.

[11] Root-Sum-Square method of propagation of mixing, transfer, Isolok™, and sample handling %RSD.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Slurry rheology (at 25°C) – consistency viscosity (cP)	< 10	5	5	5	5	10%	**Mixing:** Default minimum for slurry (liquid and solids) samples. **Transfer:** Lower batch variability effect expected on rheological properties. **Isolok:** Same as for solids concentration sample. **Handling:** Same as for solids concentration sample.
Slurry rheology (at 25°C) - yield stress (Pa)	< 1	5	5	5	5	10%	**Mixing:** Default minimum for slurry (liquid and solids) samples. **Transfer:** Lower batch variability effect expected on rheological properties. **Isolok:** Default minimum for solids sample. **Handling:** Same as for solids concentration sample.
Slurry pH	≥ 12	1	1	1	1	2%	**Mixing:** Slurry pH assumed to be the same as liquid and therefore use default minimum for liquid. **Transfer:** Default minimum for liquid. **Isolok:** Default minimum for liquid samples. **Handling:** Default minimum for liquid samples (not targeting any volatiles).
Slurry bulk density (kg/L)	< 1.5	5	***(10)***	5	5	13.2%	**Mixing:** Same as for the solids concentration sample. **Transfer:** Higher overall %RSD driven by batch-to-batch solids variations expected. Based on preliminary SSMD testing, relative batch trend of simulated HLW slurry bulk density was within 10% (ref. RPP-49740, Rev. 0). **Isolok:** Same as for the solids concentration sample. **Handling:** Same as for the solids concentration sample.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Critical velocity (ft/s)	≤ 4	10	10	0	0	14.1%	**Mixing:** RSD associated with this parameter will be driven largely by the analytical RSD for the instrument (i.e., PulseEcho). But mixing will change the recirculating flow loop composition in real time, which is detected by the Pulse-Echo, and as such mixing has the same impact as a physical sample. Default set higher than typical slurry samples since CV detection is targeting larger, heavier, and difficult to suspend solids. **Transfer:** Same rationale as for mixing. **Isolok:** Default (n/a) for in-line measurement. **Handling:** Default (n/a) for in-line measurement.
Ammonia (M)	< 0.04	1	1	1	5	5.3%	**Mixing:** Default minimum for liquid samples. **Transfer:** Default minimum for liquid samples. **Isolok:** Default minimum for liquid samples. **Handling:** Higher RSD to account for effect of volatile components.
Separable organics (visual)	no visible layer	20	10	1	1	22.4%	**Mixing:** Higher mixing impact to account for potential stratification of separated organics (i.e., floating on liquid surface). **Transfer:** Higher batch variability due to the same stratification of separable organics (i.e., may be higher in subsequent batches than captured in the pre-transfer sample). **Isolok:** Default minimum for liquid samples. **Handling:** Default minimum for liquid samples assuming no volatiles and no loss of sample due to adhesion of organics to sample bottle.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
PCB (ppm)	< 50	5	10	5	1	12.3%	**Mixing:** Default minimum for slurry samples assuming most PCBs are associated with solids. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Lower than typical slurry since PCB analysis are not sensitive to sodium precipitation or loss of volatile components.
TOC (wt%)	< 10	5	10	5	5	13.2%	**Mixing:** Targeting total liquid and solids and as such set to be the same as default minimum for slurry samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration although the concern is less with precipitation but loss of volatiles.
HLW Feed unit dose (Sv/g)	< 270	5	10	5	1	12.3%	**Mixing:** Targeting the solid fraction of the sample and as such set to be the same as default minimum for slurry samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Lower than for typical slurry sample since unit dose rate analysis is not sensitive to effect of precipitation or loss of volatiles.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Pu to metals ratio - solids (g/kg)	< 6.2	20	***(30)***	1	1	36.11%	This parameter applies to the co-precipitated Pu and not necessarily to the discrete Pu particles. The discrete fissile particles have not been evaluated from a criticality safety perspective as of yet, but this evaluation is planned (24590-WTP-PL-ENS-11-0005). See Section 3.2 and Table A-2 of this report (RPP-RPT-53343) for more discussion. **Mixing:** Highest overall RSD for tank farm mixing conservatively assumed. **Transfer:** Conservatively set to maximum RSD value from preliminary SSMD testing. SSMD testing showed that all solids are below 30% RSD at jet mixer velocity greater than 28.7 f/s in the 120" tank without accounting for uncertainty or the preliminary nature of the results. **Isolok:** Default low RSD for this parameter since sampling is not expected to affect the co-precipitated Pu/metal ratio. **Handling:** Lower than for typical slurry sample since Pu to metal ratio is not sensitive to effect of precipitation or loss of volatiles.
Pu to metals ratio - liquid (g/kg)	< 6.2	1	1	1	1	2%	**Mixing:** Set as default for liquid samples since the analysis is targeting Pu concentration in the liquid fraction only. **Transfer:** Default minimum for liquid samples. **Isolok:** Default minimum for liquid samples. **Handling:** Default minimum for liquid samples.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Pu concentration of liquids (g/L)	< 0.013	1	1	1	1	2%	**Mixing:** Set as default for liquid samples since the analysis is targeting Pu concentration in liquid only. **Transfer:** Default minimum for liquid samples. **Isolok:** Default minimum for liquid samples. **Handling:** Default minimum for liquid samples.
U fissile to U total (g/kg)	< 8.4	5	1	1	1	5.3%	**Mixing:** Set to default minimum for slurry parameter since mixing will not impact isotopic ratio. **Transfer**: Lower RSD expected than for typical slurry samples since the ratio will not change even if the batch concentration of uranium varies. **Isolok:** Default minimum for fixed fissile ratio parameter (same as Pu to metal ratio).**Handling:** Lower than typical slurry samples since $U_{fissile}/U_{total}$ ratio is not sensitive to precipitation or loss of volatiles.
HGR (gmoles H_2/L/hr @ 150°F)	2.1 E-06	5	5	5	5	10%	**Mixing:** HGR sample is targeting both liquid and solids. Default RSD to default minimum for solids samples. **Transfer:** Same as for solids concentrations sample. **Isolok:** Same as for solids concentration sample. **Handling:** HGR analysis is sensitive to loss of certain volatiles and as such set to be the same as the ammonia samples.
Temperature Change for	± 20	5	10	5	1	12.3%	**Mixing:** ASTM D5058-12 (supersedes D5058-90) stipulates mixing staged feed

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Waste Feed Compatibility (°C)		5	10	5	1	12.3%	(e.g., 10 mL) with the residual waste in feed receipt tanks (e.g., 10 mL) and therefore there are two independent samples required for this one analysis, one from tank farm and one from WTP. Assuming the same uncertainty for both samples, the mixing effect is combined statistically (Root Sum Square) together. Default both mixing RSD to be the same as solids concentration samples. **Transfer:** Assuming same transfer uncertainty, the transfer RSD is combined statistically. Default both transfer RSD to be the same as solids concentration samples. **Isolok:** Same as solids concentration samples. **Handling:** Default minimum for liquid samples since compatibility analysis is not sensitive to precipitation or loss of volatiles.
						17.4%	

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Feed temperature (°F)	< 150	5	0	0	0	5%	**Mixing:** Although this is a direct measurement (no sampling), a default RSD is assigned to account for mixing impact on variability of temperature measurements in the DST that can complicate the acceptance decision process, which is undefined at this point (e.g., use of average tank temperature, single maximum temperature, location of temperature measurement, etc.). Set default to be same as for solids concentration samples because solids distribution in the tank affect temperature distribution. **Transfer:** Temperature will be monitored during transfer and as such this term is n/a. **Isolok:** No physical samples and as such this term is n/a. **Handling:** No physical samples and as such this term is n/a.
Abrasivity	TBD	5	10	5	1	12.3%	**Mixing:** Default minimum for typical slurry samples since the analysis is targeting average particles abrasivity, not the abrasivity of specific particles. **Transfer:** Same as for solids concentration samples. **Isolok:** Default minimum for typical slurry samples. **Handling:** Default minimum for samples since average particle abrasivity is not expected to be sensitive to precipitation or sample loss. Note that this analysis assumes the analytical uncertainty for measuring abrasivity does not impact the sampling uncertainties.

Parameters	Limit	Sampling Uncertainties (%RSD)				Overall Sampling %RSD[11]	Bases and Assumptions
		Mixing	Transfer	Isolok™ Sampler	Sample Handling		
Potential New Nuclear Safety Parameters (24590-WTP-RPT-ENS-11-021)							
Upper Bound Settled Layer Shear Strength within 24 hrs (Pa)	< 200	5	10	5	5	13.2%	**Mixing:** Same as for solids concentration samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration samples.
Average Particle Density of Pre-Leached Solids (kg/L)	≤ 2.18	5	10	5	5	13.2%	**Mixing:** Same as for solids concentration samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration samples.
HLW Feed Particle size (microns)	≤ 210	5	10	5	5	13.2%	**Mixing:** Same as for solids concentration samples. **Transfer:** Same as for solids concentration samples. **Isolok:** Same as for solids concentration samples. **Handling:** Same as for solids concentration samples.

4.2.3 Estimate of Analytical Relative Standard Deviation

This section describes the development of analytical %RSD estimate. Analytical uncertainty is quantified in terms of %RSD. The lower the %RSD values, the more accurate and precise the result. It is composed of analytical errors from direct measurements in real time or laboratory sample analysis, but not both.

The analytical %RSDs are impacted mostly by techniques and equipment accuracies which, unlike the sampling %RSD, can be validated using established procedures and control charts. This report refers to analytical %RSDs that are traceable to 222-S[12] control charts (shown in parentheses) or calculated using data from analysis where control charts are available. Control charts are created from actual repetitive measurement of control samples containing known quantities of analytes in a standard solution or other simple matrix. Control charts can be used to quantify analytical errors that occur from all steps in the laboratory analytical procedure, from sample preparations to the specific equipment used.

The analytical %RSDs are compiled for each of the WAC parameter in Table 4-3. Existing analytical %RSDs are taken directly from the initial WAC DQO while a few new %RSDs are based on subjective estimate. The only exception is the CV %RSD (shown in **bold**) where the value is based on the latest PulseEcho demonstration (PNNL-19441, *Test Loop Demonstration and Evaluation of Slurry Transfer Line Critical Velocity Measurement Instruments).*

Analytical capability, as expressed through the %RSD, is evaluated against the WAC parameters and the potential new nuclear safety parameters as defined in Sections 3.1 and 3.2 respectively. The %RSDs are to represent the overall uncertainty of the analytical method, not to be confused with the Quality Control (QC) acceptance criteria in % Recovery or Relative Percent Difference (RPD). Also note that the process qualification testing that requires up to 4 L of sample in support of WTP "process-ability" (e.g., filtration) is not assessed as a part of laboratory's capability since in general they do not impact WTP's acceptance of the staged waste.

A laboratory has not been selected for waste acceptance analysis of the pre-transfer samples. For the purpose of this initial gap analysis, all analysis for feed chemical, radiochemical, and physical properties required for waste acceptance is assumed to be provided by the 222-S Laboratory (Section 5.1). Most, not all, of the existing 222-S procedures have been vetted as a part of the WTP Waste Qualification Program. Gaps in analytical capability for WAC parameters have been identified as a part of a collaborative review effort by external SMEs (SCT-M0SRV00028-00-009-01-00002, *SRNL Phase 1 Assessment of the WAC/DQO and Unit Operations for the WTP Waste Qualification Program).* The results have been reviewed and captured as appropriate in the gap analysis (see Section 6.0).

[12] The acceptability of the use of 222-S control charts is an enabling assumption for this analysis since a testing laboratory has not been selected. If a different lab is selected to perform the testing, then the gap analysis may need to be updated to incorporate new analytical techniques.

Table 4-3. Analytical %RSD.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures and References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
HLW WAC Parameters (ICD 19)					
Solids concentration (g/L)	< 200	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-512-106: Total Suspended Solids. This procedure assumes the sample does not contain appreciable amounts of easily dissolved salts.
Na Molarity (moles/L)	< 10	0	(10)	10%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-505-174, Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Scientific iCAP 6500.
Slurry rheology (at 25°C) - consistency viscosity (cP)	< 10	0	(5)	5%	**Field Measurement:** Not applicable. **Lab Measurement:** ATS-LT-519-106; ATS-LT-519-108: viscosity range of approximately 1 to 10^6 mPa-s, or Centipose (cP).
Slurry rheology (at 25°C) - yield stress (Pa)	< 1	0	(5)	5%	**Field Measurement:** Not applicable. **Lab Measurement:** ATS-LT-519-106; ATS-LT-519-108: torque range of 0.05 micronewton-meters (µNm) to 200 millinewton-meters (mNm), with a torque resolution of <1 nNm and shear rate of 0.1 to 1100s^{-1}
Slurry pH [2]	≥ 12	0	(0.1)	0.1	**Field Measurement:** Not applicable. **Lab Measurement:** LA-212-106: pH Determination Of Aqueous Samples.

[1] Uncertainties shown in a parenthesis are based on or derived from use of control charts.
[2] Uncertainties for pH is defined in terms of absolute pH (12 +/- 0.1) and not as %RSD. Source of potential pH error is based on instrument measurement accuracy.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures and References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
Slurry bulk density (kg/L)	< 1.5	0	2	2%	**Field Measurement:** Not applicable. **Lab Measurement:** Process Chemistry Evaporator Support or LA-510-112:
Critical velocity (ft/s)	≤ 4	***(7.5)***	0	7.5%	**Field Measurement:** Empirically derived RSD based on +/- 0.3 ft/s variance between visual observation and Pulse-Echo detection of CV (PNNL-19441, Tables 11.1 and 11.2). **Lab Measurement:** Not applicable.
Ammonia (M)	< 0.04	0	(7)	7%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-533-101: Cation Analysis On Dionex Model DX-500; measures NH4 LA-544-112: Micro-distillation Separation of Ammonia For Ion Chromatographic Analysis. Note that the analysis is for ammonia in liquid, not vapor.
Separable organics (visual)	no visible layer	0	n/a	n/a	**Field Measurement:** Not applicable. **Lab Measurement:** Visual inspection of sample surface for oily/glassy substance.
PCB (ppm)	< 50	0	(50)	50%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-523-140. Polychlorinated Biphenyls (PCBs) By SW-846, Method 8082A, Using Gas Chromatography With Electron Detection.
TOC (wt%)	< 10	0	(5)	5%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-342-100: Determination of Carbon by Hot Persulfate Oxidation and Coulometric Detection. LA-344-104: Total Organic Carbon (TOC) Combustion Tube Change.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures and References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
HLW Feed unit dose (Sv/g)	< 270	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** Standard radiochemistry analysis performed for each isotope or a group of isotopes (GEA). The rad. analysis in Ci/L will be converted to Sv/g dose using public dose factor for individual isotope.
Pu to metals ratio - solids (g/kg)	< 6.2	0	(3.9)	3.9%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-943-129: Determination of Plutonium by Extraction and ICP-MS or LA-508-168: Calibration and Operation of the Ortec AEA System. LA-505-174, Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Scientific iCAP 6500.
Pu to metals ratio - liquid (g/kg)	< 6.2	0	(3.3)	3.3%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-943-129: Determination of Plutonium by Extraction and ICP-MS or LA-508-168: Calibration and Operation of the Ortec AEA System. LA-505-174, Inductively Coupled Plasma (ICP) Emission Spectrometric Method for the Thermo Scientific iCAP 6500.
Pu concentration of liquids (g/L)	< 0.013	0	(2.5)	2.5%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-943-129: Determination of Plutonium by Extraction and ICP-MS or LA-508-168: Calibration and Operation of the Ortec AEA System. LA-953-104: Determination of Plutonium and Americium by Extraction with TRU Resin.
U fissile to U total – solids (g/kg)	< 8.4	0	(10.8)	10.8%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-542-104: Co-Precipitation of Transuranics for AEA Counting

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures and References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
U fissile to U total – liquid (g/kg)	< 8.4	0	(2.1)	2.1%	**Field Measurement:** Not applicable. **Lab Measurement:** LA-542-104: Co-Precipitation of Transuranics for Alpha Energy Analysis (AEA) Counting
HGR (gmoles H_2/L/hr @ 150°F)	2.1 E-06	0	20	20%	**Field Measurement:** Not applicable. **Lab Measurement:** ATS-LT-523-163: 222-S Laboratory Tracer Gas Analysis for Helium, Hydrogen and Methane Using Gas Chromatography/Thermal Conductivity Detector (GC/TCD). RSD is applicable for a "static" system and not a "flow-through" system. Flow through type technique is under development.
Temperature Change for Waste Feed Compatibility (°C)	± 20	0	1	1%	**Field Measurement:** Not applicable. **Lab Measurement:** ASTM D5058-12 (supersedes D5058-90) (mixing 10 mL staged feed with 10 mL of residual waste in feed receipt tanks). Based on Practice A of the standard and using thermocouples good to 0.1 °C precision, then a 1% RSD around the action limit is achievable. New lab procedure needs to be developed.
Feed temperature (°F)	< 150	1	0	1%	**Field Measurement:** Total RSD based on an assumed total instrument loop uncertainties of ±1.5°F from the action limit (or 1% RSD). Individual sensor accuracy for typical RTD is better than ± 1%, but the bigger influence on tank temperature may be the signal transmission loop and location of the sensors. This RTD value is considered a place-holder only until a more thorough loop analysis is done based on a completed design and temperature control strategy for the HLW feed DST. **Lab Measurement:** Not applicable.

WAC Parameters - HLW	Limit	Analytical Uncertainties		Overall Analytical %RSD	Procedures and References
		Field Measurement %RSD	Lab Measurement[1] %RSD		
Abrasivity	TBD	0	20	20%	**Field Measurement**: Not applicable. **Lab Measurement:** Final analytical technique to be determined. 222-S Lab is currently not equipped to perform ASTM G75-07 (Miller Number) or (SAR Number) testing in the hot cell.
Potential New Nuclear Safety Parameters (24590-WTP-RPT-ENS-11-021)					
Upper Bound Settled Sludge Layer Shear Strength within 24 hrs (Pa)	< 200	0	2020	2020%	**Field Measurement:** Not applicable. **Lab Measurement:** A higher RSD is assumed due to unspecified conditions required to develop a more robust analytical procedure for settled sludge shear strength measurement.
Average Particle Density of Pre-Leached Solids (kg/L)	≤ 2.18	0	55	55%	**Field Measurement:** Not applicable. **Lab Measurement:** Process Chemistry Evaporator Support or LA-510-112:
HLW Feed Particle Size (microns)	≤ 210	0	5	5%	**Field Measurement:** Not applicable. **Lab Measurement:** Larger size particle will be analyzed using sieving procedure. Fines from sieving will be using Laser Scattering Particle Size Distribution Analyzer. LA-950/950V2. Instruction Manual CODE GZ0000079069B; GZ00000032875E. Test Plans LAB-PLN-10-00011 and LAB-PLN-11-00009.

4.2.4 Estimate of Waste Feed Delivery Profile

This section describes the process used to estimate the WFD profile, as well as how to use the information to calculate the number of samples and determine potential gaps.

4.2.4.1 *HTWOS and System Plan*

The Hanford Tank Waste Operations Simulator (HTWOS) is a dynamic event-simulation model that simulates waste composition as waste moves through storage, retrieval, feed staging, and multiple treatment processes from the present day until the end of the River Protection Project (RPP) mission. It is a tool used to support WFD planning in accordance with the System Plan (ORP-11242).

The HTWOS model was used to perform a Baseline Case run to support the feed screening process. The Baseline Case is a mission scenario in the System Plan that forms the technical basis for both the near-term baseline and the out-year planning estimate. This run provides the most up to date projected compositional feed delivery profile from commissioning through the end of mission. It tracks most of the WAC parameters except for some of the physical properties (e.g., viscosity, particle size, abrasivity, etc.). It provides the expected values from which the sampling and analytical errors are applied to calculate number of samples as a quantitative measure of potential gap in the waste acceptance decision process. The Baseline Case for System Plan (Rev. 6) has already been run in support of feed screening in the IWFDP (RPP-40149-VOL2, *Integrated Waste Feed Delivery Plan Volume 2 – Campaign Plan)*. The same run was repeated with minor changes in output reporting for this initial gap analysis. Results are documented in SVF-2476, *WTP DQO Feed Screening with SP6 Data.xlsm*. The formatted data for HLW was copied and used as input for the numbers of samples calculation.

It is important to note that HTWOS estimates of as-delivered feed are traceable back to historical information and limited tank waste sample analysis (i.e., Best Basis Inventory or BBI). BBI data is subject to uncertainties associated with the collection and analysis of tank waste, Hanford Defense Waste modeling and engineering calculations. These uncertainties have not been quantified and their impact upon the HTWOS results and the associated feed delivery profile is unknown. The assessment of error and uncertainty inherent in the HTWOS-derived feed delivery profile is beyond the scope of this gap analysis. Nonetheless, feed delivery profile derived from HTWOS modeling represents the best tank waste characterization data available to date and provides a necessary enabling assumption for the analysis of staged feed presented in this report.

4.2.4.2 *Construction of Sample Size Graphs*

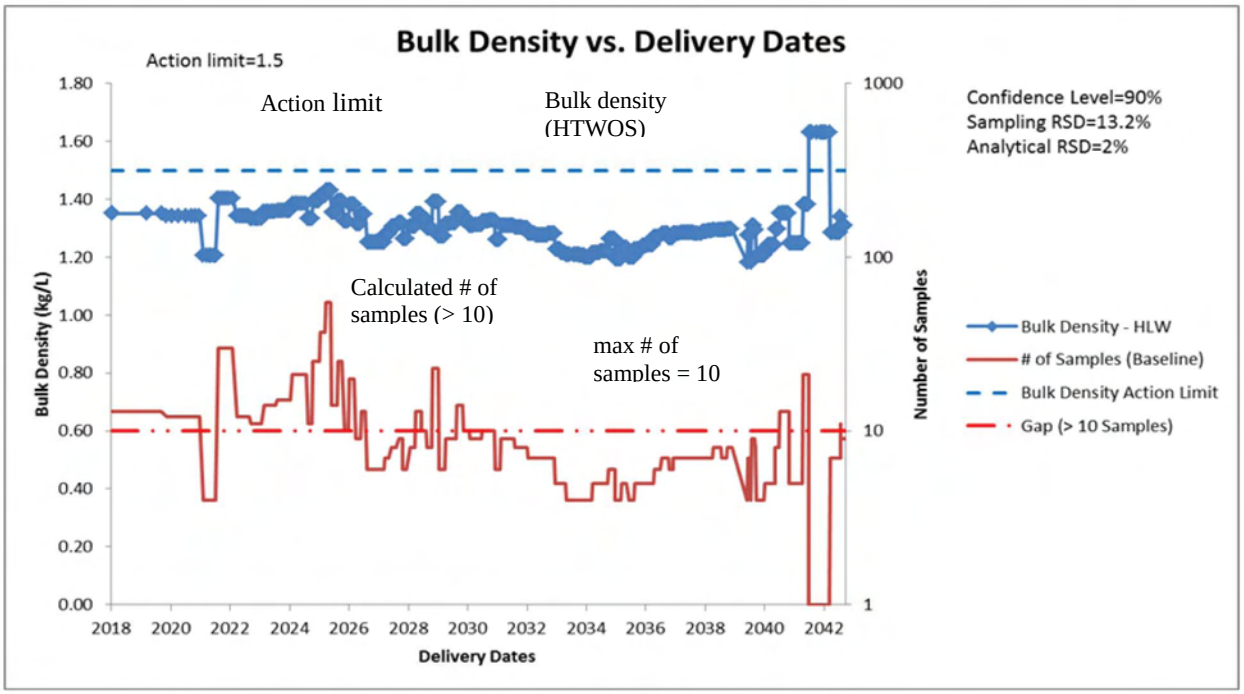
Gaps are evaluated on the statistical hypothesis testing based on the number of samples required to ensure compliance with the WAC action limit given a required confidence level. With the exception of the analyses for criticality safety limit (CSL) requirements (ratio of Pu to metal absorbers, $U_{fissile}$ to U_{total}, and Pu concentrations in liquids), all of the action limits are evaluated at a 90% confidence level. The CSL action limits are evaluated at a 95% CL (24590-WTP-RPT-

MGT-11-014). If an excessive number of samples are required based on proximity of the project feed composition value to the waste acceptance action limit, then a gap is identified. The number of samples is set to 10 as a threshold for gap analysis purpose, with the understanding that, if necessary, more samples can be taken to resolve the gap. The ten samples limit was selected to be consistent with the approach in the WAC DQO (i.e., plan to take 10 samples regardless, but analyze only three).

The number of samples calculation adheres to the method as defined in the WAC DQO process. The equation is based on EPA/240/B-06/001, Equation A-8 (see Appendix B). The numbers of samples calculated are plotted on the sample size graph generated for each of the WAC parameters (SVF-2548, *Sample Number Calculations for Initial Gap Analysis, 2010-2 Commitment 5.5.3.1.xlsm*). These graphs are constructed to provide visual at-a-glance information (see Figure 4-5):

- Projected feed compositional data from HTWOS model run (SVF-2476) vs. delivery schedule dates
- Calculated number of sample corresponding to each feed compositional data point vs. delivery schedule dates
- Waste acceptance action limit
- Maximum number of sample (=10)
- Sensitivity results

Figure 4-5. Example Sample Size Graph.



Sampling Sensitivity Analysis:

Sampling	Max. # of Samples
4.0%	**7**
13.2%	**55**
50.0%	**745**

Details on the construction and interpretation of similar sample size graphs are provided in the WAC DQO (24590-WTP-RPT-MGT-11-014). In general, the graphs are intended to highlight instances where the maximum numbers of samples are exceeded (indicative of possible gap). The number of samples value varies as a function of the difference (delta) between the projected feed composition and the action limit. The number of samples will increase exponentially as the delta gets smaller (or as the projected feed composition approaches the action limit). For a few rare instances when the feed exceeded the action limit, the number of samples is defaulted to 1 as an indication that the decision (reject) is no longer dependent on the number of samples. Interpretation of the sample size graphs are discussed as part of the gap analysis results in Section 6.0.

4.2.5 Evaluation of Waste Transferred to WTP

Not all the WAC and Potential New Nuclear Safety parameters are tracked in the HTWOS. Parameters not currently modeled in HTWOS are qualitatively assessed for potential gaps by the authors and technical studies as applicable. For most of these parameters, there is not enough characterization data or reliable correlations to support a feed screening approach (number of samples). These parameters include:

- CV
- Slurry rheology (viscosity consistency and yield stress)
- Abrasivity
- HLW feed particle size
- Upper bound settled layer shear strength
- Feed temperature
- Waste feed compatibility in terms of temperature change
- Average particle density of pre-leached solids
- Separable organics
- PCBs

Most of the above are related to the physical properties of the "as-staged" HLW feed. As cited from the latest study of the expected waste to be transferred to WTP (RPP-RPT-51652), the incidental and intentional blending of the tank wastes affects rheological properties *"…through changes in various physicochemical characteristics such as pH, chemical composition of particles and salts, concentrations of particles and salts, particle size distribution and density and shape of particles."*, and that *"…it is difficult or impossible to draw deterministic conclusions on the effect of tank waste blending on rheology. In fact, it is case-by-case as noted from the examples of actual waste blending."* For the cited reasons, the rheological parameters

are screened using a more conservative approach based on the properties reported in RPP-RPT-51652 as applicable. As already stated in Section 2.1, sampling and analytical uncertainties are applied to a bounding value or upper range that is assumed valid for all batches, instead of a nominal value for batch-to-batch, to determine if there is a potential gap in compliance. For example, if the yield stress of the slurry that can be physically transferred to WTP exceeds the initial WAC for yield stress, then a gap is flagged regardless of the actual amount, distribution, or impact on WTP operations. These types of potential gaps (or open items) do not necessarily require mitigation, but rather serves to highlight the need to develop additional understanding. A purely qualitative approach is used for screening the remaining parameters that have little supporting process information (e.g., separable organics, feed temperature, PCB, etc.). The qualitative screening of these parameters is discussed in Section 6.0.

5.0 ASSESSMENT OF CURRENT WTP CAPABILITIES

WTP capabilities in terms of PJM mixing, sampling, and heel management at the HLW Feed Receipt Vessel (HLP-VSL-00022) could drive potential changes to the initial WAC. Testing planned including the LSIT will be assessed for impact on the WTP WAC when data becomes available (2010-2 IP Commitment 5.5.3.3). Subsequent updates to the WTP WAC will be incorporated in the final gap analysis (2010-2 IP Commitment 5.5.3.9).

Until testing data is available for benchmarking against current or updated WAC parameters, this section is limited to a summary description on the laboratory capabilities to support the analytical %RSD discussion in Section 4.2.3.

5.1 LABORATORY ANALYTICAL CAPABILITY

This section discusses laboratory facilities and capabilities as a backdrop for the gap analysis. Information is excerpted in part or whole from the latest report on analytical laboratory capabilities (RPP-RPT-50014, *Qualitative Analysis of the Analytical Laboratory Capabilities Required to Support Hanford Tank Farm Closure).* Gaps or issues concluded within the RPP-RPT-50014 report are not necessarily declared as gaps in this report if they deal with capacity (turn-around-time) or budget type constraints that are more in-line with production/programmatic issues, rather than the technical capability required for making waste acceptance decisions.

As of June 30, 2012, a laboratory had not been selected to handle the pre-transfer samples analysis required to confirm the WTP WAC. A qualitative gap analysis was performed on five candidate facilities, each with distinct capabilities to support the Hanford tank closure mission (RPP-RPT-50014). The five (5) candidate laboratory facilities are the 222-S Laboratory on the Hanford site; PNNL in Richland, Washington; the Savannah River National Laboratory (SRNL) in Aiken, South Carolina; the Waste Sampling and Characterization Facility (WSCF) on the Hanford site; and the WTP-LAB that is being constructed on the Hanford site. All facilities except the WSCF can perform chemical and radiochemical characterization of tank waste, but only 222-S can currently perform analysis for volatile organic compounds (VOCs), semi-volatile compounds (SVOCs), and PCBs on site. At this time, certified radioactive material

transportation packages are limited to the Hedgehog-II type, which makes shipping multi-liter samples off-site to SRNL currently impractical.

The 222-S Laboratory is a full-service, analytical facility that handles samples of low to high radioactivity for the purpose of organic, inorganic, and radiochemistry analyses. Originally constructed to support the REDOX reprocessing plant, the 222-S laboratory now supports the environmental clean-up mission at Hanford. The capability of the 222-S Laboratory is organized into four (4) major functional areas:

- Organic. This area contains the equipment to perform extractions and analysis for PCBs, VOCs, and SVOCs. Analytical equipment includes two Gas Chromatography – Mass Spectrometry (GC-MS) and two GC-Electron Capture Detector analyzers.
- Inorganic. Samples are prepared in room 1B before analysis by Inductively Coupled Plasma – Atomic Emission Spectrophotometry (ICP-AES), Inductively Coupled Plasma – Mass Spectrometer (ICP-MS), Ion Chromatography (IC), or atomic absorption. Two of each analyzer type are provided. Other analyses include Total Inorganic Carbon/Total Organic Carbon (TIC/TOC), Thermo-Gravimetric Analysis/Differential Scanning Calorimetry (TGA/DSC), specific gravity, solids concentration, Potential of Hydrogen (pH), and hydroxide.
- Radiochemistry. The rooms on the first floor contain the equipment to perform various radionuclide separations. The radiochemical counting equipment is located in the basement and consists of Gamma Emission Analyzer (GEA), AEA, Liquid Scintillation Counting (LSC), and Gel Permeation Chromatography (GPC) analyzers.
- Process Chemistry. This area contains equipment for performing various physical characterizations of samples, including scanning electron and optical microscopy, laser-based particle size analysis, X-ray diffraction, and rheology. The area also includes hot cells for technology testing.

The analytical procedures used in 222-S are compliant with the Hanford Analytical Services Quality Assurance Requirements Document (HASQARD) and consistent with SW-846 methods for RCRA analyses. Modifications to the SW-846 methods are mainly associated with reduced sample sizes to reduce radiation dose rates and are declared to the regulator (State of Washington, Department of Ecology). The laboratory currently supports all of the tank farms operations outlined above by means of its analytical equipment, established analytical methods, and radiological facilities.

For the purpose of this initial gap analysis, the 222-S Laboratory is assumed to be the laboratory where the pre-transfer samples analysis for WTP WAC compliance will be performed, and that the supporting analytical work is performed in compliance with NQA-1-1989, *Quality Assurance Program Requirements for Nuclear Facilities*, Part II, Basic, and Part III, Supplementary Requirements, as applicable. Therefore, the analytical procedures and %RSD estimates in this report (Section 4.2.3) are traceable to 222-S. This assumption is consistent with the initial WAC DQO approach for WAC analyses.

6.0 GAP ANALYSIS

This section compares the capabilities and uncertainties compiled against the initial WAC parameters and the potential new nuclear safety parameters to assess potential gaps and open items. For those parameters that are tracked in HTWOS, the results of the comparison are presented in the form of sample size graphs. Observed gaps are summarized and likely sources of gaps discussed in Section 6.1. Parameters that are not tracked in HTWOS are addressed individually in Section 6.2.

6.1 HLW FEED SCREENING (HTWOS) AND GAPS

The screening of all the planned HLW feed campaigns (~600) against the current waste acceptance criteria action limits are presented by the use of sample size graphs. The sample size graphs are constructed using HTWOS run results generated for System Plan Baseline Case (SVF-2476) that provides the compositional data spanning the WFD schedule. The required number of samples used to decide whether the staged feed is acceptable for transfer to WTP is calculated and plotted for each compositional data point. The derivation of the associated equations used is provided in Appendix B. The complete spreadsheet calculation is documented in SVF-2548.

The sample size graphs shown (Figure 6-1 to Figure 6-13) follow a general format. The horizontal axis represents the delivery dates chronologically from hot commissioning (5/31/2018) through end of mission (2/18/2043). The left vertical axis represents the compositional data for the constituents of interest (e.g., bulk density in kg/L). The right axis represents the number of samples required, at the corresponding "mean" of the constituents of interest, for the specified confidence level and uncertainties (sampling + analytical) shown at the upper right corner of each graph. Note that some of the right axes for the number of samples are plotted in log scale (e.g. bulk density, $U_{fissile}$ to U_{total} – solids, and hydrogen generation rate). The corresponding waste acceptance action limit is plotted along with the maximum number of samples criterion (10) to provide a visual guide for at-a-glance comparison. For a few rare instances when the feed exceeded the action limit, the number of samples is defaulted to either 0 or 1 as an indication that the decision (reject) is no longer dependent on number of samples.

As a first estimate to the sensitivity of the number of samples to the assigned sampling %RSD, which by and large are qualitative "best guesses," a simple sensitivity test was performed by varying the assigned sampling %RSD value to bracket the Base Case between 2% and 50%. This simple test does not address the sensitivity of the results to the enabling assumptions. The results of this sampling sensitivity evaluation are presented directly below the sample size graph for each constituent. An additional sensitivity evaluation was performed for the $U_{fissile}$ to U_{total} parameter to determine what effect the CL has on the number of samples.

Note that different constituents may require different sample sizes, based on the mean value of the constituents. However, since the analytical results for the different constituents are often

obtained from the same samples, the number of samples required will generally be driven by the constituent that requires the largest number of samples.

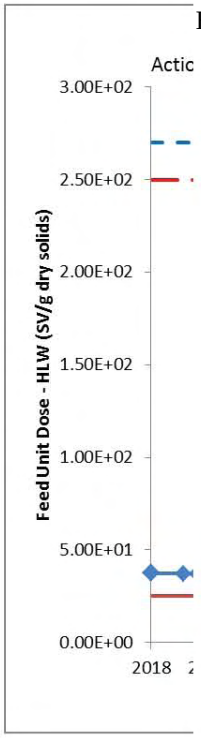
6.1.1 Results

Result from the use of HTWOS for feed screening is summarized in Table 6-1. Notwithstanding uncertainties associated with the assumptions described in Section 2.0 that have not been evaluated, out of the thirteen WAC parameters screened using HTWOS model output, three of the thirteen (3 of 13) have periods when the number of samples exceeded ten. The rest require between one to four samples, which is in-line with the WAC DQO baseline. The three that exceeded 10 samples are the same ones evaluated previously as a part of the WAC DQO. These are $U_{fissile}$ to U_{total} ratio - liquid (Figure 6-8), $U_{fissile}$ to U_{total} ratio – solids (Figure 6-9), and bulk density (Figure 6-1). As summed up by the IWFDP (RPP-40149-VOL2), the quantity of samples required is primarily driven by the $U_{fissile}$ to U_{total} ratio and, to a lesser extent, the bulk density of the deliveries. Raising the action limit for the uranium ratio is under investigation, as it would have significant benefit in reducing the number samples required. For the bulk density measurement, the staging of feed near the limits and sampling error will need to be managed to minimize the number of samples. Finally, blending or dilution may be employed to resolve most out-of-tolerance feed conditions and has the potential to reduce the number of samples required.

Table 6-1. HTWOS Feed Screening Summary.

Reference	Parameter	Max. # of Samples (Base Case)	Gap? Y/N	Comment
Figure 6-1	Bulk Density	55	N	Sensitivity analysis based on adjusting down to a 4% sampling RSD dropped the max. # of samples to 7 indicating that this parameter may be mitigated by improving sampling performance alone.
Figure 6-2	Slurry pH	2	N	# of samples < 10. Relatively insensitive to sampling %RSD.
Figure 6-3	Total Organic Carbon (TOC)	1	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-4	Ammonia	1	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-5	Pu to Metals Ratio – Liquid	2	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-6	Pu to Metals Ratio – Solids	4	N	# of samples < 10. Not sensitive to sampling %RSD.
Figure 6-7	Pu Concentration of Liquid	2	N	# of samples < 10. Not sensitive to sampling %RSD.

Reference	Parameter	Max. # of Samples (Base Case)	Gap? Y/N	Comment
Figure 6-8	$U_{fissile}$ to U_{total} – Liquid	12	N	Sensitivity analysis based on adjusting down to a 4% sampling RSD, or by adjusting down to 90% CL, effectively dropped the max. # of samples to 6 and 8 respectively, indicating that this parameter may be mitigated by improving sampling performance or by relaxing the CL alone.
Figure 6-9	$U_{fissile}$ to U_{total} – Solids	247	**Y**	# of samples >> 10. This is the main driver for excessive # of samples compared to the other parameters. See Section 6.1.1.1.
Figure 6-10	Feed Unit Dose	2	N	# of samples < 10.
	Hydrogen Generation Rate	2	**Y**	See Section 6.1.1.2.



Sampling Sensi	
Sampling	Max
4.0%	
12.3%	
50.0%	

Figure 6-11

Figure 6-12	Solids Concentration	2	N	# of samples < 10.
Figure 6-13	Sodium Molarity	2	N	# of samples < 10.

6.1.1.1 *$U_{fissile}$ to U_{total} – Solids*

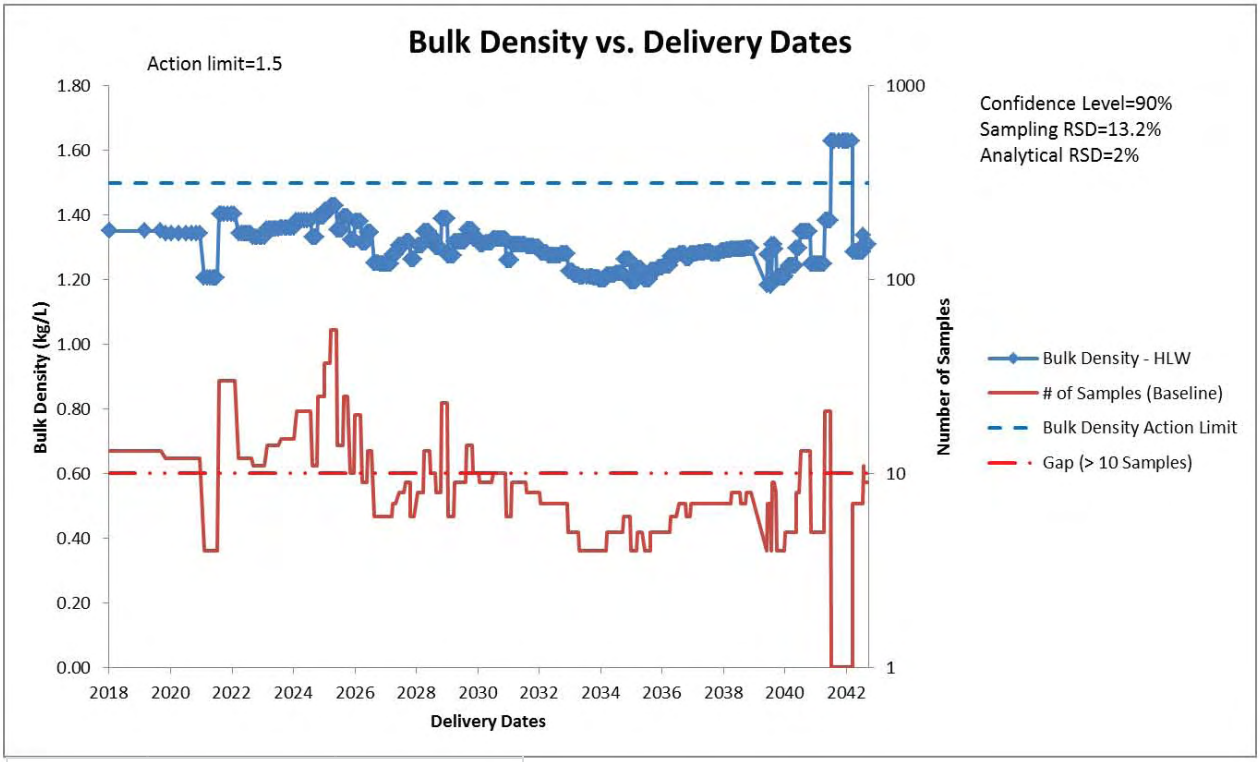
For those constituents that are tracked in HTWOS, the uncertainties introduced from sampling and analytical in most part, did not contribute to a gap. This is not surprising since most of the predicted mean values are sufficiently below the action limit. The sampling and analytical %RSD plays a minor role in general in driving the number of samples except when the mean approaches the action limit, as in the case for bulk density and the $U_{fissile}$ to U_{total} parameters. As a sensitivity check, the sampling %RSDs were set back to the original 4% as in the WAC DQO for these two constituents. The sensitivity results confirms that $U_{fissile}$ to U_{total} – solids is the only parameter driving the maximum number of required sample, and that improvement in the sampling uncertainties, i.e., capability, or reducing the CL from 95% to 90%, would not be sufficient in mitigating the gap.

6.1.1.2 *Hydrogen Generation Rate (HGR)*

One WAC parameter has an extreme sampling %RSD but didn't result in excessive number of samples. The Pu metal ratio to total solids parameter has the highest uncertainties in sampling (~38% RSD), but the feed quantity is orders of magnitude below the action limit, so the net effect on number of samples is still within an acceptable range (< 10). With the current Isolok™ testing underway to optimize the sampler performance, the overall sampling %RSD may be reduced further to provide additional margins of safety for this parameter. The high sampling uncertainties are not driving a gap for this parameter due to a higher error tolerance.

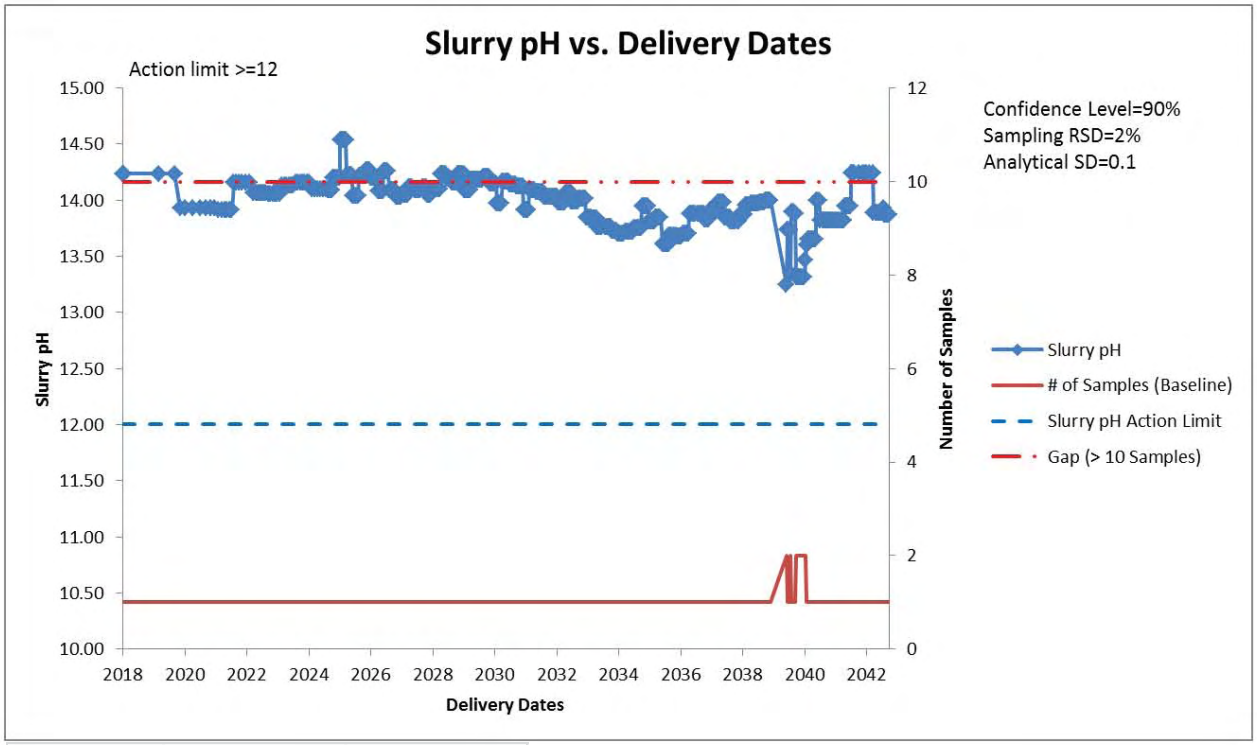
There are three (3) parameters that have high analytical %RSD (i.e. 20% or above). Two of these are not tracked in HTWOS (abrasivityand PCB), and are therefore discussed separately in Section 6.2. The one parameter tracked in HTWOS, the Hydrogen Generation Rate (HGR), has a high analytical %RSD but the expected mean is still well below the action limit so the number of samples calculated did not trigger the gap. However, the high uncertainty for HGR measurement is due to the proposed use of an analytical technique (static conditions) being developed at 222-S in a hot cell environment. The original intent was for the HGR to be calculated using radiolysis correlations, but this is now required to be measured at a given temperature. There are some inherent advantages and disadvantages for static versus flow-through type measurement techniques (SCT-M0SRV00028-00-009-01-00002). The method to measure HGR is being developed by WTP using support from SRNL. Until the technique can be demonstrated to provide reliable HGR measurement, this parameter is flagged as a gap (see Table 6-1).

Figure 6-1. Bulk Density.



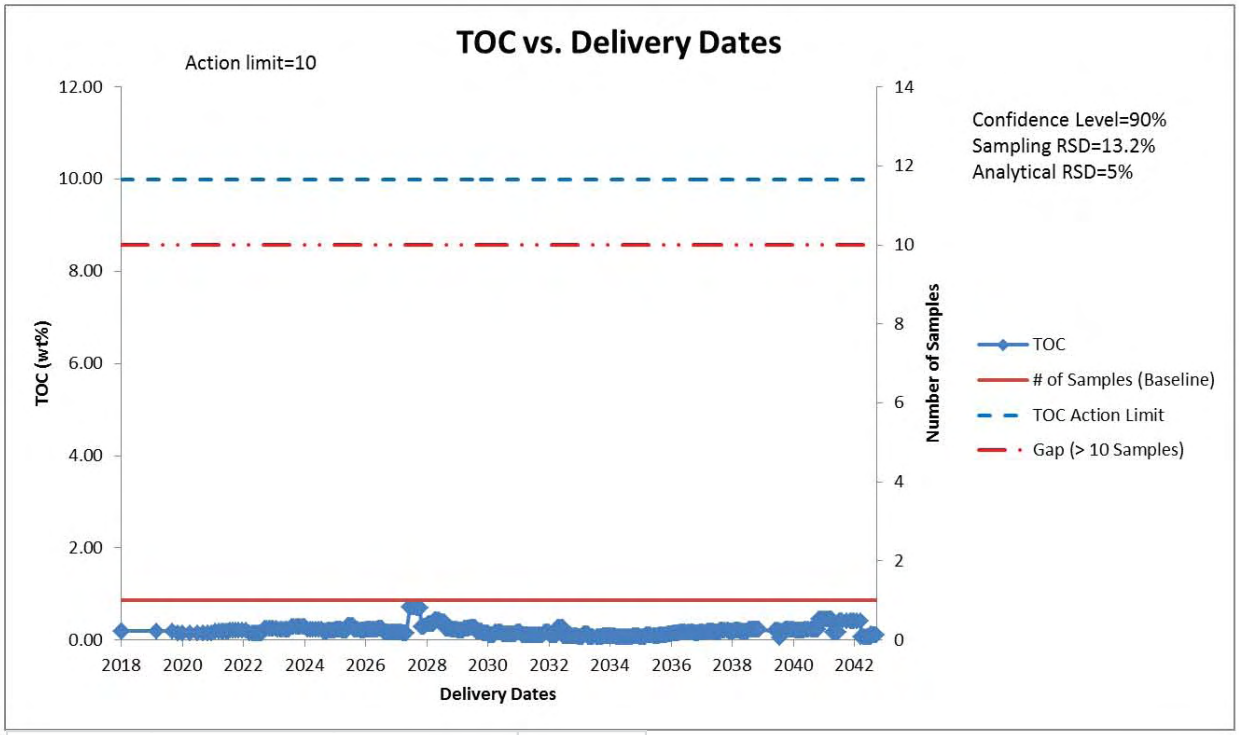
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	**7**	
13.2%	**55**	<< Base Case
50.0%	**745**	

Figure 6-2. Slurry pH.



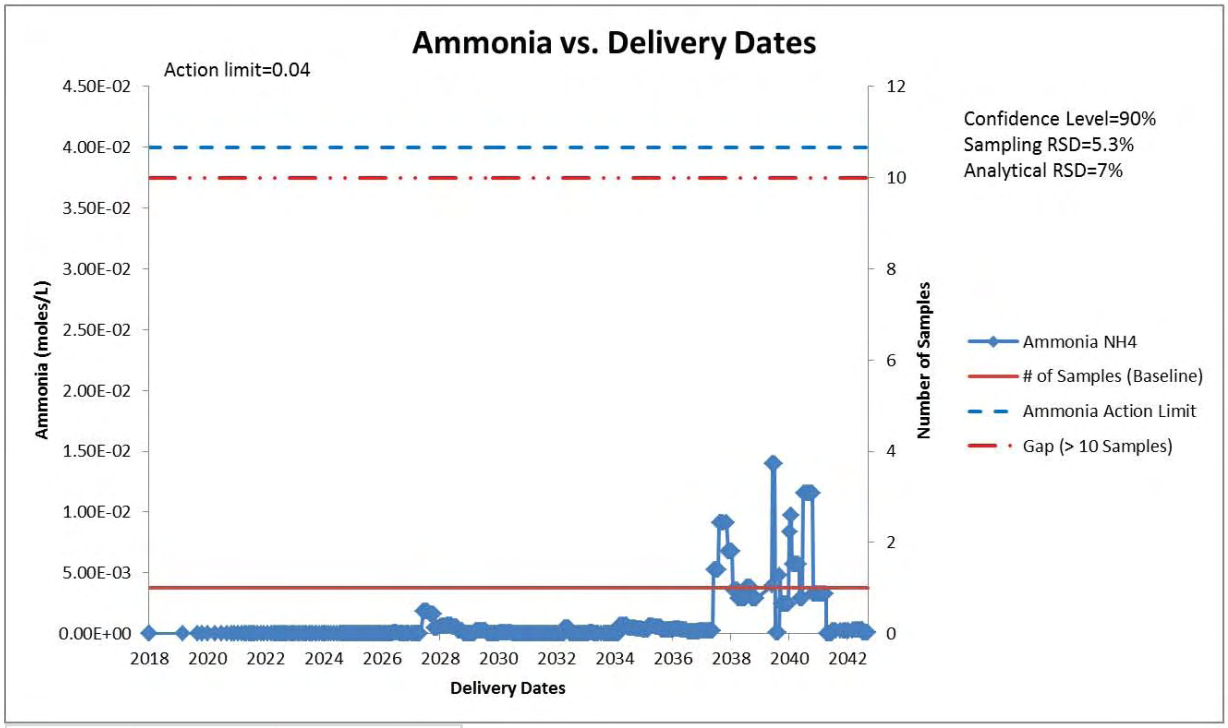
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
2.0%	**2**	**<< Base Case**
4.0%	2	
50.0%	154	

Figure 6-3. Total Organic Carbon (TOC).



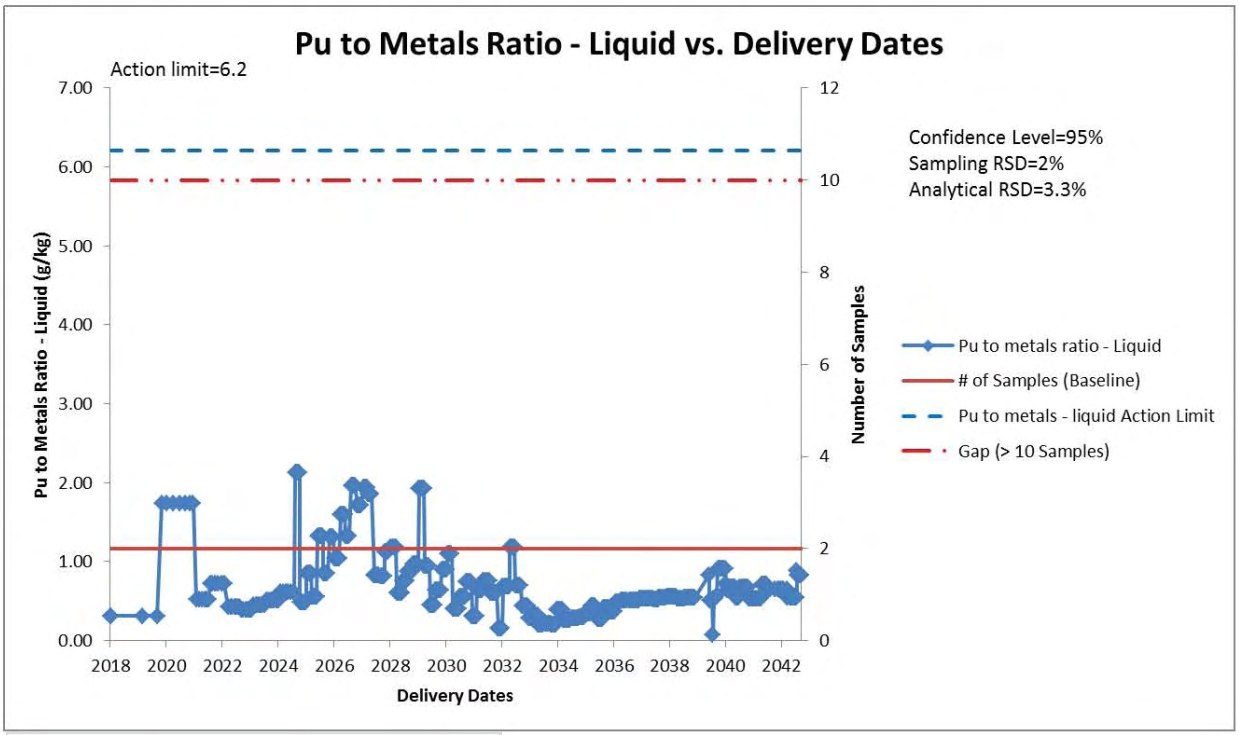
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	1	
13.2%	1	<< Base Case
50.0%	3	

Figure 6-4. Ammonia.



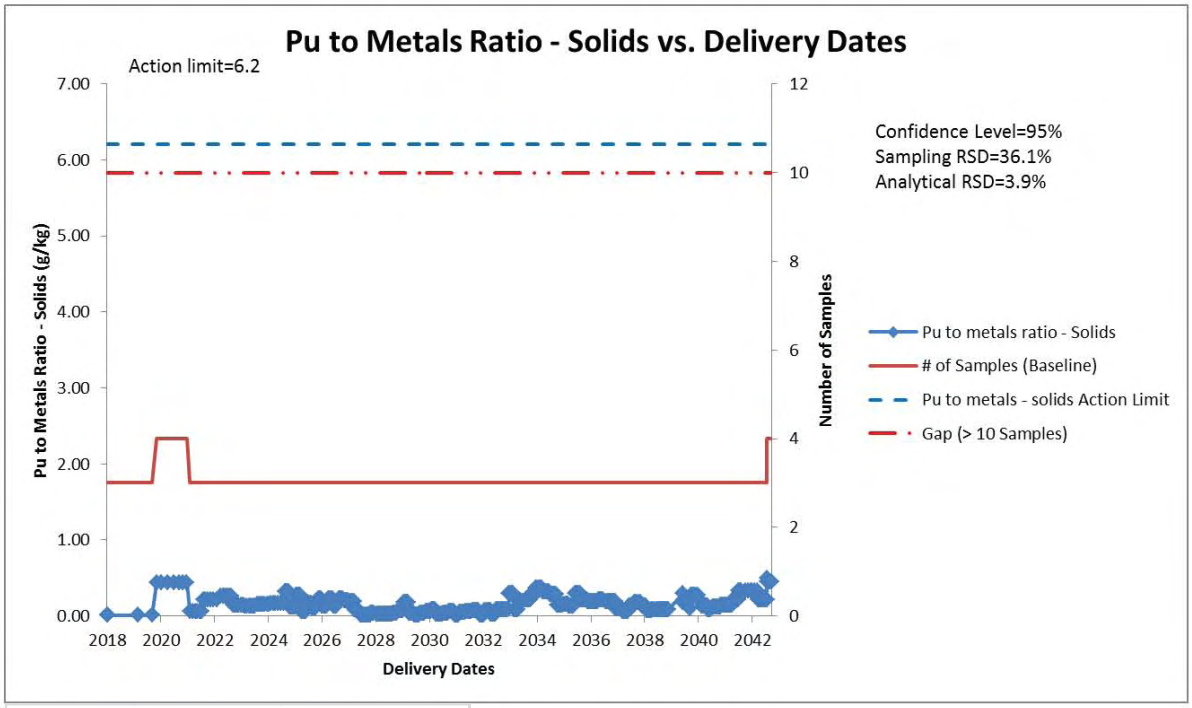
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	1	
5.3%	1	<< Base Case
50.0%	5	

Figure 6-5. Pu to Metals Ratio – Liquid.



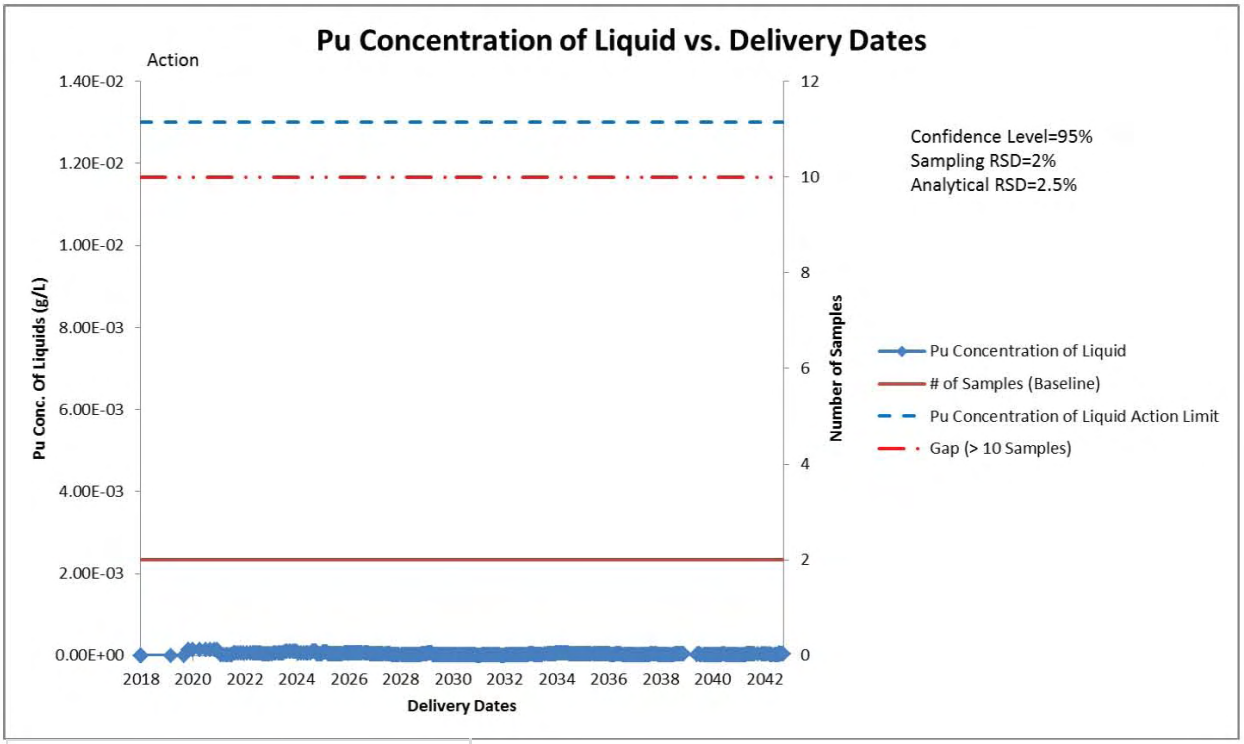
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
2.0%	2	<< Base Case
4.0%	2	
50.0%	8	

Figure 6-6. Pu to Metals Ratio – Solids.



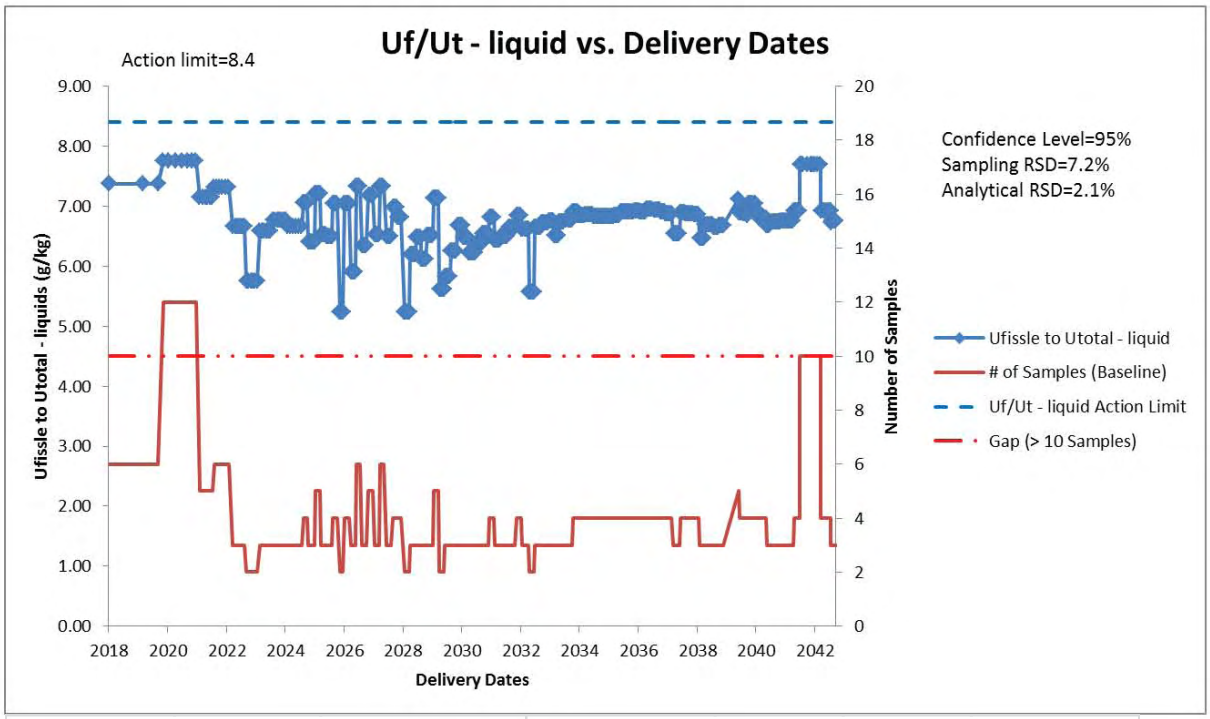
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	**2**	
36.1%	4	<< Base Case
50.0%	5	

Figure 6-7. Pu Concentration of Liquid.



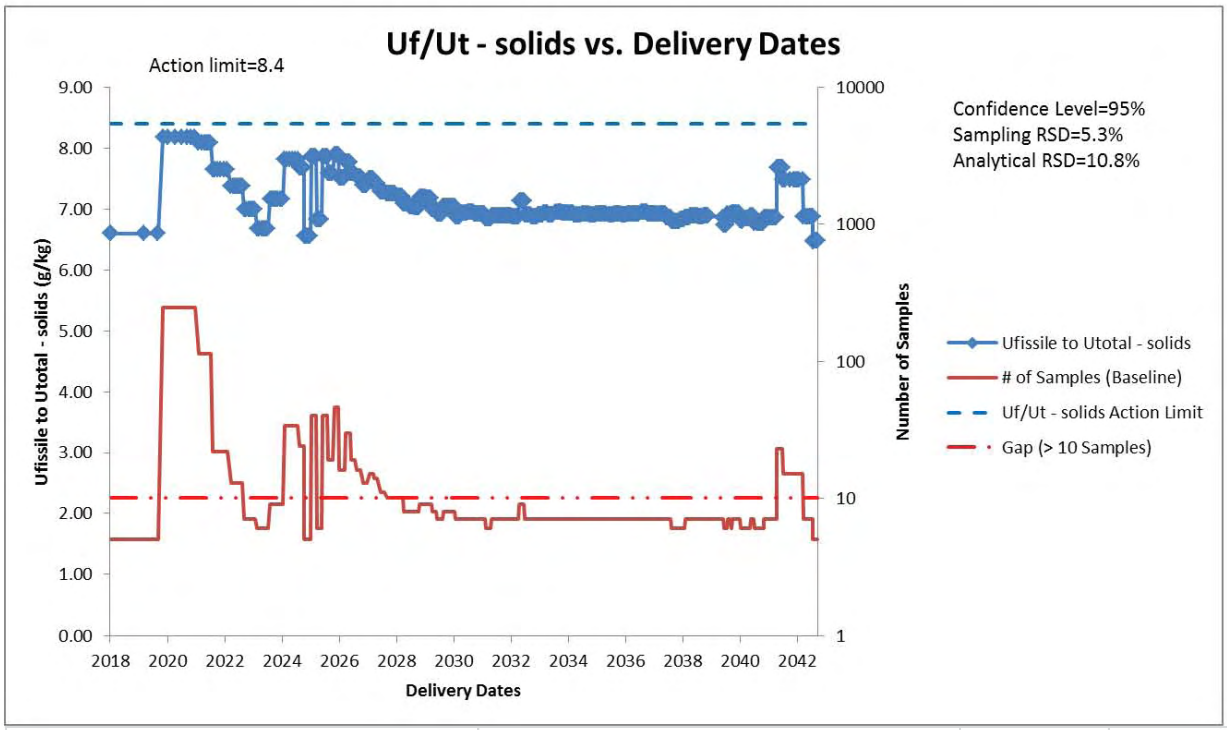
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
2.0%	2	<< Base Case
4.0%	2	
50.0%	5	

Figure 6-8. $U_{fissile}$ to U_{total} – Liquid.



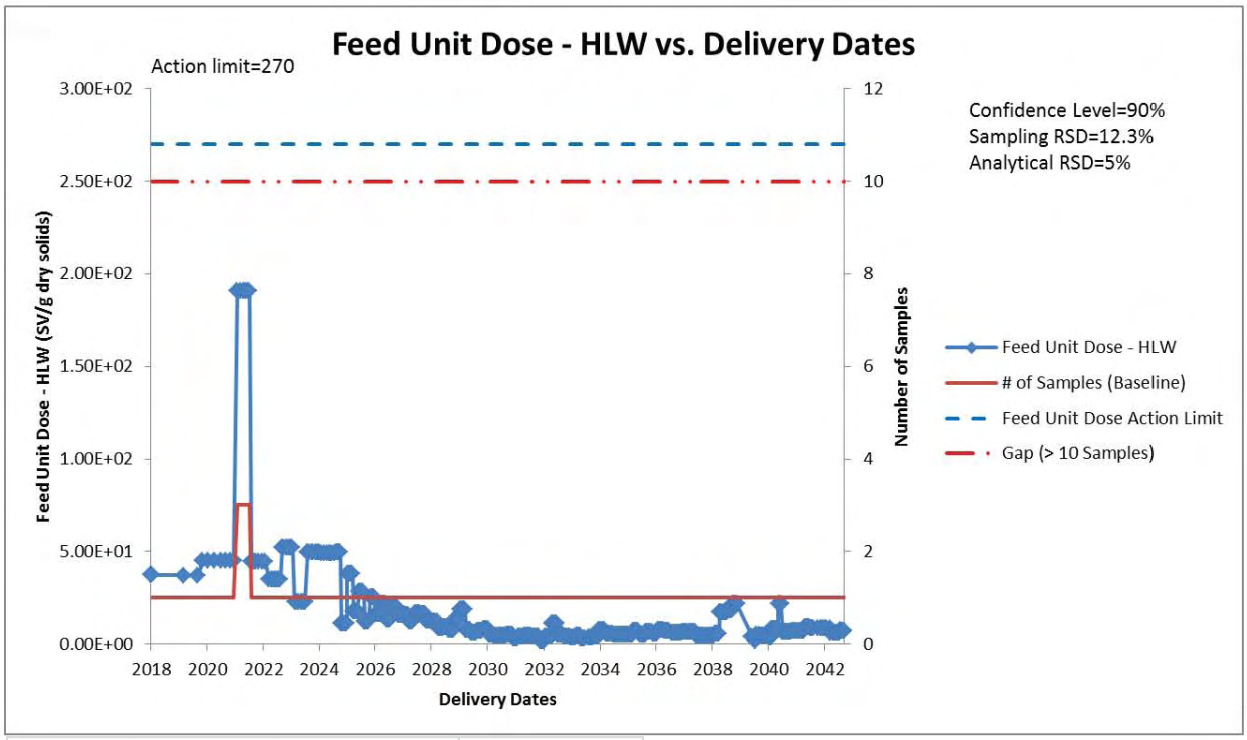
Sampling Sensitivity Analysis:			Confidence Level Sensitivity Analysis:		
Sampling	Max. # of Samples		Confidence Level	Max. # of Samples	
4.0%	6		90%	8	
7.2%	12		95%	12	<< Base Case
50.0%	458				

Figure 6-9. $U_{fissile}$ to U_{total} – Solids.



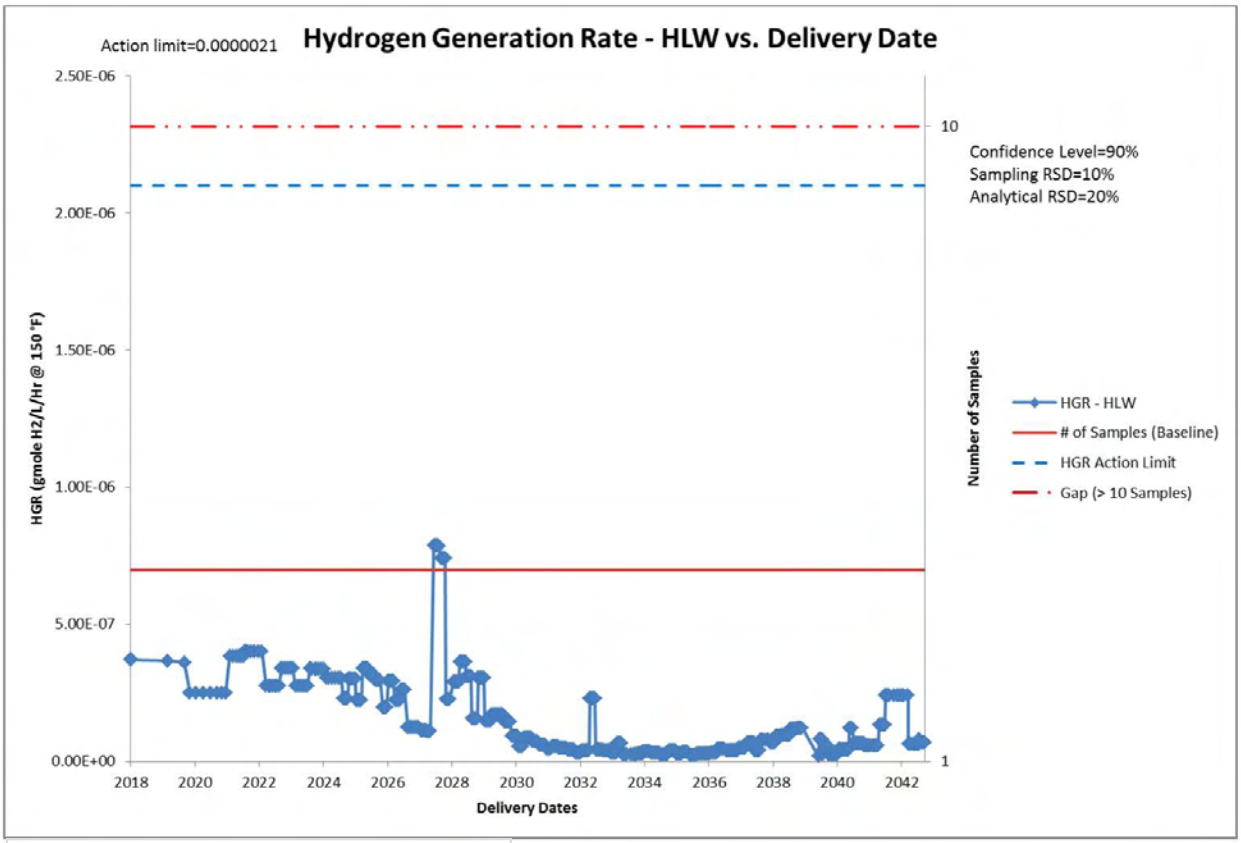
Sampling Sensitivity Analysis:			Confidence Level Sensitivity Analysis:			
Sampling	**Max. # of Samples**		**Confidence Level**	**Max. # of Samples**		
4.0%	227		90%	150		
5.3%	247		95%	247	<< Base Case	
50.0%	4434					

Figure 6-10. Feed Unit Dose.



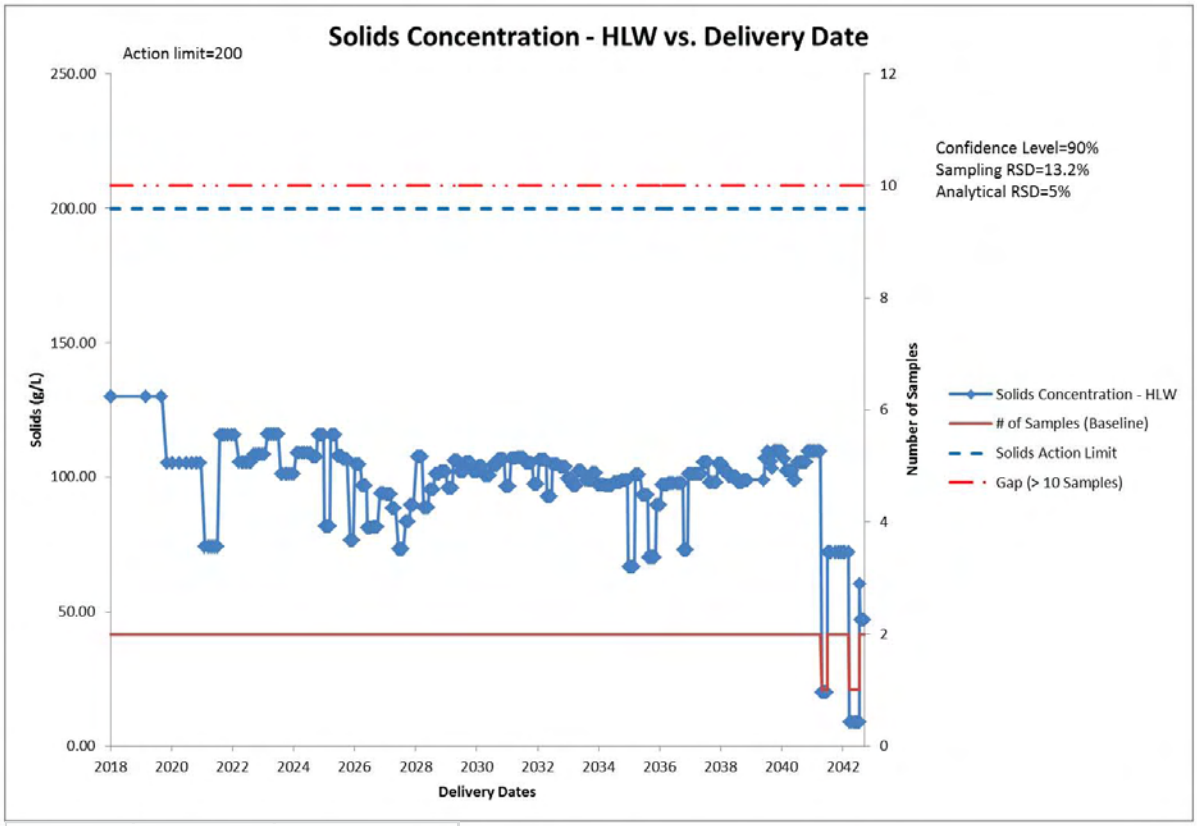
Sampling Sensi			
Sampling	Max		
4.0%			
12.3%			
50.0%			

Figure 6-11. Hydrogen Generation Rate.



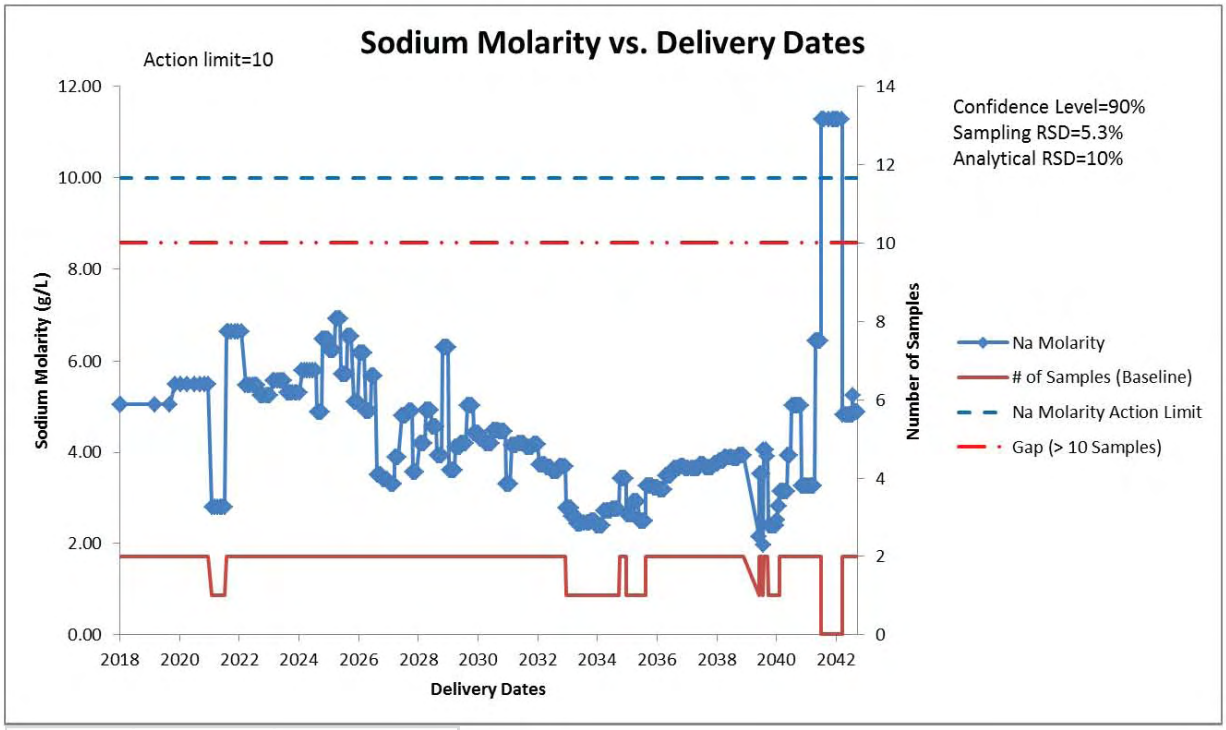
Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
10.0%	2	<< Base Case
50.0%	6	

Figure 6-12. Solids Concentration.



Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
13.2%	2	<< Base Case
50.0%	15	

Figure 6-13. Sodium Molarity.



Sampling Sensitivity Analysis:		
Sampling	**Max. # of Samples**	
4.0%	2	
5.3%	2	<< Base Case
50.0%	19	

6.2 HLW FEED SCREENING (NON-HTWOS) AND GAPS

Many of the physical properties on the list of WAC parameters (Table 3-1) and potential new nuclear safety parameters (Table 3-2) are not modeled in HTWOS. In lieu of using a compositional feed profile as a starting point, each of the parameters not modeled in HTWOS is discussed and potential gaps assessed in qualitative assumptions using available technical studies and current process information.

6.2.1 Abrasiveness

Gap: **Yes** – Based on a lack of proven analytical technique in a hot cell environment.

Abrasiveness is not currently screened as a waste acceptance parameter in the ICD 19 document. However, this is related to a "known" gap in the tank farm's ability to demonstrate compliance with particle hardness or size as reflected by ICD 19 Open Item #0015 (ICD 19, Appendix D) and, therefore, it is captured in this report for completeness and tracking purpose (see 0).

The over-riding uncertainty driving this as a gap lies in analytical capability more so than sampling or the expected mean of the feed. If there is no reliable method to verify this parameter, then the ability to make the waste acceptance decision is in question.

A 20% RSD value was assigned qualitatively for the analytical capability (Table 4-3). This is essentially a "place holder" meant to flag this as an area of concern. There is no analytical procedure for this type of measurement in the 222-S Laboratory. This capability (or lack thereof) is also identified as a gap in SCT-M0SRV00028-00-009-01-00002, *SRNL Phase 1 Assessment of the WAC/DQO and Unit Operations for the WTP Waste Qualification Program*. A direct method of measuring abrasivity is under development by WTP and SRNL to implement a procedure based on ASTM G75-07[1] as modified for radioactive environment. This test method covers a laboratory procedure that can be used to develop data from which either the relative abrasivity of any slurry (Miller Number) or the response of different wearing materials to the abrasivity of different slurries (SAR Number). A Miller instrument could be put in a hot (shielded) cell. This parameter is flagged as a gap based on a current lack of analytical capability.

6.2.2 Critical Velocity

Gap: **Yes** – PulseEcho development and field application uncertainties.

Critical velocity (CV) is a term that describes the fluid transfer velocity below which pipeline solid particulate deposition occurs. It can be estimated using correlations such as Oroskar and

[1] ASTM G75-07, Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)

Turian or AD Thomas, but for HLW staged feed to WTP, CV as a waste acceptance criterion will be measured (24590-WTP-RPT-MGT-11-014).

Based on the latest development effort by PNNL, the PulseEcho system provides accurate detection of solid settling for a 3", Schedule 40, transfer line (see Section 4.1.3.2). The current WFD configuration has the PulseEcho detector spool piece installed in the waste certification flow loop upstream of the Isolok™ Sampler. The PulseEcho system will detect solid settling during the sampling event for the pre-transfer sample, during which the transfer pump and the mixer pump(s) will be operated under conditions similar to the actual transfer to WTP (except that all flow is recirculated back into the feed tank).

Critical velocity is a slurry property measured at a point location in a horizontal pipe. The WFD system's capability to transfer large-dense particulate was evaluated in RPP-RPT-51652. The evaluation identified limits of performance, including the mixer pumps and the vertical and horizontal legs of the transfer pipeline with respect to undissolved solids size and density. As summarized in Figure 4-4, the capability of the transfer system spans a wide range of particulate size and density, from large 9,525 µm 1.43 g/mL gibbsite agglomerate to postulated 100 µm 19 g/mL plutonium metal particle (RPP-RPT-51652).

There is no gap expected in the tank farm's capability to meet the CV waste acceptance criteria based on the following preliminary testing: a) PulseEcho type device can detect CV within 0.3 ft/s; b) waste transfer system can deliver particulates that span a wide range of sizes and densities; and c) tendency for fast settling solids to be oversampled during the pre-transfer sampling event. However, a large part of this conclusion depends on how well the PulseEcho technology can be properly scaled for actual waste measurement and deployed in a field (vs. lab) application. For example, the accuracy of ± 0.3 ft/s, validated through careful visual observations of solids settling, cannot be performed in a field application. A total instrument loop uncertainties calculation must be performed for the field as-installed configuration to ensure the accuracy/precision can be maintained. External background effects not easily replicated in a controlled test environment should also be considered (e.g., dirty pipe, electronic noise/interference, etc.). This capability must be demonstrated at the conclusion of ongoing development and design work to support closure of this gap in the final gap analysis. In addition, the sensitivity of this instrument to detect settling in a more dilute feed (i.e., < 2 wt% solids) with trace quantities of large, fast settling solids has not yet been demonstrated. Therefore, this parameter is flagged and tracked as a gap based on a need to validate PulseEcho's detection accuracy with a simulant more representative of actual waste (e.g., include a broader range of particle size and density) and a design configuration more prototypic of the field application.

6.2.3 HLW Feed Particle Size

Open Item: **Yes** – Based on the potential to transfer greater than 210 µm particles to WTP and unknown safety impact.

The current action limit for this parameter as defined in Table 3-2 is ≤ 210 µm. The range of particle size that can be transferred to WTP was evaluated in RPP-RPT-51652. As stated in

RPP-RPT-51652, what is of interest for particles that will be fed to WTP is the distribution of solid particle size, shape, and density in the waste slurry delivery batches. Because the plans for retrieval, mixing, and WFD of tank wastes to WTP are not complete, it is difficult to provide accurate, quantitative estimates of the distributions of particle size, shape, and density. However, expertise and experience provides for making some qualitative or semi-quantitative judgments.

It is believed that delivered particle size is limited by the transfer pump inlet screen (e.g., ⅜-inch or 9,525 μm) or transfer pump pipe openings and that typical particle shape is an agglomerate of roughly spherical shape (RPP-RPT-51652). Any rods or sharp edges might be broken and/or worn out as the solids are agitated during retrievals, transfers, and in preparation for feeding waste to WTP. Some break up of agglomerates might occur when slurry is cycled through the mixer pumps and transfer pumps, but these WFD operations by themselves are not likely to eliminate large agglomerates. Based on this assessment alone, the upper bound range of solid particles, including agglomerates that can be transferred to WTP exceeds the current 210 μm limit (Figure 4-4).

Analytical capability is not currently driving a gap for this parameter. The common approach to particle analysis is to determine large particles by sieving. The fines from the sieving analysis can be analyzed by laser diffraction. The 222-S Laboratory currently uses a Horiba Partica LA-950v2 as a primary instrument with an analytical range of 0.01 – 1,000 μm. Particle size can also be determined by automated imaging analysis using the SEM. This method allows the sorting of particles by chemical composition while determining the cross sectional area of each particle. The analytical range is about 0.5 – 3,000 μm.

Sampling capability is potentially driving a gap for this parameter. Based on Phase 1 remote sampler demonstration (Section 4.1.3.1), there is about a 10% bias (oversample) for the larger, dense solids (up to 128 μm SS). The bias from the sampler mounted in a vertical position represents an improvement over the same measurement with the sampler mounted in a horizontal position. The exact reason for the bias is being investigated in Phase 2 testing. This bias compounds the uncertainties from tank mixing and transfer relative to spatial and temporal fluctuations. The bias could also increase a pluggage potential at the sampler from larger particles. The inside diameter of the sampler needle assembly is about 0.135 inch (~3429 μm). Assuming the agglomerates retain the largest possible size (9,525 μm), they will likely bypass the sampler due to the physical constraint of the needle size (a source of EE).

Until the impact of larger particles (up to 9,525 μm or 3/8 inch diameter) on the WTP design bases can be assessed for safety impacts, this parameter as screened is identified and tracked as a gap.

6.2.4 Average Particle Density of Pre-Leached Solids

Open Item: **Yes** – Based on the likelihood of HLW feed exceeding the average particle density limit and the misalignment between the tank farm planning basis (i.e., HTWOS) and the WTP design basis (i.e., BOD).

This parameter is referring to the average primary particle density (2.18 g/mL), not to be confused with slurry density. As discussed in Table A-2, this parameter is currently not fully covered by the CV parameter as described in the WTP Bases of Design (BOD), and therefore it is flagged for screening in this initial gap analysis. Average particle density is used in slurry transport related calculations in WTP.

Mineralogy and density data for primary particles are summarized in Table 4-4 in RPP-RPT-51652. Density values for the primary particles range from 1.8 g/mL (aluminum phosphates) to 19 g/mL (plutonium metal). A majority of the primary particles in the aluminum phases exceed the 2.18 g/mL limit (e.g., 2.4 g/mL for Gibbsite and 3.0 g/mL for Boehmite). Most of the primary particles identified in Table 4-4 in RPP-RPT-51652 exceed the 2.18 g/mL limit, with aluminum phase being the most frequently observed. However, there are many sources of uncertainties on this data as discussed in RPP-RPT-51652. The primary uncertainty is the lack of complete knowledge of the primary particles (minerals) that may appear in Hanford tank wastes. This lack of knowledge exists because there is limited mineralogy data for only 60 of 177 Single-Shell Tanks (SSTs) and DSTs. Uncertainties associated with sampling and analytical capabilities for this average density parameter are within the norm for undissolved solids in general (Table 4-2 and Table 4-3) and are not the main source of errors for this parameter.

Rather than a maximum density, this parameter is targeting the "average" density, which is dependent on the actual distribution of primary particles in the staged feed. Currently, there is insufficient data to track the distribution of primary particles/minerals in the HLW staged feed, but it has the potential for a given batch to exceed an average particle density of 2.18 g/mL. The current planning basis for all HLW feed campaigns in the HTWOS model uses a solids density of 3.0 g/mL. Lowering the density value in HTWOS could impact the overall mass balance.

Until the impact of exceeding this parameter on safe WTP processing is known, this parameter is being flagged as an open item for tracking purpose.

6.2.5 HLW Slurry Rheology – Viscosity Consistency and Yield Stress

Gap: **No**.

This waste acceptance parameter targets the viscosity and yield stress of the staged HLW feed (<10 cP and <1 Pa respectively). The data gap on rheological properties of individual waste tank has been evaluated and documented in a number of technical reports, including RPP-RPT-51652 and the latest updates in RPP-52774, *Hanford Waste Rheology Reference Report*. However, there is little conclusive study on the effect of waste blending on rheology, which is applicable to the staged feed to WTP (vs. characterization of individual waste tank). A preliminary assessment of WFD operations effect on rheology was conducted in RPP-RPT-51652. It concluded that it is difficult or impossible to draw deterministic conclusions on the effect of tank waste blending, and that measurements on actual blended waste feed are likely needed. Therefore, rather than assessing gap relative to a mean value as compared to the action limit, this report focuses on the ability to sample and analyze this parameter.

Qualitatively, this parameter can be sampled and analyzed with reasonable accuracy (i.e., 10% and 5% RSD respectively). However, applying these uncertainties to the "predicted" range of viscosities and yield stress at 10% solids (RPP-RPT-51652, Table 6-4) would yield instances where the calculated number of samples is either below 10 or set at 0, because the feed exceeded the action limit. By inspection there is only one batch that approaches the action limit for both yield stress and viscosity (T-111 2C Sludge @ 0.78 Pa and 6.7 cP). This implies that if the actual staged waste behaves as predicted, then the sampling and analysis should be able to verify waste acceptance within the maximum ten samples at 90% CL.

6.2.6 Upper Bound Settled Layer Shear Strength

Open Item: **No.**

This parameter targets the settled sludge layer shear strength as a function of time (< 200 Pa after 24 hours) in HLP-22. The latest data on settled sludge layer shear strength for actual waste testing (AZ-101, AY-102, etc.) is summarized in PNNL-20646, *Hanford Waste Physical and Rheological Properties: Data and Gaps*. However most of the shear strength data was collected for a DST with settling time that far exceeds the 24 hrs (most >100 days) of interest to WTP. One data point based on in-situ settling of AZ-101 waste is traceable to be the source of the 200 Pa action limit (PNNL-17707, *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels*, Table 2.1). However, a concern is raised in the same report indicating recent laboratory measurements on settled material from actual cladding waste composites showed unusually fast settling and high strengths, with settling occurring over a 3-hr period and the strength of the settled material ranging from 100 to 700 Pa and possibly higher. As acknowledged in the PNNL-20646 report, changes in shear strength in settled solids layers with an emphasis on shorter settling times and shear strength as a function of solids depth is not well quantified. It is being flagged as a data gap in the PNNL-20646 report.

The capability to sample and analyze this parameter is not driving a gap. Additional sample volume may be required to properly perform this analysis in the 222-S lab, but the capability exists toto measure shear strength once the settling conditions can be defined and used to develop a procedure tailored to the vessel of concern. Transferring of slurry in general (i.e., not targeting any particular undissolved solids) should be within the capability of the waste feed transfer system (RPP-RPT-51652). Preliminary Isolok™ and SSMD results to date are not directly applicable to this type of static measurement of rheological property. The real risk is in complying with the acceptance limit given the limited understanding on the behavior of the actual waste (sludge) as staged and delivered to WTP, more so than the tank farm's ability to sample, analyze, and transfer capabilities.

6.2.7 Separable Organics

Gap: **Yes –** Potential stratification of a separate organic layer that cannot be mixed or sampled using current method (i.e., waste feed certification flow loop).

This parameter targets separable organics, which is defined in ICD 19 document as *"Separable organics are organic compounds (carbon based molecules) that are present in the HLW or LAW waste streams transferred to the WTP and are present in concentrations beyond their saturation point for a particular batch inventory. The saturation point for a particular HLW or LAW waste is determined by blending the two wastes together at a minimum 8 wt% solids concentration and 10 molar sodium concentration then holding at 25 °C for 8 hrs. If the organic species separates as a solid or liquid under these conditions, the organic is deemed 'separable'."* There is no quantified action limit other than "no" separable organics defined for this parameter.

The analytical capability is not driving a gap. The current approach is based on a visual inspection of the pre-transfer sample for any reflective/oily appearance on the liquid surface under the assumption that separable organics exist as a "visible" layer (24590-WTP-RPT-MGT-11-014).

There may be a potential gap for the sampling capability. Applying the same assumption that separable organics can be observed "visually" would mean some or all of the material is present as a layer at the liquid surface in the DST. If this hypothesis is true, then the pre-transfer sampling event may not be able to capture this stratified layer (i.e., the sampler take multiple grabs of HLW at the transfer pump discharge located near the bottom of the tank). A higher %RSD (15%) is assigned to the sampling uncertainties to highlight the potential for this stratified condition. Regardless of the expected mean concentration of separable organics, if it cannot be sampled, then it will not be verified as a part of waste acceptance. The likelihood of transferring stratified organic layer increases as the tank level decreases from subsequent batch transfer. Until the impact of transferring separable organics to WTP is determined and better quantified (i.e., the current action limit does not specify a de minimis concentration level in the feed), this parameter is flagged as a gap to highlight a condition that may require an alternate verification method.

6.2.8 Waste Feed Compatibility

Gap: **No.**

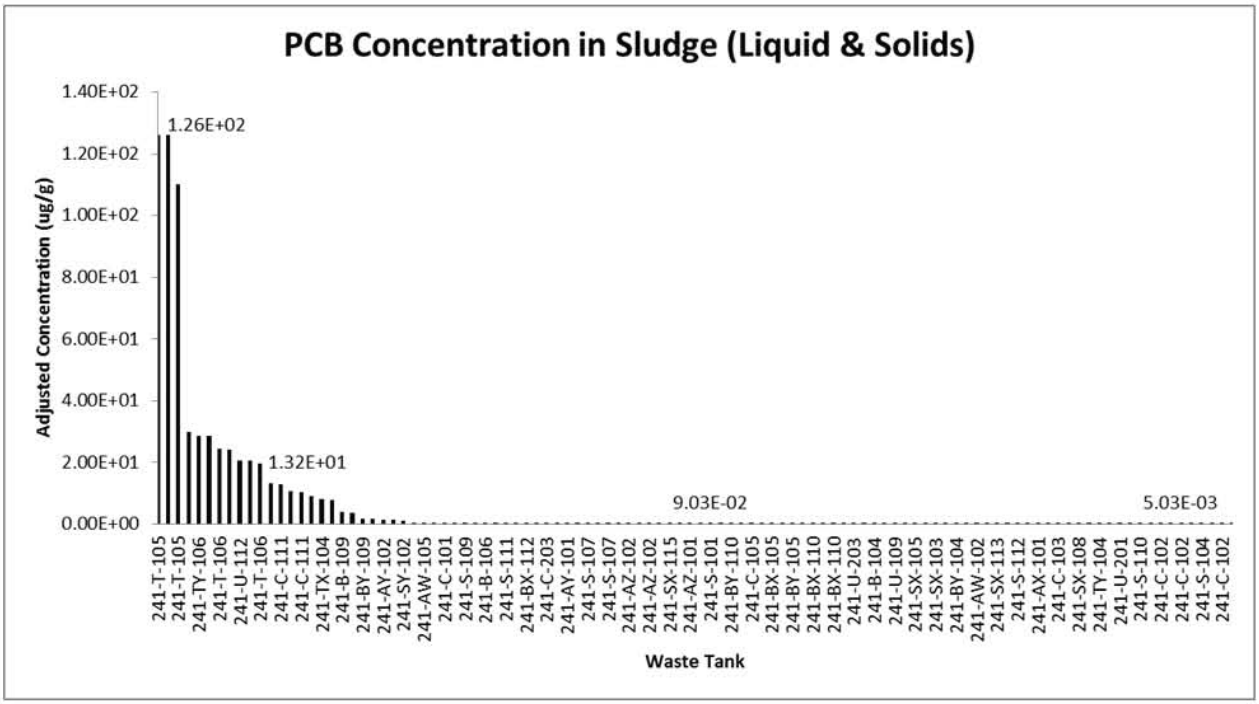
This parameter targets waste feed compatibility uses ASTM D5058-12 (supersedes D5058-90) method that looks for any temperature or rheology changes when mixing 10mL of staged feed with 10mL of residual feed in WTP receipt vessels. The rheology change (i.e., viscosity increase) is observed and not measured. ALARA concerns will most likely waive the viscosity observation from the ASTM method. The 222-S Laboratory currently does not have a procedure to perform the ASTM test; however, the technique (temperature change measurement) is reliable and accurate, so analytical capability is not expected to drive a gap for this parameter. Sampling capability is also not expected to drive a gap since this is for the pre-transfer sample and not targeting any particular composition or physical properties. The overall sampling uncertainty is higher since there are two samples required for this one parameter (a staged feed sample from the tank farm and a residual feed sample from WTP).

6.2.9 Polychlorinated biphenyl (PCB)

Gap: **Yes –** Based on high analytical %RSD.

This parameter targets total PCB (Aroclors) in the staged HLW feed. Total PCB is currently not tracked in HTWOS. The concentration is generally expected to be well below the limit of < 50 ppm for most tanks. However, there are a few problem tanks that contain an elevated concentration of PCB in the sludge phase, as shown by querying the latest Best Basis Inventory (BBI) from the Tank Waste Information Network System (TWINS) database for PCB (Aroclors) concentrations that are based on actual sample results. Results are plotted in Figure 6-14, sorted by the highest adjusted concentration. The tank with the highest amount of PCB reported is T-105, a SST with an adjusted concentration of 126 µg/g. This is the only tank that exceeds the 50 ppm action limit.

Figure 6-14. BBI Inventory of Total PCB.[1]



The sampling capability is not driving a gap. PCB is expected to be mobilized and tracked along with the HLW sludge based on observed retrieval operations for C-103 and C-106. However, the analytical uncertainty is high (50 %RSD) for this type of organic analysis due to the relatively complex laboratory procedure requiring a series of distillation/extraction steps combined with a low target limit. In this case, the high analytical %RSD could be driving a gap since there is at least one tank with high PCB concentration and several other tanks with

[1] Tank Waste Information Network System, data compiled on 9/12/2012.

concentrations that approach the action limit. This parameter is flagged as a gap at this time to highlight a potential need to refine/improve the analytical capability to ensure WAC compliance.

6.2.10 Feed Temperature

Gap: **Yes** – Based on a current lack of waste tank temperature control strategy that addresses field measurement uncertainties.

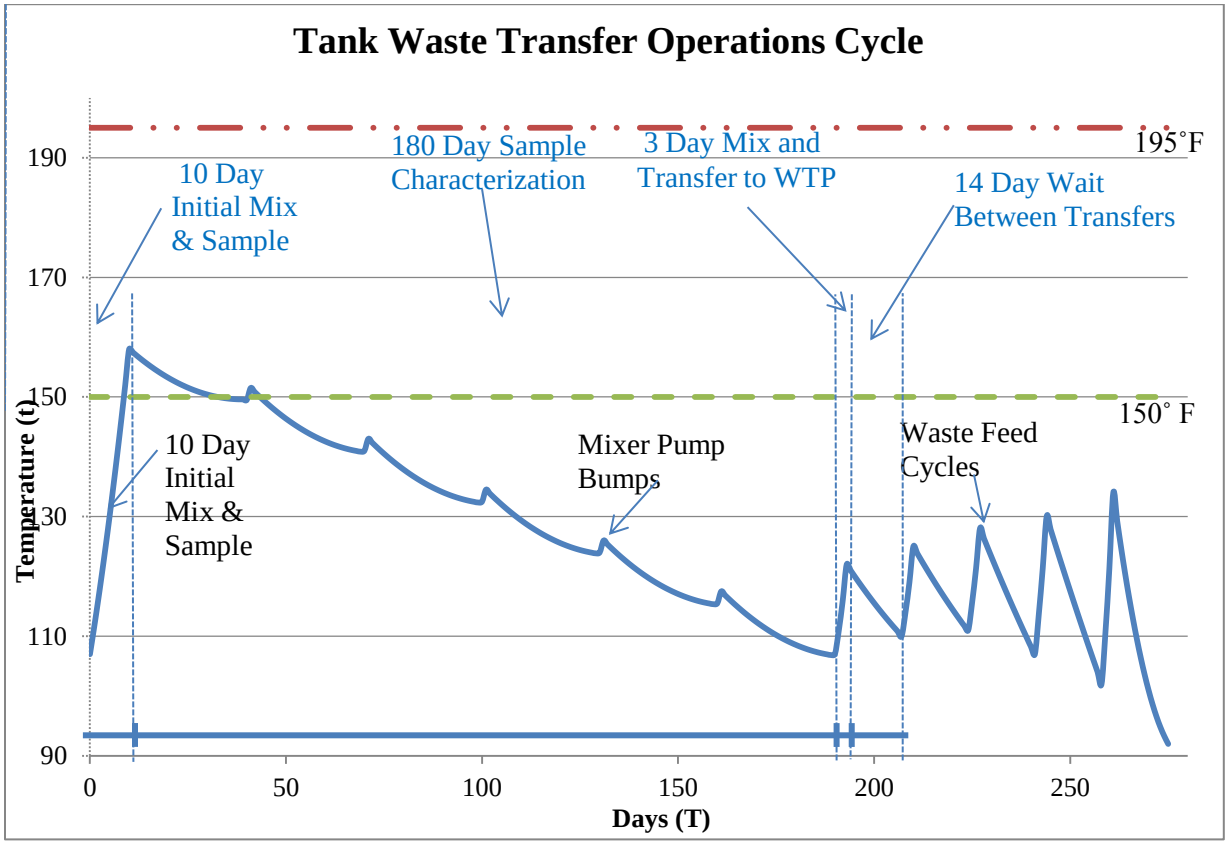
This parameter is a direct measurement (no sample) of tank waste temperature in real time. The action limit is defined as < 150 °F. This means the bulk temperature cannot exceed the limit at any time during transfers of waste to WTP.

There is no sampling requirement for this parameter, and therefore sampling capability is not driving a gap.

There may be a potential gap in the analytical (direct measurement) capability. The WFD design for tank temperature control is in-progress. The preliminary design for the AY-102 tank has a total of 98 temperature readings by thermocouple "trees" installed in different risers (RPP-RPT-53044, *Strategy and Technical Basis for Managing Flammable Gases During Tank 241-AY-102 Mixer Pump Testing*). Conceivably, the decision for starting or stopping a transfer will be based on more than one single temperature reading, perhaps an average or bulk temperatures. Temperature distribution in a DST is expected to vary with riser location, elevation, mixer pumps operation, ventilation rate, tank level changes, and other factors. While individual temperature measurement uncertainty is low, the propagation of multiple readings accounting for response time may be higher. The measurement uncertainties would be more significant as the actual tank temperature approaches the action limit. There are existing thermal hydraulic evaluations that predicted tank waste temperature during the transfer cycle (Figure 6-15). There may be times that the tank temperature will approach and at times exceed the limit (but not during transfer). There is a risk (albeit small) that the waste temperature can exceed the limit during a batch transfer to WTP. Therefore, the waste temperature control strategy must account for the total loop uncertainties and response time to protect the WAC limit during transfers to WTP. Alternative temperature measurement technologies should be evaluated as a contingency to ensure WAC compliance.

This parameter is flagged as a potential gap to track as a follow-up item to be addressed upon completion of the WFD design. Results are to be incorporated in the final gap analysis.

Figure 6-15. AY-102 Tank Waste Temperature Prediction.[1]



[1] Figure 3-9: Waste Transfer Operations Cycle for Temperature, RPP-RPT-49492, *702-AZ Thermal Hydraulic Evaluation Benchmark and Flammable Gas Analysis*

7.0 CONCLUSIONS

This report documents an initial gap analysis between the tank farm sampling system capabilities, uncertainties, and waste projected to be transferred to WTP. An initial WAC with current parameters has been defined for HLW. The tank farm's capability in meeting each WAC parameter was assessed in terms of sampling and analytical uncertainties. Staged feed delivery composition profile for HLW and available technical studies on expected waste transferred to WTP have been evaluated, incorporating the effects from sampling and analytical uncertainties.

Potential gaps and open items have been identified to highlight problem areas that can affect the waste acceptance decision. The gaps should be considered initial given they are derived using preliminary quantitative data (e.g. from preliminary mixing tests), qualitative assessments, and assumptions (e.g. tank farm waste properties are normally distributed) with associated uncertainties that have not been quantified. The gaps will be re-evaluated and addressed as the WAC DQO evolves. Furthermore, development of waste feed qualification techniques to measure hydrogen generation rate and abrasivity are at early stages. Nonetheless, these gaps and open items are starting points for focusing development/ design/ characterization efforts on areas of high uncertainties. The list(s) of gaps and open items may grow or shrink as understanding on the tank farm and WTP capabilities continues to mature. The goal is to track to closure efforts that will minimize, but not necessarily eliminate, uncertainties from the WTP waste acceptance decision.

Conclusions relative to specific WAC parameters and potential new nuclear safety parameters are summarized in Section 7.1. A path forward is suggested for handling the gaps and open items in Section 7.2.

7.1 CONCLUSIONS

As stated in DNFSB 2010-2 IP, Commitment 5.5.3.1 (Chu, 2011), this report includes the following deliverable elements and associated conclusions.

- *A definition of the initial WAC.*

The initial WAC as defined in the context of this initial gap analysis includes current HLW feed parameters from the ICD 19 including an abrasivity parameter as a proposed replacement for the nominal particle size and hardness parameters (see Table 3-1). The effort includes the evaluation of a list of potential new nuclear safety parameters from 2010-2 IP, Commitment 5.7.3.4 deliverable, 24590-WTP-RPT-ENS-11-021 (see Table 3-2).

- *A determination of the physical characteristics of waste expected to be transferred to WTP with existing feed staging and transfer systems given the uncertainty associated with tank farm characterization data.*

The physical characteristics of waste (including feed temperature and compatibility) expected to be transferred to WTP have been evaluated using a combination of HTWOS feed screening and technical reports (mainly RPP-RPT-51652). Uncertainties have been assessed using a statistical

hypothesis testing method consistent with the WAC DQO process (i.e., number of samples required to support the waste acceptance decision), and using a qualitative approach based on latest process understanding supplemented with available simulant testing data. A revision to the Initial WAC DQO (24590-WTP-RPT-MGT-11-014) is planned in 2013 after the next revision of ICD-19 (24590-WTP-ICD-MG-01-019) consistent with RPP-PLAN-53354. The reader should understand that this initial identification of gaps between the WAC and tank farm capabilities may change as the WAC DQO evolves.

- *A determination of the capability of staging tank sampling system.*

The latest concept of the tank sampling system (Isolok™ remote sampler installed in a waste certification flow loop) was reviewed. The sampling system capability was broken down into elements of sampling errors traceable to aspects of Pierre Gy's sampling principle. Uncertainties in each element are quantified and propagated in terms of %RSD numbers to assess overall sampling capability.

- *Identification of the analytical techniques necessary to determine the fraction that could exceed the WAC.*

Analytical techniques applied to each WAC and potential new nuclear safety parameter were assessed. Analytical capability was broken down into direct measurement in the field (i.e., CV and tank temperatures) and laboratory analysis. Uncertainties of analytical errors were assessed using %RSD and design information as applicable.

The initial analysis presented in this report shows that the majority of the WAC parameters do not trigger a gap. Of the thirteen (13) WAC parameters currently tracked in HTWOS, only one ($U_{fissile}/U_{total}$ – solids) is driving a gap based on the number of required samples greater than 10. The sensitivity results confirms that $U_{fissile}$ to U_{total} – solids is the only parameter driving the maximum number of required sample, and that improvement in the sampling uncertainties or reducing the Confidence Level from 95% to 90%, alone would not be sufficient in mitigating the gap.

In summary, there are seven (7) gaps identified between the tank farm's sampling and/or analytical capability in meeting some of the initial WAC parameters. The gaps should be considered initial given they are derived using preliminary quantitative data (e.g. from preliminary mixing tests), qualitative assessments, and assumptions (e.g. tank farm waste properties are normally distributed) with associated uncertainties that have not been quantified. The gaps will be re-evaluated and addressed as the WAC DQO evolves. Furthermore, development of waste feed qualification techniques to measure hydrogen generation rate and abrasivity are at early stages. Nonetheless, the initial seven identified gaps as listed by the affected WAC parameters are (see Section 6.0 for details):

- Critical velocity – PulseEcho development and field application uncertainties.
- Separable organics – Potential stratification of a separate organic layer that cannot be mixed or sampled using current method (i.e., waste feed certification flow loop).
- PCB – High analytical %RSD.

- $U_{fissile}$ to U_{total} ratio – Feed concentration close to the action limit driving a high number of required pre-transfer samples greater than 10 for some feed batches given the current feed strategy in System Plan 6.
- Hydrogen Generation Rate (HGR) – Lack of established hot cell procedures to measure generation rate compounded by high uncertainties in analytical technique (static vs. flow through).
- Feed temperature – Design is not final for this direct field measurement, and there is no defined process control strategy. Uncertainties of the final design (thermocouple "tree") may be high considering the transfer temperature could approach and may exceed action limit.
- Abrasivity – Lack of established hot cell procedures to measure abrasiveness of primary particles or agglomerates.

There are also two (2) open items identified between the tank farm's sampling and/or analytical capability in meeting some of the potential new nuclear safety parameters listed in 24590-WTP-RPT-ENS-11-021. These are binned separately from the gaps because the affected parameters are not part of the initial WAC. The two open items as listed by the affected parameters are (see Section 6.0 for details):

- Average particle density of pre-leached solids – Likelihood of HLW feed exceeding the average particle density limit and the misalignment between the tank farm planning basis (HTWOS) and WTP design basis (BOD).
- HLW feed particle size – Maximum size of particles that can be physically transferred to WTP (up to 9,525 µm) may exceed the design bases maximum. Large particles may also be bypassed (not sampled) due to size exceeding the sample port (needle) opening.

The two open items associated with the new potential nuclear safety parameters are forward looking and should be validated first through the scheduled ICD 19 update effort.

A potential new nuclear safety parameter listed in 24590-WTP-RPT-ENS-11-021, Parameter N19 in Table A-2, attempts to addresses discrete plutonium oxide particles. However, since the required criticality safety analysis of discrete fissile particles has not been completed, no specific control parameters are available for assessment in this gap analysis. Once this criticality safety analysis is completed (see planning document 24590-WTP-PL-ENS-11-0005) and if additional WAC parameters are required to ensure the safety of the WTP facilities, then these additional parameters will be evaluated for gaps.

7.2 PATH FORWARD

The role of this initial gap analysis is focused on the identification of gaps rather than mitigation. A separate mechanism is required to track and measure progress made to resolve the gaps. An actively managed database, such as the WTP PIER (24590-WTP-PIER-MGT-12-TBD), can be used to address these gaps as a collective technical issue to be resolved as an integral part of the ICD 19 update process. The PIER will drive the review of these gaps by the ICD 19 Team in the

next review cycle in 2013. The ICD 19 Team may update the ICD 19 to include these gaps as open items or issue as appropriate. These Open Items and Issue and associated mitigations will then be tracked to closure by the One System team in a way that is consistent with the Interface Management Plan (24590-WTP-PL-MG-01-001*)*. Mitigations for these gaps and open items may include updates to test requirements and inputs to equipment design. Final disposition of gaps and open items will be updated and documented in a Final Gap Analysis report in accordance with the DNFSB 2010-2 IP schedule (Commitment 5.5.3.9).

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APPENDIX A

EVALUATION OF INITIAL WAC AND POTENTIAL NEW NUCLEAR SAFETY PARAMETERS

Table A-1. Initial WAC Parameters for HLW Feed.

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W1	Solids Concentration	≤ 200 g/L	Solids are measured after holding the the tank farm sample at 25°C for 8 hours. The Basis of Design (Section 6.1.1) states that HLW feed will be between 3.8wt%-16wt% solids. This is assumed to be based on LAW limits (<3.8wt% solids) and the estimated weight percent of 200 g/L solids in a 10M Na liquid. Solids concentration in the WTP receipt vessel (HLP-22) will be controlled to meet more restrictive limitations (see Parameter N9 in Table A-2).	Y	Retained
W2	Viscosity (delivered feed)	< 1 Pa (yield stress) < 10 cP (consistency [plastic] viscosity)	HLP-22 vessel is a Newtonian vessel; therefore the yield stress cannot exceed 1Pa.	Y	Retained
W3	Slurry pH	≥ 12	Value in WAC-DQO (24590-WTP-RPT-MGT-11-014) listed at >7, but will be changed to reflected the more limiting value of ≥ 12 in the next revision.	Y	Retained
W4	Bulk Density of Slurry	< 1.5 kg/L	Bulk density of the as-delivered slurry.	Y	Retained
W5	Critical Velocity	≤ 4 ft/s	Based on a 3” transfer line and applicable to as-delivered HLW feed only.	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W6	Ammonia Concentration	< 0.04M	This value is under further consideration. An action in the WAC-DQO (24590-WTP-RPT-MGT-11-014) is to define the concentration limit as being free ammonia or dissolved ammonium.	Y	Retained
W7	Separable Organics	No Visible Layer[1]	Separable organics are not specifically addressed in the WTP safety basis. Therefore, the limit is no separable organics in the feed. This analysis will be performed by visual observation of the tank farm sample.	Y	Retained
W8	Polychlorinated Biphenyls (PCBs)	< 50 ppm	Based on regulatory compliance (see WA7890008967).	Y	Retained
W9	HLW Feed Unit Dose	< 2.9E5 Sv/L	Footnotes in Table 8 of ICD 19 state that this value is based on wet centrifuged solids and is derived from the HNF-IP-1266 value for the tank farm's controls. The value is converted to Sv/g value (270 Sv/g) by WTP assuming 66% solids fraction (volume) and 1.63 g/mL density for the wet centrifuged solids. Since the converted value is what is used by the WTP and since the values are essentially equivalent, the converted value (270 Sv/g) will be used in the initial gap analysis.	Y	Retained (see Discussion)
W10	Pu to Metals Loading Ratio	< 6.20 g/kg	Definition of Pu and "metals" provided in Section 8.1 of the CSER (24590-WTP-CSER-ENS-08-0001). Applies to both the solid and the liquid phases.	Y	Retained
W11	U Fissile to U Total	< 8.4 g/kg	Definition of U fissile and U total provided in Section 8.1 of the CSER (24590-WTP-CSER-ENS-08-0001). Applies to both the solid and the liquid phases.	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W12	Pu Concentration of Liquids	< 0.013g/L	Definition of Pu provided in Section 8.1 of the CSER (24590-WTP-CSER-ENS-08-0001).	Y	Retained
W13	Total Radioactivity in Material Fed to WTP per Year from External Sources	≤ 1.1E8 Ci/year	This parameter is included in Table 8 of ICD 19 (24590-WTP-ICD-MG-01-019). Assumed to be a maximum value.	N	Limit is a yearly limit and is not based on an individual source or sample.
W14	Hydrogen Generation Rate	≤ 2.1 E-06 gmole H_2/L/hr @ 150 ˚F	Value based on HLP-22 receiving feed at the bounding limits (10M Na and 200g/L solids). This does not account for the change to the acceptable concentrations in HLP-VSL-00022 due to mixing limitations (7M and 10wt% solids – see Parameters N9 and N10 in Table A-2). Assumed to be a maximum value.	Y	Retained
W15	Temperature	< 150˚F	This temperature is utilized in the HGR calculation (24590-WTP-M4C-V11T-00011). Note that the temperature determination is not sample based and will need to be monitored during any HLW feed transfer to the WTP. Note also that the BNI reference in the ICD is superseded (by 24590-PTF-M4C-V11T-00015). 24590-PTF-M4C-V11T-00015 provides an evaluation that assesses if 150˚F is a reasonable temperature limit for HLW feed. However, the evaluation is based on TWINS data and does not account for retrieval operations except to say that the temperature should be lower than the TWINS temperature. With two 300-HP mixer pumps running, this may not be true.	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W16	Environmental Permit Limits (such as the Regulatory Data Quality Objectives (RDQO) report constituents and negotiated concentration limits)	N/A	The compositional analysis of the waste feed will be required as a waste acceptance requirement, but the RDQO (24590-WTP-RPT-MGT-04-001) and the IHLW Waste Form Compliance Plan (24590-HLW-PL-RT-07-0001) do not stipulate specific values for waste acceptance. However, they do list constituents of concern requiring analyses.	N[2]	WAC components are specified individually. No upper limit is prescribed for the remainder of the components.
W17	Specification 7 List of Constituents and Concentrations	Specification 7	These parameters include the liquid composition limits provided in Tables TS-7.1 and TS-7.2 of Specification 7 as well as the sodium molarity limits in the table in Section 7.2.2.1. Sodium limit in included separately in Parameter W21. Note that the bulk of components from these tables are listed in Table 4-2 of the WAC-DQO (24590-WTP-RPT-MGT-11-014) and are not considered "Action Limits" at this time. The compositional analysis of the waste feed will be required as a waste acceptance requirement, but the values do not stipulate waste acceptance criteria unless they are listed individually in ICD 19. Following the completion of the WTP testing, the WTP WAC will be updated as necessary (2010-2 Commitment 5.5.3.3) and will be used as input to the final gap analysis (2010-2 Commitment 5.5.3.9). Commitment 5.5.3.3 will establish any new WTP WAC parameters based on testing (such as LSIT) and ongoing process evaluations (such as erosion/corrosion). This may result in additional Specification 7 constituents having true concentration limits.	N[2]	WAC components are specified individually. No upper limit is prescribed for the remainder of the components.

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W18	Specification 8 List of Constituents and Concentrations	Specification 8	These parameters include the solid composition limits Tables TS-8.1, TS-8.2, and TS-8.3 in Specification 8. Table TS-8.4 in Specification 8 identifies a number of other components important to HLW glass production, but these values are not specification limits as per the WTP Contract. Note that the bulk of components from these tables are listed in Table 4-2 of the WAC-DQO (24590-WTP-RPT-MGT-11-014) and are not considered "Action Limits" at this time. The compositional analysis of the waste feed will be required as a waste acceptance requirement, but the values do not stipulate waste acceptance criteria unless they are listed individually in ICD 19. Following the completion of the WTP testing, the WTP WAC will be updated as necessary (2010-2 Commitment 5.5.3.3) and will be used as input to the final gap analysis (2010-2 Commitment 5.5.3.9). Commitment 5.5.3.3 will establish any new WTP WAC parameters based on testing (such as LSIT) and ongoing process evaluations (such as erosion/corrosion). This may result in additional Specification 8 constituents having true concentration limits.	N[2]	WAC components are specified individually. No upper limit is prescribed for the remainder of the components.

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W19	Mean Size Particle	≤ 11 μm	The 11μm mean particle size value, in conjunction with the particle hardness of 4.4 Mohs [Parameter W20], is used as the erosion design basis as per the *WTP Waste Particle Size and Hardness Characterization* report (24590-WTP-RPT-M-05-001). ICD 19 provides no additional definition of a particle size distribution. The WAC-DQO (24590-WTP-RPT-MGT-11-014) does not include mean particle size as a parameter and Open Item #15 in Appendix D of ICD 19 states that this value is not likely to be measured directly and will likely be replaced. Abrasivity is included in Table 4-2 of the WAC DQO as a potential replacement.	N	Abrasivity is included in Table 4-2 of the WAC-DQO as a potential replacement and the Abrasivity parameter is included in this table as Parameter A1.
W20	Arithmetic Average Particle Hardness	≤ 4.4 Mohs	The 11μm mean particle size value [Parameter W19], in conjunction with the particle hardness of 4.4 Mohs, is used as the erosion design basis as per the *WTP Waste Particle Size and Hardness Characterization* report (24590-WTP-RPT-M-05-001). The WAC-DQO (24590-WTP-RPT-MGT-11-014) does not include mean particle size as a parameter and Open Item #15 in Appendix D of ICD 19 states that this value is not likely to be measured directly and will likely be replaced. Abrasivity is included in Table 4-2 of the WAC DQO as a potential replacement.	N	Abrasivity is included in Table 4-2 of the WAC-DQO as a potential replacement and the Abrasivity parameter is included in this table as Parameter A1.
W21	Transfer System Design	90-140 gpm 400 psi 200 ˚F 500-550 ft Head	Equipment and transfer system design parameters are from ICD 19 Table 5. These are physical design limits and are not feed acceptance criteria.	N	Physical design criteria - not HLW feed specific WAC

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
W22	Sodium Concentration	0.1 to 10 M	Sodium molarity as specified by the WTP Contract (Specification 7) and therefore carried as a WAC parameter. This parameter is not directly included in the tables in ICD 19. However, it is included by reference by Section 2.3.1 of ICD 19.	Y	Retained
W23	Total Organic Carbon (TOC)	< 10wt%	WTP Permit (WA7890008967) requirement. This parameter is not directly included in the tables in ICD 19. However, it is included by reference by Section 2.3.1 of ICD 19.	Y	Retained
W24	Waste Feed Compatibility	Δ of +/- 20 ˚C	Waste feed compatibility uses ASTM D5050-90 method that looks for any temperature or rheology changes when mixing 10mL of staged feed with 10mL of residual feed in WTP receipt vessels. The rheology change is observed and not measured. WTP Permit (WA7890008967) requirement. This parameter is not directly included in the tables in ICD 19. However, it is included by reference by Section 2.3.1 of ICD 19.	Y	Retained
A1	Abrasivity	TBD	HLP-VSL-00022 is to be designed to last 40 years. The vessel is mixed using high velocity jets and the vessel is located in a “black” cell (a cell in the facility that is inaccessible and therefore no maintenance can be performed on the vessel). Because of this, vessel erosion is a key concern to completing the WTP mission. ICD 19 (24590-WTP-ICD-MG-01-019) includes a value for average (arithmetic) particle hardness (≤ 4.4 Mohs - Parameter W20). The WAC DQO (24590-WTP-RPT-MGT-11-014) does not include particle hardness as a parameter and Open Item #15 in Appendix D of ICD 19 states	Y	Retained

#	Parameter	Value	Discussion	Retained (Y/N)	Rationale for Not Retaining
			that this value is likely to be replaced. Abrasivity is included in Table 4-2 of the WAC DQO, but no limit is provided. Abrasivity is not included directly in ICD 19. The 11µm d_{50} particle size value [Parameter W19] in conjunction with the particle hardness of 4.4 Mohs [Parameter W20], is used as the erosion design basis as per the *WTP Waste Particle Size and Hardness Characterization* report (24590-WTP-RPT-M-05-001). The final decision on abrasivity (what it is and how it is measured) may ultimately require a limitation on the d_{50} particle size. This is not included in the potential particle size parameter [N15] and may impact the description of Parameter N15 if a d_{50} particle size is ultimately specified. The WTP needs to determine if particle hardness or abrasivity is a waste acceptance parameter, how the acceptance value will be set, and how it will be determined. In addition, the impact of vessel erosion extends beyond HLP-22 and may be impacted by process operations (solids concentration, washing, leaching).		

[1]A more detailed discussion on "separable organics" and "no visible layer" is provided following Table A-1.
[2]While these sources do not have WAC limits, the components included in the RDQO and Contract Specification 7 and 8 will be analyzed for using the same rigor and requirements included in the WAC DQO in terms of quality control, detection limits, analytical method guidelines, and data reporting as the parameters with limits.

Separable organics (Parameter W7) - Specification 8 of the WTP Contract states that "The HLW feed provided will not contain a visible separate organic layer." Therefore, the presence of separable organics is determined by visual observation. Appendix C of ICD 19 provides this definition of separable organics:

> *Separable organics are organic compounds (carbon based molecules) that are present in the HLW or LAW waste streams transferred to the WTP and are present in concentrations beyond their saturation point for a particular batch inventory.*

Separable organics are further defined in ICD 19 as:

> *...organic species* [that] *separates as a solid or liquid...*

Footnote #1 for Table 8 in ICD 19 states that:

> *The Contractor* [BNI] *shall propose a deminimus concentration level for separable organics that could be sent to the WTP without adversely affecting the WTP*

Standard 2, subpart (a)(3)(viii) of the WTP Contract states that:

> *The Contractor shall evaluate the effects of trace quantities (~25 ppm) of separable organics (tributyl phosphate and normal paraffin hydrocarbon) in the tank waste liquid feed to the WTP and the fate of the separable organics within the system. Each potentially affected unit operation (including ion exchange elution and evaporation) shall be examined for process, safety, and permitting implications. Based upon the results of these tests, the Contractor shall propose a deminimus concentration level for separable organics that could be sent to the WTP without adversely affecting the WTP*

This work is tied to Contract Deliverable 2.11, which, according to Table C.5-1.1 of the WTP Contract, has a due date of 12/31/2012. The deminimus WAC parameter value for separable organics will be defined following the completion of Contract Deliverable 2.11.

In addition, it should be noted that Table 3-1 lists the parameters and the values, but it does not necessarily dictate under what conditions an individual parameter is to be evaluated. For example, a temperature is not given for viscosity [Parameter W2] nor are any handling/preparation requirements (settling, sonication, etc.) provided. Further definition of these analysis conditions will need to be determined by the WTP prior to finalizing the WAC (2010-2 Commitment 5.5.3.3).

Table A-2. Evaluation for Potential New Parameters for HLW Feed Acceptance.

#	Parameter[18]	In Table 3-1?	Discussion	New?	Value
N1	LAW feed slurry pH must be ≥ 12	No	Specific to LAW feed	No	NA
N2	LAW solids concentration must be ~3.8 wr% based on 5 M sodium supernate.	No	Specific to LAW feed	No	NA
N3	LAW slurry bulk density must be < 1.46 kg/L	No	Specific to LAW feed	No	NA
N4	LAW feed temperature must be ≥59 ˚F	No	Specific to LAW feed	No	NA
N5	LAW feed temperature must be < 120 ˚F	No	Specific to LAW feed	No	NA
N6	LAW allowable viscosity range of 1.1 cP to 26 cP	No	Specific to LAW feed	No	NA
N7	LAW feed hydrogen generation rate ≤ 3.7E-07 gmole H_2/L/Hr @ 120 ˚F	No	Specific to LAW feed	No	NA
N8	HLW transfer solids concentration must be ≤ 200 g/L	Yes	As per ICD 19, the solids concentration is determined after holding the sample at 25 ˚C for 8 hours. Included in Table A-1 as Parameter W1.	No	NA

[18] "N" parameter descriptions (except for N19) are taken directly from Section 4.4.2 of *Key Inputs, Assumptions, Safety Margin Uncertainties, and Nuclear Safety Parameters Required to be Included in the Waste Acceptance Criteria, 2010-2 Implementation Plan Commitment 5.7.3.4* (24590-WTP-RPT-ENS-11-021) and are subject to change as new information emerges for evaluation.

#	Parameter[18]	In Table 3-1?	Discussion	New?	Value
N9	HLW solids concentration of 10 grams unwashed solids/liter to a maximum of 107 g/L at 0.1 M Na to 144 g/L at 1M Na	No	The solids concentration is based on the resulting slurry in HLP-22 (the values are essentially based with a limitation of 10wt% solids). The delivered HLW feed slurry may exceed these values within the 200 g/L limit in ICD 19. The volume transferred from TFs will need to be controlled and pre-staging operations performed by WTP in order to not exceed these values.	No	NA
N10	HLW sodium content must be 0.1 to 7 M	No	The upper sodium concentration limit is based on the resulting slurry in HLP-22. The delivered HLW feed slurry may exceed this value within the 10M limit in ICD 19. The volume transferred from TFs will need to be controlled and pre-staging operations performed by WTP in order to not exceed the upper value. The lower limit of 0.1M is as per the WTP Contract, but is not considered a nuclear safety parameter.	No	NA
N11	HLW slurry pH must be ~ 12	Yes	Included in Table A-1as Parameter W3.	No	NA
N12	HLW slurry density must be between 1 and 1.7 g/ml	Yes	Upper density value is based on density AT THE PUMP SUCTION. This value is based on the mixing capabilities in HLP-22 and with 10wt% solids in 7M sodium liquid. This is not the limit for the delivered HLW feed or a limit to the average density in the vessel. Since the wt% solids and molarity in HLP-22 is limited by the feed delivery conditions, this parameter is also limited by the feed delivery conditions.	No	NA
N13	HLW feed temperature must be ≥59 ˚F	No	The lower temperature is stated in the vessel mixing assessment for HLP-22 (24590-WTP-RPT-ENG-08-021-08) and is based on the lower temperature of the black cells from the BOD. This lower temperature is not used directly in the mixing assessment for HLP-22 and is therefore not considered a potential new nuclear safety parameter.	No	NA
N14	HLW feed temperature must be < 150 ˚F	Yes	Included in Table A-1as Parameter W15.	No	NA

#	Parameter[18]	In Table 3-1?	Discussion	New?	Value
N15	HLW feed particle size ≤ 700µm	No	Table 8 of ICD 19 lists the mean particle size as ≤ 11µm with no particle size distribution provided. Section 6 of the BOD states that the expected maximum particle size for the tank farm transfers is 700µm. The listed particle size is based on RPP-9805 – the low end is the Mean 1% [0.7µm] and the high end is the 95/95 TL 99% (and is as stated in the BOD). However, the range is described as not being a limitation to feed delivery in the BOD. The feed delivery limitation is to be based on a CV of ≤ 4ft/s in a 3" pipe as per the BOD (Parameter W5 in Table A-1). Section 6 of the BOD also states that "The RPP-9805; 95% UL particle size distribution shall be used as the WTP computational design basis for pumping and line sizing of the as-received HLW feed solids." Appendix C of ICD 19 states that the particle size to be used in WTP CV calculations is the d_{95} particle size. From RPP-9805, this size is 210µm. This particle, in conjunction with the bulk/average solids density [Parameter N20], and a 30% design margin, is used to calculate the required CV of the WTP transfer pump. The ≤ 4 ft/s CV value [Parameter W5] is not used directly in WTP transfer or mixing calculations, but is expected to protect the BOD assumptions. The 210µm size is set as the limit.	Yes	≤ 210µm
N16	HL W feed hydrogen generation rate ≤ 2.1 E-06 gmole H_2/L/Hr @ 150 ˚F	Yes	Included in Table A-1as Parameter W14.	No	NA
N17	Ammonia < 0.04M	Yes	Included in Table A-1 as Parameter W6.	No	NA
N18	An average upper bound settled layer shear strength of up to 200 Pa can be expected within 24 hours.	No	Information taken from *An Approach to Understanding Cohesive Slurry Settling, Mobilization, and Hydrogen Gas Retention in Pulsed Jet Mixed Vessels* (PNNL-17707) and expected to bound the waste fed to the WTP. The vessel mixing assessment for HLP-22 (24590-WTP-RPT-ENG-08-021-08) states that ITS mixing will be employed within the 24 hours to mitigate the development of higher shear strengths. Mixing tests for HLP-22 using a 200 Pa settled simulant were deemed to be successful with no testing of higher shear strength simulants. Thus the <200P within 24 hours is set as the limit.	Yes	< 200 Pa within 24 hours

#	Parameter[18]	In Table 3-1?	Discussion	New?	Value
N19	PuO_2 particle in HLP-22	No	A discrete 10μm spherical equivalent diameter Pu oxide particle was simulated in testing the mixing capability of the HLP-22 vessel (24590-WTP-RPT-ENG-08-021-08). The term "discrete" is used because nearly all of the plutonium in the Hanford tank wastes was co-precipitated with iron and/or other neutron absorbers before being sent to the tank farms. This co-precipitation is discussed in CCN 211814 and the CSER and is utilized in the development of criticality controls in the current CSER. Additional results and analyses summarized in RPP-RPT-51652 demonstrate that there are discrete Pu particles that exceed the 10μm size (RPP-RPT-51652). Pu-Bi particles and Pu metal, which has a higher density than the oxide form of Pu, may also be present in the tank wastes . In summary, the criticality safety evaluation and control strategy to address the potential inventory of discrete fissile plutonium particles has not yet been developed. Direction (CCN 246005) and planning (24590-WTP-PL-ENS-11-0005) are that a criticality safety evaluation and controls will be developed in accordance with criticality safety requirements (24590-WTP-PL-ENS-03-013). The criticality safety controls that are selected to ensure the safety of fissile material may involve specifying additional WAC on the feed delivery to WTP. However, because the required criticality safety evaluation has not yet been completed, no specific control parameters for the WAC are available for assessment in this gap analysis and therefore this parameter will not be retained.	Yes	NANA

#	Parameter[18]	In Table 3-1?	Discussion	New?	Value
N20	Average particle density of 2.9 for pre-leached solids and 3.8 for post-leached solids.	No	The 2.9kg/L value is based on mass average maximum density for the solid particles and is assumed to be applied to the staged HLW feed in the tank farms (i.e, untreated solids). As per the BOD, this value is used for mixing and is described as not being a limitation to feed delivery. The particle density limitation is based on a CV of 4ft/s in a 3" pipe (BOD Section 6.2.1). The BOD includes another particle density value of 2.18kg/L. This value is based on a mass average density for the solid particles (not a maximum) and is assumed to be applied to the staged HLW feed in the tank farms (i.e., untreated solids). This value is used in the WTP for pump and line and is described as not being a limitation to feed delivery. As with the 2.9kg/L value, the overall particle density limitation is based on a CV of 4ft/s in a 3" pipe (BOD Section 6.2.1). The value for the post-leached solids (3.8 kg/L) is not applicable to feed receipt in HLP-22 and is therefore not addressed. The BOD text clearly states that the feed specification criterion is CV only (Parameter W5). However, the particles sizes discussed for Parameter N15 and the densities in the BOD are used as input to the WTP design and may be considered to be de facto requirements. Without a PSD, it cannot be determined by calculation if the average particle density results in a CV that exceeds 4 ft/s. Therefore, all three parameters (Parameter W5, N15, and N20) are retained. For this parameter, the lesser value of 2.18kg/L is specified. This gives a considerable degree of margin above the bulk average solids density of 2.9 kg/L.	Yes	$\leq$ 2.18kg/L
N21	Thermal conductivity of the sludge is > 0.6 W/m K	No	The derivation of this parameter is included in Appendix L of 24590-WTP-M4C-V11T-00011. This value is used to estimate the temperature rise in a settled solids layer. Derivation shows that this value is conservative and sufficiently bounding and the calculation states that the assumption for this value does not require verification.	No	NA

#	Parameter[18]	In Table 3-1?	Discussion	New?	Value
N22	The specific heat capacity of the sludge is > 2.4 kJ/kg °C	No	The derivation of this parameter is included in Appendix L of 24590-WTP-M4C-V11T-00011. This value is used to estimate the temperature rise in a settled solids layer. Derivation shows that this value is conservative and sufficiently bounding and the calculation states that the assumption for this value does not require verification.	No	NA
N23	The settled non-convective layer in a vessel is 10% by volume	No	The WTP Design Criteria Database (DCD) lists this parameter as being an assumption to accident analysis reports 24590-PTF-Z0C-10-00002 and 24590-HLW-Z0C-W14T-00021 (note that the accident analysis report specific to HLW Vitrification (24590-HLW-Z0C-W14T-00021) does not apply to Pretreatment vessel HLP-VSL-00022). The analysis performed in 24590-PTF-Z0C-10-00002 has been replaced by a steam bump analysis performed in 24590-WTP-Z0C-W14T-00015. In the more recent document, the non-convective layer assumption is replaced by a settled sludge layer assumption of 70 wt% maximum (Assumption 6 in the reference). Based on discussions with experts in this field, this assumption is conservative and defendable. Also, from Table A-2 in 24590-WTP-Z0C-W14T-00015, the safety evaluation results in over 100 hours of margin between the time to the lower flammability limit for hydrogen and the time to boil. Therefore this parameter is deemed sufficiently bounding and is not considered a potential parameter for waste acceptance.	No	NA
N24	The heat capacity for the non-convective layer is 2,850 J/(kg-K)	No	The WTP DCD lists parameter as being an assumption to accident analysis reports 24590-PTF-Z0C-10-00002 and 24590-HLW-Z0C-W14T-00021 (note that the accident analysis report specific to HLW Vitrification (24590-HLW-Z0C-W14T-00021) does not apply to Pretreatment vessel HLP-VSL-00022). The analysis performed in 24590-PTF-Z0C-10-00002 has been replaced by a steam bump analysis performed in 24590-WTP-Z0C-W14T-00015. In the more recent document, the heat capacity assumption has been expanded to include both the liquid and solid portion of the slurry (Assumption 3 in the reference). However, the more recent calculation states that the dose consequences for this analysis are not affected by this assumption and therefore the heat capacity values are not considered potential parameters for waste acceptance.	No	NA

In addition, it should be noted that Table A-2 lists the potential parameters and the values, but it does not necessarily dictate under what conditions an individual parameter is to be evaluated. For example, a temperature is not given for particle size and solids density nor is any handling/preparation requirement (holding time, sonication, etc.) provided. Further definition of these analysis conditions will need to be determined by the WTP prior to finalizing the WAC (2010-2 Commitment 5.5.3.3).

APPENDIX B

NUMBER OF SAMPLES EQUATIONS

Source of sample number formula: EPA/240/B-06/001 Guidance on Systematic Planning Using the Data Quality Objectives Process, Equation A-8.

Definitions:

$\alpha = Probability\ of\ Type\ I\ error = NORMSDIST(z_\alpha)$

$z_\alpha = NORMSINV(\alpha)$

$\beta = Probability\ of\ Type\ II\ error$

$n = number\ of\ samples$

$\sigma = Standard\ Deviation$

$AL = Action\ Limit$

$\mu = Mean$

$U = Fixed\ constant; the\ probability\ of\ accepting\ H_0\ when\ \mu = U\ is\ \beta$

$d = U - AL$

For pH:

$$H_0: \mu \leq AL$$

$$H_A: \mu > AL$$

$$n = \frac{(z_{1-\alpha} + z_{1-\beta})^2 \sigma^2}{d^2} + \frac{1}{2} z_{1-\alpha}^2$$

$$z_{1-\beta} = \sqrt{n - \frac{1}{2} z_{1-\alpha}^2} \frac{d^2}{\sigma^2} - z_{1-\alpha}$$

$$z_{1-\beta} = \sqrt{n - \frac{1}{2}\ NORMSINV\ 1-\alpha\ ^2\ \frac{U-AL}{\sigma}} - NORMSINV(1-\alpha)$$

For all other constituents:

$$H_0: \mu \geq AL$$

$$H_A: \mu < AL$$

Rejection region is all in "other" (lower) tail; replace 1-β with β, 1-α with α to reverse tails. Alternatively, deriving sample number formula for this case produces equivalent result.

$$n = \frac{(z_\alpha + z_\beta)^2 \sigma^2}{d^2} + \frac{1}{2} z_\alpha^2 = \frac{(z_{1-\alpha} + z_{1-\beta})^2 \sigma^2}{d^2} + \frac{1}{2} z_{1-\alpha}^2$$

$$z_\beta = \sqrt{n - \frac{1}{2} z_\alpha^2} \frac{d^2}{\sigma^2} - z_\alpha$$

$$z_\beta = \sqrt{n - \frac{1}{2} z_{1-\alpha}^2} \frac{U - AL}{\sigma} + z_{1-\alpha}$$

$$z_\beta = \sqrt{n - \frac{1}{2} NORMSINV(1-\alpha)^2} \frac{U - AL}{\sigma} + NORMSINV(1-\alpha)$$

APPENDIX C

SAMPLING ERRORS

This section briefly describes the Pierre Gy's seven basic sampling errors and how aspects of each are applicable to the physical collection of HLW staged waste samples. The impact from each type of error has been qualitatively assessed and factored in the estimate of sampling %RSDs. Since the DST sampling system design and testing is preliminary and evolving, the initial gap analysis helps to spot potential areas of concern such that mitigation can be incorporated in the design or tracked as an open item through final resolution. Table C-1 below itemized the types of basic errors and discuss in qualitative terms how they relates to the four types of sampling errors as defined for the HLW feed (i.e., mixing, transfer, Isolok™, and handling).

Table C-1. Sampling Errors.

Gy's Seven Basic Errors[1]	Description	Relates to
Fundamental Error (FE)	The constitution (or makeup) of the material causes it to be heterogeneous. Gy calls this the constitution heterogeneity (CH). It represents the differences between particles or molecules. The CH of solids is influenced by particle size, shape, density, chemical composition, and other physical properties.	This type of inherent error cannot be minimized as applied to DST sampling of wet slurry. FE exists even if the tank is perfectly mixed (homogenized) and the sampler system operates perfectly.
Grouping and Segregation Error (GSE)	Error due to the differences from one group of particles to another or from one part of the lot to another. Gy calls this the distribution heterogeneity (DH). It is caused by the combination of the CH, the spatial distribution of the constituents, and the shape of the lot. The sampling error resulting from grouping and segregation can be reduced by taking many small increments and compositing them to form the sample.	Short-range GSE is mostly covered by the analytical RSD for the pre-transfer sample. Long-range (large scale) GSE as applied to the DST sampling is covered as an integral part of the non-periodic and periodic heterogeneity of the DST.

[1] Patricia L. Smith, *A Primer for Sampling Solids, Liquids, and Gases – Based on the Seven Sampling Errors of Pierre Gy.*

Gy's Seven Basic Errors[1]	Description	Relates to
Long-range Non-periodic Heterogeneity Error	Processes often change over time, sometimes in short intervals and sometimes over a longer time span. This variation can be broken down roughly into random, nonrandom, and cyclic variation. Nonrandom variation is due to shifts or trends in the process. Because of this long-range fluctuation error, samples taken at different times will give different results.	**Transfer RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is transferred in subsequent batches. It is a term used to assess batch-to-batch variability over time. Variability of tank composition with decreasing tank level introduces a non-periodic heterogeneity error. Less batch-to-batch variability, the lower the transfer RSD value.
Long-range Periodic Heterogeneity Error	This periodic fluctuation error affects the variation in the process. The cause of the process cycle is not a sampling error, but a sampling error may be generated by variations in the cycle period, amplitude, and sampling frequency.	**Mixing RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the tank at the time of sampling event. It is a term used to assess mixing performance. Rotation of mixer nozzles during a batch transfer introduces periodic heterogeneity error. The cyclic operation of the Isolok™ sampler helps minimize the effect from this type of error by compositing multiple samples (~5 mL) to make up the total sample volume.
Delimitation Error (DE)	Error occurs when not every part of the lot has an equal chance of being in the sample, in other words, when the defined sample boundary is not correct.	**Isolok™ Sampler RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the recirculation flow loop. It is a term used to assess sampler design. Physical configuration of the sampler design introduces delimitation (i.e., does not take full cross-section sample of the pipe) error. The larger the cross-section to full sample flow, the lower the sampler RSD value.
Extraction Error (EE)	Error occurs if the sample that has been identified cannot be obtained. In other words, a DE may be avoided by defining a correct boundary for the sample, but if it cannot actually be recovered, then an EE is incurred.	**Isolok™ Sampler RSD**. An estimate of uncertainties relative to how "representative" the pre-transfer sample is compared to what is in the recirculation flow loop. It is a term used to assess sampler design. Physical configuration of the sampler design (e.g., size and shape of the sample annulus) introduces extraction error.

Gy's Seven Basic Errors[1]	Description	Relates to
Preparation Error (PE)	This error results from the incorrect preservation, handling, mixing, grinding, and subsampling that can result in loss, contamination, or altering of the sample such that it no longer is an accurate representation of the material being sampled.	**Sample Handling RSD**. An estimate of uncertainties from physical preparation and handling of the pre-transfer sample from the time of sampling event to laboratory analysis. It is a term used to assess the integrity of the sample. Physical handling of the sample introduces preparation error (e.g., poor vapor seal, leaks, etc.). Better preservation of the sample, the lower the sample handling RSD value.

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