RPP-RPT-43588, Rev. 0

SECONDARY WASTE/ETF PRELIMINARY PRE-CONCEPTUAL ENGINEERING STUDY

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U.S. Department of Energy Contract DE-AC27-08RV14800

EDT/~~ECN~~: 823422	UC:
Cost Center:	Charge Code:
B&R Code:	Total Pages: 101

Key Words: Secondary Waste, ETF, Engineering Study

Abstract: This pre-conceptual engineering study is intended to assist in supporting the critical decision (CD) 0 milestone by providing a basis for the justification of mission need (JMN) for the handling and disposal of liquid effluents. The current ETF baseline strategy, to accommodate WTP requirements, calls for a solidification treatment unit (STU) to be added to the ETF to provide the needed additional processing capability. This STU is to process the ETF evaporator concentrate into a cement-based waste form. The cementitious waste will be cast into blocks for curing, storage, and disposal. This pre-conceptual engineering study explores this baseline strategy, in addition to other potential alternatives, for meeting the ETF future mission needs. Within each reviewed case study, a technical and facility description is outlined, along with a preliminary cost analysis and the associated risks and benefits.

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Nancy A Fouad — 12-28-09
Release Approval — Date — Release Stamp

Approved For Public Release

RPP-RPT-43588
Revision 0

Secondary Waste – ETF
Pre-Conceptual Engineering Study

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Date Published
December 22, 2009

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Abbreviations and Acronyms

ALARA	as low as reasonably achievable
CD	critical decision
CDR	conceptual design report
CET	Concentrated Eluate Tank
CH	contact-handled
COC	contaminant of concern
CRR	carbon reduction reformer
CsIX	cesium ion-exchange
CST	crystalline silicotitanate
CW	cooling water
DMR	denitration mineralization reformer
DOE	U.S. Department of Energy
DST	double-shell tank
ECT	eluate collection tank
Ecology	Washington State Department of Ecology
EIS	environmental impact statement
ERDF	Environmental Restoration Disposal Facility
ESP	Environmental Simulation Program
ETF	Effluent Treatment Facility
EVAP	evaporator
FBSR	fluidized bed steam reforming
FRP	fiberglass reinforced plastic
GAC	granular activated carbon
HEPA	high-efficiency particulate air
HLW	high-level waste
HVAC	heating, ventilation, and air conditioning
IDF	Integrated Disposal Facility
IHLW	immobilized high-level waste
ILAW	immobilized low-activity waste
IMUST	inactive miscellaneous underground storage tanks
IX	ion-exchange
IXFT	ion-exchange feed tank
IXPT	ion-exchange product tank
IXRT	ion-exchange recycle tank
JMN	justification of mission need
LAW	low-activity waste
LERF	Liquid Effluent Retention Facility
MOSS	mobile solidification system
NEPA	National Environmental Policy Act
NOx	nitrogen-oxide compounds
NS&L	Nuclear Safety and Licensing
OGB	off-gas blower
OGC	off-gas cooler

ORP	U.S. Department of Energy, Office of River Protection
OX	oxidation
PA	performance assessment
PBF	process baghouse filter
PNNL	Pacific Northwest National Laboratory
PT	pretreatment (Facility)
RBA	radiation buffer area
RCRA	Resource Conservation and Recovery Act
RPP	River Protection Project
SALDS	state-approved land disposal site
SBS	submerged bed scrubber
SR	steam-reforming (system)
SST	single-shell tank
STT	secondary treatment train
STU	solidification treatment unit
SWRT	secondary waste receiving tank
TcIX	technetium ion-exchange
TCT	technetium concentrate tank
TFD	thin-film dryer
TOC	total organic carbon
TPA	Tri-Party Agreement
TRU	transuranic
UV	ultraviolet
WAC	waste acceptance criteria
WESP	wet electrostatic precipitator
WF	waste feed
WRPS	Washington River Protection Solutions, LLC
WTP	Waste Treatment and Immobilization Plant

Units

atm	atmosphere
BTU	British thermal unit
BV	bed volume
BV/hr	bed volume per hour
°C	degrees Celsius
Ci	curies
°F	degrees Fahrenheit
g	gram
gal	gallon
in.	inch
L	liter
lb	pound
kg	kilogram
kW	kilowatt
µCi	microcurie
mg	milligram
min	minute
MT	metric ton
MTG	metric tons equivalent glass
nCi	nanocurie
ppm	parts per million
SCFM	standard cubic feet per minute
wt%	weight percent
yr	year

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1.0 INTRODUCTION

1.1 BACKGROUND

The primary mission for the U.S. Department of Energy (DOE), Office of River Protection (ORP) is to retrieve and treat Hanford's tank waste and close the tank farms to protect the Columbia River. As of June 2008, the 177 underground storage tanks at the Hanford Site are estimated to contain 57 million gallons of mixed radioactive and hazardous waste (ORP-11242, *River Protection Project System Plan*, Rev. 4). A key aspect of implementing the ORP mission is to construct and operate the Waste Treatment and Immobilization Plant (WTP). The WTP will separate the tank waste into high-level and low-activity waste (LAW) fractions and produce a solid vitrified waste product from each fraction. The WTP is scheduled to begin operations in 2018, as outlined in ORP-11242 (Rev. 4). In the baseline case, all WTP secondary liquid process wastes are pumped to the 200 Area Effluent Treatment Facility (ETF) for treatment and subsequent disposal.

The ETF receives, treats, and disposes of liquid effluents from clean-up projects on the Hanford Site. The ETF supports the 242-A Evaporator, Mixed Waste Burial Trench and Environmental Restoration Disposal Facility (ERDF), groundwater treatment projects, and other decontamination and decommissioning projects. The liquid effluents are treated to remove toxic metals, radionuclides, and ammonia, and to destroy organic compounds. A key process and rate-limiting step in the current ETF flowsheet is the thin-film dryer (TFD) that drives off the liquid fraction of the waste, producing a powder. The powdered waste is subsequently placed in 55-gallon drums and disposed onsite. However, the current process was not designed to accommodate the increased scope and volume of secondary waste effluents that will be generated when WTP comes online. This report explores options that increase the processing capacity of ETF and eliminate powder as the secondary waste form by the time the WTP begins waste treatment and immobilization operations.

1.2 PURPOSE

Expanding ETF capabilities is needed to meet Tri-Party Agreement (TPA) milestones associated with the Hanford cleanup, reduce worker chemical and radiological exposure, meet land disposal criteria, and decrease the cost of maintaining and operating the current TFD system. The purpose of this pre-conceptual engineering study is to identify and evaluate mission needs and provide an overview of alternatives based on technical effectiveness, regulatory requirements, cost, schedule, and risk.

The ETF and associated infrastructure (i.e., utilities and buildings) must be upgraded to enable treatment and solidification of WTP secondary wastes. Potential modifications include addition of equipment to solidify concentrated liquid waste, material of construction upgrades to reduce corrosion of piping and equipment, and separations processes to remove contaminants. Additional work expected to be needed includes performance testing of solidified waste forms to demonstrate waste-form performance, and development of additional data to better characterize the range of waste compositions to be processed. Of particular interest is the ability of candidate treatment options to capture and retain the radioactive and hazardous components of the secondary wastes, or contaminants of concern (COC), that will be routed to ETF after the WTP begins operations. Specific COCs include technetium-99 (^{99}Tc), iodine-129 (^{129}I), mercury (Hg), chromium (Cr), nitrate (NO_3) and uranium (U). ^{99}Tc is a key COC as it is a mobile, long-lived radioactive isotope.

1.3 SCOPE

This pre-conceptual engineering study is intended to assist in supporting the critical decision (CD) 0 milestone by providing a basis for the justification of mission need (JMN) for the handling and disposal of liquid effluents.

The current ETF baseline strategy, to accommodate WTP requirements, calls for a solidification treatment unit (STU) to be added to the ETF to provide the needed additional processing capability. This STU is to process the ETF evaporator concentrate into a cement-based waste form. The cementitious waste will be cast into blocks for curing, storage, and disposal.

This pre-conceptual engineering study explores this baseline strategy, in addition to other potential alternatives, for meeting the ETF future mission needs. Within each reviewed case study, a technical and facility description is outlined, along with a preliminary cost analysis and the associated risks and benefits. Document sections include “Inputs and Requirements” (Section 2.0), “Existing Effluent Treatment Facility Flowsheet” (Section 3.0), “Gap Analysis” (Section 4.0), “Technical Alternatives” (Section 5.0), “Risk Assessment” (Section 6.0), and “Conclusions” (Section 7.0). Appendices include “Cesium and Technetium Removal” (Appendix A), “Steam Reforming Process for Effluent Treatment Facility Waste Solidification” (Appendix B), and “Mass Balance” (Appendix C).

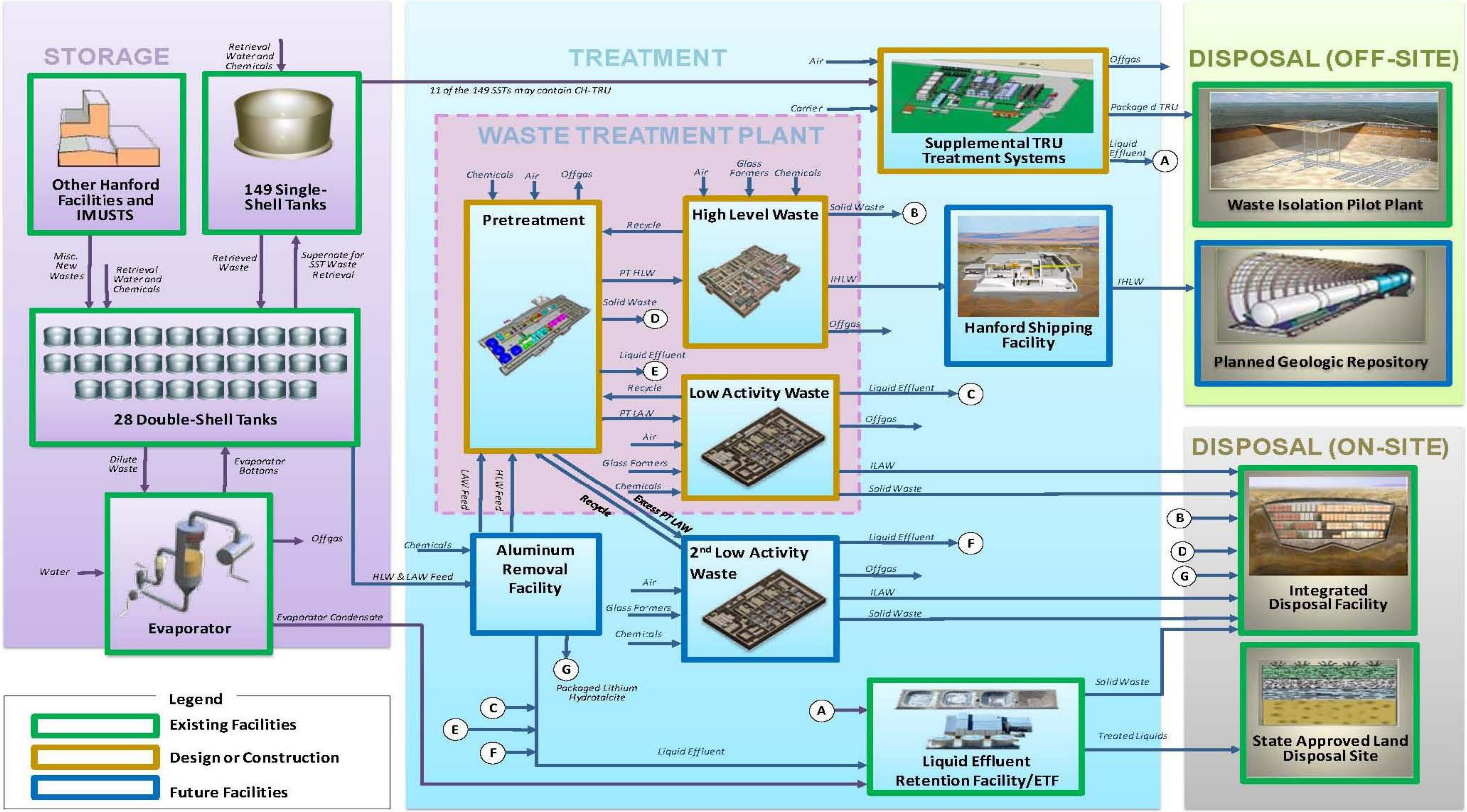
Life extension activities for the ETF are considered outside the scope of this study.

2.0 INPUTS AND REQUIREMENTS

Figure 2-1 is a simplified process flow diagram for the River Protection Project (RPP) system based on ORP-11242 (Rev. 4). The RPP system is comprised of four major subsystems (storage, treatment, offsite disposal, and onsite disposal). The ETF is an integral part of the RPP system, with a mission of processing/treating secondary wastes. The ETF functions are to receive contaminated wastewater and to treat it, producing treated wastes that are acceptable for disposal (treated wastewater, solid waste, and gaseous discharge). The ETF currently supports the 242-A Evaporator, burial grounds, groundwater treatment projects, and other decontamination and decommissioning projects (HNF-23142, *Engineering Study for the 200 Area Effluent Treatment Facility*). The current study identifies potential changes to ETF to support the WTP and later missions beginning in 2018. Based on current site planning (ORP-11242, Rev. 4), functions for ETF in the 2018 and later time frame will be limited to processing 242-A Evaporator condensate, liquid waste from the supplemental TRU treatment system, liquid waste from WTP, and miscellaneous leachates and wastewater with relatively low-level contamination.

The treatability envelope for ETF consists of a regulatory component and a design component.

Figure 2-1. River Protection Project System Simplified Process Flow Diagram.



Source: ORP-11242 Rev. 4

The regulatory envelope is bounded by environmental permits, regulations, and DOE Orders. It defines those wastes that the Liquid Effluent Retention Facility (LERF) and ETF are permitted to receive, store, treat, and dispose.

The design envelope is bounded by the operating conditions established in process flowsheets used at the LERF and ETF.

The design envelope includes all wastes that LERF and ETF are physically capable of treating, storing, and/or disposing.

The treatability envelope is the overlap of the design envelope and the regulatory envelope, consisting of the wastes that ETF is both permitted for and capable of treating. The acceptance criteria for ETF are defined by HNF-3172, *Liquid Waste Processing Facilities Waste Acceptance Criteria* (Rev. 4).

2.1 EFFLUENT TREATMENT FACILITY FEED STREAMS

The 200 Area ETF is a *Resource Conservation and Recovery Act of 1976* (RCRA) (42 USC 6901) permitted multi-waste treatment and storage unit and can accept dangerous, low-level, and mixed wastewaters for treatment. The ETF receives, treats, and disposes of liquid effluents from clean-up projects on the Hanford Site and currently supports the 242-A Evaporator, mixed waste burial trench and ERDF leachates, groundwater treatment projects, and other decontamination and decommissioning projects.

Table 2-1 provides a summary of projected waste streams from sources other than WTP to be processed by ETF in the post-2016 timeframe. These ETF feeds are predominately comprised of evaporator condensates, groundwater, and leachates with relatively low quantities of dissolved solids, radioisotopes, and other contaminants.

Table 2-1. Estimated Volumes of Wastewater Processed at Effluent Treatment Facility.

Wastewater Source	Annual Volume (millions of gallons)[1]	FY Start and/or Duration
ERDF leachate	1	On-going
Purge water	0.3	On-going
Mixed waste burial trenches leachate	0.4	On-going
Ground water ion-exchange regeneration	0.2	On-going
FFTF sodium cleanout	1	FY2016
242-A process condensate	3.5	On-going
Integrated Disposal Facility	1	
Tank farm CH-TRU waste system	0.66	FY2018

[1] FH-0702659, Attachment 1 (Murphy 2008), except 242-A process condensate, which is based on Figure 5-8 of ORP-11242, 2009, *River Protection Project System Plan*, Rev. 4, Washington River Protection Solutions, LLC, Richland, Washington

CH-TRU = contact-handled transuranic.
ERDF = Environmental Restoration Disposal Facility.
FFTF = Fast Flux Test Facility.

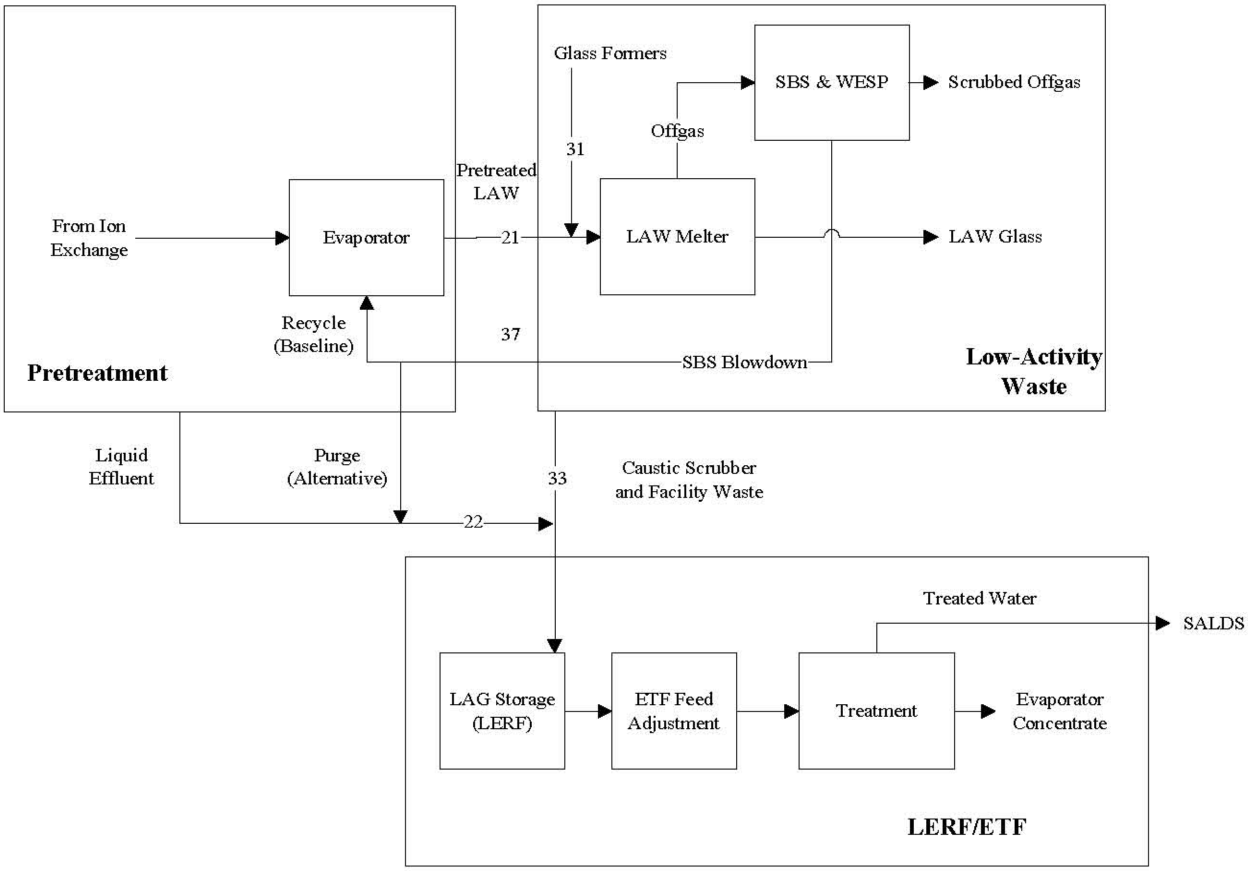
Wastewater from the WTP originates from a number of sources, including water:

- Initially in the WTP feed
- Added to the waste stream as part of the main processes
- Added for decontamination and maintenance
- Added for off-gas scrubbing, and miscellaneous laboratory and facility wastes.

Since the primary product glass contains essentially no water, all of the water sources listed above end up in the wastewater discharged to ETF (ignoring the small quantity discharged with the off-gas).

For the current study, two alternative assumptions are used for LERF/ETF waste feed that are based on alternate flowsheets for disposition of the WTP LAW melter off-gas submerged bed scrubber (SBS) blowdown (see Figure 2-2). In the WTP normal operating flowsheet, blowdown from the SBS and wet electrostatic precipitator (WESP) is recycled to an evaporator where it is mixed with other incoming waste, reconcentrated, and returned to the melter feed. Overhead condensate from the evaporator is discharged to LERF/ETF for treatment and disposal along with other WTP wastewater. This flowsheet is referred to as the "SBS blowdown recycle" mode. In the alternate "SBS blowdown discharge" mode, the SBS blowdown is discharged directly to LERF/ETF for treatment and disposal along with other WTP wastewater. Blowdown recycle is considered as baseline while discharge is an alternate or contingency operating mode.

Figure 2-2. Low-Activity Waste Melter Off-Gas Condensate Recycle Flow Diagram.



Scrubber blowdown discharge mode could be considered either to allow LAW melter operation when the internal recycle system is not available, or to purge components that build up in the recycle stream.

For the current evaluation, the SBS blowdown recycle case is based primarily on composition estimates for the WTP total waste stream (e.g., combined evaporator condensate, caustic scrubber blowdown, and miscellaneous waste sources) provided by the WTP project for use in treatability study HNF-8306, *Waste Treatment Plant Liquid Treatability Evaluation, Rev. 1* (performed in 2004). A summary of data for selected components is shown in Table 2-2.

Table 2-2. Estimated Waste Treatment and Immobilization Plant Wastewater Stream Composition Data.

Component	Units	WTP Total Waste Stream with SBS Blowdown Recycle[1]	LAW Melter Off-gas Caustic Scrubber Blowdown[2]	LAW Melter SBS Blowdown[2]
^{129}I	Ci/L	3.01E-10	3.74E-09	1.29E-07
^{99}Tc	Ci/L	6.17E-08	5.58E-08	9.14E-05
^{90}Sr	Ci/L	1.74E-07	N/A[3]	2.16E-06
^{137}Cs	Ci/L	2.51E-10	N/A[3]	9.6E-06
^{241}Am	Ci/L	3.50E-11	N/A[3]	5.44E-09
U	mg/L	9.53E-04	N/A[3]	1.82E-01
Hg	mg/L	2.00E-03	2.37E-03	4.06E-01
Cr	mg/L	9.00E-03	2.73E-02	1.53E+01
Al	mg/L	5.00E+00	1.59E+01	9.22E+00
Na	mg/L	1.91E+02	2.11E+01	1.11E+03
Carbonate	mg/L	1.91E+02	7.20E-04	1.94E+02
Pb	mg/L	5.00E-03	4.17E-03	1.04E-01
Nitrate	mg/L	1.99E+02	1.12E+04	6.36E+03
Cl	mg/L	4.12E+00	N/A[3]	1.72E+03
F	mg/L	2.42E-01	9.67E+00	1.74E+02
K	mg/L	1.2E+00	N/A[3]	1.86E+02
Ammonium	mg/L	1.16E+03	1.17E+04	1.85E+03
Nitrite	mg/L	1.00E+01	N/A[3]	1.96E+02
Phosphate	mg/L	1.1E+01	5.17E+00	3.18E+01
Fe	mg/L	1.08E-01	N/A[3]	8.95E+00
Sulfate	mg/L	1.03E+01	3.45E+02	1.33E+03
Total Dissolved Solids	mg/L	1.96E+03	2.34E+04	1.35E+04
Annual Volume	**Gallons**	**9.7E+06**	**9.7E+05**	**7.3E+05**

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[1] Based on maximum annual average values reported in HNF-8306, 2004, *Waste Treatment Plant Liquid Treatability Evaluation*, Rev. 1, Fluor Hanford, Inc., Richland, Washington.

[2] Based on RPP-43020 and SVF-1732, except for ^{90}Sr, ^{137}Cs, and ^{241}Am, which are based on the System Plan (Rev 4) mass balance summary shown in SVF-1663. (RPP-43020, 2009, *Spreadsheet Description Document for Secondary Waste Compositions*, Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington).

[3] Component concentrations are not defined in the Reference and assumed to be negligible.

Evaluation of the SBS blowdown discharge case is based primarily on data in RPP-43020, *Spreadsheet Description Document for Secondary Waste Compositions*, and SVF-1732, "Secondary Waste Expected Liquid Waste Composition.xlsx." Data for selected components not listed in these references is based on the System Plan (ORP-11242, Rev. 4) mass balance summary in SVF-1663, "Balance_Graphic_SP4_PC_2009_03_30_at_20_02_39.xls," "SP4 Planning Case-3.0-8.4r0_2009-03-30-at-20-02-39." Table 2-2 provides data from these sources for the SBS blowdown and the off-gas caustic scrubber blowdown streams. The balance of the WTP wastes are not defined in these references, but are expected to be similar to the WTP total waste stream previously defined in HNF-8306.

The concentrations of certain contaminants in WTP waste are expected to be significantly increased by SBS blowdown discharge operation. In the recycle mode SBS blowdown is sent to an evaporator for concentration. The WTP evaporator used for waste recycle has relatively high decontamination factors for most waste components, resulting in a relatively clean condensate to be discharged to ETF. The ^{129}I, ^{99}Tc, ^{137}Cs, ^{241}Am, U, Cr, F, Cl, K, and sulfate concentrations shown for the SBS blowdown in Table 2-2 are more than two orders of magnitude times the total WTP waste stream values with recycle mode operation. Even considering the effect of mixing the SBS blowdown with other relatively dilute wastes, concentrations of these components in the blended waste are expected to substantially increase with SBS blowdown discharge. A simplified mass balance for ETF is provided in Appendix C based on ETF processing waste produced in the SBS blowdown discharge mode.

2.2 REQUIREMENTS

2.2.1 Integrated Disposal Facility Waste Acceptance Criteria

The Integrated Disposal Facility (IDF) waste acceptance criteria (WAC) are defined in RPP-8402, *Waste Acceptance Criteria for the Immobilized Low-Activity Waste Disposal Facility*, Rev. 0 and draft Rev. 1.

Key requirements from the IDF WAC expected to apply to ETF solid waste include the following:

- Transuranic content (as calculated by the method described in Appendix C, Section C1.0) shall not exceed 100 nCi/g (DOE O 435.1, *Radioactive Waste Management*).
- Radiological concentrations shall not exceed the applicable concentration limits for Class C low-level waste, as defined in 10 CFR 61.55, "Waste Classification," and as described in "Branch Technical Position on Concentration Averaging and Encapsulation" (Knapp 1995, Enclosure 1).
- All containerized waste must fill at least 90 per-cent of the internal volume of the container when placed in the disposal unit, and either: 1) be a solid waste with minimum "confined" compressive strength of 85 psi, 2) be stabilized in concrete or other stabilizing agent with a minimum composite compressive strength of 85 psi, or 3) be packaged in a High Integrity Container approved by the IDF waste acceptance organization.

- The package shall not contain detectable free liquids. It is further assumed that a performance assessment will demonstrate that the waste form is acceptable at IDF.

2.2.2 Regulatory and Permitting Issues

Treated liquid effluent from the ETF is discharged to the state-approved land disposal site (SALDS) under the State Waste Discharge Permit ST4500. The permit applies the more stringent of water quality-based or technology-based limits for each parameter of concern. These limits are delineated in the permit.

To support treatment of WTP secondary wastes at ETF, a characterization study will need to be submitted to Washington State Department of Ecology (Ecology), identifying constituents of concern. Ecology may require modification of ST4500.

A number of other regulatory issues must be addressed to implement modifications to LERF/ETF, including NEPA (*National Environmental Policy Act of 1969*, 42 USC 4321) evaluations and documentation, dangerous waste permit, and air discharge permits. A detailed permitting plan has been developed by project W-601 (HNF-24260, *200 Area Effluent Treatment Facility Solidification Treatment Unit Project Permitting Plan*). A new permitting plan is currently being prepared based on updated project requirements.

2.2.3 Waste Transferred to Other Hanford Facilities

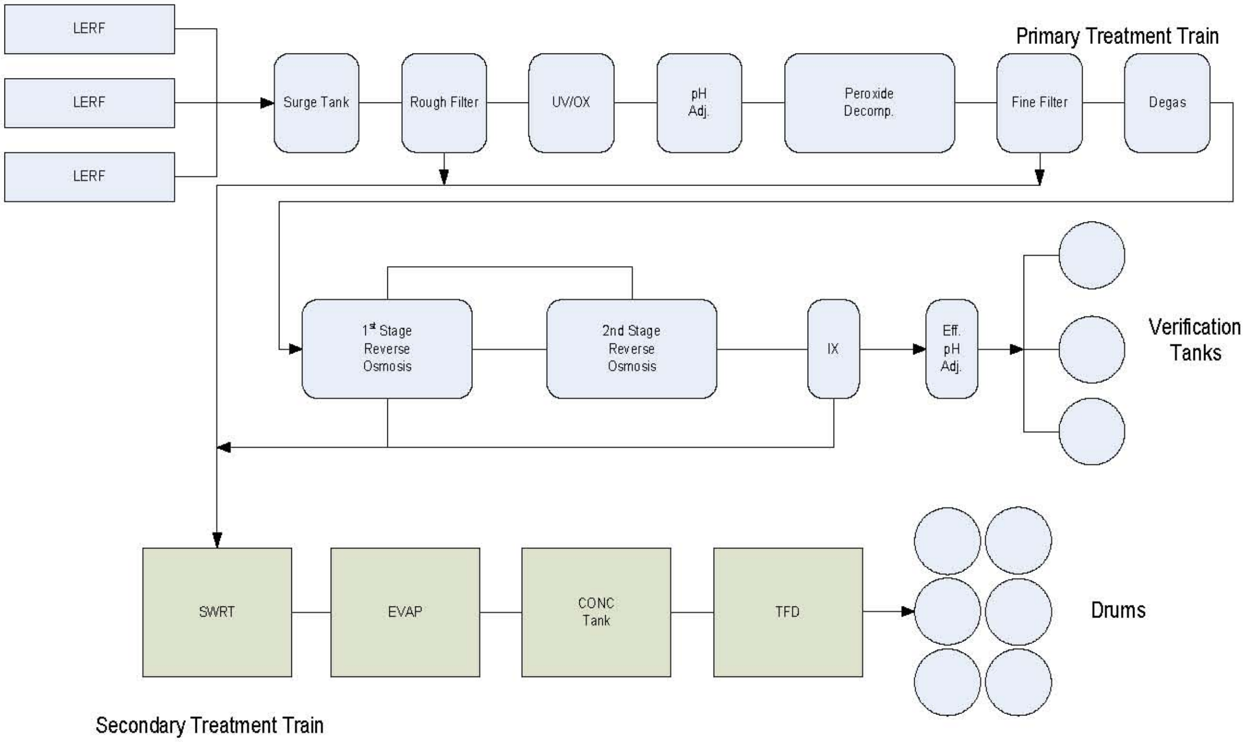
For some options, waste may be returned to other Hanford facilities. For example, evaporator concentrate could be recycled to tank farms or to WTP, or it could be transferred to IDF for solidification and disposal. Removed technetium could also be recycled to either the tank farms or WTP. The interface and transportation requirements must be defined for any such options on a case-by-case basis.

3.0 EXISTING EFFLUENT TREATMENT FACILITY FLOWSHEET

The ETF is a wastewater treatment facility capable of treating a broad range of influents. The ETF was designed with an influent rate of approximately 150 gal/min. It consists of a primary treatment train that removes and destroys contaminants via filtration, ultraviolet oxidation, reverse osmosis, and ion exchange processes; and a secondary treatment train (STT) that processes the byproducts from the primary treatment train. These STT byproducts include filter backwash, concentrate from reverse osmosis, and regeneration waste from the ion-exchange system. The STT includes an evaporator that concentrates the effluents and a TFD that converts the evaporator brine into a powder. The powders are collected in drums and disposed onsite. This existing system, however, was not designed to meet the future needs of the WTP.

The 200 Area ETF receives, treats, and disposes of liquid effluents from clean-up projects on the Hanford Site. The ETF supports the 242-A Evaporator, mixed waste burial trench and ERDF leachates, groundwater treatment projects, and other decontamination and decommissioning projects. The liquid effluents are treated to remove toxic metals, radionuclides, and ammonia, and to destroy organic compounds. A key process step in the current ETF flowsheet (Figure 3-1) is the TFD that accumulates dried solids from the waste into a powder form. However, the current process was not designed to accommodate the increased scope and volume of secondary waste effluents that will be generated when WTP begins operations.

Figure 3-1. Existing Effluent Treatment Facility Process Flow Diagram.



CONC Tank = Concentration tank
Degas. = Degasification Column
Eff. pH Adj. = Effluent pH adjustment tank
EVAP = Evaporator
IX = Ion Exchange
LERF = Liquid Effluent Retention Facility
pH Adj. = pH adjustment tank
SWRT = Secondary waste receiving tank
TFD = Thin Film Dryer
UV/OX = Ultraviolet Oxidation

The following is a brief description of the treatment processes available at the ETF:

- **Feed receipt** – ETF feed may be received either into the surge tank or directly to the treatment process.
- **Suspended solids removal** – Suspended solids removal is provided by filtration within the facility.
- **Organic destruction** – Organic destruction is accomplished through an ultraviolet light mediated oxidation process in conjunction with the addition of hydrogen peroxide.
- **pH adjustment** – Adjustment of waste stream pH throughout the facility is accomplished through addition of sodium hydroxide or sulfuric acid.

- **Hydrogen peroxide decomposition** – Residual hydrogen peroxide from the ultraviolet oxidation system is removed through the hydrogen peroxide decomposer, which uses a granulated, activated carbon column that breaks down the hydrogen peroxide.
- **Degassification** – Removal of dissolved carbon dioxide (CO_2) is accomplished in the degassifier.
- **Dissolved solids removal** – Dissolved solids removal may be provided by the reverse osmosis and/or ion-exchange processes.
- **Effluent quality verification** – Prior to discharge to disposal, effluent may be retained for verification of quality. During storage, laboratory analyses are performed to confirm compliance with the appropriate requirements before discharge. If the effluent does not meet discharge requirements, it may be returned to the facility for additional treatment.
- **Effluent disposal** – Effluents suitable for disposal are transferred through the Liquid Effluent Disposal System for release to the SALDS.
- **Secondary waste treatment** – Liquid waste from the primary treatment train is concentrated in the evaporator and/or dewatered in the TFD prior to long-term storage or final disposal.

Individual treatment processes are configured and used as needed to treat different waste streams to meet permitted discharge requirements.

The ETF process equipment is located in the process area, designated as a radiation buffer area (RBA), which consists of one large processing bay, identified as Room 131, and various process support rooms. The process bay contains the primary treatment train and secondary treatment train process equipment, including the filtration systems, ultraviolet oxidation system, hydrogen peroxide decomposer, pH adjustment systems, degasification column, reverse-osmosis system, and multiple system pumps. Tankage supporting the process includes the reverse-osmosis feed tanks, pH adjustments tanks, secondary waste receiving tanks (SWRT), concentrate tanks, dilute sulfuric acid and sodium hydroxide solution tanks, and the sump tanks (HNF-23859, *W-601 Solidification Treatment Unit, Functional Design Criteria*, page 13).

The vessel ventilation system receives off-gas from various process systems and removes particulates and organics from the off-gas using filters and carbon adsorbers. The vessel ventilation system provides contamination control within the facility by maintaining a negative pressure in the potentially contaminated process systems. Separate building ventilation systems are provided for the potentially contaminated and uncontaminated portions of the building (HNF-23859, page 14).

4.0 GAP ANALYSIS

This section discusses areas where the existing LERF/ETF facility may not satisfy requirements and objectives related to processing of future waste streams. The LERF/ETF processes liquid wastes from a number of sources that have changed over time as required to meet the needs of Hanford Site operations. Site planning calls for additional new waste streams from the WTP beginning about 2018. The current analysis considers issues related to ongoing waste flows but is primarily focused on the new wastes from the WTP.

As discussed in Section 2.0, two WTP operating modes are considered: SBS blowdown recycle and SBS blowdown discharge. Providing flexibility for ETF to process the SBS blowdown increases contamination levels in the waste and increases associated processing requirements at ETF. The gap analysis therefore considers both cases separately. The gap analysis relies in part on previous studies:

- HNF-8306, *Waste Treatment Plant Liquid Treatability Evaluation*. This study was performed in 2004 to evaluate treatment of WTP effluent by ETF. WTP waste composition was based on SBS blowdown recycle within WTP. This study identified gaps, issues, and uncertainties related to processing the WTP waste along with other ongoing wastes.
- HNF-37718, *Low Activity Waste (LAW) Facility Secondary Waste to Effluent Treatment Facility (ETF) Treatability Evaluation*. This 2008 study performed a preliminary evaluation of ETF treatment of WTP waste based on WTP operation in the SBS blowdown discharge mode. This study identified gaps, issues, and uncertainties related to processing the WTP waste in addition to other ongoing wastes.
- RPP-RPT-37924, *Secondary Waste Management Strategy for Early Low Activity Waste Treatment*. This 2008 study evaluated a number of issues related to processing and disposal of WTP waste based on WTP operation in the SBS blowdown discharge mode.
- HNF-26914, *W-601, Conceptual Design Report for Effluent Treatment Facility Solidification Treatment Unit*. The conceptual design report for the solidification system also includes a summary of the project justification.

The following sections discuss known and potential gaps and issues based on the studies cited above, changes in site planning, and updated technical information available since the referenced studies were developed. Results are discussed for each of the two processing modes.

4.1 EFFLUENT TREATMENT FACILITY WASTE FEED BASED ON MELTER SUBMERGED BED SCRUBBER BLOWDOWN RECYCLE MODE

Gaps and technical issues identified for processing WTP waste in the SBS blowdown recycle mode are as follows.

- Powder product produced by the existing TFD does not meet disposal requirements. Past attempts to treat the powder to meet the requirements have not been successful. Mercury exceeds land disposal restriction limits in the solid secondary waste powder generated by the ETF treating WTP effluents. Additionally, per the HNF-EP-0063, *Hanford Site Solid Waste Acceptance Criteria*, the solid waste disposal limits for mobility of ^{99}Tc, ^{129}I, uranium, and ^{14}C are exceeded. Based on these projections, solidification and/or encapsulation of the waste are required (HNF-8306, page ii).
- Wastes requiring solidification are significantly different than wastes the existing TFD was designed to process. The TFD function is inadequate with the range of wastes to be processed. The dryer has been marginally effective even for the current ETF process requirements. It is difficult to operate and maintain and is not as low as reasonably achievable (ALARA) with respect to personnel radiation exposure. This and additional issues related to TFD powder product disposal are discussed in HNF-26914, pages 1-2.

- The ETF process equipment has experienced corrosion problems in the past due to chloride and fluoride content of the waste. Selected equipment and piping needs to be replaced with 316 SS at a minimum to allow future wastes to be processed reliably.
- The WTP forecast for organics, based on bounding concentrations, is outside the current ETF treatability envelope. Some organics are also outside the ETF regulatory/permit ranges. Additional actions are needed to refine estimates for organic contaminants and determine impacts (if any) to ETF design, operations, and permitting (HNF-8306).
- Preliminary evaluation indicates ETF evaporator capacity is sufficient to handle waste from WTP at the current design capacity. This needs to be verified based on a refined definition of the expected range of waste quantities and compositions from all waste generators discharging to ETF.
- Potential issues have been identified related to ^{129}I off-gassing after pH adjustment (HNF-8306, HNF-37718). This may result in constraints on waste pH adjustment that force carbonate to be retained in the waste feed to the evaporator increasing the potential for scaling. Additional testing and process development work is needed to evaluate the effects of increased carbonate levels on the evaporator operation.

4.2 EFFLUENT TREATMENT FACILITY WASTE FEED BASED ON MELTER SUBMERGED BED SCRUBBER BLOWDOWN DISCHARGE MODE

Operation of WTP in the SBS blowdown discharge mode results in significant increases in contaminants in the waste stream. Components that are significantly increased include:

- Radioisotopes: ^{79}Se, ^{90}Sr, ^{99}Tc, ^{106}Ru, ^{129}I, ^{137}Cs
- Elements: Cl, Cr, F, Hg, K, Na
- Chemicals: sulfate and nitrate
- Total dissolved solids.

A simplified mass balance is provided in Appendix C based on the ETF processing waste produced in the SBS blowdown discharge mode. All gaps and issues discussed above for the SBS blowdown recycle case are also valid for the SBS blowdown discharge case. Because of the increases in waste contaminant levels, the following additional gaps and issues have been identified for the blowdown discharge case:

- Materials of construction for certain ETF process equipment and piping are unsuitable for use at high chloride and fluoride concentrations typical of SBS blowdown. Specific items (e.g., tanks, piping, etc.) with materials of construction problems are identified in RPP-RPT-37924.
- For the SBS discharge mode, the reverse-osmosis unit is not functional for concentrating the initial waste because of composition and high dissolved solids content. An alternate flowsheet/process configuration based on use of existing ETF equipment is proposed in HNF-37718 to mitigate this issue. The revised flowsheet involves bypassing reverse osmosis and processing the waste directly in the ETF evaporator. Overhead condensate from the evaporator is then processed in the reverse-osmosis unit.

- Potentially significant groundwater impacts could result from onsite disposal of solidified waste, based on the analyses presented in RPP-RPT-37924. The largest estimated impacts are for ^{99}Tc. Estimated groundwater concentrations are about 20 times the baseline value when a "low performance" ETF solid waste form is assumed. Cases presented indicate ^{99}Tc impacts to groundwater can be reduced to approximately the baseline value by increased ETF solid waste form performance and/or by reducing the ^{99}Tc content of the solidified waste form. A specific allowable or acceptable ^{99}Tc performance was not defined. It is assumed that reducing groundwater impacts to approximately the baseline level is likely to be acceptable. Smaller impacts to estimated groundwater contamination were also noted for Hg, ^{129}I, Cr, and nitrate, which could be similarly mitigated by reduced contaminant concentration or improved waste form performance.
- Radioactive contaminant levels in the waste stream are greater than those used for the existing STU design basis radiation dose rate analysis. At forecast waste feed compositions, ^{137}Cs is expected to be the dominant source of penetrating gamma radiation; therefore, the ^{137}Cs concentration is of particular concern. Estimated ^{137}Cs concentration in the SBS blowdown is near the LERF/ETF waste acceptance limit of 1E-05 Ci/L (HNF-3172). If this waste is concentrated to the normal 25 to 40 wt% solids in ETF evaporator bottoms, ^{137}Cs in the concentrate tanks and solidification process feed could be on the order of 1E-03 Ci/L. These values are much higher than the 1E-06 Ci/L value used for the solidification system dose rate analysis (HNF-26914, Appendix H). Based on discussion with ETF personnel, radiation dose rates from cesium at this level would be unacceptable for ETF evaporator operation, and would be well above levels that could be tolerated in the current solidification system design. By blending SBS blowdown with other low contamination wastes and limiting the concentration factor in the ETF evaporator, it appears feasible to limit concentration in the evaporator bottoms to about 5E-05 Ci/L. Preliminary information indicates this is within the range of past successful ETF operations. However, it is questionable if this ^{137}Cs level is acceptable for the current waste solidification system design. If not, mitigation options include some combination of: (1) reducing ^{137}Cs in the waste from WTP, (2) upgrading the waste solidification design to allow higher radiation levels, or (3) removing ^{137}Cs from the waste upstream of the solidification unit. It is recommended that ^{137}Cs levels be evaluated during the design phase with appropriate measures taken to reduce the Cs to acceptable levels via one of these mitigation options.

5.0 TECHNICAL ALTERNATIVES

Five primary technical alternatives or "cases," plus the no-action alternative were selected for further development in the current study. The purpose of this selection is not to down-select to a short list, to be further down-selected to the preferred alternative during conceptual design. Rather, the purpose of this selection is to define the expected range of reasonably likely alternatives in terms of complexity, technical difficulty, and cost.

A key initial decision in the selection process is whether to include a new facility to perform the required treatment function as one of the options. Based on previous treatability evaluations, the

ETF primary treatment train appears well suited to perform front end treatment functions to produce a treated wastewater suitable for discharge to the SALDS. Some equipment upgrades are required; however, they are relatively small as compared to designing, building, and permitting a whole new facility. The ETF is also well positioned with interconnecting transfer lines from the LERF and to SALDS. Because of cost, schedule, and logistics considerations, replacing the whole ETF front-end with a new facility is not considered to be a reasonably competitive option, and it was therefore not considered in the range of alternatives developed.

Even with the ETF facility and front-end process assumed as a starting point, a large number of alternatives remain. Potential characteristics of alternatives were identified in the following areas:

- **Product form for evaporator concentrate**: Cement/grout, calcine, glass, ceramic, liquid (shipped to others for disposition)
- **Acceptable feed composition range**: Chloride, fluoride, total dissolved solids, organics, radionuclides, etc.
- **Separations**: Removal contaminants of concern (yes or no), e.g., ^{99}Tc, ^{137}Cs, ^{129}I, Hg, etc.

Fluidized bed steam reforming was selected as representing the most complex and costly solidification process likely to be considered. Cases with process flowsheet changes and upgrades to materials of construction were included to increase the wastes that can be accepted for processing. A case with removal of ^{99}Tc and ^{137}Cs was included as a typical separations option. Two options were included based on production of a concentrated liquid waste that is transferred to others for final disposition. Based on review by the technical team, it was concluded that the range of options selected reasonably represent the range of likely options in terms of complexity, technical difficulty, and cost.

There are multiple process, equipment, and product variables to be evaluated to optimize the ETF with regard to product quality, feed processing flexibility, schedule, and cost. This study poses six basic strategies as a comprehensive representation of ETF options. These scenarios range from minimal to extensive with respect to resources and equipment and technology development. Choosing the optimal strategy will be dependent on identifying the nature of the feed, the expectations of the waste form, with respect to chemical durability and disposition, and the resource requirements for strategy implementation. Table 5-1 provides a matrix of case options selected to improve ETF function in support of overall mission needs.

Table 5-1. Summary of Secondary Waste Treatment Alternative Cases

CASE	Secondary Waste ETF Alternatives				
	ETF corrosion upgrades[1]	Solidification treatment unit[2]	Cs/Tc removal via ion exchange	Fluidized bed steam reforming[3]	Recycle brine to tank farm
1: Solidification		✓			
2: ETF corrosion upgrades/solidification	✓	✓			

3: ETF corrosion/IX/ solidification	✓	✓	✓		
4: ETF corrosion/ recycle to tank farms	✓				✓
5: ETF corrosion/steam reforming & solidification	✓			✓	
6: Do nothing					

[1] Based on Approach 1b in RPP-RPT-37924, 2008, *Secondary Waste Management Strategy for Early Low Activity Waste Treatment*, Rev. 0, CH2M HILL Hanford Group, Inc., Richland, Washington.

[2] Based on ETF solidification/secondary treatment project design and cost estimate. Grout is the identified baseline waste form.

[3] FBSR approach includes an integral step to solidify the granular FBSR product.

ETF = Effluent Treatment Facility.
IX = ion exchange.
FBSR = fluidized bed steam reforming.

5.1 CASE 1: SOLIDIFICATION

For Case 1, the LERF/ETF process and facilities are used for waste treatment with the exception of the final TFD step. In place of the TFD, a solidification process is used based on mixing additives with the evaporator concentrate to produce a cementitious solid waste form. An STU design similar to this case was previously developed (HNF-26914). Limited upgrades and equipment replacement are also provided as needed for the ETF process equipment.

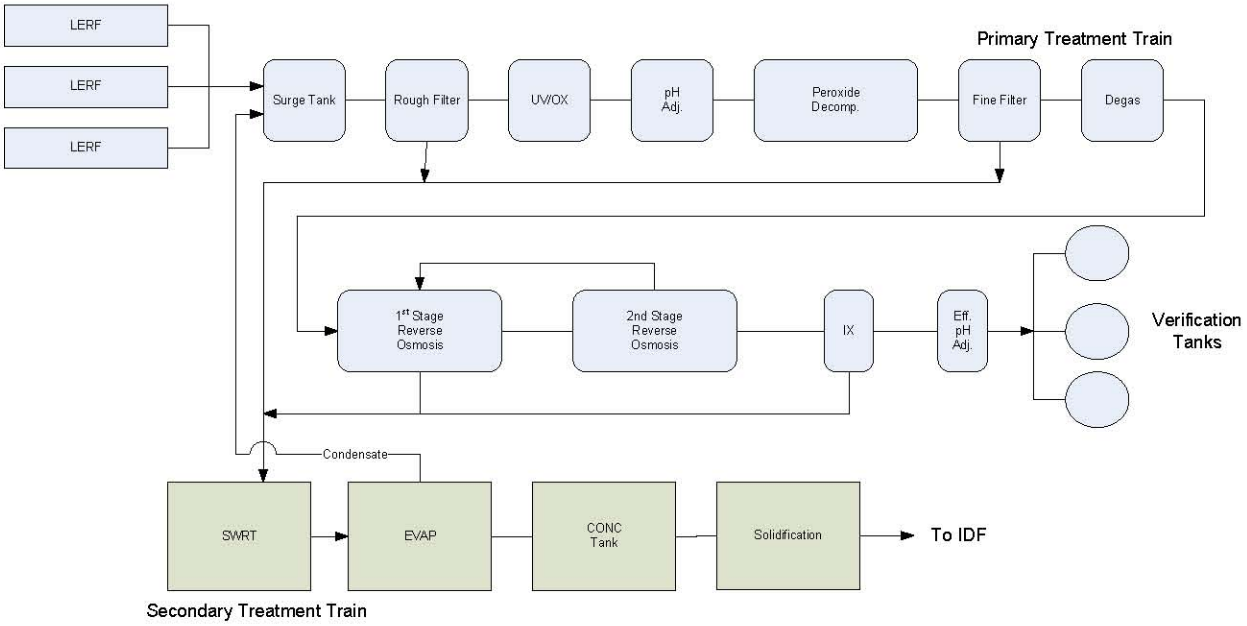
5.1.1 Technical Description

This technical alternative includes the design and construction of an STU to directly solidify the ETF evaporator concentrate (Figure 5-1). The existing ETF TFD is removed from the ETF treatment train and replaced by the STU. The existing conceptual design developed for Project W-601 is assumed for the STU as described below. Note that other solidification technologies are being investigated to improve waste form performance. Design alternatives will be reconsidered in conceptual design, and the conceptual design may differ from the description below. Case 1 also include limited upgrades to ETF equipment and piping, typically using stainless steel or fiberglass reinforced plastic (FRP) construction materials.

The STU treats and solidifies concentrate from the ETF evaporator by mixing it with dry cementitious raw materials. The waste concentrate is first cooled using a concentrate cooler for optimal processing. It is then stored and the pH is adjusted in concentrate tanks before being processed. The waste concentrate is metered as it is fed to the grout mixer using concentrate circulation pumps. The dry additives are stored in silos located outside the facility. The raw materials are individually weighed in weigh hoppers underneath the silos, and then sequentially transferred into a feed hopper located above the grout mixer using a vacuum conveyance system. The feed hopper separates the air from the solids. After all four ingredients are transferred into the feed hopper, they are gravity-fed into the grout mixer through a rotary feeder.

The ingredients are thoroughly mixed in the mixer until homogenous. Once mixing is completed, the grouted waste is emptied from the mixer by gravity into a waste containment bag supported in a loading cart (steel waste loading frame on a cart with wheels) located directly below the grout mixer. Once the mixer is empty, the loading cart containing the solidified waste containment bag is removed from the loading area using floor rails and staged to allow the grouted waste to set. Once the grouted waste has set, the solidification waste containment bag is sealed and removed from the loading cart, then cleaned, surveyed, and weighed before it is transported to an area designated for curing, awaiting shipment to the IDF for final disposal.

Figure 5-1. Flow Diagram, Solidification (Case 1).



CONC Tank = Concentration tank
Degas. = Degasification Column
Eff. pH Adj. = Effluent pH adjustment tank
EVAP = Evaporator
IDF = Integrated Disposal Facility
IX = Ion Exchange (Existing ETF)
LERF = Liquid Effluent Retention Facility
pH Adj. = pH adjustment tank
SWRT = Secondary waste receiving tank
UV/OX = Ultraviolet Oxidation
WTP = Waste Treatment Plant

5.1.2 Modifications to Facilities and Equipment

This technical alternative requires the design and construction of an STU, including additional process and solidified waste storage facilities adjacent to the ETF.

The proposed modifications to the facility for the STU include:

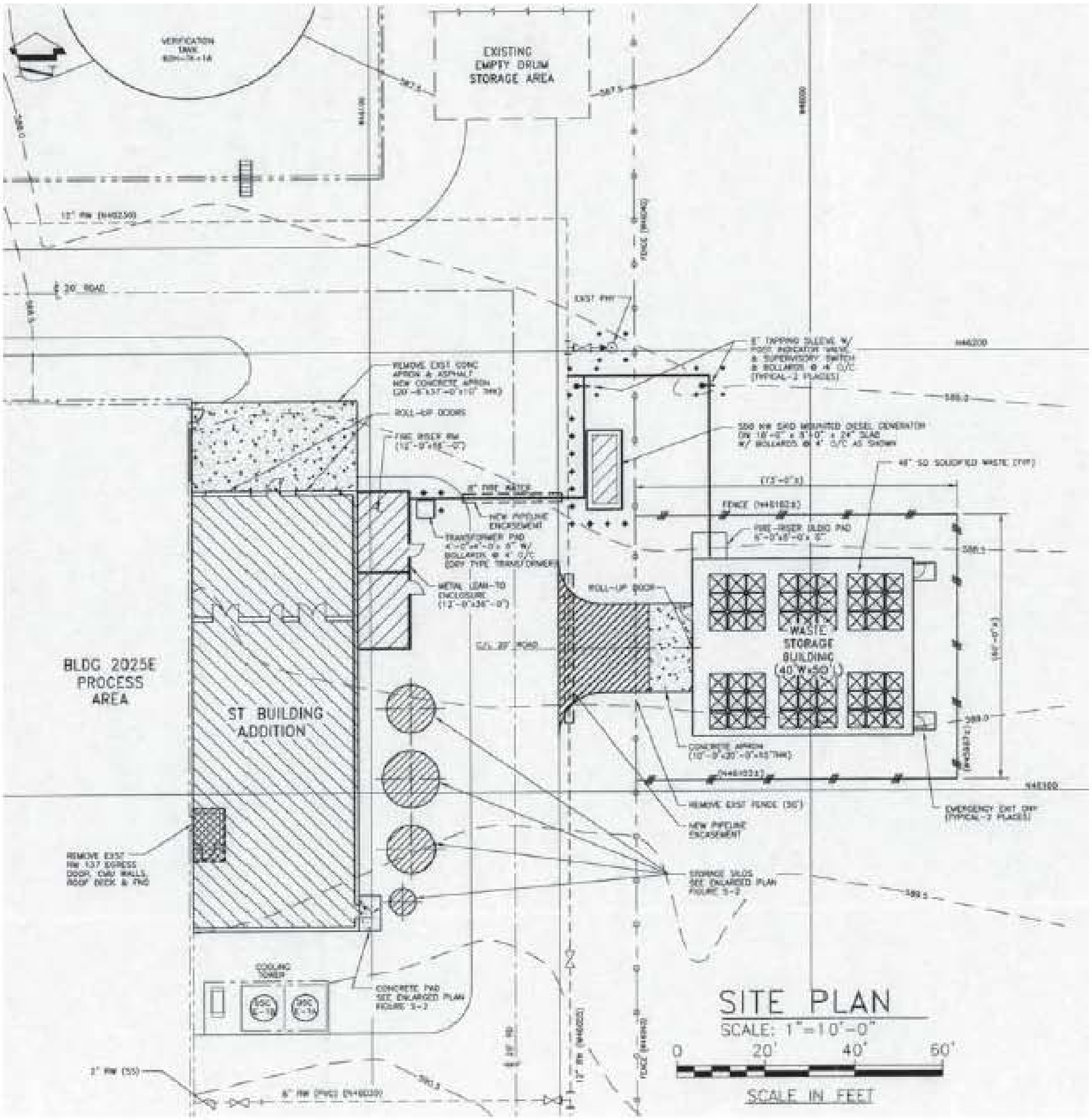
- Dry raw material receipt, storage, and metering capabilities with supplier accessibility
- Waste concentrate and dry raw material conveyance piping and equipment
- Equipment for mixing concentrate and raw materials
- Loading cart-filling and handling equipment

- Utilities or tie-in to existing ETF utilities required for operation of equipment (electrical power, water, telecommunications, etc.)
- Tie-in to existing ETF process systems for service air, verification water, cooling water, chilled water, vessel vent system, 50% NaOH, 92% H_2SO_4, and safety shower and eyewash water
- Systems to monitor, alarm, and control the solidification process
- Instrumentation to measure flow, pressure, temperature, concentration, weight, level, and pH
- Radiation monitoring instrumentation
- Ventilation/tilter system for dust and contamination control
- Flushing capability for waste concentrate transfer piping and mixing systems
- Drains, collection systems, and secondary containment systems, as necessary
- Ancillary buildings or modification to existing structures to accommodate process equipment and systems
- Additional facilities for waste storage capacity (if necessary)
- Areas for surveying, decontaminating and curing grouted waste
- Grouted waste packaging equipment.

The conceptual design includes an area for a second solidification mixing line and a new separate solidified waste storage building (Figure 5-2 and Figure 5-3). Neither of these is expected to be needed initially, but have been included for future growth.

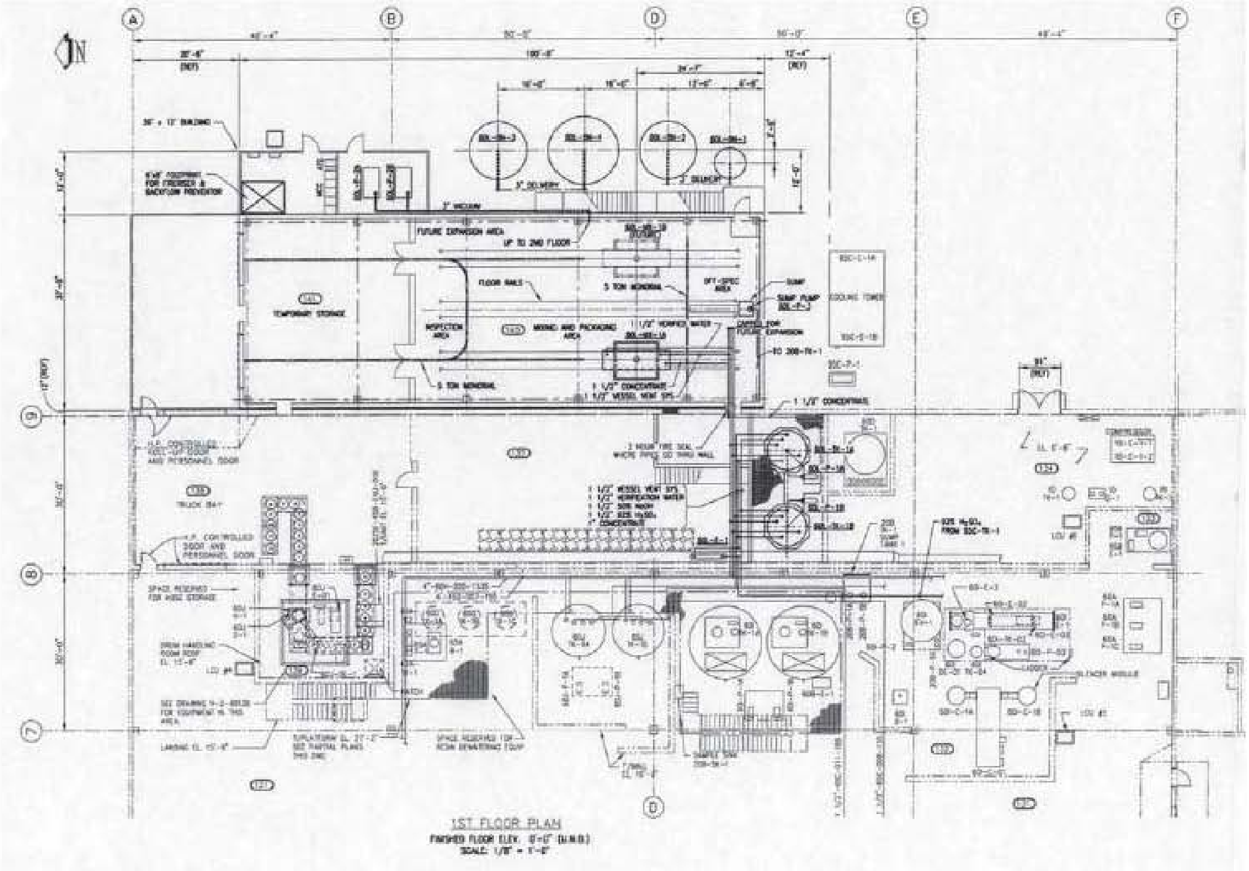
Additional modifications to the ETF consist of a 3 bank filter skid, 2 -20,000 gallon secondary waste receiver tanks- either 316 SS or FRP, 2 new pumps from 316 SS, a small day tank, a heat exchanger from the cooling water to evaporator feed, and piping that includes 316 SS, 304SS, Alloy 20, and plastic with associated level, pressure, pH instrumentation.

Figure 5-2. Solidification Facilities Site Plan for Case 1.



Reference: HNF-26914, 2005, *W-601, Conceptual Design Report for Effluent Treatment Facility Solidification Treatment Unit*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

Figure 5-3. Mechanical Equipment Layout for Case 1.



5.1.3 Cost Summary Basis

The total project costs for Case 1 were calculated based on cost information derived from:

- RPP-RPT-43787, "Secondary Waste – ETF/Solidification Preconceptual Cost Estimate"
- RPP-RPT-37924, page 147, "Estimates – 1a Concentrate/Cement at ETF," (<10,000 ppm Cl in brine)
- HNF-26914, "Estimate – HNF-26914 Solidification Treatment Unit"

Case 1 has an anticipated total project cost of $42.1 million including 50% contingency. ETF annual operating costs are estimated to increase by $3.7 million (including 25% contingency) above the current/historical operating costs. Cost estimate details are provided in Section 7.0.

5.1.4 Risks and Benefits

5.1.4.1 Identified Benefits of Case 1

Primary benefits of Case 1 include the following:

- Compared to the powder produced by the existing TFD, the STU provides a substantially improved waste form, both in terms of physical integrity and leachability/mobility of contaminants.

- The STU eliminates operability and ALARA issues related to the existing TFD.
- The STU provides increased capacity for solidification of evaporator concentrate as compared to the no-action case (Case 6).
- Upgrades to ETF provide the minimum process capability and flexibility expected to be needed to process future wastes.

5.1.4.2 Risks Identified for Case 1

Primary risks and uncertainties identified for Case 1 include the following:

- Ability to meet waste disposal requirements is not certain. Performance requirements for IDF waste disposal and the resulting WAC are not provided at this time. Performance of alternate waste forms is currently being assessed in a separate task (Pierce et. al. 2009). Initial work has downselected options to three waste types for further testing and evaluation: cast stone (cement/grout), chemically bonded phosphate ceramics, and geopolymers. Cast stone is compatible with the existing STU design; however, the other two options would require potentially significant changes to the design. An increase in project cost appears likely if a solid waste option other than cast stone is selected.
- Chloride and fluoride concentration in the waste must be limited. ETF process equipment corrosion problems are expected if waste with high chloride or fluoride is to be processed. This option is expected to limit acceptable evaporator waste concentration factors for certain wastes and may not be compatible with WTP operation in the SBS blowdown discharge mode.
- With ETF waste feed near the ^{137}Cs waste acceptance limit defined in HNF-3172 (Rev. 4), radiation levels in the STU may make operation difficult or impractical with the current STU design. Estimated ^{137}Cs concentrations in the SBS blowdown discharge mode are well above STU design basis levels; therefore, additional design changes may be needed to make the Case 1 design compatible with this WTP operating mode.
- Process issues that remain to be resolved include concentration and behavior of organics in the ETF process. Preliminary estimates indicate organics in WTP wastes are outside the ETF design and permit ranges. Performance of the ETF organic destruction process is uncertain with the WTP wastes. These issues were identified in previous treatability studies and have not yet been fully resolved (HNF-8306, HNF-37718).
- Potential issues have been identified related to ^{129}I off-gassing after pH adjustment (HNF-8306, HNF-37718). This may result in constraints on waste pH adjustment that force carbonate to be retained in the waste feed to the evaporator increasing the potential for scaling. Additional testing and process development work is needed to evaluate the effects of increased carbonate levels on the evaporator operation.
- Preliminary evaluation indicates ETF evaporator capacity is sufficient to handle waste from WTP at the current design capacity. This needs to be verified based on a refined definition of the expected range of waste quantities and compositions from all waste generators discharging to ETF.
- A number of regulatory and permitting issues are identified in HNF-37718. Permitting delays could impact the construction and operation schedule for ETF. While these must

be worked to gain regulatory approval, they generally appear to be fairly routine, with the exception of the waste form/disposal issue listed above.

5.1.4.3 Authorization Basis

The LERF and ETF are classified as less than Hazard Category 3 nuclear facilities. Changes identified for Case 1 are not expected to change this classification.

General Services is the highest safety designation anticipated for any element of this project. The ETF auditable safety analysis (HNF-SD-ETF-ASA-001, *200 Area ETF Auditable Safety Analysis Report*) will be updated appropriately.

5.1.4.4 Technical Maturity

The cast stone or grout technology for waste solidification is considered to be mature, demonstrated technology. However, improvements such as additives to reduce mobility of contaminants and/or alternate waste forms may require testing and development work. Ongoing lab testing and disposal facility performance assessments may determine that the performance of cast stone/grout is unacceptable or that another solidification method is more acceptable. This would impact the conceptual design alternatives analysis and potentially require restart of the conceptual design process—causing a cost/schedule impact.

The composition and quantity of WTP wastes are expected to vary significantly over time due to changes in WTP waste feed composition, operational changes, maintenance, etc. There is also significant uncertainty in current estimates for some components. These uncertainties may be reduced by obtaining additional test data, data from operating facilities, and WTP waste feed characterization data. However, significant residual uncertainty is expected to remain until WTP in is full operation. These risks can be mitigated by additional work to refine expected composition ranges and/or by implementing a robust ETF design with ability to accommodate substantial variation in waste feed compositions.

5.2 CASE 2: EFFLUENT TREATMENT FACILITY CORROSION UPGRADES AND SOLIDIFICATION

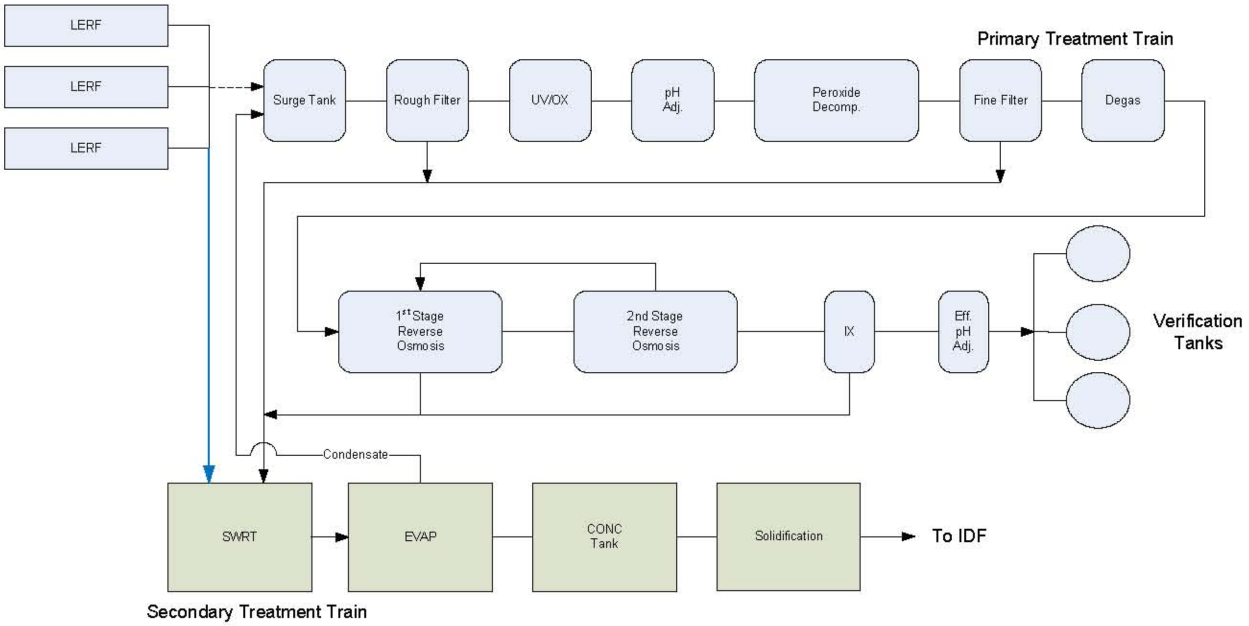
Case 2 includes addition of a new waste solidification system similar to that described for Case 1, plus additional upgrades to ETF process equipment to allow processing of waste with high concentrations of chloride, fluoride, and total dissolved solids. ETF upgrades include changes to materials of construction for tanks, equipment, and piping that are in contact with waste with high chloride and fluoride concentrations, and changes to the operational flowsheet.

5.2.1 Technical Description

The overall process flow diagram for Case 2 is shown in Figure 5-4. The front-end waste treatment process is similar to the existing ETF systems discussed in Section 3.0, with the exception that a revised routing is provided that allows the incoming waste to flow directly to the evaporator without first passing through the primary treatment train. Overhead condensate from the evaporator is then processed through the primary treatment train per the existing ETF flowsheet.

Evaporator bottoms are cooled and transferred to the concentrate tanks, which provide lag storage. From the concentrate tanks, the waste is transferred to the STU where it is mixed with additives and cast into blocks. After curing, the blocks are transported to the IDF for disposal. Additional discussion of the STU is provided in Section 5.1 (Case 1).

Figure 5-4. Solidification Plus Effluent Treatment Facility Corrosion Upgrades (Case 2)



CONC Tank = Concentration tank
Degas. = Degasification Column
Eff. pH Adj. = Effluent pH adjustment tank
EVAP = Evaporator
IDF = Integrated Disposal Facility
IX = Ion Exchange (Existing ETF)
LERF = Liquid Effluent Retention Facility
pH Adj. = pH adjustment tank
SWRT = Secondary waste receiving tank
UV/OX = Ultraviolet Oxidation
WTP = Waste Treatment Plant
___________. = Alternate route

Process operations are expected to be essentially the same as the existing LERF/ETF facility (Section 3.0) with the following exceptions:

- Flexibility is provided for selection of two operational flowsheets depending on the waste to be processed (Figure 5.4). Waste with high dissolved solids bypasses the primary treatment train and is directed to a SWRT, and then to the evaporator. In the alternate flowsheet low dissolved solids waste is directed first to the primary treatment train (e.g., filtration, pH adjustment, oxidation, degasification, reverse osmosis, and mixed-bed ion exchange). Concentrated waste from the primary treatment train flows to the secondary waste treatment tank and then the evaporator. In both cases, overhead condensate from the evaporator is processed through the primary treatment train.

- Waste blending and control of evaporator concentration ratios are used as needed to control ^{137}Cs concentration in the evaporator bottoms to avoid excessive radiation dose rates in the vicinity of the evaporator, concentrate tanks, and STU (discussed further in Section 5.2.4.4 below).
- Concentrate from the evaporator flows to the concentrate tanks, which provide lag storage, and then to the STU for solidification. Solidified blocks of waste from the STU are moved to an interim storage facility and cured on-site until shipment to the IDF.

A simplified mass balance is provided in Appendix C based on ETF processing waste produced in the SBS blowdown discharge mode.

5.2.2 Modifications to Facilities and Equipment

Required upgrades to the ETF liquid processing systems are based on HNF-37718 and include addition of corrosion-resistant SWRTs, concentrate tanks, and associated piping and equipment that contact the liquid waste. Compared to Case 1, these upgrades increase the range of acceptable ETF waste feeds by expanding the allowable concentration ranges for chlorides, fluorides, and total dissolved solids.

Preliminary estimates indicate organics in WTP wastes are outside the ETF design and permit ranges. Performance of the ETF organic destruction process is uncertain with the WTP wastes. Previous treatability studies have identified uncertainties in primary process train steps related to oxidation of organics and behavior of ^{129}I (HNF-8306, HNF-37718). Specific design changes have not been made based on these issues. They are considered to be adequately covered by contingency in the cost estimates provided in Section 7.0.

Case 2 also includes design and construction of an STU to stabilize and solidify the ETF residue, as described for Case 1. The STU has been designed to address deficiencies in the current thin-film evaporator related to both operability and acceptability of the product waste form.

Changes to the main ETF process building for this option include addition of new upgraded tanks and associated equipment and piping, piping changes needed to allow alternate flowsheet operation, and interface connections with the STU. As shown in Figure 5-5, the new tanks are located near the existing ETF process area.

The solidification treatment unit is located in a building extension adjacent to the existing ETF. A description of the STU process and facility is provided in Section 5.1.

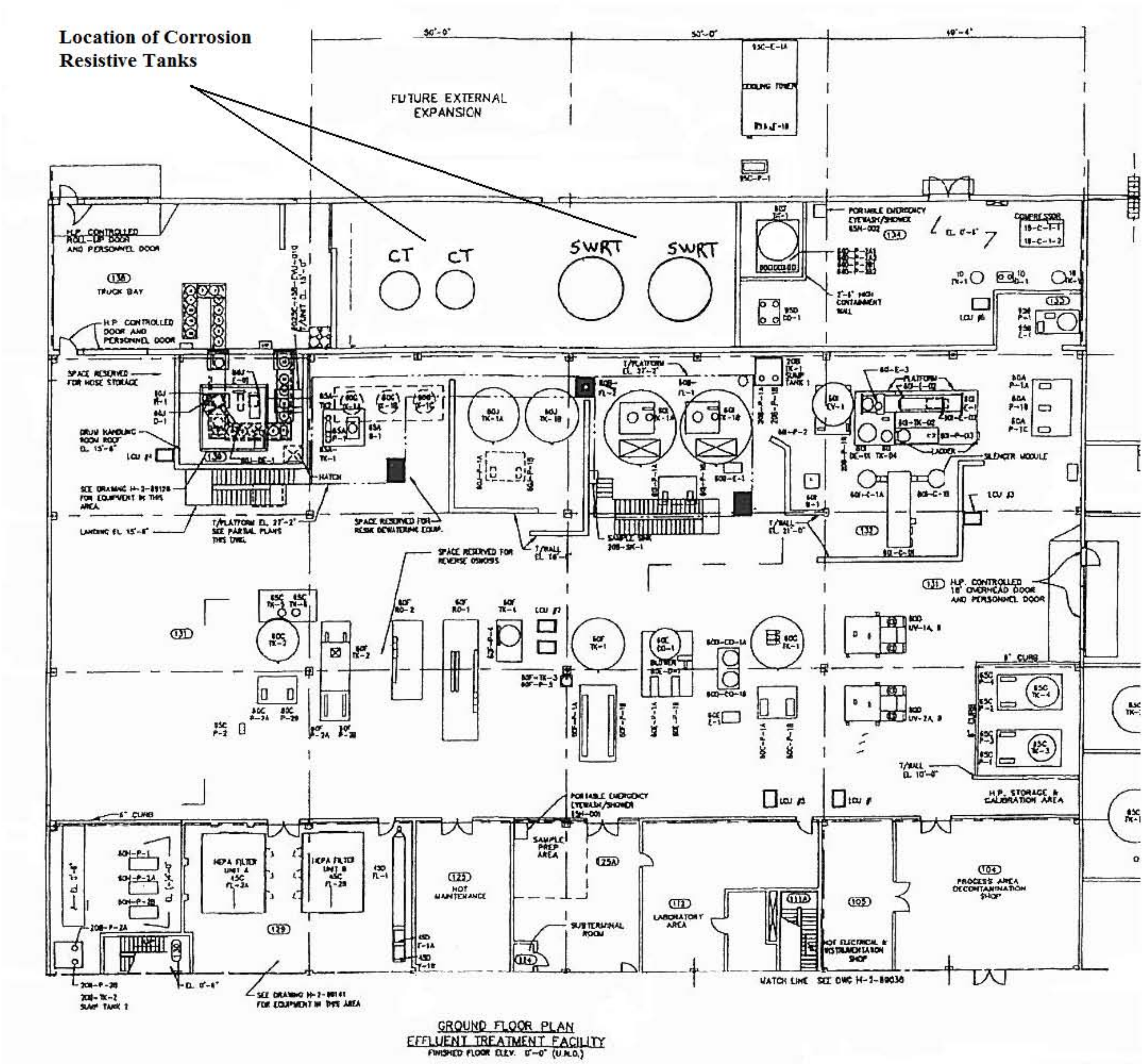
5.2.3 Cost Summary Basis

Total project costs for Case 2 were calculated based on cost information found in:

- RPP-RPT-43787, “Secondary Waste – ETF/Solidification Preconceptual Cost Estimate”
- RPP-RPT-37924, page 161, total project costs include “Estimate – 1b Concentrate/ Cement at ETF” (>10,000 ppm Cl in brine)
- HNF-26914, “Estimate – HNF-26914 Solidification Treatment Unit,” and “ETF Handi Report for ETF Upgrades 2007 and 2008”

Case 2 has an anticipated total project cost of $47.8 million including 50% contingency. ETF annual operating costs are estimated to increase by $3.5 million including 25% contingency above the current/historical operating costs. Cost estimate details are provided in Section 7.0.

Figure 5-5. Modifications to Effluent Treatment Facility Process Building for Case 2.



5.2.4 Risks and Benefits

5.2.4.1 Identified Benefits of Case 2

Primary benefits of Case 2 include the following:

- Compared to the powder produced by the existing TFD, the STU provides a substantially improved waste form, both in terms of physical integrity and leachability/mobility of contaminants.

- The STU eliminates operability, waste composition flexibility, and ALARA issues related to the existing TFD.
- The STU provides increased capacity for solidification of evaporator concentrate as compared to the no-action case (Case 6).
- Upgraded materials of construction for ETF process equipment significantly increases the range of wastes that can be processed in ETF and reduce potential maintenance and down time issues related to equipment corrosion. With identified materials upgrades, the ETF will be able to process wastes with high chloride and fluoride concentrations typical of WTP waste when operating in the SBS blowdown discharge mode (HNF-37718).
- Flowsheet changes to bypass the primary treatment train increase the range of wastes that can be processed in ETF. Wastes with high dissolved solids content or with scale-forming components are difficult or impractical to process in the current reverse-osmosis system. The revised flowsheet addresses this problem by transferring such waste directly to the evaporator while bypassing the reverse-osmosis unit.

5.2.4.2 Risks Identified for Case 2

Primary risks and uncertainties identified for Case 2 include the following:

- Ability to meet waste disposal requirements is not certain. For the SBS blowdown discharge case, waste form performance required to avoid significant increases in groundwater contamination is substantially more stringent than currently defined performance requirements for the STU. Impacts from increased ^{99}Tc contamination are of particular concern.
- With ETF waste feed that is near the ^{137}Cs waste acceptance limit defined in HNF-3172 (Rev. 4), radiation levels in the STU may make operation difficult or impractical with the current STU design. Estimated ^{137}Cs concentrations are well above STU design basis levels. A more detailed study is needed to determine feasibility of operating the STU at forecast contamination levels and/or if design changes are needed.
- Preliminary estimates indicate organics in WTP wastes are outside the ETF design and permit ranges. Performance of the ETF organic destruction process is uncertain with the WTP wastes.
- Preliminary evaluation indicates ETF evaporator capacity is sufficient to handle waste from WTP at the current design capacity. This needs to be verified based on a refined definition of the expected range of waste quantities and compositions from all waste generators discharging to ETF.
- Potential issues have been identified related to ^{129}I off-gassing after pH adjustment (HNF-8306, HNF-37718). This may result in constraints on waste pH adjustment that force carbonate to be retained in the waste feed to the evaporator increasing the potential for scaling. Additional testing and process development work is needed to evaluate the effects of increased carbonate levels on the evaporator operation.
-

- A number of regulatory and permitting issues are identified in HNF-37718. While these must be worked to gain regulatory approval, they generally appear to be fairly routine, with the exception of the waste form/disposal issue listed above.

5.2.4.3 Technical Maturity

Processes and technology for Case 2 are considered to be mature and relatively low risk, with the possible exception of product waste forms. If advanced, high-performance waste forms are required to meet disposal requirements, significant technology development and testing could be required.

The composition and quantity of WTP wastes are expected to vary significantly over time due to changes in WTP waste feed composition, operational changes, maintenance, etc. There is also significant uncertainty in current estimates for some components. These uncertainties may be reduced by obtaining additional test data, data from operating facilities, and WTP waste feed characterization data. However, significant residual uncertainty is expected to remain until WTP in is full operation. These risks can be mitigated by additional work to refine expected composition ranges and by implementing a robust ETF design with ability to accommodate substantial variation in waste feed compositions.

5.2.4.4 Radiation Protection

The LERF/ETF waste acceptance limit for ^{137}Cs in HNF-3172 (Rev. 4), Table D-1, is well above the concentration used for the STU design basis radiation dose rate analysis. With forecasted SBS blowdown compositions, ^{137}Cs is expected to be the dominant source of penetrating gamma radiation. Therefore, the ^{137}Cs concentration is of concern for operations. Estimated ^{137}Cs concentration in the SBS blowdown is on the order of the HNF-3172 limit of 1E-05 Ci/L. If this waste is concentrated to the normal 25 to 40 wt% solids in ETF evaporator bottoms, ^{137}Cs in the concentrate tanks and solidification process feed could be on the order of 1E-03 Ci/L. These values are much higher than the 1E-06 Ci/L value used for the solidification system dose rate analysis (HNF-26914, Appendix H). Based on discussion with ETF personnel, radiation dose rates from cesium at this level would be unacceptable for ETF evaporator operation, and would be well above levels that could be tolerated in the current solidification system design. By blending SBS blowdown with other low contamination wastes, and limiting the concentration factor in the ETF evaporator, it appears feasible to limit concentration in the evaporator bottoms to about 5E-05 Ci/L. Preliminary information indicates this is within the range of past successful ETF operations; however, it is questionable if it is acceptable for the current STU design. If not, mitigation options could include some combination of: (1) reduce ^{137}Cs in the waste from WTP, (2) upgrade the waste solidification design to allow higher radiation levels, or (3) remove ^{137}Cs from the waste upstream of the solidification unit (this alternative is discussed under Case 3). A more detailed study is needed to determine feasibility of operating the STU at forecasted contamination levels and/or if design changes are needed.

5.2.4.5 Solid Waste Disposal

This study assumes the solidified waste form will be disposed at the onsite IDF. A study performed in 2008 (RPP-RPT-37924) included an evaluation of Case 2 and several other options for treating WTP waste from SBS blowdown. The study found that potentially significant groundwater impacts could result from disposal of solidified waste produced from SBS blowdown at the IDF. The largest estimated impacts are for ^{99}Tc. Estimated groundwater concentrations are about 20 times the baseline value when a "low performance" ETF solid waste form is assumed. Alternatives presented indicate ^{99}Tc impacts to groundwater can be reduced to approximately the baseline value by increased ETF solid waste form performance and/or by reducing the ^{99}Tc content of the solidified waste form. A specific allowable or acceptable ^{99}Tc performance was not defined. It is assumed that reducing groundwater impacts to approximately the baseline level is likely to be acceptable. Smaller impacts to estimated groundwater contamination were also noted for Hg, ^{129}I, Cr, and nitrate, which could be similarly mitigated by reduced contaminant concentration or improved waste form performance.

5.2.4.6 Authorization Basis

The ETF facility is classified as a below-Hazard Category 3 nuclear facility. Future modifications to the ETF for Case 2 are expected to allow retention of this classification.

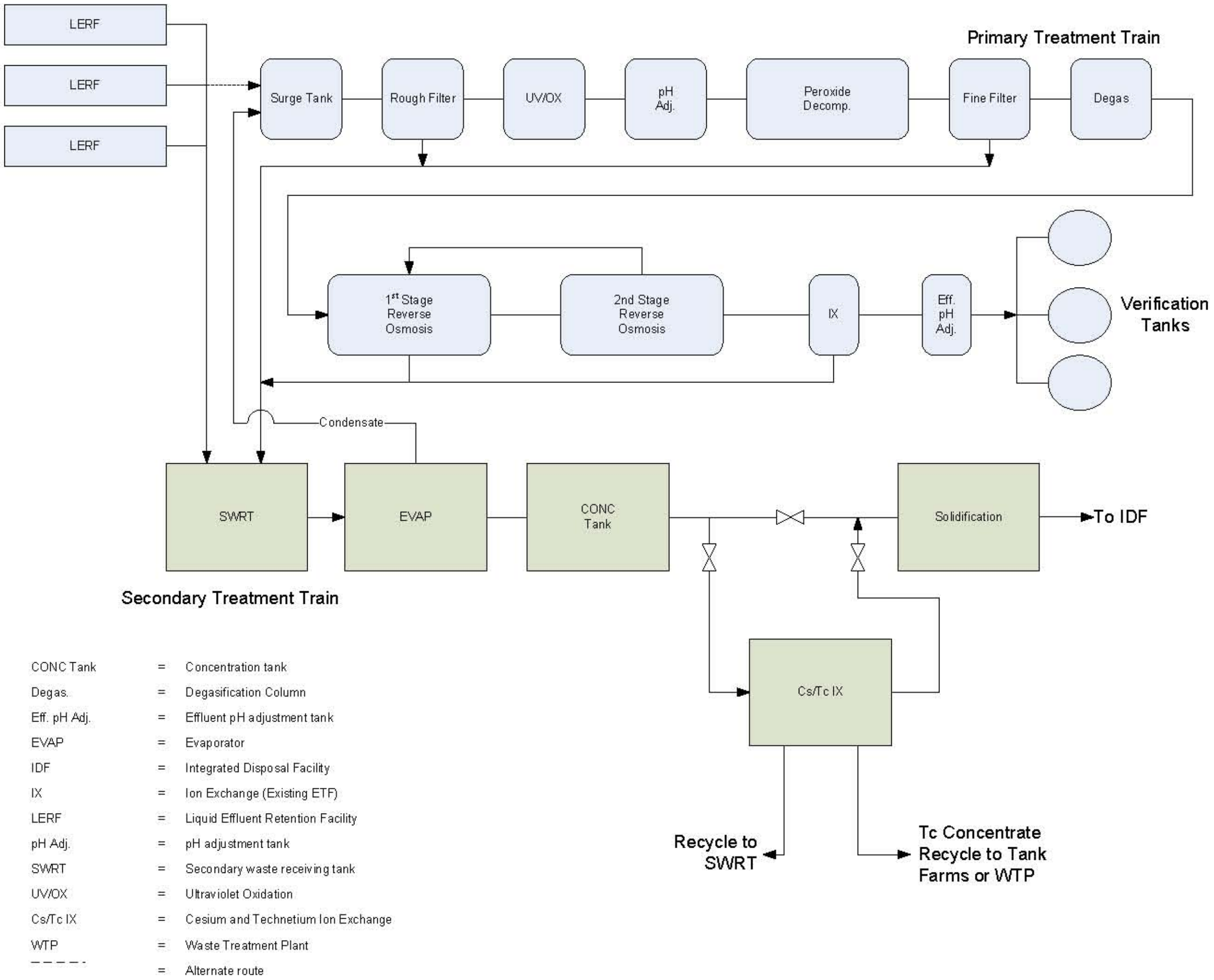
5.3 CASE 3: EFFLUENT TREATMENT FACILITY CORROSION UPGRADES, ION EXCHANGE, AND SOLIDIFICATION

Case 3 includes upgrades to ETF process equipment to facilitate processing of waste with high concentrations of chloride, fluoride, and total dissolved solids as described for Case 2; addition of an STU as described for Case 1 and 2; and addition of ion-exchange systems to remove ^{99}Tc and ^{137}Cs from the waste. The ^{99}Tc and ^{137}Cs ion-exchange systems would be housed in a new facility located near ETF.

5.3.1 Technical Description

The overall process flow diagram for Case 3 is shown in Figure 5-6. The front-end waste treatment process is similar to the existing ETF systems discussed in Section 3.0, with the exception that alternate routing is provided to allow incoming waste to bypass the primary treatment train and flow directly to the secondary treatment train (evaporator) similar to Case 2. Overhead condensate from the evaporator is processed through the primary treatment train per the existing ETF flowsheet.

Figure 5-6. Flow Diagram-Solidification, Corrosion Upgrades, and Ion Exchange (Case 3).



Evaporator bottoms are cooled and transferred to the concentrate tanks, which provide lag storage. From the concentrate tanks, the waste may be transferred either to the STU or to the ion-exchange facility for cesium and technetium removal. Treated waste from the ion-exchange facility is returned to the STU where it is mixed with additives and cast into blocks. After curing, the blocks are transported to the IDF for disposal. See Case 1 (Section 5.1) for additional discussion of the STU, and Case 2 (Section 0) for additional discussion of the ETF upgrades.

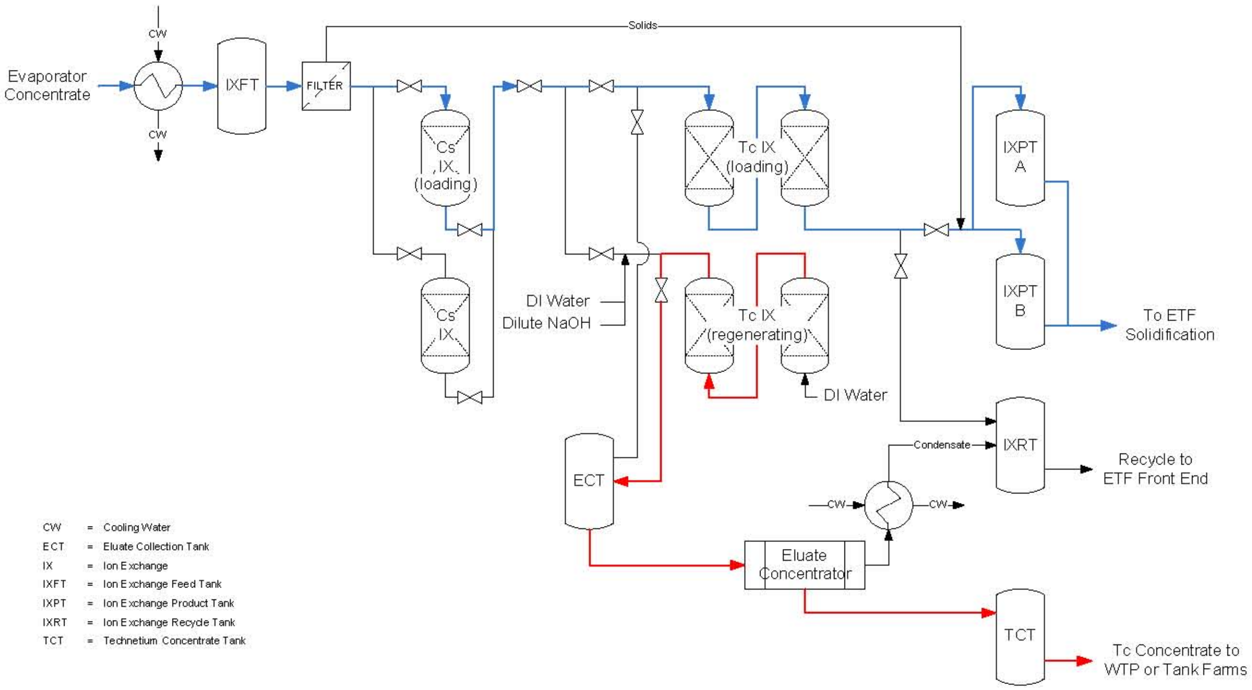
ETF process operations are expected to be essentially the same as the existing LERF/ETF facility (Section 3.0) with the following exceptions:

- Flexibility is provided for selection of two operational flowsheets depending on the waste to be processed. Waste with high dissolved solids bypasses the primary treatment train and is directed to a SWRT, and then to the evaporator. In the alternate flowsheet low dissolved solids waste is directed first to the primary treatment train (e.g., filtration, pH adjustment, oxidation, degasification, reverse osmosis, and mixed-bed ion exchange). Concentrated waste from the primary treatment train flows to the secondary waste treatment tank and then the evaporator. In both cases, overhead condensate from the evaporator is processed through the primary treatment train.

- Waste blending and control of evaporator concentration ratios are used as needed to control ^{137}Cs concentration in the evaporator bottoms to avoid excessive radiation dose rates in the vicinity of the evaporator, concentrate tanks, and STU (discussed further in Section 5.2.4.4).
- Concentrate from the evaporator flows to the concentrate tanks, which provide lag storage. If cesium and/or technetium removal is required, the waste may be directed from the concentrate tanks to cesium/technetium ion exchange. Low contamination waste that does not require cesium or technetium removal is transferred directly to the STU.
- Treated waste from cesium/technetium ion exchange is returned to the STU for solidification. Solidified blocks of waste from the STU are moved to an interim storage facility and cured on-site until shipment to the IDF.

The ion-exchange flow diagram is shown in Figure 5-7. Concentrate from the ETF concentrate tanks is cooled and accumulated in the ion-exchange feed tank (IXFT). From the IXFT, the stream is filtered prior to entering the cesium ion-exchange (CsIX) column and then flows to the top of the primary technetium ion-exchange (TcIX) column, where the technetium is removed and loaded onto the resin. From the primary technetium column, the stream then flows through the secondary technetium column and then to one of the ion-exchange product tanks (IXPT-A or IXPT-B) prior to transfer to the ETF waste solidification system. Solids removed by filtration upstream of ion-exchange are rinsed with water to remove contaminated liquid and transferred to the IXPTs and then the ETF waste solidification system to be incorporated into the solid waste form.

Figure 5-7. Ion Exchange Flow Diagram.



The CsIX media is not regenerable. When the media is spent, it must be replaced with a new column with fresh ion-exchange media. Two columns are provided to allow continuous operation with one column, while the other is being changed out. The TcIX media is periodically regenerated by eluting with heated deionized water. Two sets of TcIX columns are provided. This allows continuous operation with one column set, while the other is being regenerated. Additional detailed information on the ion-exchange system design is provided in Appendix A.

5.3.2 Modifications to Facilities and Equipment

Required upgrades to the ETF liquid processing systems are based on HNF-37718, and include addition of corrosion-resistant SWRTs, concentrate tanks, and associated piping and equipment that contact the liquid waste as discussed in Section 0 for Case 2. Case 3 also includes design and construction of an STU to stabilize and solidify the ETF residue as described in Section 5.1 for Case 1.

Addition of CsIX and TcIX systems is unique to Case 3. This requires new CsIX and TcIX columns together with feed and product lag storage tanks, equipment for handling the technetium column eluate, and associated support equipment. Key process equipment is described in Table 5-2. Appendix A provides additional information on the ion-exchange process and equipment design concept.

Table 5-2. Cesium/Technetium Ion-Exchange Major Equipment.

Item	Quantity	Size	Description
Cesium ion-exchange columns	2	Primary vessel 16-in. diameter by 6-ft high, with integral shielding 48-in. diameter by 9 ft	Disposable column with contained ion-exchange media. 50-gal exchange media bed volume.
Technetium ion-exchange columns (primary and secondary)	4	12-in. diameter by 48-in. high	Corrosion resistant materials to allow high Cl and F concentration.
Feed, product, and recycle tanks IXFT, IXPT-A, IXPT-B, and IXRT	4	7,500-gal volume, atmospheric pressure	7.5-ft diameter FRP with agitator and recirculation pump.
Eluate collection tank	1	1,200 gal nominal volume, atmospheric pressure	SST or polymeric
Technetium concentrate tank	1	50 gal, atmospheric pressure	SST
Eluate concentrator	1	60-lb water per hour net boil-up rate	Electric boiler, 24 kW estimated power. Water-cooled condenser.

FRP = fiberglass reinforced plastic.
IXFT = ion-exchange feed tank.
IXPT = ion-exchange product tank.
IXRT = ion-exchange recycle tank.
SST = single-shell tank.

Case 3 includes a new ion exchange facility to house the process equipment. Figure 5-8 provides a preliminary facility concept. The facility is expected to be about 30 ft x 56 ft x 20 ft. The outer building shell is primarily for weather protection. Confinement of radioactive materials is provided by internal ventilation enclosures, process equipment, and associated ventilation systems. The facility will be located near ETF to facilitate transfers to and from the ion-exchange system. Figure 5-8 and Figure 5-9 provide conceptual design configurations for the ion-exchange facility.

Figure 5-8. Ion-Exchange Facility Configuration (overhead view).

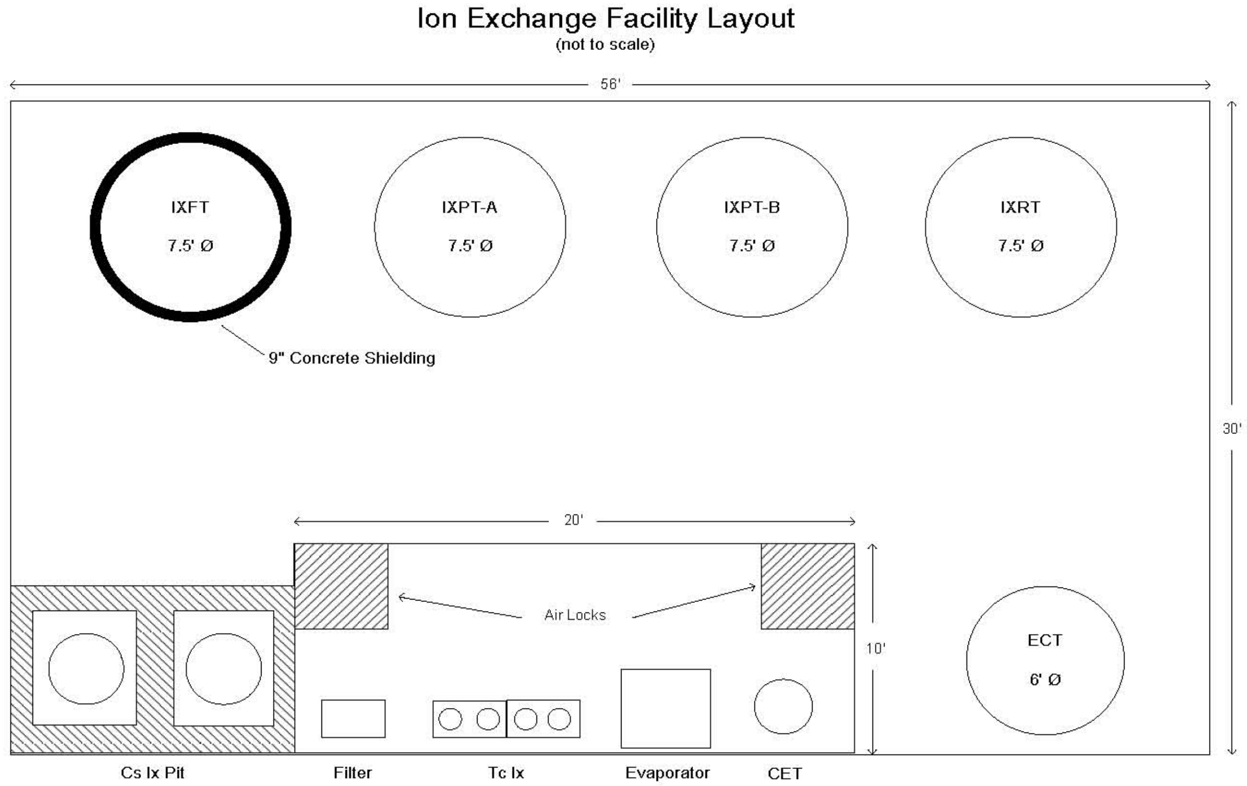
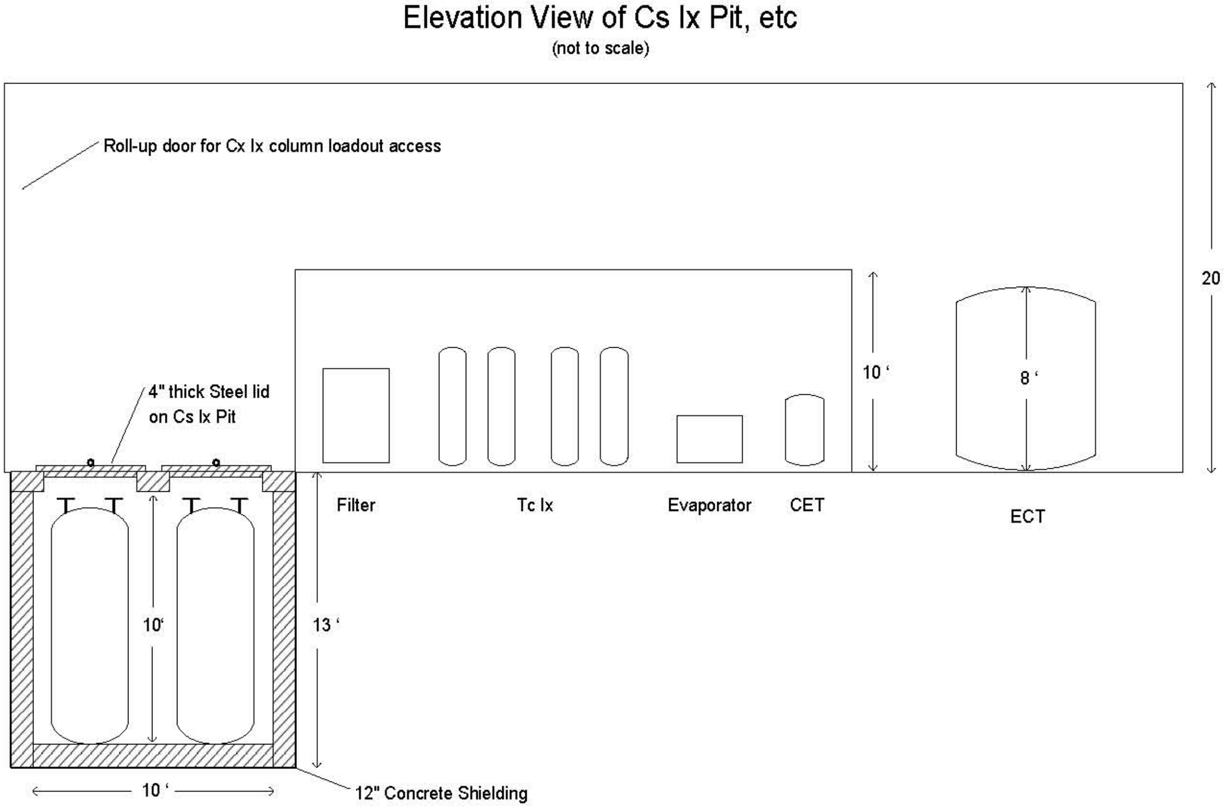


Figure 5-9. Ion-Exchange Facility Configuration (elevation view).



5.3.3 Cost Summary Basis

The total costs for Case 3 are projected based on information from:

- RPP-RPT-43787, "Secondary Waste – ETF/Solidification Preconceptual Cost Estimate"
- RPP-RPT-37924, page 251, "Estimate – 5b Technetium Ion Exchange," and "Estimate – HNF-26914 Solidification Treatment Unit"
- RPP-RPT-37924, page 251, costs for operations are from "Estimate – 5b Technetium Ion Exchange," and "ETF Handi Report for ETF Upgrades 2007 & 2008."

Case 3 has an anticipated total project cost of $89.5 million including 50% contingency. ETF annual operating costs are estimated to increase by $8.7 million above the current/historical operating costs (includes 25 % contingency). Cost estimate details are provided in Section 7.0.

5.3.4 Risks and Benefits

5.3.4.1 Identified Benefits of Case 3

The primary benefits of Case 3 include the following:

- Reduced ^{137}Cs and ^{90}Sr levels in the STU and solidified waste product are expected to significantly reduce dose rates to workers, while simplifying operations and maintenance and improving overall operating efficiency.

- Reduced ^{99}Tc in the solidified waste product increases the probability that a waste form can be produced that will be acceptable for disposal at the IDF. The risk of needing changes to the existing STU design, and the waste form development and testing work needed, are also expected to be reduced.
- Compared to the powder produced by the existing TFD, the STU provides a substantially improved waste form, both in terms of physical integrity and leachability/mobility of contaminants.
- The STU eliminates operability and ALARA issues related to the existing TFD.
- The STU provides increased capacity for solidification of evaporator concentrate as compared to the no-action case (Case 6).
- Upgraded materials of construction for ETF process equipment significantly increases the range of wastes that can be processed in ETF. With identified materials upgrades, the ETF will be able to process wastes with high chloride and fluoride concentrations typical of WTP waste when operating in the SBS blowdown discharge mode (HNF-37718).
- Flowsheet changes to bypass the primary treatment train increase the range of wastes that can be processed in ETF. Wastes with high dissolved solids content or with scale-forming components are difficult or impractical to process in the current reverse-osmosis system. The revised flowsheet addresses this problem by transferring such waste directly to the evaporator, while bypassing the reverse-osmosis unit.

5.3.4.2 Risks Identified for Case 3

Primary risks and uncertainties identified for Case 3 include the following:

- The ability to meet waste disposal requirements is not certain. For SBS blowdown discharge operations, the waste form performance required to avoid significant increases in groundwater contamination are substantially more stringent than performance requirements for the STU as currently defined. Risk is reduced compared to Case 2 due to removal of ^{99}Tc; however, other issues remain. Additional discussion is provided in Section 5.3.4.55.
- The identified technetium removal process has been demonstrated on actual radioactive waste but the composition ranges were different than the current proposed application. Additional technical evaluation and testing are needed to finalize process definition and verification of performance.
- The identified cesium removal process has been demonstrated on actual radioactive waste but the composition ranges were different than the current proposed application. Additional technical evaluation and testing are expected to be needed to finalize process definition and verification of performance.
- Process issues that remain to be resolved include concentration and behavior of organics, carbonates, and ^{129}I in the ETF process. These issues were identified in previous treatability studies and have not yet been fully resolved (HNF-8306, HNF-37718).
- A number of regulatory and permitting issues are identified in HNF-37718. These issues must be resolved to gain regulatory approval, but generally appear to be fairly routine with the exception of the waste form/disposal issue described above.

5.3.4.3 Technical Maturity

Processes and technology for Case 3 are considered to be mature and relatively low risk, with the possible exceptions of product waste forms and ion-exchange processes. The identified cesium and technetium removal processes have been demonstrated on actual radioactive waste but the composition ranges were different than the current proposed application. Additional technical evaluation and testing are expected to be needed to finalize process definition and verification of performance. If advanced high performance waste forms are required to meet disposal requirements, significant technology development and testing could be required.

Similar to other cases, there is significant uncertainty in the waste feed compositions and product performance requirements.

5.3.4.4 Radiation Protection

Section 5.2.4.4 discusses issues related to radiation dose rates around process equipment. Case 3 mitigates this by removing ^{137}Cs from the waste upstream of the STU, resulting in ^{137}Cs concentrations that are in line with the STU design basis level. A more detailed optimization study is needed to determine if cesium removal is the most cost-effective solution. If cesium removal is deleted, the technetium removal process will function similarly to what is shown in Appendix A. However, in this case it may be feasible to install the technetium removal equipment in ETF and/or the STU without the need for a new separate facility.

5.3.4.5 Solid Waste Disposal

This study assumes the solidified waste form will be disposed at the onsite IDF. A study performed in 2008 (RPP-RPT-37924) evaluated several options for treating WTP waste from SBS blowdown. The study found that potentially significant groundwater impacts could result from disposal of solidified waste produced from SBS blowdown at the IDF. The largest estimated impacts are for ^{99}Tc. Estimated groundwater concentrations are about 20 times the baseline value when a “low performance” ETF solid waste form is assumed. Data presented indicate ^{99}Tc impacts to groundwater can be reduced to approximately the baseline value by increased ETF solid waste form performance and/or by reducing the ^{99}Tc content of the solidified waste form. A specific allowable or acceptable ^{99}Tc performance was not defined. Case 3 is expected to adequately mitigate the ^{99}Tc groundwater impacts based on the assumption that reducing groundwater impacts to approximately the baseline level is acceptable. Smaller impacts to estimated groundwater contamination were also noted for Hg, ^{129}I, Cr, and nitrates, which could be mitigated by reduced contaminant concentration or improved waste form performance.

Spent ion-exchange media will be disposed of at Hanford Site burial grounds. Characterization and packaging requirements must be developed in accordance with the burial ground WAC. While there could be unexpected problems, this is not expected to present a substantial risk.

5.3.4.6 Authorization Basis

The ETF facility is classified as a below-Hazard Category 3 nuclear facility and future modifications for Case 3 are expected to retain this classification, including the new ion-exchange facility (Appendix A, Section A5.1).

5.4 CASE 4: EFFLUENT TREATMENT FACILITY CORROSION UPGRADES AND RECYCLE TO TANK FARMS

Rather than design and construct an STU, Case 4 proposes that concentrated treated liquids from ETF be recycled back to the tank farms. This recycle step could be accomplished by direct pipeline transfer or by tanker trucks. Case 4 also provides upgrades to the existing ETF by adding corrosion-resistant tanks and associated piping to come in contact with the LAW effluent as described for Case 2.

5.4.1 Technical Description

Waste is received at LERF and processed in ETF to produce an evaporator concentrate as described for Case 2. The evaporator concentrate is then recycled to the Hanford tank farms. Two sub-options are considered for transporting the evaporator concentrate: (1) tank truck, and (2) pipeline.

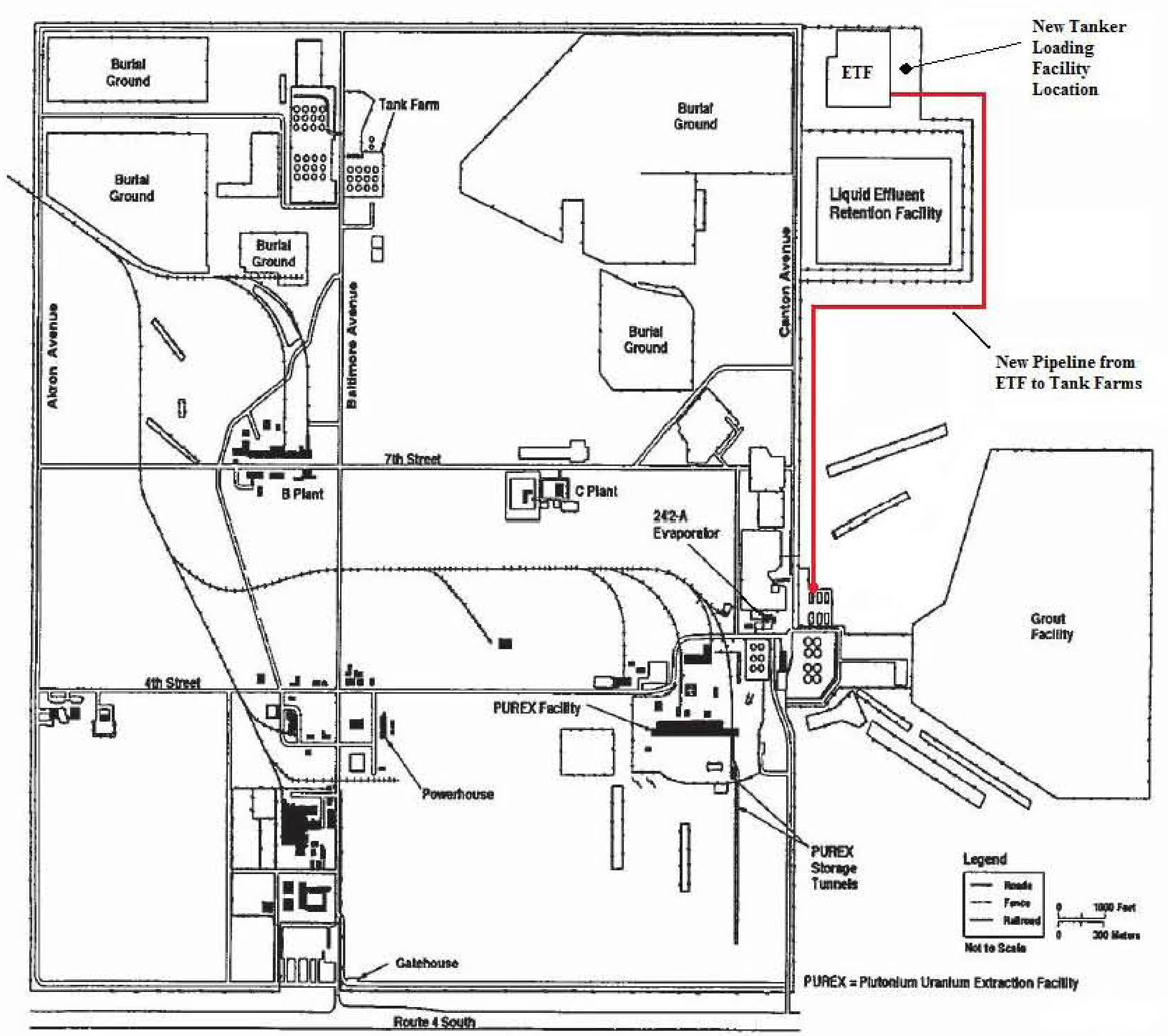
For the tank truck option, approximately 84 truck loads per year are estimated, based on 5,000 gal of evaporator concentrate per load (see Appendix C).

5.4.2 Facility Description

5.4.2.1 Recycle Effluent Treatment Facility Evaporator Concentrate to Tank Farms via Tanker Truck

In this option, the ETF evaporator concentrate is transported to the tank farms via tanker truck where it is off-loaded into a double-shell tank (DST). This approach requires construction of a separate tanker loading facility to the east of the ETF (Figure 5-10). The new facility requires a building approximately 75 ft x 100 ft with a confinement ventilation system. The building is capable of holding a tanker and tractor, plus tanks and equipment for a solids removal and a handling system. The solids removal system is located in a separate room to provide containment of the radioactive solids.

Figure 5-10. Layout for Piping and/or Tanker Location for Case 4.



The equipment in the building consists of:

- A tank to receive evaporator brine from the ETF concentrate tanks; the tank is constructed of fiberglass-reinforced plastic (FRP) or Inconel[1]
- An agitator for the brine receiving tank
- An Inconel pump and piping system to move the brine from the receipt tank to the solids removal system
- A solids removal and handling system, most likely a filter press
- A conveyed drum system to receive the solids from the filter press

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[1] Inconel is a registered trademark of Special Metals Corporation.

- A tank to receive the liquid effluent from the solids removal system; the tank is constructed of FRP or Inconel
- A pump and piping system to transfer from the effluent tank to a tanker; the wetted parts of the pump and piping are constructed of Inconel
- New tankers from corrosion resistant material such as Inconel, hastelloy,[2] etc.

In addition, unloading technology must be installed at a currently undefined location (does not currently exist).

5.4.2.2 Recycle Effluent Treatment Facility Evaporator Brine to Tank Farms via New Pipeline

This approach requires a new pipeline from the ETF to the tank farms that meets all current requirements for tank farm pipelines (e.g., double encasement, leak detection, etc.). It is assumed that this pipeline will run from the ETF to the SN-701 pipeline near the 242-A Evaporator (Figure 5-10). This requires approximately 6,000 feet of new pipe.

Evaporator brine is transferred to the tank farms at a minimum of 1,500 gal every two days to 3,000 gal every two weeks, depending on the processing rate and evaporator concentration factor.

5.4.3 Cost Summary Basis

The total costs for Case 4 tanker truck and the pipeline options are estimated based on information from:

Pipeline option

- RPP-RPT-43787, "Secondary Waste – ETF/Solidification Preconceptual Cost Estimate"
- RPP-RPT-37924, page 187, "Estimate – 2b (Transfer Brine to TF via Pipeline)," and "ETF Handi Report for ETF Upgrades 2007 and 2008"

This case has an anticipated total project cost of $46.9 million including 50% contingency. The increase in annual operating cost is estimated at $1.1 million including 25% contingency above the current ETF operating costs. Cost estimate details are provided in Section 7.0.

Trucking option

- RPP-RPT-43787, "Secondary Waste – ETF/Solidification Preconceptual Cost Estimate"
- RPP-RPT-37924, page 174, "Estimate – 2a (Transfer Brine to TF via Truck)," and "ETF Handi Report for ETF Upgrades 2007 and 2008"

This case has an anticipated total project cost of $35.7 million including 50% contingency. ETF annual operating costs are estimated to increase by $1.2 million including 25% contingency above the current/historical operating costs.

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[2] Hastelloy is a registered trademark of Haynes International, Inc.

5.4.4 Risks/Benefits

5.4.4.1 Identified Benefits of Case 4

The primary benefits of Case 4 include the following:

- Liquid recycle to the tank farms eliminates operability, waste composition flexibility, and ALARA issues related to the existing TFD.
- The liquid recycle option provides increased capacity for disposition of evaporator concentrate as compared to the no-action case (Case 6).
- Recycle of liquid waste to the tank farms eliminates issues related to solidified waste form disposal.
- Upgraded materials of construction for ETF process equipment significantly increase the range of wastes that can be processed in ETF. With identified materials upgrades, the ETF will be able to process wastes with high chloride and fluoride concentrations typical of WTP waste when operating in the SBS blowdown discharge mode (HNF-37718).
- Flowsheet changes to bypass the primary treatment train increase the range of wastes that can be processed in ETF. Wastes with high dissolved solids content or with scale-forming components are difficult or impractical to process in the current reverse-osmosis system. The revised flowsheet addresses this problem by transferring such waste directly to the evaporator while bypassing the reverse-osmosis unit.

5.4.4.2 Risks Identified for Case 4

Primary risks and uncertainties identified for Case 4 include the following:

- Recycle to the tank farms eliminates the ability to purge dissolved and suspended solids, including volatile components that tend to build up in the SBS recycle stream. This may result in increased LAW glass production and other negative impacts to WTP.
- This alternative will result in increased tank farm waste volumes. The available tank farm waste volume is currently limited and is forecasted to drop to near zero.
- Facilities for unloading tankers into the tank farms are not currently available and would need to be developed for the trucking option.
- Relatively frequent transfers to the tank farms would be required for the pipeline option because of waste inventory limits at ETF. This could create operational conflicts with tank farm operations and increased tank farm operating costs.
- Radionuclide concentration limits for tanker shipments may restrict concentration factors in the ETF evaporator, increasing waste volumes to be shipped.
- Liquid waste loading and unloading operations increase the risks of spills and worker exposure.
- Process issues that remain to be resolved include concentration and behavior of organics and ^{129}I in the ETF process. These issues were identified in previous treatability studies and have not yet been fully resolved (HNF-8306, HNF-37718).

- A number of regulatory and permitting issues are identified in HNF-37718. While these issues must be resolved to gain regulatory approval, they generally appear to be fairly routine.

5.4.4.3 Regulatory

The acceptance of the LAW effluent at the LERF/ETF is contingent on the necessary permit modification and notifications being completed.

5.4.4.4 Authorization Basis

The ETF facility is classified as a below-Hazard Category 3 nuclear facility and future modifications for Case 4 are expected to enable retention of this classification.

5.4.4.5 Technical Maturity

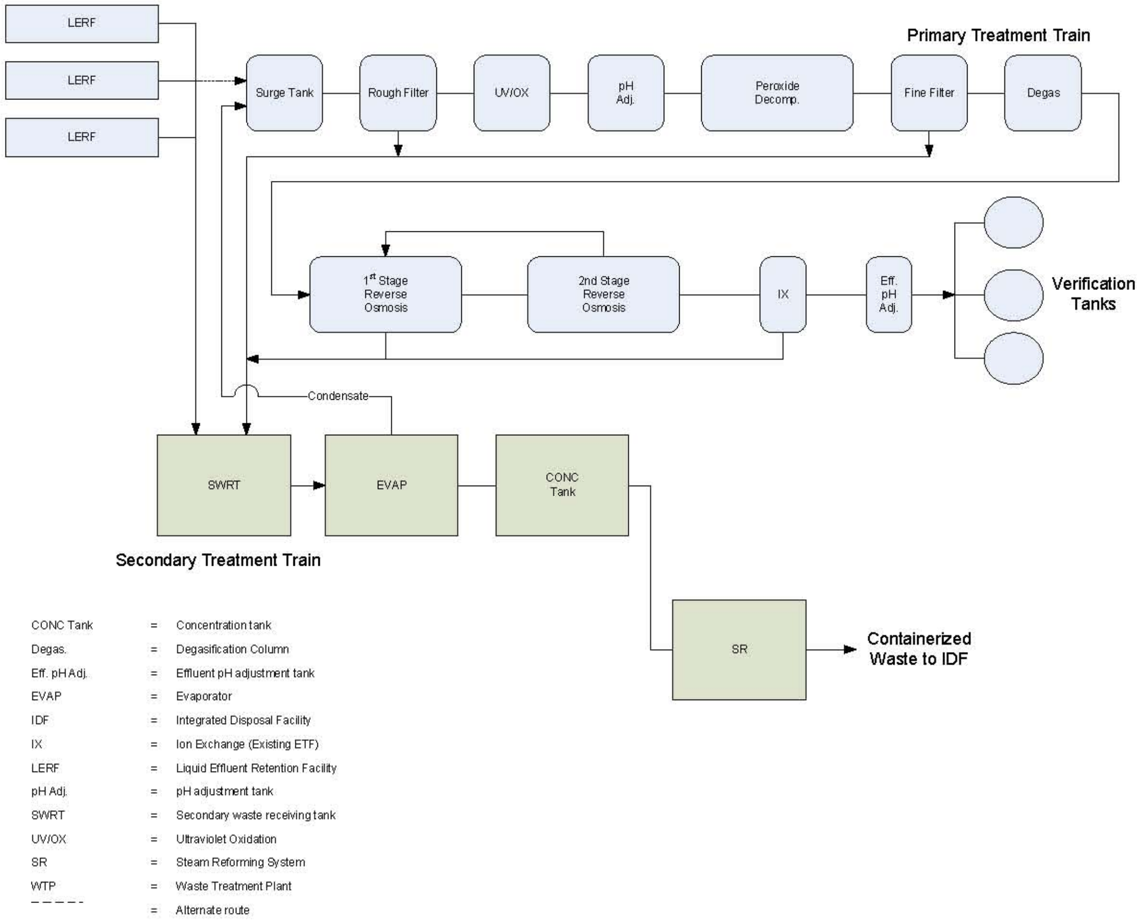
The technologies required for Case 4 are considered to be mature. The design concept is at a pre-conceptual study stage and requires substantial development to finalize a conceptual design.

5.5 CASE 5: EFFLUENT TREATMENT FACILITY CORROSION UPGRADES, STEAM REFORMING, AND SOLIDIFICATION

5.5.1 Technical Description

This option chooses steam reforming as the method of addressing technetium, cesium and other mobile COCs in the effluent waste streams. Steam reforming has been demonstrated to immobilize a wide variety of LAW using technetium and cesium simulants at the laboratory and pilot-plant scale. The aqueous wastes are denitrated in the presence of super-heated steam using clay and carbon as co-reactants with the wastes. The resultant granular mineralized waste chemically bonds ^{99}Tc, ^{137}Cs, RCRA metals Cr and Ni, and anions SO_4, I, F, and Cl within its chemical structure. The design also provides for an integral solidification step of the granular, mineralized waste, removing the need for an additional STU. Figure 5-11 indicates the process flow modified to include a steam-reforming process as the waste solidification step.

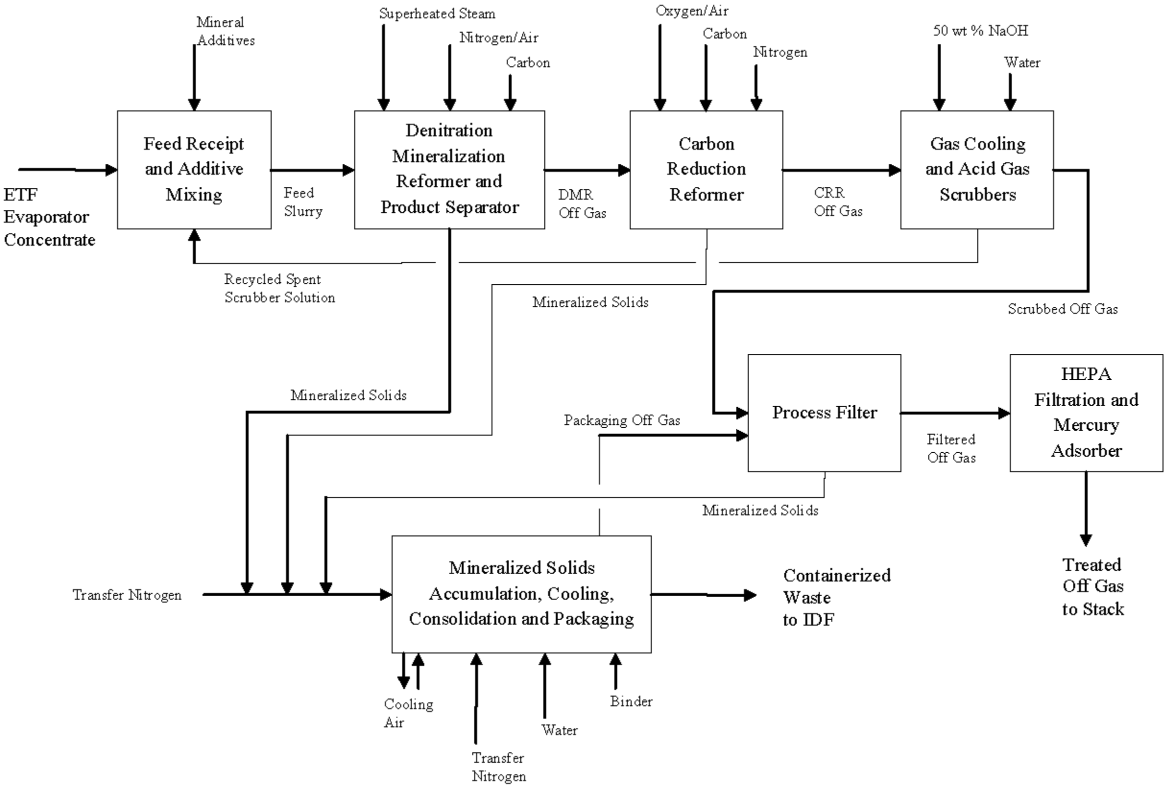
Figure 5-11. Process Flow Diagram Incorporating Steam Reforming as the Waste Solidification Process.



A generic steam-reforming process producing a mineralized product has been used to bound the system supporting ETF operation. Figure 5-12 provides a summary of unit operations used in the generic process to estimate material flows. The generic process flowsheet has not been optimized for ETF support, and significant improvements would likely be available to reduce system cost if selected for implementation. Appendix B provides a more detailed description of the steam-reforming process.

To produce a mineralized steam reformer product, concentrate from the ETF evaporator is mixed with kaolin clay and fed to the denitration mineralization reformer (DMR). The DMR operates at about 640 °C in a chemical-reducing mode to evaporate liquids, convert nitrates to nitrogen gas, and convert the non-volatile constituents of the feed into a granular solid product. Solid product from the DMR is removed and pneumatically transferred to a solids collection and binder addition system. Carbon or charcoal is added to the DMR, where reactions with steam create a reducing environment. The process gas from the DMR consists mainly of water vapor, nitrogen, carbon dioxide, carbon monoxide, and hydrogen, with small amounts of nitrogen-oxide compounds (NO_X).

Figure 5-12. Simplified Process Flow Diagram for a Generic Steam-Reforming Process.



The DMR off-gas stream is introduced into the bottom of a second steam reformer, the carbon reduction reformer (CRR). Oxygen/nitrogen mixtures are injected through gas nozzles positioned above the fluidizing gas distributors through which the DMR process gas flows into the CRR to supply sufficient oxygen to maintain a set bed temperature. The solids collected in the CRR are pneumatically transferred to the solids collection and binder addition system.

The CRR off-gas stream, now primarily composed of nitrogen, oxygen, water, and carbon dioxide, is cooled by direct water injection in the off-gas cooler (OGC) and filtered in the process baghouse filter (PBF). Scrubbers are assumed to be included upstream of the PBF to control acid gases in the reformer off-gas for the generic process flow diagram. A reheater is provided to avoid condensation during filtration. The primary process off-gas joins with the solids collection and binder addition system off-gas and is filtered through a high-efficiency particulate air (HEPA) filter. A granular-activated carbon (GAC) bed is used to remove mercury. The GAC can be bypassed, depending on the type of feed being processed by the system. Treated gases are discharged to a permitted stack via the off-gas blower(s) (OGB).

Solids discharged from the DMR, CRR, and PBF are pneumatically transferred to a solids collection and consolidation system using pressurized nitrogen. Transferred solids are combined in one of two product receiver vessels where they are cooled by a recirculating nitrogen stream. Cooling gas is recirculated from the product receiver vessels through a filter, cooler (gas to air heat exchanger), and blower prior to being returned to the product receivers. Nitrogen bled from the solids collection and consolidation system is combined with other system off-gases at the HEPA filter inlet.

The granular product is converted to a monolithic solid by mixing with cementitious binders (cement or grout). The mixing process is performed directly in the disposal drum. Cooled solids, water, and cementitious additives are metered into the disposal drum and blended with a mechanical mixer. The drum is then sealed with a lid and the mixture cures, forming a solid block inside the disposal drum. Sealed drums of solidified waste are transported to the IDF for disposal.

5.5.2 Facility Description

Implementation of the steam-reforming system option requires retrofit of all piping, tankage, and equipment that contacts the WTP effluent feed with corrosion-resistant materials as part of the ETF upgrade. These upgrades are described in Section 0.

The STU is replaced in this option by installation of a steam-reforming system, which consists of the following components:

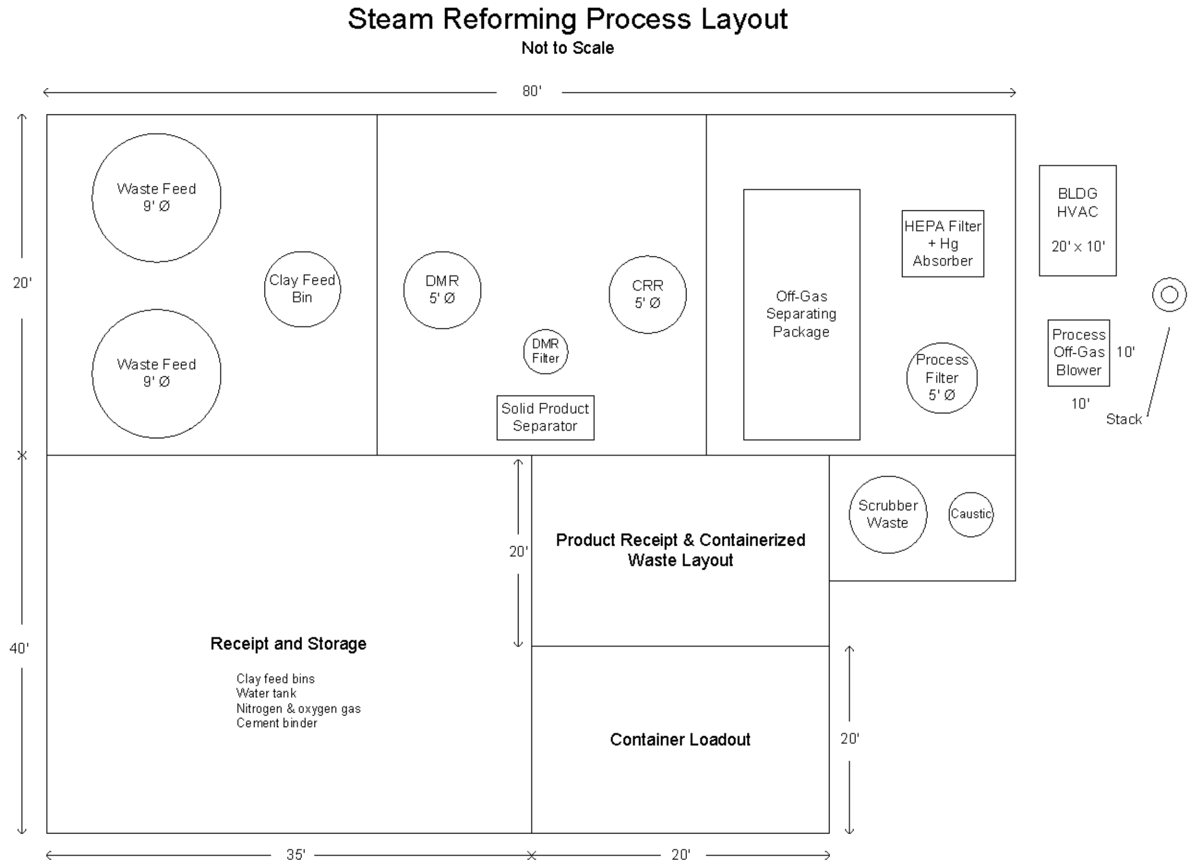
- Waste and additive feeders
- Waste mix tank
- DMR
- CRR
- Process filter
- Off-gas treatment system
- Process supply systems (carbon, nitrogen, oxygen, water, 50 wt % NaOH, cement binder)
- Binder addition and packaging system.

Appendix B provides a preliminary list of process equipment associated with the steam-reforming system.

The facility concept supporting the steam-reforming system is based on enclosing the primary equipment and containing radionuclide contaminated materials in a separate facility located near the existing ETF. Concentrations of ^{137}Cs in the mineralized waste solid are similar to those used as a design basis for the WTP LAW Vitrification Facility (~0.5 Ci/m^3 for mineralized solids versus a design basis of 0.3 Ci/m^3 in LAW glass). Therefore, dose rates in the vicinity of equipment pieces are anticipated to be at a level that allows for a remotely operated, contact-maintained operating philosophy as the basis for facility concept development.

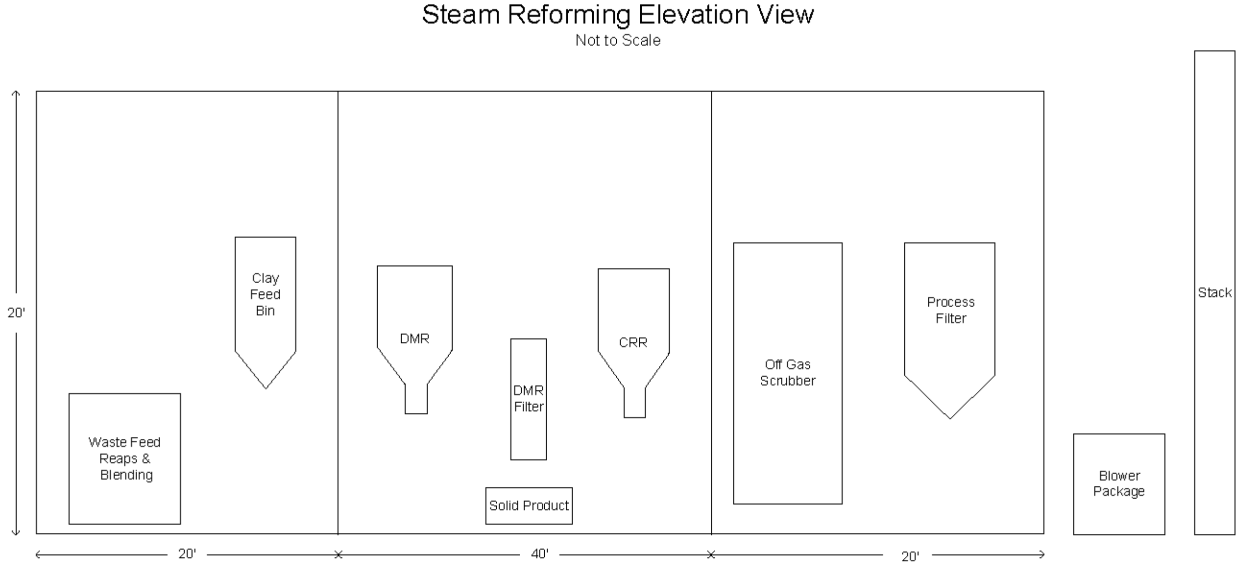
Material inventory estimates provided in Appendix B indicate that the facility is projected to be less than Hazard Category 3. A preliminary steam-reforming system facility layout is provided in Figure 5-13. The layout is based on the equipment sizing estimates shown in Figure 5-13, with contingency space allocated for piping. The layout is focused on the process equipment enclosures and space allocations for essential material supply systems. Area allocations for operating personnel (e.g., control rooms, change rooms, office space, etc.) are not included in the facility layout.

Figure 5-13. Steam Reforming Process Layout.



An elevation view of the steam reforming process layout is shown Figure 5-14.

Figure 5-14. Steam Reforming Process Layout (elevation view).



5.5.3 Cost Summary Basis

The Case 5 cost estimates are based on information provided by:

- "ETF Handi Report for ETF Upgrades 2007 and 2008," and "Estimate – Steam Reforming from Savannah River Remediation Tank 48"
- "Estimate – Solidification Unit from Energy Solutions," costs for operations are from the ETF Handi Report for 2007 and 2008.

Case 5 has an anticipated total project cost of $291.7 million plus contingency. It is assumed that 1/2 of the current operating costs for the ETF will be required for the steam-reforming system. ETF annual operating costs are estimated to increase by $23.4 million plus contingency above the current/historical operating costs. Cost estimate details are provided in Section 7.0.

5.5.4 Risks and Benefits

5.5.4.1 Identified Benefits of Case 5

Primary benefits of Case 5 are summarized below:

- The steam-reforming process provides a consolidated solid waste for disposal that satisfies physical integrity requirements for disposal at the IDF with contaminant leachability/mobility comparable to LAW glass.
- The steam-reforming process is likely to resolve any solid waste disposal issues that may exist due to the potential presence of organics in ETF evaporator concentrate.
- The steam-reforming process eliminates operability and ALARA issues related to the existing TFD.
- The steam-reforming process provides increased capacity for solidification of evaporator concentrate as compared to the no-action case (Case 6).
- Steam reforming may provide capability to dispose of spent activated carbon and/or ion-exchange resins from WTP.
- Upgraded materials of construction for ETF process equipment significantly increase the range of waste that can be processed in ETF. With the identified materials upgrades, the ETF will be able to process wastes with high chloride and fluoride concentrations typical of WTP waste when operated in the SBS blowdown discharge mode.
- Flowsheet changes to bypass the reverse-osmosis unit increase the range of wastes that can be processed in ETF. Waste with high dissolved solids content or with scale-forming components are difficult or impractical to process in the current reverse-osmosis system. The revised flowsheet addresses this problem by transferring such waste directly to the evaporator while bypassing the reverse-osmosis unit.

5.5.4.2 Risks Identified for Case 5

Primary risks and uncertainties identified for Case 5 are summarized below:

- Specific tests of the steam-reformer process using waste compositions equivalent to the ETF evaporator concentrate have not been performed and represent a process flowsheet uncertainty. Results from testing may modify equipment sizing and the unit operations selected for incorporation in the generic steam-reforming process used in this study.

- Waste solute components in the ETF evaporator concentrate are dominated by ammonium nitrate in an aqueous solution. The steam-reforming process is projected to ultimately decompose ammonium nitrate to elemental gaseous components (N_2 and H_2O) resulting in relatively high concentrations of radionuclides in the waste form produced from a waste that was originally relatively dilute. The preliminary material balance estimates a consolidated waste form ^{137}Cs concentration of ~0.5 Ci/m^3, which exceeds the design basis (0.3 Ci/m^3) used for LAW glass from the WTP. Dose rates associated with the steam-reforming consolidated waste represent an issue to be resolved for disposal at the IDF.
- The path of ^{129}I through the steam-reforming process represents a process uncertainty. The generic steam-reforming material balance assumes that little ^{129}I is incorporated in the mineral product and is captured by GAC beds in the off-gas system. This implies that ^{129}I in the ETF evaporator concentrate would ultimately be disposed when off-gas treatment carbon beds are replaced. Development of an acceptable disposal path for carbon beds containing ^{129}I may be considered a process risk.
- Implementation of the steam-reforming process represents a significant expansion to the ETF structures. Assuming larger projects inherently contain a larger risk of schedule delay, there is a risk that the steam-reforming system will not be available to support the startup of the WTP.

5.5.4.3 Authorization Basis

The ETF is classified as a below-Hazard Category 3 nuclear facility and future modifications for Case 5 are expected to enable retention of this classification.

Unit operations associated with the steam-reforming process operate at relatively high temperature (comparable to glass melter temperatures) and slightly below atmospheric pressure. Therefore, while fluidized bed operation represents a new technology for the Hanford Site, it appears that analogs are generally available for incorporation of the operation in the authorization basis.

The DMR is operated under reducing conditions, producing a gas phase containing 4% hydrogen. Controls for this type of operation are assumed to be similar to that implemented in commercial applications of the steam-reforming technology, but will be new to the Hanford Site.

Use of oxygen gas as a process feed material is performed in other industries, but is uncommon at the Hanford Site. Commercial standards for receipt, storage, and piping of oxygen gas are assumed to be implemented as part of the facility design. Use of these systems will require incorporation in the authorization basis.

5.5.4.4 Technical Maturity

The process and equipment systems for fluidized bed steam reforming to process low-activity radioactive waste are considered a technically mature process. A full-scale facility is currently in operation for processing commercial nuclear waste materials. The commercial facility has been in operation since 1999. Low-activity slurry wastes with high water, high organic, and iron content have been received, processed, and packaged for disposal at feed rates in excess of 1,000 lb/hr. Over 250,000 ft^3 of highly radioactive ion-exchange resins, carbon, oils, plastic cellulose, and other organic and aqueous wastes, with contact dose rates of up to 500 R/hr, have been processed by the commercial facility.

Pilot-scale testing has been performed to investigate application of the steam-reforming process to DOE wastes. Demonstration programs have been completed producing both mineral and carbonate solid waste forms, depending on the application. Waste feed compositions tested include simulant modeling LAW from the Hanford Site, sodium-bearing waste from the Idaho National Laboratory, and Tank 48H from the Savannah River Site. Pilot-scale testing includes both 6-in. and 15-in. fluidized bed reformers. The full-scale facility was scaled up from 15-in. fluidized bed testing to a 45-in. system in the final plant design.

Tests described in WSRC-STI-2008-00268, *Mineralization of Radioactive Wastes by Fluidized Bed Steam Reforming (FBSR): Comparisons to Vitreous Waste Forms, and Pertinent Durability Testing*, based on steam-reforming product obtained from pilot-scale tests using Hanford LAW simulant indicate that the mineral product is as durable or, in some respects, more durable that LAW glass. Monoliths formed from binder (cement) addition to the granular mineral product produced a final solid waste form with a density greater than 1.6 kg/L and compressive strength exceeding 800 psi (WSRC-STI-2006-00033, *Fluidized Bed Steam Reformer (FBSR) Product: Monolith Formation and Characterization*). The primary open technical maturity issue with the steam-reforming process appears to be a lack of testing with waste compositions specific to the ETF waste concentrate proposed in this option and incorporation of the test results into the unit operations selected for the process flowsheet.

5.6 CASE 6: DO-NOTHING ALTERNATIVE

In Case 6, the ETF is maintained in its current state.

5.6.1 Technical Description

The ETF supports the 242-A Evaporator, mixed waste burial trench and ERDF leachates, groundwater treatment projects, and other decontamination and decommissioning projects. The liquid effluents are treated to remove toxic metals, radionuclides, and ammonia, and to destroy organic compounds. A key process step in the current ETF flowsheet is the TFD that produces a powder product form. However, the current process was not designed to accommodate the increased scope and volume of secondary waste effluents that will be generated when WTP begins operations. ETF operations are already strained with the current flowsheet design due to the problems encountered with the TFD. The existing design will be unable to meet the increased effluent volume and waste stream chemistry generated by LAW and WTP operational demands. The ETF has experienced corrosion problems in the past, which are expected to become more severe when processing WTP secondary waste.

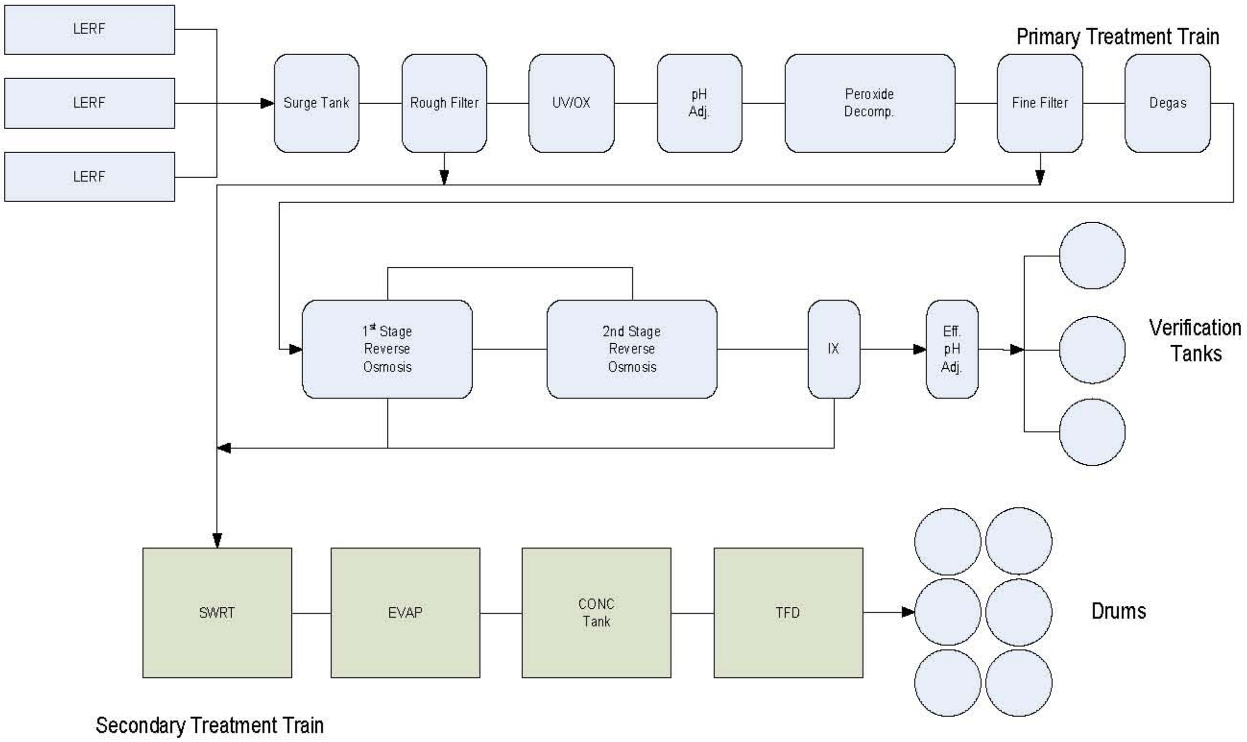
This technical option assumes that the ETF will continue operations without any upgrades to the equipment or facilities. It also does not provide for a solidification option for the powdered secondary wastes, nor does it provide for upgrades to the existing ETF in the form of added corrosion-resistant piping, tanks, and equipment.

As Case 6 cannot support the changing mission of ETF to meet WTP needs, it is not a viable option.

5.6.2 Facility Description

Case 6 requires no changes to the existing ETF operations or facilities. The existing ETF facility and flowsheet are described in Section 3.0. Figure 5-15 is a diagram of the current ETF process flow.

Figure 5-15. Existing Effluent Treatment Facility Process Flow Diagram.



CONC Tank = Concentration tank
Degas. = Degasification Column
Eff. pH Adj. = Effluent pH adjustment tank
EVAP = Evaporator
IX = Ion Exchange
LERF = Liquid Effluent Retention Facility
pH Adj. = pH adjustment tank
SWRT = Secondary waste receiving tank
TFD = Thin Film Dryer
UV/OX = Ultraviolet Oxidation

5.6.3 Cost Summary Basis

Case 6 (do-nothing case) was not included in the cost estimation matrix. While Case 6 requires no capital expenditures, it will result in increased costs to WTP due to lost productivity and work stoppages due to the inability to process secondary effluent waste streams.

Cost estimates for other options represent estimated added cost for ETF above the no-action alternative.

5.6.3.1 Risks/Benefits

Case 6 will be unable to support WTP operations as designed. From a risk basis, Case 6 is not a viable option.

5.6.3.2 Authorization Basis

The LERF and ETF are classified as less than Hazard Category 3 nuclear facilities with an existing authorization basis.

5.6.3.3 Technical Maturity

The ETF has been successfully functioning in support of the 242-A Evaporator, mixed waste burial trench and ERDF leachate disposal, groundwater treatment projects, and other decontamination and decommissioning projects around the Hanford Site for years. However, this technology was not designed based on the flowsheet demands that will be required of it when WTP operation begins.

Technology is available to augment the current ETF design in support of that mission. The previous five case studies (excluding the do-nothing case) outlined in this section provide potential options to improve ETF capabilities and support mission needs.

6.0 RISK ASSESSMENT

Operation of WTP, 242-A Evaporator, and other site waste generators requires the ETF or an alternate treatment facility to accept liquid waste for treatment. Primary programmatic risks are that the ETF cannot accept the waste when needed, resulting in shutdown of the upstream facilities, or that limitations on the quantity and composition of wastes ETF accepts constrain upstream operations at WTP or other generators resulting in operational impacts, increased costs, and/or schedule delays. Another risk is that the ETF solid waste product does not meet IDF acceptance requirements, or conversely that the impact of ETF solid waste product to the IDF performance assessment results in increased costs, schedule delays, or other impacts to IDF. Individual risk items that contribute to these overarching risks are identified in Section 5.0 for the alternative cases. Table 6-1 is a list of risks and mitigating actions from a draft risk management plan currently under development (RPP-PLAN-43455, *Solidification Treatment Unit & Secondary Waste Treatment – Effluent Treatment Facility Risk Management Plan*). It is not necessarily limited to the six individual cases discussed in this report.

Table 6-1. Secondary Waste Risk List (3 sheets).

	Activity	Risk	Probability	Consequence	Mitigation
1.	LDA-1015000 (conceptual design) LDA-1012120 (specification) LDA-105210 (flowsheet)	Secondary waste feed composition estimates do not have sufficient accuracy to support design or the PA. WTP modeling of the caustic scrubber is not a thermodynamic model. Actual stream composition for Na, CO_3, and NO_3 used as design inputs may be inaccurate, which could result in redesign. WTP is not scheduled to provide emission information until July 2010, which is not soon enough to support completion of the conceptual design process flowsheet/mass balance.	High	Medium	Bounding numbers are being used for modeling Improve model of caustic scrubber Assume risk/monitor
2.	RA-21350 (research formulations)	Waste form testing methodology inadequacies do not support waste form selection decision. PNNL lab testing (baseline is cementitious product) may determine that another solidification method is more acceptable, causing an impact to the conceptual design alternatives analysis and potentially causing a restart of the conceptual design process – causing a cost/schedule impact.	Medium	Medium	Use independent review with panel of experts to recommend/approve testing methodology Use existing data
3.	LDA-105210 (flowsheet)	Solidified secondary liquid waste composition and volume estimates are not known with sufficient accuracy to provide input to design or PA	Low	High	Use conservative parameters in testing
4.	LDA-1015000 (conceptual design)	Performance requirements for IDF waste disposal are not provided at this time. IDF disposal limitations are needed from the EIS.	Medium	High	Assume risk/monitor
5.	RA-21350 (research formulations) RA-21448 (technetium preliminary report)	Testing does not demonstrate sufficient COC retention and IDF PA is impacted. If the cementitious product does not perform as required, a new waste form will be explored. PNNL screening test data will be available by March 2010.	Medium	High	Assume risk/monitor Continue testing New disposal technology must be developed

Table 6-1. Secondary Waste Risk List (3 sheets).

Activity		Risk	Probability	Consequence	Mitigation
6.	LDA-105210 (flowsheet)	ETF may be required to process LAW SBS (WTP) liquid blowdown. Additional unit operations are required such as cesium ion-exchange. This only applies if early LAW treatment is initiated – currently outside the baseline.	High	Very High	Assume risk/monitor Prepare flowsheet
7.	General	Inadequate funding or delay in funding – reduced or delayed funding profile does not support completing work as scheduled, leading to inefficiencies in work performance, protracted schedule, increased escalation, and consequently increased total project cost. ETF upgrades are required to handle WTP secondary waste volume. WTP cannot operate efficiently and effectively without upgrades to ETF.	Medium	Very High	Assume risk/monitor
8.	General	Scope of project increases (e.g., disposition of solid secondary waste such as spent ion-exchange resin, loaded activated charcoal, poisoned catalyst, or failed melters and other equipment has not been budgeted). Quantities of waste are uncertain. Ability to dispose of the solids in IDF is uncertain as COC content and leach rates are unknown. Additional information will be available in the September 2009 Solid Waste Report, and from PNNL testing results in March 2010.	Medium	Medium	Initiate project to define scope. Provide budget.
9.	A-1012390 (CD-0 approval)	CD-0 not received in a timely fashion from DOE causing schedule impacts	High	Medium	Monitor schedule with ORP
10.	LDA-1012340 (capital determination)	Project is determined to be capital, which requires line item funding and results in schedule impacts. WRPS will address funding in October 2009; anticipate results prior to CD-0.	Medium	Medium	Perform capital determination

Table 6-1. Secondary Waste Risk List (3 sheets).

Activity		Risk	Probability	Consequence	Mitigation
11.	General	Additional ETF feed streams are identified that impact the flowsheet and equipment design (lithium bayer, TRU, second LAW facility, etc.)	High	Medium	Monitor other WRPS internal projects Perform alternative analyses in conceptual design
12.	LDA-105210 (flowsheet)	Secondary waste compositions from WTP process models are not charge balanced, and the composition must be adjusted to produce a simulant. Errors introduced during charge balancing may impact simulant development and thereby PA input.	Low	Medium	Include expert independent scientific panel for review. Coordinate charge balance methods with other Hanford waste generators.
13.	General	ETF cannot be used to treat secondary liquid waste	Low	High	Perform alternative analyses in Conceptual Design
14.	General	Hazard Category becomes ≥3	Medium	Low	Plan NS&L approach based on Hazard Category 3
15.	LDA-1015000 (conceptual design)	Existing data is insufficient to support completion of site evaluation, resulting in additional cost and time for obtaining borehole data. Geotechnical soils data may not be required for conceptual design, but will be required for preliminary design development.	Low	Very Low	Confirm data requirements with WRPS Civil Engineering
16.	General	Permitting delays construction/operation of ETF	Low	Low	Assume risk/monitor

Source: RPP-PLAN-43455, 2009, *Solidification Treatment Unit & Secondary Waste Treatment – Effluent Treatment Facility Risk Management Plan*, Draft, Washington River Protection Solutions, LLC, Richland, Washington

CD = critical decision.
COC = contaminant of concern.
DOE = U.S. Department of Energy.
EIS = environmental impact statement.
ETF = Effluent Treatment Facility.
IDF = Integrated Disposal Facility.
LAW = low-activity waste.
NS&L = Nuclear Safety and Licensing.
ORP = Office of River Protection (DOE).
PA = performance assessment.
PNNL = Pacific Northwest National Laboratory.
SBS = submerged bed scrubber.
TRU = transuranic.
WRPS = Washington River Protection Solutions, LLC.
WTP = Waste Treatment and Immobilization Plant.

Section 5.0 describes anticipated risks and benefits associated with each case scenario. Each case represents technical alternatives to support of the WTP mission needs with regard to processing secondary effluent wastes. Ultimately, evaluation of risk will be contingent upon the outcome of CD-0. It is essential to know what the chosen immobilization technology for ETF secondary wastes will be, and what processing enhancements to the ETF will be, to accurately predict the associated risks.

Recurring concerns regarding ETF support of future missions include, but are not limited to:

- Uncertainty and variability in the composition and quantities of feed streams to be processed by ETF
- Defining the WAC for the solidified waste product, particularly with regard to waste form limitations, acceptable quantity/concentration of COCs, and retention of COCs.
- Defining waste form disposal requirements
- Ability of ETF organic oxidation system to effectively process WTP wastes.
- Potential for evaporator scaling or other processing problems related to use of existing equipment for processing wastes significantly outside the range they were designed for.
- Retaining the ETF less than Hazard Category 3 nuclear facility designation
- Materials of construction/corrosion issues.

These risks and concerns are discussed on a case-by-case basis in Section 5.0.

7.0 CONCLUSIONS

The 200 Area ETF receives, treats, and disposes of liquid effluents from clean-up projects on the Hanford Site. The ETF supports the 242-A Evaporator, mixed waste burial trench and ERDF leachates, groundwater treatment projects, and other decontamination and decommissioning projects. The liquid effluents are treated to remove toxic metals, radionuclides, and ammonia, and to destroy organic compounds. A key process step in the current ETF flowsheet is the TFD that produces a powder that is subsequently placed in 55-gal drums and disposed onsite. The current process was not designed to accommodate the increased scope and volume of secondary waste effluents that will be generated when WTP begins operation. Plans are to increase the capacity of ETF to process the secondary wastes generated when the WTP begins waste treatment and immobilization operations.

Modifications of the ETF will be necessary to support WTP operations. The intent of this pre-conceptual engineering study is to present potential alternative scenarios to improve the functionality of ETF in support of future WTP operations. Five variables were identified for examination, in various combinations, to define the range of needed upgrades in terms of cost, complexity, and technical difficultly. These variables are as follows:

- Upgrade ETF facilities with corrosion-resistant equipment, tankage and piping,
- Identify solidification technology and construct an STU

- Remove cesium and technetium from the liquid effluents using ion-exchange
- Install a fluidized bed steam-reforming facility to process ETF evaporator concentrate
- Recycle concentrated waste to the tank farms.

Six different cases were examined using various permutations of these variables. Each case presents descriptions of the associated technology, facilities, costs, benefits, and risks anticipated. Included in these descriptions are potential facility layout designs, equipment requirements, and process flow diagrams. Each case was also examined with regard to cost, as discussed in Section 7.1.

7.1 COSTS

Cost estimate information for the alternatives is provided in Table 7-1 and Table 7-2. A cost estimate is not provided for Case 6 (do-nothing alternative), which requires no capital expenditures and no increase in ETF operating costs. Table 7-1 provides a cost range for each case, representing the nominal cost estimate for each case and +50%/-10% contingency allowances.

**Table 7-1. Secondary Waste Effluent Treatment Facility
Primary Alternative Cost Range.**

Case					
1	Limited ETF Upgrades/Solidification	Total Project cost	Plus 50%	Nominal	Minus 25%
			$ 42.1Million	$28.1 Million	$21.1 Million
		Annual Ops	Plus 25%	Nominal	Minus 10%
			$3.7 million	$2.9 Million	$2.7 Million
2	ETF Corrosion Upgrades/ Solidification	Total Project cost	Plus 50%	Nominal	Minus 25%
			$47.8 Million	$31.9 Million	$23.9 Million
		Annual Ops	Plus 25%	Nominal	Minus 10%
			$3.5 Million	$2.8 Million	$2.5 Million
3	ETF Corrosion Upgrades/Ion Exchange/ Solidification	Total Project Cost	Plus 50%	Nominal	Minus 25%
			$89.5 Million	$59.7 Million	$44.7 Million
		Annual Ops	Plus 50%	Nominal	Minus 10%
			$8.7Million	$5.8 Million	$5.2 Million
4A	ETF Corrosion Upgrades/Recycle to Tank Farms via pipe line	Total Project Cost	Plus 50%	Nominal	Minus 25%
			$46.9 Million	$31.2 Million	$23.1 Million
		Annual Ops	Plus 25%	Nominal	Minus 10%
			$1.1 Million	$0.9 Million	$0.8 Million
4B	ETF Corrosion Upgrades/Recycle to Tank Farms via truck	Total Project Cost	Plus 50%	Nominal	Minus 25%
			$35.7 Million	$23.8 Million	$17.8 Million
		Annual Ops	Plus 25%	Nominal	Minus 10%
			$1.2 Million	$1 Million	$.9 Million
5	ETF Corrosion Upgrades/Steam Reforming & Solidification	Total Project Costs	Plus 50%	Nominal	Minus 25%
			$292 Million	$194 Million	$146 Million
		Annual Ops	Plus 25%	Nominal	Minus 10%
			$23.4 Million	$18.7 Million	$16.8 Million
6	Do Nothing				

Source: RPP-RPT-43787, 2009, *Secondary Waste – ETF/Solidification Pre-Conceptual Cost Estimate*, Draft, Washington River Protection Solutions, LLC, Richland, Washington.

ETF = 200 Area Effluent Treatment Facility.

Table 7-2 provides a summary of major cost elements included in the nominal cost estimate for each case. An overview of the scope and estimating approach for the major cost elements is provided in the following sections.

Table 7-2. Summary of Nominal Cost Estimates.

Cost Element	Case 1	Case 2	Case 3	Case 4a	Case 4b	Case 5
Project Management	$3,699,448	$3,691,810	$4,212,204	$3,288,769	$3,288,769	$7,923,885
Project Support	$3,303,698	$3,506,061	$4,922,006	$2,979,206	$2,979,206	$11,993,591
Permitting Support	$704,166	$794,984	$3,534,652	$704,153	$483,204	$3,534,652
Safety Analysis	$697,002	$697,002	$1,903,845	$1,462,659	$1,462,659	$3,411,846
Engineering Design	$6,051,258	$6,051,258	$10,411,981	$2,346,342	$1,396,342	$8,554,718
Engineering During Construction	$1,490,155	$1,510,945	$1,538,433	$2,067,107	$1,491,054	$6,760,701
Procurement	$2,814,798	$4,470,001	$10,063,389	$7,340,511	$3,702,901	$119,146,731
Construction	$6,223,015	$7,478,426	$11,859,035	$6,469,586	$5,047,990	$4,598,563
Startup and Testing	$269,567	$333,440	$3,977,632	$324,668	$324,668	$6,705,284
Operational Readiness Review	$492,228	$492,228	$1,486,342	$1,486,342	$1,486,342	$3,106,159
Escalation	$2,374,002	$2,830,860	$5,746,868	$2,788,868	$2,109,177	$18,701,185
Total Project	$28,119,337	$31,857,014	$59,656,388	$31,258,210	$23,772,312	$194,437,314
Annual Operations	$2,330,670	$2,224,670	$4,646,726	$703,816	$661,984	$15,041,795
Transport &Disposal	$46,140	$46,140	$46,140	$-	$172,474	$46,140
Escalation	$571,262	$545,786	$1,116,833	$169,127	$141,432	$3,626,355
Total Annual Operations	$2,948,072	$2,816,596	$5,809,699	$872,943	$975,890	$18,714,291

Source: RPP-RPT-43787, 2009, *Secondary Waste – ETF/Solidification Pre-Conceptual Cost Estimate*, Draft, Washington River Protection Solutions, LLC, Richland, Washington.

7.1.1 PROJECT MANAGEMENT

Project management is the incremental increase for the specific project management and project management support required for each approach from the project inception to the start up of the facility. The estimates include both the cost of Hanford Site personnel and subcontracted services. The estimated cost is based on a consistent level of staffing from the beginning of the project through startup. The management costs after startup are included in the operating cost. The cost estimates do not include any incremental increase to the overall site management.

7.1.2 ENGINEERING/DESIGN

The engineering/design includes Title I and Title II Design and Title III Engineering during construction. Engineering/design also includes engineering support, which provides the project manager with supporting functions such as design reviews and environmental, safety and health support. The basis for the engineering/design cost estimate is a combination of identifying the labor required to provide the needed support and percentages of construction and material costs from previous experience.

7.1.3 PROCUREMENT

Procurement includes procurement of major equipment, significant fabricated items and procurement support. The equipment and significant items of fabrication were determined from the available preliminary design information. Prices for equipment and fabricated items were obtained from suppliers and recent construction at the tank farms. The cost estimates for procurement support was developed using the staffing for similar activities recently completed at the tank farms.

7.1.4 CONSTRUCTION

Construction includes procurement of the minor materials and equipment, field construction, equipment installation, construction management and construction support. The quantities of materials and equipment were determined from the available preliminary design information. Prices for materials and equipment were obtained from equipment suppliers and recent construction experience at the tank farms. Field construction and installation costs are based on recent tank farm experience on similar facilities. The cost estimates for procurement support, construction management and construction support were developed using the staffing for similar projects recently completed at the tank farms.

7.1.5 Startup

The estimated cost of startup is based on the number of systems included in the startup and the complexity of the systems, including the number of procedures and the amount of training required. Startup includes both Hanford Site labor and subcontracted services to perform the following tasks:

- Develop, review, and approve a plan for the facility/system startup
- Develop, review, and approve an operational readiness review or readiness assessment
- Develop or revise the operating procedures
- Develop the needed training material and train the trainers; operator training is included in the operations
- Conduct the system tests in accordance with the test plan.

7.1.6 Operations and Maintenance

The cost estimate for operations is the incremental cost above the current ETF and tank farm baseline operations on an annual basis. Operations is the incremental increase associated with operating, maintaining, and managing the additional systems installed but does not include additional administrative oversight. The specific scope of the operations function includes shift operations personnel, other personnel that support shift operations (radiological control, engineers, planners, craft personnel, and necessary supplies and consumables), and sampling and analysis.

The specific scope of the maintenance function includes the activities necessary to maintain operable equipment in a calibrated and functionally tested condition to be compliant with authorization bases, regulatory requirements, and to support plant operation. This includes preventive maintenance and calibration work packages, planning, scheduling, and set up of preventive maintenance activities, work package preparation, and approval for work. The scope includes labor for the pre-job meetings, performance of preventive maintenance, and post-maintenance testing.

8.0 REFERENCES

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APPENDIX A

CESIUM AND TECHNETIUM REMOVAL

A1.0 CESIUM AND TECHNETIUM REMOVAL PROCESS SUMMARY

Study Case 3 includes removal of cesium and technetium from the evaporator concentrate prior to solidification. This appendix describes an example ion-exchange system concept developed for this option. The concept is not intended to represent a preferred or selected concept but rather provides the basis for a rough order of magnitude cost estimate and an indication of the relative size and complexity of this option.

The primary reason for considering cesium removal is to reduce contamination levels and radiation dose rates in downstream solidification and solid product-handling systems. An optimization study could be considered later to evaluate the relative advantages and disadvantages of upgrading the downstream system designs to facilitate operation at higher dose rates versus removal of cesium prior to solidification.

The primary reason for considering technetium removal is to reduce potential impact to the disposal system performance assessment resulting from high levels of technetium in the solidified product.

A1.1 Overall Process Design Concept

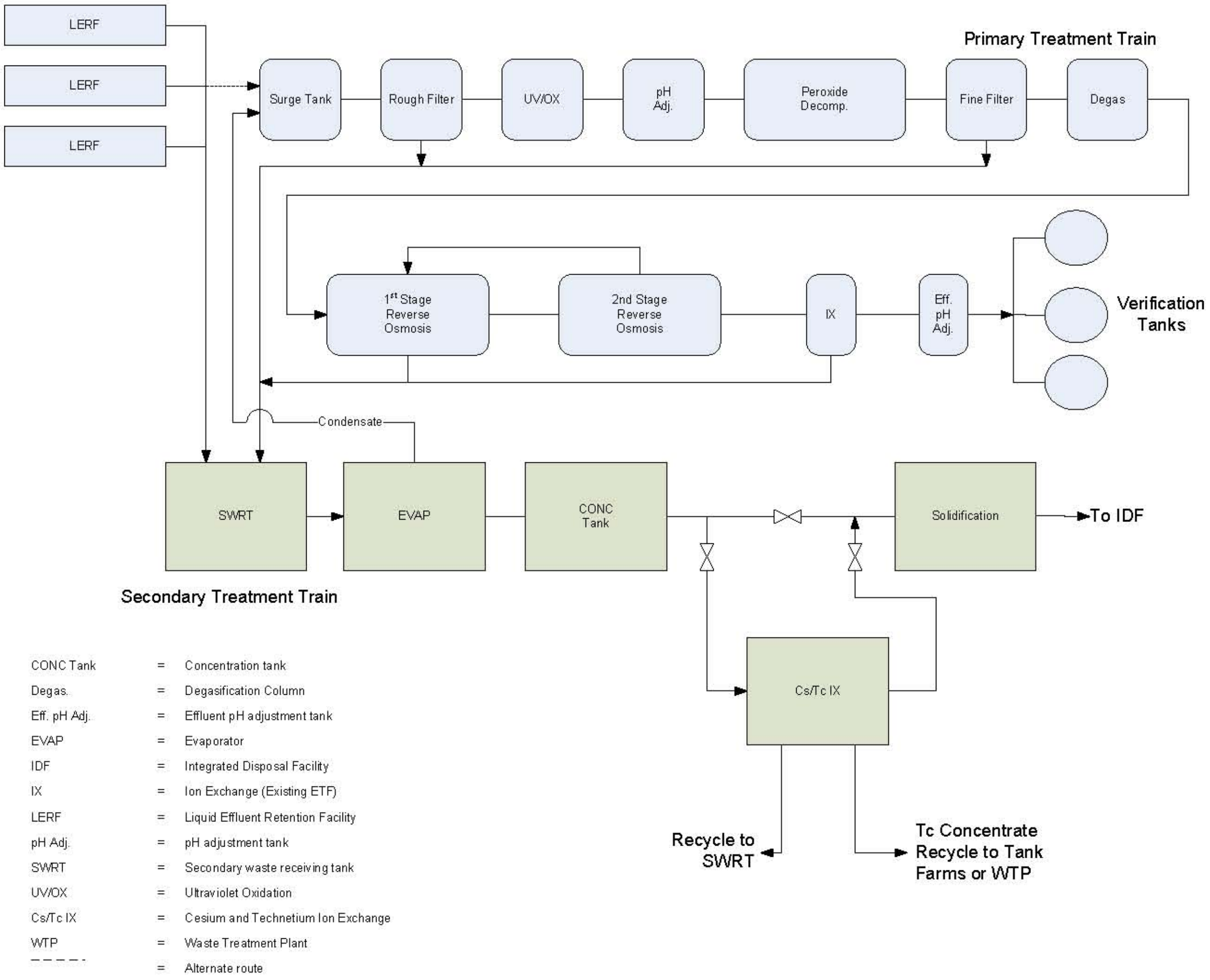
Figure A-1 illustrates how the ion-exchange system interfaces with the balance of the Effluent Treatment Facility (ETF) systems, and Figure A-2 provides a flow diagram for the ion-exchange system. The overall scheme is based on the ETF process approach defined in the 2008 treatability study (HNF-37718, *Low Activity Waste (LAW) Facility Secondary Waste to Effluent Treatment Facility (ETF) Treatability Evaluation*) (option 1b, greater than 10000 ppm Cl + F case), with the exception that an ion-exchange step is added to remove cesium and technetium from the evaporator concentrate before it is transferred to the solidification unit.

Figure A-1 shows the modified ETF process flow diagram. The front-end waste treatment process is similar to the existing ETF systems, with the exception that alternate routing is provided to allow incoming waste to bypass the primary treatment train and flow directly to the secondary treatment train (evaporator). Overhead condensate from the evaporator is processed through the primary treatment train per the existing ETF flowsheet.

Evaporator bottoms are cooled and transferred to the concentrate tanks, which provide lag storage. If cesium and/or technetium removal is required, the waste may be directed from the concentrate tanks to cesium/technetium ion exchange. Low contamination waste that does not require cesium or technetium removal is transferred directly to the solidification treatment unit (STU). Treated waste from the ion-exchange facility is returned to the STU, where it is mixed with additives and cast into blocks. After curing, the blocks are transported to the Integrated Disposal Facility (IDF) for disposal.

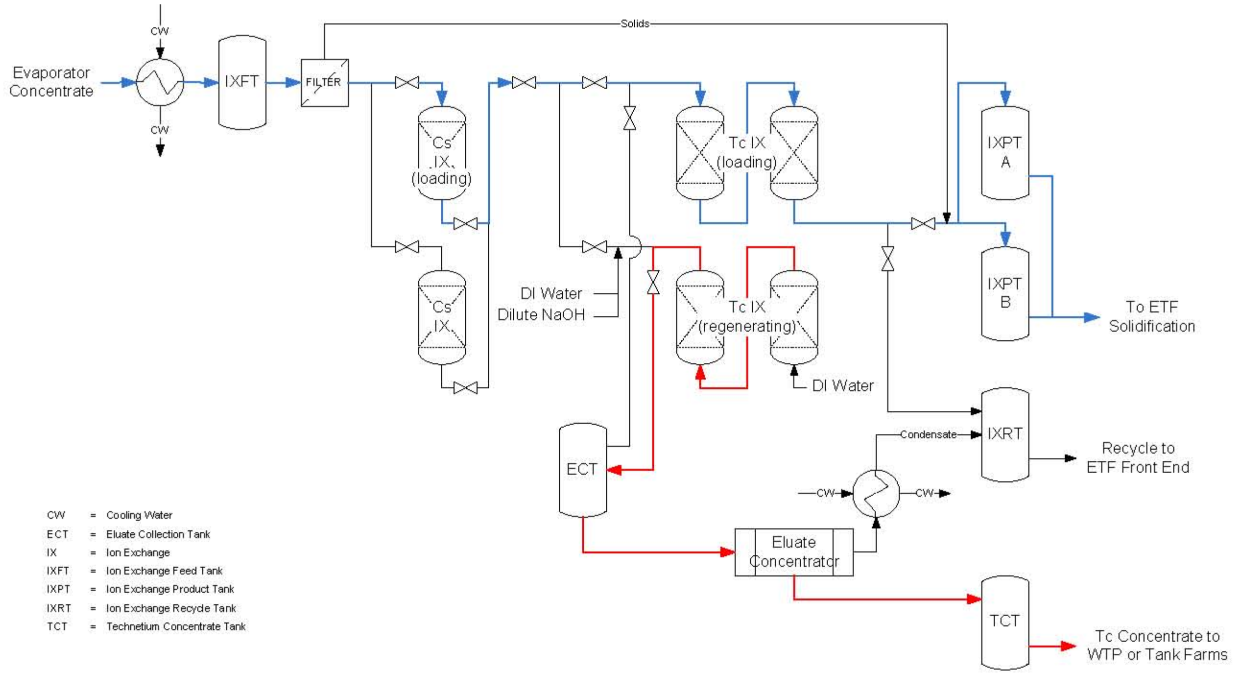
The ion-exchange units are arranged in series with cesium removal first, followed by technetium removal. A nonregenerable/single-use, ion-exchange media is selected for cesium ion exchange (CsIX), while a regenerable resin is selected for technetium ion exchange (TcIX). The system is designed for essentially continuous operation. A two-column system is used for cesium. One column is in use for cesium removal, while the other is valved out for bed replacement. For technetium removal, two sets of columns are provided. One set (primary and secondary column) is in operation for technetium removal, while the second set is being regenerated.

Figure A-1. Flow Diagram, Solidification, Effluent Treatment Facility Upgrades, and Ion Exchange (Case 3)



CONC Tank = Concentration tank
Degas. = Degasification Column
Eff. pH Adj. = Effluent pH adjustment tank
EVAP = Evaporator
IDF = Integrated Disposal Facility
IX = Ion Exchange (Existing ETF)
LERF = Liquid Effluent Retention Facility
pH Adj. = pH adjustment tank
SWRT = Secondary waste receiving tank
UV/OX = Ultraviolet Oxidation
Cs/Tc IX = Cesium and Technetium Ion Exchange
WTP = Waste Treatment Plant
- - - - = Alternate route

Figure A-2. Cesium and Technetium Removal Process Flow Diagram.



The ion-exchange flow diagram is shown in Figure A-2. Concentrate from the existing ETF concentrate tanks is cooled and accumulated in the ion-exchange feed tank (IXFT). From the IXFT, the stream is filtered prior to entering the CsIX column and then flows to the top of the primary TcIX column where the technetium is removed and loaded onto the resin. From the primary technetium column, the stream flows through the technetium secondary column and then flows to one of the ion-exchange product tanks (IXPT-A or IXPT-B) prior to transfer to the ETF waste solidification system. Solids removed by filtration upstream of the ion-exchange system are rinsed with water to remove contaminated liquid and transferred to the IXPTs and then to ETF waste solidification system to be incorporated into the solid waste form.

Ion-exchange system sizing is based on an average flow of 0.75 gal/min, which provides ample capacity to process expected high contamination level wastes from the Waste Treatment and Immobilization Plant (WTP) (see Appendix C). It is assumed that evaporator concentration factors and waste blending are controlled to limit ^{137}Cs concentration in the evaporator concentrate to about 5E-05 Ci/l. This implies an evaporator concentration factor of about 5, if the feed is near the ETF feed limit of 1E-05 Ci/L. To limit contamination levels and worker dose rates, the cesium concentration in the ion-exchange product is reduced to 1.0E-06 Ci/L or less, consistent with the design basis of the solidification treatment system (HNF-26914, *W-601, Conceptual Design Report for Effluent Treatment Facility Solidification Treatment Unit*, Appendix H).

The concept is based on using most of the existing ETF solidification system design with minimal modifications. A separate ion-exchange facility will be constructed to receive waste from the evaporator concentrate tanks, and treated waste will be returned to the planned solidification system (see Figure A-1). Locating the ion-exchange columns in a separate facility is expected to allow each facility to remain less than Hazard Category 3 without excessive operational constraints (see Section A5.1).

A2.0 CESIUM REMOVAL PROCESS

For the example cesium ion exchange (CsIX) process, a crystalline silicotitanate (CST) ion exchange media is selected based on compatibility with the waste stream and relatively high loading capacity. The CST media is non-regenerable and spent media must be replaced. The CST media has been used for cesium removal from waste at Oak Ridge and has been extensively studied for other applications within the DOE complex. A recent literature review is available on ion-exchange technology, including CST (WSRC-STI-2007-00609, *Literature Reviews to Support Ion Exchange Technology Selection for Modular Salt Processing*).

Modeling results for cesium ion-exchange columns using CST are presented in WSRC-STI-2007-00315, *Modeling of Ion-Exchange for Cesium Removal from Dissolved Saltcake in SRS Tanks 1-3, 37, and 41*. Results are given for liquid flow rates equivalent to 0.4 to 4 times the bed volume per hour (BV/hr), with a nominal case of 1.4 BV/hr. Based on results presented in WSRC-STI-2007-00315, 0.9 BV/hr is selected as the basis for column sizing for the current study. Using a feed flow of 0.75 gpm and 0.9 BV/hr, the calculated bed volume is 50 gal. A nominal 16-in. diameter column requires a bed height of 58 in. for this bed volume. For preliminary sizing purposes, a total column vessel height of 72 in. (6 ft) is specified to allow for screens and freeboard below and above the bed.

The equilibrium loading factor based on the WSRC-STI-2007-00315 data is on the order of 500 Ci/l in bed/Ci/liter in waste feed; however, waste compositions assumed in WSRC-STI-2007-00315 are on the order of 1 mole/liter of hydroxide. For the ETF application, it is assumed that the waste will be adjusted to approximately pH 6. At this lower pH, the equilibrium loading factor for CST is substantially increased (see WSRC-MS-98-00601, for example). Therefore, for the current study, an equilibrium loading factor is used of 1,500 Ci/l in bed/Ci/liter in liquid phase.

Assuming the bed will be replaced when it becomes loaded to 2/3 of the equilibrium loading, a total of 2/3 × 1500 × 50 = 50,000 gal will be processed during each loading cycle. The maximum curie loading is estimated as:

Max ^{137}Cs/column load = 50,000 × 3.79 liters × 5E-05 Ci/L= 9.5 Ci.

The CST media is also expected to remove most ^{90}Sr in the waste.

Assuming a design feed rate of 0.75 gpm and 50,000-gal loading capacity, the minimum loading time is about:

50,000/(0.75 × 60 × 24) = 46 days

Based on a total operation efficiency of 70%, the average time between column changeout is on the order of every two months.

Two columns are used in parallel; one available for treating waste, and the other undergoing bed replacement. Multiple options could be considered for bed replacement, including: (1) fluidize bed and transfer to a transport/disposal container, and (2) remove column and replace with a new one preloaded with ion-exchange media. For the current study the second option is assumed. To facilitate handling and shipment, the column includes integral shielding to limit surface contact dose rates to about 100 mR/hr. With integral concrete shielding, the column diameter is expected to be about 4 ft in diameter. This can be reduced by use of steel shielding.

A3.0 TECHNETIUM REMOVAL PROCESS

This section provides an example processing concept based on use of ion exchange to remove technetium from the WTP waste stream. The current study is not intended to provide a comprehensive evaluation of ion-exchange options. Rather, it is intended to provide a screening assessment of technetium removal. Therefore, a single ion-exchange resin option is presented to gain perspective on the cost and complexity of facilities needed to treat the waste stream. With the selected ion-exchange resin, there are a number of additional options. Again, a single implementation concept is presented herein. The option presented may be considered as a base case that other options could be compared with in the future, if technetium removal is pursued further.

A3.1 Ion-Exchange Resin Selection

Several types of ion-exchange media are available that could be considered for removal of technetium from the waste. If the waste is first concentrated to relatively high dissolved salts concentration, SuperLig 639 resin appears to be a reasonable choice. For low dissolved salts concentration, other resins would likely be preferred (e.g., Reillex HPQ). Since a relatively high dissolved solids stream is expected to be available (ETF evaporator concentrate) and process performance/test data is available for the SuperLig 639 resin, this combination is used for the example process design concept.

A3.2 Process Flowsheet

The ion-exchange flow diagram is shown in Figure A-2. Waste received from CsIX flows to the primary technetium column, then to the secondary ion-exchange column, and then to an IXPT.

Periodically the resin becomes loaded and must be regenerated. The normal regeneration cycle is as follows:

- Flow from then CsIX is valved out and waste feed is replaced with deionized water flowing in the forward direction to displace waste in the ion-exchange columns. Near the end of the waste displacement cycle, the discharge stream will become fairly dilute and technetium levels may begin to increase in the discharge from the secondary column. To avoid impacts to waste solidification, discharge from the secondary column may be diverted to the ion exchange recycle tank (IXRT) in the later part of the waste displacement cycle.
- When the waste displacement cycle is complete, technetium is eluted from the resin by passing heated (65 °C) deionized water through the columns in the reverse direction (up flow). Eluate is directed to the eluate collection tank (ECT).
- When elution is complete, the columns are regenerated using dilute sodium hydroxide solution (0.25 molar).

- The ion-exchange columns are now ready for another loading cycle, which is initiated by changing the valving and starting flow from a CsIX and discharge to an IXPT.

The IXRT is provided to collect dilute waste to be returned to the ETF front end for concentration. This tank also allows product from ion exchange to be recycled during start-up testing and troubleshooting to assure material with high technetium concentration is not transferred to the solidification unit.

A3.3 Eluate Disposition

Two options have been identified for disposition of the eluate. The WTP planned to concentrate the eluate in an evaporator and recycle the concentrated liquid to the high-level waste (HLW) process. An alternate approach is to absorb technetium from the eluate onto a silica-based anion exchange resin. This resin would be a relatively small volume product that could be recycled to the HLW process or incorporated into a solid waste form for onsite or offsite disposal (Gula and Harvey 1998, Bond et al. 1999). Both evaporation and sorption on silica-based ion-exchange media appear reasonably feasible. However, sorption on silica is expected to produce a greater than class C waste; therefore, recycle to the HLW process is likely to be the only viable option for disposal. Selection of the preferred approach would require a more in-depth study. Therefore, for the current study concentration by evaporation is assumed. The concentrated eluate is a relatively low-volume product that could likely be recycled to tank farms or to WTP. Condensate from the eluate concentrator is recycled to ETF via the IXRT.

A3.4 Technetium Removal Performance

The SuperLig 639 resin has been demonstrated to be effective for removing technetium in the pertechnetate form (+7 oxidation state). For example, in a series of five tests using the same bed of resin and waste from Hanford tank 241-AW-101, 99.94% of the technetium was removed. However, the resin is not effective for removing technetium present in lower oxidation states. Because the +7 oxidation state is more volatile than the lower oxidation states, it is reasonable to expect that technetium in the melter off-gas and off-gas scrubber blowdown is primarily in the +7 state. However, data to verify this expectation has not yet been identified. In any case, there is likely to be at least a trace in lower oxidation states, which could make achieving very high removal efficiencies (99.9+%) impractical with this resin.

Available test results are primarily for solutions with sodium concentration near 5 molar. It is not certain how a lower sodium salt concentration affects resin performance. If waste evaporation upstream of ion exchange cannot achieve the sodium salt concentrations needed for optimal resin performance, additional soluble sodium salts can be added to the evaporator concentrate if needed. If so, the added salts would be selected to minimize impact to the downstream waste solidification process.

A3.5 Equipment Requirements

TcIX column sizing is based on a nominal design basis flow of 0.75 gpm. Two ion-exchange column sets are used to allow essentially continuous operation. Based on the cited references, the column feed rate per hour should be three times the ion-exchange bed volume (BV) for the primary column. On this basis, the bed volume for the primary column is:

BV = (0.75 gpm × 60 min/hr)/(3 BV/hr) = 15 gal or 2 ft^3

Assuming a 1-ft diameter bed, the required bed is 2.6 ft deep. A total column size of 1 ft in diameter by 4 ft high is specified to allow room for screens and freeboard above and below the bed. The secondary column is operated as a guard column, and could possibly be smaller. However, for the current evaluation, it is assumed to be identical to the primary column. Total system volume (two column beds plus the empty volume above and below beds) is about three times the primary column BV.

Based on the cited references, loading capacity is expected to be about 250 BV, or

250 × 15 gal = 3,750 gal.

Cycle time for the loading step is therefore 250 BV/(3 BV/hr) = 83 hours. This allows about three days for the alternate column set to complete regeneration and preparation for use when loading capacity of the first set becomes exhausted.

A3.5.1 Ion Exchange Feed and Recycle Tank Sizing

The ETF solidification treatment conceptual design includes two new 2,500-gal concentrate tank (HNF-26914, Figure P-2). This tank size holds about two days feed and product flow, which provides reasonable flexibility for operations. Therefore, for the current study the same standardized tank system design concept is selected for the ion exchange feed tank (IXFT), ion exchange product tanks (IXPT-A and IXPT-B), and ion exchange recycle tank (IXRT). Each tank system includes a 2500 gallon fiberglass reinforced plastic (FRP) tank with agitator and recirculation/transfer pump.

A3.5.2 Eluent and Dilute Caustic Systems

Based on the cited references, the flow rate of deionized water during initial waste displacement and 0.25 molar sodium hydroxide during the regeneration step are estimated at 3 BV/hour or 0.75 gpm (forward direction). Approximately 4 BV of each are estimated for each cycle (about 130% of total system volume). Heated (65 °C) deionized water flow during elution is reduced to 1 BV/hour or 0.25 gpm (reverse direction). Nominal eluent quantity indicated in the WTP document is 22 BV, while the more recent test reports indicate that with 65 °C water, 12 to 16 BV should be adequate. However, in the tests, each column was eluted separately; whereas for the current process, the columns are eluted in series (i.e., eluate discharge from the secondary column flows to the primary column). Therefore, for the current process, the 22 BV value appears reasonable (based on the BV of the primary column only) and will be used. Associated stream quantities per cycle and equipment sizing are as follows:

- Eluate flow is estimated at 22 x 15 gal bed volume = 330 gal/cycle. The ECT is sized at a nominal 1,200 gal capacity to provide operating flexibility.
- Dilute caustic flow is estimated at 4 x 15 gal bed volume = 60 gal/cycle. To reduce frequency of dilute caustic makeup, a nominal 500 gal supply tank is specified for dilute caustic supply. A separate receiver tank is not needed for the dilute caustic column regeneration step.

- Deionized water for the initial waste displacement step is estimated at 4 x 15 gal bed volume = 60 gal/cycle. A separate receiver tank is not needed for the waste displacement step.
- Heating 0.25 gpm of deionized water eluent from 10 °C to 65 °C would require about 4 kW. To provide additional design margin, the heater specification is based on heating 0.3 gpm from 5 °C to 70 °C, increasing the required water heater capacity to about 6 kW.

A3.5.3 Eluate Processing

Eluate flow per cycle is estimated at 330 gal. Based on an 83-hr total cycle time, this equates to 4 gal/hour or 30 lb/hour average for the overall cycle. To allow operational flexibility, the eluate evaporator is sized for a net boil-up rate of 60 lb water per hour. Estimated power requirement is 24 kW, including a nominal 25% allowance for heat losses and inefficiencies.

A concentration factor of 50/1 is expected for the eluate concentrator based on Section 2.8.3 of 24590-WTP-RPT-PT-02-005, *Flowsheet Bases, Assumptions and Requirements, Rev. 1* (not included in Rev. 4 of this document). Technetium concentrate production is estimated at 330/50 or 6.6 gal/cycle. Based on an 83-hr cycle time, this equates to about 1.9 gal/day. It is assumed that the technetium concentrate will be transported by truck to either WTP or the tank farms for recycle. Other disposition options might be considered, such as periodic transfer to WTP via reverse flow in the pipeline used to transfer waste from WTP to the Liquid Effluent Retention Facility (LERF)/ETF. Recycle to the WTP pretreated HLW stream could be a particularly desirable option since it would result in immobilizing significantly more of the site technetium inventory in HLW glass and hence less would be disposed on the Hanford Site.

The technetium concentrate tank is sized at 50 gal to provide capacity for about 4 weeks of production. If periodic transfer to WTP via pipeline is used to recycle the concentrate, a larger batch size would likely be preferable to reduce the frequency of transfers.

A4.0 PROCESS EQUIPMENT LIST

Table A-1 is the process equipment list for the cesium and technetium ion-exchange systems. Only major equipment is shown. Minor equipment, valves, instrumentation, piping, and facility equipment are not included at this time.

Table A-1. Cesium/Technetium Ion-Exchange Process Equipment List. (2 sheets)

Item	Quantity	Size	Description
Cesium ion-exchange columns	2	Primary vessel 16-in. diameter by 6 ft high. With integral shielding 48-in. diameter by 9 ft to top of shielding. Allow 10-ft length to top of piping connections.	Disposable column with contained ion exchange media. 50-gal exchange media bed volume.

Table A-1. Cesium/Technetium Ion-Exchange Process Equipment List. (2 sheets)

Item	Quantity	Size	Description
Technetium ion-exchange columns (primary and secondary)	4	12-in. diameter by 48 in. high	Corrosion resistant materials to allow high Cl and F concentration.
Evaporator concentrate cooler	1	80,000 BTU/hour duty	Water cooled. Sized to cool 0.75 gpm of evaporator concentrate from 190 °F to 80 °F with 25% design allowance.
Feed, product, and recycle tanks IXFT, IXPT-A, IXPT-B, and IXRT	4	7,500-gal volume, atmospheric pressure	7.5-ft diameter FRP with agitator and recirculation pump. Use same design as solidification CDR concentrate tank A and B (HNF-26914,[1] Figure P-2).
Eluate collection tank	1	1,200-gal nominal volume, atmospheric pressure	SST or polymeric
Technetium concentrate tank	1	50 gal, atmospheric pressure	SST
Dilute caustic tank	1	500 gal, atmospheric pressure	SST or polymeric
Ion-exchange tank recirculation and transfer pumps (for IXFT, IXPT-A, IXPT-B, and IXRT)	4	33 gpm at 44 ft, 1.5 HP/316L SST	Corrosion resistant materials to allow high Cl and F concentration. Use same design as solidification CDR concentrate tank A and B (HNF-26914,[1] Figure P-2).
Dilute caustic feed pump	1	3 gpm	Materials compatible with dilute sodium hydroxide.
Ion-exchange feed filter	1	2 gpm flow capacity, with solids back flush capability	Corrosion resistant materials to allow high Cl and F concentration.
Eluent preheater	1	6 kW	Capable of preheating nominal 18 gal/hour of deionized water from 5 °C to 75 °C
Eluate concentrator	1	60 lb water per hour net boil-up rate	Electric boiler, 24 kW estimated power. Water-cooled condenser.
Deionized water supply	1	2 gpm flow capacity	Approximately 3,000 gal/month.

[1] HNF-26914, 2005, *W-601, Conceptual Design Report for Effluent Treatment Facility Solidification Treatment Unit*, Rev. 0, Fluor Hanford, Inc., Richland, Washington.

CDR = conceptual design report.
FRP = fiberglass reinforced plastic.
IXFT = ion-exchange feed tank.
IXPT = ion-exchange product tank.
IXRT = ion-exchange recycle tank.
SST = single-shell tank.

A5.0 FACILITY CONCEPT

A preliminary process facility concept is illustrated in Figure A-3 through Figure A-5. The process facility is about 30 ft by 56 ft by 20 ft high. The CsIX columns are located in shielded pits to reduce dose rates to workers in the facility. Shielding is also provided around the IXFT but is not expected to be needed for the other tanks or equipment handling waste downstream of the CsIX. The filters, TcIX columns, eluate concentrator, and concentrated eluate tank are located in a confinement/ventilation enclosure to prevent spread of contamination to the operating area during operation and maintenance of this equipment. The outer building shell is primarily for weather protection. Confinement of radioactive materials is provided by internal ventilation enclosures, process equipment, and associated ventilation systems. The facility will be located near ETF to facilitate transfers to and from the ion-exchange system.

Figure A-3. Preliminary Ion-Exchange Facility Configuration.

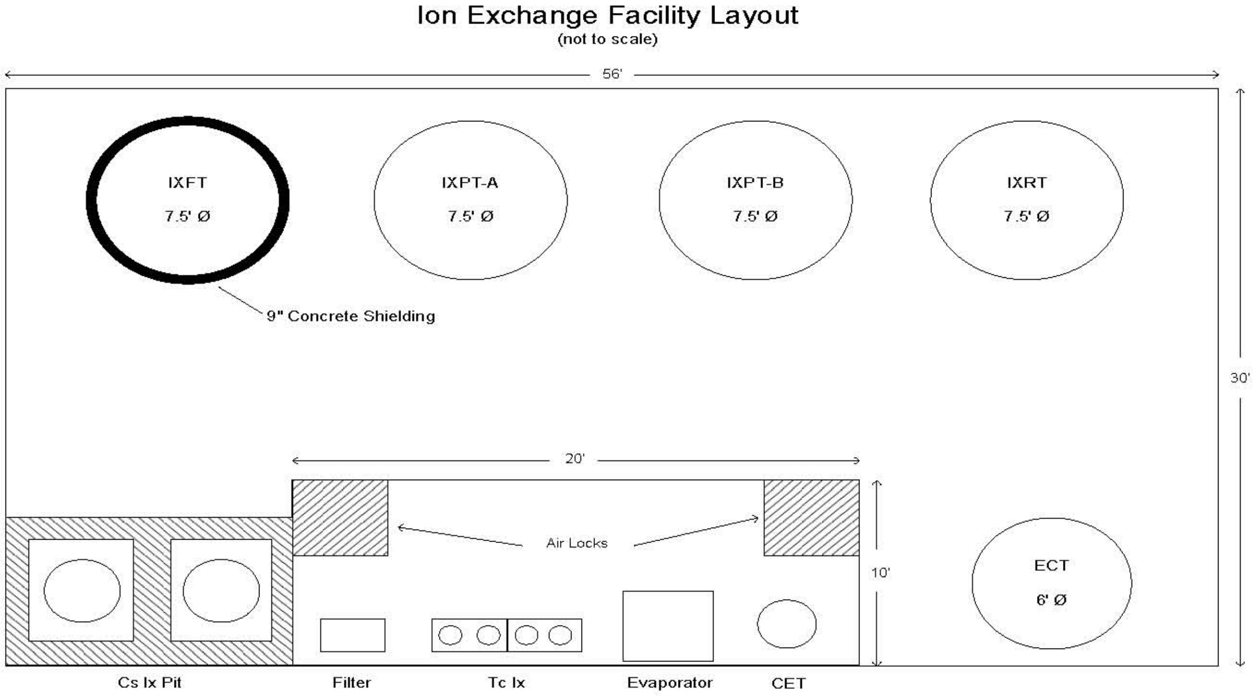


Figure A-4. Ion-Exchange Tanks (elevation view).

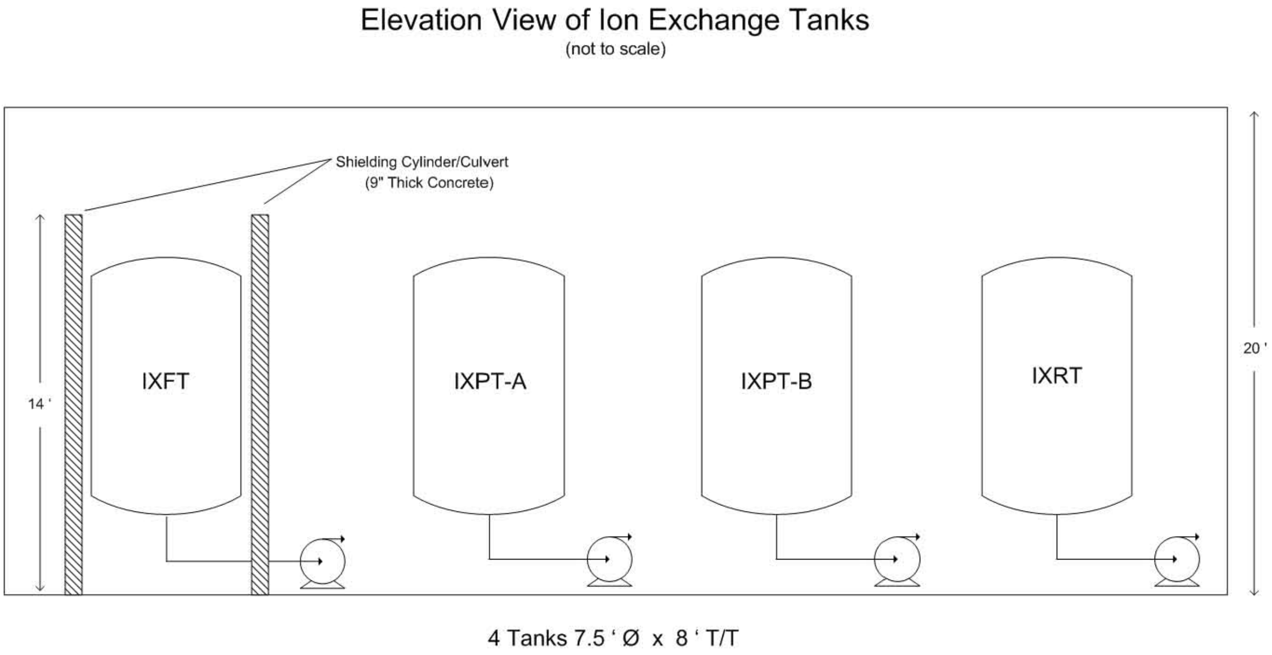
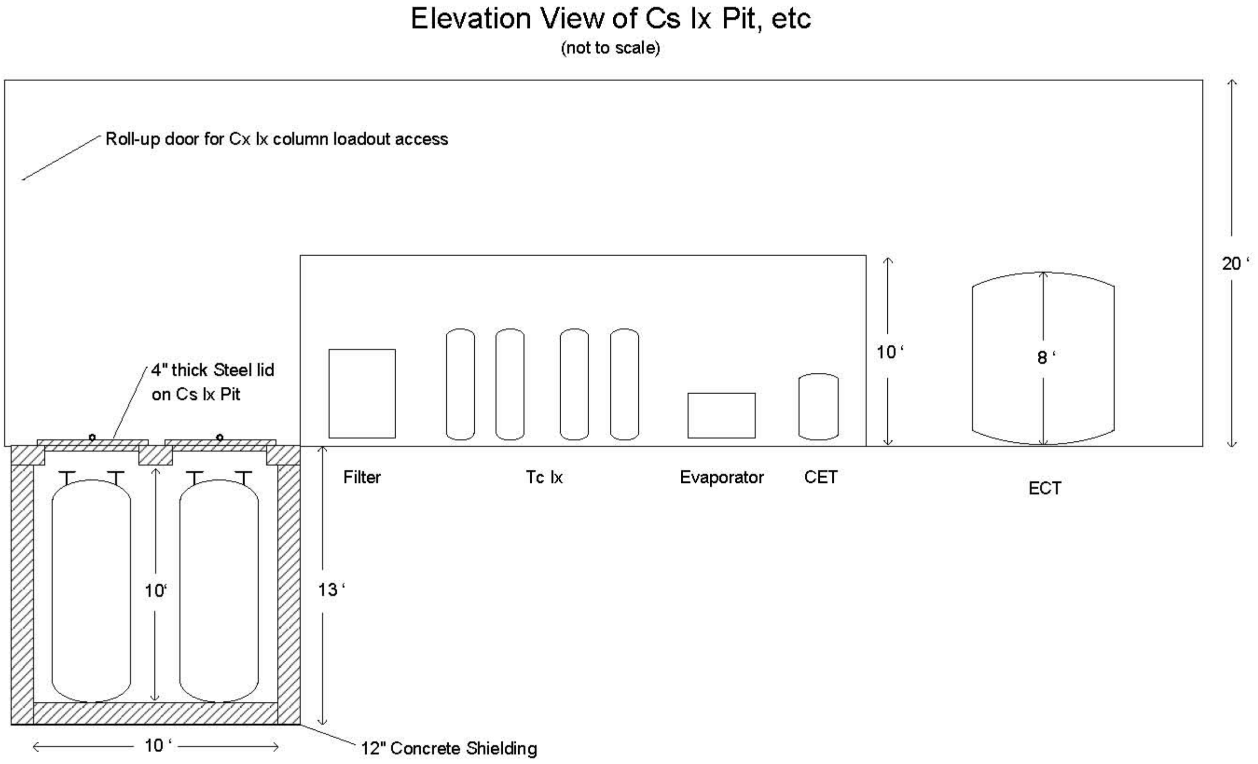


Figure A-5. Cesium Ion-Exchange Pit Infrastructure (elevation view).



A5.1 Safety Classification

As discussed in Section A2.0, a loaded ion-exchange column is estimated to contain 9.5 Ci of ^{137}Cs. The CST ion-exchange media may also remove ^{90}Sr from the waste. In this case, the evaluation must also consider the ^{90}Sr. The ratio of ^{90}Sr to ^{137}Cs in the submerged bed scrubber (SBS) blowdown is about 0.23 Ci/Ci per the WTP mass balance given in SVF-1663, "Balance_Graphic_SP4_PC_2009_03_30_at _20_02_39.xls," "SP4 Planning Case-3.0-8.4r0_2009-03-30-at-20-02-39." Using this ratio, a column loaded with 9.5 Ci of ^{137}Cs would also contain about 2.2 Ci of ^{90}Sr. Category 3 quantities for ^{137}Cs and ^{90}S are 60 Ci, and 16 Ci, respectively (DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, Attachment 1), give ratios of estimated column loading to Category 3 quantities of 16% and 14%, respectively.

Based on available information, ^{129}I is the only other isotope to be a signification consideration relative to Category 3 limits. The ^{129}I concentration in the SBS blowdown is 1.29 E-07 Ci/L per RPP-43020, *Spreadsheet Description Document for Secondary Waste Expected Liquid Waste Composition*. Assuming a 5X concentration factor in the evaporator, the concentration in the concentrate transferred to ion exchange is 6.5E-07 Ci/L. If the feed tank and both product tanks are filled to 2,500 gal with this waste, the total ^{129}I content is 1.8E-02 Ci. This is about 30% of the Category 3 quantity of 0.06 Ci for ^{129}I.

These values indicate that it should be feasible to classify the ion-exchange facility as less than Hazard Category 3. However, the results are high enough to suggest that operational monitoring and control of inventories is required to assure the facility remains within the limits.

A6.0 REFERENCES

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APPENDIX B

STEAM-REFORMING PROCESS FOR EFFLUENT TREATMENT FACILITY WASTE SOLIDIFICATION

B1.0 STEAM REFORMING PROCESS SUMMARY

Study Case 5 includes replacing the existing Effluent Treatment Facility (ETF) waste solidification system with a steam-reforming process that produces a mineralized solid waste form. The mineralized waste is an alternative to other waste forms that exhibit improved leach resistance for radionuclides (e.g., ^{99}Tc) incorporated in the solid waste. The mineralized waste is produced in a granular form that is consolidated by addition of a binder as part of the packaging operation that is suitable for containerized waste disposal at the Integrated Disposal Facility (IDF). This appendix describes a generic steam-reforming process concept developed for this option. The concept is not intended to represent a preferred or selected concept, but rather provides the basis for a rough order of magnitude cost estimate and an indication of the relative size and complexity of this option.

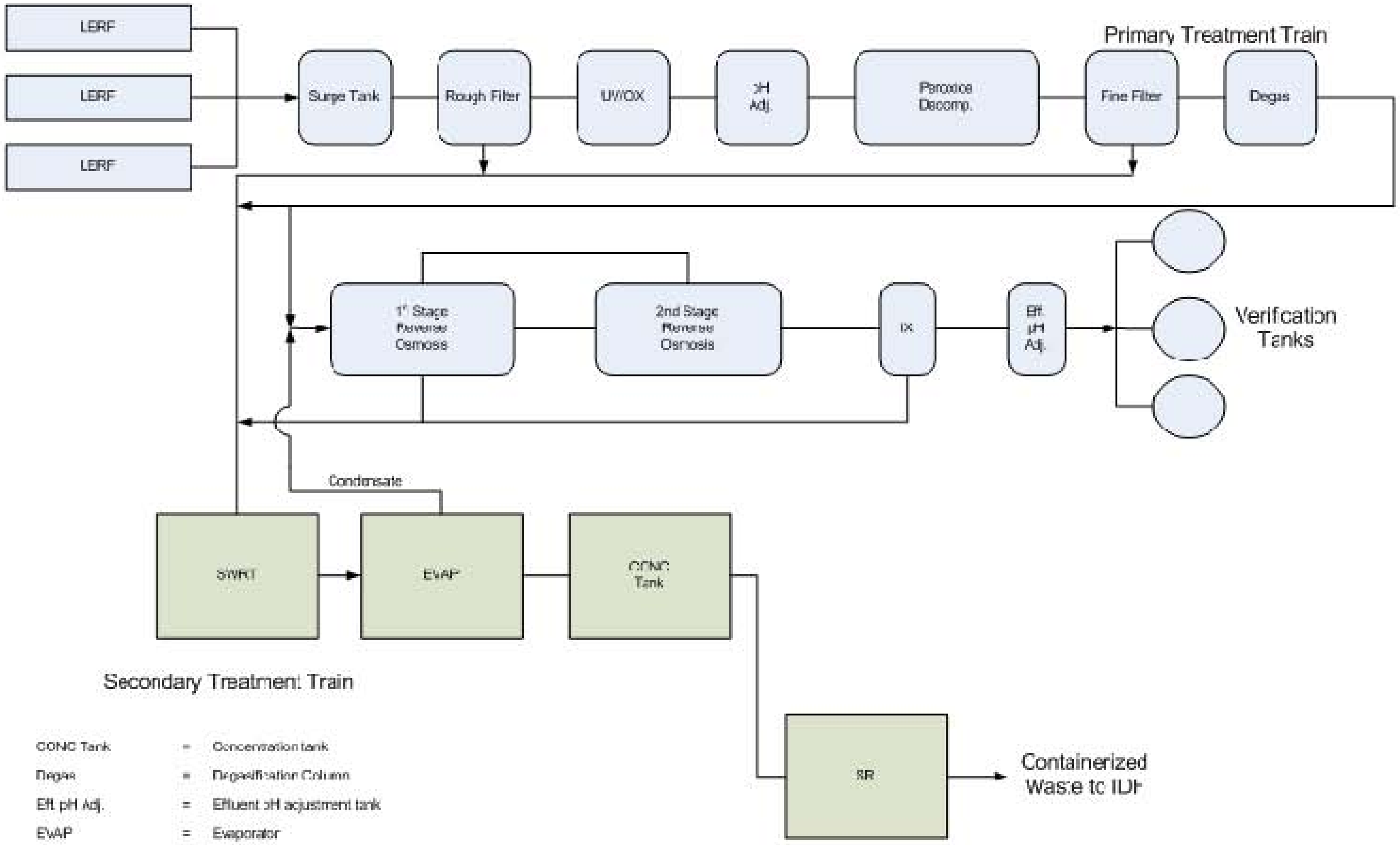
B1.1 Overall Steam Reforming Process Design Concept

Figure B-1 illustrates how the steam reforming system interfaces with the balance of the ETF systems. The overall scheme is based on the ETF process approach defined in the 2008 treatability study (HNF-37718, *Low Activity Waste (LAW) Facility Secondary Waste to Effluent Treatment Facility (ETF) Treatability Evaluation*) (option 1b, greater than 10000 ppm Cl + F case), with the exception that a steam-reforming process is used for solidifying chemical components present in the evaporator concentrate.

Figure B-2 shows the modified ETF process flow diagram. From lag storage at the Liquid Effluent Retention Facility (LERF), the waste flows first through the existing ETF front-end system: roughing filter; ultraviolet/oxidation (UV/OX), pH adjustment, fine filter, and degas. The waste is then transferred to the secondary waste receiver tank (SWRT), and then to the evaporator. Concentrate from the evaporator is cooled and discharged to the existing ETF concentrate tanks. From the concentrate tanks, the waste is transferred to the steam-reformer system. Condensate from the evaporator is treated in the existing reverse osmosis, ion-exchange, and verification tanks prior to discharge.

Evaporator concentrate is transferred to a separate facility containing the steam-reforming system. A separate facility is proposed because the steam-reforming process equipment is significantly different from existing systems within the ETF, requiring the supply of bulk solids and gases as inputs to the process unit operations. The process would be expected to replace the existing ETF solidification system.

Figure B-1. Effluent Treatment Facility Process Flow Diagram with Steam Reforming as the Waste Solidification Process.



CONC Tank = Concentration tank
Degas = Degasification Column
Eff pH Adj. = Effluent pH adjustment tank
EVAP = Evaporator
IDF = Integrated Disposal Facility
IX = Ion Exchange (Existing ETF)
LERF = Liquid Effluent Retention Facility
pH Adj. = pH adjustment tank
SWRT = Secondary waste receiving tank
UV/OX = Ultraviolet Oxidation
SR = Steam Reforming System
WTP = Waste Treatment Plant

B1.2 Generic Steam Reforming Process Description

A generic steam-reforming process producing a mineralized product has been used as a description of the process used to bound the system supporting ETF operation. Figure B-2 provides a summary of the unit operations used in the generic process to estimate material flows. The generic process flowsheet has not been optimized for ETF support, and significant improvements would likely be available to reduce the system cost if selected for implementation.

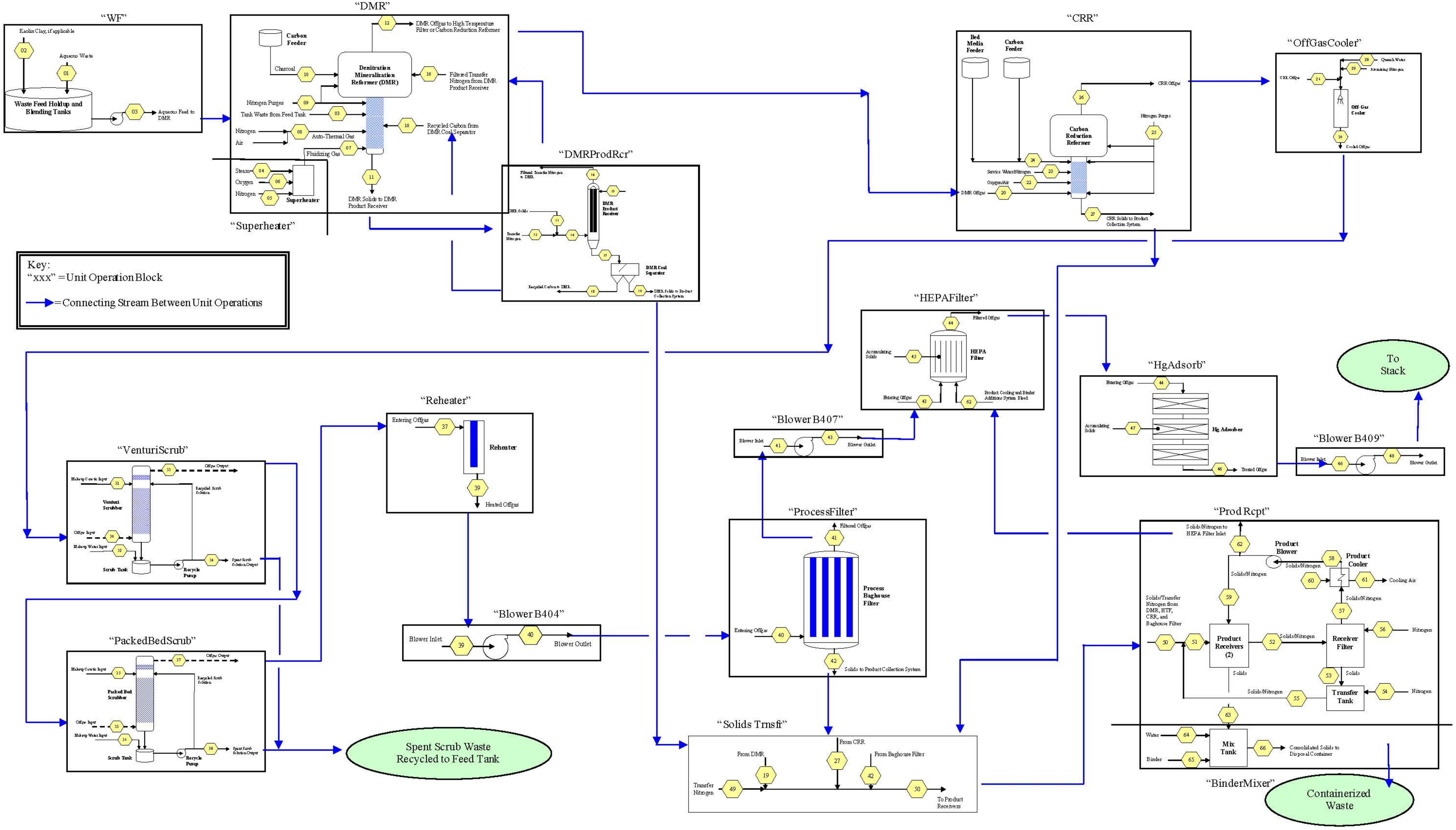
To produce a mineralized steam reformer product, concentrate from the ETF evaporator is mixed with kaolin clay and fed to the denitration mineralization reformer (DMR). The DMR operates at about 640 °C in a chemical-reducing mode to evaporate liquids, convert nitrates to nitrogen gas, and convert the nonvolatile constituents of the feed into a granular solid product. Solid product from the DMR is removed and pneumatically transferred to a solids collection and binder addition system. Carbon or charcoal is added to the DMR where reactions with steam create a reducing environment. The process gas from the DMR consists mainly of water vapor, nitrogen, carbon dioxide, carbon monoxide, and hydrogen, with small amounts of NO_X.

The DMR off-gas stream is introduced into the bottom of a second steam reformer, the carbon reduction reformer (CRR). Oxygen/nitrogen mixtures are injected through gas nozzles positioned above the fluidizing gas distributors through which the DMR process gas flows into the CRR to supply sufficient oxygen to maintain a set bed temperature. The solids are pneumatically transferred to the solids collection and binder addition system.

The CRR off-gas stream, now primarily composed of nitrogen, oxygen, water, and carbon dioxide, is cooled by direct water injection in the offgas cooler (OGC) and filtered in the process baghouse filter (PBF). Scrubbers are assumed to be included upstream of the PBF to control acid gases in the reformer off-gas. A reheater is provided to avoid condensation during filtration. The primary process off-gas joins with the solids collection and binder addition system off-gas and is filtered through a (high-efficiency particulate air) HEPA filter. A granular activated carbon (GAC) bed is used to remove mercury. The GAC can be bypassed, depending on the type of feed being processed by the system. Treated gases are discharged to a permitted stack via the off-gas blower(s) (OGB).

Solids discharged from the DMR, CRR, and PBF are pneumatically transferred to a solids collection and consolidation system using pressurized nitrogen. Transferred solids are combined in one of two product receiver vessels where the solids are cooled by a recirculating nitrogen stream. The cooled solids drop into a mix tank to be combined with binder material and water. The consolidated waste solids are then transferred to a disposal container where the binder sets. Cooling gas is recirculated from the product receiver vessels through a filter, cooler (air-to-air heat exchanger), and blower prior to being returned to the product receivers. Nitrogen bled from the solids collection and consolidation system is combined with other system off-gases at the HEPA filter inlet.

Figure B-2. Generic Steam Reforming Process Flow Diagram for Preliminary Material Balances.



The DMR is a fluidized bed vessel designed to operate in an autothermal steam-reforming mode to evaporate water, reduce nitrates to nitrogen, volatize and reform organics, and convert waste metal cations to metal oxides. For the mineral product material and energy balance, the DMR denitrifies and converts the waste to solid mineral phases that capture sulfur, fluoride, chloride, and phosphate compounds in the mineralized solid product cage structure. The mineral phases bind radionuclide and chemical species within the crystalline structure of the mineral. The particular mineral phases that form depends on the additives co-fired in the steam reformer with the waste. For this application, SiO_2 and Al_2O_3 in the form of kaolin clay are added with the waste feed to produce mineral product characterized by nepheline.

Solid reductant (charcoal) and liquid waste are continuously fed to the DMR, along with gaseous additives. Waste is fed to the reformer via nozzles that disperses waste liquid within the fluidized bed. Fluidizing gas is added at the bottom of the DMR to maintain agitation of the bed solids. Both the fluidizing gas (superheated stream) and autothermal gas (mixture of nitrogen and air) can be used to add reacting gases (steam and oxygen) to the DMR that result in production of the desired waste solids. Water vapor is produced in a steam generator unit prior to being introduced to the superheater. Examples of the reactions that occur in the DMR are shown in Table B-1.

Table B-1. Example Denitration Mineralization Reformer Reaction Stoichiometry – Reducing Conditions.

Waste Component Decomposition Reactions:
$NH_4NO_3\ (aq) \rightarrow 0.75N_2\ (g) + 0.5NO_2\ (g) + 2H_2O(g)$
$2\ NaNO_3(aq) \rightarrow Na_2O(s) + 2\ NO_2(g) + 0.5\ O_2\ (g)$
Gas Phase Reactions:
$2\ NO_2\ (g) \rightarrow 2NO\ (g) + O_2\ (g)$
$2\ NO_2\ (g) + 4\ H_2\ (g) \rightarrow N_2(g) + 4\ H_2O\ (g)$
Solid Phase Reactions:
$C\ (s) + 2\ H_2O\ (g) \rightarrow CO_2(g) + 2\ H_2\ (g)$
$C\ (s) + O_2\ (g) \rightarrow CO_2(g)$
$3\ Na_2O\ (s) + 3\ Al_2Si_2O_7\ (s) \rightarrow Na_6Si_6O_{27}(s)$
$2\ NaCl\ (aq) + 3\ Na_2O\ (s) + 3\ Al_2Si_2O_7\ (s) \rightarrow Na_6Al_6Si_6O_{24} \cdot 2NaCl\ (s)$

The composition of evaporator concentrate processed by the steam reformer system for application in the ETF is dominated by ammonium nitrate. Ammonium nitrate thermal decomposition products are reported to vary with temperature, as shown in Table B-2. The current material balances are approximated based on the stoichiometry indicated at an operating temperature of 860 °C.

Table B-2. Summary of Ammonium Nitrate Thermal Decomposition Modes.

Reaction	Temperature, °C
$NH_4NO_3 \rightarrow NH_3\ (g) + HNO_3\ (g)$	
$NH_4NO_3 \rightarrow N_2O\ (g) + 2\ H_2O\ (g)$	320
$NH_4NO_3 \rightarrow 0.75\ N_2\ (g) + 0.5\ NO_2\ (g) + 2\ H_2O\ (g)$	860
$NH_4NO_3 \rightarrow N_2\ (g) + 2\ H_2O\ (g) + 0.5\ O_2\ (g)$	950
$8\ NH_4NO_3 \rightarrow 5\ N_2\ (g) + 4\ NO\ (g) + 2\ NO_2\ (g) + 16\ H_2O\ (g)$	560
$NH_4NO_3 \rightarrow 0.5\ N_2\ (g) + NO\ (g) + 2\ H_2O\ (g)$	260

Source: Oh, J.H., D.S. Hwang, K.I. Lee, U.D Choi, S.T. Hwang, J.H. Park, and S.J. Park, 2006, "Stabilization of Uranium Sludge from a Conversion Plant through Thermal Decomposition," *Journal of Industrial Engineering Chemistry*, Vol. 12, No. 5, 682-688.

Solids produced by the DMR are transferred to the DMR product receiver and coal separation system by a pneumatic transfer line using nitrogen as the motive force. DMR solids are separated from the transfer nitrogen in the DMR product receiver and added to the DMR off-gas in the DMR vessel freeboard. The DMR coal separator separates unreacted charcoal from solids produced by the DMR and recycles reductant to the fluidized bed.

Operation of the DMR is supported by nitrogen purges that add to gas flows in the system. These purges control gas flows in piping during introduction of charcoal to the DMR and support operation of instrumentation within the process vessels. Off-gas from the DMR is routed to the CRR for further treatment.

The DMR product receiver and coal separator provides the capability of collecting solids produced in the DMR fluidized bed and separating unreacted carbon from the solids for return to the DMR. The system includes an approximation of a pneumatic transfer system to move solids through piping from the DMR to the DMR product receiver using nitrogen as the motive force. Transfer nitrogen passes through a filter in the DMR product receiver to be returned to the DMR freeboard region.

The CRR oxidizes residual components (i.e., unreacted carbon and hydrogen) that are present in the DMR off-gas. The CRR off-gas stream is primarily composed of nitrogen, oxygen, water, and carbon dioxide. The CRR system is equipped with a bed media drain that is operated to remove the waste solids carried over from the DMR.

The CRR is a fluidized bed steam reformer where the solid particles are primarily composed of bed media and DMR mineralized solids. The DMR off-gas is used as the CRR fluidizing gas. Carbon reacts with oxygen fed to the CRR to generate heat and allow operation at a nominal temperature of 1000 °C. The capability to feed water to the CRR is also available to control the system operating temperature.

The OGC uses a direct contact water spray to cool the CRR off-gas from CRR exit temperature to a nominal temperature of 150 °C.

The scrubbers provide a system for removal of acid gases from off-gases. While alternatives may be available to control acid gas formation, scrubbers have been included in the generic process for conservatism. Off-gas is contacted with a scrub solution in the scrubber vessel. Caustic is added to the system to neutralize absorbed acid gases and produce a near neutral pH solution containing sodium salts. The process was conceptually developed based on a system that re-circulates liquid through the packed bed from liquid holdup in a tank. Spent scrubber waste is currently projected to be recycled to the DMR feed tank.

A reheater is provided for elevating the off-gas temperature above the dew point to prevent moisture from condensing downstream and damaging equipment.

The PBD removes entrained solids (filters) from a gas stream. The removal efficiency is an inherent property of the filter design and its filter media. In this application, the filter has two discharges: a filtered off-gas stream and a removed solids stream.

The HEPA filter removes entrained solids (filters) from a gas stream. The removal efficiency is an inherent property of the filter design and its filter media. Separated particulates accumulate on the filter media.

Filtered off-gas may be routed to a mercury removal system for further processing. The sulfur-impregnated GAC bed removes elemental mercury vapor and ^{129}I from the off-gas stream prior to release to the environment via the facility stack.

Solids discharged from the DMR, CRR, and PBF are pneumatically transferred to a solids collection and consolidation system using pressurized nitrogen. Transferred solids are combined in one of two product receiver vessels where they are cooled by a recirculating nitrogen stream. Cooling gas is recirculated from the product receiver vessels through a filter, cooler (gas to air heat exchanger), and blower prior to being returned to the product receivers. Nitrogen bled from the solids collection and consolidation system is combined with other system off-gases at the HEPA filter inlet.

The granular product is converted to a monolithic solid by mixing with cementitious binders (cement or grout). The mixing process is performed directly in the disposal drum. Cooled solids, water, and cementitious additives are metered into the disposal drum and blended with a mechanical mixer. The drum is then sealed with a lid and the mixture cures, forming a solid block inside the disposal drum. Sealed drums of solidified waste are transported to the IDF for disposal. Binder addition estimates are based on testing reported in WSRC-WTI-2006-00033, *Fluidized Bed Steam Reformer (FBSR) Product: Monolith Formation and Characterization.*

Solids that are not initially captured in a product receiver are routed to the receiver filter as part of the recirculating cooling nitrogen. A majority of the solids entering the receiver filter are removed from the recirculating nitrogen, dropped into the transfer tank, and pneumatically transferred back to a product receiver using pressurized nitrogen as the motive force. Nitrogen is assumed added at the receiver filter to back-pulse filter elements. Nitrogen gas passing through the receiver filter is routed to an air-cooled heat exchanger (product cooler) before passing through the product blower for recycle to a product receiver. A bleed stream of nitrogen is routed from the product blower outlet to the HEPA filter inlet of the offgas treatment system.

Material and energy balances were performed based on the generic process flow diagram shown in Figure B-2. Results based on a waste concentrate with the composition summarized in Table B-3 and processing rate of 0.75 gpm are summarized on Figure B-3.

Table B-3. Waste Concentrate Component Concentrations Used as a Basis for Steam-Reformer Material Balance Estimates.

Compound	gmol/L	Compound	gmol/L
$Al(NO_3)_3$	7.26E-03	NaCl	1.07E-01
$CaCO_3$	1.12E-03	Na_2CrO_4	1.89E-03
$Cd(NO_3)_2$	1.28E-06	NaF	6.31E-02
$Fe(NO_3)_2$	1.03E-03	$NaNO_2$	2.74E-02
$Hg(NO_3)_2$	1.31E-05	NaOH	6.82E-02
KNO_3	3.06E-02	Na_3PO_4	2.62E-03
NH_4NO_3	2.16E+00	Na_2CO_3	1.96E-02
$(NH_4)_2SO_4$	1.20E-01	$Pb(NO_3)_2$	3.39E-06
NH_4Cl	2.05E-01	TOC	9.07E-01
$Ni(NO_3)_2$	1.97E-05		

Notes:

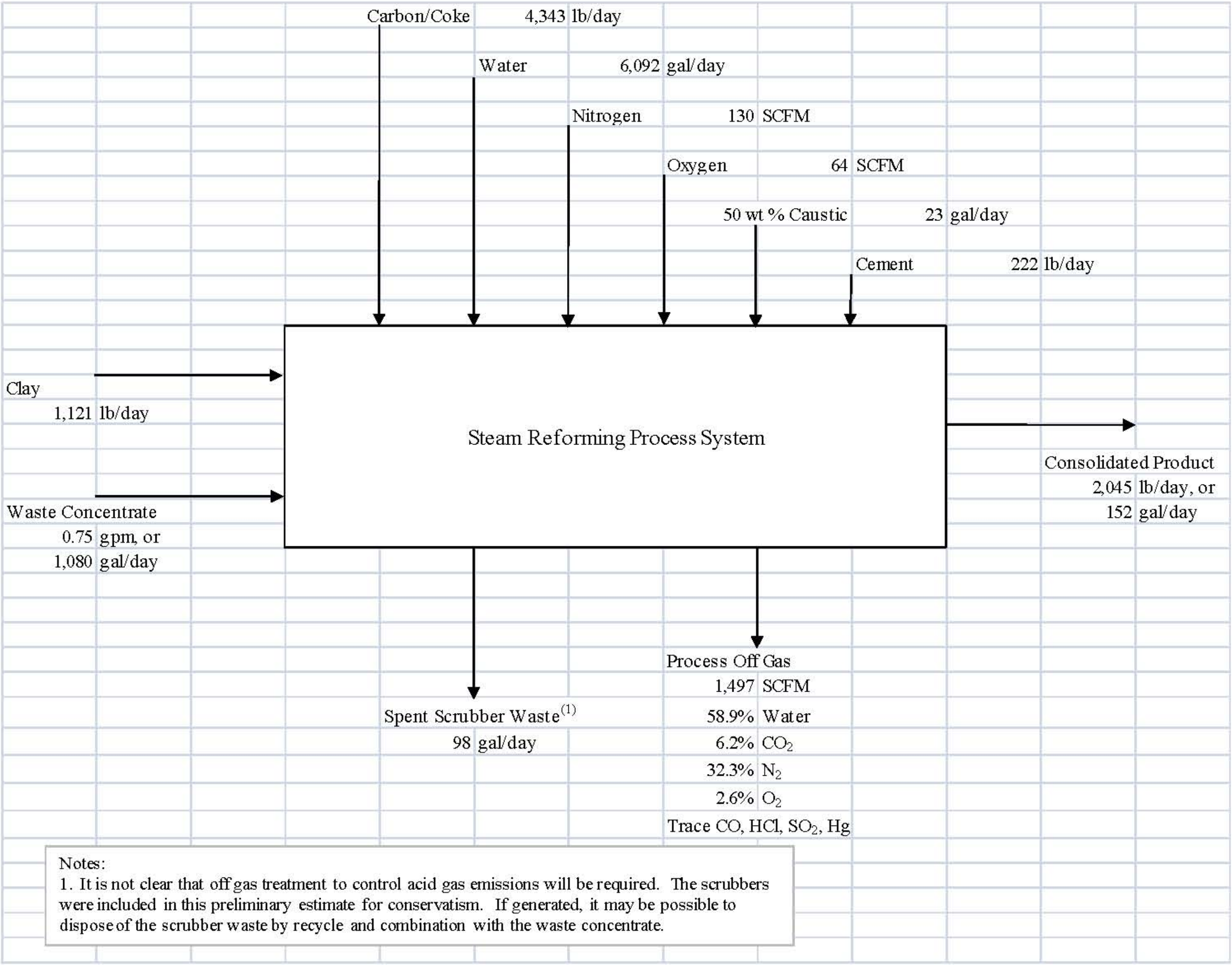
[1] Based on estimate of concentrate from Effluent Treatment Facility concentrator.

[2] Feed compositions were provided as estimates of cation and anion concentrations. Feed ions were modified by adjusting the total NH_4^+ ion concentration to produce a charge balanced solution.

[3] NaOH additions to the indicated feed concentration were required to close the mass balance and produce sufficient nepheline to mineralize the indicated concentrate components. The feed NaOH was increased by 0.5 gmol/L to complete the calculations.

TOC = total organic carbon.

Figure B-3. Summary Material Balance Estimate for a Steam Reformer System Supporting the Effluent Treatment Facility Operation.



Notes:
1. It is not clear that off gas treatment to control acid gas emissions will be required. The scrubbers were included in this preliminary estimate for conservatism. If generated, it may be possible to dispose of the scrubber waste by recycle and combination with the waste concentrate.

B2.0 PRELIMINARY STEAM REFORMING SYSTEM EQUIPMENT LIST

Detailed equipment sizing has not been performed for the generic steam reformer system. However, mass and energy balances are dependent on producing specific superficial velocities and goal reactant residence times within the fluidized bed reactors. Therefore, the material balances are dependent on the reformer equipment size. The material balances summarized by Figure B-3 are based on a DMR with 36-in. diameter fluidized bed and 60-in. diameter freeboard region. The overall DMR reactor height is approximately 15 ft. The CRR equipment size envelope is similar to that of the DMR.

A preliminary equipment list for the steam-reformer system concept is provided in Table B-4, based on Figure B-2 and the summary material balance shown in Figure B-3.

Table B-4. Preliminary Steam-Reforming System Process Equipment List. (2 sheets)

Item	Quantity	Size	Description
Receipt and mixing tanks	2	Assumed 5,000 gal for each tank	Support processing ~1,100 gal/day
Clay addition bin	1	Capacity to supply clay as 5,000-lb batch to receipt tank	
Denitration mineralization reformer	1	Envelope bounded by 5 ft diameter by 15 ft tall	
Product separator and carbon recycle system	1	Not sized	
Steam superheater	1	Support ~1,000 lb/hr superheated steam at 600°C and 1 atm	
DMR carbon feed bin		Support carbon feed of ~2,400 lb/day	
Carbon reduction reformer	1	Envelope bounded by 5 ft diameter by 15 ft tall	
CRR carbon feed bin	1	Support carbon feed of ~2,400 lb/day	
CRR startup bed media bin	1	Not sized	Intermittent use for startup
Off-gas cooler	1	Support off-gas flow of ~1,500 SCFM	
Off-gas scrubber package	1	Support off-gas flow of ~1,500 SCFM	Includes one venturi scrubber and one packed bed scrubber, each with scrub solution accumulation and recycle tanks
Off-gas heater	1	Support off-gas flow of ~1,500 SCFM	
Process baghouse filter	1	Support off-gas flow of ~1,500 SCFM	

Table B-4. Preliminary Steam-Reforming System Process Equipment List. (2 sheets)

Item	Quantity	Size	Description
HEPA filter	1	Support off-gas flow of ~1,500 SCFM	
Mercury adsorption system	1	Support off-gas flow of ~1,500 SCFM	
Off-gas blowers	3 process, 2 building ventilation	Process off-gas ~1,500 SCFM Building ventilation – TBD	
Off-gas and building ventilation discharge stack	1	Process off-gas ~1,500 SCFM, plus building ventilation	
Solids product accumulation and cooling system	1	Support throughput of ~2,000 lb/day solids	Includes two product receiver vessels, receiver filter, transfer tank, gas recirculation blower, and forced air cooled gas-air heat exchanger
Binder addition, mixing, and containerization system	1	Support loadout of ~150 to 200 gal/day of containerized solids	
Spent scrubber solution accumulation tank	1	Assumed 5,000 gal tank for conservatism	Support accumulation of ~100 gal/day and periodic transfer to receipt tanks for recycle
50 wt% caustic receipt and storage tank	1	Assume 1,000 gal tank for conservatism	Supply ~30 gal/day
Bulk clay receipt and storage bin	1	Supply ~1,500 lb/day	
Bulk carbon receipt and storage bin	1	Supply ~5,000 lb/day	
Bulk binder (cement) receipt and storage bin	1	Supply ~250 lb/day	
Nitrogen gas receipt and storage system	1	Supply ~200 SCFM	
Oxygen gas receipt and storage system	1	Supply ~100 SCFM	
Process water supply system	1	Supply ~10,000 gal/day	

CRR = carbon reduction reformer.
DMR = denitration mineralization reformer.
HEPA = high efficiency particulate air.
TBD = to be determined.

B3.0 STEAM REFORMING SYSTEM FACILITY CONCEPT

The facility concept supporting the steam-reforming system is based on enclosing the primary equipment containing radionuclide contaminated materials in a separate facility located near the existing ETF. Mineralized waste solid ^{137}Cs concentrations are similar to that used as a design basis for the Waste Treatment and Immobilization Plant (WTP) Low-Activity Waste (LAW) Vitrification Facility (~0.5 Ci/m^3 for mineralized solids versus a design basis of 0.3 Ci/m^3 in LAW glass). Therefore, dose rates in the vicinity of equipment pieces are anticipated to be at a level that allows for a remote-operated, contact-maintained operating philosophy as the basis for facility concept development. The following section describes the basis for anticipated facility hazard classification and presents a preliminary facility layout.

B3.1 Hazard Classification

The projected inventory of key radioisotopes is compared with Hazard Category 3 limits from DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, Attachment 1, for the steam-reforming facility in Table B-5. Based on this comparison, it appears that the steam-reforming system will satisfy criteria to be less than Hazard Category 3.

Table B-5. Comparison of Steam Reforming System Radionuclide Inventory to Hazard Classification Category 3 Limits.

Isotope	DOE-STD-1027-92[1] Category 3 (Ci)	Liquid Waste Inventory, Ci(2,3)	Mineral Solids Inventory, Ci(4,5)	Total Steam Reforming System Inventory, Ci	Ratio: Total Inventory divided by Category 3 Limit
^{90}Sr	16	0.45	0.3	0.75	0.047
^{99}Tc	1700	22	14	36	0.022
^{137}Cs	60	2.9	1.8	4.7	0.078
^{239}Pu	0.52	3×10^{-4}	5×10^{-5}	3.5×10^{-4}	7×10^{-4}
^{241}Am	0.52	3×10^{-3}	5×10^{-4}	3.5×10^{-3}	0.007

Notes:

[1] DOE-STD-1027-92, 1997, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, Change Notice No. 1, U.S. Department of Energy, Washington, D.C.

[2] Assumes liquid waste inventory defined by 37,850 L holdup (2 – full @ 5,000 gal/tank).

[3] Assumed evaporator concentrate radionuclide concentrations: ^{90}Sr = 1.2 E-05 Ci/L, ^{99}Tc = 5.9 E-04 Ci/L, ^{137}Cs = 7.6 E-05 Ci/L, ^{239}Pu = 7.6 E-09 Ci/L, and ^{241}Am = 6.8 E-08 Ci/L.

[4] Estimated mineralized waste inventory estimated at 3.482 m^3 (DMR holdup ~ 600 L, CRR holdup ~ 800 L, DMR product receivers [2 @ 110 gal] ~833 L, product receiver system filter ~208 L, product receiver mix tank ~208 L, and allowing storage of four containers awaiting shipment [4 @ 55 gal] ~833 L). Bulk mineralized product density estimated at 1.36 kg/L for a total holdup mass of 4.74 MT mineralized product.

[5] Mineralized product radionuclide concentrations estimated at: ^{90}Sr = 0.083 Ci/m^3, ^{99}Tc = 4.07 Ci/m^3, ^{137}Cs = 0.52 Ci/m^3, ^{239}Pu = 0.01 nCi/g, and ^{241}Am = 0.11 nCi/g.

CRR = carbon reduction reformer.
DMR = denitration mineralization reformer.

B3.2 Preliminary Facility Layout

A preliminary steam-reforming system facility layout is shown in Figure B-4 and Figure B-5. The layout is based on the equipment sizing estimates shown in Table B-4, with contingency space allocated for piping. The layout is focused on the process equipment enclosures and space allocations for essential material supply systems. Area allocations for operating personnel (control rooms, change rooms, office space, etc.) are not included in the facility layout.

Figure B-4. Steam Reforming Process Layout.

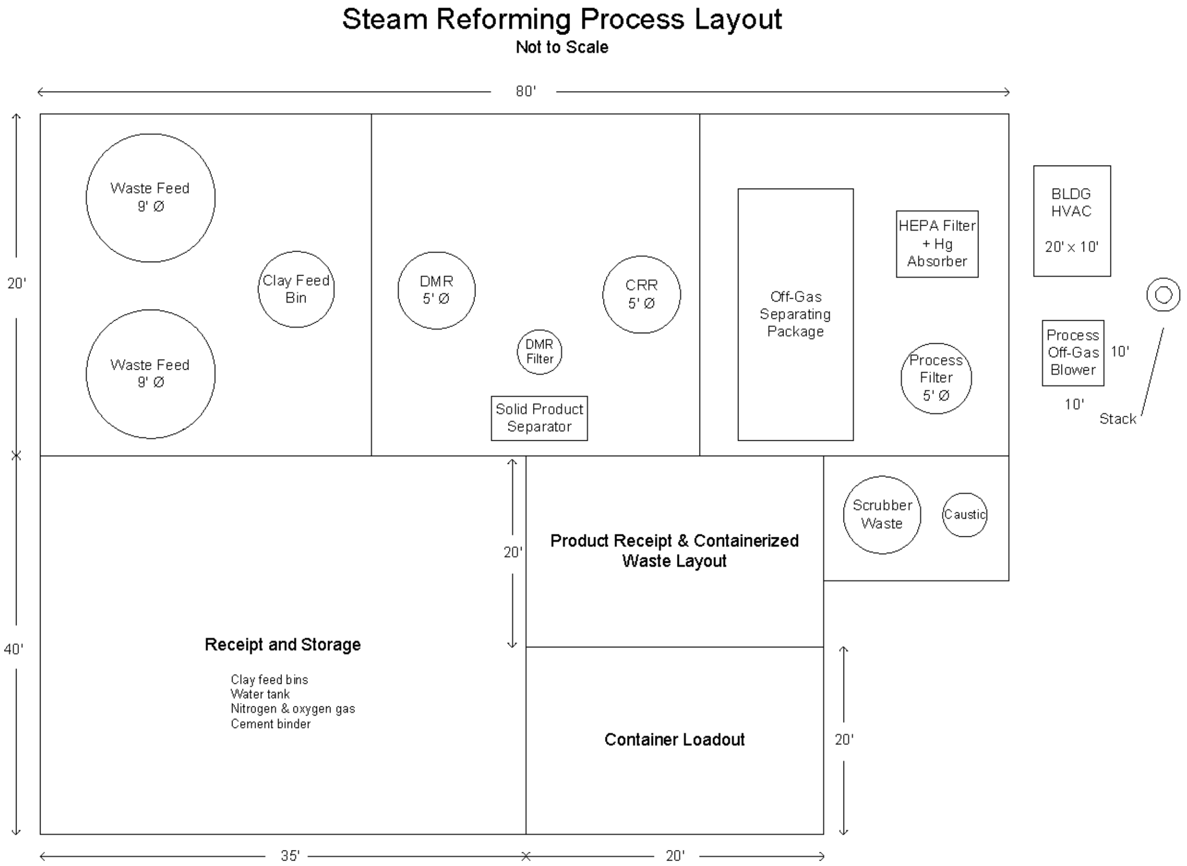
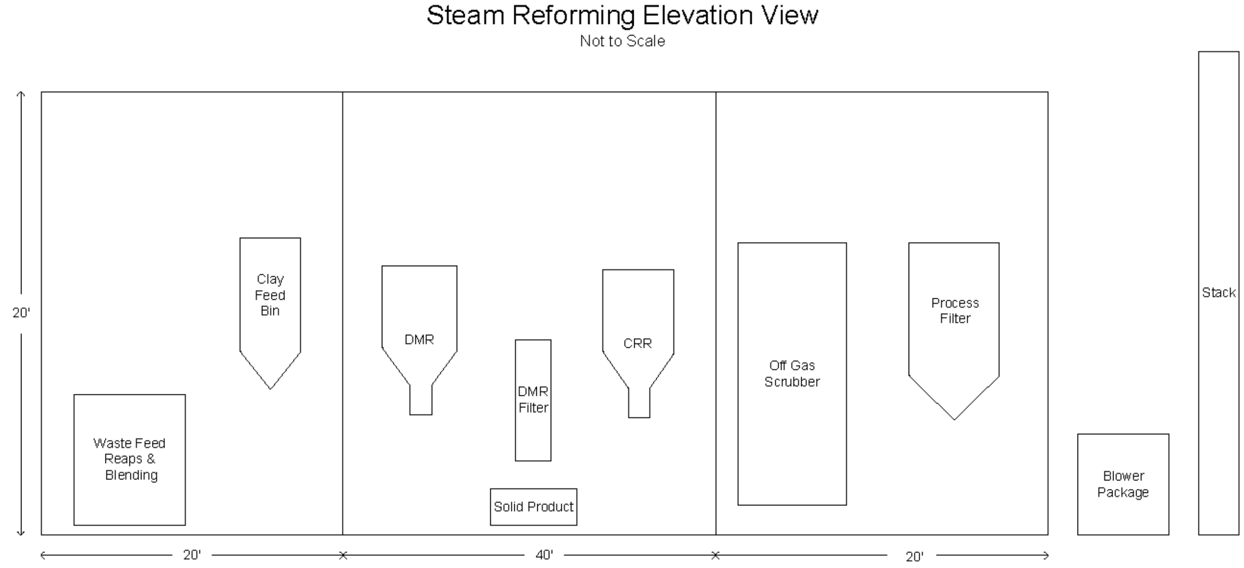


Figure B-5. Steam Reforming Process Layout (elevation view).



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APPENDIX C

MASS BALANCE

A simplified mass balance is provided in this appendix to illustrate approximate Liquid Effluent Retention Facility (LERF)/Effluent Treatment Facility (ETF) average flows. When the Waste Treatment and Immobilization Plant (WTP) is operating, it is expected to generate waste at a fairly constant rate. However, other waste sources are more sporadic. Table C-1 shows expected annual ETF waste feed sources. The mass balance includes flows from the submerged bed scrubber (SBS) blowdown discharge mode per SVF-1732, "Secondary Waste Expected Liquid Waste Composition.xlsx," and other WTP wastes per HNF-8306, *Waste Treatment Plant Liquid Treatability Evaluation.* This implies that WTP is in full operation in the SBS blowdown discharge mode. If WTP is in only partial operation, wastes from the balance of WTP will be reduced compared to what is shown (e.g., the proposed "early LAW" approach).

Table C-2. Effluent Treatment Facility Evaporator Concentrate and Solids Product.

provides estimated evaporator concentrate data and solidified product data applicable to Cases 2 and 3. Evaporator concentrate and solid product quantities and contaminant levels will be reduced for Case 1 if WTP is operating in the SBS blowdown recycle mode. The ETF evaporator normally concentrates the waste to about 25 to 40 wt% solids. However, it is assumed that the evaporator concentration factor is limited to limit cesium concentrations to less than 5 E-05 Ci/L. For the mass balance, the average cesium concentration is about one-half of this limiting value. This results in less than 20 wt% solids loading in the evaporator concentrate. Even with this conservative approach, the results show that a nominal 0.75 gpm evaporator concentrate production rate is adequate if waste processing is spread out fairly evenly over the year (70% total operating efficiency). A higher capacity for downstream processing of the evaporator concentrate may be required if waste is accumulated and processed periodically on a campaign basis.

Table C-3 compares average evaporator concentrate composition to the Class A concentration limits defined in Title 10, *Code of Federal Regulations*, Part 61.55 (10 CFR 61.55), "Waste Classification," Tables 1 and 2. The waste is estimated to exceed Class A limits by 15% on average. This should be acceptable, except for cases that involve tank truck transportation of the liquid waste, which are expected to require all shipments to be less than Class A. Since waste composition will fluctuate with time, it is not reasonable to expect the average concentration to be 100% of the Class A limit. If it is assumed that 75% of Class A limits can be achieved on an annual average basis, the concentrated waste volume must increase to about 420,000 gal/year. Assuming 5,000 gal of evaporator concentrate per shipment results in an estimated 84 shipments per year.

Table C-1. Effluent Treatment Facility Feed Streams.

Component	Units	Caustic Scrubber Blowdown[2]	SBS Blowdown[3]	Other WTP[4]	242-A Evap. Cond.[5]	Other Site Wastes[6]	Total
Volume	gal/year	9.70E+05	7.30E+05	8.00E+06	2.44E+06	4.60E+06	1.67E+07
Volume	liters/yr	3.67E+06	2.76E+06	3.03E+07	9.22E+06	1.74E+07	6.33E+07
^{90}Sr	Ci/yr	N/A[7]	5.94E+00	5.22E+00	2.35E-01	N/A[7]	1.14E+01
^{137}Cs	Ci/yr	N/A[7]	2.64E+01	7.55E-03	1.65E-02	N/A[7]	2.64E+01
^{239}Pu	Ci/yr	N/A[7]	2.74E-03	N/A[7]	2.22E-05	N/A[7]	2.76E-03
^{241}Am	Ci/yr	N/A[7]	1.50E-02	1.05E-03	N/A[7]	N/A[7]	1.60E-02
^{129}I	Ci/yr	1.38E-02	3.56E-01	9.04E-03	3.75E-05	N/A[7]	3.78E-01
^{99}Tc	Ci/yr	2.05E-01	2.51E+02	1.85E+00	1.27E-04	N/A[7]	2.53E+02
Solids[1]	Kg/yr	8.60E+04	3.71E+04	7.61E+04	9.63E+03	1.74E+04	2.26E+05

[1] Total dissolved and suspended solids.

[2] Based on SVF-1732, 2009, "Secondary Waste Expected Liquid Waste Composition.xlsx," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.

[3] Based on SVF-1732 except ^{90}Sr, ^{137}Cs, ^{239}Pu, ^{241}Am, which are based on the SVF-1663 total divided by 25 years operation (SVF-1663, 2009, "Balance_Graphic_SP4_PC_2009_03_30_at_20_02_39.xls," "SP4 Planning Case-3.0-8.4r0_2009-03-30-at-20-02-39," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington).

[4] Based on HNF-8306, 2004, *Waste Treatment Plant Liquid Treatability Evaluation*, Rev. 1, Fluor Hanford, Inc., Richland, Washington.

[5] Based on SVF-1663 totals divided by 25 years operation.

[6] Volumes based on FH-0702659, Attachment 1 (Murphy 2008) waste sources expected to continue after 2018, average1000 mg/L solids content is assumed. (Murphy, C. M., 2008, "Mission Need Statement for Obtaining Additional Liquid Waste Processing Capabilities at Hanford" (Letter FH-0702659 to D. A. Brockman, Manager, U.S. Department of Energy, Richland Operations Office, February 14), Fluor Hanford, Inc., Richland, Washington.)

[7] Components not provided in cited source. Quantity is assumed to be negligible compared to other sources.

SBS = submerged bed scrubber.
WTP = Waste Treatment and Immobilization Plant.

Table C-2. Effluent Treatment Facility Evaporator Concentrate and Solids Product.

Effluent Treatment Facility Concentrate				Solid Product (Case 2 and 3)	
Component	Units	Per Year	Ci/L or Kg/L	Dry additive per year	STU product per year
Volume	Gallons	2.8E+05			
Volume	Liters	1.0E+06			1.6E+06
^{90}Sr	Ci	1.14E+01	1.09E-05		
^{137}Cs	Ci	2.64E+01	2.53E-05		
^{239}Pu	Ci	2.76E-03	2.64E-09		
^{241}Am	Ci	1.60E-02	1.53E-08		
^{129}I	Ci	3.78E-01	3.62E-07		
^{99}Tc	Ci	2.53E+02	2.42E-04		
Solids[1]	kg	2.26E+05	2.16E-01	1.6E+06[2]	2.8E+06

[1] Total dissolved and suspended solids.

[2] Based on 1.5 kg of dry additives per liter of concentrated waste.

Table C-3. Comparison to Class A Waste Limits.

Component	Units	Evaporator Concentrated (Ci/L)	Class A Limit (Ci/L)[1]	Concentrate/ Class A limit (Ci/Ci)
^{90}Sr	Ci	1.09E-05	4.00E-05	2.73E-01
^{137}Cs	Ci	2.53E-05	1.00E-03	2.53E-02
^{239}Pu	Ci	2.64E-09	1.00E-05	2.64E-04
^{241}Am	Ci	1.53E-08	1.00E-05	1.53E-03
^{129}I	Ci	3.62E-07	8.00E-06	4.52E-02
^{99}Tc	Ci	2.42E-04	3.00E-04	8.08E-01
Total				1.15E+00

[1] As defined in 10 CFR 61.55, "Waste Classification," *Code of Federal Regulations*, Tables 1 and 2.

REFERENCES10 CFR 61.55, "Waste Classification," *Code of Federal Regulations*.

HNF-8306, 2004, *Waste Treatment Plant Liquid Treatability Evaluation*, Rev. 1, Fluor Hanford, Inc., Richland, Washington.

Murphy, C. M., 2008, "Mission Need Statement for Obtaining Additional Liquid Waste Processing Capabilities at Hanford" (Letter FH-0702659 to D. A. Brockman, Manager, U.S. Department of Energy, Richland Operations Office, February 14), Fluor Hanford, Inc., Richland, Washington.

SVF-1663, 2009, "Balance_Graphic_SP4_PC_2009_03_30_at_20_02_39.xls," "SP4 Planning Case-3.0-8.4r0_2009-03-30-at-20-02-39," Rev. 1, Washington River Protection Solutions, LLC, Richland, Washington

SVF-1732, 2009, "Secondary Waste Expected Liquid Waste Composition.xlsx," Rev. 0, Washington River Protection Solutions, LLC, Richland, Washington.