Retrieval/Ex Situ Thermal Treatment Scoring Interaction Report

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ABSTRACT

A retrieval/ex situ thermal treatment technology process option for the Idaho National Engineering Laboratory transuranic waste pits and trenches is presented. A system performance score is calculated, and assumptions, requirements, and reference baseline technologies for all subelements are included.

SUMMARY

This report presents a retrieval/ex situ thermal treatment technology reference baseline for scoring new or developmental technologies for the Buried Waste Integrated Demonstration (BWID) Program. It consists of a scoring matrix and baseline suite of technologies for a system design concept for the Radioactive Waste Management Complex transuranic pits and trenches, and derives a system scoring matrix from that concept.

The configuration option used as the basis for this report is a retrieval/ex situ thermal treatment system with interim storage following retrieval and a metal presort before treatment. The retrieval technology uses remote excavator with an enclosed conveyor transport. The treatment technology uses desorption/incineration followed by arc melting. This process option was presented in an earlier report and has been populated in this report by commercial off-the-shelf or construct-to-specification hardware.

The configuration option consists of 40 functional subelements and represents a cradle-to-grave description of the remediation system. A block diagram of the option is presented, and each subelement is described in four sections: Technical Background and Assumptions, Requirements, Process Functional Description, and Reference Baseline Technology.

Twenty-three system performance measures are presented. These are based on the BWID Performance-Based Technology Selection Filter (PBTSF) scoring methodology and represent performance metrics that have been developed to evaluate systems and technologies. Finally, a system performance score is calculated based on PBTSF scoring formulas.

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ACRONYMS

BSG	Borosilicate glass
BWID	Buried Waste Integrated Demonstration
CAM	Continuous air monitor
COTS	Commercial off-the-shelf
DOE	U. S. Department of Energy
FTE	Full time equivalent
HLW	High-level waste
HPM	High vapor pressure metal
INEL	Idaho National Engineering Laboratory
LLW	Low-level waste
NESHAPS	National Emission Standards for Hazardous Air Pollutants
OU	Operable unit
OSHA	Occupational Safety and Health Administration
PAN	Passive active neutron
PBTSE	Performance-based technology selection filter
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SWEPP	Stored Waste Isolation Pilot Plant
TDF	Technology Design File
TRU	Transuranic
TSA	Transuranic Storage Area
UBC	Uniform Building Code
VOC	Volatile organic compound
WAC	Waste Acceptance Criteria

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1. INTRODUCTION

The mission of the Buried Waste Integrated Demonstration (BWID) systems analysis study is to identify and evaluate systems for remediation of transuranic (TRU)-contaminated waste pits and trenches located within the Subsurface Disposal Area (SDA) of the Idaho National Engineering Laboratory (INEL). One objective of the study has been to develop a performance-based technology selection filter (PBTSF) and scoring matrix to evaluate candidate systems and their enabling technologies. This report presents a scoring matrix and baseline suite of technologies for a retrieval and thermal ex situ waste treatment design concept for the Radioactive Waste Management Complex (RWMC) TRU pits and trenches and derives a system scoring matrix from that concept. The purpose for generating the design concept and system scoring matrix is to provide a technology reference baseline for scoring new or developmental technologies.

The configuration option used as the basis for this report is a retrieval/ex situ thermal treatment concept with interim storage following retrieval and a metal presort before treatment. The retrieval technology uses a remote excavator with an enclosed conveyor transport, and the treatment technology uses desorption/incineration followed by arc melting. This process option was presented in an earlier report¹ as Option E, Retrieval/Interim Storage/Metals Sort/Thermal Treatment, and has been supplemented in this report by commercial off-the-shelf (COTS) or construct-to-specification hardware.

2. GOALS AND OBJECTIVES

The BWID PBTSF has been developed to evaluate systems and technologies. The primary objective of this report is to derive and present system level scores for the retrieval/ex situ thermal treatment configuration option in 23 performance areas. This activity also includes selecting or defining reference baseline enabling technologies for 40 functional subelements within the configuration option.

3. WASTE AREA GROUP AND OPERABLE UNIT DESCRIPTION

3.1 Waste Area Group 7

Waste Area Group 7 encompasses the RWMC, which was established in 1952, and is a controlled area for disposal of solid radioactive wastes generated by U. S. Department of Energy (DOE) operations at the INEL and other DOE sites. Fourteen operable units (OUs) have been identified at RWMC involving approximately 384,000 yd³ of potentially contaminated soil spread over 144 acres. RWMC includes the Transuranic Storage Area (TSA) and SDA. SDA, which is the location of the largest remediation activity at the INEL, is a confirmed release site (see Figure 1). Findings from environmental monitoring activities have determined that migration of TRU radionuclides has occurred to the 110-ft sedimentary interbed beneath RWMC. The aquifer is located 600 ft below the surface at this location. In addition, organic constituents have been detected in the aquifer.

3.2 Operable Unit 7-13

OU 7-13 is defined as the pits and trenches containing TRU-contaminated waste at the RWMC SDA. These wastes include TRU, low-level (LLW), and mixed waste in solid and liquid form. Disposal of TRU-contaminated wastes at SDA ceased in 1970. Since then, TRU wastes have been stored aboveground. The exact number of pits and trenches containing TRU will be determined. Soils around or beneath the pits and trenches contaminated by TRU and hazardous wastes are also included in this OU.

Figure 1. Map of the SDA and RWMC at the INEL.

4. REMEDIATION SYSTEM DESCRIPTION

4.1 Overview

Once the pits and trenches are characterized and their contents exhumed, the waste debris/soil is packaged and transported to interim storage. When a treatment facility is operational, the packaged waste will be withdrawn from interim storage and treated. (Current INEL environmental reports^a state that wastes exhumed from waste pits and trenches in OU 7-13 will be placed in interim storage until a suitable treatment facility is operational.) Treatment will involve size reduction and metal sort. The remaining nonmetallic waste streams will be incinerated and recombined with the sorted metals before final high-temperature thermal treatment. Final waste forms will be assayed and designated as LLW or TRU. LLW will be disposed of at the INEL RWMC. TRU waste will be packaged to meet INEL TRU Waste Acceptance Criteria (WAC) and transported to an INEL interim storage facility until a permanent repository for treated buried waste is opened. Appendix A provides the OU 7-13 waste pit and trench characteristics.

4.2 Functional Subelements

The configuration option consists of 40 functional subelements. A block diagram of the option is presented in Figure 2. The function of each subelement is described in the following sections.

4.2.1 Functional Subelement 1.0 Site/Waste Characterization

4.2.1.1 Background Technical Information and Assumptions. The waste pits were excavated to the underlying basalt layer and backfilled with 2 to 5 ft of soil to provide a level floor. The waste trenches were excavated to the basalt layer, approximately 10 ft down and averaging 7 ft wide and up to 1800 ft long.² Following excavation, wastes were placed into the pits and trenches. From 1952 to 1963, the waste containers were stacked to optimize disposal space. During 1963 to 1969, the waste packages were randomly dumped into the pits and trenches to limit worker radiation exposure. In 1969, the waste containers were once again stacked to optimize disposal volume. Once emplaced, the wastes were backfilled and covered with silty clay and sandy soil.

Figure 3 illustrates a cross-section of a typical OU 7-13 waste pit or trench and identifies terms used throughout this report. This subelement ensures that no portion of the original pit or trench volume is bypassed during retrieval and minimizes the amount of nonwaste material retrieved.

4.2.1.2 Requirements. The following shall be determined during site/waste characterization:

- Vertical boundaries of the waste pits and trenches
- Depth of the basalt underlying the waste pits and trenches
- Depth of the overburden/waste interface for each waste pit and trench
- Location of any outsize waste in the waste seam.

^a Unpublished report, "INEL Environmental Restoration Standard Planning Assumptions," May 1992.

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Figure 2. Retrieval/interim storage/metals sort/ thermal treatment option.

Figure 2. continued.

Figure 3. Cross-section of a typical OU 7-13 waste pit or trench.

4.2.1.3 Process Functional Description. This subelement cannot be represented as a self-contained, stand alone system. Its purpose is to survey the buried waste site to determine the depth to the basalt, location of the edges of buried stacks of drums and boxes, and if possible, the original excavation boundary. The depth to the basalt and original excavation boundary are the required outputs of this subelement. However, research has shown that locating the original excavation boundary is not feasible. The data from this investigation will be used to establish the surveyed boundaries that will locate the specific volume to be excavated. The operational aspects of this investigation will involve gathering historical records for the targeted retrieval site, subcontracts to geophysical survey contractors to survey the site with acoustic instrumentation, ground penetrating radar instrumentation, soil conductivity instruments, and boreholes around the buried debris. The contractor, along with INEL investigators, will reduce the data and summarize the results about the depth to the basalt, edge locations of buried debris, and any indication of the location of the original pit boundaries.

4.2.1.4 Reference Baseline Technology. Commercial water well drilling will be used to obtain depth to basalt and cuttings samples for analysis of contaminants.

Records will be reviewed to estimate set boundaries and determine the variety of contaminants that were disposed.

4.2.2 Functional Subelement 2.0 Belowgrade Isolation

4.2.2.1 Background Technical Information and Assumptions. The basalt is assumed to offer belowgrade horizontal isolation of the waste. The subsurface basalt depth is less than 30 ft for any given waste pit or trench.

The concern about leakage through the barriers is mitigated by INEL RWMC site renovations performed under the 300-year flood drainage program.

The defined waste seam will be established by an institutional review of the estimated boundaries (see Figure 3). Establishment of the defined waste seam will be performed by institutional entities. This group will be expected to identify the defined waste seam boundary for each pit or trench that includes some margin in addition to the estimated boundary values.

The pits and trenches are assumed to be too close together to remediate individually. For purposes of evaluation, the pits and trenches will be grouped into seven units. Unit 1 will enclose all pits and trenches between trench 17 on the south, trench 1 on the north (approximately 700 x 1200 ft). Unit 2 will enclose pit 3 (approximately 450 x 150 ft). Unit 3 will enclose pits 4, 6, 10, 11, 12, 13, trench 36, and all pit and trenches in between (approximately 750 x 1500 ft). Unit 4 will enclose pit 5 (approximately 400 x 600 ft). Unit 5 will enclose pits 17, 16, and 15 ("L" shaped, approximately 950 x 60 ft length apart and 550 x 350 ft along the base). Unit 6 will enclose trenches 20 and 12 on the south, trenches 41 and 34 on the north, and all trenches in between (approximately 2,500 x 200 ft). Unit 7 will enclose Pit 14 (approximately 70 x 1000 ft).

4.2.2.2 Requirements. Engineered barriers shall be constructed extending vertically from the surface to the basalt at the location of the defined waste seam to provide belowgrade isolation of the volume to be remediated. The engineered barriers shall be designed to meet or exceed all the applicable Federal, state, and DOE structural safety standards for mining or excavations.

4.2.2.3 Process Functional Description. H-pilings and I-pilings will be used, which are standard COTS items typically used in the mining industry. The pilings are pounded into the basalt (maximum 30 ft) and will completely encompass three sides of each unit, which are described in the assumptions (see Section 4.2.2.1). The pilings will be pinned belowgrade as the waste is retrieved.

4.2.2.4 Reference Baseline Technology. The defined waste seam will be established by an institutional review of the estimated boundaries (see Section 4.2.2.1).

The technology used for belowgrade isolation will be H-pilings and Sheet-pilings.

4.2.3 Functional Subelement 3.0 Abovegrade Containment

4.2.3.1 Background Technical Information and Assumptions. The entire abovegrade containment shall have a facility classification of moderate hazard in accordance with UCRL-15910, *Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomenon Hazard*³ and Radioactive Solid Waste Facility in accordance with DOE Order 6430.1A "General Design Criteria".⁴

Replacing structural supports during waste retrieval will require personnel dressed in bubble suits.

4.2.3.2 Requirements. The abovegrade containment structure(s) must encompass the entire volume currently being excavated. The abovegrade containment structure(s) shall be designed and constructed to meet the following applicable INEL building standards: DOE 6430.1A, UCRL-15910, "DOE-ID Architectural Engineering Standards,"⁵ *Operational Safety Design Criteria Manual*,⁶ and industry standard Uniform Building Code (UBC).

The abovegrade containment structure(s) shall be designed to

1. Control contamination from beta, gamma, alpha, and hazardous sources to allow maintenance repair or replacement of systems
2. Allow all necessary activities to support ancillary activities conducted within the containment structure such as retrieval, package, and transport of excavated waste
3. Allow ingress/egress of all equipment and personal necessary to perform all waste retrieval activities
4. Allow the egress of retrieved waste packaged for transport
5. Have temperature and humidity control so that the environment is regulated within the limits required for maintenance repair or replacement activities in a beta, gamma, alpha, and hazardous contaminated environment.

The abovegrade containment structure will hold all operations from overburden retrieval to transport to interim storage/treatment.

4.2.3.3 Process Functional Description. The primary containment is a Herculite sheet (or some other flexible membrane) draped around and fastened to a frame spanning about 150 ft, which contains the retrieval equipment, and is connected to a high efficiency particulate air (HEPA)

filtering system. The secondary containment is a steel frame with stainless steel, welded seam walls with an airlock entry large enough to accommodate ingress and egress of the overburden removal and retrieval equipment. The third containment is a steel frame with painted steel welded seam walls and an airlock entry large enough to accommodate ingress and egress of the overburden removal and retrieval equipment. The secondary and tertiary containment structures will be designed to meet UCRL-15910 and DOE-6430.1A, Section 1324, building requirements and will encompass each area described in Section 4.2.2.1. The internal structural supports must be designed so that they can be repositioned during the retrieval process because they will originally be placed in the waste seam. The repositioning will occur after a portion of the waste has been retrieved. The new supports will be set into the basalt where waste has been removed.

4.2.3.4 Reference Baseline Technology. The confinement structure is a commercially fabricated structure (size limited to standard commercial fabrication techniques) consisting of three barriers with one way ventilation air flow from areas of least contamination (tertiary) through increasingly contaminated areas (secondary) and exhausted from areas of greatest contamination (primary) through HEPA filters. The primary barrier is a flexible membrane; the secondary barrier is being a welded stainless steel skin; the tertiary is a steel-skinned structure.

4.2.4 Functional Subelement 4.0 Overburden Characterization

4.2.4.1 Background Technical Information and Assumptions. Before removal of overburden, an extensive characterization of the overburden will be performed.

4.2.4.2 Requirements. The characterization will locate any regions of contamination within the pit or trench overburden. Characterization techniques must be able to sample for radioactive, including TRU, and characteristic and listed hazardous contaminants defined in the BWID systems analysis requirements.⁷

4.2.4.3 Process Functional Description. Grid markings will be made in 4-ft squares of the overburden surface for removal, and random core sampling within each grid will be performed in diameter cores, 4 in. deep. Each core will then be spread thin and horizontal on a survey pad and scanned for alpha using standard alpha survey instruments. No indications of contamination will allow release of the gridded surface to a depth of 6 in. and subsequent removal of the overburden. Post-removal random sampling of overburden stockpiles shall be performed for verification of survey results.

4.2.4.4 Reference Baseline Technology. Commercial tools and instruments grid will be used for marking, shallow core sampling, and standard alpha scanning.

4.2.5 Functional Subelement 5.0 Overburden Removal

4.2.5.1 Technical Background and Assumptions. It is assumed that the overburden is not contaminated. The tertiary containment structure will be completed before any overburden is removed. However, the primary and secondary containment structures are not required during overburden removal.

4.2.5.2 Requirements. Up to 75% of the estimated overburden depth for each pit or trench will be removed. Sufficient overburden will left in place to minimize the possibility of inadvertent contamination exposure. The removal process will separate contaminated (radioactive and hazardous) from noncontaminated overburden.

Overburden removal operations must control contamination from beta, gamma, alpha, and the hazardous constituents defined in the BWID systems analysis requirements⁷ to levels that would allow maintenance to service or repair equipment.

These systems shall meet or exceed all Federal, state, and DOE nuclear standards for explosion proof and fire protection and suppression.

4.2.5.3 Process Functional Description. Overburden removal will be accomplished using commercially available soil stripping equipment. The overburden will be removed in 4-in. layers until 75% of the overburden has been removed (as determined by characterization).

4.2.5.4 Reference Baseline Technology. Commercially available soil stripping equipment will be used.

4.2.6 Functional Subelement 6.0 Storage of Contaminated Overburden

4.2.6.1 Technical Background and Assumptions. It is assumed that there will be no contaminated overburden. Up to 25% of the overburden will be handled as contaminated and included in the input waste stream to the melter. This volume is referred to as contaminated in subsequent sections.

4.2.6.2 Requirements. Contaminated overburden must be stored within the abovegrade containment structure(s) and physically separated from retrieved noncontaminated and nonassayed overburden.

Stored contaminated overburden shall not cause a criticality. Stored contaminated overburden shall have beta, gamma, alpha, and hazardous contamination control compatible with containment requirements (see Section 4.2.3.2).

4.2.6.3 Process Functional Description. A weather shield and LLW box capable of storing 10% of the total overburden will be used.

4.2.6.4 Reference Baseline Technology. Commercial standard weather shields and waste boxes will be used.

4.2.7 Functional Subelement 7.0 Noncontaminated Overburden Storage

4.2.7.1 Technical Background and Assumptions. This volume represents 75% of the total overburden.

4.2.7.2 Requirements. Retrieved noncontaminated overburden shall be stored in weather shielded storage. If the noncontaminated storage is located outside the containment building, the noncontaminated overburden shall be surveyed to ensure that it is free of beta, gamma, alpha, and hazardous contamination before removal from the containment building.

4.2.7.3 Process Functional Description. Noncontaminated overburden will be stored outside of the secondary containment and inside the tertiary containment. There is no technology for this, just a space.

4.2.7.4 Reference Baseline Technology. Commercial building construction will be used.

4.2.8 Functional Subelement 8.0 Retrieval

4.2.8.1 Technical Background and Assumptions. This subelement includes the apparatus to remove all remaining overburden and the waste from the ground.

Multiple gantry apparatus or end effectors will be used because it is not clear that the structures can be disassembled/reassembled or built once the secondary and tertiary containment structures are completed.

4.2.8.2 Requirements. The retrieval system shall comply with the following:

- Exhume material within the waste seam and transfer that material to a waste conveyance system
- Operate within the temperature and humidity limits inside the containment structure
- Accommodate operations, maintenance, and repair in a beta, gamma, alpha, and hazardous contamination environment
- Ensure that a criticality cannot occur.

Retrieval operations must identify and accommodate atypical waste objects (object or material incompatible with the retrieval system) or high radiation sources. Identification may involve characterization at the dig-face. To accommodate atypical waste objects, the retrieval system may move these objects and stabilize them in the retrieval pit or other designated area to prevent contamination spread and/or to shield high sources of radiation as stated in system requirements.⁷ Retrieval operations may bypass these stabilized objects and continue normal operations until such time that special case equipment and procedures will allow for their removal.

The retrieval system shall meet or exceed all applicable Federal, state, and DOE nuclear standards for explosion proof and fire protection and suppression.

Retrieval operations and waste packaging for conveyance will be designed so that personnel exposure to radiation will comply with DOE Order 5480.11 "Radiation Protection for Occupational Workers"⁸ and personnel exposure to hazardous materials will comply with all applicable Occupational Safety and Health Administration (OSHA) standards.

4.2.8.3 Process Functional Description. Excavation activities are performed using standard commercially available equipment and procedures. The equipment is operated via an operator in the cab. The cab is modified for safety to allow easy access and provide shielding and isolation. The operator is bubble suited for contamination control. Sets of dual operators working for a given time period per exposure limits are a required for safety.

4.2.8.4 Reference Baseline Technology. Commercial excavation equipment will be modified to allow in cab operation by operators wearing bubble suits. Maintenance of equipment will require entry by personnel wearing bubble suits.

4.2.9 Functional Subelement 9.0 Waste Conveyance

4.2.9.1 Technical Background and Assumptions. The conveyance functional subelement includes all apparatus to convey the retrieved waste or removed overburden within the containment structure.

4.2.9.2 Requirements. The waste conveyance system shall comply with the following:

- Designed so that a criticality event cannot occur
- Designed to accommodate operations, maintenance, and repair in a beta, gamma, alpha, and hazardous contamination environment
- Meet or exceed all Federal, state, and DOE nuclear systems' standards for explosion proof and fire protection and suppression
- Operate within the temperature and humidity limits in the containment structure
- Designed so that personnel exposure to radiation will comply with DOE Order 5480.11
- Designed so that personnel exposure to hazardous materials will comply with all applicable OSHA standards.

4.2.9.3 Process Functional Description. An enclosed conveyance system will be used, including side and cross conveyors, with elevators between the two and waste boxes. The conveyors and elevators are standard enclosed equipment. A funnel is used to direct waste from the excavation equipment into temporary waste boxes on the conveyor.

The waste containers will be heat wrapped with a cellophane like material, swiped, and surveyed for alpha contamination and decontaminated and surveyed for beta/gamma radiation. The box will then be loaded onto a truck and transported onsite to the size reduction/packaging facility.

4.2.9.4 Reference Baseline Technology. Commercially fabricated, material handling equipment will be used. Maintenance will require entry by personnel wearing bubble suits.

4.2.10 Functional Subelement 10.0 Size Reduce

4.2.10.1 Technical Background and Assumptions. The waste in the waste stream will undergo size reduction.

4.2.10.2 Requirements. A size reduction shall occur to the extent necessary so that the waste is in a form compatible with the radiological/volatile organic compound (VOC) assay technology. The size reduction system shall comply with the following:

- Designed to accept all waste of the composition and size described in system requirements⁷
- Designed so that a criticality event cannot occur
- Designed to accommodate operations, maintenance, and repair in a beta, gamma, alpha, and hazardous contamination environment

- Meet or exceed all Federal, state, and DOE nuclear systems' standards for explosion proof and fire protection and suppression
- Operate within the temperature and humidity limits in the containment structure
- Designed so that personnel exposure to radiation will comply with DOE Order 5480.11
- Designed so that personnel exposure to hazardous materials will comply with all applicable OSHA standards.

4.2.10.3 Process Functional Description. Size reduction of items will be to approximately a 6 in. maximum diameter.

4.2.10.4 Reference Baseline Technology. Manual remote size reduction of large items will be performed using standard tooling coupled to remote operated manipulators. Other items will be sized reduced with commercial shredders. Size reduction will be performed remotely within a structurally sound enclosure designed for fires and small explosions.

4.2.11 Functional Subelement 11.0 Radioactive and VOC Assay

4.2.11.1 Technical Background and Assumptions. The INEL TRU WAC¹⁰ will be used for interim storage and is assumed to cover hazardous, LLW, low-level mixed, TRU mixed waste.

All waste arriving at the assay system can be isolated into near 55-gal drum volumes using standard commercially fabricated equipment for assay.

4.2.11.2 Requirements. The radioactive/VOC assay system shall comply with the following:

- Designed so that a criticality event cannot occur
- Designed to accommodate operations, maintenance, and repair in a beta, gamma, alpha, and hazardous contamination environment
- Meet or exceed all Federal, state, and DOE nuclear systems' standards for explosion proof and fire protection and suppression
- Meet requirements of the interim storage WAC (INEL TRU WAC)
- Operate within the temperature and humidity limits in the containment structure
- Designed so that personnel exposure to radiation will comply with DOE Order 5480.11
- Designed so that personnel exposure to hazardous materials will comply with all applicable OSHA standards
- Capable of measuring radioactive constituents, including TRU and organic compounds, identified in the BWID system analysis requirements.⁷

4.2.11.3 Process Functional Description. Assays will be performed in batch mode following size reduction. TRU, surface gamma, and VOC assay will not necessarily be concurrent but may be sequential. Assay, system, or subsystem may be paralleled to meet system throughput.

4.2.11.4 Reference Baseline Technology. Assay equipment will be used that is similar to the Stored Waste Isolation Pilot Plant (SWEPP) passive active neutron (PAN) for TRU assay in accordance with interim storage WAC. Standard gamma instrumentation for external radiation of containers will be used. Commercial volatile organic sniffers, such as gas chromatographs or mass spectrometers, will be used to detect selected VOCs in accordance with interim storage WAC.

4.2.12 Functional Subelement 12.0 Packaging

4.2.12.1 Technical Background and Assumptions. All retrieved waste (including hazardous, LLW and low-level mixed waste) can be packaged and transported to interim storage.

4.2.12.2 Requirements. The retrieved and assayed waste stream shall be packaged and labeled to meet all of the RWMC transportation requirements,^{9,10,11} and INEL TRU WAC. The packaging system shall comply with the following:

- Designed so that a criticality event cannot occur
- Designed to accommodate operations, maintenance, and repair in a beta, gamma, alpha, and hazardous contamination environment
- Meet or exceed all Federal, state, and DOE nuclear systems' standards for explosion proof and fire protection and suppression
- Operate within the temperature and humidity limits in the containment structure
- Designed so that personnel exposure to radiation will comply with DOE Order 5480.11
- Designed so that personnel exposure to hazardous materials will comply with all applicable OSHA standards.

4.2.12.3 Process Functional Description. A connecting conduit will run from the size reduction unit to a double-lid drum passout that will be used to package the size reduced waste into 55-gal drums. Double-lid passout is standard COTS.

4.2.12.4 Reference Baseline Technology. A double-lid drum passout will be used to package sized waste into 55-gal drums.

4.2.13 Functional Subelement 13.0 Transportation

4.2.13.1 Technical Background and Assumptions. Transportation to interim storage can occur within the RWMC and, thus, will not have to fully comply with Reference 12.

4.2.13.2 Requirements. RWMC transportation requirements.¹¹

4.2.13.3 Process Functional Description. Transportation from the size reduction and assay facility to interim storage will be via forklift or forklift loading the 55-gal drums onto a flatbed truck.

4.2.13.4 Reference Baseline Technology. Commercial forklift and truck transfer will be used.

4.2.14 Functional Subelement 14.0 INEL Interim Storage

4.2.14.1 Technical Background and Assumptions. Interim storage facilities will be constructed and operated by INEL waste management operations. Interim storage facilities will accept all elements of the waste stream (hazardous, LLW, low-level mixed, TRU, and TRU-mixed). The interim storage facility will be approved to store RCRA wastes. The interim storage WAC is assumed based upon the INEL TRU WAC.^a

4.2.14.2 Requirements. The interim storage facility will be capable of storing the packaged waste until the thermal treatment facility is ready to accept waste. Waste package assay data will be retained.

4.2.14.3 Process Functional Description. The interim storage facility is a commercially fabricated structure classified as a low hazard facility per UCRL 15910. Ventilation airflow is controlled and exhausted through HEPA filters. Radiation monitoring activities for alpha, beta, and gamma as well as RCRA contaminants are routine.

4.2.14.4 Reference Baseline Technology. A commercially fabricated structure will be used with commercially standard support and monitoring equipment.

4.2.15 Functional Subelement 15.0 Transportation to Treatment

4.2.15.1 Technical Background and Assumptions. The treatment facility is not collocated with interim storage; however, it is located within the INEL.

4.2.15.2 Requirements. INEL transportation requirements will be used.^{11,12}

4.2.15.3 Process Functional Description. A commercial forklift will be used to load the waste drums onto a flatbed truck and transfer to storage.

4.2.15.4 Reference Baseline Technology. A commercial forklift will be used to load the waste drums onto a flatbed truck and transfer to storage.

4.2.16 Functional Subelement 16.0 Treatment Facility General Requirements

4.2.16.1 Technical Background and Assumptions. The treatment facility has a classification of moderate hazard per UCRL-15910 and a Radioactive Solid Waste Facility in accordance with DOE 6430.1A, Section 1324, with selected requirements from DOE 6430.1A, Section 1304, for a Plutonium Handling Facility.

The entire thermal processing line can be designed, constructed, and tested to maintain alpha contamination controls.

4.2.16.2 Requirements.

- A minimum of double confinement in accordance with DOE 6430.1A shall exist between normally contaminated areas and uncontrolled areas.

- Equipment designs and interfaces shall be designed to maintain alpha, beta, and gamma contamination confinement.
- All systems in the treatment facility shall be designed so that a criticality event cannot occur. The treatment facility will follow criticality control requirements per DOE 5480.5¹³ and DOE-ID 5480.5A., "Safety of Nuclear Facilities."¹⁴
- These systems shall meet or exceed all Federal, state, and DOE nuclear systems' standards for explosion proof and fire protection and suppression.
- All systems in the treatment facility will be designed so that personnel exposure to radiation will comply with DOE Order 5480.11.
- All systems in the treatment facility will be designed so that personnel exposure to hazardous materials will comply with all applicable OSHA standards.
- The overall treatment facility and operational systems shall meet the requirements for a Radioactive Solid Waste Facility in accordance with DOE 6430.1A, Section 1324.⁴

Additional high-level requirements are contained in Reference 15.

4.2.16.3 Process Functional Description. The treatment facility shall be designed in accordance with the restrictive standards of DOE 6430.1A, Section 1324, with selected requirements from Section 1304, and UCRL 15910. These standards institute special design considerations for handling the waste input and withstanding natural hazard disasters such as seismic activity, high winds, and floods.

Triple confinement (primary, secondary, and tertiary) of the waste shall be maintained between the actual waste stream and environment to prevent and/or mitigate any potential releases of hazardous or radioactive material to the environment or public above established release limits.

The entire primary confinement shall be fabricated to minimize the potential for alpha, beta, and gamma contamination leakage to the exterior of the primary confinement and to minimize holdup areas internal to the primary confinement. Methods to accomplish this shall include

1. Stainless steel seam welded construction
2. Details of fabrication to minimize holdup including standardized minimum radius details
3. Once through airflow with total system draft and vacuum control of each subelement
4. Airlocks at the inlet and outlet of the treatment line
5. Normally closed passive internal isolation devices at interface locations
6. Normally open control signal actively controlled isolation devices
7. Hands off operation, remote directed operations only, and double-lid interfaces for access control.

4.2.16.4 Baseline Technology. The construction will be commercial design to specification and a high integrity structure.

4.2.17 Functional Subelement 17.0 Treatment Facility Receiving

4.2.17.1 Technical Background and Assumptions. The receiving subelement performs the functions of accepting transported material supplied by the transportation-for-treatment subelement. Temporary storage for queuing may or may not be a required function.

4.2.17.2 Requirements. Waste from the transportation system shall be received and stored until conveyance is ready to accept the waste.

4.2.17.3 Process Functional Description. The treatment facility receiving station will receive packaged waste in boxes or barrels from the interim storage facility. The waste containers will be off-loaded from a transport truck to a loading dock using a forklift. The receiving facility may provide for short-term storage of the packages. Inventory and other data generated from the interim storage process, such as radiation levels, and content descriptions, will be recorded for processing information. The waste packages will be placed into the beginning of the waste treatment line using a forklift or crane and then placed on a power roller conveyor for transport into the receiving airlock. The airlock will consist of dual sets of triple doors to regulate the airflow through the airlock and into the primary confinement.

4.2.17.4 Reference Baseline Technology. A commercial forklift and hoist material handling will be used.

4.2.18 Functional Subelement 18.0 Treatment Waste Conveyance

4.2.18.1 Technical Background and Assumptions. The conveyance functional subelement includes all apparatus to convey the retrieved waste or removed overburden within the treatment containment structure.

4.2.18.2 Requirements. The waste conveyance system shall comply with the following:

- Designed to accommodate operations, maintenance, and repair in a beta, gamma, alpha, and hazardous contamination environment
- Operate within the temperature and humidity limits in the containment structure
- Capable of conveying all the various forms of wastes within the treatment facility
- Convey necessary process feedstocks and process byproducts
- Not change waste characteristics.

4.2.18.3 Process Functional Description. The treatment system waste conveyance for solid state and liquid state molten waste from the initial airlock to the ending airlock for storage for transfer to assay is accomplished by

- Self-powered rollers in the packaged state at the beginning of the process for incoming waste and at the end of the process for packaged monoliths. These types of rollers can be easily removed for replacement when necessary.
- Gravity drop or via gravity assist feed. This is the primary means for conveyance of the waste in the noncontained state from one subelement to the next and dictates the overall layout of the process line from a starting point at an initial high elevation to an ending point at some lower elevation.
- Extrusion of the waste from an extrusion device into and through a feed tube. This type of conveyance enables the feeding of the waste to the next subelement in a regulated uniform and controlled condition flow.
- Ram feeders for transfer and rough conditioning of the waste piles within a particular subelement. The rams can be powered electrically, hydraulically, or manually. For this design concept, the rams are powered by electrical power screws (electric motor coupled to leadscrew and rollernuts).
- Gravity assisted rotating conveyors. These types of conveyors (rotary kiln and rotary conveyor) are inclined rotating tubes and use gravity to help move the waste along the tube axis.
- Buoyancy from the differences in density of liquid states between liquid slag and liquid metal.
- Gravity flow of liquid material slag and metal.

The treatment system waste conveyance for offgas and primary confinement airflow is derived from the implementation of the contamination control philosophy of once-through system airflow. This philosophy dictates that airflow shall be from areas of lower contamination to areas of higher contamination. This is accomplished by

- Draft control of each subelement in the primary confinement. Draft control is the regulation of the number of airchanges in each subelement and is accomplished by controlling the differential pressure between subelements (primarily at the interface boundaries).
- Pressure control of each subelement in the primary confinement. Pressure control of the system is accomplished by providing induced draft fans at the outlet of the offgas systems with suction heads greater than the sum total of all the individual subelement pressure drops. The entire primary confinement is under negative pressure (slight to medium vacuum) with the most remote subelement establishing the starting point for pressure control.

To maintain system and subelement draft and pressure control and maintain a balanced total system through varying process conditions, two offgas systems are dictated. One system is tailored to the subelements that support incineration treatment, and the other system is tailored to the subelements that support the vitrification treatment. The need for two systems is based on the relative size and operating ranges of each system and the types of gaseous by-products requiring treatment.

The waste conveyance for offgas treatment liquid solutions is by pumps and for sludge and solid wastes by extrusion devices.

4.2.18.4 Reference Baseline Technology. Commercially available or fabricated equipment will be used, such as self-powered roller conveyors, powered rams, and a fabricated structure for gravity transfer (drop). See Section 4.2.18.3.

4.2.19 Functional Subelement 19.0 Size Reduction

4.2.19.1 Technical Background and Assumptions. Much effort has been spent on characterization of the RWMC buried waste. The basis for characterization are from past reports, sampling programs, and other efforts; however, because past practices allowed for much less stringent disposal methods, a large degree of inaccuracy must be assumed for any published numbers. The thermal treatment scenarios consider the waste input stream to contain these waste categories and contaminated soil in varying amounts and percentages.

The size reduction required for processing is assumed less restrictive than for assay monitoring. Thus, it is assumed that size reduction performed earlier (see subelement 10.0) meets size requirements for follow-on processes within treatment system. Also, it is assumed that interim storage containers will become part of the waste stream and thus must be size reduced.

4.2.19.2 Requirements. The process must be capable of reducing the containers size to meet size requirements of the downstream treatment process.

4.2.19.3 Process Functional Description. This size reduction unit has an input of box or barrel packages containing previously size reduced waste from interim storage activities. The function of this size reduction unit is to size, shred, and mix the container and waste and extrude the resulting waste stream through a nominal 12-in. extrusion tube to the next subelement for gross parameter characterization.

4.2.19.4 Reference Baseline Technology. A commercially available shredder/extruder will be used.

4.2.20 Functional Subelement 20.0 Pretreatment Characterization

4.2.20.1 Technical Background and Assumptions. It is assumed that the thermal process treatment owner will require independent characterization data for efficient and safe operations.

4.2.20.2 Requirements. Gross VOCs will be monitored as identified in Table 2 of Technology Design File (TDF), "BWID System Requirements," SA-2.0¹⁶ to assist in melter performance and maintain safe operations. Gross radionuclides and radiation levels will be monitored to assist in process safety controls and quality control of the final waste form. Other gross concentrations of constituents will be monitored that are difficult to process such as chlorides, high vapor pressure metals (HVPs), and sulfur. The constituents that are difficult to process are determined by the melting technology chosen.

Data acquisition will be compatible with downstream processes.

4.2.20.3 Process Functional Description. The waste characterization subelement provides an inspection area that enables the thermal treatment operations personnel to obtain information as

necessary for efficient and safe operations of the thermal treatment processing subelements. Waste enters the waste characterization chamber through an extrusion tube from the shredder. The waste is then manipulated using a ram device and remote operated manipulators. Normally, hand-held portable instruments are used in conjunction with manipulators, or instruments are permanently mounted on the chamber walls. Valuable information includes combustible/noncombustible mix, rough heating value estimates, identification of large quantities of difficult to process wastes, such as chlorines, sulfur, nitrates, and aluminum, gross radiation values, and estimates of volatile and semivolatile organics. Remote operated manipulators are provided to manipulate the waste as necessary. A special case waste outlet is also provided by a double-lid barrel passout to remove potential special case waste from the waste stream.

4.2.20.4 Reference Baseline Technology. A commercially fabricated enclosure will be used with commercially available standard equipment, such as manipulators, instruments and detectors (Schilling manipulators and standard detectors).

4.2.21 Functional Subelement 21.0 Metals Sort

4.2.21.1 Technical Background and Assumptions. It is assumed that atypical waste is not included in the main waste stream.

4.2.21.2 Requirements. Metals will be sorted from the waste stream. A bulk processing rate will be necessary to be compatible with interfacing subelements.

4.2.21.3 Process Functional Description. Metals are sorted using manual remote operated manipulators in a pick and place mode operated by distance located technicians with remote video.

4.2.21.4 Reference Baseline Technology. Commercially available remote operated manipulators will be used. Commercial remote video will be used.

4.2.22 Functional Subelement 22.0 Thermal Desorber

4.2.22.1 Technical Background and Assumptions. Nitrates are assumed to begin decomposing at temperatures as low as 300°C when held for a sufficient time (on the order of 2 minutes). Material Safety Data Sheets refer to decomposition at somewhat higher temperatures (400°C for potassium nitrate, 380°C for sodium nitrate).

4.2.22.2 Requirements. Waste stream constituents will be heated to a temperature of 300 to 500°C and held at this temperature for a minimum of 2 minutes. The desorber must be capable of processing all the waste entering the input side and be capable of variable temperature control over the 300 to 500°C range to accommodate variations in the input feed.

4.2.22.3 Process Functional Description. The waste entering the feed tube is at a nominal 70°F. The thermal desorber heats up the waste to a nominal 300 to 500°C to initiate decomposition of nitrates, evaporate volatiles and some semivolatiles, dehumidify metal oxides, and dry (moisture) the waste for further incineration. The act of thermal desorption reduces the chances for pulsing in the incinerator and increases the level of operating safety.

4.2.22.4 Reference Baseline Technology. The equipment subelement will use commercially designed and fabricated to specification equipment, employing standard engineering principles based on proven technology. An external electrically heated thermal tube with contained extruded material flow will be used.

4.2.23 Functional Subelement 23.0 Incinerator

4.2.23.1 Technical Background and Assumptions. Incineration/pyrolysis of the waste stream is performed to combust the majority of the combustible portion (including organics) of the waste stream. Low temperature incineration may be preferred for reduction in corrosion and erosion of the incinerator. This also may result in reduction in plugging potential of the ash and residuals in the material handling system.

It is desirable to adopt a design that will produce a minimum offgas flow rate. This will simplify any necessary offgas treatment system.

The inclusion of an afterburner in the system following the incinerator is assumed to be a requisite for compliance with regulations for destruction of contaminants.

4.2.23.2 Requirements. Incineration/pyrolysis of the waste stream will be performed. Downstream input requirements and system throughput processing rate will be met.

4.2.23.3 Process Functional Description. The incinerator is a propane fuel-fired rotary kiln operated in the controlled air mode at substoichiometric to stoichiometric conditions. The temperature is maintained in the range of 1400 to 1800°F. Organics and combustible waste are volatilized for further complete combustion in the afterburner. A percentage of the fixed carbon, minor products of incomplete combustion, and a high percentage of the HVPMS remain in the ash stream for further processing in the melter, melter afterburner, and melter offgas system. By maintaining the kiln in the controlled air mode, greater control of combustion can be maintained, pulsing conditions can be lessened or avoided, and products of high temperature combustion (such as NO_x) and ash slagging can be decreased in the kiln. Associated problems with high temperature combustion can be transferred to other components that can be operated in a more controlled fashion. Also, the volume of air required to be handled by the incinerator offgas system can be reduced, therefore reducing the overall size of this offgas system. A recognized problem with operating in this mode is the kiln sensitivity to infiltration air. However, this potential problem is partially solved by using an extrusion continuous feed system and is further solved by requiring quality design and fabrication specifications for potential air infiltration points such as the seals.

4.2.23.4 Reference Baseline Technology. The equipment subelement will use commercially designed and fabricated to specification equipment, employing standard engineering principles based on proven technology. Propane fire rotary kiln with high integrity rotating seals will be used. Seal technology for alpha will be demonstrated but not proven (recognized problems with seals for control of alpha contamination).

4.2.24 Functional Subelement 24.0 Afterburner

4.2.24.1 Technical Background and Assumptions. The output stream from the afterburner is assumed to contain H₂O, CO, CO₂, and HVPMS (such as mercury, lead, cadmium, and arsenic), HVPM oxides, halogens, sulfur compounds, combusted organics, products of incomplete combustion,

particulates, and some radionuclides (Cs^{137} , potential minor quantities of TRU oxides, and other LLW radionuclides).

One possible design will maintain the offgas stream for a minimum time at a minimum temperature (approximately >2 seconds at >1850°F) to ensure complete combustion.

4.2.24.2 Requirements. The afterburner shall ensure 99.9999% (1 part in 10^6) combustion of all organics in the offgas stream.

4.2.24.3 Process Functional Description. Total system offgas and controlled draft airflow is divided into two offgas systems each with its own afterburner. Division into two systems is necessary due to the practical limitations and operating ranges associated with the incinerator with its associated draft control airflow and the melter with its associated draft control airflow. The two offgas systems, including afterburners, are identical systems, each with the same capacity sized to the larger incinerator system. This arrangement affords full redundancy in afterburners and offgas and draft control airflow cleansing at the expense of running the melter offgas system under normal operations at a reduced capacity. Capability to transfer offgas cleaning operations from one system to the other is considered an enhancement of this reference baseline.

The input to the incinerator afterburner consists of the (1) volatilized gas stream resulting from the incinerator combustion, (2) draft control airflow from the upstream pretreatment chambers to the initial airlock, and (3) downstream draft control airflow to the point of the inlet to the melter feed device (mixer/extruder). This total airflow first passes through a dust cyclone to separate large particulate from the gas stream and feeds this particulate back to the ash stream. The gas stream then enters the afterburner that is a vertical chamber maintained at 2000 to 2200°F and sized to ensure a gas residence time of greater than 2 seconds. Residence time at temperature is measured by rings of thermocouples located at the ends of the afterburner. The afterburner is maintained in the excess oxygen mode using oxygen gas injection to ensure complete oxidation of the organics. Temperature is maintained using the heat released during combustion or by heat input from auxiliary heat sources, such as propane or fuel fired torches or inert gas fired plasma torches. Complete destruction of organics is ensured by the designed residence time at temperature in an excess oxygen environment. Potential operation below design limits that could result in offgas release above permit limitations originating from pulses of organic volatiles released during incineration of a combustible, loaded heterogeneous feed stream is reduced and/or eliminated by over capacity design (or by the high instantaneous heat output capability of the plasma torches coupled with oxygen injection and controlled by sensing and feedback circuitry).

The input to the melter afterburner consists of (1) offgas resulting from the melting process of noncombustible material and from combustion and volatilization of residual carryover of combustibles and fixed carbon in the ash stream and (2) draft control airflow from the melter taps and downstream slag and metals barrel fill and cool down lines to the point of the barrel input and output airlocks. The offgas flow travels through a dust cyclone similar to the incinerator dust cyclone but smaller, and an afterburner and offgas cleaning system identical to the incinerator offgas system but operated at reduced capacity.

4.2.24.4 Reference Baseline Technology. The equipment subelement will use commercially designed and fabricated to specification equipment, employing standard engineering principles based on proven technology. Commercially fabricated refractory lined ducts will be used that are coupled to refractory lined dust cyclones and coupled to refractory lined afterburner chamber with propane, fuel, or plasma fired auxiliary heating. Standard instrumentation and circuitry will be used.

4.2.25 Functional Subelement 25.0 Mixer

4.2.25.1 Technical Background and Assumptions. Incinerator output (subelement 23.0) will be mixed with metals from subelement 21.0. Flux may be added to meet the input requirements of the oxidizing slag metal/metal tapping melter. The mixer will blend the constituents into a relatively homogenous mix. It is assumed that neither the output of the incinerator/pyrolizer or metals sort require size reduction to ensure the mix is homogeneous enough to meet melter input requirements.

4.2.25.2 Requirements. Feedstock will be mixed and blended.

4.2.25.3 Process Functional Description. The ash stream output from the rotary kiln is combined with a gravity dumped, stored metals stream from the metals sort storage chamber at the output of the rotary kiln. The ash exiting the kiln is at a temperature of 1400 to 1800°F and presents a potential materials corrosion problem for the mixer. The metals are combined with the ash stream resulting in partial cooling of the ash and heating of the metals. The metals/ash stream still presents a potential corrosion problem; therefore, the stream is passed through a rotary conveyor to cool the ash/metals stream to a temperature within the operating limits of the melter mixer/extruder. The mixer/extruder also has the capability to size reduce the ash/metals stream in the event any slagging or clumping had occurred in the ash/metals stream. Inputs of additional contaminated soil and/or solid additives are injected into the mixer for blending into the ash/metals stream, and this entire melter feed stream is again size reduced to an optimum size for input into the melter. The mixer/extruder extrudes the feedstream through a feed tube and into the top of the melter on a continuous or intermittent basis. The extrusion tube, while in the filled state, acts as a barrier to airflow and as a point of separation between the incinerator offgas system and melter offgas system.

4.2.25.4 Reference Baseline Technology. A commercially available mixer/shredder/extruder will be used.

4.2.26 Functional Subelement 26.0 Oxidizing Slag, Oxidizing Metal/Metal Tapping Melter

4.2.26.1 Technical Background and Assumptions. The composition of the molten slag output stream is assumed to be an iron enriched basalt matrix with dissolved metal oxides and TRU and LLW contaminants. This assumption is based on work as reported in References 17, 18, 19, and 20.

The offgas stream from the high temperature melter is assumed to potentially contain H₂O, CO, CO₂, and HVPs (such as mercury, lead, cadmium, and arsenic), HVP oxides, halogens, sulfur compounds, combusted organics, particulates, and some radionuclides (Cs¹³⁷, potential minor quantities of TRU oxides, and other LLW radionuclides).

The metals contained in the molten metal output stream are assumed to be mainly iron with other trace metals included.

4.2.26.2 Requirements. Input requirements of downstream subelements will be met.

Operating temperature will be high enough to melt metals and melt the basaltic soils maintaining an adequate viscosity for the homogeneous slag frit/monolith subelement. The melter output shall contain none of the organic constituents found in the system requirements.⁷

A waste will be produced that is no longer considered a hazardous waste per 40 CFR 261, "Identification and Listing of Hazardous Waste."

4.2.26.3 Process Functional Description. The melter is a top loaded, cold wall skull melter equipped with teapot (manometer) type taps for slag and metals tapping. Heat is supplied to the feedstock and melt by plasma arcs operating in the transferred arc mode, and oxygen is injected into the melt by oxygen lances. Slag and metals melt under the combined intense heat of plasma arcs and joule heating effect of operation in the transferred arc mode and partition in the bottom of the melter because of the differences in density between the slag and metal. The slag is less dense than the metal and floats on top of the metal. Melter temperature is in the molten steel range ($>1650^{\circ}\text{C}$, 3000°F). Feedstock enters the top center of the melter through an extrusion tube and forms a cold cap. Turbulence and mixing of the melt are maintained by action of the arcs and current paths, convection currents, and controlling the feedstock input rate from the extruder. Metals and slag are tapped via continuous pour taps. An offgas line exits the top of the melter to a dust cyclone. Vents in the tap chambers connect to the offgas system and draft control ducts from the barrel fill and cool down lines. Access to the flow lines for oxygen lance removal of potential plugs is a design feature. The entire melter system is maintained within a structurally sound and ventilated separate confinement volume with isolation devices at the inlets and outlets.

4.2.26.4 Reference Baseline Technology. The equipment subelement will be commercially designed and fabricated to specification equipment, employing standard engineering principles based on proven technology (high-temperature electric arc melter with continuous pour slag and metals taps).

4.2.27 Functional Subelement 27.0 Homogeneous Slag Frit/Monolith

4.2.27.1 Technical Background and Assumptions. The composition of the molten slag output stream is assumed to be an iron enriched basalt matrix with dissolved metal oxides and TRU and LLW contaminants. This assumption is based on experimental and calculated work as reported in References 17, 18, 19, and 20.

The output of the melter is assumed to be slag frit or monolith, whichever form enables a high quality, high reliability radioactive assay.

4.2.27.2 Requirements. The molten slag will be received from the melter and cast into monoliths or processed into a frit form. The waste form will prevent the release of radionuclides and heavy metals.

4.2.27.3 Process Functional Description. Functional descriptions are provided for subelement 26.0, Oxidizing Slag, Oxidizing Metals/Metal Tapping Melter and subelement 35.0, Heat Treat/Controlled Cool.

4.2.27.4 Reference Baseline Technology. An industry standard, continuous pour melter taps with a gravity feed of material into standard drums (automatic indexing of drums for fill) for monolith production. Drum fill line will be contained within commercially fabricated and ventilated confinement structure.

4.2.28 Functional Subelement 28.0 Tapped Metal

4.2.28.1 Technical Background and Assumptions. No radionuclides, or only very minor quantities of radionuclides, are expected to be partitioned into the molten metals stream. The radionuclides are expected to be partitioned into the slag, with potentially some carryover into the offgas system. However, radiological controls must still be emplaced on the metals stream.

The metals contained in the molten metal output stream are assumed to be mainly iron with other trace metals included.

A high reliability assay of the metals is assumed to be possible in the monolith form.

4.2.28.2 Requirements. The molten metal will be received from the melter and cast into monolith forms.

A waste will be produced that is no longer considered a hazardous waste per 40 CFR 261.

4.2.28.3 Process Functional Description. Functional descriptions are provided for subelement 26.0, Oxidizing Slag, Oxidizing Metals/Metal Tapping Melter and subelement 35.0, Heat Treat/Controlled Cool.

4.2.28.4 Reference Baseline Technology. An industry standard, continuous pour melter taps with a gravity feed of material into standard drums (automatic indexing of drums for fill) for monolith production. Drum fill line will be contained within commercially fabricated and ventilated confinement structure.

4.2.29 Functional Subelement 29.0 Offgas Treatment

4.2.29.1 Technical Background and Assumptions. The offgas stream to the offgas treatment system is assumed to contain H₂O, CO₂, HVPs (such as mercury, lead, cadmium, and arsenic), HVP oxides, halogens, sulfur compounds, combusted organics, particulates, and some radionuclides (Cs¹³⁷, potential minor quantities of TRU oxides, and other LLW radionuclides).

The offgas unabated release calculations are assumed to confirm the potential for discharge of radionuclides resulting in effective dose equivalents greater than allowable per 40 CFR 61.93, "Emission Monitoring and Test Procedures."

4.2.29.2 Requirements. The offgas treatment system shall clean the offgas stream of all constituents to allow operations within applicable Federal and state air permit requirements.

In accordance with DOE 6430.1A, "General Design Criteria," 40 CFR 60, "Standards of Performance for New Stationary Sources," 40 CFR 61, "National Emissions Standards for Hazardous Air Pollutants," and ANSI N13.1, the offgas treatment system shall be equipped with air monitoring instruments to detect radionuclides and hazardous constituents listed in the BWID systems analysis requirements.⁷ The final released offgas effluent shall be monitored for any normally or accidentally release radionuclides via an isokinetic sampling system.

The offgas system must be maintained at a sufficient negative pressure to draw all gaseous flows through the systems and still maintain adequate negative pressure at the most remote location.

4.2.29.3 Process Functional Description. The offgas treatment system starts after the afterburners with the full offgas flow at a temperature of 2000 to 2200°F. The full flow equals the sum of the combustion generated offgas stream and the draft control generated airflow stream. The full flow is termed as offgas because it has gone through the afterburner and must be treated.

The offgas cleaning system presented is used as a reference baseline system for comparison and scoring only. This system is based on an in situ vitrification system that has been demonstrated at tests at the Hanford Site. It is also recognized that this system is not optimal for this treatment process especially concerning the treatment capability for NOx and heavy metals such as lead and mercury but could be optimized during a continued design phase. Offgas systems are typically custom designed for a particular application with the combination of several components each with a particular cleansing ability for a particular offgas product all working as a total system to meet final emissions criteria.

The system presented is a wet system with high total system pressure drop that dictates the need for large high vacuum induced draft suction fans (blowers). Offgas exits the afterburner at 2000 to 2200°F and first enters a roughing water-based spray quench chamber to cut the temperature to approximately to 550°C (1000°F). Spray solution is collected in a sump tank. The offgas exits this chamber and enters a venturi ejector scrubber where spray solution fluid is injected, atomized by the action of the venturi, and scrubbed by chemical reaction of the small atomized solution and gas stream. Particulates adhere to the atomized droplets and condense into large droplets at the venturi throat because of decreased velocity and a drop in pressure. The large droplets collect, and a solution with scrubbed elements is collected in the tank. The offgas continues into a hydrosonic scrubber that acts similarly to the venturi but increasingly scrubs the gas stream. Scrub solution is injected, atomized, and recondensed, and liquid condensate is collected in a sump tank. The hydrosonic scrubber also uses pressure drop to induce flow and scrubbing action. The offgas exits the scrubber and enters a separator, condenser, and a final separator chain to eliminate fine water/solution mist. Solution is collected in a sump tank. Chemistry control is maintained on the scrub solution tanks to maintain effective scrubbing capabilities in the components. The cleaned offgas then passes through a reheater to evaporate any remaining moisture and prevent final filter clogging. The stream then enters a bank of redundant prefilters and final HEPA filters. Metal HEPA filters are used for this baseline case to enable cleaning via back flushing and filter mechanical rigidity. The offgas is then drawn into the induced draft blower fans (point of greatest system vacuum) and is exhausted through the fan/blowers out the stack. The stack is continuously monitored by temperature, flow, and pressure instrumentation, redundant continuous air monitors (CAM) for radioactivity, and redundant continuous isokinetic air samplers (filters and sample gas volumes) for laboratory analysis of stack emissions.

Sludge is continuously removed from the collection tanks, compressed to remove liquid, and dried to remove remaining moisture.

4.2.29.4 Reference Baseline Technology. The equipment subelement system will be commercially designed and fabricated to specification equipment, employing standard engineering principles based on proven technology (wet venturi offgas cleansing system and HEPA filtering).

4.2.30 Functional Subelement 30.0 Mixer

4.2.30.1 Technical Background and Assumptions. Residue from the offgas treatment process (subelement 29.0) may not meet the input requirements of the joule heated residue melter (subelement 31.0). Borosilicate glass (BSG) frit will be added as necessary. The mixer will blend the

residue and BSG frit into a relatively homogenous mix. It is assumed that neither the BSG frit or offgas residue require size reduction to ensure the mix is adequately homogenous.

4.2.30.2 Requirements. Feedstock will be mixed and blended to meet melter input requirements. The resulting mix will be transported to the joule heated melter.

4.2.30.3 Process Functional Description. The offgas system residue consists of sludge removed from the wet offgas system solution tanks. This dried sludge is fed into a mixer/extruder and blended with a glass forming feedstock. The mixture is then extruded into and through an extrusion tube into a low-temperature glass melter.

4.2.30.4 Reference Baseline Technology. A commercially available mixer/shredder/extruder will be used.

4.2.31 Functional Subelement 31.0 Offgas Residue Melter

4.2.31.1 Technical Background and Assumptions. Melter temperature is assumed to be a nominal 2000°F (1100°C) based on operating temperatures for melters designed for vitrification of high-level waste (HLW) using BSG.

4.2.31.2 Requirements. Operating temperature will be high enough to melt the BSG frit and residue and low enough to hold the contaminants (HVPs, metal oxides, radionuclides, etc.) in solution. The output must be compatible with downstream processes. A waste will be produced that is no longer considered a hazardous waste per 40 CFR 261.

4.2.31.3 Process Functional Description. The sludge/glass former mixture is extruded into and through an extrusion tube into the top of a metal joule heated stirred glass melter. The melt glass product is tapped and deposited into barrels in a barrel fill station. The barrel fill station and transfer line are similar in design to the slag and metals fill station and line of the primary melter. Offgas from the melter and draft control airflow from the barrel fill chamber and conveyor line are ducted and routed back to the inlet of the primary melter offgas afterburner.

A recognized alternative to forming a glass product from the offgas residue stream is a low temperature solidification option using sulfur polymer cement, which may result in a better waste form for capturing heavy metals (lead and mercury would still be a problem).

4.2.31.4 Reference Baseline Technology. A commercially available, medium-temperature glass melter (stirred glass Inconel 690 joule heated melter) will be used.

4.2.32 Functional Subelement 32.0 Offgas Frit/Monolith

4.2.32.1 Technical Background and Assumptions. The composition of the molten slag output stream is assumed to be a BSG matrix with dissolved metal oxides and potentially minor quantities of TRU and LLW contaminants.

4.2.32.2 Requirements. The molten slag will be received from the melter and cast into monoliths or processed into a frit form. Output will be compatible with downstream processes.

4.2.32.3 Process Functional Description. Descriptions are provided in subelements 31.0, 26.0, and 35.0. The glass product is cast into monoliths forms contained in barrels, decontaminated, swiped, and surveyed as clean before exiting through an airlock to the storage and transfer station.

4.2.32.4 Reference Baseline Technology. An industry standard, continuous pour melter taps with the gravity feed of material into standard drums (automatic indexing of drums for fill) for monolith production. Drum fill line will be contained within commercially fabricated and ventilated confinement structure.

4.2.33 Functional Subelement 33.0 Post-Treatment Radioactive Assay

4.2.33.1 Technical Background and Assumptions. It is assumed that pretreatment characterization will not satisfy the requirements for classifying output waste form.

An advantage, for thermally processing this type of waste is to convert the as received waste stream into a form that will enhance the ability to obtain TRU concentration data with reduced uncertainty.

The bases for this reduction in uncertainty of assay data are

- The geometry of the assay form can be optimized for the assay equipment (geometry of choice enables consistent geometrical calibration factors).
- Vitrification and homogenization eliminate density variances.
- Vitrification and homogenization eliminate radionuclide distribution variances (fully dissolved radionuclides and complete mixing).
- Vitrification and homogenization enhance the predictability of self shielding (alpha) unknowns.
- Vitrification and geometry of choice allow for reduced assay time because of assay of a known form with decreased variances and enable assay data to be collected at a waste throughput rate of tons per day.
- Vitrification and enhanced assay capability allow for post-treatment sort of TRU and LLW based on reliable and consistent assay data.
- Vitrification and enhanced assay capability increases the ability to identify radionuclides and quantify concentrations of the radionuclides. This enhanced capability increases the credibility of the data and allows for further rational disposition decisions.

4.2.33.2 Requirements. To meet the assay requirements, it is necessary to identify and quantify radionuclides so that waste can be assigned as LLW, reclassified LLW, or TRU as follows:

- $\text{TRU} > 100 \text{ nCi/g}$ - TRU
- $10 \text{ nCi/g} < \text{TRU} < 100 \text{ nCi/g}$ - reclassified LLW

- TRU < 10 neg - LLW.

4.2.33.3 Process Functional Description. SWEPP will be used for this function.

4.2.33.4 Reference Baseline Technology. SWEPP will be used for this function.

4.2.34 Functional Subelement 34.0 Post-Treatment Medium Temperature Fusing/Remelt

4.2.34.1 Technical Background and Assumptions. This subsystem may be unnecessary if a monolith is cast during initial thermal treatment. The output of frit or monolith from the primary thermal treatment subsystem is dependent on the physical form required to enhance the assay capabilities and produce lower uncertainty reliability assay data.

4.2.34.2 Requirements. The IEB frit will be cast into an assay compatible physical form.

4.2.34.3 Process Functional Description. The IEB frit will be fused or remelted and cast into a monolith.

4.2.34.4 Reference Baseline Technology. Medium temperature melter operating at a nominal 2500°F (1400°C).

4.2.35 Functional Subelement 35.0 Heat Treat/Controlled Cool

4.2.35.1 Technical Background and Assumptions. The purpose of this functional subelement is to change the microstructure of the cast monolith waste form so that the resulting waste form has low leach rate and high durability.

This subelement along with the fusing/remelt subelement may be unnecessary functions if assay systems are identified that can provide high quality, reliable data from a monolith cast block direct from the primary thermal process subelement.

4.2.35.2 Requirements. Cooling will be controlled to optimize the microstructure and meet leach rate and durability requirements.

The subsystem shall include nondestructive test capabilities to verify the integrity of the final waste form.

4.2.35.3 Process Functional Description. Clean empty metal barrels enter a barrel fill chamber through an airlock via a power roller conveyor and are preheated by the ambient temperature within the fill chamber. During the fill sequence, a barrel is positioned under the melter tap opening. The melter tap control is operated, and the molten slag pours out of the tap opening and drops vertically through air filling the barrel to a preset point. The slag temperature and viscosity are measured during the fill process, and a molten slag sample is taken using a standard metals sampling cup by a remote operated manipulator. The sample cup is passed out of the fill chamber through a double-lid passout port and analyzed for physical and chemical properties as well as radioactive isotopes. The tap control is operated again, and the molten slag flow is stopped. The sample is coded to the filled barrel, and the barrel accepted or rejected for further assay and disposal after the process line on the basis of the sample analysis. Rejected slag barrels are transferred back to the beginning of the line for reprocessing.

The powered roller conveyor is then indexed to position a new empty barrel. The barrels advance along the line through an interface door into the controlled cooling furnace. The heat treat/controlled cooling furnace consists of a metals type electric resistance annealing furnace. The molten slag filled barrels enter the furnace on a powered roller conveyor, and are incrementally transferred through the furnace at a controlled rate. Temperature at the inlet end is maintained at approximately 1350°C (2460°F), and incrementally reduced and maintained along the length of the furnace to approximately 800°C (1470°F). The total transfer time between temperatures is approximately 8 hours. The barrels continue on the line through a thermal barrier along the powered roller conveyor into a quench chamber. Inside the quench chamber, the temperature of the slag filled barrels is reduced from approximately 800°C (1470°F) to a nominal ambient temperature of 21°C (70°F) by a cooled air quench. Nominal transfer time through the quench chamber is 2 hours. The barrels continue on the power roller conveyor through an interface door and into the decontamination and package chamber.

Molten metals are removed by a means similar to the slag with the exception that no attempt is made to control the cooling or quench the metals. The metals are allowed to cool at a nominal rate along the entire length the line and pass into a decontamination and package chamber similar to the slag line.

4.2.35.4 Reference Baseline Technology. The equipment subelement will use commercially designed and fabricated to specification equipment, employing standard engineering principles based on proven technology (commercial annealing furnace using powered rollers for transport and a furnace contained within a structurally sound and ventilated confinement).

4.2.36 Functional Subelement 36.0 TRU Packaging

4.2.36.1 Technical Background and Assumptions. The designated disposition is for interim storage at the INEL pending resolution and opening of a permanent repository for TRU/TRU-mixed buried waste.

4.2.36.2 Requirements. Packaging requirements shall meet current INEL TRU WAC criteria.⁹

4.2.36.3 Process Functional Description. In the packaging chamber, the barrel exterior is decontaminated, and a lid is placed on the barrel and sealed. The sealed barrel is then decontaminated swiped and surveyed for loose contamination. Barrels verified clean of exterior contamination are transferred out of the packaging area through an airlock and into a storage area for transfer back to the receiving area for rejected barrels or to SWEPP for further assay and verification of TRU activity levels (<10 nCi/g, 10 to 100 nCi/g, or >100 nCi/g) and segregation before disposal into permanent disposal facilities.

4.2.36.4 Reference Baseline Technology. Commercial material handling equipment, overhead crane, forklift, and commercial radiation swipe and survey instruments will be used.

4.2.37 Functional Subelement 37.0 Final Package Assay

4.2.37.1 Technical Background and Assumptions. Previous assays will be performed to verify the level and kind of activity in the waste form product.

4.2.37.2 Requirements. Final assay and external contamination swipe surveys will be conducted for INEL TRU WAC.¹⁰

4.2.37.3 Process Functional Description. This function entails only a swipe survey to verify the container exterior is free from loose contamination.

4.2.37.4 Reference Baseline Technology. Standard instrumentation will be used for gamma, beta, and alpha radiation contamination swipe and survey, and standard instrumentation will be used for gamma radiation survey of container for shipping manifest.

4.2.38 Functional Subelement 38.0 INEL TRU Interim Storage

4.2.38.1 Technical Background and Assumptions. Interim storage facilities will comply with the following:

- Constructed and operated by INEL waste management operations
- Accept all elements of the waste stream (hazardous, low-level, low-level mixed, TRU, and TRU-mixed)
- Approved to store RCRA wastes.

The interim storage WAC is assumed to be based upon the INEL TRU WAC.⁹

4.2.38.2 Requirements. Retrievable storage at the INEL will be used.

4.2.38.3 Process Functional Description. The interim storage facility is a commercially fabricated structure classified as a low hazard facility per UCRL 15910. Ventilation airflow is controlled and exhausted through HEPA filters. Radiation monitoring activities for alpha, beta, and gamma as well as RCRA contaminants are routine.

4.2.38.4 Reference Baseline Technology. A commercially fabricated structure with commercially standard support and monitoring equipment will be used.

4.2.39 Functional Subelement 39.0 Reclassified LLW Packaging

4.2.39.1 Technical Background and Assumptions. It is assumed that reclassified LLW has the same INEL WAC as LLW.

4.2.39.2 Requirements. Packaging and disposal shall be in accordance with INEL LLW WAC.¹⁰

4.2.39.3 Process Functional Description. The barrel exterior will be decontaminated and a list installed. The barrel will then be sealed and surveyed for loose contamination. Barrels verified free of external contamination will be transferred out of the packaging chamber through an airlock.

4.2.39.4 Reference Baseline Technology. Commercial material handling equipment, overhead crane, forklift, and commercial radiation swipe and survey instruments will be used.

4.2.40 Functional Subelement 40.0 LLW Packaging INEL Disposal

4.2.40.1 Technical Background and Assumptions. The waste derived from fixing the offgas residue into BSG is assumed to be LLW and melter product <10 nCi/g as determined by post-treatment radioactive assay (subelement 33.0). The potential for TRU elements to be carried off into the offgas waste stream is considered to be small.

4.2.40.2 Requirements. Packaging shall be in accordance with INEL LLW WAC.¹⁰

4.2.40.3 Process Functional Description. NA

4.2.40.4 Reference Baseline Technology. INEL LLW WAC will be used.

5. SYSTEM PERFORMANCE MEASURES

5.1 General

This section summarizes the values assigned to system performance measures associated with the Retrieve/Ex situ Thermal Treatment configuration option. These measures are defined as system technical or institutional characteristics used as inputs for scoring formulas. These formula scores are multiplied by utility functions and summed in weighted averages to generate the category figures of merit and overall system score in Section 7 of this report.

The numerical values of the system performance measures are derived from published performance data from vendors supplying the equipment or hardware used and from engineering estimates.

5.2 Performance Measure Values

A list of the system performance measures is provided below. Numerical values for each measure are presented with the basis for that value. The measures are presented in the order in which they first appear in "Trade-Off Study Performance Measures," TDF No. SA-4.103, BWID Systems Analysis.²¹

1. V_o = Volume (m^3) of output material from the process that requires monitoring and storage (includes any contaminated process material)

= 141,391 m^3 (185,043 yd^3) (0.0283 m^3/ft^3)

= 1,593,921 ft^3 (waste + soil A40 mix)
+ 3,402,253 ft^3 (soil only A100)
4,996,174 ft^3 (185,043 yd^3) glass/ceramic (IEB) final waste form

The overburden is assumed to be uncontaminated (Section 4.2.5.1) and 75% will be removed before treatment (Section 4.2.5.2).

12,059,707 ft^3 total input volume
-2,740,683 ft^3 removed uncontaminated overburden (.75 overburden)
9,319,024 ft^3 net volume treated

Waste + Soil Treatment:

Assume 40% base case soil loading with waste input (A40 mix IEB)¹⁷

Container volume = 2,325,251 ft^3

Treated waste (60%) and soil (40%) volume (A40 mix):

60% = 2,325,251 ft^3 (waste volume)
40% = 1,550,167 ft^3 (soil volume)
100% = 3,875,418 ft^3 (A40 waste/soil mix)

Treated waste + soil final waste form volume (IEB-A40):

Container volume (1/3.72 waste only reduction factor)

$$\begin{array}{r} 2,325,251 \text{ ft}^3 \\ \times 0.269 \\ \hline 625,067 \text{ ft}^3 \end{array}$$

Soil volume (1/1.60 soil reduction factor)

$$\begin{array}{r} 1,500,167 \text{ ft}^3 \\ \times 0.625 \\ \hline 968,854 \text{ ft}^3 \end{array}$$

$$\begin{array}{r} \text{Total: } 625,067 \text{ ft}^3 \\ \quad 968,854 \text{ ft}^3 \\ \hline 1,593,921 \text{ ft}^3 \end{array}$$

(Approximate A40 volume reduction factor = 2.43/1):
(3,875,418/2.43 = 1,594,822 ft³)

Soil only treatment:

Treated soil volume at A100 mix (100% soil):

$$\begin{array}{r} 9,319,024 \text{ ft}^3 \text{ net treated volume} \\ - 3,875,418 \text{ ft}^3 \text{ A40 waste/soil mix} \\ \hline 5,443,606 \text{ ft}^3 \text{ soil only (A100)} \end{array}$$

Treated soil final waste form volume (IEB):

$$\begin{array}{r} 5,443,606 \text{ ft}^3 \text{ soil only (A100)} \\ \times 0.625 \text{ applied volume reduction factor (1.60/1): (1/1.60 soil only volume reduction)} \\ \hline 3,402,253 \text{ ft}^3 \text{ IEB A100 volume} \end{array}$$

<u>Compaction Ratio:</u> ¹⁹		<u>Value</u>
Soil only	<u>Slag (S.G.=3.2)</u>	1.60/1
	Soil (S.G.=2.0)	
Waste only	<u>Container volume</u>	3.72/1
	Dense waste	
Waste + entrained	<u>Extraction volume</u>	2.13/1
	Waste + entrained/1.60	
Waste + entrained + under	<u>Extraction + underburden</u>	1.94/1
	Waste + (entrained + underburden)/1.60	
Waste + all soil	<u>Extraction + underburden + overburden</u>	1.81/1
	Waste + (all soil)/1.60	

Basis is from estimates of volumes and masses from Pit 9 of the SDA with thermal treatment producing a glass/ceramic final waste form.¹⁹

Offgas treatment systems may need to be accounted for or explicitly discounted. Residual will ratio approximately 1:10 against frit supply¹⁹ and may affect throughput above.

$$\begin{aligned} 2. \quad V_i &= \text{volume (m}^3\text{) of waste seam, matrix, overburden, and horizontal plume as} \\ &\quad \text{defined in the input requirements} \\ &= 341,489 \text{ m}^3 \text{ (12,059,707 ft}^3\text{)} \end{aligned}$$

Volumes are as follows:¹

2,325,251 ft³ container volume
3,954,692 ft³ soil volume (matrix)
3,654,245 ft³ overburden soil
2,120,375 ft³ underburden (matrix)
5,144 ft³ subsidence

$$\begin{aligned} \text{Total} &= 12,059,707 \text{ ft}^3 \\ &= 341,489 \text{ m}^3 \end{aligned}$$

Underburden and soil volume are included in matrix per input requirements.

$$\begin{aligned} 3. \quad V_g &= \text{volume (m}^3\text{) of contaminated process material produced by the system} \\ &= 10,000 \text{ m}^3 \end{aligned}$$

Engineering baseline estimate of constituents of V_g include

- Operations solid waste (antiCs)
- Contaminated discarded hardware
- HEPA filters
- Stabilized offgas residual solids.

Note that $V_g = 10,000 \text{ m}^3$ (approximately 100 semitruck loads) is an engineering baseline estimate over the life of the project for relative scoring purposes. Elimination or reduction of operations solid waste, contaminated discarded hardware, and HEPA filters, will reduce V_g .

$$\begin{aligned} 4. \quad E &= \text{mean fraction of allowable emissions} \\ &= 1 \end{aligned}$$

The range for this measure is from 0 to 1. A value of zero represents zero emissions (which implies reduced permitting). A value of 1 represents the maximum quantity of

emissions allowed by the approved permits and licenses for operations. New or improved technologies that reduce any or all emissions will reduce this measure (example, if a new technology enables emissions to be reduced to the 80% level, then $E = 0.8$)

5. E_{ret} = mean fraction of allowable emissions
 $= 1$

This will equal E for the technology reference baseline system, but E may change as different technologies are considered.

6. F_s = COTS functional subelements
 $= 31.7$

COTS are those components that are not designed and fabricated only for the application in the design concept. The fraction of COTS reflects the major interfaced components within a subelement that can be reconfigured (or that have standard interfaces) and are COTS. F_s is an input to the reconfigurability performance measure, and thus cost is not used as a metric in the calculation below.

COTS fractions are engineering estimates based on vendor surveys and reviews of similar systems.

Number	Subelement	COTS Fraction
1.	Site/Waste Characterization	1
	Commercial water well drilling technology to obtain depth to basalt and cuttings samples for analysis of contaminants. Records review for estimation of boundaries and variety of contaminants disposed.	
2.	Belowgrade Isolation	1
	Sheet piling and H-pilings, commercially available and used in the mining industry.	
3.	Abovegrade Containment	0.5
	There are three containment structures. Each is manufactured to specification. Air filtration system is COTS.	
4.	Overburden Characterization	0.7
	Standard equipment.	

5.	Overburden Removal System is COTS.	1
6.	Storage of Contaminated Overburden Fabricate to specifications.	0.7
7.	Noncontaminated Overburden Storage Fabricated to specifications.	0.7
8.	Retrieval Modified commercial equipment, labor intensive.	0.7
9.	Waste Conveyance COTS elevators will be highly modified.	0.6
10.	Size Reduce Highly modified commercial equipment and housings.	0.5
11.	Radioactive and VOC Assay SWEPP similar equipment and procedures. Accuracy and reliability of data sufficient for pretreatment data collection and characterization. System is fabricate to specification with commercial equipment.	0.8
12.	Packaging Standard equipment and procedures.	1.0
13.	Transportation	1.0
14.	INEL Interim Storage Building is fabricate to specification. Intrabuilding conveyance is COTS.	1.0
15.	Transportation to Treatment Transport truck, loading and device(s) are COTS.	1.0

17. Treatment Facility Receiving 1.0

Building is fabricate to specification. Conveyance (crane or forklift) and handling (forklift) is COTS.

18. Treatment Waste Conveyance 0.6

Components of the treatment system waste conveyance for solid state and liquid state molten waste from the initial airlock to the ending airlock for storage for transfer to assay are separately considered below:

- a. Self powered rollers in the packaged state at the beginning of the process for incoming waste and at the end of the process for packaged monoliths. These are COTS and are used by the commercial glass industry and for general material handling applications.
- b. Gravity drop or gravity assist feed. Feed function only components are fabricate to specification. Dual use components (such as the rotary kiln) are COTS.
- c. Extrusion of the waste from an extrusion device into and through a feed tube. Extruder and feed tube is COTS.
- d. Electrical, manual, or hydraulic Ram feeders for transfer and rough conditioning of the waste piles within a particular subelement. These are design to specification.
- e. Gravity assisted rotating conveyors. These types of conveyors (rotary kiln and rotary conveyor) are inclined rotating tubes and utilize gravity to help move the waste along the tube axis. This type of conveyor is commercially available and is assumed to be COTS.
- f. Buoyancy due to the differences in density of liquid states between liquid slag and liquid metal.
- g. Gravity flow of liquid material slag and metal. Containment and guidance of the flow is COTS.

The treatment system waste conveyance for offgas and primary confinement airflow is derived from the implementation of the contamination control philosophy of once-through system airflow. This philosophy dictates that airflow shall be from areas of lower contamination to areas of higher contamination. This is accomplished by

- (1) Draft control of each subelement in the primary confinement is accomplished by controlling the differential pressure between subelements (primarily at the interface boundaries). Fans, valving, and controls are COTS. Support structure, ducting, and containment are fabricated to specification.
- (2) Pressure control of each subelement in the primary confinement. Pressure control of the system is accomplished by providing induced draft fans at the outlet of the offgas systems with suction heads greater than the sum total of all the individual subelement pressure drops. The entire primary confinement is under negative pressure (slight to medium vacuum) with the most remote subelement establishing the starting point for pressure control. COTS and nonCOTS components same as (1) above.

To maintain system and subelement draft and pressure control and maintain a balanced total system through varying process conditions, two offgas systems are dictated. One system is tailored to the subelements that support incineration treatment, and the other system is tailored to the subelements that support the vitrification treatment. The need for two systems is based on the relative size and operating ranges of each system types of gaseous by-products that require treatment.

The waste conveyance for offgas treatment liquid solutions is by pumps and for sludge and solid wastes by extrusion devices.

19. Size Reduction 0.9

Shredders are assumed. These are commercially available and widely used in the hazardous and municipal solid waste industry.

20. Pretreatment Characterization 0.9

Commercial hand held and wall mounted instrumentation. Manipulators and double-lid passout are COTS. Ram, enclosure, and isolation gates are fabricate to specification.

21.	Metals Sort	0.9
	Manipulators, manipulator tools, magnet(s), metal transfer cart, double-lid passout, extruder, and extrusion tube are COTS. Ram, enclosure, and isolation gates are fabricate to specification.	
22.	Thermal Desorber	1.0
	Resistance heater external to extrusion tube. COTS.	
23.	Incinerator	0.5
	COTS rotary kiln. Alpha control seals are fabricate to specification per patented design. However, reliability of seals is unproven; therefore, value is discounted to 0.5.	
24.	Afterburner	0.8
	Fabricate to specifications.	
25.	Mixer	0.9
	Modified commercial equipment.	
26.	Oxidizing Slag and Metal/Metal Tap Melter	0.6
	Modified commercial equipment of fabricate to specification. Customized, enhanced operating procedures.	
27.	Homogeneous Slag Frit/Monolith	0.8
	Modified commercial equipment and operating procedures.	
28.	Tapped Metal	
	Modified commercial equipment and operating procedures.	
29.	Offgas Treatment	0.8
	Fabricate to specification.	
30.	Mixer	0.9
	Modified commercial equipment.	
31.	Offgas Residue Melter	0.9
	Modified commercial equipment.	

32.	Offgas Frit/Monolith	0.8
	Modified commercial equipment and operating procedures.	
33.	Post-Treatment Radioactive Assay	0.4
	SWEPP similar equipment and procedures. Limited proven accuracy and reliability for low specific activity measurements.	
34.	Post-Treatment Fusing/Remelt	1.0
	Dummy variable for consistency. Subelement combined with controlled cooling.	
35.	Heat Treat/Controlled Cool	0.9
	Modified commercial equipment.	
36.	TRU Waste Packaging	1.0
	Standard packaging.	
37.	Final Package Assay	1.0
	Standard instruments.	
38.	INEL TRU Interim Storage	0.8
	Fabricate to specification discounted because of WAC and operating unknowns.	
39.	Reclassified LLW Packaging	1.0
	Standard equipment and procedures.	
40.	LLW Packaging INEL Disposal	1.0
	Standard equipment and procedures. Existing WAC.	
7.	F_t = Total functional subelements	
	= 40	

The configuration option functional subelements are

1. Site/waste characterization
2. Belowgrade isolation
3. Abovegrade containment
4. Overburden characterization

5. Overburden removal
6. Storage of contaminated overburden
7. Noncontaminated overburden storage
8. Retrieval
9. Waste conveyance
10. Size reduce
11. Radioactive and VOC assay
12. Packaging
13. Transportation
14. INEL interim storage
15. Transportation to treatment
17. Treatment facility receiving
18. Treatment waste conveyance
19. Size reduction
20. Pretreatment characterization
21. Metals sort
22. Thermal desorber
23. Incinerator
24. Afterburner
25. Mixer
26. Oxidizing slag, oxidizing metal/metal tapping melter
27. Homogeneous slag frit/monolith
28. Tapped metal
29. Offgas treatment
30. Mixer
31. Offgas residue melter
32. Offgas frit/monolith
33. Post-treatment radioactive assay
34. Post-treatment medium temperature fusing/remelt
35. Heat treat controlled cool
36. TRU waste packaging
37. Final package assay
38. INEL TRU interim storage
39. Reclassified LLW packaging
40. LLW packaging INEL disposal.

8. $F_{\text{ref}} =$ total functional subelements for technology baseline reference option
 $= 40$

This equals F_i for the technology baseline system. Note that F_i may change as technologies are assessed that increase or reduce the number of subelements within the process option.

9. $N_{\text{OS}} =$ number of predefined out of scope input that the system can remediate
 $= 8$

Engineering baseline estimate for the defined in-scope waste stream is the buried waste located at the RWMC. Engineering baseline estimate is that the system can remediate the following solid waste streams:

1. LLW
2. MLLW
3. Alpha LLW
4. Mixed alpha LLW
5. Mixed TRU (non-WIPP certifiable TRU)
6. TRU
7. Municipal
8. Sanitary.

Estimate derived from review of declared waste streams on the INEL as listed in the INEL roadmap document.²²

10. N_{ref} = number of predefined out of scope inputs the baseline reference system can remediate
- = 8

This is equal to N_{OS} for the reference baseline technology option.

11. T_l = time until line item and capital equipment replacement costs exceed 50% of acquisition cost
- = 15 years

Engineering baseline estimate is that for the length of the remediation activity (8.3 years). The replacement costs will be less than 50% of the acquisition costs.

12. T_r = time to remediate V_l
- = 8.3 years

Engineering baseline estimate for nominal size operational throughput rate of approximately 15 ton/h at 60% availability. This estimate was derived by $V_i = 12,059,707 \text{ ft}^3 \times \text{bulk average density} = 109 \text{ lbs/ft}^3 (2000 \text{ lbs/ton} \times 15 \text{ ton/hour} \times 24 \times 365 \times .6)^2$

Total waste volume = 24% of total input volume. This consists of metals (22% of waste fraction at 96 lb/ft³), sludge (33% of waste volume at 67 lb/ft³), combustibles (20% of waste volume at 17 lb/ft³), other (25% of waste volume at 40 lb/ft³). Total soil volume = 76% of total input volume. Soil at 2.0 g/cc (S.G. = 2.0) = 125 lb/ft³.

Average density = $.76(125) + .24(56.6) = 108.6 \text{ lb/ft}^3$

13. A = availability
- = 0.60

Engineering baseline estimate is productive operations (treating waste) of 3 shifts per day (24 h/day) running 5 days per week, with normal maintenance activities occurring on the weekend on a 3 shift per day operation.

Semiannual shutdowns of 1 month duration (60 day/year), 3 shift operation (24 h/day) for extended maintenance, repair, and decontamination activities.

$$\begin{aligned}
 A &= \frac{(365-60) \text{ days} \times (7-2) \text{ days}/7 \text{ days} \times 24 \text{ h/day}}{365 \text{ days} \times 24 \text{ h/day}} \\
 &= 5225 \text{ h}/8760 \text{ h} \\
 &= 0.60
 \end{aligned}$$

$$\begin{aligned}
 14. \quad T_h &= \text{Time to remediate } 50\% \text{ of } V_i \\
 &= 4.2 \text{ years (one-half total period)}
 \end{aligned}$$

The year total is an engineering baseline estimate based on linear remediation efforts (takes one-half the time to remediate one-half the waste).

$$\begin{aligned}
 15. \quad T_{\max} &= \text{maximum time (years) allowed for the remediation process} \\
 &= 20 \text{ years}
 \end{aligned}$$

Estimated start year 2000, complete 2020.

$$\begin{aligned}
 16. \quad C_{is} &= \text{important-to-safety capital expense} \\
 &= \$45.1 \text{ M}
 \end{aligned}$$

Important-to-safety capital estimated expense is \$45.1 M²³

$$\begin{aligned}
 17. \quad C_m &= \text{cost (life cycle)} \\
 &= \$511 \text{ M}
 \end{aligned}$$

This is an estimated operational life cycle cost. Total estimated cost is \$511 M²³.

$$\begin{aligned}
 18. \quad C_d &= \text{number of subelements demonstrated under similar site and waste conditions} \\
 &= 34
 \end{aligned}$$

All subelements blocks with the exception of those listed below are judged to have been demonstrated as adequate for the scope of this configuration option.

- Subelement 8.0, Retrieval
- Subelement 11.0, Radioactive and VOC Assay (particularly VOC assay at high throughput rate)
- Subelement 26.0, Oxidizing Slag, Oxidizing Metal/Metal Tapping Melter
- Subelement 31.0, Offgas Residue Melter
- Subelement 33.0, Post-treatment Assay (below 10 nCi/g)
- Subelement 35.0, Heat Treat Controlled Cool

19. C_s = number of subelements similar to a technology demonstrated under similar site and waste conditions

= 5

Functional subelement 33.0, Post-Treatment Assay (below 10 nCi/g), nor has a similar technology been demonstrated under the conditions stated. Other undemonstrated technologies listed under item 18 have had similar technologies demonstrated under similar site and waste conditions.

20. R_p = hazard index with process (reference 10^{-6})

= 1

This value represents remediation of existing conditions to minimum acceptable levels.

21. R_{np} = hazard index without process (reference 10^{-6})

= 5

This value represents an engineering estimate for the purpose of this report only and does not reflect any known or published data by others. This value reflects judgement that remediation activities are required to be performed.

22. R_{pc} = excess lifetime cancer risk with process

= 1×10^{-6}

Short-term worker, including radionuclides and nonradionuclides. As above, this value represents an engineering estimate for the purpose of this report only and does not reflect any known or published data by others. This value reflects judgement that remediation activities are required to be performed.

23. R_{npc} = excess lifetime cancer risk without process

= 5×10^{-6}

Future no action, average resident, including radionuclides and other carcinogens. This value represents remediation of existing conditions to minimum acceptable levels.

$$\begin{aligned} 24. \quad C_n &= \text{number of subelements not able to be demonstrated prior to full scale} \\ &\quad \text{implementation} \\ &= 0 \end{aligned}$$

Note that $C_t = C_n + C_s + C_d + \text{dissimilar demonstrable subelements}$.

$$\begin{aligned} 25. \quad N_p &= \text{estimated gross number of permits required} \\ &= 8 \end{aligned}$$

A listing of major permits or licenses required is below.

1. Idaho State Facility Siting License
2. RCRA Part A and B
3. Prevention of Significant Deterioration Permit (Air Emissions - Idaho)
4. National Emission Standards for Hazardous Air Pollutants (NESHAPS) Approval to Construct (mercury emissions)
5. Idaho Air Quality Permit to Construct
6. National Pollution Discharge Elimination System (NPDES) permit
7. Wastewater Land Application Permit (Idaho)
8. NRC Operating License

Note that archeological, endangered species (ESA), and historic (NHPA) permits not included or considered.²⁴

$$\begin{aligned} 26. \quad W_{no} &= \text{volume of waste that cannot currently be moved to offsite disposal} \\ &= 0 \end{aligned}$$

Engineering baseline estimate is that all waste treated can be moved to offsite disposal.

$$\begin{aligned} 27. \quad L &= \text{operation labor hours} \\ &= 219,450 \text{ h} \end{aligned}$$

A 5225 operation h/year x 10 year x 42 mean full time equivalent (FTE)/shift.

$$\begin{aligned} 28. \quad O &= \text{operation hours} \\ &= 52,250 \text{ h} \end{aligned}$$

A 5225 h/year x 10 year.

29. y_{ED} = mean years of specialized training (academic and facility specific)
 = 2.8 years/person

Summary of staff follows:

<u>Position</u>	<u>Number</u>	<u>Years</u>
General and Administrative		
Manager	1	20
Supervisor	3	10
Characterization/Retrieval		
Supervisor	1	10
Technicians	5	5
Laborers	45	0.5
Interim Disposition		
Technicians	1	5
Laborers	3	0.5
Storage/Transport/Receive		
Technicians	1	5
Laborers	6	0.5
Size Reduce/Assay		
Technicians	3	5
Laborers	3	0.5
Sort		
Technicians	2	5
Treatment		
Supervisor	3	1
Technicians	15	5
Laborers	6	0.5
Assay		
Technicians	6	5

Post-Treat

Technicians	6	5
Laborers	3	0.5

Package/Disposition

Supervisor	1	10
Technicians	6	5
Laborers	6	0.5
people	126	
person year		351

$$126/3 = 42 \text{ mean FTE/shift}$$

$$351/126 = 2.8 \text{ average years ed/person}$$

30. y_{ref} = mean years of specialized training (academic and facility specific) for the reference baseline technology option
- = 2.8 year

This is equal to y_{ED} for the reference baseline technology option. Note that y_{ED} may change as various technologies are considered.

31. T_d = total critical path time to demonstrate
- = 24 months

Engineering baseline estimate is for a 2 year design and construction schedule prior to operation. Time until demonstration and time until operation are the same.

32. T_{br} = time to begin remediation
- = 7 years

Seven years is an engineering baseline estimate based on remediation activities starting in the year 2000, which is based on policy decisions (record of decision).

6. TRADE-OFF SCORE SUMMARY

General Categories			
☒ Effectiveness	0.932	±	0.0 %
☐ Implementability	0.745	±	0.0 %
☐ Cost	0.850	±	0.0 %
Final Score:		0.843	± 0.0 %

Performance Measures			
☒ Volume Reduction	0.586	±	0.0 %
☐ Waste Generation	0.971	±	0.0 %
☐ Compliance w/ARARs	1.000	±	0.0 %
☐ Flexibility of Design	0.793	±	0.0 %
☐ Reconfigurability	1.000	±	0.0 %
☐ Robustness	1.000	±	0.0 %
☐ Expected Lifetime	1.807	±	0.0 %
☐ Availability	0.600	±	0.0 %
☐ Throughput	0.757	±	0.0 %
☐ Effective Benefit	0.790	±	0.0 %
☐ Environ/Health	0.953	±	0.0 %

☐ Data ☐ Weights
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Volume Reduction

This score assesses the ability of the system to reduce waste volume.

$$E_1 = 1 - \frac{V_o}{V_i}$$

Vo = Cubic meters of output material from the process that requires monitoring and storage.

Vi = Cubic meters of waste matrix, overburden and horizontal plume as defined in the system requirements.

Vo =

141391 ± 0.0 %

Vi =

341489 ± 0.0 %

Unweighted

E₁ = 0.586 ± 0.0 %

☐ Data
☐ Weights

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☒ Waste Generation	0.971		0.0	
☐ Compliance w/ARARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

Waste Generation

This score assesses the ability of the system to minimize waste generation.

$$E_2 = 1 - \frac{V_g}{V_i}$$

V_g = Cubic meters of contaminated process material produced by the system.

V_i = Cubic meters of waste matrix, overburden and horizontal plume as defined in the system requirements.

V_g = 10000 ± 0.0 %

V_i = 341489 ± 0.0 %

Unweighted

E₂ = 0.971 ± 0.0 %

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score:

0.843

±

0.0

%

☐ Data
☐ Weights
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Compliance w/ARARs

This score is a measure of the degree to which process-specific ARARs are satisfied.

$$E_3 = \frac{E}{E_{ref}}$$

E = The total number of process-specific ARARs satisfied by the technology process option.

E_{ref} = The total number of process-specific ARARs associated with any technology process option being considered.

E
=

1

±

0.0

%

E_{ref}
=

1

±

0.0

%

Unweighted

$$E_3 =$$

E₃
=

1.000

±

0.0

%

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☒ Compliance w/ARARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score: 0.843 ± 0.0 %				

☐ Data ☐ Weights Help New Quit

Flexibility of Design

This score is a measure of the flexibility of the system to undergo modification after construction.

$$E_4 = \frac{F_s}{F_t}$$

Fs = Number of functional subelements whose requirements are met with commercial off-the-shelf technologies.

Ft = Total number of functional sub-elements.

$F_s =$ 31.7 ± 0.0 %

$F_t =$ 40 ± 0.0 %

Unweighted
 $E_4 =$ 0.793 ± 0.0 %

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/ARARs	1.000		0.0	
☒ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

☐ Data
 ☐ Weights

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score:	0.843	±	0.0	%

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/ARARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☒ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

Reconfigurability

This score assesses the ability to reconfigure the system or subsystems after construction.

$$E_5 = \frac{F_t}{F_{ref}}$$

F_t = Total number of functional subelements.

F_{ref} = Total functional subelements for technology baseline reference option.

F_t = 40 ± 0.0 %
 F_{ref} = 40 ± 0.0 %

Unweighted

E_5 = 1.000 ± 0.0 %

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

☐ Data
☐ Weights
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Robustness

This is a measure of the system's ability to accomodate unanticipated inputs without modification to the system.

$$E_6 = \frac{N_{os}}{N_{ref}}$$

Nos = Number of predefined out-of-scope inputs in the input system requirements that the system can remediate.

Nref = Number of predefined out-of-scope inputs the baseline reference system can remediate.

N_{os} =

8

±

0.0

%

N_{ref} =

8

±

0.0

%

Unweighted

$$E_6 = \text{1.000 ± 0.0 %}$$

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/RRARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☒ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

☐ Data
☐ Weights
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Expected Lifetime

This score measures the ability of the system to remain operational throughout the remediation process.

$$E_7 = \frac{T_l}{T_r}$$

T_l = Time (years) until line item and capital equipment costs exceed 50 % of acquisition cost.

T_r = Time (years) it will take to remediate VI.

T_l = 15 ± 0.0 %

T_r = 83 ± 0.0 %

Unweighted
E₇ = 1.807 ± 0.0 %

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/ARARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☒ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

☐ Data ☐ Weights

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/RRARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☒ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

Availability

This score is the fraction of time that the system is available during the remediation process.

$E_8 = A$

A = The fraction of time during the remediation process that the system is available.

A = 0.60 ± 0.0 %

Unweighted

$E_8 =$ 0.600 ± 0.0 %

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score:				
	0.843	±	0.0	%

☐ Data
☐ Weights
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Throughput

Throughput is measured as the time per unit of waste remediated.

$$E_g = 1 - K_s \frac{T_r}{V_i}$$

V_i = Volume (cubic meters) of waste matrix, overburden, and horizontal plume as defined in the input system requirements.
 T_r = Time in years to remediate V_i .
 K_s = A site-specific normalizing constant.

V_i	=	341489	±	0.0	%
T_r	=	8.3	±	0.0	%
K_s	=	10000			
Unweighted					
E_g	=	0.757	±	0.0	%

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/ARRAs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☒ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

☐ Data
 ☐ Weights

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score:	0.843	±	0.0	%

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/RRARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☒ Effective Benefit	0.790		0.0	
☐ Environ/Health	0.953		0.0	

Effective Benefit

Effective benefit is measured in terms of the time required to remediate 50% of the waste.

$$E_{10} = 1 - \frac{T_h}{T_{max}}$$

Th = The time in years to remediate 50 % of VI.

Tmax = The maximum time in years allowed for the remediation process.

Th = 4.2 ± 0.0 %

Tmax = 20 ± 0.0 %

Unweighted

E10 = 0.790 ± 0.0 %

General Categories

☒ Effectiveness	0.932	±	0.0	%
☐ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

Environ/Health

This score assesses the ability of the system to maintain a safe environment.

$$E_{11} = 1 - \frac{C_{is}}{C_m}$$

C_{is} = The total capital expenses which are "important-to-safety" items (\$k).
C_m = The total life-cycle cost (\$k).

C_{is} = 23900 ± 0.0 %

C_m = 511000 ± 0.0 %

Unweighted

E₁₁ = 0.953 ± 0.0 %

Performance Measures

☐ Volume Reduction	0.586	±	0.0	%
☐ Waste Generation	0.971		0.0	
☐ Compliance w/ARARs	1.000		0.0	
☐ Flexibility of Design	0.793		0.0	
☐ Reconfigurability	1.000		0.0	
☐ Robustness	1.000		0.0	
☐ Expected Lifetime	1.807		0.0	
☐ Availability	0.600		0.0	
☐ Throughput	0.757		0.0	
☐ Effective Benefit	0.790		0.0	
☒ Environ/Health	0.953		0.0	

☐ Data
☐ Weights
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Quit

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score: 0.843 ± 0.0 %				

☐ Data ☐ Weights Help New Quit

Technical Risk

This is assessed as the proportion of the system that uses proven or similar-to-proven technology under similar waste and site conditions.

$$I_1 = \frac{C_d + C_s}{F_t}$$

C_d = Number of subelements of demonstrated technologies.
 C_s = Number of subelements of similar-to-demonstrated technologies.
 F_t = Total number of subelements in a configuration option.

C_d =	34	±	0.0	%
C_s =	0		0.0	
F_t =	40		0.0	
Unweighted				
I₁ =	0.850	±	0.0	%

Performance Measures

☒ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

☐ Data ☐ Weights
Help New Quit

Non-carcinogenic Risk

This score assesses the ability of the system to maintain an environment free from non-carcinogenic risks.

$$I_2 = 1 - \frac{R_p}{R_{np}}$$

R_p = Hazard index with the process.

R_{np} = Hazard index without the process.

R_p =

1

±

0.0

%

R_{np} =

5

±

0.0

%

Unweighted

I₂ =

0.800

±

0.0

%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☒ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score: 0.843 ± 0.0 %				

☐ Data ☐ Weights
Help New Quit

Carcinogenic Risk

This score assesses the ability of the system to maintain an environment free from carcinogenic risks.

$$I_3 = 1 - \frac{R_{pc}}{R_{npc}}$$

R_{pc} = Cancer incidence with the process.

R_{npc} = Cancer Incidence without the process.

R_{pc} =

.000001

±

0.0

%

R_{npc} =

.000005

±

0.0

%

Unweighted

I₃ =

0.800

±

0.0

%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☒ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

☐ Data
 ☐ Weights

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score:
0.843
±
0.0
%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☒ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

System Implementability

The demonstrability of the system is assessed as the fraction of subelements not able to be demonstrated before full-scale implementation.

$$I_4 = 1 - \frac{C_n}{F_t}$$

C_n = Number of subelements in the configuration whose requirements are satisfied with technologies that are not able to be demonstrated prior to full-scale implementation.

F_t = Total number of subelements in the configuration.

C_n =

0

±

0.0

%

F_t =

40

±

0.0

%

Unweighted

I₄ =

1.000

±

0.0

%

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score:				
	0.843	±	0.0	%

☐ Data
 ☐ Weights

Site Conditions

This score is based on the fraction of subelements previously fielded and operated in a similar environment.

$$I_5 = \frac{C_d + C_s}{F_t}$$

C_d = Number of subelements of demonstrated technologies.
 C_s = Number of subelements of similar-to-demonstrated technologies.
 F_t = Total number of subelements in a configuration option.

C _d =	34	±	0.0	%
C _s =	0	±	0.0	%
F _t =	40	±	0.0	%
	Unweighted			
I ₅ =	0.850	±	0.0	%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☒ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

☐ Data
☐ Weights
Help
New
Quit

Permits

The number of permits required to perform remediation activities is an indication of regulatory complexity.

$$I_6 = \frac{1}{N_p + 1}$$

N_p = Estimated gross number of permits required to perform the remediation.

N_p = 8

Unweighted

I₆ = 0.111

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☒ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score:				
	0.843	±	0.0	%

☐ Data ☐ Weights
Help New Quit

Off-site Disposal

This score is a function of the fraction of waste that can be shipped off-site.

$$I_7 = 1 - \frac{W_{no}}{V_i}$$

W_{no} = Cubic meters of waste that cannot be moved to offsite disposal.

V_i = Cubic meters of waste matrix, overburden, and horizontal plume as defined in the system requirements.

W_{no} =

0

±

0.0

%

V_i =

341489

±

0.0

%

Unweighted

I₇ =

1.000

±

0.0

%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☒ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score: 0.843 ± 0.0 %

☐ Data
☐ Weights
Help
New
Quit

Automation

This score is a measure of the amount of automation in the system, and is the ratio of operation hours to labor hours.

$$I_8 = \frac{O}{L}$$

O = Hours of operation required for the remediation.

L = Total labor hours required to operate the remediation system.

O =

52250

±

0.0

%

L =

219450

±

0.0

%

Unweighted

$$I_8 = \text{0.238} \pm \text{0.0} \%$$

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☒ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

☐ Data
 ☐ Weights

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	

Final Score:
0.843
±
0.0
%

Training

This score is based on the mean years of specialized training required to operate the system.

$$I_g = \frac{Y_{ed}}{Y_{ref}}$$

Y_{ed} = The mean years of specialized training required to operate the remediation system.

Y_{ref} = The mean years of specialized training (academic and facility-specific) for the reference baseline technology option.

Y_{ed} =

2.8

±

0.0

%

Y_{ref} =

2.8

±

0.0

%

Unweighted

I_g =

1.000

±

0.0

%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☒ Training	1.000		0.0	
☐ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

☐ Data
☐ Weights

General Categories

☐ Effectiveness	0.932	±	0.0	%
☒ Implementability	0.745		0.0	
☐ Cost	0.850		0.0	
Final Score:	0.843	±	0.0	%

Performance Measures

☐ Technical Risk	0.850	±	0.0	%
☐ Non-carc Risk	0.800		0.0	
☐ Carcinogenic Risk	0.800		0.0	
☐ Sys Implementability	1.000		0.0	
☐ Site Conditions	0.850		0.0	
☐ Permits	0.111		0.0	
☐ Off-site Disposal	1.000		0.0	
☐ Automation	0.238		0.0	
☐ Training	1.000		0.0	
☒ Time to Demonstrate	0.900		0.0	
☐ Implementation Risk	0.650		0.0	

Time to Demonstrate

This score is measured as the critical path from initiation of design to initial operation at demonstration.

$$I_{10} = 1 - \frac{T_d}{T_{max}}$$

Td = Time in years until the system can be demonstrated.

Tmax = Maximum number of years allowed for the remediation process.

$T_d =$

 $±$

 $%$

$T_{max} =$

 $±$

 $%$

Unweighted

$I_{10} =$

 $±$

 $%$

General Categories			☐ Data ☐ Weights <input type="button" value="Help"/> <input type="button" value="New"/> <input type="button" value="Quit"/>		
☐ Effectiveness	0.932	±	0.0	%	<div style="border: 1px solid black; padding: 5px; text-align: center;"> Implementation Risk </div> <div style="border: 1px solid black; padding: 5px; text-align: center;"> This score is based upon the scheduled time from evaluation of design to the beginning of operation. </div> <div style="text-align: center; margin-top: 20px;"> $I_{11} = 1 - \frac{T_{br}}{T_{max}}$ </div> <div style="text-align: left; font-size: small;"> <p>T_{br} = Time in years it takes to build and begin operation of the remediation system.</p> <p>T_{max} = Maximum number of years allowed for the remediation process.</p> </div> <div style="margin-top: 20px;"> $T_{br} =$ <input style="width: 50px; text-align: center;" type="text" value="7"/> ± <input style="width: 50px; text-align: center;" type="text" value="0.0"/> % $T_{max} =$ <input style="width: 50px; text-align: center;" type="text" value="20"/> ± <input style="width: 50px; text-align: center;" type="text" value="0.0"/> % </div> <div style="text-align: center; margin-top: 10px;"> Unweighted $I_{11} =$ <input style="width: 50px; text-align: center;" type="text" value="0.650"/> ± <input style="width: 50px; text-align: center;" type="text" value="0.0"/> % </div>
☒ Implementability	0.745		0.0		
☐ Cost	0.850		0.0		
Final Score:			0.843	± 0.0 %	

Performance Measures		
☐ Technical Risk	0.850	± 0.0 %
☐ Non-carc Risk	0.800	0.0
☐ Carcinogenic Risk	0.800	0.0
☐ Sys Implementability	1.000	0.0
☐ Site Conditions	0.850	0.0
☐ Permits	0.111	0.0
☐ Off-site Disposal	1.000	0.0
☐ Automation	0.238	0.0
☐ Training	1.000	0.0
☐ Time to Demonstrate	0.900	0.0
☒ Implementation Risk	0.650	0.0

General Categories				☐ Data ☐ Weights <input type="button" value="Help"/> <input type="button" value="New"/> <input type="button" value="Quit"/>			
☐ Effectiveness	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.932</div>	±	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.0</div>	%			
☐ Implementability	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.745</div>	±	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.0</div>	%			
☒ Cost	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.850</div>	±	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.0</div>	%			
Final Score:		<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.843</div>	±	<div style="border: 1px solid black; display: inline-block; padding: 2px 10px;">0.0</div>	%		

Performance Measures ☒ Life Cycle <div style="display: inline-block; text-align: center;"> <div style="border: 1px solid black; padding: 2px 10px;">0.850</div> ± <div style="border: 1px solid black; padding: 2px 10px;">0.0</div> % </div>	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Life Cycle This score is a measure of the total cost of the system. </div> <div style="text-align: center; margin-bottom: 10px;"> $C_1 = 1 - K_c \frac{C_m}{V_i}$ </div> <p> <i>C_m</i> = Total life cycle cost (\$k). <i>V_i</i> = Cubic meters of waste matrix, overburden and horizontal plume as defined in the system requirements. <i>K_c</i> = Site-specific normalization constant. </p> <div style="margin-bottom: 10px;"> <i>C_m</i> = <div style="border: 1px solid black; padding: 2px 10px;">511000</div> ± <div style="border: 1px solid black; padding: 2px 10px;">0.0</div> % </div> <div style="margin-bottom: 10px;"> <i>V_i</i> = <div style="border: 1px solid black; padding: 2px 10px;">341489</div> ± <div style="border: 1px solid black; padding: 2px 10px;">0.0</div> % </div> <div style="margin-bottom: 10px;"> <i>K_c</i> = <div style="border: 1px solid black; padding: 2px 10px;">0.1</div> </div> <div style="text-align: center; margin-bottom: 10px;"> Unweighted </div> <div> <i>C₁</i> = <div style="border: 1px solid black; padding: 2px 10px;">0.850</div> ± <div style="border: 1px solid black; padding: 2px 10px;">0.0</div> % </div>
--	--

General Categories				☒ Data ☐ Weights Help New Quit			
☐ Effectiveness	0.932	±	0.0	%			
☐ Implementability	0.745	±	0.0	%			
☒ Cost	0.850	±	0.0	%			
Final Score:				0.843	±	0.0	%

Performance Measures				
☐ Life Cycle	0.850	±	0.0	%

Data #1				
A	=	0.60	±	0
C _d	=	34	±	0
C _{is}	=	23900	±	0
C _m	=	511000	±	0
C _n	=	0	±	0
C _s	=	0	±	0
E	=	1	±	0
E _{ref}	=	1	±	0
F _s	=	31.7	±	0
F _t	=	40	±	0
F _{ref}	=	40	±	0
Next Page				

General Categories				☒ Data ☐ Weights <input type="button" value="Help"/> <input type="button" value="New"/> <input type="button" value="Quit"/>	
☐ Effectiveness	0.932	±	0.0	%	
☐ Implementability	0.745		0.0		
☒ Cost	0.850		0.0		
Final Score:			0.843	±	0.0
%					

Performance Measures			
☐ Life Cycle	0.850	±	0.0
%			

Data #2			
K _c	=	0.1	
K _s	=	10000	
L	=	219450	± 0
N _{ref}	=	8	± 0
N _{os}	=	8	± 0
N _p	=	8	
O	=	52250	± 0
R _{np}	=	5	± 0
R _{npc}	=	.000005	± 0
R _p	=	1	± 0
R _{pc}	=	.000001	± 0
<input type="button" value="Previous Page"/>		<input type="button" value="Next Page"/>	

General Categories

☐ Effectiveness

0.932 ± 0.0 %

☐ Implementability

0.745 ± 0.0 %

☒ Cost

0.850 ± 0.0 %

Final Score:

0.843 ± 0.0 %

Performance Measures

☐ Life Cycle

0.850 ± 0.0 %

☒ Data
☐ Weights

Help

New

Quit

Data #3

T_{br} = 7 ± 0

T_d = 2 ± 0

T_h = 4.2 ± 0

T_l = 15 ± 0

T_{max} = 20 ± 0

T_r = 8.3 ± 0

V_g = 10000 ± 0

V_i = 341489 ± 0

V_o = 141391 ± 0

W_{no} = 0 ± 0

Y_{ed} = 28 ± 0

Y_{ref} = 28 ± 0

Previous Page

☐ Data ☒ Weights Help New Quit																																																							
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> <h3 style="text-align: center; margin: 0;">General Categories</h3> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">☐ Effectiveness</td> <td style="width: 20%; text-align: center; border: 1px solid black;">0.932</td> <td style="width: 10%; text-align: center;">±</td> <td style="width: 20%; text-align: center; border: 1px solid black;">0.0</td> <td style="width: 10%; text-align: right;">%</td> </tr> <tr> <td>☐ Implementability</td> <td style="text-align: center; border: 1px solid black;">0.745</td> <td></td> <td style="text-align: center; border: 1px solid black;">0.0</td> <td></td> </tr> <tr> <td>☒ Cost</td> <td style="text-align: center; border: 1px solid black;">0.850</td> <td></td> <td style="text-align: center; border: 1px solid black;">0.0</td> <td></td> </tr> </table> <div style="margin-top: 10px;"> Final Score: 0.843 ± 0.0 % </div> </div> <div style="border: 1px solid black; padding: 5px;"> <h3 style="text-align: center; margin: 0;">Performance Measures</h3> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;">☐ Life Cycle</td> <td style="width: 20%; text-align: center; border: 1px solid black;">0.850</td> <td style="width: 10%; text-align: center;">±</td> <td style="width: 20%; text-align: center; border: 1px solid black;">0.0</td> <td style="width: 10%; text-align: right;">%</td> </tr> </table> </div>				☐ Effectiveness	0.932	±	0.0	%	☐ Implementability	0.745		0.0		☒ Cost	0.850		0.0		☐ Life Cycle	0.850	±	0.0	%																																
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☒ Cost	0.850		0.0																																																				
☐ Life Cycle	0.850	±	0.0	%																																																			
<div style="border: 1px solid black; padding: 5px;"> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;">Effectiveness: _____</td> <td style="width: 20%; text-align: right;">1</td> </tr> <tr><td>Volume Reduction:</td><td style="text-align: right;">1</td></tr> <tr><td>Waste Generation:</td><td style="text-align: right;">1</td></tr> <tr><td>ARAR Compliance:</td><td style="text-align: right;">1</td></tr> <tr><td>Flexibility of Design:</td><td style="text-align: right;">1</td></tr> <tr><td>Reconfigurability:</td><td style="text-align: right;">1</td></tr> <tr><td>Robustness:</td><td style="text-align: right;">1</td></tr> <tr><td>Expected Lifetime:</td><td style="text-align: right;">1</td></tr> <tr><td>Availability:</td><td style="text-align: right;">1</td></tr> <tr><td>Throughput:</td><td style="text-align: right;">1</td></tr> <tr><td>Effective Benefit:</td><td style="text-align: right;">1</td></tr> <tr><td>Environ/Health:</td><td style="text-align: right;">1</td></tr> <tr> <td>Implementability: _____</td> <td style="text-align: right;">1</td> </tr> <tr><td>Technical Risk:</td><td style="text-align: right;">1</td></tr> <tr><td>Non-Carcinogenic Risk:</td><td style="text-align: right;">1</td></tr> <tr><td>Carcinogenic Risk:</td><td style="text-align: right;">1</td></tr> <tr><td>System Implementability:</td><td style="text-align: right;">1</td></tr> <tr><td>Site Conditions:</td><td style="text-align: right;">1</td></tr> <tr><td>Permits:</td><td style="text-align: right;">1</td></tr> <tr><td>Off-site Disposal:</td><td style="text-align: right;">1</td></tr> <tr><td>Automation:</td><td style="text-align: right;">1</td></tr> <tr><td>Training:</td><td style="text-align: right;">1</td></tr> <tr><td>Time to Demonstrate:</td><td style="text-align: right;">1</td></tr> <tr><td>Implementation Risk:</td><td style="text-align: right;">1</td></tr> <tr> <td>Cost: _____</td> <td style="text-align: right;">1</td> </tr> <tr><td>Life Cycle:</td><td style="text-align: right;">1</td></tr> </table> </div>				Effectiveness: _____	1	Volume Reduction:	1	Waste Generation:	1	ARAR Compliance:	1	Flexibility of Design:	1	Reconfigurability:	1	Robustness:	1	Expected Lifetime:	1	Availability:	1	Throughput:	1	Effective Benefit:	1	Environ/Health:	1	Implementability: _____	1	Technical Risk:	1	Non-Carcinogenic Risk:	1	Carcinogenic Risk:	1	System Implementability:	1	Site Conditions:	1	Permits:	1	Off-site Disposal:	1	Automation:	1	Training:	1	Time to Demonstrate:	1	Implementation Risk:	1	Cost: _____	1	Life Cycle:	1
Effectiveness: _____	1																																																						
Volume Reduction:	1																																																						
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Robustness:	1																																																						
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Environ/Health:	1																																																						
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Training:	1																																																						
Time to Demonstrate:	1																																																						
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Cost: _____	1																																																						
Life Cycle:	1																																																						

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Appendix A

INEL OU 7-13 Waste Pit and Trench Characteristics Tables

Table A-1. Excavation details for selected trenches at the SDA.

Trench no.	Mean surface elevation (ft)	Mean basalt surface elevation (ft)	Average estimated overburden (ft)	Estimated excavated depth ^a (ft)	Estimated width (ft)	Estimated length (ft)	Surface area (ft ²)	Excavated volume (ft ³)
1	5,012.9	4997	3.8	10.1	7	1149	8043	81,243
2	5,012.1	4993	4.0	13.1	6	1106	6636	86,932
3	5,012.6	4993	4.0	13.6	6	1111	6666	90,658
4	5,013.0	4993	4.0	14.0	6	1117	6702	93,828
5	5,013.6	4997	3.8	14.6	6.6	1166	7696	112,362
6	5,012.7	4993	4.0	13.7	6	1119	6714	91,982
7	5,014.2	4997	3.8	11.4	6.6	1161	7656	87,278
8	5,013.1	4993	4.0	14.1	6	1120	6720	97,752
9	5,013.8	4997	3.8	11.0	6.6	1152	7603	83,633
10	5,012.6	4993	4.0	13.6	6	1121	6726	91,474

a. The excavated depth was calculated by taking the difference between the surface and basalt elevations. From this value, the estimated overburden was subtracted out. Finally, an additional 2 ft (1 ft for basalt overburden and 1 ft for depth of buried waste from original surface elevation) were subtracted out.

Table A-2. Various physical characteristics of soil and sediment samples from the RWMC wells.

Well no.	Depth interval		Specific gravity	Bulk density (g/cm ³)	Porosity (percent)	Moisture content (percent)	Vertical hydraulic conduct (m/day)
	Top	Bottom					
92	2 ft 6 in.	5 ft	2.65	1.87	34.3	12.9	5.5×10^{-4}
94	6 ft 6 in.	8 ft 3 in.	2.67	2.02	30.5	16.4	2.7×10^{-4}
95	10 ft	12 ft 6 in.	2.66	1.70	41.0	13.2	7.9×10^{-3}

Table A-3. Properties of soil and sediment samples from the RWMC wells.

Well no.	Depth Interval		Particle size distribution (%) ^a			Clay minerals (%) moisture			Cation exchange capacity (meg/100 g)
	Top	Bottom	Clay	Silt	Sand	Kaolinite	Illite	Montmorillonite	
92	2 ft 6 in.	5 ft	21.2	48.8	30.1	2	5	5	14
94	6 ft 6 in.	8 ft 3 in.	38.7	56.5	4.8	3	9	4	23
95	10 ft	12 ft 6 in.	38.5	55.6	5.9	1	4	3	17
Median ^b			35.3	56.0	7.3	2	7	6	21

a. Clay <0.004 mm
Silt 0.004 - 0.062 mm
Sand 0.062 - <2.00 mm.

b. Median of eight samples.

Table A-4. Particle size distribution for subpit samples (in percent of analyzed sample).^a

Sample ^b no.	Depth (m)	Clay <0.004 mm	Silt 0.004- 0.0625 mm	Sand very fine 0.0625- 0.125 mm	Sand fine 0.125- 0.25 mm	Sand medium 0.25-0.5 mm	Sand ^c coarse 0.5-1 mm
EWR-1-4	0.91	53.3	38.5	4.8	2.3	0.9	0.1
EWR-1-3	1.22	41.0	30.1	11.0	17.7	0.2	0
EWR-1-2	1.52	54.7	40.1	4.1	0.7	0.2	0.1
EWR-1-1	1.83	23.5	69.8	6.0	0.6	0	0.1

a. Analyzed by the USGS Hydrologic Laboratory, Denver, Colorado.

b. All samples from surficial deposits.

c. No particles coarser than 1 mm observed.

Table A-5. Mineralogy for subpit samples (in percent of analyzed sample).^a

Sample ^b no.	Depth (m)	Quartz	Potassium feldspar	Plagioclase	Calcite	Pryoxene dioxide	Clay minerals	Total percent
EWR-1-4	0.91	27	≤5	11	1	4	70	113+ ^c
EWR-1-3	1.22	29	≤6	10	0	9	55	103+
EWR-1-2	1.52	15	≤3	6	41	≤9	25	87+
EWR-1-1	1.83	29	5	12	13	≤9	40	99+

a. Analyzed by the USGS Hydrologic Laboratory, Denver, Colorado.

b. All samples from surficial deposits.

c. Due to high percentage of clay minerals.

Table A-6. Clay mineralogy of selected surficial sediment samples (in percent of total clay minerals/percent of original bulk samples).^a

Sample	Depth (m)	Chlorite	Illite	Mixed layer clays (illite/smectite)	Smectite	Kaolinite	Cation exchange capacity ^b	Carbonate content (CaCO ₃) percent
EW-1-4	0.91	0/03	6/25	45/32	13/9	6/4	27	0
EW-1-3	1.22	0/03	0/16	48/26	15/9	6/3	27	2.3
EW-1-2	1.52	0/03	6/9	31/8	24/6	9/2	11	36.1
EW-1-1	1.83	0/03	2/12	30/12	26/10	12/5	11	10.8

a. Analyzed by the USGS Hydrologic Laboratory, Denver, Colorado.

b. In milliequivalents per 100 g.

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