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Annual Status Update for OWL

Spent Fuel and Waste Disposition

Prepared for
U.S. DOE
Spent Fuel and Waste
Science and Technology

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Sandia National Laboratories

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APPENDIX E
NFCSC DOCUMENT COVER SHEET[1]

Name/Title of Deliverable/Milestone/Revision No. Annual Status Update for OWL / M2SF-22SN010309082 / Rev: initial (00)

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(Name/Signature)

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Quality Rigor Level for Deliverable/Milestone[2]	☐ QRL-1 ☐ Nuclear Data	☐ QRL-2	☒ QRL-3	☐ QRL-4 Lab QA Program[3]

This deliverable was prepared in accordance with Sandia National Laboratories
(Participant/National Laboratory Name)

QA program which meets the requirements of

☒ DOE Order 414.1 ☐ NQA-1 ☐ Other

This Deliverable was subjected to:

☒ Technical Review ☐ Peer Review

Technical Review (TR)
Review Documentation Provided
☐ Signed TR Report or,
☐ Signed TR Concurrence Sheet or,
☒ Signature of TR Reviewer(s) below

Peer Review (PR)
Review Documentation Provided
☐ Signed PR Report or,
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Name and Signature of Reviewers
Teklu Hadgu (SNL) *Teklu Hadgu*

NOTE 1: *Appendix E should be filled out and submitted with the deliverable. Or, if the PICS:NE system permits, completely enter all applicable information in the PICS:NE Deliverable Form. The requirement is to ensure that all applicable information is entered either in the PICS:NE system or by using the NFCSC Document Cover Sheet.*

- *In some cases there may be a milestone where an item is being fabricated, maintenance is being performed on a facility, or a document is being issued through a formal document control process where it specifically calls out a formal review of the document. In these cases, documentation (e.g., inspection report, maintenance request, work planning package documentation or the documented review of the issued document through the document control process) of the completion of the activity, along with the Document Cover Sheet, is sufficient to demonstrate achieving the milestone.*

NOTE 2: *If QRL 1, 2, or 3 is not assigned, then the QRL 4 box must be checked, and the work is understood to be performed using laboratory QA requirements. This includes any deliverable developed in conformance with the respective National Laboratory / Participant, DOE or NNSA-approved QA Program.*

NOTE 3: *If the lab has an NQA-1 program and the work to be conducted requires an NQA-1 program, then the QRL-1 box must be checked in the work Package and on the Appendix E cover sheet and the work must be performed in accordance with the Lab's NQA-1 program. The QRL-4 box should not be checked.*

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ACKNOWLEDGEMENTS

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ACRONYMS

ASTM	American Society for Testing and Materials
BWR	boiling water reactor
C.E.	common era
CoC	Certificate of Compliance
dbo schema	database owner schema
dev schema	development schema
DHLW	DOE-managed (as) high-level radioactive waste
DOE	U.S. Department of Energy
DOE-EM	DOE Office of Environmental Management
DOE-NE	DOE Office of Nuclear Energy
DOT	U.S. Department of Transportation
DSNF	DOE-managed spent nuclear fuel
EBR-II	Experimental Breeder Reactor II
ECN	External Collaboration Network
EMT	electrometallurgical treatment
ER	electrorefiner
FFTF	Fast Flux Test (Reactor) Facility
FRG	Federal Republic of Germany
FYxxxx	fiscal year xxxx (four-digit year)
GDSA	geologic disposal safety assessment
HIP	hot isostatic press (ed/ing)
HLW	high-level radioactive waste
INL	Idaho National Laboratory
ISO	International Standards Organization
LWR	light water reactor
MOX	mixed oxide (fuel)
MS	Microsoft
NA	not applicable
NAC	Nuclear Assurance Corporation

n.d.	no date; used for references for which no date is available
NWTRB	Nuclear Waste Technical Review Board
NQA-1	Nuclear Quality Assurance-1
NRC	U.S. Nuclear Regulatory Commission
OUO	official use only
OWL	Online Waste Library
PA	performance assessment
PWR	pressurized water reactor
QA	quality assurance
R&A	review and approval
RAMPAC	RAdioactive Materials PACkages
RCRA	Resource Conservation and Recovery Act
ROD	Record of Decision
SAND	Sandia National Laboratories report
SFWST	Spent Fuel & Waste Science and Technology
SFDB	Spent Fuel Database
SNF	spent nuclear fuel
SNL	Sandia National Laboratories
SQL	Structured Query Language
SRN	Sandia Restricted Network
SRS	Savannah River Site
SSRS	SQL Server Reporting Services
TAD	transportation, aging, and disposal
TMI	Three Mile Island
TRIGA	Training Research Isotopes–General Atomics
TRISO	tristructural-isotropic
TRU	transuranic
TSPA	total system performance assessment
UNF	used nuclear fuel
UNF-ST&DARDS	Used Nuclear Fuel-Storage, Transportation & Disposal Analysis Resource and Data Systems
U.S.	United States
UUR	unclassified unlimited release

WFDOE	Waste Form Disposal Options Evaluation
WIPP	Waste Isolation Pilot Plant
YM SAR	Yucca Mountain Safety Analysis Report

Selected Units

Bq	becquerel
ft	foot
GWd	gigawatt·days
in.	inch
lb	pound
MTU	metric ton of uranium

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SPENT FUEL AND WASTE DISPOSITION STATUS OF OWL UPDATES

1. INTRODUCTION

This report represents completion of milestone deliverable M2SF-22SN010309082 *Annual Status Update for OWL*, which is due on November 30, 2021 as part of the fiscal year 2022 (FY2022) work package SF-22SN01030908. This report provides an annual update on status of FY2021 activities for the work package "OWL - Inventory – SNL". The Online Waste Library (OWL) has been designed to contain information regarding United States (U.S.) Department of Energy (DOE)-managed (as) high-level waste (DHLW), DOE-managed spent nuclear fuel (DSNF), and other wastes that are likely candidates for deep geologic disposal. Links to the current supporting documents for the data are provided when possible; however, no classified or official-use-only (OUO) data are planned to be included in OWL. There may be up to several hundred different DOE-managed wastes that are likely to require deep geologic disposal. This report contains new information on sodium-bonded spent fuel waste types and wastes forms, which are included in the next release of OWL, Version 3.0, on the Sandia National Laboratories (SNL) External Collaboration Network (ECN). The report also provides an update on the effort to include information regarding the types of vessels capable of disposing of DOE-managed waste.

In FY2021, the primary tasks consisted of (1) using the lessons learned from the release of OWL Version 2.0 to finalize the change control and release processes, (2) collecting and adding information regarding sodium-bonded spent fuel waste types and wastes forms to OWL, and (3) advancing the effort to add new information on the types of vessels capable of disposing of DOE-managed waste to OWL. The results of the first task are documented in *OWL Change Control Process* (Weck et al. 2021c) and *OWL Release Process* (Weck et al. 2021b). The results of the second task are included in OWL Version 3.0.

The third task above is part of the ongoing multiyear expansion activities for OWL planned for continuation in FY2022 and beyond. OWL will be augmented to include data sets for available vessels (e.g., cans, canisters, casks, waste packages). The types of information being compiled include dimensional characteristics (inner and outer), weights, regulatory certification for usage, waste types and waste forms that could potentially utilize these vessels, material properties of the vessels as appropriate, etc. These data sets will be incorporated in much the same manner as the data for the waste types and waste forms currently included in OWL.

Other planned expansion activities support a goal of giving OWL the ability to generate turn-key inventory-related output files according to end-user specifications such that the resulting files are ready for use as input for postclosure performance simulations. In particular, new OWL features and capabilities will be developed to facilitate active integration with the geologic disposal safety assessment (GDSA) computational framework. GDSA is itself evolving as the GDSA team builds its capability as a postclosure safety performance assessment (PA) tool. The new OWL features for GDSA support will likely include an automated interface for users to define a desired inventory and/or other information for input parameter files through selection of options such as (1) the desired wastes/waste forms, (2) the specific waste package or other vessel from appropriate possibilities, and (3) the year/date of the inventory. Once the selections are made, OWL would then generate one or more downloadable files in the desired format to provide input parameters for GDSA use. Preliminary discussions with the GDSA team began in FY2021 to start setting the stage for continued cooperation in FY2022 and beyond. The potential for other teams utilizing software codes for other purposes (e.g., codes for process modeling outside of the GDSA framework or for storage/transportation systems assessments) to benefit from similar integration efforts will also be explored in the future.

While the OWL database is the focus of this annual status update report, it does not attempt to reproduce the OWL content in the current public release. Section 1 provides introductory information on the OWL purpose, scope, and work package history as well as back ground information on key definitions, the waste types and waste forms included in OWL, and the OWL architecture and components. The status update itself is located in Section 2, which describes advances in the development of the OWL database structure and content, including changes implemented in the new public release (Version 3.0) as well as the ongoing expansion effort to include vessel information in OWL. Other topics addressed in Section 2 include the finalization of processes governing changes to the database and the release of new database versions, preliminary work to develop new OWL features to support GDSA, and the potential integration of information from other databases. Section 3 provides a summary of the report. Appendix A presents an example of how the change control processes are being used to govern the work on adding vessel-related information to OWL along with some specific examples of candidate vessels identified through data mining. The *OWL User's Guide* (SNL 2021), which includes a change history of the database, is reproduced in Appendix B.

1.1 OWL Purpose, Scope, and Work Package History

In 2014, SNL led an analysis of the disposal of both commercial spent nuclear fuel (SNF) and DHLW and DSNF in the variety of disposal concepts being evaluated within the previous Used Fuel Disposition Campaign and generated a report titled *Evaluation of Options for Permanent Geologic Disposal of Used Nuclear Fuel and High-Level Radioactive Waste Inventory in Support of a Comprehensive National Nuclear Fuel Cycle Strategy* (SNL 2014). For convenience, that report is referred to herein as the WFDOE, an acronym for *Waste Form Disposal Options Evaluation*. That Used Fuel Disposition Campaign work covered a comprehensive inventory and a wide range of disposal concepts and provided the impetus for developing the OWL database and for evaluating waste form characteristics. These two activities—developing the OWL database and evaluating of waste form characteristics—were part of the same work package until FY2021. The two activities were considered complementary because evaluation of waste characteristics includes assessing the inventory data and ensuring information exists for disposal-relevant radionuclides. However, as work on the two activities evolved, the decision was made to separate them. January of 2021 marked publication of the last combined report, *Annual Status Update for OWL and Waste Form Characteristics* (Weck et al. 2021a), which addressed FY2020 activities. This current annual status report documenting FY2021 activities under the work package "OWL - Inventory – SNL" is focused solely on the OWL database.

The FY2021 activities related to the evaluation of waste forms were conducted under the work package SF-21SN01030902 "Waste Form Testing, Modeling, and Performance – SNL". The first progress report (milestone deliverable M4SF-21SN010309021 *Modeling Activities Related to Waste Form Degradation: Progress Report*) was released on June 30, 2021 (Jove-Colon et al. 2021).

The remainder of this subsection presents the purpose and scope of the OWL database as well as a summary of the work package history from its inception in FY2016 to FY2020, the last year the OWL database and waste form evaluation activities were combined.

Purpose of the OWL Database—The purpose of OWL is two-fold. The first purpose is to provide a consolidated single source of information on the many different DOE-managed radioactive wastes that are likely to require deep geologic disposal, such that one can easily query the data. The second purpose is to provide input parameter files with relevant information on waste types, inventory, waste form characteristics, vessels, etc. for PA analyses in the context of the GDSA framework. Much progress has already been made on fulfilling the first purpose, given that OWL was publicly released in FY2019 and afterwards entered the cycle of having improvements made for new releases. The second purpose of being able to support GDSA with input parameter files is a work in progress.

Scope of the OWL Database—The OWL database itself provides the documentation and delivery of the full array of information/data for the waste types and potential waste forms for use in GDSA evaluations for generic repository analyses. The scope of the inventory information included in OWL covers DSNF and DHLW, both of which are currently planned for disposal in a deep geologic repository. Note that the DHLW includes wastes that may be dispositioned in the future with a waste classification different than high-level radioactive waste (HLW), a possibility that would perhaps entail a different disposal pathway. In the future, the scope of database content will also include vessel-related information.

OWL Work Package History (FY2016–FY2020)—As stated above, the OWL work package previously included development of the OWL database plus the evaluation of waste form characteristics. Some highlights of the work done between FY2016 and FY2020 appear below.

The initial effort on the work package was documented in *The On-line Waste Library (OWL): Usage and Inventory Status Report* (Sassani et al. 2016). This report provided the initial development status including (1) development of the preliminary inventory for engineering/design/safety analyses, (2) assessment of the major differences of this included inventory relative to that in other analyzed repository systems and the potential impacts to disposal concepts, and (3) the initial design and development of the prototype version of OWL to manage the information of all those wastes and their waste forms. In addition, Sassani et al. (2016) reported on the identification of potential candidate waste types and waste forms that might be added to OWL in the future to the full list from the WFDOE (SNL 2014, Table C-1).

Sassani et al. (2016) also discussed the Wilson (2016) preliminary inventory for initial GDSA analyses. That inventory includes both DHLW and DSNF waste canister counts and thermal information (Wilson 2016, Tables 2-1 and 2-3 to 2-6). The Wilson (2016) report describes each waste form in terms of both average radionuclide content and average thermal output evolution. The tabulation includes canister counts and ranges of thermal characteristics for each DHLW and DSNF waste form considered (Wilson 2016). The various types of DSNF are listed in Appendix A of Sassani et al. (2016, 2017) for the ~2,485 DSNF canisters (Wilson 2016, Table 2-1). The DHLW canister counts are given in Wilson (2016) in Tables 2-3 through 2-6, respectively, for Savannah River Site (SRS) glass (7,824 canisters), Hanford glass (11,800 canisters), Idaho National Laboratory (INL) hot isostatic pressed (HIP) calcine (4,391 canisters), and additional Hanford glass from vitrifying the contents of the Cs and Sr capsules (340 canisters; also SNL 2014).

Sassani et al. (2017) provided an update to Sassani et al. (2016) and included the following:

- An updated set of inputs (Sassani et al. 2017, Section 2.3) on various additional waste forms covering both DSNF and DHLW for use in the inventory represented in the GDSA analyses
- Summaries of evaluations initiated to refine specific characteristics of a particular waste form for future use (Sassani et al. 2017, Section 2.4)
- Updated development status of the OWL database (Sassani et al. 2017, Section 3.1.2) and an updated user guide to OWL (Sassani et al. 2017, Section 3.1.3)
- Status updates (Sassani et al. 2017, Section 3.2) for the OWL inventory content, data-entry checking process, and external OWL beta testing initiated in FY2017

Sassani et al. (2017) updated the preliminary FY2016 inventory by adding the additional possible waste forms (DOE 2014) not previously included in GDSA representations, for which GDSA evaluation of thermal or radionuclide inventory aspects may be somewhat expanded compared to the previous analyses. Specifically, this expansion included the following:

- The 340 canisters of glass from vitrifying the contents of the Cs and Sr capsules at Hanford (Wilson 2016, Table 2-6)
- The 34 canisters of Hanford Federal Republic of Germany (FRG) glass, which has been designated as remote-handled transuranic (TRU) waste (Bounini and Anderson 2000), though it may be disposed in a deep geologic repository with other heat-producing waste
- The planned waste form for calcine waste, which is a HIP waste form (glass ceramic), with ~10 HIP cans loaded/stacked into naval canisters for a total of ~320 canisters (~5.5 ft diameter × ~15 ft height naval canisters/waste packages containing ~10 HIP cans each; SNL 2014)

Although most of these updates are relatively small from the standpoint of inventory mass, they may have implications for analyses of thermal effects. The reason is that some of these added wastes tend to have higher average thermal loads per canister than the inventory previously evaluated in GDSA. Additionally, some of these waste forms represent larger waste packages, which may expand handling and emplacement considerations (e.g., planned calcine HIP waste form waste packages).

In Sassani et al. (2017), a number of questions regarding the characteristics of various waste forms led to three studies on waste form characteristics details. The first study assessed the potential sinks for ^{129}I in the various processes at the SRS that form the HLW glass and estimated the ^{129}I content of the SRS glass. The second study assessed the quantity of ^{135}Cs contained in the Cs capsules and in the FRG glass at Hanford. Estimates of the quantities of ^{135}Cs and ^{129}I are documented in Price (2018) and Savannah River Remediation (2018), respectively. The third study validated characteristic isotopic ratios for various waste forms included in postclosure performance studies. This aspect arose because of questions regarding the relative contributions of radionuclides from disparate waste forms in GDSA results, particularly radionuclide contributions of DSNF versus DHLW glass.

Sassani et al. (2017) reported on the OWL database updates in three areas. First, additional data for waste types (and their potential waste forms) and source documentation were added to OWL to flesh out its content covering DHLW and SNF. Second, in conjunction with further data entry, a process of checking the data entered into OWL against the source documentation was launched to search for and rectify any errors in data entry. This checking was performed by technical individuals independent of the data-entry process. These individuals documented any issues noted and resolved the issues with the data-entry staff. Third, because OWL was modified throughout the year in terms of its interface and features, another process to assess the usability of OWL was completed. This process consisted of an external OWL beta test involving technical staff from within the DOE Office of Nuclear Energy (DOE-NE) and DOE Office of Environmental Management (DOE-EM), as well as at other national laboratories, using OWL. Feedback on the utility and content of OWL was provided.

In FY2018, the OWL team pursued three studies to evaluate/redefine waste form characteristics and/or performance models (Sassani et al. 2018). The first study evaluated characteristic isotopic ratios for various waste forms included in postclosure performance studies to delineate isotope ratio tags that may quantitatively identify each waste form. In the second study, the team evaluated the basis for using the glass waste degradation rate models to simulate degradation of the HIP calcine waste form. The third study is an investigation of the performance behavior of tristructural-isotropic (TRISO) particle fuels. The effort includes development of a stochastic model for the degradation of those fuels that accounts for simultaneous corrosion of the silicon carbide (SiC) layer and the radionuclide diffusion through it.

In FY2019 activities included evaluations of waste form characteristics and waste form performance models, updates to the OWL development, and overview descriptions of the management processes for OWL (Sassani et al. 2019). Those updates to OWL included an updated user’s guide, additions to the OWL database content for waste types and waste forms, changes implemented as a result of the beta testing. The first public release of OWL (Version 1.0) occurred in FY2019. In addition, work began on developing methods for interfacing with the DOE SNF Database (DOE 2007) at INL on the numerous entries for DOE-managed SNF (DSNF). This effort involved defining preliminary data exchanges to facilitate future testing of integration protocols. The INL database is also sometimes referred to as the Spent Fuel Database or the SFDB, which is the acronym that will be used in this report.

FY2019 also marked the start of work on change control and release management processes for OWL development, version control, and archiving to ensure configuration management of the database after the initial release. This work became one of two focus areas for FY2020 OWL database activities. The other focus area was the preparation OWL Version 2.0, which was publicly released in November of 2020. As mentioned above, the lessons learned on Version 2.0 were used to finalize and document those processes in two reports (Weck et al. 2021b, 2021c). These two reports were reproduced in appendices of the FY2020 M2 annual status milestone report (Weck et al. 2021a), which was originally planned for November 2020 but was released in January 2021. These processes are also discussed in Section 2.3.

Besides the FY2020 activities to update the OWL database, Weck et al. (2021a) also documented the FY2020 activities with respect to the evaluation of waste form characteristics. Section 3.3.2.6 of Weck et al. (2021a) summarized work performed to understand better the Stage-III (higher) glass degradation rates due to transitions from steady state degradation rates (i.e., from the lower Stage-II rates). This effort included evaluating the glass degradation data sets in terms of fluid compositional evolution and changes to secondary phase formation. As mentioned previously, FY 2020 marked the last year that the OWL database and the evaluation of waste form characteristics were combined in a single work package, the result being that Weck et al. (2021a) is the last combined report.

1.2 Background Information

For convenience, a list of key definitions for this report is presented in Section 1.2.1. Section 1.2.2 briefly introduces the OWL architecture and components, including the three OWL environments hosting three different versions of OWL. Each version of OWL has multiple components including a database and SharePoint site. This information is important to the status update discussions in Section 2.

1.2.1 Key Definitions

The following key definitions clarify the meaning of certain terms that are used in a specific manner within OWL and this status report. These terms may or may not be defined in the same manner in other reports cited herein.

Waste Type—The currently existing materials (in whatever form, abundance, and location they occupy) that either are or will be processed into some waste form to be disposed of in a deep geologic repository. Some waste types may have more than one possible waste form depending on the processing needed prior to disposal, whereas waste types that require no processing other than packaging may equate to a single waste form. In this report and in the OWL database, the waste type is sometimes referred to more simply as the "waste", a usage that is still distinguishable from the "waste form" or "disposal form".

Waste Form—The end-state material, as packaged, that is to be disposed of in a deep geologic repository. Examples include commercial SNF and HLW glass. For this report, a vessel that cannot be separated easily from the waste form is considered to be part of the waste form. For instance, a glass pour canister is essential for making the glass waste form. The HLW glass is poured into the canister; the canister is not removed easily and it is not intended to contain other waste forms or waste types. Therefore, the glass pour canister is considered part of the waste form.

Vessel—A canister, container, cask, overpack, etc. that can serve as a single layer in a nested system designed to surround and contain[a] the waste form for the purposes of storage, transportation, and/or disposal.

Waste Group—A set of waste forms with similar disposal characteristics such as expected postclosure degradation behavior; radionuclide inventory; thermal output; physical dimensions; chemical reactivity; packaging of the waste form; and safeguards and security needed for handling, transporting, and disposing of the waste form in the context of the disposal concepts. The groupings referred to in this report are consistent with the ten groups defined in WFDOE (SNL 2014) and discussed further in Section 2.4.

[a] Unless stated otherwise in this report, "to contain" something means "to hold" it. The term does not imply containment in the regulatory sense, e.g., the definition provided by transportation regulations in 10 CFR 71: "*Containment system* means the assembly of components of the packaging intended to retain radioactive material during transport."

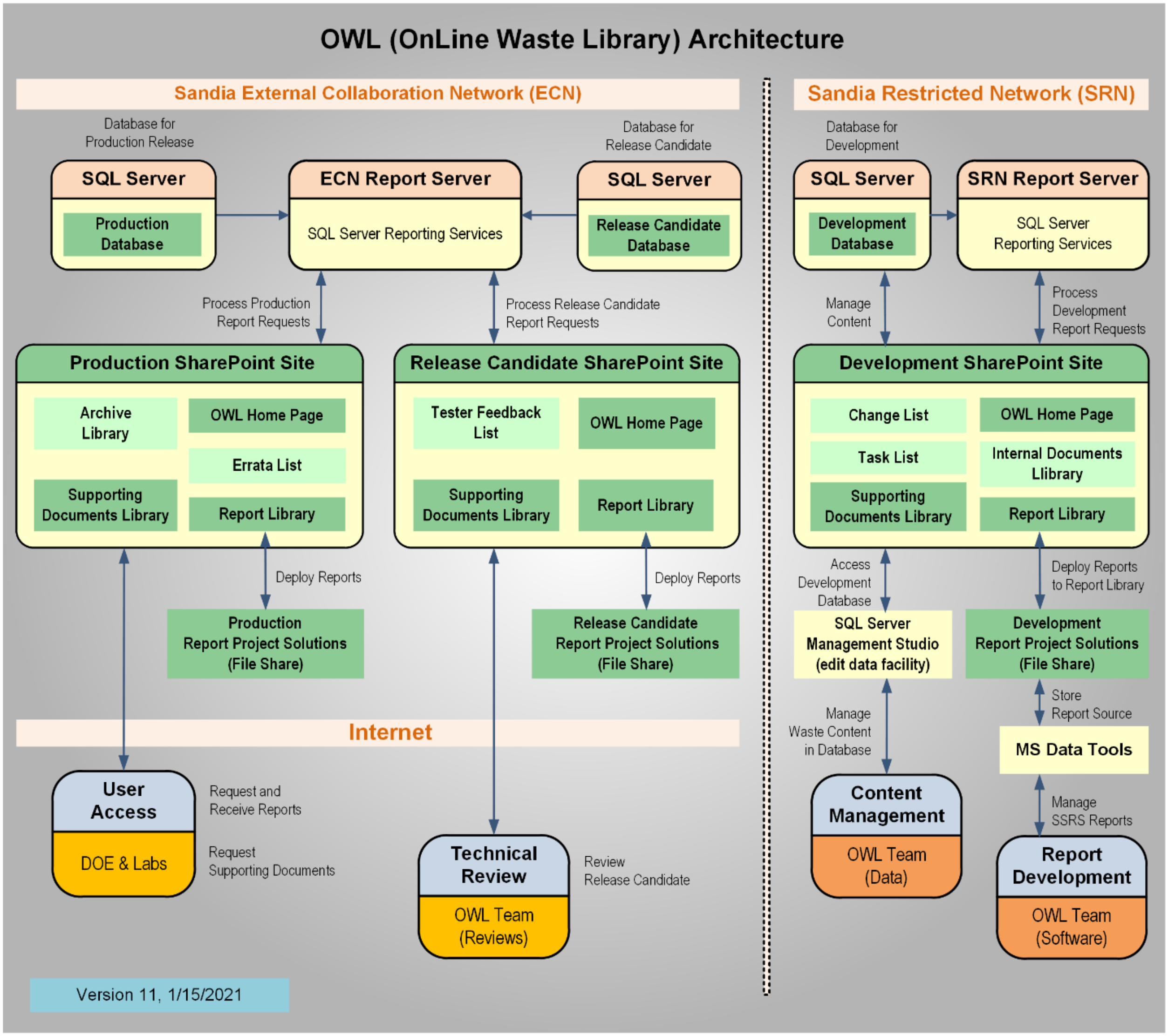
1.2.2 OWL Architecture and Components

OWL development was guided by the SNL software development methodology documented on an internal SNL wiki site (Lane 2017). This methodology provides requirements for software documentation and version control, user access, and archival of system components. A key feature of this methodology is the use of multiple environments for developing software systems.

Depicted in Figure 1-1, the OWL architecture consists of three versions of OWL residing in three different environments. To the right of the figure is the development version of OWL, which resides in the Development Environment on the Sandia Restricted Network (SRN). The Development Environment is where all modifications to OWL originate except those that must be implemented directly to the Production SharePoint Site. Examples of possible modifications include database content changes, structural changes to tables, the addition or revision of supporting documents, the addition or revision of stored calculation tools, and the addition or revision of database reports. The middle of Figure 1-1 shows the release candidate version of OWL, which resides in the Release Candidate Environment on the ECN. Finally, the production release version, which resides in the Production Environment on the ECN, is seen to the left.

Figure 1-1 also illustrates how users and developers access the different versions of OWL. The development version of OWL is available only to the OWL team, which has access to the SRN. The release candidate is available to the OWL team as well as any person participating in the independent technical review. Because the release candidate is hosted on the ECN, which is available through the internet, access can be granted to technical reviewers from SNL, other national laboratories, or DOE. ECN access requires coordination with SNL for the creation of an ECN account with a username and password. In addition, because SharePoint provides the user interface, the appropriate SharePoint permission level must be granted by adding the new user to the OWL Visitors group. Once permission is granted, a link to the SharePoint site is sent to the new user. The ECN also hosts the production version of OWL, which is a public release with an unclassified unlimited release (UUR) designation. Users from DOE or one of the national laboratories do not need anything for access beyond an ECN account and assignment of the appropriate SharePoint permission level.

The OWL components existing in each environment are displayed in Figure 1-1. Each OWL environment contains a database and SharePoint site, both named according to the applicable environment, as well as other components. There are two types of system components: (1) major components (darker green shading) common to all environments such as the database and SharePoint site, and (2) local components specific to the particular environment. Further information on the system components is provided in Weck et al. (2021b, 2021c). The processes used to develop and release OWL are discussed in more detail in Section 2.3 as well as Weck et al. (2021b, 2021c).



NOTE: Darker green shade indicates an OWL major component; lighter green shade indicates an OWL local component.
MS = Microsoft
SQL = Structured Query Language
SSRS = SQL Server Reporting Services

Figure 1-1. High-level Architecture of OWL showing the Three Versions Existing within the Development, Release Candidate, and Production Environments

2. MANAGING INVENTORY DATA AND SUPPORTING POSTCLOSURE PERFORMANCE ASSESSMENTS

In FY2016, the first OWL prototype was created with restricted access on the internal SNL network. A year later (FY2017), the OWL was moved to an external interface for beta testing by limited DOE and national laboratory staff. The first public release of OWL (Version 1.0) occurred in FY2019 on the SNL ECN. With the release of Version 1.0, efforts widened to include not only the development of new capabilities and features of OWL, but also the maintenance and configuration control of OWL as seen and used by the public (i.e., the OWL version in the Production Environment). In FY2020, work began on developing two complementary processes: a change control process and a release process. Version 2.0 of OWL was released in late FY2020, becoming a practical test of the draft processes. On the basis of the lessons learned, the OWL team finalized the two processes in early FY2021 (Weck et al. 2021b, 2021c). Released in November 2021, the current version of OWL (Version 3.0) was modified to add sodium-bonded spent fuel, correct a minor error with the Inventory Calculator, and improve the graphical display of inventory and thermal data. OWL (Version 3.0) contains information for 18 different wastes with 16 potential (planned or proposed) unique waste forms.

As stated in Section 1.1, OWL was designed for two purposes: (1) to manage information on DOE-managed wastes likely to require deep geologic disposal, such that one can easily query the data including inventory-specific data, and (2) to provide input parameter files with relevant information on waste types, inventory, waste form characteristics, vessels, etc. for PA analyses in the context of the GDSA framework.

This section summarizes the progress made on fulfilling both OWL purposes with emphasis on advances made in FY2021. Section 2.1 describes the development of the OWL database structure including (1) the information modeling for the waste and waste form information, (2) the current user interface to access the information, and (3) the work on structural changes to support the expansion to add vessel information. Section 2.2 addresses modifications to OWL content, particularly the addition of sodium-bonded spent fuel and the status of efforts needed to support OWL integration with the DOE SFDB (DOE 2007) at INL. Section 2.3 provides an overview of the OWL change control and release processes finalized in early FY2021. Finally, Section 2.4 discusses the future development of new OWL features and capabilities to support postclosure PA in the context of the GDSA effort.

2.1 Development of the OWL Database Structure

The current OWL database structure is designed to manage information on DOE-managed waste and waste forms. The initial development focus was on building a functional database structure with a user-friendly interface and populating that structure with the information on waste types and waste forms. Much of the basic information modeling used to develop database tables and the user interface was completed in FY2017 (Sassani et al. 2017), with incremental improvements since then.

Section 2.1.1 describes the information on wastes and waste forms used for information modeling in OWL. The status of the current user interface for accessing and displaying information is provided in Section 2.1.2. Section 2.1.3 addresses the progress made on information modeling and the associated database structure needed to support the planned expansion of OWL to include vessel information.

2.1.1 OWL Waste and Waste Form Information Modeling

OWL is designed to contain information on radioactive wastes and waste forms with links to the current supporting documents for the data. The detailed information model structure for wastes and waste forms in OWL is given in Sassani et al. (2017, Appendix B). Only minor updates to the information model structure have been required since that time. Note that no classified or OUO data or supporting documents are included or planned to be included at this point since the intent is to ensure OWL is suitable for UUR designation.

There may be up to several hundred different DOE-managed wastes that are likely to require deep geologic disposal. The DOE has a database, the SFDB, that contains information regarding the SNF that DOE manages. As discussed in Section 2.2.2, OWL is not intended to replicate this database and the information in it; the idea is to take advantage of that existing data set by incorporating selected data fields from it into OWL, thereby making those data fields available for use in postclosure PA. While the OWL information modeling will be adjusted as needed to support SFDB integration, the details are still under development. Therefore, the discussion below focuses on the waste and waste form information modeling developed for OWL independent of what changes may happen due to SFDB integration.

The information modeling development for OWL accommodates a number of different types of information that are currently available or could be available for each waste (and its alternative waste forms):

- Waste characteristics
  - Narrative description of waste (some waste types have variable processing characteristics because the processing or treatment of the waste is currently in progress leaving the processed or treated portion with different characteristics than the remaining unprocessed or untreated portion, e.g., SRS tank waste [processing in progress]; sodium-bonded fuel [treatment in progress]; Hanford tank waste [once treatment starts, situation will be similar])
  - Type of waste (HLW or SNF or other)
  - Origin of waste (commercial, DOE-managed (as), foreign, research, other?)
  - Total quantity of waste (volume and/or mass as appropriate)
  - Physical form of waste (e.g., rods, plates, powder, liquid, glass)
  - Dimensional characteristic of waste (if a solid waste)
  - Radionuclide inventory and thermal information (for reported baseline date with options to show calculated projections (1) in tabular form for any user-selected date from the current year to the year 3000 or (2) in graphical form over time for 200 years in the future)
  - Bulk chemistry of the waste (noting hazardous constituents)
  - Resource Conservation and Recovery Act (RCRA) considerations (e.g., not an issue, characteristic, listed)
- Current storage information
  - Current storage location (e.g., INL, Hanford)
  - Description of current storage method (e.g., tanks, canisters, high-integrity canisters, capsules)

- Number of current containers
- Dimensions of current storage method (per container, as appropriate)
- Volume of current storage method (per container, as appropriate)
- Mass of packaged waste as it currently exists (per container, as appropriate)
- Radionuclide inventory and thermal information at specified times on a per-container basis (or as available)
- Current status (e.g., awaiting treatment, awaiting packaging, ready for disposal)

- Planned or alternative processing and packaging options for final disposition
  - Description of baseline/alternative processing and/or packaging for disposal, including options for processing and/or packaging
  - Number of baseline/alternative packages
  - Dimensions of baseline/alternative package
  - Volume of baseline/alternative package
  - Mass of baseline/alternative package
  - Status of baseline/alternative planned processing (e.g., none, in progress, under development)
  - Status of baseline/alternative packaging (e.g., ready, being developed)
  - Radionuclide inventory and thermal information for treated/packaged waste at specified times on a per-package basis (or as available)
- Transportation considerations (e.g., certified transport canister exists (yes/no))
- Current base-line disposition pathway (e.g., deep geologic disposal in a repository for HLW and/or SNF, Waste Isolation Pilot Plant (WIPP), or to be determined)
- Copies of any Record of Decisions (RODs) or agreements affecting the waste and its associated plans (linked to the specific data provided)
- Effects of ROD on waste (e.g., date of promised removal from state)
- Option to have the OWL team pass a user request for further information to responsible contact(s) currently in charge of the waste types and forms for storage oversight, for processing, etc. (with the intent being to keep information about the responsible contact internal to OWL)

2.1.2 User Interface for OWL Waste and Waste Form Information

As mentioned in Section 1.2.2, the OWL user interface is provided through a SharePoint site. Figure 2-1 is a screenshot of the Production SharePoint Site home page on the ECN for OWL Version 3.0. The home page contains a short description of the database, a link to the *OWL User's Guide*, a link to the Errata List, Announcements, and a series of links to various database reports under the heading "For More Information About…" (often referred to in this report as the "Report List").

Figure 2-1. Home Page Screenshot for OWL Production SharePoint Site

The main source of information on the various options for queries and reports available in OWL is the *OWL User's Guide*. For the user's convenience, a link to the current *OWL User's Guide* is provided not only on the home page, but on all database reports generated within OWL. Version 3.0 of the *OWL User's Guide* (SNL 2021), which corresponds to OWL Version 3.0, is reproduced in Appendix B.

Aside from the home page, all other database content is viewed by the end user through database reports, called SQL Server Reporting Services (SSRS) reports, created on the demand by the user. The Report List on the home page provides access to the following SSRS reports:

- **DOE-Managed Wastes**—Search on all the wastes as well as view waste details and supporting documents
- **Waste Forms**—Search waste disposal forms, their related wastes, and supporting documents
- **Inventory Calculator**—Calculate the inventory of a selected waste in a chosen year
- **200-Year Inventory and Thermal Output**—Display the projected inventory and thermal output of wastes and radionuclides by year for the next 200 years
- **Baseline Radionuclide Inventory in Each Waste**—View baseline radionuclide inventory as of a specified date for each waste
- **Radionuclides**—View radionuclides, their properties, and supporting documents
- **Supporting Documents**—Display "List of Supporting Documents" with the ability to open or download the documents

Taking advantage of the web-based interface, these SSRS reports can have links allowing users to access information available in other reports. Descriptions and screenshots of this primary set of database reports are provided below. Note that the reports all have a standard OWL banner at the top with the report title, the OWL release stamp, and links for the home page, the DOE-Managed Wastes report, and *OWL User's Guide*. There is also a footer with the date/time stamp when the report was run, a contact email, and information specific to Sandia and DOE. The top banner and footer have been removed from the report screenshots for simplicity.

DOE-Managed Wastes—Because of the way the database is structured, users who select the DOE-Managed Wastes option can sort waste by facility (e.g., Hanford, INL, SRS), and waste classification (e.g., HLW, SNF). This feature makes it easy to identify all the HLW types captured in OWL that are currently at Hanford, for example, which is similar to the DOE SFDB capabilities.

Figure 2-2 is a screenshot of the visual display of the Waste Forms report in which users can select wastes by Facility and/or Waste Classification as well as sort by Waste, Classification, or Storage Facility (using the up/down arrows). The total volume and total radioactivity of each waste are also shown.

Because there is a large variety of waste information, the user can click on any waste for additional waste detail information. For example, Figure 2-3 provides a sample screenshot of the waste detail that appears when "Savannah River Glass Waste" is selected. The first two sections load first, giving the user the following options for what type of additional detail to display:

1. Waste Characteristics
2. Waste Source
3. Disposal Waste Forms
4. Disposal Waste Form Characteristics

5. Radionuclide Inventory
6. Radionuclide Characteristics
7. Waste Supporting Documents
8. Waste Contacts.

The bottom part of Figure 2-3 shows the display provided when both "Waste Characteristics" and "Disposal Waste Forms" are selected.

To filter Wastes, click on item's text below

Select a Facility Name

- ALL
- Hanford
- Idaho National Lab
- Savannah River Site

Select a Waste Classification

- ALL
- High Level Waste
- Spent Nuclear Fuel
- Transuranic (TRU) Waste

Waste (click on Name for details)	BaseLine Inventory Date	Waste Classification	Waste Description	Storage Facility	Total Volume	Total Radioactivity
Calcine Waste	Jan 01, 2016	High Level Waste	This waste is a solid granular material derived from liquid wastes produced by reprocessing SNF.	Idaho National Lab	160,000 Cubic Feet	31,300,000 Curies
Cesium and Strontium Capsules	Jan 01, 2016	High Level Waste	This waste consists of 1335 CsCl capsules and 601 SrF2 capsules, each about 21 inches tall and 3 inches in diameter. They are currently managed as high-level waste and stored in pools at the Waste Encapsulation and Storage Facility at Hanford	Hanford	128 Cubic Feet	93,600,000 Curies
Experimental Breeder Reactor-II (EBR-II) Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded driver SNF from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark IV Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess the other EBR-II SNF and FFTF driver SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	1295 Cubic Feet	1,090,000 Curies
Experimental Breeder Reactor-II (EBR-II) Experimental Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded experimental driver SNF from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark IV Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess the other EBR-II SNF and FFTF driver SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	106 Cubic Feet	100,000 Curies
Experimental Breeder Reactor-II (EBR-II) Radial Blanket Spent Nuclear fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded blanket SNF from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark V Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess the other EBR-II SNF and FFTF driver SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	384 Cubic Feet	81,200 Curies
Fast Flux Test Facility (FFTF) Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded driver SNF from the Fast Flux Test Facility (FFTF). The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark IV Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess EBR-II SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	34 Cubic Feet	20,600 Curies
Fermi-1 Blanket Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded blanket fuel from Fermi-1. This fuel has not been selected for electrorefining, as have the other sodium-bonded spent fuels.	Idaho National Lab	671 Cubic Feet	2,320 Curies
German Glass Waste	Jan 01, 1987	Transuranic (TRU) Waste	This waste consists of 34 canisters of glass prepared by Pacific Northwest Laboratory to provide heat and radiation sources for repository testing by the Federal Republic of Germany in the Asse salt mine. This waste has been classfied as RH-TRU but does not meet the requirements of the WIPP Waste Acceptance Criteria and so cannot be disposed of at the WIPP. Two of the 34 canisters are thought to contain depleted uranium and natural thorium, but no cesium or strontium. The 34 canisters are currently stored in 6 CASTOR casks and 2 GNS casks.	Hanford	936 Cubic Feet	17,200,000 Curies
Hanford Tank Waste (CH-TRU)	Jan 01, 2008	Transuranic (TRU) Waste	This waste is material that can be contact handled (CH) and is a subset of the 54.6 million gallons of liquid waste stored at Hanford. It may be transuranic (TRU) waste but has not officially been determined to be so by the DOE.	Hanford	189,000 Cubic Feet	25,100 Curies

Figure 2-2. Partial View of DOE-Managed Wastes Report Showing Wastes, Waste Classification, Description, Storage Facility, Total Volume, and Total Radioactivity

Savannah River Glass Waste

Waste Classification	Waste Description	Storage Facility	Produced By	Is Mixed Waste?	Baseline Inventory Date & Inventory Calculator	
High Level Waste	This waste consists of 4,179 vitrified glass logs produced in the Defense Waste Processing Facility at the Savannah River Site from reprocessing waste that was in tanks at the Savannah River Site	Savannah River Site	Government	No	12/31/2018	Inventory Calculator

Display Specific Waste Information by Expanding (+) the Type of Content Listed Below

⊟ 1. Waste Characteristics ⊞ 2. Waste Source ⊟ 3. Disposal Waste Forms ⊞ 4. Disposal Waste Form Characteristics ⊞ 5. Radionuclide Inventory ⊞ 6. Radionuclide Characteristics ⊞ 7. Waste Supporting Documents ⊞ 8. Waste Contacts

1. Waste Characteristics

Characteristic	Characteristic Description	Value	Supporting Document
Average thermal output of a unit of the nuclear waste	Average thermal output of a canister of glass waste as of the baseline date	40 Watts	SRS Glass Waste Information
Diameter of the nuclear waste container	Diameter of a container of glass waste	2 Feet	Evaluation of Options for Permanent Geologic Disposal of Spent Nuclear Fuel and High Level Radioactive Waste in Support of a Comprehensive National Nuclear Fuel Cycle Strategy: Volume II: Appendices
Length of the nuclear waste container	Height of a container of glass waste at Savannah River	10 Feet	Evaluation of Options for Permanent Geologic Disposal of Spent Nuclear Fuel and High Level Radioactive Waste in Support of a Comprehensive National Nuclear Fuel Cycle Strategy: Volume II: Appendices
Number of containers	Number of containers of glass waste at Savannah River as of December 2018.	4,179	Liquid Waste System Plan, Revision 21
Physical form of the waste	Physical form of the glass waste at Savannah River	Borosilicate glass	Liquid Waste System Plan, Revision 21
Total radioactivity - the total curies of all the radionuclides in the waste as of the baseline date	Total radioactivity of glass waste at Savannah River	45,600,000 Curies	SRS Glass Waste Information
Total volume of the waste as currently stored, including any packaging	Total volume of glass waste at Savannah River	129,000 Cubic Feet	SRS Glass Waste Information

3. Disposal Waste Forms

Waste Form	Description	Projected or Existing	Preferred or Alternative	Quantity	Supporting Document
Glass waste	Glass logs in canisters	Existing	Preferred	4,179 2 ft. diameter, 10 ft. tall canisters	Liquid Waste System Plan, Revision 21

Figure 2-3. Waste Detail for Savannah River Glass Waste with Additional Selection of Options 1 and 3 for Waste Characteristics and Disposal Waste Forms Respectively

Waste Forms—As seen in Figure 2-4, the Waste Forms report provides the following information for each disposal waste form: the related waste type(s), waste form description, whether the waste form is projected or existing, whether the waste form is the result of the preferred or alternative treatment, the projected or existing quantity, the projected or existing volume, and the supporting document. Clicking on a specific waste form produces a report giving the waste form characteristics. For example, Figure 2-5 shows the resulting report for Savannah River Glass Waste.

Waste Types and Associated Disposal Waste Forms

Waste	Disposal Waste Form	Waste Form Description	Projected or Existing	Preferred or Alternative	Quantity	Volume	Supporting Document
Calcine Waste	Calcine Waste cemented without vitrification	Direct cementation of the calcine waste without vitrification.	Projected	Alternative	18,000 2 ft. diameter, 10 ft. tall canisters	570,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine waste that has been hot isostatically pressed, with additives	Calcine waste treated by hot isostatic pressing, including silica, titanium and calcium sulfate (glass ceramic). Processing the calcine with the silica and titanium is needed to eliminate RCRA hazardous waste characteristics.	Projected	Preferred	4,045 Cans of calcine that have been hot isostatically pressed	190,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine waste that has been hot isostatically pressed, without additives	Calcine waste treated by hot isostatic pressing without silica, titanium and calcium sulfate (glass ceramic).	Projected	Alternative	3,236 Cans of calcine that have been hot isostatically pressed	150,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine Waste Vitrified following Separation	Calcine waste that has been vitrified following separation.	Projected	Alternative	1,190 2 ft. diameter, 10 ft. tall canisters	37,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine Waste Vitrified without Separation	Calcine waste that has been vitrified without separation.	Projected	Alternative	12,000 2 ft. diameter, 10 ft. tall canisters	380,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine Waste without further treatment	Calcine waste that is disposed of without further treatment.	Existing	Alternative	6,100 2 ft. diameter, 10 ft. tall canisters	190,000 cubic feet	On-Line Waste Library Supporting Information
Cesium and Strontium Capsules	Cs and Sr capsules	Cs and Sr capsules, as-is, disposed of in waste packages designed for a deep borehole, 18 capsules per package	Existing	Alternative	108 8.625 in. diameter, 16 ft. tall waste packages	686 cubic feet	Deep Borehole Disposal Safety Analysis
	Vitrified Cs and Sr from capsules	Glass logs in canisters	Projected	Preferred	340 2 ft. diameter, 15 ft. tall canisters	16,000 cubic feet	Vitrification of Cs and Sr Capsules
Experimental Breeder Reactor-II (EBR-II) Driver Spent Nuclear Fuel	Ceramic Waste Form	Glass-bonded sodalite material produced from mixing cooled, crushed salt from the electrorefiner with zeolite and borosilicate binder glass. The reported quantity and volume represent the quantity and volume of ceramic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.	Projected	Preferred	96 2 ft. diameter, 10 ft. tall canister	60 cubic meters	Source Terms for HLW Glass Canisters
	Electrorefiner Salt Waste Form from Driver Sodium-Bonded Spent Fuel	A LiCl-KCl salt mix with lesser amounts of NaCl produced from electrorefining driver sodium-bonded spent fuels from both the EBR-II and the FFTF. This waste form would be disposed of without further treatment or processing (i.e., as salt)	Projected	Alternative	9 27 cm diamter, 155 cm tall stainless-steel disposal canister	0.8 cubic meters	Initial Performance Assessment to Evaluate Technical Feasibility of Direct Disposal of Electrorefiner Salt Waste in Salt Repository
	Metallic Waste Form	A Fe-Cr-Ni-Zr mixture and an iron solid solution phase that are interspersed on a microscopic scale and are produced from electrorefiner metal waste stream in the form of ingots. The quantity and volume reproted represent the quantity and volume of metallic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.	Projected	Preferred	6 2 ft. diameter, 10 ft. tall canister	1.2 cubic meters	Source Terms for HLW Glass Canisters
Experimental Breeder Reactor-II (EBR-II) Experimental Driver Spent Nuclear Fuel	Ceramic Waste Form	Glass-bonded sodalite material produced from mixing cooled, crushed salt from the electrorefiner with zeolite and borosilicate binder glass. The reported quantity and volume represent the quantity and volume of ceramic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.	Projected	Preferred	96 2 ft. diameter, 10 ft. tall canister	60 cubic meters	Source Terms for HLW Glass Canisters
	Electrorefiner Salt Waste Form from Driver Sodium-Bonded Spent Fuel	A LiCl-KCl salt mix with lesser amounts of NaCl produced from electrorefining driver sodium-bonded spent fuels from both the EBR-II and the FFTF. This waste form would be disposed of without further treatment or processing (i.e., as salt)	Projected	Alternative	9 27 cm diamter, 155 cm tall stainless-steel disposal canister	0.8 cubic meters	Initial Performance Assessment to Evaluate Technical Feasibility of Direct Disposal of Electrorefiner Salt Waste in Salt Repository
	Metallic Waste Form	A Fe-Cr-Ni-Zr mixture and an iron solid solution phase that are interspersed on a microscopic scale and are produced from electrorefiner metal waste stream in the form of ingots. The quantity and volume reproted represent the quantity and volume of metallic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.	Projected	Preferred	6 2 ft. diameter, 10 ft. tall canister	1.2 cubic meters	Source Terms for HLW Glass Canisters
Experimental Breeder Reactor-II (EBR-II) Radial Blanket Spent Nuclear fuel	Ceramic Waste Form	Glass-bonded sodalite material produced from mixing cooled, crushed salt from the electrorefiner with zeolite and borosilicate binder glass. The reported quantity and volume represent the quantity and volume of ceramic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.	Projected	Preferred	96 2 ft. diameter, 10 ft. tall canister	60 cubic meters	Source Terms for HLW Glass Canisters
	Electrorefiner Salt Waste Form from Blanket Sodium-Bonded Spent Fuel	A LiCl-KCl salt mix with lesser amounts of NaCl produced from electrorefining blanket sodium-bonded spent fuels from the EBR-II. This waste form would be disposed of without further treatment or processing (i.e., as salt)	Projected	Alternative	6 27 cm diameter, 155 cm tall stainless-steel disposal canister	0.5 cubic meters	Initial Performance Assessment to Evaluate Technical Feasibility of Direct Disposal of Electrorefiner Salt Waste in Salt Repository
	Metallic Waste Form	A Fe-Cr-Ni-Zr mixture and an iron solid solution phase that are interspersed on a microscopic scale and are produced from electrorefiner metal waste stream in the form of ingots. The quantity and volume reproted represent the quantity and volume of metallic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.	Projected	Preferred	6 2 ft. diameter, 10 ft. tall canister	1.2 cubic meters	Source Terms for HLW Glass Canisters

Figure 2-4. Partial View of Waste Forms Report Showing Waste Forms, Description, Related Waste Types, Various Properties, and Supporting Documents

Clear Characteristics

Disposal Waste Form Characteristics

Waste Form	Form Characteristic	Characteristic Description	Value & Unit	Supporting Document
Glass waste	Annealing range	Annealing range of HLW borosilicate glass (lower value)	450 degrees C	SRS Glass Waste Characteristics
	Annealing range	Annealing range of HLW borosilicate glass (upper value)	500 degrees C	SRS Glass Waste Characteristics
	Average thermal output	Average thermal output of a canister of glass waste at Savannah River as of the baseline date	40 watts	SRS Glass Waste Information
	Compressive strength	Compressive strength of HLW borosilicate glass	550 MPa	SRS Glass Waste Characteristics
	Density	Density of HLW borosilicate glass	2.75 g/cubic cm	SRS Glass Waste Characteristics
	Diameter of container	Nominal outer diameter of container of glass waste at Savannah River	61 cm	SRS Glass Waste Characteristics
	Heat capacity	Heat capacity of HLW borosilicate glass	0.83 J/g-K (at 25 C)	SRS Glass Waste Characteristics
	Height of container	Height of container of glass waste at Savannah River	3.00 m	SRS Glass Waste Characteristics
	Mass of loaded glass container	Maximum weight of container of glass waste at Savannah River	2,500 kg	SRS Glass Waste Characteristics
	Softening point	Softening point of HLW borosilicate glass	500 degrees C	SRS Glass Waste Characteristics
	Tensile strength	Tensile strength of HLW borosilicate glass	57 MPa	SRS Glass Waste Characteristics
	Thermal conductivity	Thermal conductivity of HLW borosilicate glass	0.95 W/m-K (at 100 C)	SRS Glass Waste Characteristics
	Total volume	Total volume of waste at Savannah River that exists as glass as of December 2018.	129,000 cubic feet	SRS Glass Waste Information

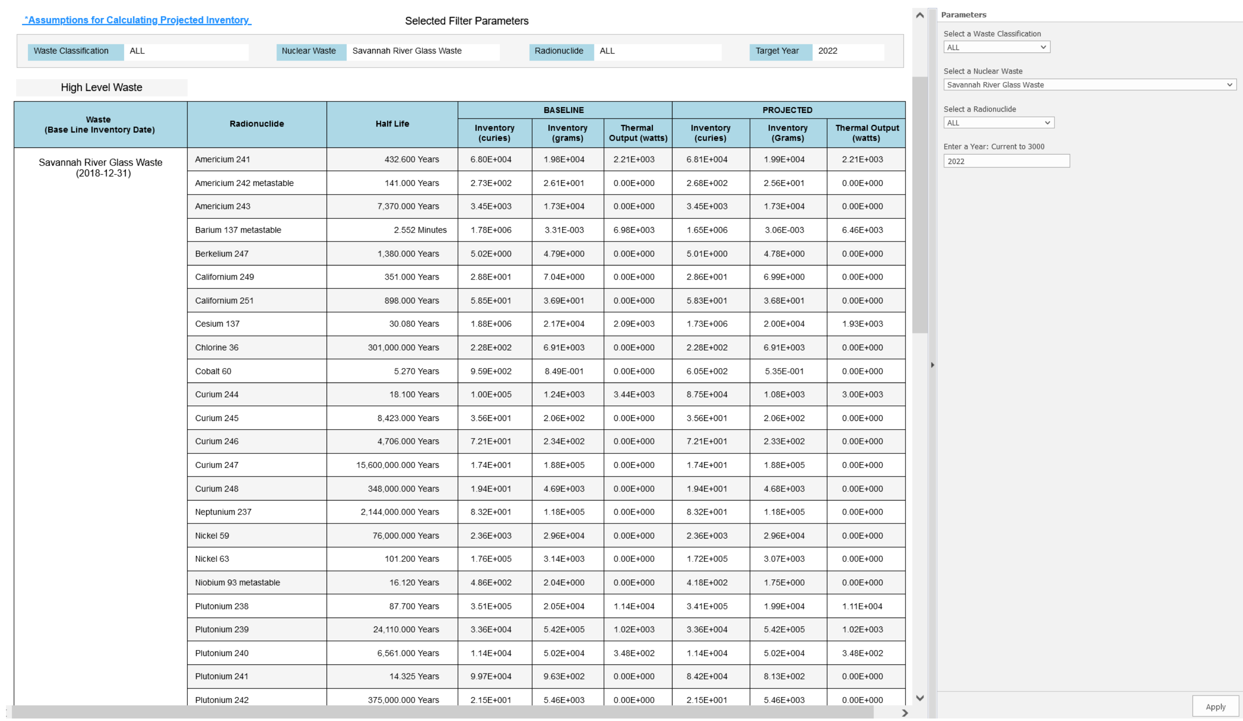
Waste Types and Associated Disposal Waste Forms

Waste	Disposal Waste Form	Waste Form Description	Projected or Existing	Preferred or Alternative	Quantity	Volume	Supporting Document
Savannah River Glass Waste	Glass waste	Glass logs in canisters	Existing	Preferred	4,179 2 ft. diameter, 10 ft. tall canisters	129,000 cubic feet	Liquid Waste System Plan, Revision 21

Figure 2-5. Disposal Waste Form Characteristics for Savannah River Glass Waste

Inventory Calculator—The OWL database features a Radionuclide Inventory Calculator, which is made possible through the use of a stored calculation tool. The user makes selections from the following options: waste classification (all, HLW, SNF, or TRU), nuclear waste (all or any of the different waste types), radionuclide (all or a specific radionuclide), and year (anything from current year to 3000 C.E.). Based on those selections, the Radionuclide Inventory Calculator does the necessary calculations using the inventory information stored in OWL and returns the results in an SSRS report. The user can access supporting documents for the basic information stored in OWL as well as documentation regarding the calculation methods used by the Radionuclide Inventory Calculator. OWL database reports can be generated to provide the inventory in various units, such as volumes, radioactivity, and/or thermal output of wastes as they currently exist.

Figure 2-6 provides an example screenshot of the projected inventory database report generated by the Radionuclide Inventory Calculator for "Savannah River Glass Waste" from the baseline inventory date to the selected target year 2200. On the right is the panel showing the filter selections used for the calculation.


*Assumptions for Calculating Projected Inventory

Selected Filter Parameters

Waste Classification	ALL	Nuclear Waste	Savannah River Glass Waste	Radionuclide	ALL	Target Year	2022

High Level Waste

Waste (Base Line Inventory Date)	Radionuclide	Half Life	BASELINE Inventory (curies)	BASELINE Inventory (grams)	BASELINE Thermal Output (watts)	PROJECTED Inventory (curies)	PROJECTED Inventory (Grams)	PROJECTED Thermal Output (watts)
Savannah River Glass Waste (2018-12-31)	Americium 241	432.600 Years	6.80E+004	1.98E+004	2.21E+003	6.81E+004	1.99E+004	2.21E+003
	Americium 242 metastable	141.000 Years	2.73E+002	2.61E+001	0.00E+000	2.68E+002	2.56E+001	0.00E+000
	Americium 243	7,370.000 Years	3.45E+003	1.73E+004	0.00E+000	3.45E+003	1.73E+004	0.00E+000
	Barium 137 metastable	2.552 Minutes	1.78E+006	3.31E-003	6.98E+003	1.65E+006	3.06E-003	6.46E+003
	Berkelium 247	1,380.000 Years	5.02E+000	4.79E+000	0.00E+000	5.01E+000	4.78E+000	0.00E+000
	Californium 249	351.000 Years	2.88E+001	7.04E+000	0.00E+000	2.86E+001	6.99E+000	0.00E+000
	Californium 251	898.000 Years	5.85E+001	3.69E+001	0.00E+000	5.83E+001	3.68E+001	0.00E+000
	Cesium 137	30.080 Years	1.88E+006	2.17E+004	2.09E+003	1.73E+006	2.00E+004	1.93E+003
	Chlorine 36	301,000.000 Years	2.28E+002	6.91E+003	0.00E+000	2.28E+002	6.91E+003	0.00E+000
	Cobalt 60	5.270 Years	9.59E+002	8.49E-001	0.00E+000	6.05E+002	5.35E-001	0.00E+000
	Curium 244	18.100 Years	1.00E+005	1.24E+003	3.44E+003	8.75E+004	1.08E+003	3.00E+003
	Curium 245	8,423.000 Years	3.56E+001	2.06E+002	0.00E+000	3.56E+001	2.06E+002	0.00E+000
	Curium 246	4,706.000 Years	7.21E+001	2.34E+002	0.00E+000	7.21E+001	2.33E+002	0.00E+000
	Curium 247	15,600,000.000 Years	1.74E+001	1.88E+005	0.00E+000	1.74E+001	1.88E+005	0.00E+000
	Curium 248	348,000.000 Years	1.94E+001	4.69E+003	0.00E+000	1.94E+001	4.68E+003	0.00E+000
	Neptunium 237	2,144,000.000 Years	8.32E+001	1.18E+005	0.00E+000	8.32E+001	1.18E+005	0.00E+000
	Nickel 59	76,000.000 Years	2.36E+003	2.96E+004	0.00E+000	2.36E+003	2.96E+004	0.00E+000
	Nickel 63	101.200 Years	1.76E+005	3.14E+003	0.00E+000	1.72E+005	3.07E+003	0.00E+000
	Niobium 93 metastable	16.120 Years	4.86E+002	2.04E+000	0.00E+000	4.18E+002	1.75E+000	0.00E+000
	Plutonium 238	87.700 Years	3.51E+005	2.05E+004	1.14E+004	3.41E+005	1.99E+004	1.11E+004
	Plutonium 239	24,110.000 Years	3.36E+004	5.42E+005	1.02E+003	3.36E+004	5.42E+005	1.02E+003
	Plutonium 240	6,561.000 Years	1.14E+004	5.02E+004	3.48E+002	1.14E+004	5.02E+004	3.48E+002
	Plutonium 241	14.325 Years	9.97E+004	9.63E+002	0.00E+000	8.42E+004	8.13E+002	0.00E+000
	Plutonium 242	375,000.000 Years	2.15E+001	5.46E+003	0.00E+000	2.15E+001	5.46E+003	0.00E+000

Parameters

Select a Waste Classification: ALL

Select a Nuclear Waste: Savannah River Glass Waste

Select a Radionuclide: ALL

Enter a Year: Current to 3000: 2022

Apply

Figure 2-6. Partial View of Report from Radionuclide Inventory Calculator showing Projected Inventory from the Baseline Inventory of Savannah River Glass Waste to the Target Year of 2,200

200-Year Inventory and Thermal Output—In addition to providing the ability to calculate projected inventory for a specific target year, the database can calculate and visually display the projected inventory and thermal output by year for the next 200 years. The calculation results are shown in charts (Figure 2-7) with user controls available to change the display according to the selected waste and radionuclide options. Figure 2-7 displays the results for all wastes in OWL. Note that the user can also display results for individual wastes and/or individual radionuclides. The option to display the inventory in either curies or becquerels is also provided.

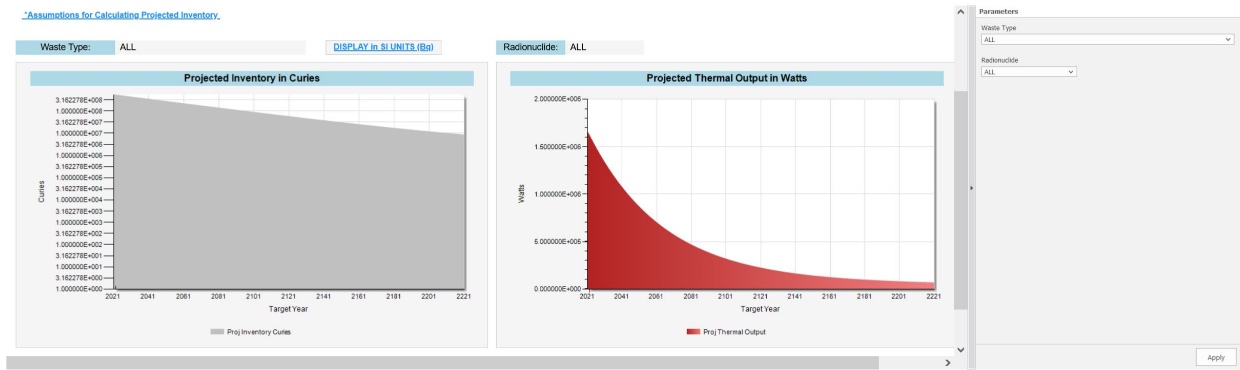
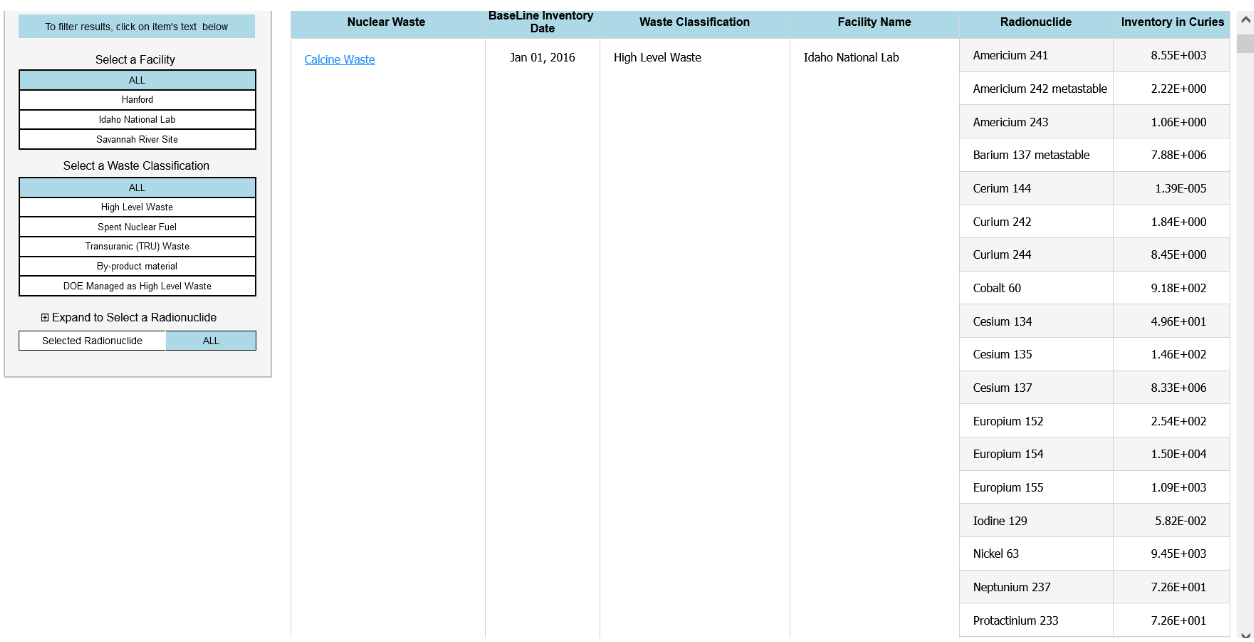


Figure 2-7. Visual Display of Calculated Projected Activity and Thermal Output for a Waste by Year for the Next 200 Years

Baseline Radionuclide Inventory in Each Waste—As seen in Figure 2-8, this report provides the baseline inventory as of the date specified in the supporting document for each waste type. Clicking on a particular waste type brings up the associated waste detail such as that in Figure 2-3. The panel on the left allows the user to filter by facility, waste classification, and/or radionuclide.



Nuclear Waste	BaseLine Inventory Date	Waste Classification	Facility Name	Radionuclide	Inventory in Curies
Calcine Waste	Jan 01, 2016	High Level Waste	Idaho National Lab	Americium 241	8.55E+003
				Americium 242 metastable	2.22E+000
				Americium 243	1.06E+000
				Barium 137 metastable	7.88E+006
				Cerium 144	1.39E-005
				Curium 242	1.84E+000
				Curium 244	8.45E+000
				Cobalt 60	9.18E+002
				Cesium 134	4.96E+001
				Cesium 135	1.46E+002
				Cesium 137	8.33E+006
				Europium 152	2.54E+002
				Europium 154	1.50E+004
				Europium 155	1.09E+003
				Iodine 129	5.82E-002
				Nickel 63	9.45E+003
				Neptunium 237	7.26E+001
				Protactinium 233	7.26E+001

Figure 2-8. Partial View of Report for Baseline Radionuclide Inventory in Each Waste with Filtering Options Panel

Radionuclides—Currently, the OWL database captures information on 87 radionuclides. Figure 2-9 provides a screenshot from a database report showing a sample of the radionuclide information. Clicking on one of the projected inventory links brings up a screen with graphs similar to those seen in Figure 2-7 for projected inventory and thermal output, the exception being that the figure shows all radionuclides while the graphs accessed through clicking a link in the Radionuclides report (Figure 2-9) will be specific to the selected radionuclide.

Radionuclide	Description	Half Life		Atomic Mass (u)	Thermal Output (watts/kCi)	Parent Radionuclide	Inventory Ratio	Supporting Document
Ac-227	Actinium 227	21.77 Years	Projected Inventory (200 years)	227.00				Ac-227 Nuclear Data
Al-26	Aluminum 26	717,000.00 Years	Projected Inventory (200 years)	26.00				Al-26 Nuclear Data
Am-241	Americium 241	432.60 Years	Projected Inventory (200 years)	241.00	32.450	Pu-241		Am-241 Nuclear Data
Am-242	Americium 242	16.02 Hours	Projected Inventory (200 years)	242.00		Am-242m	0.995	Am-242 Nuclear Data
Am-242m	Americium 242 metastable	141.00 Years	Projected Inventory (200 years)	242.00				Am-242m Nuclear Data
Am-243	Americium 243	7,370.00 Years	Projected Inventory (200 years)	243.00				Am-243 Nuclear Data
Ba137-m	Barium 137 metastable	2.55 Minutes	Projected Inventory (200 years)	137.00	3.920	Cs-137	0.950	Ba-137m Nuclear Data
Bk-247	Berkelium 247	1,380.00 Years	Projected Inventory (200 years)	247.00				Bk-247 Nuclear Data
C-14	Carbon 14	5,700.00 Years	Projected Inventory (200 years)	14.00				C-14 Nuclear Data
Cd-113m	Cadmium 113 metastable	14.10 Years	Projected Inventory (200 years)	113.00				Cd-113m Nuclear Data
Ce-144	Cerium 144	284.91 Days	Projected Inventory (200 years)	144.00				Ce-144 Nuclear Data
Cf-249	Californium 249	351.00 Years	Projected Inventory (200 years)	249.00				Cf-249 Nuclear Data
Cf-251	Californium 251	898.00 Years	Projected Inventory (200 years)	251.00				Cf-251 Nuclear Data

Figure 2-9. Partial View of Radionuclides Report

Supporting Documents—An effort from FY2017 to FY2018 consisted of loading supporting documents into OWL to provide the underpinning sources and to supplement the database content. With each OWL release, modifications are made to the Supporting Documents Library as needed to ensure the database content is adequately supported by the appropriate documents. In OWL Version 3.0, there are 273 documents integrated with the database content; these can be accessed and viewed from within OWL. Figure 2-10 provides a screenshot sample of documents available.

As part of the effort to provide supporting documents for each waste, the Excel™ spreadsheet for each waste that can be used to calculate its inventory and thermal output and (in some cases) the volume of waste was turned into a pdf. Results from the beta testing of OWL indicated that users sometimes had trouble opening or viewing the spreadsheets as Excel™ spreadsheet files, so the spreadsheets were formatted appropriately, checked, and saved as pdf files before being sent through SNL's review and approval (R&A) process. Thus, each spreadsheet can be viewed and is referenceable. The original Excel™ spreadsheet is available upon request via an email to OWL@sandia.gov.

Title	Document Description	Comments	Author	Publisher, Date	Copyright Restrictions	Document Availability
105-K Basin Material Design Basis Feed for SNF Project Facilities	This report gives the design basis feeds for SNF project facilities	HNF-SD-SNF-TI-009, Volume 1, Rev. 3	M.J. Packer	Numatec Hanford, Inc., November 4, 1999	None	Internal Full Document
1995 Settlement Agreement between the State of Idaho, the U.S. Department of Energy, and the Department of the Navy	This is the settlement agreement reached by the State of Idaho, the U.S. Department of Energy, and the Department of the Navy regarding the management of naval SNF.	None	U.S. Courts District of Idaho	United States Courts District of Idaho, October 17, 1995	None	Internal Full Document
2008 Addendum to the 1995 Settlement Agreement	This is an addendum to the 1995 settlement agreement.	None	The State of Idaho, the Department of Energy, and the Department of the Navy	The State of Idaho, the Department of Energy, and the Departmentof the Navy, 2008	None	Internal Full Document
Ac-227 Nuclear Data	This data sheet gives the half-life of Ac-227.	Available at http://www.nndc.bnl.gov/	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Activity of Fuel Batches Processed Through Hanford Separations Plants, 1944 Through 1989	This report estimates the activity of fuel batches processed at Hanford through 1989.	RPP-13489 Rev. 0	Wootan, D. W. and S. F. Finfrock	CH2MHill, November 2002	None	Internal Full Document
Al-26 Nuclear Data	This data sheet gives the half-life of Al-26.	Available at http://www.nndc.bnl.gov/	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Am-241 Nuclear Data	This data sheet gives the half-life and decay energies of Am-241, which are used to calculate decay heat	Available at http://www.nndc.bnl.gov/	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Am-242 Nuclear Data	This data sheet gives the half-life and branching fraction of Am-242.	Available at http://www.nndc.bnl.gov	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Am-242m Nuclear Data	This data sheet gives the half-life and branching fraction for Am-242m.	Available at http://www.nndc.bnl.gov	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Am-243 Nuclear Data	This data sheet gives the half-life of Am-243	Available at http://www.nndc.bnl.gov	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Analysis of DWPF Sludge Batch 6 (Macrobatch 7) Pour Stream Glass Samples	This report provides the radionuclide inventory in a sample of sludge from macrobatch 7 at Savannah River.	SRNL-STI-2011-00555	F. C. Johnson	Savannah River Nuclear Laboratory, February 2012	None	Internal Full Document
Analysis of DWPF Sludge Batch 7a (Macrobatch 8) Pour Stream Samples	This report provides the radionuclide inventory in a sample of sludge from macrobatch 8 at Savannah River.	SRNL-STI-2012-00017	F. C. Johnson and J. M Pareizs	Savannah River National Laboratory, October 2012	None	Internal Full Document
Analysis of Sludge Batch 4 (Macrobatch 5) for Canister S02902 and Sludge Batch 5 (Macrobatch 6) for Canister S03317 DWPF Pour Stream Glass Samples	This report provides the radionuclide inventory in samples of sludge from macrobatch 5 and macrobatch 6	SRNL-STI-2010-00435	M. M. Reigel and N. E. Bibler	Savannah River National Laboratory, September 2010	None	Internal Full Document
Analysis of the Sludge Batch 7b (Macrobatch 9) DWPF Pour Stream Sample	This report provides the radionuclide inventory in a sample of sludge from macrobatch 9 at Savannah River.	SRNL-STI-2013-00462	F. C. Johnson, C. L. Crawford, and J.M. Pareizs	Savannah River National Laboratory, November 2013	None	Internal Full Document
Appendix D Na Bonded Fuel EIS	This is the EIS to support decisions on disposal of Na Bonded Fuel.	DOE-EIS-0306_Vol 2-2000	U. S. Department of Energy	U. S. Department of Energy, 2000	None	Internal Full Document
Ba-137m Nuclear Data	This data sheet gives the half-life and decay energies of Ba-137 metastable, which are used to calculate decay heat.	Available at http://www.nndc.bnl.gov	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Bk-247 Nuclear Data	This data sheet gives the half-life of Bk-247.	Available at http://www.nndc.bnl.gov	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
C-14 Nuclear Data	This data sheet gives the half-life of C-14.	Available at http:/www.nndc.bnl.gov	National Nuclear Data Center	National Nuclear Data Center, March 2017	None	Internal Full Document
Calcine Disposition Project Technology Maturation Plan	This document presents a detailed discussion of INL calcine and plans for processing and disposal.	PLN-1482	Calcine Disposition Project	Idaho Cleanup Project, 2012	None	Internal Full Document
Calcine radionuclide content	This is an excerpt from "Evaluation of Options for Permanent Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste"	SAND2014-0189	Sandia National Laboratories	Sandia National Laboratories, April 2014	None	Internal Full Document
Calcine Radionuclide Inventory	This is a pdf of a spreadsheet that calculates the radionuclide inventory and thermal output of the calcine HLW at INL on a user-selected target date.	SAND2018-1574 O	L. Price	Sandia National Laboratories, April 2018	None	Internal Full Document

Figure 2-10. Database Report Sample of Supporting Documents

2.1.3 Structural Considerations for Vessel-Related Expansion of OWL

From the beginning, the plan for OWL has been to allow the database to evolve over time in terms of both content and capability. One of OWL's primary functions is to provide access to information on DOE-managed wastes that are likely to be disposed of in a mined geologic repository. As a complement to this function, OWL is being expanded to include information on the vessels capable of disposing of that DOE-managed waste, with the ancillary aspects of storing and transporting those wastes/waste forms.

Terminology Clarification—Note that certain "vessels" are considered a part of the waste form if that vessel cannot be separated easily from the waste form. As such, those vessels are already included in the descriptions in the waste form information of OWL and would not, in general, be added in this expanded OWL vessel information. A good example is the glass pour canister that is essential for making the glass waste form. The glass pour canister contains the glass waste form, but is not easily removed, and is not intended to contain other waste forms or waste types. There are also exceptions such as when the vessel itself has an alternative use for a different waste/waste form—either existing or officially planned—that does not permanently bind it to the waste/waste form in that alternative. For example, glass canisters have no existing or planned alternative uses that would justify inclusion in OWL as a vessel (i.e., no planned or alternative use involving some other waste/waste form that would be contained therein). In summary, within OWL, the generic term "vessel" will be used to describe a can, canister, container, cask, overpack, waste package, etc. that can serve as a single layer in a nested system designed to surround and contain[b] the waste form for potential disposal, storage, or transportation uses.

In past OWL reports (e.g., Weck et al. 2021a), the potential population of vessels for inclusion in OWL was discussed in terms of three groups: (1) Group 1, which consists of vessels that exist and are used for DOE-managed wastes, (2) Group 2, which consists of vessels that do not exist yet, but are part of official DOE planning for storage, transportation and/or disposal of DOE-managed waste, and (3) Group 3, which consists of vessels that exist and are available for use with commercial SNF.

However, this grouping scheme can be confusing because there are vessels that exist that are used for both commercial SNF and DOE-managed waste. In other words, they are part of both Groups 1 and 3. The difficulty is that the grouping scheme is mixing two types of information. The first is whether the vessel exists or is somewhere in the design stage. The second focuses on the vessel contents (e.g., DOE-managed wastes, commercial SNF, or both). The grouping scheme does not serve any purpose other than as a tool for discussing the potential vessel population. There are specific fields already planned to capture this type of information more efficiently. Going forward, this grouping scheme will not be discussed to avoid potential confusion.

Leveraging Other DOE Databases—Information on vessels used for commercial SNF is already part of the Used Nuclear Fuel-Storage, Transportation & Disposal Analysis Resource and Data Systems (UNF-ST&DARDS) database at Oak Ridge National Laboratory. The OWL team does not intend to duplicate the information in that database. Instead, the plan is to explore ways to integrate with UNF-ST&DARDS in the future so the relevant content can be leveraged. However, if the OWL team finds information regarding a vessel being used for DOE-managed waste as well as commercial SNF, that information is captured when found rather than later when integration with UNF-ST&DARDS has been achieved.

In addition, the DOE SFDB at INL is another database with information of potential interest to OWL users. Section 2.2.2 discussed leveraging information specific to waste and waste forms involving DOE SNF. However, this database also contains information regarding the vessels currently storing the DOE SNF. As a result, preliminary integration discussions have included information on vessels as well as DOE SNF. Because there will be some overlap between vessel information gathered through data mining and that potentially available through DOE SFDB integration, consideration is being given regarding how best to incorporate the relevant DOE SFDB vessel information to ensure a consistent and coherent vessel data set within OWL.

Another DOE database called RAMPAC (DOE n.d. [no date]; https://rampac.energy.gov/) provides documents on RAdioactive Materials PACkages certified by DOE, the U.S. Nuclear Regulatory Commission (NRC), and the U.S. Department of Transportation (DOT). While this database does not contain tabular information that can be integrated with OWL, it can serve as a resource for vessel-related documents.

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[b] As stated previously, "to contain" something in this context means "to hold" it. The term does not imply containment in the regulatory sense, e.g., the definition provided by transportation regulations in 10 CFR 71: "*Containment system* means the assembly of components of the packaging intended to retain radioactive material during transport."

Preliminary Vessel-Related Information Modeling—The ongoing data mining effort targets certain types of information for each vessel. This information serves two purposes: (1) provide a basis for the information modeling needed to determine the fields for database vessel tables as well as the relationships between the tables, and (2) facilitate data entry and checking when the tables are ready to be populated. The current focus is on information modeling and development of the vessel tables. The information gathered through data mining thus far can be organized into two main categories as follows:

- Vessel general information (primarily descriptive information)
  - Vessel name
  - Vessel category (waste package, canister, container, cask, overpack, etc.)
  - Purpose (storage, transportation, or disposal) and purpose type (primary or alternative)
  - Additional vessel(s) (identifies the inner and outer vessel layers needed in combination with the vessel; each additional vessel is mapped to a position relative to vessel, a purpose type, and a purpose)
  - Vessel description (brief text about vessel; can include content about components, configuration, basket, etc.)
  - Diagram
  - Material(s)
  - Development status (indicator of whether vessel exists, is in some stage of planning, or is conceptual in nature)
  - Waste form (identifies the waste form in OWL that is associated with the vessel) or waste form name and description if the waste form is not in OWL (e.g., commercial SNF)
  - DOE facility (general facility identification only; specific locations within the site will not be given to help ensure information remains suitable for UUR designation)
  - License/certification (confidence-building documentation; may specify alternative to license or certification such as DOE safety report as appropriate)
  - Relevant regulations, codes, and standards (list reflects what is found in supporting document(s) and as such may or may not be comprehensive)
  - Disposal licensing considerations (description of any information, especially from the NRC, that pertains to disposal licensing of the vessel)
  - Supplier (entity that supplied or may supply the vessel to DOE; not necessarily the manufacturer)
  - Capacity
  - Other loading considerations (beyond properties given below)

- Vessel properties (characterized by numbers and units)
  - Cavity diameter
  - Cavity length
  - Cavity width
  - Cavity height

- Available cavity volume
- Outer diameter
- Maximum outer diameter
- Outer length
- Outer width
- Outer height
- Minimum outer length
- Maximum outer length
- Wall thickness
- Vessel bottom thickness
- Vessel lid thickness
- Top shield plug thickness
- Empty weight
- Loaded weight
- Maximum loaded weight

The fact that some fields above have a maximum version or both a minimum and maximum version whereas others do not is simply an outgrowth of what has been found in the data mining. Of course, not every field will be applicable to every vessel, but the database structure accounts for this situation. The data mining conducted thus far has shown that the types and level of detail of information available for any given vessel vary greatly between vessels. An initial set of fields is being created for the tables, but the database is not locked into the initial set of fields. If need be, new fields can be created on the fly while the tables are still being tested or even later if there is a need after data entry has been started. There can even be changes after the vessel information has been included in an OWL release. The only requirement is that any actions taken must be done in accordance with the OWL change control process (Weck et al. 2021c).

As is standard practice for OWL, the information for vessels will have clear ties to the associated supporting documents to ensure traceability. Those supporting documents will be integrated into OWL's existing Supporting Documents Library with the links to source information contained in the data tables. In addition, any supporting document that is a diagram of the vessel will be flagged as such so that the user interface can provide easy access.

Vessel-Related Change Control Implementation and Example Vessels—Appendix A describes how the full scope of the planned vessel-related work fits within the framework of the change control process documented in Weck et al. (2021c). The change "Enhance OWL with New Vessel Information" has been entered into the Change List and a set of associated tasks have been entered into the Task List. The status of the tasks is discussed and a schematic of the preliminary information modeling architecture for vessel tables, including the relationships between tables, is provided. In addition, some examples of vessels are discussed in Appendix A. The examples were selected to display some of the variety within the pool of vessels identified by the data mining thus far. Some of the example vessels currently exist and some are partially designed. Some are developed solely for DOE use and some have commercial use as well. The primary purpose may be storage, transportation, disposal, or some combination thereof. In addition, each example vessel is subject to a hierarchy that dictates the layering used in a nested system of vessels. In fact, being part of a nested system of vessels is something all vessels, not just the example vessels, appear to have in common. A vessel typically needs one or more additional vessels to fulfill its intended function, be it for storage, transportation, or disposal.

Summary—The effort to include vessel information in OWL is large and complex. Although significant progress has been made, it is expected that an OWL release with vessel information will occur at some point beyond the current fiscal year. Future work includes continued data mining, further development and refinement of the database structures, data entry, and data checking. Eventually, when plans for integration with the DOE SFDB and the UNF-ST&DARDS database come to fruition, there will also be the work of incorporating the vessel-related information from the other databases into OWL.

2.2 Development of OWL Content

As new information on DOE-managed wastes and waste forms becomes publicly available, the OWL team modifies OWL content to ensure (1) information on DOE-managed wastes and waste forms already in OWL is updated as appropriate and (2) information on DOE-managed wastes and waste forms not already in OWL are added to the database. Modifications to update or add content to OWL are governed by the change control process discussed further in Section 2.3.1.

Section 2.2.1 describes the effort to add sodium-bonded fuel produced from DOE's experimental fast-neutron breeder reactor program to OWL Version 3.0. The scope of the content addition includes the descriptive and numerical data along with all of the supporting documentation.

Besides modifying OWL to reflect information released into the public literature, the OWL team is pursuing a strategy of integration with existing DOE databases to leverage information relevant to OWL. Section 2.2.2 provides the status of ongoing efforts to integrate OWL with INL's SFDB, which is a Nuclear Quality Assurance-1 (NQA-1) database with over 700 entries of DSNF (DOE 2007).

2.2.1 Addition of Sodium-Bonded Spent Fuel in OWL Inventory Content

In FY2021, the OWL team focused on adding new content to the database to account for the sodium-bonded spent fuel produced from DOE's experimental fast-neutron breeder reactor program. These efforts resulted in sodium-bonded spent fuel being included in OWL Version 3.0 released in November 2021. The data for the following have been incorporated into OWL: (1) the associated spent fuel wastes, (2) electrometallurgical treatment (EMT) produced wastes/waste forms, and (3) other planned waste forms that are being, or are planned to be, produced. These wastes represent a large number of waste types and waste forms in OWL because they have been categorized based on the reactor of origin and the type of fuel (driver versus blanket) from each nuclear reactor (Price 2021a, 2021b). Note that the EMT process can also be referred to as an electrorefiner (ER) process. Both terms are used interchangeably in this report and in OWL.

Sodium-bonded spent fuel wastes have been produced at three separate facilities, i.e., the Experimental Breeder Reactor II (EBR-II) facility in INL, the Hanford Fast Flux Test (Reactor) Facility (FFTF), and the Detroit Edison Fermi Nuclear Power Plant facility (DOE 2014). Waste types for the existing spent fuels have been defined in OWL for each of these facilities. Operation of these reactors involved two types of fuel: driver fuel and blanket fuel. The EBR-II facility further differentiates between driver fuel and experimental driver fuel. Waste types have been defined in OWL for each of these fuel types.

Data entry has been completed on the waste types for sodium-bonded fuels from reactors EBR-II, FFTF, and Fermi, and their potential wastes/waste forms generated via EMT (note that the DOE ROD (DOE 2000a) directs EMT processing for only the first two of these, with the Fermi sodium-bonded blanket fuels awaiting further disposition). This procedure includes an ER process that produces salt waste and metallic waste (DOE 2014). The procedure also produces a uranium metal product that is intended for future beneficial use. Because the uranium product is an intended useful recovery of the uranium, it is ***not*** a waste or waste form listed within OWL. The mass of the uranium product is included in the OWL supporting documentation for mass balance calculations of the various wastes/waste forms from the sodium-bonded spent fuels (Price 2021b).

DOE decided in 2000 to treat some of the sodium-bonded SNF using electrochemical treatment in two ERs (DOE 2000a): the Mark-IV ER and the Mark-V ER. Both ERs are in the Hot Fuels Examination Facility of Fuel Conditioning Facility at INL. The Mark-IV ER has been used to treat some of the EBR-II and FFTF driver SNF, which have low quantities of Pu. The Mark-V ER has been used to treat a small portion of the EBR-II blanket SNF, which has high quantities of Pu. The metallic waste produced by the Mark-IV ER is combined with the metallic waste from the Mark-V ER to create metal ingots intended for disposal.

At this point in time, there are multiple existing wastes associated with the sodium-bonded fuels:

- EBR-II Driver SNF
- EBR-II Experimental Driver SNF
- EBR-II Radial Blanket SNF
- FFTF Driver SNF
- Fermi-1 Blanket SNF
- Mark IV Salt Waste
- Mark V Salt Waste
- Metallic Waste (includes material from both the Mark IV and Mark V ERs)

Each of these existing wastes is a “Waste Type” in OWL as shown in Figure 2-11.

To filter Wastes, click on item's text below

Select a Facility Name

- ALL
- Hanford
- Idaho National Lab
- Savannah River Site

Select a Waste Classification

- ALL
- High Level Waste
- Spent Nuclear Fuel
- Transuranic (TRU) Waste

Waste (click on Name for details)	BaseLine Inventory Date	Waste Classification	Waste Description
Calcine Waste	Jan 01, 2016	High Level Waste	This waste is a solid granular material derived from liquid wastes produced by reprocessing SNF.
Experimental Breeder Reactor-II (EBR-II) Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded driver fuel from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining.
Experimental Breeder Reactor-II (EBR-II) Experimental Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded experimental driver fuel from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining.
Experimental Breeder Reactor-II (EBR-II) Radial Blanket Spent Nuclear fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded blanket fuel from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining.
Fast Flux Test Facility (FFTF) Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded driver fuel from the Fast Flux Test Facility. The treatment method selected for this waste is electrorefining.
Fermi-1 Blanket Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded blanket fuel from Fermi-1. This fuel has not been selected for electrorefining, as have the other sodium-bonded spent fuels.
Mark IV Salt Waste	Sep 30, 2017	High Level Waste	This waste is salt waste produced from electrorefining sodium-bonded driver fuel in the Mark IV electrorefiner. As of the baseline inventory date, 1.36 MTHM of driver sodium-bonded spent fuel had been reprocessed in the Mark IV electrorefiner. This waste represents the salt waste currently in the Mark IV electrorefiner.
Mark V Salt Waste	Sep 30, 2017	High Level Waste	This waste is salt waste produced from electrorefining sodium-bonded blanket fuel in the Mark V electrorefiner. As of the baseline inventory date, 3.68 MTHM of blanket sodium-bonded spent fuel had been reprocessed in the Mark V electrorefiner. This waste represents the salt waste currently in the Mark V electrorefiner.
Metallic Waste from Electrorefining	Sep 30, 2017	High Level Waste	This waste is metal ingot waste produced from electrorefining sodium-bonded spent fuel. As of the baseline inventory date, three metal ingots had been produced.
Sodium Bearing Waste	Jan 01, 2012	Transuranic (TRU) Waste	This waste is composed primarily of decontamination solutions, but includes small fractions of first (1%), second (2%) and third (4%) cycle extraction wastes from fuel reprocessing.

Figure 2-11. Partial Screenshot of Waste Types Showing Those Associated with Sodium-Bonded Spent Fuel

The definition of waste forms in OWL is structured around the five spent fuels above and the three possible future outputs of the EMT procedure. The metallic waste produced by the EMT process is itself an alloyed metallic waste form as described in DOE (2000a). Two waste form pathways have been proposed for the salt waste. The currently preferred option (DOE 2000a) is to create a glass-bonded sodalite (ceramic waste form) material that encapsulates the salt waste. An alternative calling for direct disposal of the salt waste without further treatment has been proposed (Wang et al. 2011; Lee et al. 2013; SNL 2014; Rechard et. al. 2017).

For all the other wastes and associated disposal waste forms in OWL, the "rule" has been that each disposal waste form could be associated with only one waste type. However, because of the complexities associated with the multiple types of sodium-bonded spent fuel, the multiple waste streams for each spent fuel, and the plan to combine EMT waste streams from more than one type of sodium-bonded spent fuel into a single waste form, the decision was made to change that "rule". For Version 3.0, the OWL database was restructured so that a disposal waste form, such as metallic waste, can be associated with more than one waste type. Thus, four new disposal waste forms were input into OWL as shown in Figure 2-12:

- Ceramic Waste Form
- ER Salt Waste Form from Driver Sodium-Bonded Spent Fuel
- ER Salt Waste Form from Blanket Sodium-Bonded Spent Fuel
- Metallic Waste Form

Mark IV Salt Waste	Ceramic Waste Form	Glass-bonded sodalite material produced from mixing cooled, crushed salt from the electrorefiner with zeolite and borosilicate binder glass. The reported quantity and volume represent the quantity and volume of ceramic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.
	Electrorefiner Salt Waste Form from Driver Sodium-Bonded Spent Fuel	A LiCl-KCl salt mix with lesser amounts of NaCl produced from electrorefining driver sodium-bonded spent fuels from both the EBR-II and the FFTF. This waste form would be disposed of without further treatment or processing (i.e., as salt)
Mark V Salt Waste	Ceramic Waste Form	Glass-bonded sodalite material produced from mixing cooled, crushed salt from the electrorefiner with zeolite and borosilicate binder glass. The reported quantity and volume represent the quantity and volume of ceramic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.
	Electrorefiner Salt Waste Form from Blanket Sodium-Bonded Spent Fuel	A LiCl-KCl salt mix with lesser amounts of NaCl produced from electrorefining blanket sodium-bonded spent fuels from the EBR-II. This waste form would be disposed of without further treatment or processing (i.e., as salt)
Metallic Waste from Electrorefining	Metallic Waste Form	A Fe-Cr-Ni-Zr mixture and an iron solid solution phase that are interspersed on a microscopic scale and are produced from electrorefiner metal waste stream in the form of ingots. The quantity and volume reported represent the quantity and volume of metallic waste produced by electrorefining all sodium-bonded spent fuel (driver and blanket) from the EBR-II and the FFTF.

Figure 2-12. Partial Screenshot of Disposal Waste Forms Showing Disposal Waste Forms Associated with Sodium-Bonded Spent Fuel

The Ceramic Waste Form represents the disposal waste form resulting from the treatment option preferred by the DOE (DOE 2000a) and is associated with the four sodium-bonded spent fuels destined for reprocessing (i.e., all but Fermi-1), the Mark-IV Salt Waste, and the Mark-V Salt Waste. The ER Salt Waste Form from Driver Sodium-Bonded Spent Fuel represents an alternative disposal waste form that has been proposed by others and is associated with the EBR-II Driver SNF, EBR-II Experimental Driver SNF, the FFTF Driver SNF, and the Mark-IV Salt Waste. Likewise, the ER Salt Waste Form from Blanket Sodium-Bonded Spent Fuel also represents an alternative disposal waste form that has been proposed by others and is associated with the EBR-II Radial Blanket SNF and the Mark-V Salt Waste. The Metallic Waste Form represents the disposal waste form resulting from the treatment option preferred by the DOE (DOE 2000a) and is associated with the four sodium-bonded spent fuels destined for reprocessing and the Metallic Waste.

2.2.2 Status of Integration with the DOE SFDB (INL)

Although the DSNF inventory for N-reactor has been entered directly into the OWL database for use directly in GDSA analyses (primarily because this represents the major mass of DSNF), it is neither efficient nor desirable to re-enter the other 700+ entries of DSNF in the INL's SFDB, an NQA-1 database (DOE 2007). As such, the OWL team is working with INL staff to develop a plan for OWL to synchronize periodically with the SFDB. Note that both the sodium-bonded SNF and the Canyon Stabilization SNF are each planned to be further treated in some fashion as opposed to being directly disposed of as SNF. As such, they need to be entered into OWL separately to capture those non-SNF waste forms. The addition of sodium-bonded fuel to OWL is discussed in Section 2.2.1. Because of the nature of the SFDB content, care is being taken to select a subset of information fields to be supplied to OWL that is sufficient for performance analyses of the back end of the fuel cycle (primarily disposal). The current work in this area is delineating exactly what the desired data fields from the SFDB are for use in OWL. For example, numbers of DSNF elements, masses, and dimensions are all parameters that are desired for constraining numbers and types of canisters for storage or disposal. But there are many additional fields that would perhaps be useful beyond those. Location information would be limited to the DOE facility of storage (e.g., Hanford, INL) to help ensure OWL can be made publicly available with no restrictions.

The preliminary mechanism identified for this interface synchronization is a spreadsheet output from the SFDB that would contain a listing of the ~700+ DSNF items and selected data fields (currently being identified). This mechanism would allow for a computer script to be constructed to read the SFDB spreadsheet information and enter that information into the OWL database automatically, obviating human-based data-entry checking via a checksum arrangement. Using such an automated process should facilitate wholesale replacement of the SFDB information upon each spreadsheet update (either with some notation in the spreadsheet on the data that have changed or via an automated file comparison process to highlight the changes). This process would also facilitate using a waste grouping structure for these DSNF items being input into OWL as part of the assimilation process. That is, instead of listing each of the specific DSNF item separately, they may be assigned, for example, to their respective group of the 34 DSNF groups (Section 2.4). Grouping in this manner will be evaluated for comparison of efficiency versus limitations for analyses. At this point, a draft set of characteristics has been sent to the INL SFDB staff who will generate a draft spreadsheet for evaluation by the OWL team.

Regardless of the ultimate representation in OWL, the spreadsheet report generated from the SFDB would be listed as the source/supporting document from the SFDB. However, the spreadsheet itself would be available only upon request. During OWL beta testing, issues were encountered regarding opening actual spreadsheets online. As a result, only pdf versions of spreadsheets will be made available online through OWL.

Currently, initial planning calls for such synchronizations to occur twice annually with about two to three months lead time prior to OWL version updates to allow time to deal with any unforeseen issues with the file handling.

2.3 Development of OWL Change Control and Release Processes

An important part of the infrastructure supporting OWL is a coherent suite of processes that work together to preserve information integrity and traceability as the database evolves over time. By FY2017, progress on OWL development prompted the initiation of a data-entry checking process to verify the validity of the information/data already included in primary data sets for the essentially complete waste types. Over the next few years, the data-entry checking process was formalized and refined. With the first public release of OWL (Version 1.0) in FY2019, much of the effort in FY2020 focused on developing the change control process to govern how changes are made to OWL and the release process to govern how a new version of OWL is released to the public. The data-entry checking process became one part of the more comprehensive change control process. The preparation and release of OWL Version 2.0 in FY2020 served as a test case for the two draft processes. Based on the lessons learned, the OWL team finalized the change control process and the release process in early FY2021 (Weck et al. 2021b, 2021c). Descriptions of the change control process and the release process are provided below in Section 2.3.1 and Section 2.3.2 respectively.

2.3.1 OWL Change Control Process

The OWL change control process (Weck et al. 2021c) ensures that changes made to the parts of OWL seen by the public are approved and implemented appropriately. The change control process does not apply to all parts of OWL in all environments. Some parts are governed by the release process or other parts exist solely for internal use by the OWL team. For example, the change control process applies to the public version of OWL in the Production Environment except for a few items controlled by the release process, e.g., the archival area, the update of the *OWL User's Guide*, and the resetting of the Errata List (Section 2.3.2; Weck et al. 2021b). The change control process governs changes to items in the Development Environment and Release Candidate Environment that will eventually be migrated to the Production Environment according to the release process. In contrast, it does not apply to items like the Internal Documents Library in the Development Environment or to the structure of the Release Candidate Tester Feedback List in the Release Candidate Environment, both of which are not publicly available because they are for internal use only. Weck et al. (2021c) provides further details about which parts of each OWL environment are controlled by the change control process.

All changes governed by the change control process are implemented and managed through the Change List and Task List on the OWL Development SharePoint Site. The suite of defined processes that constitute the OWL change control process includes provisions specifying that the implemented changes are independently reviewed and that the reviews are documented. In addition, the defined processes ensure that the stored OWL content, the results of calculations done by OWL, and the methods used to do the calculations are transparent and traceable.

The subsections below describe (1) the change drivers and mechanisms (Section 2.3.1.1), (2) how the Change List and Task List are used for change management (Section 2.3.1.2), (3) the activity categories, which allow defined process steps to be assigned to tasks on the Task List (Section 2.3.1.3), (4) the independent reviews—checking or internal—required before task completion (Section 2.3.1.4), (5) the mechanisms available for reporting errors and making suggestions (Section 2.3.1.5), and (6) an example of an error correction implemented using the change control process (Section 2.3.1.6).

Detailed examples of how the change to add sodium-bonded fuel to OWL and the change to enhance OWL with vessel information fit within the change control process framework are provided in Section 4.4 of Weck et al. (2021c). A summary of the example for the vessel-related change is provided in Appendix A.

2.3.1.1 Change Drivers and Mechanisms

The most obvious driver of change is planned updates/modifications to the OWL structure or content to respond to the priorities of the Spent Fuel & Waste Science and Technology (SFWST) disposal research and development program. In addition, there are multiple other mechanisms capable of triggering the need to modify OWL including (1) discovery of newer published documents that supersede the supporting technical documents for data in OWL, (2) receipt of updates from the SFDB as discussed above, (3) receipt of new information with supporting documentation from DOE/national laboratory staff responsible for the wastes, (4) identification of any types of issues by OWL users via the OWL email service, (5) changes to data used from the National Nuclear Data Center, and (6) discovery of errors. Currently, a user can provide feedback through the OWL email service. However, consideration is being given to developing a more refined user feedback process to enable users to ask questions, provide feedback, and report errors. This feedback information could be used to evaluate the need to plan changes in new OWL versions. Regardless of the driver for change, all changes in OWL are implemented through the change control process. Weck et al. (2021c) provides detailed examples of how various types of changes ranging from error corrections to modifications to the OWL structure (i.e., capabilities) are implemented, tracked, and documented.

2.3.1.2 Change Management through Change List and Task List

The key infrastructure elements supporting the change control process are the Change List and Task List, which reside on the OWL Development SharePoint Site. When a change to OWL is approved, it is entered on the Change List. Each change has various properties (i.e., metadata fields) associated with it including a field to track status. A list of the properties is provided in Section 4.1 of Weck et al. (2021c). Changes are identified as being in one of three categories: (1) Errata, (2) Planned Work – New, and (3) Planned Work – Revisions. Each change has at least one associated task, but complicated changes may have several associated tasks. Other properties include the priority level, the target OWL release version in which the change is expected to appear, the impacted area of OWL, and the origin of the change. The latter is helpful in identifying changes resulting from user feedback or from the release candidate technical review. Like any SharePoint list, the Change List can be sorted and filtered as appropriate; several custom views have been created for use by OWL team members.

Each task listed for a change in the Change List is entered on the Task List along with the properties for that task (Weck et al. 2021c, Section 4.2). One of the properties is the activity assigned to the task. Different activity categories have been defined according to the process steps needed to complete the activity. Thus, assigning an activity to a task means assigning a discrete set of process steps that must be followed. The progress through the assigned process steps can be tracked through some of the properties on the Task List. One property specifically tracks the task status, and other properties support the task review process steps. In addition, one of the properties identifies whether one task in a suite of related tasks is a predecessor to another task, meaning that the predecessor task must be started, and in some cases must be completed, before the other task can be started.

Another property related to tracking progress is focused on a particular process step. This property identifies whether there are objects in the dev schema that must be moved to the dbo schema. A schema acts as a virtual container for objects that belong to the group designated by the schema. The dev and dbo schemas are part of the Development Environment. The term "dev" stands for "development" and is used to identify the schema for structural elements like database tables and stored calculation tools that are still under development. When development of these objects is finished, the objects are moved to the dbo schema. The term "dbo" stands for "database owner" and is used to identify the schema for objects that are ready to be included in a release candidate version of OWL. Moving from the dev to the dbo schema requires a request for service outside of the OWL team, so separate identification of this property aids the OWL team in ensuring the service request is completed.

Besides task properties related to track progress on activity process steps, there are also two properties intended to facilitate the release process. One property identifies any new or updated supporting documents created as result of the task. The other property does the same for SSRS reports. This information is collected so that when the next version of OWL is released, the OWL team members moving OWL from the Development Environment to the Release Candidate Environment and then to the Production Environment know which supporting documents and/or SSRS reports need to be moved or deleted. The Change List and Task List are also used during the release process as resources for generating the change history from the previous OWL release to the new release.

All tasks associated with a change in the Change List must be completed before the change can be marked as complete.

2.3.1.3 Defined Process Steps through Assigned Activity Categories

Twelve different activity categories are available for assignment to a task. These activities address the full range of types of changes that may be made to OWL. Each activity category has a defined set of process steps. A full description of the activities as well as the related process steps and process diagrams are provided in Weck et al. (2021c, Section 4.3). A list of the activity categories is provided below:

- Develop Strategy for Change Implementation
- Correct Content Errors
- Update Existing Content
- Add New Content
- Correct Stored Calculation Tools and SSRS Reports
- Update Existing Tables
- Update Existing Stored Calculation Tools
- Update Existing SSRS Reports
- Create New Tables
- Create New Stored Calculation Tools
- Create New SSRS Reports
- Manage SharePoint Site

The activity categories listed above differentiate between tasks that impact the content of OWL and tasks that impact the structure of OWL. In this context "content" refers to data, supporting documents, and links between data and supporting documents. Activities related to "content" are primarily implemented by the OWL technical data specialists. In the same vein, "structure" refers to the database, SSRS reports, the SharePoint site, and stored calculation tools. Activities related to "structure" are primarily implemented by the OWL technical software specialists. Completion of a change may require multiple types of expertise. For resource planning purposes, it is important to distinguish between work that must be completed primarily by technical data specialists and work that must be completed primarily by technical software specialists.

The first eleven of the twelve activities in the list above involve one of three actions: correcting something, updating something, or creating something new. The actions focus on content, stored calculation tools, SSRS reports, or tables. Note that the concept of correcting errors does not apply to tables. Tables cannot be "wrong" in the same sense that numerical values can be wrong. That said, changes to what is needed or desired from the table structures and relationships can be addressed through updating existing tables and/or creating new tables.

Changes managed under the first eleven activities are made in the Development Environment. The release process (Section 2.3.2) is then used to ensure the integrity of the changes as the OWL team transfers copies of relevant files and deletes obsolete files first on the Release Candidate Environment and then on the Production Environment. The release process does not start until all changes made in the Development Environment for the next release are reviewed and completed.

The twelfth activity, “Manage SharePoint Site”, involves all three actions (correct, update, create) with the focus being the Production SharePoint Site, specifically the home page, the Errata List structure, and the Errata List content involving the home page. Errata List content involving errors in database content, stored calculation tools, or SSRS reports are governed by the other activities.

Two items on the Production Site home page are not governed by the activity “Manage SharePoint Site”. The release stamp is managed by the release process (Section 2.3.2). The Announcements List does not need to be managed by the change control process or the release process. It serves as a vehicle to facilitate communication with the end user; it does not contain database content nor does it support the integrity of the content. In addition, the activity does not apply to the other parts of the Production SharePoint Site. Other activities address changes to the temporary pages generated by SSRS Reports, the Report Library storing SSRS reports, and the Supporting Documents Library. The Archive Library is managed by the release process.

While most OWL changes migrate from the Development Environment to the Production Environment during the release process, this mechanism does not work with the changes addressed by the activity “Manage SharePoint Site”. The Errata List only exists in the Production Environment. With respect to the home page, SharePoint does not allow for whole sets of changes to be copied from a home page in one environment to a home page in another environment. As a result, changes to the Production Site home page must be made individually to that home page. However, because the content of the Production SharePoint Site home page is seen by the public, only the Announcements List is allowed to change between releases. The timing of all other home page changes is determined by the release process even though the actual change implementation is managed under the change control process. An independent review of the change on the Production SharePoint Site home page is required before the task can be marked complete in the Task List.

One goal of the process steps for the different activities is to ensure that tasks are planned, implemented, and independently reviewed before they are marked as complete. The details of implementation obviously vary depending on the activity. Another goal of the activity process steps is to ensure the OWL content and results from stored calculation tools are transparent and traceable. No OUO information is included in OWL. All OWL content is tied to the original source within the database structure and that source is available to the user in the OWL Supporting Documents Library. While the user can go to the Supporting Documents Library, there are also links available to provide easy access to the document associated with a particular piece of information. Occasionally a supporting document is subject to copyright or some other restriction. In this case, permission to publicly release the document as part of OWL is sought. If the document cannot be provided, a summary identifying and describing the document is provided in the public release of OWL so that the content is still traceable to the original source. In addition, stored calculation tools are documented both in terms of the OWL content being used and the calculations being done. The documentation is stored in the Supporting Documents Library and made available to the user through links, which ensures that the results from stored calculation tools are also transparent and traceable.

2.3.1.4 Required Checking and Internal Reviews

As stated above, the change control process specifies that changes and associated tasks are entered into a tracking system (i.e., Change List and Task List described in Section 2.3.1.2). The tasks are assigned to activities with defined process steps (Section 2.3.1.3), one of which is always a review conducted by someone independent of the work to ensure the task fulfills the intended purpose.

The nature of the review depends on what is being reviewed (Weck et al. 2021c, Section 4.5). Tasks involving data entry are subject to a rigorous checking process. This checking process is an outgrowth of the data-entry checking process initiated in FY2017. Years of practical experience since then have resulted in a robust checking process ensuring that the data are entered accurately and that they are traceable to the relevant supporting documents.

The checker documents any issues identified for the data reviewed and resolves those issues with the following steps:

1. Print the OWL data report to a Microsoft Word file.
2. Highlight in the file all data entries as verified or potentially at issue (e.g., green highlight => verified; red or yellow highlight => potential issue).
3. Summarize outstanding issues in an email to the technical data specialists and the work package manager (at least) with email documentation of resolution of each issue.

In this process, each potential issue is clarified and resolved via discussion and definition of summary solutions, with involvement from technical management as needed to define the path for correction. Each issue and its resolution, including specific changes planned as a part of that resolution, are documented. Before the change control process was implemented, that documentation was deposited in a supporting document data-entry checking folder for the relevant version of OWL and archived with that version. Now, the Task List is used to facilitate and document the review process. The Review Comments field on the Task List is available for brief comments. In addition, the Task List allows for uploading any relevant review documents (i.e., files and emails) and attaching them to the task.

The review process for changes to OWL structure varies depending on what is being reviewed. In this report, structure is used in a broad sense; it can refer not only to the tables, but also to the stored calculation tools, the SSRS reports, and the Production SharePoint Site. The nature of stored calculation tools makes them suitable for a checking review similar to that done for content. A reviewer can do the same calculation(s) independently and check against the results of the stored calculation tool. The reviewer also makes sure the calculation methods are documented and available. The other three—tables, SSRS reports, and Production SharePoint Site—are subjected to an internal review with more subjective criteria, usually based on functionality and aesthetics.

2.3.1.5 Mechanisms for Error Reporting and Suggestions

As OWL is used, errors and suggested revisions can be identified either internally by the OWL team or externally by users via the OWL email address. With respect to errors, an initial evaluation is done to confirm that the identified error is valid and in need of correction. For suggested revisions, the initial evaluation considers whether the suggested change should be approved for implementation in OWL. In either case, if the initial evaluation results in the approval of a future change to OWL, the appropriate information is added to the Change List and Task List. The information includes the required corrections for identified errors and a description of the modifications needed to respond to suggested revisions. The lists can also be used to prioritize the items, assign completion to a future version of OWL, maintain a status of completion, and provide other relevant information. Because changes to correct errors are not accessible until the next OWL version release, an Errata List of known errors and the planned corrections is made available to users on the OWL Production SharePoint Site home page. The Errata List is one of the few parts of the Production SharePoint Site that can be updated between releases. During the release process, the Errata List is reset to remove entries for previously identified errors being corrected with the OWL version being released.

2.3.1.6 Change Control for Error Resolution

The identification and correction of errata is part of the change control process for OWL. All of the tools of the change control process, discussed above, are involved in the correction of errata. A recent example illustrates the implementation of this process.

A technical data specialist identified errors in the Inventory Calculator SSRS report during work involved with a task that addresses planned revisions to OWL. The projected inventory for ^{242}Cm was incorrect for several, but not all, of the OWL wastes. An erratum was entered on the Errata List on the OWL Production site and a change was entered on the Change List on the OWL Development site. A task was created on the Task List on the OWL Development site to determine the extent of condition and identify the source of the error.

A technical data specialist conducted a review of the results from the Inventory Calculator for all OWL wastes and all radionuclides reported for those wastes. This review showed that the projected inventory of ^{242}Cm was incorrect for only four wastes and that projected quantities of all other radionuclides were correct. In OWL ^{242}Cm is assumed to be in secular equilibrium with its parent, ^{242m}Am; the activity of ^{242}Cm is 83% of the activity of ^{242m}Am. All of the wastes for which the erratum issue was identified have one thing in common. In all four cases there was no reported value for the activity of ^{242m}Am in the waste. This observation suggested that there could be a problem with the way that the ^{242}Cm activity was being calculated. At this point the technical data specialist coordinated with an OWL technical software specialist to determine how the stored calculation tool for the Inventory Calculator SSRS report was calculating the value for ^{242}Cm activity.

Working together, the technical data and technical software specialists established the source of the incorrect values. When there was no value for the activity of ^{242m}Am, the stored calculation tool was using the value for the activity of ^{241}Pu to calculate the value for ^{242}Cm. This situation was determined to be a legacy issue, i.e. the value for the activity of ^{241}Pu remained in the stored calculation tool from an earlier calculation. Since there was no value for ^{242m}Am for the new calculation, the tool completed the calculation using the legacy value.

The OWL team decided that the best way to address this issue was to add an inferred value for the activity of ^{242m}Am to the inventory of wastes that lacked this value. The reasoning, of course, is that ^{242m}Am is produced as part of the nuclear fission process, and if its short-lived daughter ^{242}Cm is present in the waste, ^{242m}Am must also be present in the waste but is simply not being reported in the relevant supporting document. One of the limitations on OWL is that the supporting documents that supply the inventory information may not report values for all radionuclides that are present in the waste.

A new task was added to the Task List to implement this solution. The technical data specialists used the secular equilibrium relationship to estimate the activity of ^{242m}Am in each waste. This value was added to the waste inventories in the database and the appropriate supporting documents were revised to incorporate the new information and explain how it was derived. These changes were implemented in OWL Version 3.0 and the Errata List was updated to remove the erratum since it has been corrected.

This example provides an illustration of the complexities that can be involved in error resolution for a database like OWL. It also illustrates the importance of having a team with a range of expertise that can work together effectively.

2.3.2 OWL Release Process

As discussed in Section 1.2.2, the approach used to develop and release OWL is based on the SNL software development methodology documented on an internal SNL wiki site (Lane 2017). This methodology promotes the use of multiple environments; for OWL, the applicable environments are the Development Environment, the Release Candidate Environment, and the Production Environment (Figure 1-1).

The initial OWL production release version, released at the end of FY2019, was designated as Version 1.0. The numbering scheme is modeled after the recognized practice of "semantic versioning" (Preston-Werner n.d.). While this scheme incorporates a three-part version (major.minor.patch), OWL uses just the first two parts (major.minor). For example, Version 2.1 would refer to the first minor update to major Version 2.0. Within OWL, the nomenclature is sometimes shortened to "V2.0" rather than "Version 2.0" for convenience. A major version may include significant changes to system components such as the database, the supporting documents, and the database reports. Minor version updates typically only involve changes to the OWL data (or supporting document) content such as data corrections and new data content, though minor fixes to new aspects of the previous major release are also possible. In any new version, all system components in the Production Environment are released together as one version. Individual components are not released separately. The one caveat is the *OWL User's Guide*, which is an item within a system component (i.e., the Supporting Documents Library) that can be updated and corrected in the Production Environment after an OWL release. In general, major version updates are expected to occur around the end of a fiscal year. Minor version updates are expected to occur in the mid-fiscal year (i.e., February to March) time frame (on an "as-needed" basis). Minor releases are optional and as such may or may not be issued during any particular year.

The Production SharePoint Site home page identifies the relevant version number, the production or release date, and the Sandia National Laboratories report (SAND) number issued for the release. This OWL release stamp—version number, production date, and SAND number—is also included on the web page displays generated by SSRS reports. As of the release of Version 3.0, only some of the output files available to export SSRS report information include the release stamp, with the goal being to ensure that it is included in all output files at some point in the future. OWL provides users the option of exporting information from the web page displays in various output file formats. This stamp adds transparency and traceability to the exported output files and will facilitate users making comparative evaluations if a new version of OWL has been implemented since the output files were generated.

Once the OWL team decides that the version of OWL in the Development Environment is ready to be released as a new version, the release process is implemented. A version number is assigned to the environment and a release candidate of the components is created on the SNL ECN. The Release Candidate Environment is used to conduct multiple reviews (including the SNL R&A process) and additional testing as appropriate. This environment is accessible only to the OWL team and OWL reviewers.

All changes made since the previous version (e.g., corrections, updates, and new additions for the database content and functionality) are recorded in a release change history report, which is stored as an internal document in the OWL Development Environment. When the OWL release candidate passes the reviews and final testing (i.e., is approved through SNL's R&A system), it is moved into the Production Environment on the ECN. The release date for the version is entered in the database, where it is used in the display of the release stamp on database reports, output files, and other OWL components.

In the postproduction phase of the release process, an archive of the released version is created in the OWL Archive Library of the Production Environment on the ECN. The archive consists of all the OWL components and is identified by version/release date. Note also that archives of production releases are not deleted, and therefore the archive can be used to restore previous versions if necessary. The archive serves both as a backup for the current version and as a complete record of the modifications to all the OWL components.

The last step is to update the *OWL User's Guide*, which occurs at some point—typically about a month—after a release. Updates to this report involve, at the least, appending the change history for the latest release to the *OWL User's Guide* Appendix A based on the release change history report created earlier in the release process. Because the information is appended to the existing content, the appendix contains a complete and continuous history of version changes since the release of OWL Version 1.0. A second type of modification that occurs only if needed involves updating the document to reflect any significant changes made to content and/or functionality in the new OWL release. In addition, error corrections can be processed in the update if needed. When a new version of the *OWL User's Guide* is ready, the OWL team replaces the old version with the new version in all OWL environments.

At this time, OWL Version 3.0 has been released and the postprocessing is complete. The updated *OWL User's Guide* (Version 3.0; SNL 2021) is reproduced in Appendix B to help provide a better understanding of OWL capabilities and user interface. Appendix A of the *OWL User's Guide*, which contains the OWL change history, has been relabeled as Attachment B-1 to avoid confusion with the appendices in this annual status update report.

Table 2-1 shows the high-level steps used to develop a schedule for an OWL production release. Details of these steps are provided in Weck et al. (2021b) with the exception of Steps 3.d, 5.a, and 5.g, all of which were added during the release of OWL Version 3.0. Step 3.d helps with the management of the Tester Feedback List in the Release Candidate Environment. Steps 5.a and 5.g pertain to the items in the Announcement List on the Production SharePoint Site home page. On the list is an item created during the previous release that indicates the previous version of OWL is ready for use. In step 5.a, this item is replaced with a new announcement informing end users not to use OWL because a new version release is in progress. OWL will not function properly while the tasks in Step 5 “Create Production from Release Candidate” are being carried out. Step 5.g ensures that, once the rest of Step 5 is done, the do-not-use announcement is replaced with the announcement that the new version of OWL is ready for use.

Table 2-1. High-Level Steps Supporting OWL Production Release

Step	Task
1	**Lockdown OWL changes and prepare for new release.**
	a. Move dev database objects to dbo.[a]
	b. Verify OWL team has stopped all OWL changes.
	c. Create the release schedule using the Release Schedule Template.
	d. Create new release information in Release Table.
	e. Create lists of added/changed items in the various OWL components for the new release.
	f. Create the Release Change Document.
2	**Create Release Candidate from Development.**
	a. Copy supporting documents for this release from Development to Release Candidate.
	b. Update release status in the Development Release Table.
	c. Copy the Development database to the Release Candidate database.
	d. Import reports from the Development Report Project to the Release Candidate Report Project and deploy to Release Candidate SharePoint Report Library.
3	**Perform technical review of Release Candidate.**
	a. Perform technical review of Release Candidate and record comments to be addressed in Tester Feedback List.
	b. If corrections are needed, make changes in Development and migrate to Release Candidate.
	c. Repeat step 3 until there are no outstanding comments to be addressed.
	d. Remove Tester Feedback items.
4	**Submit Release Candidate to R&A to obtain SAND number.**
	a. Submit Release Candidate to R&A.
	b. If R&A is not approved, make changes in Development and migrate changes to Release Candidate.
	c. Repeat steps 4a and 4b until R&A is approved and SAND Number is obtained.
	d. Update Development and Release Candidate Release Tables with SAND Number, production status, and production date.
5	**Create Production from Release Candidate.**
	a. Add announcement in Production SharePoint that site is being updated for new release.
	b. Copy release supporting documents from Release Candidate to Production.
	c. Copy Release Candidate database to Production database.
	d. Import reports from Release Candidate Report Project Solution to Production Report Project Solution and deploy to Production Report Library.
	e. Update Errata List to remove items corrected in release.
	f. Update the Production SharePoint home page with new release information and update Report List if new reports added.
	g. Change announcement in Production SharePoint that site is now available for use.
6	**Perform postproduction.**
	a. Create new Release folder in Archive Library.
	b. Generate .zip file of Production SharePoint supporting documents, then copy to Archive Release folder.
	c. Generate .zip file of Production Report Project Solution and copy to Archive Release folder.
	d. Export the Production Report Library and copy to Archive Release folder.
	e. Copy current OWL Production database backup to Archive Release folder.
	f. Copy the SharePoint site items to the Archive Release folder.
	g. Update *OWL User's Guide* and replace in all OWL environments.

NOTE: [a] The term “dev” stands for “development” and “dbo” stands for database owner. The dev schema is used to organize objects under development while the dbo schema organizes objects that are deemed ready to be included in the next OWL release. R&A = review and approval.

2.4 Development of New OWL Features To Support GDSA

One of the new features planned for OWL is the capability to provide input parameter files to the GDSA framework, which itself is evolving because the GDSA team continues to build its capabilities as a PA tool. According to Mariner et al. (2020, Section 2.2), the computational framework for GDSA consists of the following: (1) input parameter database, (2) software for sampling, sensitivity analysis, and uncertainty quantification (Dakota), (3) petascale multiphase flow and reactive transport code (PFLOTRAN), working with coupled process model codes, and (4) computational support software and scripts for meshing, processing, and visualizing results. The two primary components are PFLOTRAN and Dakota. Preliminary postclosure PA analyses are currently being conducted within the GDSA framework to study various representative disposal concepts (i.e., mined repositories in salt, clay/shale rocks, and crystalline [e.g., granitic] rocks). These preliminary analyses improve the understanding of the behavior of these generic systems while also providing suitable test subjects for building and testing new or enhanced GDSA capabilities.

A key goal for OWL planning is to facilitate complementary development of OWL and the GDSA framework, thereby allowing OWL to change and grow in a manner that can better meet the needs of GDSA, even as the GDSA needs change and grow. As a result, increased communication between the OWL team and the GDSA team is expected starting in FY 2022. This communication will lay the foundation for future integration based on an improved understanding of the anticipated GDSA needs versus the possible solutions that could be achieved with new OWL features. The OWL team will also explore the potential for codes serving purposes outside the GDSA framework (e.g., other process modeling efforts or storage/transportation systems assessments) to benefit from similar integration efforts.

OWL has a number of characteristics that make the database attractive in terms of building the capability to support GDSA and codes serving other purposes. These characteristics are discussed further below.

OWL Content Is Suitable To Provide Input Parameters to GDSA—Current GDSA development efforts focus on assuming the waste forms are commercial SNF, namely pressurized water reactor (PWR) SNF assemblies. However, the source of the radionuclide inventory inputs can vary depending on the disposal concept being considered. For example, according to Section 2.5 in LaForce et al. (2020), simulations of the high-temperature shale repository use nominal and bounding initial radionuclide inventories and waste package power outputs as functions of time that were constructed with assembly and fuel characteristics from the Unified Database (Clarity et al. 2017; Banerjee et al. 2016). However, in Section 4.1.2 of LaForce et al. (2020), simulations of the salt repository were reported as using radionuclide inventories and decay beat versus time curves based on inventories in Carter et al. (2013).

At some point in the future, PA simulations will likely be expanded to include the full range of waste forms intended for disposal in a mined geologic repository, i.e., the commercial SNF including PWR and boiling water reactor (BWR) assemblies plus the waste forms from nuclear waste managed by DOE. The information on DOE-managed waste (DHLW, DSNF, and other wastes) is at the heart of OWL. Each waste type in the OWL database is associated with a variety of information such as the associated waste form and waste form characteristics, the facility at which the waste currently resides, the reported quantities in terms of volume and mass, the radionuclides present, etc. In addition, OWL is being expanded to include information about vessels currently being used for storage and transportation as well as those vessels that exist or are in some stage of planning that could be used for storage, transportation, and/or disposal (Section 2.1.3). Nevertheless, one of the potential issues in supporting GDSA in the future is the fact that OWL contains the DOE portion of the waste information but not the commercial portion. Further communication with the GDSA team will be needed to determine the best path forward with respect to development of OWL capabilities to support GDSA analyses.

Even if consideration of inventory is limited to the current and planned OWL content, more substantive communication with the GDSA team will be needed to determine what the initial set of GDSA information needs might be. Possibilities include information regarding the initial radionuclide inventory for DOE-managed waste for the entire simulated repository or perhaps just the inventory associated with a particular waste package type along with estimates of the expected number of that waste package type. Perhaps there will be a need to consider which waste forms might be in which waste package types and again what the quantities of those waste package types might be, especially if waste form degradation for DSNF is not assumed to be instantaneous as was done for the Yucca Mountain Safety Analysis Report (YM SAR) in the *Yucca Mountain Repository License Application* (DOE 2008).

If GDSA has a need to associate some characteristic or attribute with each waste form and that characteristic or attribute is not currently in OWL, the database can be modified accordingly. For example, GDSA may need certain information associated with a waste grouping scheme for DSNF along with a representative waste form for each group. This approach has been used in the past as a means of dealing with the large number of different DSNF types.

A number of published reports and meeting documents have focused on the management of the more than 200 DSNF types into groups for specific purposes, such as disposition in geological repositories. A representative example of such attempts to selectively group DSNF was documented in 1997 in the report *Grouping Method to Minimize Testing for Repository Emplacement of DOE UNF* (DOE 1997). This report suggested the partition of DSNF into 11 groups for testing purposes, based on the examination of available data and information and associated degradation models of DSNF. The behaviour of DSNF in terms of time-to-failure and release rate was found to be primarily influenced by fuel matrix and cladding, while seven other parameters (i.e., burnup, initial enrichment, cladding integrity, fuel geometry, radionuclide inventory, fission gas release, and moisture content) had only limited impact on fuel behaviour (DOE 1997, 1998a). However, subsequent discussions suggested that this 11-group partition is not suitable for other analyses, such as criticality evaluations in support of DSNF repository disposal, and a new partition into 34 intermediate condensed DSNF groups was proposed based on fuel matrix, cladding, cladding condition, and enrichment (DOE 2002).

For the purpose of total system performance assessment (TSPA), those 34 DSNF groups could be reduced to 16 groups for the TSPA, with the seminal rationale for such partitioning documented in the report *DOE UNF Information in Support of TSPA-VA* (DOE 1998b, Figure 5-1). Further details for grouping are presented in the report *DOE UNF Grouping in Support of Criticality, DBE, and TSPA-LA* (DOE 2000b). According to the DOE grouping team assessment, the 34 intermediate condensed DSNF groups in support of the postclosure safety case could be further reduced to 13 groups for the purpose of postclosure PA analyses (DOE 2002), with a subsequent refinement to 11 DSNF groups for TSPA (by placing the plutonium/uranium nitride fuels in the “miscellaneous fuel” group (Group 10 below) due to their small quantity and the uranium beryllium oxide fuels into the “uranium oxide” group (Group 8 below) owing to their similarities). The final DSNF TSPA grouping in support of the YM SAR (DOE 2008) for the purpose of postclosure safety is given below:

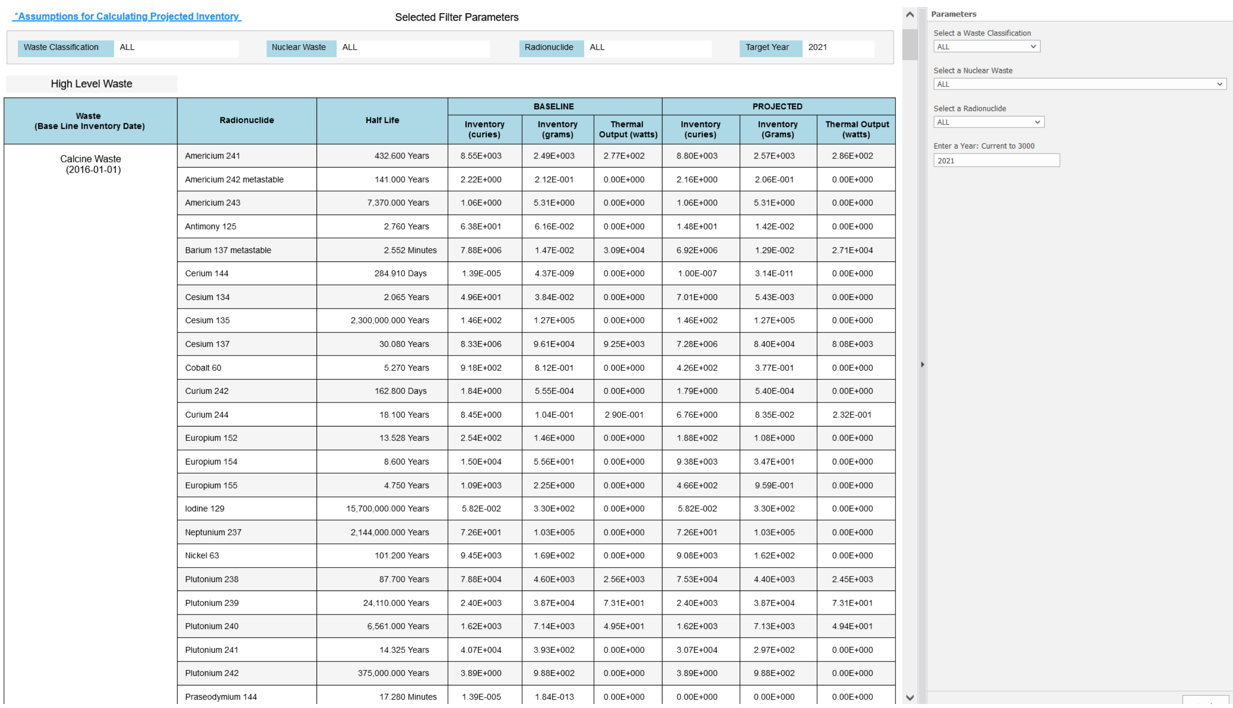
- **Group 1**—Naval SNF (Classified used nuclear fuel [UNF] from surface ship/submarine assemblies)
- **Group 2**—Plutonium/uranium alloy (Fermi Core 1 and 2 UNF)
- **Group 3**—Plutonium/uranium carbide (FFTF-Test Fuel Assembly UNF)
- **Group 4**—Mixed oxide (MOX) and plutonium oxide (FFTF-Demonstration Fuel Assembly/FFTF-Test Demonstration Fuel Assembly UNF)
- **Group 5**—Thorium/uranium carbide (Fort St. Vrain UNF)
- **Group 6**—Thorium/uranium oxide (Shippingport light water reactor [LWR] UNF)
- **Group 7**—Uranium metal (N-Reactor UNF)
- **Group 8**—Uranium oxide (Three Mile Island [TMI]-2 core debris)
- **Group 9**—Aluminum-based UNF (Foreign Research Reactor UNF)
- **Group 10**—Miscellaneous Fuel
- **Group 11**—Uranium-zirconium hydride (Training Research Isotopes–General Atomics (TRIGA) UNF)

The aforementioned 11 DSNF groups were also used in the TSPA for Site Recommendation in FY1999 (DOE 2002).

If GDSA team would like waste form information within OWL to be associated with a particular grouping scheme or some other characteristic or attribute not currently in OWL, the database can be modified to address that need.

OWL Content Is Actively Maintained, Updated, and Expanded as Appropriate—Each current release of OWL is actively maintained ensuring errors identified by any source are investigated. If an identified error is verified as needing correction, that error is acknowledged and fixed in a future release. In addition, the types and amounts of DOE-managed waste are expected to change over time. For example, OWL already has information on the HLW glass stored at the SRS. The ongoing nature of the activities at SRS means that updated information regarding the HLW glass is periodically released. Once it is released, the relevant information within OWL is updated accordingly. Similarly, OWL may be expanded to include new information on a waste type and/or waste form that does not yet exist within OWL. A recent example of this type of expansion is the inclusion of sodium-bonded fuel (Section 2.2.1), which was added to OWL Version 3.0. Another example of the expansion of OWL content is the planned new area for vessel information (Section 2.1.3).

OWL Can Be Modified To Provide Additional Information through Postprocessing Capabilities—Information requests for GDSA input parameter files generated by OWL need not be limited to the basic content residing in OWL. Stored calculation tools can be created within OWL to provide results of calculations using OWL content. For example, OWL currently has a Radionuclide Inventory Calculator, which is made possible through the use of a stored calculation tool. Figure 2-13 is a screen shot of the Radionuclide Inventory Calculator, also described in Section 2.1.2. On the right is the panel allowing users to make various selections for waste classification (all, HLW, SNF, or TRU), nuclear waste (all or any of the waste types), radionuclide (all or a specific radionuclide), and year (anything from current year to 3000). Based on those selections, the Radionuclide Inventory Calculator does the necessary calculations and returns the results in an SSRS report. In a similar manner, stored calculation tools specifically designed to meet the postprocessing needs of GDSA can be created.



*Assumptions for Calculating Projected Inventory

Selected Filter Parameters

Waste Classification	ALL	Nuclear Waste	ALL	Radionuclide	ALL	Target Year	2021

High Level Waste

Waste (Base Line Inventory Date)	Radionuclide	Half Life	BASELINE			PROJECTED		
			Inventory (curies)	Inventory (grams)	Thermal Output (watts)	Inventory (curies)	Inventory (Grams)	Thermal Output (watts)
Calcine Waste (2016-01-01)	Americium 241	432.600 Years	8.55E+003	2.49E+003	2.77E+002	8.80E+003	2.57E+003	2.86E+002
	Americium 242 metastable	141.000 Years	2.22E+000	2.12E-001	0.00E+000	2.16E+000	2.06E-001	0.00E+000
	Americium 243	7,370.000 Years	1.06E+000	5.31E+000	0.00E+000	1.06E+000	5.31E+000	0.00E+000
	Antimony 125	2.760 Years	6.38E+001	6.16E-002	0.00E+000	1.48E+001	1.42E-002	0.00E+000
	Barium 137 metastable	2.552 Minutes	7.88E+006	1.47E-002	3.09E+004	6.92E+006	1.29E-002	2.71E+004
	Cerium 144	284.910 Days	1.39E-005	4.37E-009	0.00E+000	1.00E-007	3.14E-011	0.00E+000
	Cesium 134	2.065 Years	4.96E+001	3.84E-002	0.00E+000	7.01E+000	5.43E-003	0.00E+000
	Cesium 135	2,300,000.000 Years	1.46E+002	1.27E+005	0.00E+000	1.46E+002	1.27E+005	0.00E+000
	Cesium 137	30.080 Years	8.33E+006	9.61E+004	9.25E+003	7.28E+006	8.40E+004	8.08E+003
	Cobalt 60	5.270 Years	9.18E+002	8.12E-001	0.00E+000	4.26E+002	3.77E-001	0.00E+000
	Curium 242	162.800 Days	1.84E+000	5.55E-004	0.00E+000	1.79E+000	5.40E-004	0.00E+000
	Curium 244	18.100 Years	8.45E+000	1.04E-001	2.90E-001	6.76E+000	8.35E-002	2.32E-001
	Europium 152	13.528 Years	2.54E+002	1.46E+000	0.00E+000	1.88E+002	1.08E+000	0.00E+000
	Europium 154	8.600 Years	1.50E+004	5.56E+001	0.00E+000	9.38E+003	3.47E+001	0.00E+000
	Europium 155	4.750 Years	1.09E+003	2.25E+000	0.00E+000	4.66E+002	9.59E-001	0.00E+000
	Iodine 129	15,700,000.000 Years	5.82E-002	3.30E+002	0.00E+000	5.82E-002	3.30E+002	0.00E+000
	Neptunium 237	2,144,000.000 Years	7.26E+001	1.03E+005	0.00E+000	7.26E+001	1.03E+005	0.00E+000
	Nickel 63	101.200 Years	9.45E+003	1.69E+002	0.00E+000	9.08E+003	1.62E+002	0.00E+000
	Plutonium 238	87.700 Years	7.88E+004	4.60E+003	2.56E+003	7.53E+004	4.40E+003	2.45E+003
	Plutonium 239	24,110.000 Years	2.40E+003	3.87E+004	7.31E+001	2.40E+003	3.87E+004	7.31E+001
	Plutonium 240	6,561.000 Years	1.62E+003	7.14E+003	4.95E+001	1.62E+003	7.13E+003	4.94E+001
	Plutonium 241	14.325 Years	4.07E+004	3.93E+002	0.00E+000	3.07E+004	2.97E+002	0.00E+000
	Plutonium 242	375,000.000 Years	3.89E+000	9.88E+002	0.00E+000	3.89E+000	9.88E+002	0.00E+000
	Praseodymium 144	17.280 Minutes	1.39E-005	1.84E-013	0.00E+000	0.00E+000	0.00E+000	0.00E+000

Parameters
Select a Waste Classification
ALL
Select a Nuclear Waste
ALL
Select a Radionuclide
ALL
Enter a Year: Current to 3000
2021

Figure 2-13. Screenshot of Radionuclide Inventory Calculator Showing User Selection Panel on Right Allowing for Filtering of Results

OWL Can Be Modified Allowing User Selections and Input File Generation in Desired Format— The GDSA framework has input parameter needs for PFLOTRAN and for coupled process models (Mariner et al. 2020). The input for any given PFLOTRAN simulation is provided by an input deck created for that simulation. Communication between the GDSA and OWL teams will be needed to determine how OWL-generated files can best interface with the GDSA framework. The new OWL capabilities can be developed to ensure that any input parameter files generated by OWL adhere to the format and data-handling specifications required to allow the OWL-generated files to be read and incorporated into the GDSA framework. There may be a need for OWL to generate only one standard file type or a suite of standard file types. With coordination between the GDSA and OWL teams, the design for various input file types—content and format as well as options providing for file customization—can be established. As was mentioned previously, the file content can reflect the original content of OWL, the results from one or more stored calculation tools, or some combination of the two. Once the design has been established, the OWL team can modify the OWL database to provide the desired user interface and file generation and export capabilities. The GDSA team will be consulted during development as appropriate to ensure the new database features meet GDSA needs in terms of functionality and ease of use before being included in a public release of OWL.

OWL Is Available to the Public without Restrictions—OWL content and any additional information created through stored calculation tools are available to the public without restrictions. The OWL database is subject to SNL's R&A procedures, and each OWL release has a SAND number signifying that it has been approved for a UUR designation. As a result, there are no restrictions on the use of the information coming from the database.

OWL Content Is Transparent and Traceable to the Original Source—All OWL content is tied to the original source within the database structure and that source is available to the user in the OWL Supporting Documents Library. While the user can go to the Supporting Documents Library, there are also links available to provide easy access to the document associated with a particular piece of information. Occasionally a supporting document is subject to copyright or some other restriction. In this case, permission to publicly release the document as part of OWL is sought. If the document cannot be provided, a summary identifying and describing the document is provided in the public release of OWL so that the content is still traceable to the original source. In addition, stored calculation tools are documented both in terms of the OWL content being used and the calculations being done. The documentation is stored in the Supporting Documents Library and also made available to the user through links, which means that the results from stored calculation tools are also transparent and traceable.

OWL Changes and Releases Are Governed by Change Control and Release Management Processes—After the release of OWL Version 1.0, detailed processes controlling OWL changes and public releases were developed and tested using the preparation and release of OWL Version 2.0. The processes were revised according to lessons learned during testing and finally documented in Weck et al. (2021b, 2021c). These processes are also briefly discussed in Section 2.3. The effort to ensure that OWL content is transparent and traceable is incorporated into the change control process. The release management process ensures that a change history is generated for each OWL release after Version 1.0 and appended to an appendix in the *OWL User's Guide.* Appendix B of this report contains a copy of Version 3.0 of the *OWL User's Guide* (SNL 2021). The change history documenting changes from OWL Version 1.0 to Version 3.0 is shown in Attachment B-1 (renamed as an attachment to avoid confusion with appendices in this report).

The change control and release management processes were developed and implemented to provide confidence in the integrity of OWL information and to ensure that OWL can be used even in a more rigorous quality assurance (QA) environment. These processes will be actively maintained and updated as appropriate, giving OWL the flexibility to respond to changing needs. This aspect of OWL may prove beneficial if the QA requirements for GDSA analyses change in the future.

Summary—OWL has multiple characteristics that make the database attractive in terms of building the capability to generate input parameter files for use within the GDSA computational framework as well as codes serving other purposes. The information derived from OWL is (1) suitable for use in input files, (2) actively maintained, updated, and expanded as needed, (3) augmentable through the development of stored calculation tools, (4) transparent and traceable to the original source, and (5) available for UUR designation. A new interface feature can be developed to allow the user to select and customize downloadable input parameter files in the appropriate formats. Finally, OWL is subject to change control and release management processes, thereby increasing confidence in the integrity of database content and functionality while providing the flexibility to respond to a more rigorous QA environment.

3. SUMMARY

This report represents completion of milestone deliverable M2SF-22SN010309082 *Annual Status Update for OWL*, which is due on November 30, 2021 as part of the FY2022 work package SF-22SN01030908. This report provides the annual update on status of FY2021 OWL activities for the work package "OWL - Inventory - SNL". Work on the OWL database is guided by two purposes. The first purpose is to provide a user-friendly, consolidated single source of information on DHLW, DSNF, and other DOE-managed wastes that are likely candidates for deep geologic disposal. There may be up to several hundred different DOE-managed wastes suitable for inclusion in OWL. Because DOE programs involving nuclear waste continue to evolve, the content suitable for OWL continues to evolve as well. To fulfill the first purpose, OWL is updated periodically to capture applicable information as it is publicly released. For example, when updated information on SRS glass waste is released, OWL is updated to include the information. The second purpose is to provide input parameter files with relevant information on waste types, inventory, waste form characteristics, vessels, etc. for PA analyses in the context of the GDSA framework. There is also the potential for codes outside of the GDSA framework (e.g., process modeling codes not coupled to GDSA or storage/transportation systems assessments) to benefit from similar integration efforts.

The primary FY2021 tasks for OWL consist of (1) using the lessons learned from the release of OWL Version 2.0 to finalize the change control and release processes (2) adding information regarding sodium-bonded spent fuel waste types and wastes forms to OWL, and (3) advancing the effort to enhance OWL with new information on the types of vessels capable of disposing of DOE-managed waste.

Completion of OWL Change Control and Release Processes—An important part of the infrastructure supporting OWL is a coherent suite of processes that preserve information integrity and traceability as the database evolves over time. As discussed in Section 2.3, planning for the change control and release processes started in FY2019 along with the first public release of OWL (Version 1.0). Much of FY2020 was spent developing the details before putting the draft processes in to practice with the release of OWL Version 2.0 in late FY2020. Using the lessons learned, the processes were revised and finalized in FY2021, resulting in the documents *OWL Change Control Process* (Weck et al. 2021c) and *OWL Release Process* (Weck et al. 2021b). These documents were also reproduced as appendices in the annual status M2 milestone report for FY2020 OWL activities (Weck et al. 2021a).

The change control process and the release process work together to ensure the quality of the public version of OWL. OWL is maintained and updated with the use of three environments: the Development Environment, the Release Candidate Environment, and the Production Environment. Each environment has the appropriate OWL database and SharePoint site components. The change control process governs all changes that will eventually appear in the publicly released version of OWL in the Production Environment. In general, changes to OWL are made first in the Development Environment. When it is time for a public release, the release process controls the migration of changes to the Release Candidate Environment for technical and R&A review, and then to the Production Environment for public release. Changes to the Production SharePoint Site (governed by the change control process) are implemented in conjunction with the public release (governed by the release process). The release process also controls archival of the previous version of OWL and updating the *OWL User's Guide* as appropriate to support the new OWL release.

The change control process specifies that changes and associated tasks are entered into a tracking system. The tasks are assigned to activities with defined process steps, one of which is always a review by someone independent of the work to ensure the task fulfills the intended purpose. Tasks involving data entry or development of stored calculation tools are subject to a rigorous checking process.

The change control process also includes steps to ensure the OWL content and results from stored calculation tools are transparent and traceable. No OUO information is included in OWL. All OWL content is tied to the original source within the database structure and that source is available to the user in the OWL Supporting Documents Library. While the user can go to the Supporting Documents Library, there are also links available to provide easy access to the document associated with a particular piece of information. Occasionally a supporting document is subject to copyright or some other restriction. In this case, permission to publicly release the document as part of OWL is sought. If the document cannot be provided, a summary identifying and describing the document is provided in the public release of OWL so that the content is still traceable to the original source. In addition, stored calculation tools are documented both in terms of the OWL content being used and the calculations being done. The documentation is stored in the Supporting Documents Library and also made available to the user through links, which means that the results from stored calculation tools are also transparent and traceable.

The OWL release process ensures that all OWL releases go through independent technical review and R&A review before being posted to the Production Environment for public access. In addition, each public release version has a release stamp indicating the version number, release date, and SAND number. The release stamp is also included on the web page displays generated by SSRS reports. As of the release of OWL Version 3.0, only some of the output files available to export SSRS report information include the release stamp, with the goal being to ensure that it is included in all output files at some point in the future. The postprocessing and archival steps include gathering the change history from the previous release being archived to the new release just posted. This change history is appended to an appendix in the *OWL User's Guide.* Appendix B of this report contains a copy of Version 3.0 of the *OWL User's Guide*, which corresponds to OWL Version 3.0*.* The change history documenting OWL changes from Version 1.0 to Version 3.0 is shown in Attachment B-1. Because the change histories are always appended, each version of the *OWL User's Guide* will contain an appendix with a running history of all changes organized according to the OWL release version since Version 1.0.

The change control and release processes were developed and implemented to provide confidence in the integrity of OWL information and to ensure that OWL can be used even in a more rigorous QA environment. These processes will be actively maintained and updated as appropriate, giving OWL the flexibility to respond to changing needs. This aspect of OWL may prove beneficial if the QA requirements for GDSA analyses change in the future.

Addition of Sodium-Bonded Spent Fuel to OWL—The recent inventory data entry focused on the sodium-bonded spent fuel produced from DOE's experimental fast-neutron breeder reactor program (Section 2.2.1). The data for the associated spent fuel wastes, EMT produced wastes/waste forms, and other planned waste forms that are being, or are planned to be, produced have been incorporated into OWL Version 3.0. These wastes represent a large number of waste types and waste forms in OWL because they have been classified based on the reactor of origin and the type of fuel (driver versus blanket) from each nuclear reactor.

At this point in time, there are eight waste types that have been entered into the OWL to reflect five spent fuels and the three possible outputs of the EMT procedure. Defining the associated waste forms for these eight waste types presented a challenge. In the past, the OWL database structure allowed only one waste type to be associated with each disposal waste form. It was discovered that this one-to-one relationship was too limited to address the complexities associated with the multiple types of sodium-bonded spent fuel, the multiple waste streams for each spent fuel, and the plan to combine EMT waste streams from more than one type of sodium-bonded spent fuel into a single waste form. As a result, the OWL database was restructured so that a disposal waste form, such as metallic waste, can be associated with more than one waste type. Four new disposal waste forms were entered into OWL, two of them reflecting the preferred treatment option and two of them associated with the proposed alternative treatment options.

Advances in the Vessel-Related Enhancement of OWL—The addition of vessel information to OWL is a complex, multiyear effort. As discussed in Section 2.1.3, the plan for OWL since its inception has been to allow the database to evolve over time in terms of both content and capability. One of OWL's primary functions is to provide access to information on DOE-managed wastes likely to be disposed of in a mined geologic repository. The OWL expansion to include information on the vessels capable of disposing of that DOE-managed waste, with the ancillary aspects of storing and transporting those wastes/waste forms, is seen as a complement to this function.

Thus far, development efforts for the vessel area have emphasized mining the literature, determining which pieces of information (i.e., database fields) to capture for each vessel, and building the necessary database structure into OWL. The initial focus for data mining is on the vessels—existing or in some design stage—that are used or intended to be used for DOE-managed wastes.

Appendix A describes how the full scope of the planned vessel-related work fits within the framework of the change control process. The change "Enhance OWL with New Vessel Information" has been entered into the Change List and a set of associated tasks has been entered into the Task List. The statuses of the tasks are discussed and a schematic of the preliminary information modeling architecture for vessel tables, including the relationships between tables, is provided. In addition, some examples of vessels are discussed in Appendix A. The examples were selected to display some of the variety within the pool of vessels identified by the data mining thus far. Some of the example vessels currently exist and some are partially designed. Some are developed solely for DOE use and some have commercial use as well. The primary purpose may be storage, transportation, disposal, or some combination thereof. In addition, each example vessel is subject to a hierarchy that dictates the layering used in a nested system of vessels. In fact, being part of a nested system of vessels is something all vessels, not just the example vessels, appear to have in common. A vessel typically needs one or more additional vessels to fulfill its intended function, be it for storage, transportation, or disposal.

The effort to include vessel information in OWL is large and complex. Although significant progress has been made, it is expected that an OWL release with vessel information will occur at some point beyond the current fiscal year.

Future Work on OWL—Future work on OWL is expected to emphasize the following areas:

- **Maintaining and Updating OWL**—There is an ongoing need to maintain OWL to ensure identified errata are documented and corrected and to update the database as newly released information on DOE-managed wastes becomes available.
- **Continuing Effort on Vessel-Related Enhancement**—As discussed above, the effort to add vessel information to OWL is a complex, multiyear endeavor. Future work includes continued data mining, further development and refinement of the database structures (i.e., tables, stored calculation tools if any, and SSRS reports for display), data entry, and data checking. Eventually, when plans for integration with the DOE SFDB and the UNF-ST&DARDS database come to fruition, there will also be the work of incorporating the relevant information from the other databases into OWL.
- **Exploring Integration Possibilities with the GDSA Framework and Codes Serving Other Purposes**—Another multiyear expansion activity for OWL planned for FY2022 and beyond involves exploring integration possibilities with the GDSA computational framework and possibly codes serving other purposes (Section 2.4). The concept is to add new features to OWL capable of generating turn-key downloadable files for use as parameter inputs for simulations. Communication between the GDSA team and the OWL team can facilitate complementary development paths allowing OWL to evolve in a manner that facilitates integration with the GDSA framework as it also evolves. In addition, the potential for codes serving other purposes (e.g., process modeling codes not coupled to GDSA or storage/transportation systems assessments) to benefit from similar integration efforts will be explored in the future. The new OWL features for GDSA support will likely include an automated interface for users to define a desired inventory and/or other information for input parameter files through selection of options such as (1) the desired wastes/waste forms, (2) the specific waste package or other vessel from appropriate possibilities, and (3) the year/date of the inventory. Once the selections are made, OWL would then generate one or more downloadable files in the desired format to supply input parameters to the GDSA framework.
- **Investigating Opportunities To Leverage Information in Other DOE Databases**—The DOE has other databases containing information that is attractive for use in OWL. Rather than try to duplicate this information, the preference is to leverage the information of interest. For example, Section 2.2.2 discusses plans for cooperation with INL regarding the SFDB, an NQA-1 database (DOE 2007) with information regarding DOE-managed SNF and the associated vessels. Although the inventory for N-reactor fuel has already been entered directly into the OWL database and is appropriate for use in GDSA analyses (primarily because N-reactor fuel represents the major mass of DSNF), it is not efficient, nor desirable, to re-enter the other 700+ entries of DSNF that reside in the INL's SFDB. Because the SFDB contains classified information, care is being taken to select a subset of information fields to ensure OWL will remain designated as suitable for UUR. The details of cooperation are complex and will require further discussion with INL before implementation is possible.

  Another DOE database of interest is the UNF-ST&DARDS database at Oak Ridge National Laboratory. This database contains information on commercial SNF and related vessels. Again, the OWL team would rather leverage information of interest from UNF-ST&DARDS than try to duplicate it.

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4. REFERENCES

Banerjee, K., K.R. Robb, G. Radulexcu, P.L. Miller, J.M. Scaglione, J.M. Cuta, and H. Liljenfeldt 2016. *UNF-ST&DARDS: A Unique Tool for Automated Characterization of Spent Nuclear Fuel and Related Systems.* PATRAM 2016, Japan Society of Mechanical Engineers and Atomic Energy Society of Japan, Kobe, Japan.

Bounini, L. and S. Anderson 2000. *Project Management Plan for Transuranic and Transuranic Mixed Waste per Tri-Party Agreement M-91-03*. HNF-6287, Revision 1. Richland, WA: Fluor Hanford.

Carrell, R. 2002. *Annex D-200 Area Interim Storage Area Final Safety Analysis Report*. HNF-3553, Vol. 5, Rev. 2.

Carter, J.T., A.J. Luptak, J. Gastelum, C. Stockman, and A. Miller 2013. *Fuel Cycle Potential Waste Inventory for Disposition.* FCRD-USED-2010-000031, Revision 6. Aiken, SC: Savannah River National Laboratory.

Clarity, J.B., K. Banerjee, H.K. Liljenfeldt, W.J. Marshall 2017. As-Loaded Criticality Margin Assessment of Dual-Purpose Canisters Using UNF-ST&DARDS*. Nuclear Technology* 199 (3): 245–275.

DOE (U.S. Department of Energy) 1997. *Grouping Method to Minimize Testing for Repository Emplacement of DOE UNF*. DOE/UNF/REP-008. *Washington*, DC: Department of Energy, Office of Environmental Management.

DOE 1998a. *DOE UNF Grouping Meeting Minutes, November 17–18, 1998*. Washington, DC: U.S. Department of Energy, Office of Environmental Management.

DOE 1998b. *DOE UNF Information in Support of TSPA-VA.* DOE/UNF/REP-0027. Washington, DC: U.S. Department of Energy, Office of Environmental Management.

DOE 2000a. 65 FR 56565 (September 19, 2000). *Department of Energy; Record of Decision for the Treatment and Management of Sodium-Bonded Spent Nuclear Fuel.*

DOE 2000b. *DOE UNF Grouping in Support of Criticality, DBE and TSPA-LA*. DOE/UNF/REP-046. Washington, DC: U.S. Department of Energy, Office of Environmental Management.

DOE 2002. *DOE Spent Nuclear Fuel Information in Support of TSPA-SR*. DOE/SNF/REP-047, Revision 2. Idaho Falls, ID: U.S. Department of Energy, Idaho Operations Office.

DOE 2007. *General Description of Database Information Version 5.0.1*. DOE/SNF/REP-094. Idaho Falls, ID: Idaho National Laboratory.

DOE 2008. *Yucca Mountain Repository License Application.* DOE/RW-0573, Update No. 1. Washington, DC: U.S. Department of Energy, Office of Civilian Radioactive Waste Management.

DOE 2014. *Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel.* Washington, DC: U.S. Department of Energy, Office of Nuclear Energy.

Greene, S.R., J.S. Medford, and S.A. Macy 2013. *Storage and Transport of Cask Data for Used Commercial Nuclear Fuel-2013 U.S. Edition*. ATI-TR-13047. Oak Ridge, TN: EnergX, LLC.

Jove-Colon, C. F., L. Criscenti, M. Padilla, P. Weck, H. Moffat, and D. Sassani 2021. *Modeling Activities Related to Waste Form Degradation: Progress Report.* M4SF-21SN010309021; SAND-2021-7941R. Albuquerque, NM: Sandia National Laboratories.

LaForce, T., K.W. Chang, F.V. Perry, T.S. Lowry, E. Basurto, R. Jayne, D. Brooks, S. Jordan, E. Stein, R. Leone, M. Nole. 2020. *GDSA Repository Systems Analysis Investigations in FY2020.* M2SF-20SN0190304052; SAND2020-12028 R. Albuquerque, NM: Sandia National Laboratories.

Lane, J. 2017. "5.b Development Methodologies." Last modified on Sep 06, 2017. Available internal to Sandia National Laboratories only. https://snl-wiki.sandia.gov/display/SDL/5.b+Development+Methodologies.

Lee, J.H., M. Simpson, and Y. Wang 2013. *Initial Performance Assessment to Evaluate Technical Feasibility of Direct Disposal of Electrorefiner Salt Waste in salt Repository.* SAND2013-7304P; FCRD-UFD-2013-000275. Albuquerque, NM: Sandia National Laboratories.

Mariner, P.E., M.A. Nole, E. Basurto, T.M. Berg, K.W. Chang, B.J. Debusschere, A.C. Eckert, M.S. Ebeida, M. Gross, G.E. Hammond, J. Harvey, S.H. Jordan, K.L. Kuhlman, T.C. LaForce, R.C. Leone, W.C. McLendon III, M.M. Mills, H.D. Park, F.V. Perry, A. Salazar III, D.T. Seidl, S.D. Sevougian, E.R. Stein, L.P. Swiler 2020. *Advances in GDSA Framework Development and Process Model Integration.* M2SF-20SN010304042; SAND 2020-10787 R. Albuquerque, NM: Sandia National Laboratories.

NRC (Nuclear Regulatory Commission) 2019. *Certificate of Compliance for Radioactive Material*. CoC 9796, Rev. 2; Docket No. 71-9796; Package ID No. USA/9796/B(U)F-96. Washington, DC: U.S. Nuclear Regulatory Commission.

NWTRB (Nuclear Waste Technical Review Board) 2017. *Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel: Report to the United States Congress and the Secretary of Energy*. Arlington, VA: Nuclear Waste Technical Review Board.

Preston-Werner, T. n.d. "Semantic Versioning 2.0.0." English version. https://semver.org.

Price, L. 2018. "Cs-135 Content of Cesium Capsules and Strontium/Cesium Heat Sources - 18509," *44th Annual Waste Management Conference (WM2018), March 18-22, 2018*. WM-18509. Phoenix, AZ: Waste Management Symposia, Inc.

Price, L. 2021a. *On-Line Waste Library Supporting Information*.SAND2021-7609. Albuquerque, NM: Sandia National Laboratories.

Price, L. 2021b. *Sodium-Bonded Fuel and Waste Information.* SAND2021-7768 O. Albuquerque, NM: Sandia National Laboratories.

Rechard, R.P., T. Hadgu, Y. Wang, L. Sanchez, P. McDaniel, C. Skinner, and N. Fathi 2017. *Technical Feasibility of Direct Disposal of Electrorefiner Salt Waste*. SAND-2017-10554. Albuquerque, NM: Sandia National Laboratories.

Sassani, D.C., P. Brady, L. Criscenti, N. Fluke, F. Gelbard, M. Padilla, L. Price, J. Prouty, R. Rechard, M. Rigali, R. Rogers, A. Sanchez, J. Tillman, W. Walkow, and P. Weck. 2019. *Online Waste Library (OWL) and Waste Forms Characteristics Annual Report*, M2SF-19SN010309013, SAND-2019-10722 R. Albuquerque, NM: Sandia National Laboratories.

Sassani, D., P. Brady, F. Gelbard, L. Price, J. Prouty, R. Rechard, M. Rigali, R. Rogers, A. Sanchez, W. Walkow, and P. Weck 2018. *Inventory and Waste Characterization Status Report and OWL Update.* M2SF-18SN010309013; SAND-2018-12352 R. Albuquerque, NM: Sandia National Laboratories.

Sassani, D., J.-H Jang, P. Mariner, L. Price, R. Rechard, M. Rigali, R. Rogers, E. Stein, W. Walkow, and P. Weck 2016. *The On-line Waste Library (OWL): Usage and Inventory Status Report.* FCRD-UFD-2016-000080; SAND-2016-9485 R. Albuquerque, NM: Sandia National Laboratories.

Sassani, D., L. Price, R. Rechard, R. Rogers, W. Walkow, A. Johnson, A. Sanchez, P. Mariner, M. Rigali, E. Stein, and P. Weck 2017. *Inventory and Waste Characterization Status Report.* SFWD-SFWST-2017-000014; SAND-2017-10260 R. Albuquerque, NM: Sandia National Laboratories.

Savannah River Remediation 2018. *Evaluation of I-129 Concentration Data to Improve Liquid Waste Inventory Projections.* SRR-CWDA-2015-00077, Revision 2. Aiken, SC: Savannah River Remediation, LLC.

SNL (Sandia National Laboratories) 2014. *Evaluation of Options for Permanent Geologic Disposal of Used Nuclear Fuel and High-Level Radioactive Waste Inventory in Support of a Comprehensive National Nuclear Fuel Cycle Strategy.* FCRD-UFD-2013-000371, Revision 1; SAND-2014-0187P; SAND-2014-0189P. Albuquerque, NM: Sandia National Laboratories.

SNL 2021. *OWL User's Guide.* SAND-2021-15753 O. Albuquerque, NM: Sandia National Laboratories.

Wang, Y., M. Simpson, J. Rath, F. Hansen, J.H. Lee, C. Jove-Colon, K. McMahon, and P. Swift 2011. "Closing the Nuclear Fuel Cycle with Salt." *13th International High-Level Radioactive Waste Management Conference 2011 (IHLRWMC 2011)*. Proceedings of meeting held April 10-14, 2011, Albuquerque, NM.

Weck, P., P. Brady, L. Criscenti, N. Fluke, F. Gelbard, M. Padilla, L. Price, J. Prouty, R. Rechard, M. Rigali, R. Rogers, A. Sanchez, D. Sassani, J. Tillman, W. Walkow 2021a. *Annual Status Update for OWL and Waste Form Characteristics.* M2SF-21SN010309012; SAND-2021-0994 R. Albuquerque, NM: Sandia National Laboratories.

Weck, P., N. Fluke, L. Price, J. Prouty, R. Rogers, D. Sassani, J. Tillman, W. Walkow 2021b. *OWL Release Process.* SAND2021-0522. Albuquerque, NM: Sandia National Laboratories.

Weck, P., N. Fluke, L. Price, J. Prouty, R. Rogers, D. Sassani, W. Walkow 2021c. *OWL Change Control* Process. SAND2021-0519. Albuquerque, NM: Sandia National Laboratories.

Wilson, J. 2016. *Decay Heat of Selected DOE Defense Waste Materials*. FCRD-UFD-2016-000636; SRNL-RP-2016-00249. Aiken, SC: Savannah River National Laboratory.

APPENDIX A—IMPLEMENTING THE CHANGE "ENHANCE OWL WITH NEW VESSEL INFORMATION"

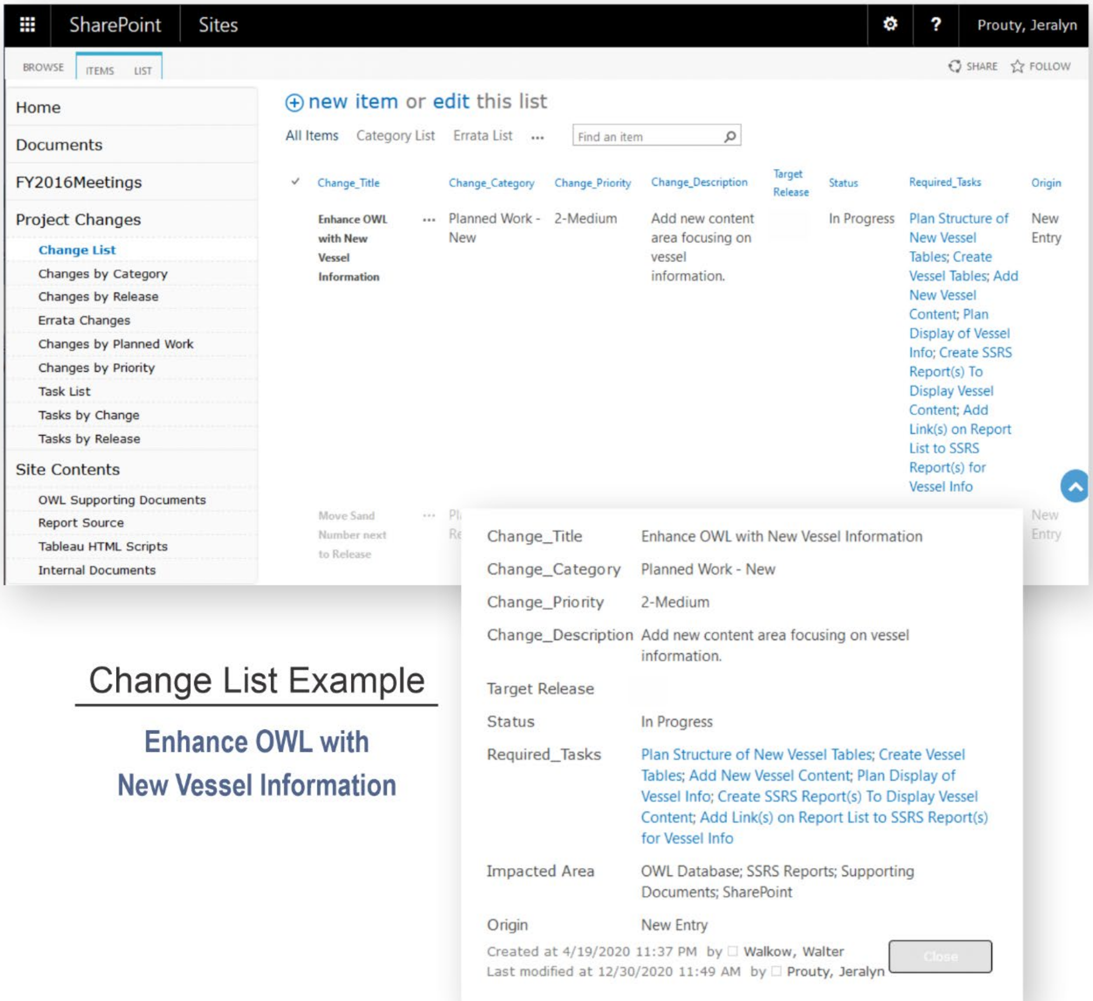
A-1. Using the OWL Change Control Process for Vessel Information

As discussed in Section 2.1.3, OWL is being expanded to include information on vessels capable of disposing of that DOE-managed waste, with the ancillary aspects of storing and transporting those wastes/waste forms. In accordance with the process documented in *OWL Change Control Process* (Weck et al. 2021c), the change "Enhance OWL with New Vessel Information" has been entered into the Change List with a set of associated tasks entered into the Task List. Figure A-1 shows the screenshots of the change "Enhance OWL with New Vessel Information" and the associated change properties.

Six tasks needed to implement the change were entered into the Task List as follows:

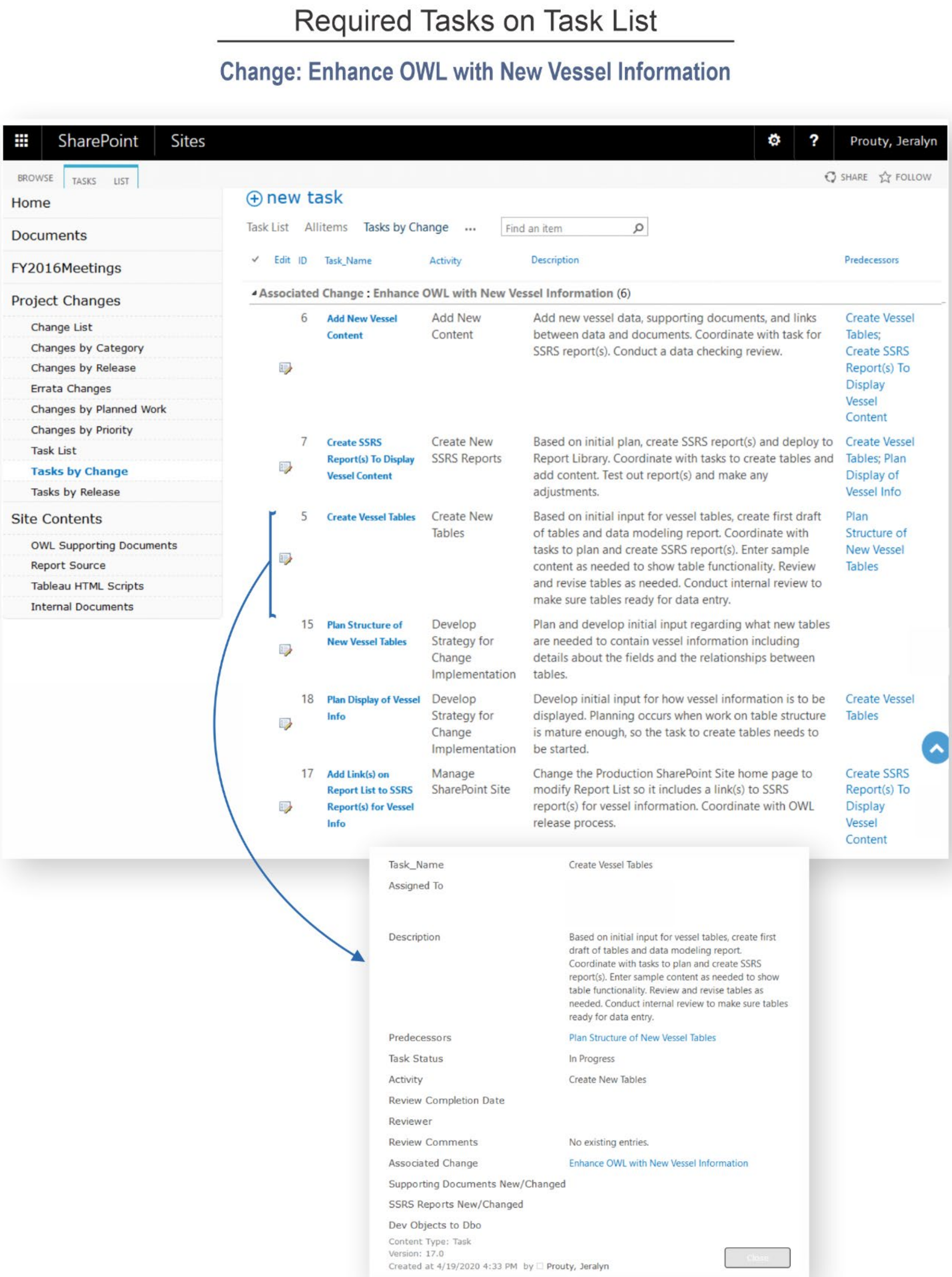
1. **Plan Structure of New Vessel Tables**
   Activity: "Develop Strategy for Change Implementation"
2. **Create Vessel Tables**
   Activity: "Create New Tables"
3. **Add New Vessel Content**
   Activity: "Add New Content"
4. **Plan Display of Vessel Info**
   Activity: "Develop Strategy for Change Implementation"
5. **Create SSRS Report(s) To Display Vessel Content**
   Activity: "Create New SSRS Reports"
6. **Add Link(s) on Report List to SSRS Report(s) for Vessel Info**
   Activity: "Manage SharePoint Site"

The above list also shows the activity assigned to each task based on the nature of the task. The OWL change control process identifies twelve possible activity types; each type has its own set of process steps governing the workflow (Weck et al. 2021c, Section 4.3). Figure A-2 is a screenshot of the required tasks in the Task List organized by change along with an exploded view of properties for one of the tasks. In Figure A-2, certain tasks are listed as predecessors of other tasks. For the Task List in general, the term "predecessor" is defined broadly in that the predecessor task must be started but does not have to be finished before the successor task is started. Note that the numbered list above shows the general order of tasks, though some tasks will be worked on concurrently. The order of the tasks in the Task List does not conform to the expected workflow.



Source: Weck et al. 2021c, Figure 16.

Figure A-1. Screenshots of Change List Entry and Associated Properties for the Change “Enhance OWL with New Vessel Information”



Source: Weck et al. 2021c, Figure 17.

Figure A-2. Task List Screenshots showing Required Tasks to Implement Change “Enhance OWL with New Vessel Information” as well as Properties for One of the Tasks

A detailed discussion of the expected workflow for the six tasks with respect to the change control process is in Weck et al. (2021c, Section 4.4). The discussion in that report also addresses the interplay between the change control process and the release process (Weck et al. 2021b) required to implement any change in a publicly released version of OWL. In brief, the OWL team makes changes first in the OWL Development Environment according to the change control process. With respect to the six tasks above, Tasks 1 and 4 involve planning rather than making actual changes. Tasks 2, 3, and 5 involve the types of changes made in the OWL Development Environment under the purview of the change control process. When ready, they will be independently reviewed in the Development Environment before being designated as complete and ready for release. Later, the release process will be used to ensure that those changes are migrated correctly to the Release Candidate Environment for an independent review of the release candidate version of OWL and then to the Production Environment for public release.

Task 6 is different because it involves adding a link or links to the Report List on the Production SharePoint Site home page. Unlike the changes in Tasks 2, 3, and 5, the change in Task 6 cannot be made by transferring copies of files developed and approved in the Development Environment. Because of the nature of SharePoint, any change to a SharePoint site home page must be made directly to that home page; it cannot be made in another home page in a different OWL environment and then transferred. For this reason, the change control process for this task focuses on the Production SharePoint Site instead of the Development SharePoint Site. The link or links will be added first to the Development SharePoint Site home page so the OWL team can access the SSRS report(s). During the release process, the same link or links will be added to the Release Candidate SharePoint Site home page, where the technical review of the release candidate version of OWL—part of the release process—will ensure that the link or links make sense to an end user. The timing of when the OWL team will update the Report List on the Production SharePoint Site home page will be governed by the release process. However, the change control process will govern the steps taken to do the update, thereby ensuring that the added link or links provided in the public release are subject to an independent review.

The six tasks on the Task List reflect direct changes to the database or planning for those changes, and as such they are subject to the change control process. While mining the literature for vessel information is an important effort that informs the actions needed to implement five of the six tasks, the data mining itself is not a direct change nor is it planning for a change to the database. As such, it is not subject to the change control process, hence its absence from the Task List. Nevertheless, the ongoing data mining effort is a large and complex undertaking. As discussed further in Section A-2, there is a great deal of variability in the types and level of detail of information available for different vessels. However, enough progress has been made to allow for some initial planning of the vessel table structure as well as the creation of early drafts of the tables in the database. Thus, Tasks 1 and 2 are in progress; the other tasks have not been started. Figure A-3 depicts the preliminary OWL information modeling architecture for vessel tables, including the relationships between tables.

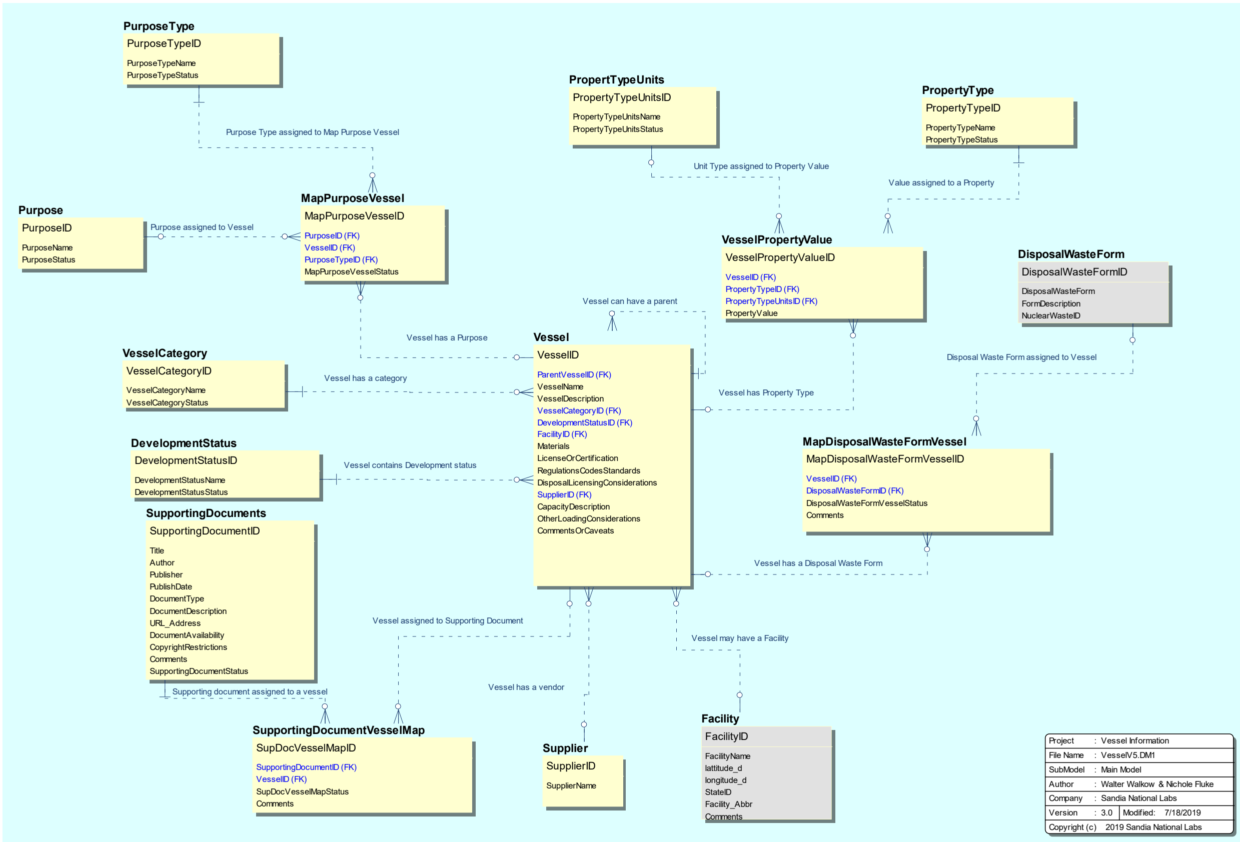


Figure A-3. Preliminary OWL Information Modeling Architecture for Vessel Tables

A-2. Examples of Vessels Identified through Data Mining

As discussed in Section A-1, the data mining effort provides the foundation for the majority of the tasks associated with the change “Enhance OWL with New Vessel Information”. Some of the vessels actually exist while others are in various stages of planning and design. The types and level of detail of information available for any given vessel vary greatly. The emphasis has been on vessels that are either planned for use or are already in use for DOE-managed wastes. These vessels may have been developed for DOE use or may have originally been developed for commercial use. Detailed information on commercial vessels is already part of the UNF-ST&DARDS database at Oak Ridge National Laboratory, and a future effort is planned for integrating with that database. In the meantime, information from other sources about commercial vessels being used to store and/or transport DOE-managed waste is being processed as part of the data mining effort.

Five different vessels are presented below as examples of the vessel information found through data mining. The example vessels are the following:

- Transportation, Aging, and Disposal (TAD) Canister
- Waste Package (21-PWR/44-BWR TAD, also known as a TAD waste package)
- M-290 Transportation Cask
- NUHOMS 12-T Dry Shielded Canister
- Modified NAC-1 Cask

Table A-1 provides a summary of some of the descriptive information available for the example vessels, which were selected to display some of the variety within the pool of vessels identified by the data mining thus far. Some of the vessels currently exist and some are only partially designed. Some are developed solely for DOE use and some have commercial use as well. The primary purpose may be storage, transportation, disposal, or some combination thereof. In addition, each vessel is subject to a hierarchy that dictates the layering used in a nested system of vessels. In fact, being part of a nested system of vessels is something all vessels, not just the example vessels, appear to have in common. A vessel typically needs one or more additional vessels to fulfill its intended function, be it for storage, transportation, or disposal. The additional vessel(s) may be inner or outer layers relative to the vessel of interest depending on the situation. Although the TAD canister and TAD-bearing waste package are intended for commercial SNF, they are included in the list because they serve as straightforward examples of (1) two layered vessels working together for the purpose of disposal, (2) two partially designed vessels that have standing as part of recognized DOE planning or decisions, and (3) two vessels intended solely for DOE use. They are also discussed in the YM SAR (DOE 2008).

The subsections below provide more information about each example vessel as well as tables of physical attributes.

Table A-1. Descriptive Information for the Five Example Vessels

Descriptive Attribute	TAD Canister	Waste Package (21-PWR/44-BWR TAD)	M-290 Transportation Cask	NUHOMS 12-T Dry Shielded Canister	Modified NAC-1 Cask
Primary Purpose	Transportation and Disposal	Disposal	Transportation	Storage and Transportation	Storage
Vessel Hierarchy (layering of vessels)[a]	Transportation/Inner Layer – None Transportation/Outer Layer – Transportation Cask Disposal/Inner Layer – None Disposal/Outer Layer – Waste package (21-PWR/44-BWR TAD)	Disposal/Inner Layer – TAD Canister Disposal/Outer Layer – None	Transportation/Inner Layer – The cask is licensed to transport both canistered and bare fuel Transportation/Outer Layer – None	Storage/Inner Layer – Canisters of TMI-2 Fuel Debris Storage/Outer Layer – NUHOMS 12-T horizontal storage module (storage overpack) Transportation/Inner Layer – None Transportation/Outer Layer – MP-187 (transportation and transfer cask)	Storage/Inner Layer – LWR Canister Storage/Outer Layer – ISO Shipping Container (tall or short)
Description	The TAD canister is a right circular cylinder with components including a canister shell, lid(s), and other required components (e.g., basket for holding fuel assemblies, thermal shunts, neutron absorbers) needed to perform its functions.	Waste package consists of two concentric cylinders. Inner vessel includes inner cylinder, bottom inner lid, and closure inner lid. Outer corrosion barrier includes outer cylinder, outer bottom lid and top closure outer lid. Configuration: 21-PWR/44-BWR TAD	The cask is part of a shipping container system (including specialized rail car) used by Navy to transport Naval SNF from shipyard to INL	Dry shielded canister consists of cylindrical shell with welded top and bottom cover plates forming a containment boundary. Baskets provide heat transfer paths, criticality control and structural support.	The modified NAC-1 cask is a smooth-surface, right circular cylinder with an inner and outer shell. It has been modified such that impact limiters protrude radially at both ends. Modifications also include removal or plugging of several valves connected to the confinement cavity, removal of anti-rotational lugs in the interior cavity to accommodate the LWR canister, and replacement of neutron shield tank pressure relief penetrations with threaded solid plugs.

Table A-1. Descriptive Information for the Five Example Vessels (continued)

Descriptive Attribute	TAD Canister	Waste Package (21-PWR/44-BWR TAD)	M-290 Transportation Cask	NUHOMS 12-T Dry Shielded Canister	Modified NAC-1 Cask
Development Status	Partially Designed	Partially Designed	Exists	Exists	Exists
Contents	Commercial SNF assemblies	1 TAD canister containing commercial SNF assemblies	Canisters of Naval SNF	Canisters of TMI-2 fuel debris	1 LWR canister containing commercial PWR assemblies (Calvert Cliffs and Point Beach)
DOE Facility	NA	NA	Shipped to INL	INL	Hanford Site
Licensing/ Certification	Unlicensed; planned to be part of NRC-certified system	Unlicensed; planned to be part of NRC-certified system	NRC certified under 10 CFR 71 (CoC 9796 R2)	NRC certified (SNM-2508) for storage at INL	DOE safety evaluation: Carrell, R. 2002. *Annex D-200 Area Interim Storage Area Final Safety Analysis Report*. HNF-3553, Rev. 2. March.

NOTE: [a] For vessel layering, inner and outer layer designations are relative to the position of the vessel in the column header.
BWR = boiling water reactor
CoC = Certificate of Compliance
DOE = Department of Energy
INL = Idaho National Laboratory
ISO = International Standards Organization
LWR = light water reactor
NA = not applicable
NAC = Nuclear Assurance Corporation
NRC = Nuclear Regulatory Commision
PWR = pressurized water reactor
SNF = spent nuclear fuel
TAD = transportation, aging, and disposal
TMI = Three Mile Island

Source: TAD Canister: DOE 2008.
Waste Package (21-PWR/24 BWR TAD): DOE 2008.
M-290: NRC 2019.
NUHOMS 12-T: Greene et al. 2013.
Modified NAC-1: Carrell, R. 2002.

A-2.1 TAD Canister

The TAD canister was designed for use on the Yucca Mountain Project. The intended uses included transportation, aging, and disposal of commercial SNF. Detailed design information for the TAD canister has not been developed. A performance specification was developed for selected system components in support of the YM SAR. Table A-2 provides the physical properties of the TAD canister.

The plan presented in the YM SAR was based on loading the majority of commercial SNF into TAD canisters at the utilities. The TAD canisters would be sealed at the utilities and transported to the repository. At the repository the TAD canisters would be loaded into TAD waste packages (21-PWR/44-BWR TAD) and emplaced into the repository. There are provisions in the plan for loading some, approximately 10%, of the TAD canisters at the repository. There are also provisions for aging, or storing, TAD canisters on the surface before loading them into TAD waste packages. Surface aging would be determined by operational considerations.

Table A-2. Physical Properties of TAD Canister

Physical Property	Value
Canister Height	186.0 – 212.0 in.
Canister Diameter	66.5 in.
Maximum Weight – TAD Canister and Waste Package Spacer	54.25 tons
Content Specification – Fuel Types	PWR & BWR assemblies
Content Specification Limit – PWR Assemblies	Less than 5% initial enrichment
Content Specification Limit – PWR Assemblies	80 GWd/MTU or less
Content Specification Limit – PWR Assemblies	No less than 5 yr cooling time
Content Specification Limit – BWR Assemblies	Less than 5% initial enrichment
Content Specification Limit – BWR Assemblies	75 GWd/MTU or less
Content Specification Limit – BWR Assemblies	No less than 5 yr cooling time

NOTE: BWR = boiling water reactor
PWR = pressurized water reactor
TAD = transportation, aging, and disposal

Source: DOE 2008, Section 1.5.1.1.1.2.1.4.

A-2.2 Waste Package (21-PWR/44-BWR TAD)

The TAD waste package was intended for disposal of commercial SNF in a TAD canister at Yucca Mountain (DOE 2008, Section 1.5.2). The waste package consists of two concentric cylinders; the TAD canister fits inside the waste package inner cylinder. The inner cylinder is Stainless Steel Type 316 (UNS S31600) and the waste package outer barrier (i.e., outside of the outer cylinder) is bounded by a layer of Alloy 22 (UNS N06022). The Alloy 22 is a corrosion resistant material that is included in the design to enhance the long-term performance of the waste package. Table A-3 lists the physical properties of the TAD waste package.

Table A-3. Physical Properties of Waste Package (21-PWR/44-BWR TAD)

Physical Property	Value
Waste Package Length	230.32 in.
Waste Package Outer Diameter	77.28 in.
Loaded Weight	162,055 lb
Capacity	1 TAD canister

NOTE: TAD = transportation, aging, and disposal
Source: DOE 2008, Table 1.5.2-3.

A-2.3 M-290 Transportation Cask

The M-290 is the rail transportation cask developed by the Navy. In 2013, the NRC licensed this cask for the transportation of both bare fuel and canistered SNF, with the last supplement being processed in 2019 (NRC CoC 9796 R2 [NRC 2019]). The certificate pertains to transporting A1W and A1G spent fuel modules. In 2017, the Nuclear Waste Technical Review Board (NWTRB) reported that the Navy is planning to use the casks to ship the Naval SNF from the sites where the spent fuel is removed from naval vessels to INL for storage (NWTRB 2017). The cask can also be used for transport of the SNF to a future repository.

According to NWTRB (2017), the details of the configuration of the vessel internal contents vary depending on nature of the fuel being transported. The most significant differences relate to whether bare fuel or canistered SNF is being transported. However, characteristics derived from the fuel configuration and use can also be important. The Navy is expected to develop 16 different core dependent safety analysis reports for R&A by NRC. Each of the 16 will reflect a distinct configuration of Naval SNF. The physical properties of the cask are listed in Table A-4.

Table A-4. Physical Properties of M-290 Transportation Cask

Physical Property	Value
Maximum Height (Including Domes)	361.5 in.
Maximum Outer Diameter	128 in.
Maximum Weight (Including Contents)	520,000 lb
Cavity Diameter	71 in.
Cavity Height	242 in.
Body Outer Diameter – upper section	92.15 in.
Body Outer Diameter – lower section	96.15 in.
Body Steel Wall Thickness – upper section	10.6 in.
Body Steel Wall Thickness – lower section	12.6 in.

Source: NRC 2019.

A-2.4 NUHOMS 12-T Dry Shielded Canister

Manufactured by Transnuclear Inc., the NUHOMS storage system is a storage and transport system reported in Greene et al. (2013, pp. 139–176). This system relies on a dry shielded canister, a transfer cask, a horizontal storage module made of reinforced concrete, and a transportation cask. There are multiple dry shielded canisters designed for different uses. According to Greene et al. (2013), NRC issued SNM-2508 on March 19, 1999 for the use of NUHOMS 12-T dry shielded canister to store TMI-2 fuel debris canisters at INL. The "12" indicates that the dry shielded canister can contain 12 canisters and the "T" means that it is transportable. As of March 2013 (the date of the report), 345 TMI-2 canisters had been loaded into 29 NUHOMS 12-T dry shielded canisters, which were then placed into horizontal storage modules for storage. The M-187 cask was identified as the transfer cask and the transportation cask for the NUHOMS 12-T dry shielded canister.

Table A-5 provides the physical properties for the NUHOMS 12-T dry shielded canister recorded in Greene et al. 2013. The NUHOMS 12-T dry shielded canister was also mentioned by the NWTRB in a report to Congress and the Secretary of Energy written in 2017 (NWTRB 2017, Section 5.1.1.1).

Table A-5. Physical Properties of NUHOMS 12-T Dry Shielded Canister

Physical Property	Value
Materials of Construction (canister body, basket, shield plugs)	carbon steel
Overall Length	163.5 in.
Cross Section	67.2 in.
Cavity Length	151 in.
Wall Thickness	0.625 in.
Loaded Weight	<70,000 lb
Design Heat Rejection	0.86 kW
Maximum Burnup	3.2 GWD/MTU
Cavity Atmosphere	air
Capacity (intact assemblies)	12 TMI-2 fuel debris canisters

NOTE: TMI = Three Mile Island

Source: Greene et al. 2013, unnumbered table on p. 66.

A-2.5 Modified NAC-1 Cask

The modified NAC-1 cask is part of a nested system used for storage at Hanford. Table A-6 lists some of the physical properties of the cask. A DOE safety evaluation documented by Carrell (2002) is the primary information source. The NWTRB later discussed the cask in a 2017 report to Congress and the Secretary of Energy (NWTRB 2017, Section 4.1.2).

The modified NAC-1 cask is a right, circular cylinder with an inner and outer shell. Each modified NAC-1 cask contains one LWR canister, which serves as the innermost layer in the vessel hierarchy. The LWR canister contains commercial PWR assemblies (Calvert Cliffs and Point Beach) and provides a confinement boundary during storage. The modified NAC-1 cask provides structural protection and shielding. It is placed in an International Standards Organization (ISO) shipping container (tall or short) for storage. In this case, the shipping container is intended only to provide shelter; it is not meant for on-site or off-site transportation.

Manufactured by Nuclear Assurance Corporation (NAC) International, the NAC-1 cask (unmodified) was licensed by the NRC to transport LWR spent fuel and waste material. Later at Hanford, the cask was modified for storage and on-site transportation purposes as follows: (1) impact limiters were changed to protrude radially at both ends, (2) several valves connected to the confinement cavity were removed or plugged, (3) anti-rotational lugs to the cavity interior were removed to accommodate the LWR canister, and (4) neutron shield tank pressure relief penetrations were replaced with threaded solid plugs. When the cask was modified, the NRC license for transportation was not retained. Therefore, while the modified NAC-1 casks can be transported on site, they cannot be transported off site from Hanford unless the appropriate NRC transportation license is obtained.

Table A-6. Physical Properties of Modified NAC-1 Cask

Physical Property	Value
Materials of Construction	Main Structures: stainless steel Shielding: chemical-grade lead Axial Fins at Lead/Steel Interface: copper Capscrews for Closure Lid: ASTM A-320, Grade L43, low alloy steel O-ring Seals for Closure Lid: polytetrafluoroethelene Impact Limiters: balsa, stainless steel, asbestos
Cavity Diameter	13.50 in.
Cavity Length	178.0 in.
Wall Thickness	0.3125 in.
Maximum Outer Diameter	50 in.
Outer Length (including impact limiter)	214 in.
Vessel Lid Thickness	7.5 in.
Loaded Weight	47,150 lb

NOTE: ASTM = American Society for Testing and Materials

Source: Carrell 2002.

A-3. Summary Observations

As indicated by the example vessels shown above, there is a great deal of variety within the population of vessels identified through data mining the literature. Basic descriptive information includes determining whether the vessels (1) actually exist or not, (2) are used for DOE-managed waste, commercial SNF, or both, and (3) are used for storage, transportation, disposal, or some combination. Vessels must be considered in terms of a vessel hierarchy consisting of vessel layers nested inside one another to accomplish the purpose of storage, transportation, or disposal. The hierarchy associated with a vessel may change if the purpose changes (e.g., the same inner vessel may use a storage overpack, a transportation cask, or a disposal waste package depending on the situation). The OWL table structure is being designed to make these kinds of relationships between vessels clear.

A challenging aspect of the data mining is that there is also variety in the type and level of detail of information available for different vessels. Part of that variability is a function of whether the vessel exists or not. For example, a vessel that exists and has been licensed for storage or transportation by the NRC will have far more information available than a vessel that is in the preliminary design stage. Nevertheless, a comparison of Table A-4, Table A-5, and Table A-6 reveals that, even for existing vessels, variation exists in the types of information reported. As a result, it is natural and expected that only a portion of the available fields in the vessel tables will be populated for any given vessel. Data mining of public documents really is a case of "what you see is what you get".

The variety in the nature of the vessels as well as the type and level of detail of the information available must be taken into account in the design of the vessel tables and the relationships between the tables. Care must also be taken in designing the links to the waste/waste form area of OWL. Another challenge in the future will be designing the user interface with controls to select what the user wants to see and determining how that information is going to be displayed. For the five vessel examples above, the choice was made to have a summary table (Table A-1) allowing for a comparison of certain information for all five examples. Then individual tables (Table A-2 to Table A-6) with physical properties for one example vessel at a time were presented. Similarly, there will be a need to allow users to pick one or more displays that allow for a comparison of information for multiple vessels. There will also be a need to allow users to pick one or more displays that provide more detailed information about a single vessel. In the end, the goal is to add useful information on vessels to OWL and to provide the user easy ways to examine the information at a high level or drill down to details to get what he or she needs.

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APPENDIX B—*OWL USER'S GUIDE*

The links to the *OWL User's Guide* are available to the user on the OWL home page and on all of the SSRS reports. The process for updating the document is governed by the OWL release process (Section 2.3.2; Weck et al. 2021b). At some point—typically about a month—after the release of a new version of OWL, the OWL team updates the *OWL User's Guide* and replaces the old version with the new version in all OWL environments. This action is the last step in the postprocessing phase of the release process.

The updated *OWL User's Guide* (Version 3.0; SNL 2021) corresponding to the current OWL release (Version 3.0) is reproduced below. The formatting from the *OWL User's Guide* has been retained for consistency with the original document. For example, the subheads are unnumbered, the fonts are different, and the figures do not have captions. The links in the *OWL User's Guide* to various locations in the document are shown through appropriate formatting, but they are not active in this appendix. In addition, Appendix A of the *OWL User's Guide* has been relabeled as Attachment B-1 to avoid confusion with the appendices in this annual status update report.

SAND2021-15753 O

OWL User's Guide – Version 3.0
December 13, 2021

The purpose of the Online Waste Library (OWL) (https://collaborate.sandia.gov/sites/OWL/SitePages/Home.aspx) is to provide a single site that contains information on the many different U.S. Department of Energy (DOE)-managed wastes that are likely to require deep geologic disposal. Generally, these wastes are classified as either spent nuclear fuel (SNF), high-level waste (HLW), or transuranic waste (TRU). A complete list of all the DOE-managed wastes that are in OWL is available by clicking on "DOE-Managed Wastes" on the home page. TRU waste that is already destined for WIPP is not included in OWL, and commercial SNF that is not managed by the DOE is also not included in OWL.

Note that Firefox and Chrome are the recommended browsers, as there are limitations on the use of other browsers.

Navigation

Clicking on an item to open it, such as a link to a document, opens the item in a new window. To close the item, simply close the window. To go back to the previous webpage, click on the window containing that page. Many webpages allow you to navigate back to the Home Page, to the DOE-Managed Wastes webpage, or to the User Guide via links in the upper left corner of the webpage.

Printing and Saving

To print or save a webpage, click on "Actions" in the upper left corner of the webpage you wish to print or save. From the drop-down menu that appears, select "Print" if you want to print the webpage or "Export" if you wish to save it in a different format (e.g., pdf, Excel, Word).

How Do I….?

See which wastes are included in OWL?
See which wastes are at a particular site?
See the DOE-managed wastes by classification (high-level waste, spent nuclear fuel, or transuranic waste)?
See what the DOE has planned or proposed with respect to the disposal waste forms for the wastes?
See the radionuclide inventory of a particular waste?
See the radionuclide inventory of a particular waste or wastes as of a specific date (year)?
See a graph showing the total radioactivity and thermal output of a waste (or all wastes) over the next 200 years?
See a list of radionuclides included in OWL?
See a list of documents used to support the information in OWL?

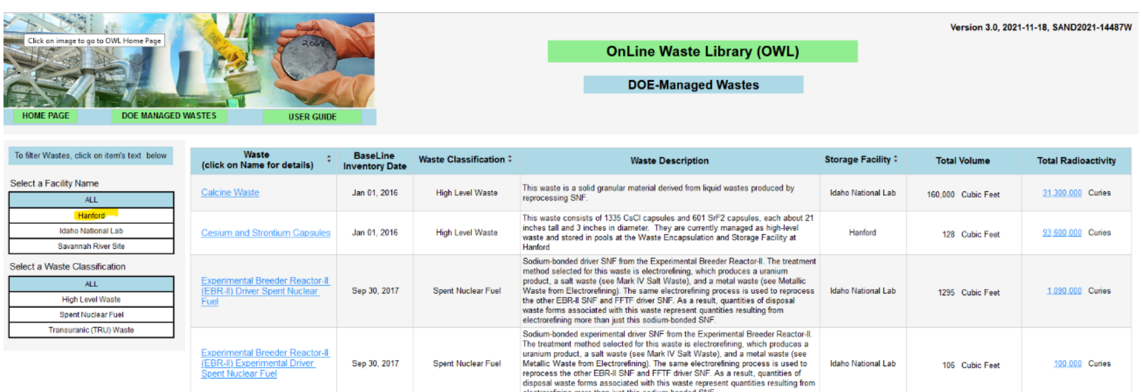
See which wastes are included in OWL?

Click on "DOE-Managed Wastes" from the home page.

See which wastes are at a particular site?

Click on "DOE-Managed Wastes" from the home page, then select the name of the desired facility from the selection pane on the left side of the page. In the example shown below, Hanford is selected.

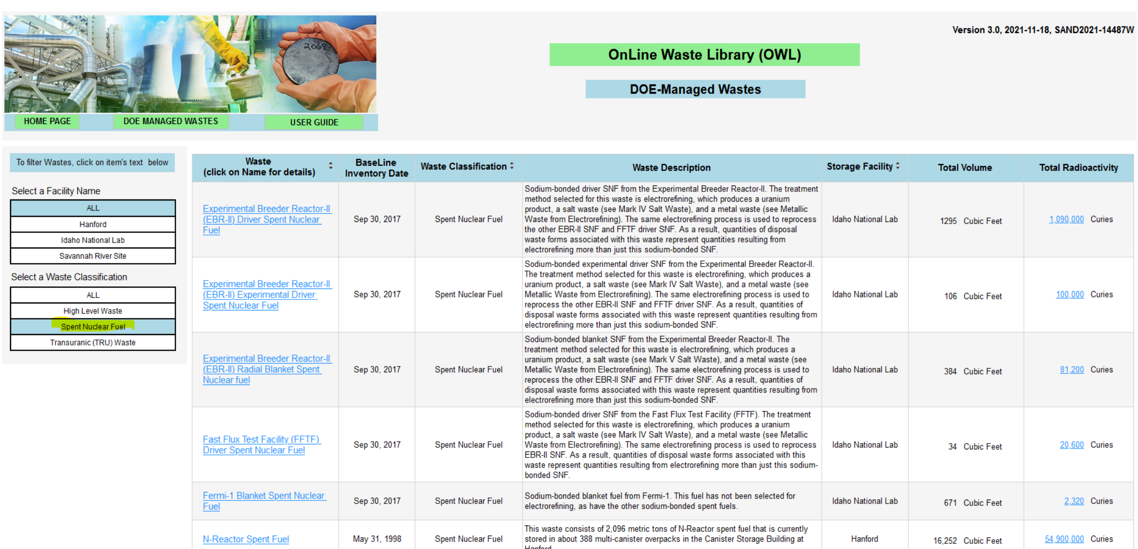
Then



See the DOE-managed wastes by classification (high-level waste, spent nuclear fuel, or transuranic waste)?

Click on “DOE-Managed Wastes” from the home page, then select the desired waste classification from the selection pane on the left side of the page. In the example shown below, “Spent Nuclear Fuel” is selected.

then



Waste (click on Name for details)	BaseLine Inventory Date	Waste Classification	Waste Description	Storage Facility	Total Volume	Total Radioactivity
Experimental Breeder Reactor-II (EBR-II) Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded driver SNF from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark IV Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess the other EBR-II SNF and FFTF driver SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	1295 Cubic Feet	1,090,000 Curies
Experimental Breeder Reactor-II (EBR-II) Experimental Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded experimental driver SNF from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark IV Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess the other EBR-II SNF and FFTF driver SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	106 Cubic Feet	100,000 Curies
Experimental Breeder Reactor-II (EBR-II) Radial Blanket Spent Nuclear fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded blanket SNF from the Experimental Breeder Reactor-II. The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark V Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess the other EBR-II SNF and FFTF driver SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	384 Cubic Feet	81,200 Curies
Fast Flux Test Facility (FFTF) Driver Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded driver SNF from the Fast Flux Test Facility (FFTF). The treatment method selected for this waste is electrorefining, which produces a uranium product, a salt waste (see Mark IV Salt Waste), and a metal waste (see Metallic Waste from Electrorefining). The same electrorefining process is used to reprocess EBR-II SNF. As a result, quantities of disposal waste forms associated with this waste represent quantities resulting from electrorefining more than just this sodium-bonded SNF.	Idaho National Lab	34 Cubic Feet	20,600 Curies
Fermi-1 Blanket Spent Nuclear Fuel	Sep 30, 2017	Spent Nuclear Fuel	Sodium-bonded blanket fuel from Fermi-1. This fuel has not been selected for electrorefining, as have the other sodium-bonded spent fuels.	Idaho National Lab	671 Cubic Feet	2,320 Curies
N-Reactor Spent Fuel	May 31, 1998	Spent Nuclear Fuel	This waste consists of 2,096 metric tons of N-Reactor spent fuel that is currently stored in about 388 multi-canister overpacks in the Canister Storage Building at Hanford.	Hanford	16,252 Cubic Feet	54,900,000 Curies

See what the DOE has planned or proposed with respect to the disposal waste forms for the wastes?

Click on "Waste Forms" from the home page, then select the waste form in which you are interested. In the example shown below, "Calcine waste that has been hot isostatically pressed, with additives" was selected.

Sandia National Laboratories

OWL   Home

ONLINE WASTE LIBRARY (OWL)   V3.0, 11/18/2021, SAND2021-14487W

The online waste library contains information regarding DOE-managed (as) high-level waste (HLW), spent nuclear fuel (SNF), and other wastes that are likely candidates for deep geologic disposal, with links to the current supporting documents for the data (when possible).

Users Guide

Errata - reported data errors

Find Information About ...

- DOE-Managed Wastes
- Waste Forms
- Inventory Calculator
- 200-Year Inventory and Thermal Output
- Baseline Radionuclide Inventory in Each Waste
- Radionuclides
- Supporting Documents

then

OnLine Waste Library (OWL)

Waste Types and Disposal Waste Forms

Version 3.0, 2021-11-18, SAND2021-14487W

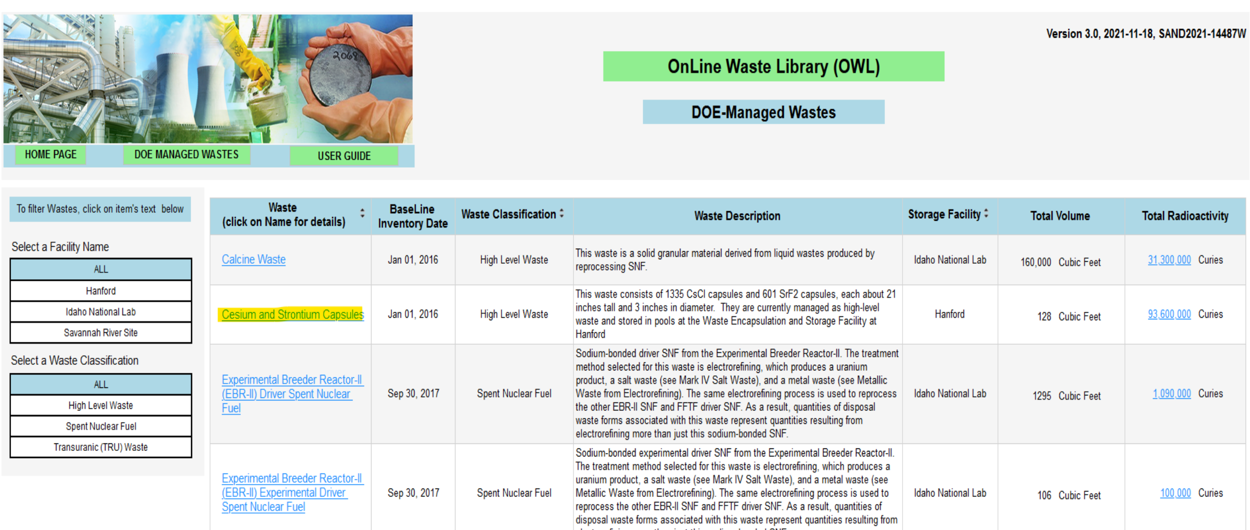
Waste Types and Associated Disposal Waste Forms

Waste	Disposal Waste Form	Waste Form Description	Projected or Existing	Preferred or Alternative	Quantity	Volume	Supporting Document
Calcine Waste	Calcine Waste cemented without vitrification	Direct cementation of the calcine waste without vitrification.	Projected	Alternative	18,000 2 ft. diameter, 10 ft. tall canisters	570,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine waste that has been hot isostatically pressed, with additives	Calcine waste treated by hot isostatic pressing, including silica, titanium and calcium sulfate (glass ceramic). Processing the calcine with the silica and titanium is needed to eliminate RCRA hazardous waste characteristics.	Projected	Preferred	4,045 Cans of calcine that have been hot isostatically pressed	190,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine waste that has been hot isostatically pressed, without additives	Calcine waste treated by hot isostatic pressing without silica, titanium and calcium sulfate (glass ceramic).	Projected	Alternative	3,236 Cans of calcine that have been hot isostatically pressed	150,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine Waste Vitrified following Separation	Calcine waste that has been vitrified following separation.	Projected	Alternative	1,190 2 ft. diameter, 10 ft. tall canisters	37,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine Waste Vitrified without Separation	Calcine waste that has been vitrified without separation.	Projected	Alternative	12,000 2 ft. diameter, 10 ft. tall canisters	380,000 cubic feet	On-Line Waste Library Supporting Information
	Calcine Waste without further treatment	Calcine waste that is disposed of without further treatment.	Existing	Alternative	6,100 2 ft. diameter, 10 ft. tall canisters	190,000 cubic feet	On-Line Waste Library Supporting Information
Cesium and Strontium Capsules	Cs and Sr capsules	Cs and Sr capsules, as-is, disposed of in waste packages designed for a deep borehole, 18 capsules per package	Existing	Alternative	108 8.625 in. diameter, 16 ft. tall waste packages	686 cubic feet	Deep Borehole Disposal Safety Analysis
	Vitrified Cs and Sr from capsules	Glass logs in canisters	Projected	Preferred	340 2 ft. diameter, 15 ft. tall canisters	16,000 cubic feet	Vitrification of Cs and Sr Capsules

See the radionuclide inventory of a particular waste?

There are three different ways to do this. One way is to click on “DOE-Managed Wastes” from the home page, then click on the name of the waste, then click on the plus sign (+) next to “5. Radionuclide Inventory.” This will display the inventory (in Curies) for the waste. In the example below, Cesium and Strontium Capsules is the waste selected.

then

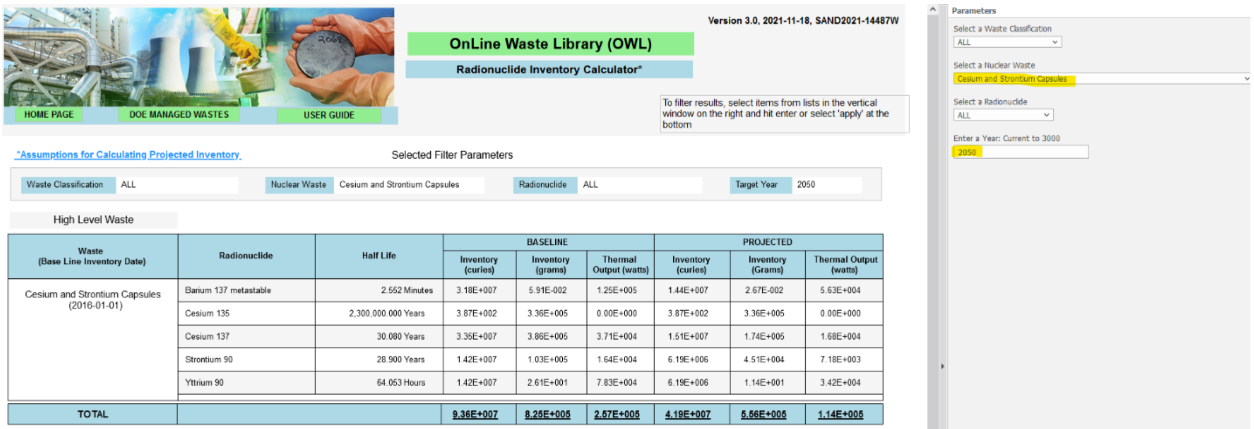


then

-OR-

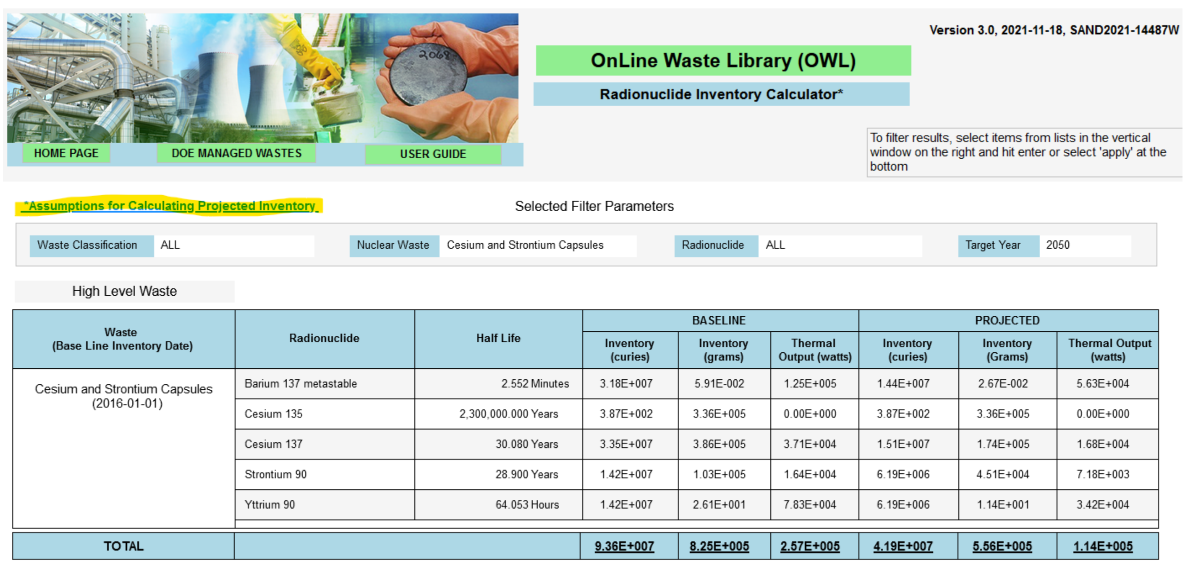
The second way is to click on “Inventory Calculator” from the home page. This will display the inventory (in Curies and grams) of every radionuclide in every waste, along with the thermal output of heat-generating radionuclides in every waste, both as of the baseline date for the waste and at some specified time (date). From the Radionuclide Inventory Calculator page, you can filter the wastes by waste classification, waste, and radionuclide, and you can select the year for which you would like the inventory calculated. After making these selections, hit “Enter” on your keyboard or click “Apply” on the lower right side of the webpage. In the example below, the inventory for the Cesium and Strontium Capsules is calculated for 2050.

Then



Waste (Base Line Inventory Date)	Radionuclide	Half Life	BASELINE Inventory (curies)	BASELINE Inventory (grams)	BASELINE Thermal Output (watts)	PROJECTED Inventory (curies)	PROJECTED Inventory (Grams)	PROJECTED Thermal Output (watts)
Cesium and Strontium Capsules (2016-01-01)	Barium 137 metastable	2.552 Minutes	3.18E+007	5.91E-002	1.25E+005	1.44E+007	2.67E-002	5.63E+004
	Cesium 135	2,300,000.000 Years	3.87E+002	3.36E+005	0.00E+000	3.87E+002	3.36E+005	0.00E+000
	Cesium 137	30.080 Years	3.35E+007	3.86E+005	3.71E+004	1.51E+007	1.74E+005	1.68E+004
	Strontium 90	28.900 Years	1.42E+007	1.03E+005	1.64E+004	6.19E+006	4.51E+004	7.18E+003
	Yttrium 90	64.053 Hours	1.42E+007	2.61E+001	7.83E+004	6.19E+006	1.14E+001	3.42E+004
TOTAL			9.36E+007	8.25E+005	2.57E+005	4.19E+007	5.56E+005	1.14E+005

You can see the assumptions made in calculating radionuclide inventories by clicking on “*Assumptions for Calculating Projected Inventory.”

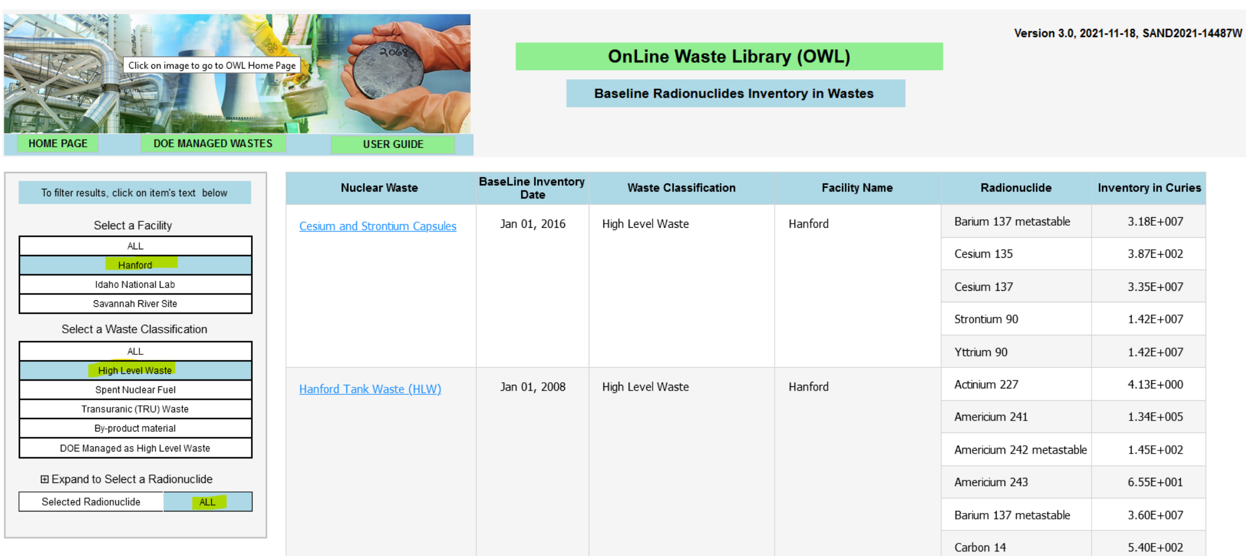


Waste (Base Line Inventory Date)	Radionuclide	Half Life	BASELINE Inventory (curies)	BASELINE Inventory (grams)	BASELINE Thermal Output (watts)	PROJECTED Inventory (curies)	PROJECTED Inventory (Grams)	PROJECTED Thermal Output (watts)
Cesium and Strontium Capsules (2016-01-01)	Barium 137 metastable	2.552 Minutes	3.18E+007	5.91E-002	1.25E+005	1.44E+007	2.67E-002	5.63E+004
	Cesium 135	2,300,000.000 Years	3.87E+002	3.36E+005	0.00E+000	3.87E+002	3.36E+005	0.00E+000
	Cesium 137	30.080 Years	3.35E+007	3.86E+005	3.71E+004	1.51E+007	1.74E+005	1.68E+004
	Strontium 90	28.900 Years	1.42E+007	1.03E+005	1.64E+004	6.19E+006	4.51E+004	7.18E+003
	Yttrium 90	64.053 Hours	1.42E+007	2.61E+001	7.83E+004	6.19E+006	1.14E+001	3.42E+004
TOTAL			9.36E+007	8.25E+005	2.57E+005	4.19E+007	5.56E+005	1.14E+005

-OR-

The third way is to click on “Baseline Radionuclide Inventory in Each Waste” from the home page. This will display the inventory (in Curies) of every radionuclide in every waste as of the baseline date for that waste. You can filter the number of wastes or radionuclides that appear by selecting a facility, a waste classification, and/or a radionuclide from the selection boxes on the left side of the page. In the example shown below, the facility selected is Hanford, the waste classification selected is High Level Waste, and all radionuclides are shown.

then

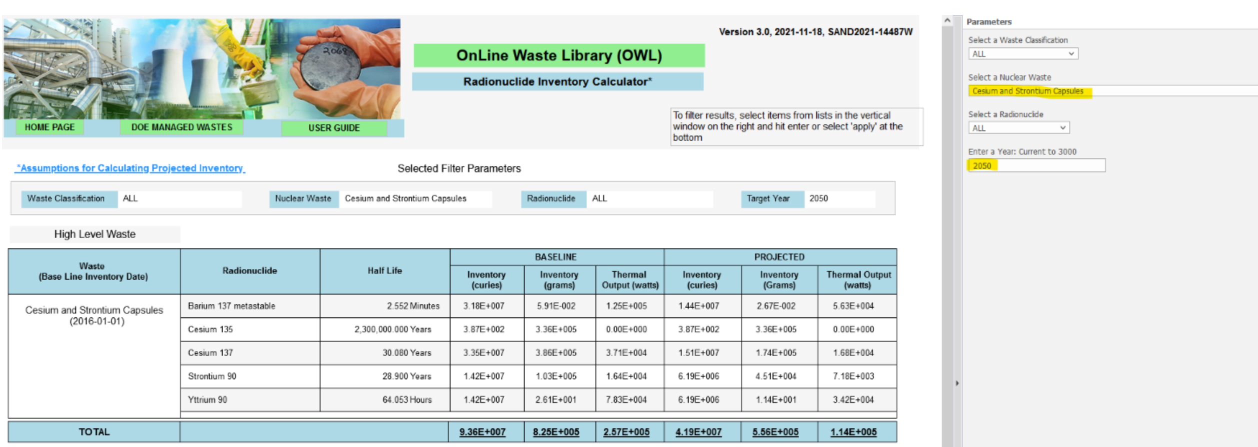


Nuclear Waste	BaseLine Inventory Date	Waste Classification	Facility Name	Radionuclide	Inventory in Curies
Cesium and Strontium Capsules	Jan 01, 2016	High Level Waste	Hanford	Barium 137 metastable	3.18E+007
				Cesium 135	3.87E+002
				Cesium 137	3.35E+007
				Strontium 90	1.42E+007
				Yttrium 90	1.42E+007
Hanford Tank Waste (HLW)	Jan 01, 2008	High Level Waste	Hanford	Actinium 227	4.13E+000
				Americium 241	1.34E+005
				Americium 242 metastable	1.45E+002
				Americium 243	6.55E+001
				Barium 137 metastable	3.60E+007
				Carbon 14	5.40E+002

See the radionuclide inventory of a particular waste or wastes as of a specific date (year)?

Click on "Inventory Calculator" from the home page. This will display the inventory (in Curies and grams) of every radionuclide in every waste, along with the thermal output of heat-generating radionuclides in every waste, both as of the baseline date for the waste and at some specified time (date). Select the desired date (year) from the selection pane on the right side of the page and click on "Apply" on the bottom of the right side of the page or hit "Enter" on your keyboard. You can filter the list of radionuclides displayed by selecting the waste classification, a particular waste, or a radionuclide from the selection pane on the right side of the page and clicking on "Apply" on the bottom of the right side of the page or hitting "Enter" on your keyboard. In the example below, Cesium and Strontium capsules is the selected waste and the year for which the inventory is selected is 2050.

then

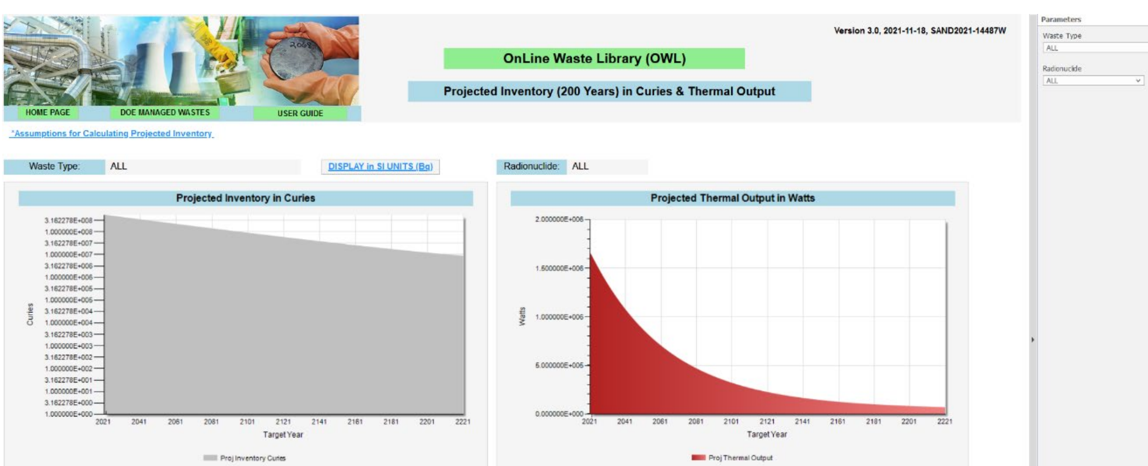


Waste (Base Line Inventory Date)	Radionuclide	Half Life	BASELINE			PROJECTED		
			Inventory (curies)	Inventory (grams)	Thermal Output (watts)	Inventory (curies)	Inventory (Grams)	Thermal Output (watts)
Cesium and Strontium Capsules (2016-01-01)	Barium 137 metastable	2.552 Minutes	3.18E+007	5.91E-002	1.25E+005	1.44E+007	2.67E-002	5.63E+004
	Cesium 135	2,300,000.000 Years	3.87E+002	3.36E+005	0.00E+000	3.87E+002	3.36E+005	0.00E+000
	Cesium 137	30.080 Years	3.35E+007	3.86E+005	3.71E+004	1.51E+007	1.74E+005	1.68E+004
	Strontium 90	28.900 Years	1.42E+007	1.03E+005	1.64E+004	6.19E+006	4.51E+004	7.18E+003
	Yttrium 90	64.053 Hours	1.42E+007	2.61E+001	7.83E+004	6.19E+006	1.14E+001	3.42E+004
TOTAL			9.36E+007	8.25E+005	2.57E+005	4.19E+007	5.56E+005	1.14E+005

<u>See a graph showing the total radioactivity and thermal output of a waste (or all wastes) over the next 200 years?</u>

Click "200-Year Inventory and Thermal Output" from the home page. This will display a graph of the total radioactivity of all the wastes and the thermal output of all the wastes over the next 200 years. You can switch between Curies and GBq for the projected inventory by clicking on "Display in SI Units (Bq)" or "Display in Curies," as appropriate. You can filter the wastes included in the graphs by selecting the waste type or radionuclide from the selection pane on the right side of the page and clicking on "Apply" on the bottom of the right side of the page or hitting "Enter" on your keyboard. In the example shown below, "All" waste types is selected and "All" radionuclides is selected.

then



See a list of radionuclides included in OWL?

Click on “Radionuclides” from the home page. This will display a list of all radionuclides in OWL, along with the half-life of each radionuclide, a link to a graph of the inventory of that radionuclide over the next 200 years, its atomic mass, its heat generation rate (if applicable), its parent radionuclide (if needed for radioactive decay calculations), and its decay ratio (if needed for radioactive decay calculations). Radionuclides can be sorted alphabetically, by half-life, by atomic mass, and by thermal output by clicking on the up and down triangles in the header row of the table. In the example shown below, radionuclides are sorted by decreasing half-life.

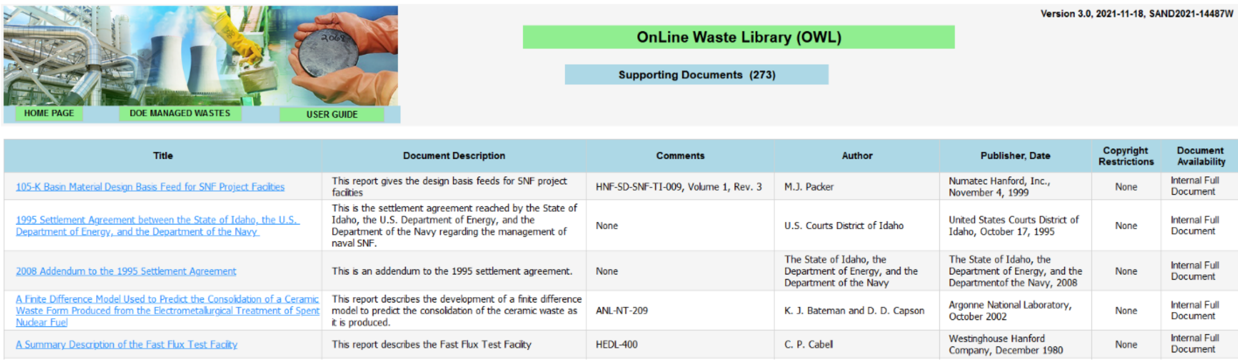
Then

Radionuclide	Description	Half Life		Atomic Mass (u)	Thermal Output (watts/kCi)	Parent Radionuclide	Inventory Ratio	Supporting Document
Sb-126m	Antimony 126 metastable	11.00 seconds	Projected Inventory (200 years)	126.00		Sn-126	1.000	Sb-126m Nuclear Data
Rh-106	Rhodium 106	30.10 Seconds	Projected Inventory (200 years)	106.00		Ru-106	1.000	Rh-106 Nuclear Data
Ba-137m	Barium 137 metastable	2.55 Minutes	Projected Inventory (200 years)	137.00	3.920	Cs-137	0.950	Ba-137m Nuclear Data
Tl-208	Thallium-208	3.05 Minutes	Projected Inventory (200 years)	208.00		U-232	0.359	Tl-208 and Bi-212 Nuclear Data

See a list of documents used to support the information in OWL?

Click on "Supporting Documents" from the home page. This will display a list of all the supporting documents found in OWL, along with a description of the document, any comments (such as report number), author(s), publisher, and date of publication. Clicking on the document title will open the document in a new browser window.

then



Title	Document Description	Comments	Author	Publisher, Date	Copyright Restrictions	Document Availability
105-K Basin Material Design Basis Feed for SNF Project Facilties	This report gives the design basis feeds for SNF project facilities	HNF-SD-SNF-TI-009, Volume 1, Rev. 3	M.J. Packer	Numatec Hanford, Inc., November 4, 1999	None	Internal Full Document
1995 Settlement Agreement between the State of Idaho, the U.S. Department of Energy, and the Department of the Navy	This is the settlement agreement reached by the State of Idaho, the U.S. Department of Energy, and the Department of the Navy regarding the management of naval SNF.	None	U.S. Courts District of Idaho	United States Courts District of Idaho, October 17, 1995	None	Internal Full Document
2008 Addendum to the 1995 Settlement Agreement	This is an addendum to the 1995 settlement agreement.	None	The State of Idaho, the Department of Energy, and the Department of the Navy	The State of Idaho, the Department of Energy, and the Departmentof the Navy, 2008	None	Internal Full Document
A Finite Difference Model Used to Predict the Consolidation of a Ceramic Waste Form Produced from the Electrometallurgical Treatment of Spent Nuclear Fuel	This report describes the development of a finite difference model to predict the consolidation of the ceramic waste as it is produced.	ANL-NT-209	K. J. Bateman and D. D. Capson	Argonne National Laboratory, October 2002	None	Internal Full Document
A Summary Description of the Fast Flux Test Facility	This report describes the Fast Flux Test Facilty	HEDL-400	C. P. Cabell	Westinghouse Hanford Company, December 1980	None	Internal Full Document

The information available by clicking on each of the links under "Find Information About…" on the OWL home page is discussed below.

DOE-Managed Wastes

The information for each waste on this webpage includes its baseline inventory date, its classification (SNF, HLW, or TRU), a description of the waste, where it is stored, its current total volume, and its total radioactivity as of the baseline date. Clicking on the name of the waste opens a Waste Detail Report for that waste. This webpage reports whether the waste was produced by the government, whether it is a mixed waste, and its baseline inventory date, and contains links that present:

- A graphical representation of the projected inventory and thermal output of the waste over the next 200 years (Projected Inventory link)
- Waste Characteristics - thermal output, chemical constituents present, dimensions of the nuclear waste container, the number of containers of the waste, and the physical form of the waste
- Waste Source
- Disposal Waste Forms
- Disposal Waste Form Characteristics – thermal output, dimensions of the waste form, mass of the waste form
- Radionuclide Inventory – Activity (Curies) of each radionuclide reported or calculated to be present in the waste
- Radionuclide Characteristics – half-life and decay ratio (where applicable) for each radionuclide in the inventory for that waste
- Waste Supporting Documents – a list of all documents used as sources of information for that waste. Clicking on the title of a supporting document will open that document in a new window
- Waste Contacts – the name and contact information for a person who is knowledgeable about that waste.

Waste Forms

Each waste also has a “disposal waste form.” For some wastes, such as N-reactor spent fuel or Savanah River glass waste, the waste is intended to be disposed of without further treatment. Hence, the current waste is also the disposal waste form. For other wastes, such as the Hanford tank wastes, the current plan is to treat the waste prior to disposal. For these wastes, the current waste is not the disposal waste form, and possible waste forms are presented. For each disposal waste form, OWL indicates whether the waste form already exists or is planned, and whether the waste form has been declared by the DOE to be the preferred waste form or if it is an alternative to that preferred waste form. All wastes and their associated waste forms are available by clicking on “Waste Forms” on the home page.

Inventory Calculator

Clicking on “Inventory Calculator” from the home page opens a page that gives the radionuclide inventory and thermal output of each waste as of its baseline date and allows the user to calculate the inventory and thermal output at a user-specified year. The selection pane for the parameters for the calculation is on the right side of the page. You can select the waste classification (HLW, SNF, or TRU), a specific nuclear waste, a radionuclide, and a year. Click on the “Apply” button on the bottom of the right side of the page after selecting the desired parameters to generate the report. The selection pane on the right side of the page can be made to disappear by clicking on the triangle in the gray bar to the left of the selection pane. Assumptions that were made in calculating the inventory can be seen by clicking on “Assumptions for Calculating Projected Inventory” at the top of the Radionuclide Inventory Calculation page.

200-Year Inventory and Thermal Output

Clicking on “200-Year Inventory and Thermal Output” from the home page opens a page that gives a graphical representation of the inventory and thermal output of the user-selected waste and radionuclide over the next 200 years. The selection pane for the waste type and radionuclide is on the right side of the page. You can select a particular waste (or all of the wastes) and a particular radionuclide (or all of the radionuclides). Click on the “Apply” button on the bottom of the right side of the page after selecting the desired parameters to generate the report. The selection pane on the right side of the page can be made to disappear by clicking on the triangle in the gray bar to the left of the selection pane.

Baseline Radionuclide Inventory in Each Waste

Clicking on “Baseline Radionuclide Inventory in Each Waste” from the home page opens a page that gives the inventory of each radionuclide in each waste as of the baseline date for each waste. On the left side of the page the user can select wastes by facility or by classification and can select “all” radionuclides or a specific radionuclide.

Radionuclides

Clicking on “Radionuclides” from the home page opens a page that gives the following information for each radionuclide in the OWL database: name, half-life, atomic mass, thermal output (if applicable), its parent (if applicable), the inventory ratio with the parent (if applicable), and a link to the supporting document for some of the information for that radionuclide.

Supporting Documents

Clicking on “Supporting Documents” from the home page opens a page that lists the following information for the supporting documents in the OWL: title of the document, a description of the document, document number (if applicable), URL address (if applicable), the author, the publisher, the date and whether there are copyright restrictions. Clicking on the title of the document will open a new webpage displaying the document or will open a dialog box that allows the user to open the document, save the document, or save the document with another name.

Waste-Specific Spreadsheets

Each waste has a spreadsheet that gives the inventory and thermal output as of the baseline date and allows the user to calculate the inventory and thermal output as of a user-specified target date. Depending on the waste, spreadsheets may also have other information, such as the volume of the waste as currently stored. These spreadsheets are displayed in pdf format to allow users to view the spreadsheet without needing access to Excel™. If you would like the Excel™ version of the spreadsheet, please send an email to OWL@sandia.gov specifying which spreadsheet(s) you would like.

Access, Questions or Comments

If you would like access to OWL, or if you have any questions or comments, please send an email to OWL@sandia.gov.

Attachment B-1– Change History

On-Line Waste Library - Production Date: 11/18/2021, SAND2021-14487W
Changes for Version 3.0 - Major Update

Category	Change Title	Change Description
Errata	Correct Erratum Identified in the Inventory Calculator	The Inventory Calculator report has a default projected date of 2021. When you open the report the values for Cm-242 in Calcine waste are Baseline = 1.84E+000 curies & Projected = 2.57E+004 curies. Hanford HLW Baseline = 1.20E+002 curies & Projected = 2.88E+004 curies. Hanford RH-TRU Baseline = 1.11E+000 curies & Projected = 7.00E+003 curies. Hanford CH-TRU Baseline = 3.96E-002 curies & Projected = 7.43E+001 curies. The baseline inventory values are correct but the projected values cannot be correct. The source of the error is unclear, but it is noted that in each of these cases the parent Rn - Am-242m is absent from the waste inventory. The problem may be with the stored calculation tool for this SSRS report.
Planned Work - New	Add Sodium-Bonded Spent Fuel Waste Type and Waste Forms to OWL	Add information regarding sodium-bonded spent fuel, its quantities, planned treatments, and current status to the OWL database.
Planned Work - Revisions	Modify 200-Year Inventory and Thermal Graphs	Implement improvements to the 200-year inventory and thermal graphs, per the discussion during the OWL teleconference on October 20, 2020.

On-Line Waste Library - Production Date: 11/13/2020, SAND2020-12464W

Changes for Version 2.0 - Major Update

Category	Change Title	Change Description
Errata	Fix Typo on Production SharePoint Site Home Page	On the Production SharePoint Site home page in the announcement identifying recommended browsers, "FIrefox" should be "Firefox". Note also that in the first announcement "initial" is spelled "intial". However, that error does not need fixing since the first opportunity to fix it (i.e., during release of OWL version 2.0) is also when the announcement will be deleted because it will be out of date. Note that the task to fix this typo cannot be done until the Production SharePoint Site is updated during the release process.
	Correct Error on Thermal Graph for Cs-137 and Pu-238 in Hanford Tank Waste (CH-TRU)	In the 200 Year Inventory and Thermal Output report, when Cs-137 or Pu-238 and Hanford Tank Waste (CH-TRU) are selected, the thermal graph comes up with an error – “Axis Object – auto Interval doesn’t have proper value.”
	Identify secular equilibrium between Pa-233 and Np-237 as well as between Th-231 and U-235.	The decay calculations for Pa-233 and Th-231 should reflect that Pa-233 is in secular equilibrium with Np-237 and that Th-231 is in secular equilibrium with U-235. This can be fixed in the database. Pa-233 and Th-231 are not important radionuclides, so the impact of this error is insignificant.
	Update the total radioactivity for the Hanford Cesium and Strontium Capsules	Modify the total radioactivity for the Hanford Cesium and Strontium Capsules to reflect appropriate significant figures. The current value of 93,575,237.7 Curies will be changed to 93,600,000 Curies.
	Change INEEL identification to INL	"Idaho National Engineering and Environmental Laboratory (INEEL)" became "Idaho National Laboratory (INL)" in 2005 after consolidation, so all instances of INEEL should be changed to INL.
	Correct Barium-137 metastable designation	The designation for Barium-137 metastable should be changed from Ba 137-m to Ba-137m in dbo.RadioNuclide in the database.
	Fix 200-Year Inventory and Thermal Output Report	In the 200 Year Inventory and Thermal Output report, the thermal output for Cm-244 is not shown. According to the Radionuclide Inventory Calculator, though, this radionuclide does produce heat. The fix may involve simply re-running a stored calculation.
Planned Work - Revisions	Move Sand Number next to Release	Sand Number is related to the Release, move it next to Release on Home Page and on SSRS reports
	Link Liquid Waste Plans Revs. 17, 19, and 21 to Savannah River Tank Waste	Three SRS Liquid Waste System Plans (Revs. 17, 29, and 21) are in the list of Supporting Documents but are not linked to Savannah River Tank Waste, so that when a user looks at the Supporting Documents for the SR Tank Waste, these three documents do not appear. They do not support any data directly, but provide background information.

	Delete "Idaho National Lab - Navy" from the Baseline Radionuclide Inventory in Waste SSRS report	Change how the drop-down list is generated so that "Idaho National Lab - Navy" does not appear.

On-Line Waste Library - Production Date: 9/30/2019, SAND2019-11783W

Changes for Version 1.0 - Initial Release

No Changes - Initial Release