Enterprise-wide Assessment of the Department of Energy's Packaging and Shipping of Radioactive Waste

Final Report

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Acronyms

AK	Acceptable Knowledge
BEA	Battelle Energy Alliance, LLC
CBFO	Carlsbad Field Office
CFR	Code of Federal Regulations
CNS	Consolidated Nuclear Security, LLC
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EA	Office of Enterprise Assessments
EM	Office of Environmental Management
EM NV	Environmental Management Nevada Program
EPA	U.S. Environmental Protection Agency
FBP	Fluor-BWXT Portsmouth, LLC
FMP	Fluor Marine Propulsion, LLC
GSTR	Generator Site Technical Review
ICP	Idaho Cleanup Project
LANL	Los Alamos National Laboratory
LLW	Low-Level Waste
MLLW	Mixed Low-Level Waste
NA-30	Deputy Administrator for Naval Reactors
NDA	Non-Destructive Assay
NE	Office of Nuclear Energy
NEPS	Navarro Environmental Program Services
NNSA	National Nuclear Security Administration
NNSS	Nevada National Security Site
NTESS	National Technology and Engineering Solutions of Sandia, LLC
NWP	Nuclear Waste Partnership, LLC
PK	Process Knowledge
QA	Quality Assurance
RTR	Real-Time Radiography
RWAP	Radioactive Waste Acceptance Program
SC	Office of Science
Triad	Triad National Security, LLC
TRU	Transuranic
VE	Visual Examination
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant
WRM	Weapons Related Material
Y-12	Y-12 National Security Complex

Enterprise-wide Assessment of the Department of Energy's
Packaging and Shipping of Radioactive Waste
August 2019 – March 2020

Summary

Scope

The Deputy Secretary of Energy, in a July 9, 2019 memorandum, directed the Office of Enterprise Assessments (EA) to conduct U.S. Department of Energy (DOE)-wide assessments of procedures and practices for packaging and shipping radioactive waste. In response, EA conducted assessments of the higher risk low-level waste (LLW), mixed low-level waste (MLLW), and transuranic (TRU) waste management programs. The assessments were performed from August 2019 through March 2020 and resulted in 16 interim assessment reports. The objective of each assessment was to evaluate the performance of radioactive waste management packaging and shipping processes from waste characterization and generation through waste stream control, packaging, and shipping of LLW, MLLW, and TRU waste for disposal. This report provides an analysis of these individual assessments and identifies both best practices and recommendations, with the goal of promoting organizational learning and improving performance.

Background

Given the broad range of organizations and operations that were assessed, the results described in the report should be viewed as potentially applicable to any radioactive waste management program, not just those assessed. In addition, this report evaluates the self-assessments performed as directed by the DOE National Nuclear Security Administration (NNSA) and Office of Environmental Management (EM) following a non-compliant (i.e., not meeting the disposal facility waste acceptance criteria (WAC)) waste shipment involving weapons related material from the Y-12 National Security Complex (Y-12). This report also examines the series of 13 radioactive waste peer reviews directed by the Secretary of Energy for consistency with EA assessments. The peer reviews were jointly conducted by NNSA, EM, the Office of Nuclear Energy, and the Office of Science to identify best practices in radioactive waste governance and management and to support continuous improvement; the final report was dated March 2020.

Significant Results for Key Areas of Interest

Overall, DOE radioactive waste management requirements and programs are generally adequate, and the assessed sites implement adequate programs for managing, ensuring quality, and oversight of LLW/MLLW and TRU waste packaging and shipping processes. In many cases, this assessment found positive trends in several areas, as illustrated by the numerous best practices. In the few instances where mishandling of waste was observed, the appropriate organizations effectively identified and corrected the problems. None led to any appreciable consequences. The assessment also did not find any conditions similar to those that led to the non-compliant waste shipment from Y-12 in July 2019. With a few exceptions addressed in this report, waste management personnel have adequate experience, training, and qualifications to help ensure that waste management processes are appropriately implemented.

However, this report identified specific weaknesses across multiple organizations in several areas. The weaknesses are identified below in the context of these key assessment areas of interest. The most significant contributing causes to these weaknesses are: inadequate direction provided in governing DOE directives; insufficient oversight and assessment by DOE field elements and contractors at the point of waste origination; the lack of change management implemented when processes or methods change associated with waste generation; limited training provided by contractors for personnel beyond those in the waste management organization; and the limited use of issues management programs to document and

trend non-compliant conditions. Recommendations are provided to address the weaknesses and the contributing causes.

Y-12 Non-Compliant Waste Shipment

The Y-12 Consolidated Nuclear Security, LLC (CNS) response to the July 3, 2019, notification of non-compliant shipments to the Nevada National Security Site (NNSS) was timely and comprehensive. CNS appropriately suspended all waste shipments (LLW/MLLW and weapons related material) the next day. CNS subsequently developed a corrective action plan addressing needed improvements. At the completion of EA's interim assessments at Y-12 and NNSS, shipments from Y-12 to NNSS had not resumed; a plan to identify all actions required to resume such shipments was under discussion.

DOE Directives

DOE directive requirements for managing, packaging, and shipping/transportation of radioactive waste are generally adequate. The directives define the elements of a radioactive waste management program to be implemented, the programmatic requirements for each waste type, and general requirements for Federal oversight of these processes with some recommended improvements. However, the directives do not adequately address requirements for the development and implementation of the radioactive waste management basis or equivalent documents, waste stream controls at the point of waste origination, chemical compatibility evaluations, and formal change control. EM has recognized that these directives are out of date and has initiated updates.

Waste Management Programs and Implementation

Overall, sites implement adequate waste management programs and associated controls that ensure a high likelihood of proper characterization and compliant packaging and shipping of waste containers from LLW, MLLW, and TRU waste streams for disposal. For the most part, characterization processes are effective in identifying waste stream constituents to meet treatment, storage, and disposal facility WAC. In addition, for TRU waste, waste generators across the enterprise effectively implement a centralized process for waste characterization and certification, coordinated by the final disposal facility, the Waste Isolation Pilot Plant (WIPP); the centralized process was enhanced after the 2014 container overpressurization event at WIPP, resulting in more consistent process implementation.

The assessed sites have implemented effective waste stream control processes (personnel training, waste stream management and tracking systems, activity-level procedures, and waste originator support) to ensure the integrity of the waste stream by preventing the introduction of non-compliant materials. Waste packaging and transportation processes and performance comply with DOE and U.S. Department of Transportation (DOT) regulations, as well as disposal site WACs. The waste management processes at the assessed sites have improved based on lessons learned from past events. There are some exceptions; at several sites, training is not routinely provided to all personnel who introduce waste into a stream, and container movement operations are sometimes unnecessary and repetitive, thereby increasing the risk of container damage.

Contractor Quality Assurance Processes

Site waste management quality assurance process implementation generally meets the associated DOE requirements in the areas of management/independent assessments and issues management, and these processes are leading to improvements. However, management assessments focusing on generator waste management performance at the point of waste origination were not evident at many sites, and at four sites, the team observed issues management processes not being used as required for all issues.

DOE Field Element Oversight

DOE field element waste management oversight personnel are qualified or are being qualified to meet the appropriate standard, and they are actively engaged in operational awareness of waste management

activities. However, field elements at four sites were understaffed or had staff with competing job assignments that reduced their available time for examining waste management activities. Some oversight reports contained limited evaluation of contractor performance against the requirements of DOE Manual 435.1-1, *Radioactive Waste Management Manual*, and the reports from five field elements focused on program status (e.g., status of activities and schedules) and did not discuss overall performance. Without this information, field elements have not effectively allocated their resources to areas of higher programmatic risk and have missed opportunities to identify performance problems.

Directed Self-Assessments

Most NNSA and EM sites included in this EA assessment adequately performed self-assessments in response to memoranda issued by NNSA and EM after the Y-12 non-compliant waste shipment to NNSS. NNSA and EM provided guidance to perform a broad evaluation of radioactive waste management. Most self-assessments included one or more field-level reviews of radioactive waste management operations and were effective in making valuable observations. However, self-assessments by four sites were not fully responsive, in that the sites did not evaluate their most recent waste management performance by making new observations, but instead relied on previous or outdated assessment data. Further, participation in self-assessments by Federal field elements was variable. In many cases the self-assessment was conducted in a collaborative manner involving both site contractor and field element; in one instance, the field element shadowed the contractor self-assessment, and in others, the field element did not participate in assessing either contractor or field element performance. Per the direction from the Office of Science, its laboratories established a common understanding of the lessons learned from the Y-12 incident to support continuous improvement, rather than performing a self-assessment of their radioactive waste management program. The Waste Generator Services organization of the Office of Nuclear Energy's contractor, Battelle Energy Alliance, LLC, also provided lessons learned training on the Y-12 event to their staff.

Peer Reviews

EA site assessments and the peer reviews directed by the Secretary of Energy had different objectives and consequently focused on different aspects of radioactive waste management programs. The EA assessments focused on site performance of characterizing, packaging, and shipping LLW, MLLW, and TRU waste for disposal, including related quality assurance and Federal oversight. In contrast, peer reviews were conducted by small, short duration (typically two days) teams (typically four Federal managers) focusing on governance, oversight, contractor assurance, and risk management. Where overlap occurred, EA assessments and peer reviews had similar conclusions. Both concluded that the implementation of radiological waste management processes across the DOE complex is sound, and also identified there are challenges that if left uncorrected would pose a risk to future performance. Additionally, EA assessments and peer reviews both provided site-specific and broad management best practices to be shared across the complex to help improve performance.

Best Practices

The assessment identified 11 best practices implemented by DOE program offices, field elements and contractors that are summarized below and more fully described in Section 3.0 of the report.

- Two Federal best practices were identified in the areas of integration of Federal personnel in the performance of contractor oversight and multiple enhancements to the TRU waste characterization process since the WIPP events of 2014.

- Several contractor best practices were identified in the areas of real-time radiography, estimating container radiological contents, waste chemical compatibility determination guidance, use of a unique set of guiding principles, waste package compliance verification, use of dedicated compliant vehicles

for waste shipments, grading of management self-assessments to improve assessment quality, and the use of external expertise to support waste management assessments.

Recommendations

The assessment identified 11 recommendations for DOE program offices, field elements, and contractors. These are summarized below and more fully described in Section 4.0 of the report.

- **DOE program offices** should establish a working group to discuss and evaluate DOE complex-wide approaches to waste management programs and lessons learned; and ensure that field element staffing levels, work priorities, and Federal oversight are sufficient to evaluate contractor performance.

- During the next revision of DOE Manual 435.1-1, EM should provide expectations for the site radioactive waste management basis; provide expectations for waste stream control at the point of waste origination; require evaluation and control of potentially incompatible chemical combinations; require a documented change control process; and clearly indicate expectations for field element and contractor oversight/assessment of activities at the point of waste origination to ensure WAC compliance.

- **DOE field elements** should provide additional focus, during their waste management assessments, on generator performance at the point of waste origination or repackaging. The Carlsbad Field Office should also specify the requirements for managing non-compliances identified during generator site technical review oversight activities. Environmental Management Nevada Program should require that generators periodically assess the performance of waste management activities from waste planning through shipment. Environmental Management Nevada Program should also specify the process for NNSS and the waste generator sites to regain approval for waste shipments to NNSS after a suspension.

- **DOE contractors** should specify the radioactive waste training requirements for individuals who are intermittent generators; evaluate the practices for data entry into electronic waste tracking database systems; minimize excessive or unnecessary waste container movements and handling; provide additional assessment focus on generator performance at the point of waste origination or repackaging; and apply issues management processes to manage all non-conforming waste management conditions.

Enterprise-wide Assessment of the Department of Energy's Packaging and Shipping of Radioactive Waste

1.0 Introduction

The Deputy Secretary of Energy, in a July 9, 2019 memorandum, directed the Office of Enterprise Assessments (EA) to conduct U.S. Department of Energy (DOE)-wide assessments of procedures and practices for packaging and shipping radioactive waste. In response, EA performed assessments of DOE and contractor organizations across the complex that implement the higher risk low-level waste (LLW), mixed low-level waste (MLLW), and transuranic (TRU) waste management programs. The assessments resulted in 16 interim assessment reports. The objective of each assessment was to evaluate the performance of radioactive waste management packaging and shipping processes from waste characterization and generation through waste stream control, packaging, and shipping of LLW, MLLW, and TRU waste for disposal.

This report provides an analysis of these individual assessments and identifies both best practices and recommendations, with the goal of promoting organizational learning and improving performance. Given the broad range of organizations and operations that were assessed, the results described in the report should be viewed as potentially applicable to any radioactive waste management program. In addition, the team reviewed the self-assessments performed as directed by the DOE National Nuclear Security Administration (NNSA) and Office of Environmental Management (EM) following a non-compliant (i.e., not meeting the disposal facility waste acceptance criteria (WAC)) waste shipment involving weapons related material (WRM) from the Y-12 National Security Complex (Y-12). This assessment also examined the series of 13 radioactive waste peer reviews directed by the Secretary of Energy. The peer reviews were jointly conducted by NNSA, EM, the Office of Nuclear Energy (NE), and the Office of Science (SC) to identify best practices in radioactive waste governance and management and to support continuous improvement; the final report was dated March 2020.

The onsite portions of these assessments were conducted from August 2019 through March 2020 in accordance with the *Plan for the Office of Enterprise Assessments Assessment of Radioactive Waste Management Activities Across the U.S. Department of Energy Enterprise.*

Upon completion of the onsite portion of each site assessment, the assessment team briefed site representatives on the conclusions of the assessment, including site-specific positive attributes, findings, deficiencies, other areas of weakness, opportunities for improvement, and interim recommendations. The team then prepared an interim report documenting the site's performance and provided it to the site for a factual accuracy review. In accordance with DOE Order 227.1A, *Independent Oversight Program*, and DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy*, it is expected that the DOE sites will address findings and deficiencies through their issues management systems.

This report addresses the adequacy of DOE directives, site implementation practices, elements of contractor quality assurance (QA), and Federal oversight as they relate to packaging and shipping of radioactive waste at the assessed sites. Assessment results identified best practices, which are safety-related practices, techniques, processes, or program attributes observed during an assessment that may merit consideration by other DOE and contractor organizations. Where similar issues were identified at multiple sites, recommendations are provided for senior line management's consideration as opportunities to improve the effectiveness of programs or management across the DOE complex, and to promote organizational learning.

The members of the assessment team, the Quality Review Board, and management responsible for this report are listed in Appendix A. The scope and methodology are discussed in Appendix B. The radioactive waste management interim reports are listed in Appendix C and can be found on EA's "Assessment Documents" website at https://www.energy.gov/ea/listings/assessment-documents. Specific hyperlinks for each interim report are also in Appendix C.

2.0 Results

Overall Status

Overall, DOE site contractors have developed and implemented effective procedures and practices for the proper characterization, waste stream control, packaging, and shipping of radioactive waste for disposal. This assessment found positive trends in several areas. For the most part, waste management personnel have adequate experience, training, and qualifications to help ensure that waste management processes are appropriately implemented. In the few instances where the mishandling of waste was observed, the appropriate organizations effectively identified and corrected the problems. None led to any appreciable consequences. The assessment did not find any conditions similar to those that led to the non-compliant waste shipment from Y-12 in July 2019.

Although the assessment team identified no problem areas that rose to the level of a DOE-wide finding as defined in DOE Order 227.1A, they did identify specific weaknesses across multiple organizations in several areas. These weaknesses are described in the following sections. The most significant contributing causes to these weaknesses are: needed improvements in governing DOE directives; insufficient oversight and assessment by DOE field elements and contractors at the point of waste origination; the lack of change management implemented for changes in waste generation processes or methods; limited training provided by contractors for personnel beyond those in the waste management organization; and the limited use of issues management programs to document and trend non-compliant conditions. Recommendations are provided to address the weaknesses and the contributing causes.

Evaluation of Past Events in Relation to Current Practices

Five radiological waste-related events identified over the last six years involved DOE packaging and shipments that did not meet disposal requirements:

- Shipment of WRM waste from Y-12 to the Nevada National Security Site (NNSS) that was noncompliant with the WAC – July 2019

- Savannah River Site HB Line TRU waste drum not meeting absorbent-to-liquid ratio requirements – September 2018

- Overpressurized drum event involving reactive materials and flammable gases in radioactive waste at the Accelerated Retrieval Project V at the Idaho Cleanup Project (ICP) – April 2018

- Nuclear Fuel Services, Inc. shipment of waste for disposal at NNSS as LLW but containing chromium, which was not allowed by the NNSS waste acceptance criteria (WAC) – June 2016

- Los Alamos National Laboratory (LANL) shipment of TRU waste drums to the Waste Isolation Pilot Plant (WIPP) resulted in a radiological release because of drum overpressure from a chemical reaction – February 2014.

The assessment team evaluated these events and identified that the events generally shared two or more of the following conditions:

- Inadequate acceptable knowledge (AK) documentation or inadequately trained AK personnel to support proper characterization of waste streams
- Organizations not flowing down requirements into waste management processes and procedures
- An incorrect or incomplete change in a waste generator's process or procedure
- Compartmentalization of classified information affecting the flow of appropriate information
- Inadequate dissemination of lessons learned from previous similar events
- Overreliance on the waste generator's use of process knowledge (PK) in the absence of confirming measurements or direct sampling and analysis.

During the site assessments, these conditions were considered in evaluating waste management processes. At all assessed sites where events occurred, corrective actions have been taken and the current waste management processes are generally adequate, with the exception of one site where corrective actions are still under way. All other assessed sites demonstrated knowledge of the lessons learned from the past events and most incorporated improvements to their waste management procedures and practices when appropriate to ensure that waste packages comply with all applicable requirements and criteria for existing waste streams.

The Consolidated Nuclear Security, LLC (CNS) response to the July 3, 2019, notification of non-compliant WRM shipments from Y-12 to the NNSS disposal site was timely and comprehensive. Following the discovery of a prohibited item in a past classified waste shipment to the NNSS disposal site, CNS immediately notified NNSS. An extent-of-condition review identified additional non-compliant shipments to NNSS, going back to 2013. CNS appropriately suspended all waste shipments (LLW/MLLW and WRM) the next day. CNS subsequently developed a corrective action plan addressing needed improvements in LLW/MLLW and WRM handling processes. At the completion of EA's interim assessments at Y-12 and NNSS, shipments from Y-12 to NNSS had not resumed; a plan to identify all actions required to resume such shipments was under discussion.

2.1. Technical Adequacy of DOE Policies and Directives

DOE Order 435.1, *Radioactive Waste Management*, and DOE Manual 435.1-1, *Radioactive Waste Management Manual*, define the elements of a waste management program; specify the overarching requirements for contractor radioactive waste characterization, certification, packaging, and transportation processes; and specify general requirements for Federal oversight of these processes. Field element managers of all assessed DOE sites have incorporated these directives into their contract requirements, as required. In addition, DOE Guide 435.1-1, *Implementation Guide for Use with DOE Manual 435.1-1*, gives the DOE complex extensive implementation guidance.

The current DOE radioactive waste management directives were first issued in 1999; minor administrative changes have been made since then. Before this enterprise-wide assessment, EM, as the Office of Primary Interest for these directives, recognized the need to update the directives and is working to revise them, in part to address feedback from a 2017 EA targeted assessment of waste management. EA provided additional input to EM in August 2019 in response to the Deputy Secretary of Energy's

July 9, 2019, memorandum. This assessment identified the following additional weaknesses in the current directives: (**Recommendation**)

- **Non-prescriptive requirements.** In some cases, DOE Manual 435.1-1 requirements do not always ensure that appropriate controls are implemented to address uncertainties and vulnerabilities in a site's waste management program. The requirements in the manual are sometimes modified with the phrase "to the extent practical," leaving broad discretion in meeting and/or allowing requirements to be overridden based on current operational conditions, with no documented basis or analysis of the DOE liabilities and associated risk. For example, with respect to the requirement to reduce void space between the waste and its container "to the extent practical," most assessed sites do not take specific measures to minimize void space in the waste. Revising DOE Manual 435.1-1 to require that site management provide the basis for actions taken to address compliance with the "to the extent practical" allowance would improve consistency and rigor in identifying and controlling risk, while still allowing sites to tailor controls to address unique hazards or operations. This basis for action could be described in the site's radioactive waste management basis or equivalent document.

- **Waste stream control requirements for the point of waste origination.** DOE Manual 435.1-1 requires waste generators of each waste type to establish a waste certification program; this requirement is the only control imposed on waste generators. Site waste management personnel have consistently interpreted this requirement as applying only to waste package verification. Point-of-origination controls at the assessed sites range from clearly defined procedural requirements to the absence of any such requirements. Revising DOE Manual 435.1-1 to include requirements for waste stream control at the point of waste origination would help ensure the adequacy of waste stream segregation and control by mitigating the potential for introducing prohibited items or incompatible materials.

- **Lack of expectations to implement industry standards for evaluating the chemical and physical stability of waste forms.** Neither DOE Manual 435.1-1 nor DOE Guide 435.1 provides expectations for acceptable methodologies of evaluating and controlling potentially incompatible chemical combinations, oxidizers, or reactive chemicals within LLW/MLLW. The 2014 drum overpressurization event at WIPP demonstrated the potential risks associated with chemical and physical instability within radioactive waste. Since then, the National TRU Program has required generators to evaluate potentially incompatible or reactive chemical combinations in TRU waste. However, at four sites, the team observed that potential chemical incompatibility or reactivity is not formally evaluated in LLW/MLLW.

- **Lack of change control requirements for waste generator processes.** DOE Manual 435.1-1 does not require a formal control process when waste generation processes are changed or modified in response to operating experience and changing conditions. At some sites, field-level changes and adjustments to waste management forms, such as those addressing waste container bagout, packing, and maintenance activities, do not always receive a formal review to assess the significance of the change with regard to waste requirements. Instead, change control is an informal practice that personnel use to make changes to the approval documentation for a waste stream, usually involving forms, which normally fall below the threshold of the site's formal change control processes. Applying formal change control to all waste generation processes would provide consistency and help ensure that modifications are effectively evaluated to reduce the risk of introducing prohibited items or incompatible materials into waste streams.

- **Ambiguous expectations for contractor and field element oversight of generator performance at the point of waste origination or repackaging.** DOE Order 435.1 and DOE Manual 435.1-1

broadly require DOE elements and contractors to ensure that radioactive waste management activities are systematically planned, documented, executed and evaluated. At most sites, contractor and field element oversight have focused on the waste management organization activities, not on waste origination in other line organizations. Revising DOE Order 435.1 and DOE Manual 435.1-1 Chapter III (TRU) and Chapter IV (LLW/MLLW) to address assessment requirements to ensure oversight of radioactive waste management activities beginning at the point of waste origination would improve the processes for identifying problems that impact the integrity of the waste stream.

2.2. Current Contractor Practices for Radioactive Waste Management

For the most part, DOE sites systematically implement the DOE waste management requirements for waste characterization, waste stream control, packaging, and shipping. Except for some site-specific areas needing improvement, which are detailed in the interim reports, sites have implemented multiple layers of defense (defense-in-depth controls) to reduce the likelihood of introducing prohibited items into LLW, MLLW, and TRU waste streams, and to ensure proper characterization, waste stream control, packaging, and shipping of radioactive waste for disposal. The waste practices and procedures for TRU were found to be more consistent than for LLW/MLLW in some areas, such as providing documented aids to ensure chemical compatibility in waste streams. This consistency in TRU waste management is partially due to improvements in TRU processes, communications, and heightened levels of collaboration among the TRU sites complex-wide since the drum overpressurization event at WIPP in 2014. The equivalent level of improvement in processes, communications, and collaboration was not evident within the LLW/MLLW community. Forming a community of practice with membership from each of the LLW/MLLW waste sites may improve performance across the complex. (**Recommendation**)

Waste Characterization

DOE Manual 435.1-1 defines waste characterization as: "The identification of waste composition and properties, by review of acceptable knowledge (which includes process knowledge), or by nondestructive examination, nondestructive assay, or sampling and analysis, to comply with applicable storage, treatment, handling, transportation, and disposal requirements." All assessed sites have defined and characterized waste streams through application of PK, sampling and analysis, or a combination of these waste characterization processes, in accordance with the relevant WAC. The EA assessment team evaluated these processes through interviews, procedure and work product reviews, and observations.

Waste characterization is inextricably linked to the WAC documents for the intended treatment, storage, or disposal site, which specify the requirements, terms, and conditions under which the disposal sites will accept waste. The WIPP WAC and the NNSS WAC provide a mostly comprehensive set of requirements for waste acceptance to ensure safe disposal. Notably, the WIPP WAC requires a pedigreed and technically defensible chemical compatibility evaluation to be performed to analyze chemical hazards in mixed TRU waste. This assessment identified two weaknesses in the NNSS WAC: (**Recommendation**)

- The NNSS radioactive waste acceptance program (RWAP) waste stream approval process relies primarily on document reviews. After RWAP approves a site waste profile, periodic RWAP facility evaluations (audits or surveillances) do not always include field performance inspections at the point of waste origination to verify continued consistency with the originally characterized waste profile; RWAP personnel reported that they rely on the sites to perform such verifications. In addition, most sites' independent and management assessments/surveillances do not include such periodic field verifications.

- Environmental Management Nevada Program (EM NV) has no established guidance or process for regaining approval to resume shipments of waste to NNSS following suspension. Specifically, for the

recent Y-12 shipment suspension, EM NV and their contractor, Navarro Environmental Program Services (NEPS) RWAP personnel have not developed a plan to identify all actions required to resume Y-12 waste shipments to NNSS.

At all assessed sites, the processes for characterizing waste are well defined in implementing procedures and consistent with the requirements set forth by the WAC associated with the storage or disposal facility to which the waste is being sent. All sites have developed and implemented further processes for characterizing LLW/MLLW and TRU waste to verify or validate the initial descriptions and PK. These processes employ a variety of techniques, including non-destructive assays (NDAs) using gamma spectroscopy or neutron emissions measurements, direct sampling analyzed by liquid scintillation, gas proportional alpha/beta spectroscopy, mass spectroscopy, laboratory chemical analysis, visual examination (VE), transmission radiography (real-time radiography, or RTR), and dose-to-curie content modeling calculations. At ICP, Fluor Idaho's rigorous TRU waste characterization processes, such as RTR, NDA, and VE, are also commonly applied to LLW and MLLW streams, exceeding the practices typically implemented for LLW and MLLW streams at other sites. (**Best Practice**) Additionally, National Technology and Engineering Solutions of Sandia, LLC (NTESS) at Sandia National Laboratories, New Mexico, applies conservative characterization estimates of container contents to ensure that waste shipments do not exceed any WAC or Department of Transportation (DOT) regulations. For example, tritium activity in waste packages is based on the highest assay results. (**Best Practice**)

All assessed sites appropriately train and qualify the personnel who characterize waste. Personnel responsible for assessing PK are adequately trained and qualified to provide and document accurate information about the materials introduced into the waste based on initial inventory records. This information includes descriptions of the materials, physical form, and isotopic and chemical constituents. AK experts are highly specialized and well-trained to perform assessments, acquire information, and analyze data to generate AK that is adequate to support waste characterization. Analytical laboratory operators and technicians who perform sampling and analysis are experienced (i.e., demonstrated thorough knowledge of detection technologies, processes, and equipment operation) and properly evaluated data results to ensure accurate waste characterization. When needed, personnel currently supporting the characterization of radioactive waste have appropriate security clearances and sufficient access to classified information to allow proper verification of classified items in the waste stream.

Much of the TRU waste shipped to WIPP was generated by historical processes that are not currently in operation and are therefore dependent on AK determinations. The WIPP WAC drives the development of consistent and thorough waste characterization processes at each site that ships TRU waste to WIPP. All assessed sites that ship TRU waste to WIPP perform AK assessments for all certified TRU waste streams to ensure implementation of the "Enhanced AK" process developed since the 2014 WIPP drum overpressurization event. In addition, the WIPP WAC requires other characterization measurement processes (e.g., VE, RTR, NDA, and flammable gas analysis) to confirm AK assessments for waste packages from certified TRU waste streams. For each of these TRU waste characterization processes, the WIPP contractor, Nuclear Waste Partnership, LLC (NWP), has developed and implemented adequate procedures. The reviewed AK summary reports and assessments demonstrated extensive detail and rigor, providing added assurance of proper waste characterization and support to other NDA activities.

All assessed sites implement adequate procedures and practices for sampling and analyzing waste packages to determine isotopic content and radioactivity level to conform to relevant WAC requirements. The sampling and analysis processes deployed at the sites are appropriately tailored for the specific waste streams. The processes for characterizing LLW/MLLW and TRU waste using sampling and analysis are effectively implemented for all reviewed facility waste streams to ensure conformance to the WAC. A best practice identified for Fluor-BWXT Portsmouth, LLC (FBP), CNS, and Triad National Security, LLC (Triad) is the use of surrogate containers and sources to test the detector systems and model the

potential error in estimating the isotope activity caused by waste distribution, self-shielding, and geometries of larger LLW/MLLW containers. These models provide a determination of potential impacts of variations in source distribution and self-shielding within standard waste package matrices and help ensure the accuracy of the waste package characterization. (**Best Practice**)

Furthermore, the assessed sites that conduct NDA participate in the NDA Performance Demonstration Program, through which the Carlsbad Field Office (CBFO) approves the use of waste container assay systems. Sites with TRU waste streams evaluate a series of drums that contain surrogate radioactive materials provided by a third party; the drum contents are unknown to the evaluating site. The site's NDA results are then compared to the known contents of the drums to demonstrate proficiency. The centralized process for TRU waste characterization and certification at all sites that ship TRU waste, (with the exception of the Advanced Mixed Waste Treatment Program at the ICP) is implemented through the Central Characterization Program and is coordinated by the WIPP contractor, NWP, under CBFO oversight. The enhancement of this centralized structure for TRU waste management and the oversight thereof, which was initiated after the 2014 events at the WIPP facility, has resulted in generally consistent program implementation.

Waste Stream Control

Waste streams must meet the WAC of the facility to which the generator intends to transfer waste for treatment, storage, or disposal. Therefore, control of waste management processes from point of waste origination to closure of the final compliant waste package is necessary to ensure mitigation of uncertainties and vulnerabilities. Waste stream control is supported by a collection of defense-in-depth controls including a dedicated management framework, activity-level procedures, personnel training, waste stream management and tracking systems, and waste originator support. Overall, assessed sites have implemented effective processes to ensure the integrity of the waste stream by preventing the introduction of non-compliant materials. The EA assessment team evaluated these processes through interviews, procedure and work product reviews, and observations.

The assessed sites have established the foundation for an effective approach to waste stream control through procedures, training and competencies, tracking systems, and expert support. One contractor, Fluor Marine Propulsion LLC (FMP), has comprehensively integrated and improved multiple components of its waste management program by establishing a set of guiding principles. FMP management and personnel have embraced and implemented the guiding principles throughout all levels to develop a comprehensive radioactive waste management program. The guiding principles are know before do, cradle to grave, generators own the waste, minimize, and segregate. **(Best Practice)** The program integrates several notable FMP practices addressing the use of technical work instructions; engineering resolution of issues; training on practices and processes supporting the characterization and certification of waste for all workers who generate waste; formal annual justification for retention of radioactive material; detailed training on waste certification processes for radioactive waste representatives within each organization generating radioactive waste; and knowledge management action plans.

As demonstrated during interviews, observations of activity-level work, and review of training records, sites generally provide effective waste management training. Waste originators demonstrated appropriate knowledge of approved waste streams and the associated defense-in-depth controls to prevent the introduction of prohibited articles. Waste originators recognized their role as the first line of defense for proper waste characterization and waste stream control, and all waste management program leaders assigned waste management personnel to provide support and guidance to waste originators when needed. Waste management personnel performing waste verification and packaging in various facilities demonstrated consistency in their approach and alignment with implementing procedures. Additionally,

the CH2M HILL Plateau Remediation Company 324 Building Disposition Project uses a high-fidelity mockup facility to effectively train operators and refine work processes.

However, training and qualification weaknesses were identified at seven sites, such as overdue required training; an organizational unit self-exempting its employees from required waste management training due to competing training priorities; some categories of personnel (maintenance, radiological control technicians, and some waste originators) who generate and dispose of LLW/MLLW not being required to have waste management training; and lapses in qualifications. (**Recommendation**)

All assessed sites implement adequate waste stream management and tracking systems (most are electronic databases) to ensure proper management of waste stream constituents, from characterization through generation, packaging, certification, and shipping. These waste tracking systems consistently capture the basis for waste characterization, provide criteria for identifying proper waste streams, and specify the required review and approval processes. However, for some electronic waste tracking systems, independent verification of input is not required, and queries of information to support QA of waste constituents and locations sometimes rely on free-form data entry in searchable fields; at some sites, this issue has contributed to erroneous search results and inefficient accounting of waste. Also, unused and optional fields are not always clearly defined and specified in the electronic systems, potentially leading to ambiguity and inconsistency. At one site, this issue contributed to misunderstandings by state regulators regarding the location of waste containers. In addition, due to a lack of uniform guidance across that site, different contractor organizations sometimes took slightly different approaches to using the information in the tracking system database. (**Recommendation)**

For the most part, procedures are effective for radioactive waste stream control. For example, at Sandia National Laboratories, New Mexico, NTESS procedures require the generator to enter a Waste Description and Disposal Request that tracks characterization, packaging, certification, and shipping. In another example, at Idaho National Laboratory, Battelle Energy Alliance, LLC (BEA) procedures require a Waste Inventory Sheet in both work orders and lab instructions that assigns a unique number to a waste container and provides supporting information for proper waste characterization. These processes also provide for a chain of custody of the waste until final disposition. These approaches reduce error-likely situations that could result in a non-compliant waste package. In contrast, some sites' work-level procedures lack the specificity needed for effective waste segregation and control.

Observed waste stream practices at the point of waste origination are generally adequate, with some sites using uniquely designed or labeled waste disposal receptacles to reduce the potential for placing waste in the incorrect waste stream. However, at four sites the team observed container labeling issues, such as collocated LLW/MLLW containers of similar appearance (i.e., same color and size) with limited content identification (i.e., tape with handwritten designations), and mislabeled and unlabeled waste containers; such configurations produce error-likely situations.

Sites generally provide waste management support to the waste originators, most by deploying expert staff directly to field activities and a few providing on-call support. The expert staff assistance has also included the development of detailed guidance to help waste originators address requirements effectively. For example, NTESS has developed a comprehensive manual for waste originators to address requirements for waste characterization and segregation for all waste types, and further supplements it with on-call waste management support. This approach – providing a comprehensive manual with expert staff support – has resulted in a more consistent approach to waste stream control and improved implementation of the waste management processes. Additionally, at LANL, Triad developed and issued a formal procedure for LLW/MLLW generators to determine waste chemical compatibility based on EPA-600/2-80-076, *A Method for Determining the Chemical Compatibility of Hazardous Waste*. (**Best Practice**)

Final Packaging and Shipping/Transportation

Transportation and packaging requirements are established in DOE Order 460.1D, *Hazardous Materials Packaging and Transportation Safety;* DOE Order 460.2A, *Departmental Materials Transportation and Packaging Management*; and DOT regulation 49 CFR 171-180, *Hazardous Material Regulation*. Packaging and shipping/transportation processes that implement these requirements ensure compliant waste packages and safe shipping of all radioactive waste types. The assessed sites implemented these requirements effectively and have established practices that provide reasonable assurance that waste packaging complies with WAC requirements; that waste container movement operations do not create non-compliant conditions or put workers at unnecessary risk; and that final loading and closure of waste containers is performed in a way that protects the integrity of waste streams. The EA assessment team evaluated these processes through interviews, review of procedures and shipping records, and observation of packaging and shipping processes.

Sites ensure that waste packages meet the relevant WAC through various approaches to verification. All sites maintain qualified and certified staff to ensure compliant waste packaging. Observations of packaging activities showed adequate procedures and practices for control and verification of waste streams prior to placing waste into the final package. Waste package certifications that are required by the treatment, storage, and disposal facility WAC were performed adequately by the appropriate personnel. In addition, at LANL and NNSS, Triad and Mission Support and Test Services, LLC, respectively, verify waste package compliance through a dual independent verification process that provides increased confidence that waste packages do not contain prohibited items. (**Best Practice**)

Most sites performed well-coordinated container movements to support packaging and shipping/ transportation. Several sites use their waste tracking system effectively to coordinate and minimize waste movements, and at one site, UCOR uses radio frequency identification to enhance tracking of onsite waste movements. However, at some sites, potentially unnecessary and repetitive container movement operations could increase the risk of misplacements, damaged containers, or drop events. (**Recommendation**)

Processes for final transport loading and shipping ensure compliance with WAC requirements and DOT regulations. Sites consistently demonstrated adequate completion of necessary documentation to support waste shipments, which was appropriately reviewed and approved by qualified individuals to meet DOT regulations and treatment, storage, and disposal facility WAC. Many contractors survey tractors and trailers for radioactive contamination before allowing the vehicles on site to be used for shipping radioactive waste. Most contractors have fostered a mutual understanding of these expectations with their shippers. Due to FMP's rigorous enforcement of the radiological release criteria, the shippers now dedicate certain known clean and compliant vehicles. This practice efficiently and proactively ensures that trailers and transport rigs used for FMP radioactive waste shipments are releasable per applicable Naval Nuclear Propulsion Program requirements and DOE and DOT regulations, whereas other sites have sometimes received and used trailers with residual contamination from non-DOE shipments, exceeding DOE regulations for release. (**Best Practice**) Additionally, some sites use expert outside support or have State police verification (e.g., Hanford and ICP).

2.3. Contractor QA Processes in Support of Waste Management

DOE QA requirements related to radioactive waste management are established in DOE Order 414.1D, *Quality Assurance,* and 10 CFR 830.120, *Quality Assurance Requirements.* Site waste management QA performance is generally adequate to meet DOE QA requirements in the areas of management/independent assessments and issues management. Personnel are knowledgeable of the procedures and practices for assessment planning and performance and issues management. The EA

assessment team evaluated these processes through interviews, procedure and work product reviews, and observations.

Assessments

Generally, assessment schedules specify the planned radioactive waste management assessments to be conducted. Most assessment reports that EA reviewed effectively communicate scope, objectives, requirements, interview results, and activity-level work observations. For TRU waste, centralized management of waste certification by CBFO provides for more consistent assessment of TRU waste generation operations. Two contractors, FBP and CNS, have implemented a management self-assessment grading practice to provide feedback to the assessor and improve the quality of management assessments, resulting in the addition of more performance-based lines of inquiry. (**Best Practice**).

One contractor, FMP, incorporates periodic peer reviews, assist visits, and communities of practice into its waste management assessment program, resulting in significant performance improvements despite an already high level of performance. In addition to the independent assessments that many other sites rely on, the FMP waste management organizations at least annually perform critical self-assessments of their management and implementation of FMP's radioactive waste programs. FMP functional leads for radioactive waste processing and shipping critically assess performance in their areas every trimester to identify and resolve cross-organizational weaknesses before significant deficiencies or non-compliances occur. FMP's Waste and Shipping Community of Practice also has monthly teleconferences to share knowledge between its sites on significant ongoing issues, lessons learned, training opportunities, and potential process improvement ideas. **(Best Practice)**

However, LLW/MLLW management assessments that focused on generator waste management performance at the point of waste origination were not evident at seven sites. While not explicitly required, the lack of assessments that focus on the point of waste origination is a missed opportunity to identify and correct deficiencies at the earliest point in the waste management process and increases reliance on downstream waste management processes to identify non-compliances in the waste stream. Robust waste stream control at the point of waste origination provides greater confidence in the waste generation process and helps ensure that the waste has been placed in the correct waste stream. (**Recommendation**)

At many sites, contractors' management and independent assessments over the past two years focused either on confirmation of AK used to establish the waste stream or on waste management performance downstream from the point of waste origination (i.e., waste stream control, packaging, and shipping). This assessment focus is modeled on what was historically conducted by the disposal sites' review of their waste certification processes. For example, the NNSS RWAP audit checklists focus on waste characterization and waste stream control, packaging, and shipment, with no attention to waste originators as the first line of defense in waste stream compliance. Because of the Y-12 WAC non-compliance incident, the RWAP lines of inquiry have been revised to focus more on waste generator personnel.

Issues Management

Most sites consistently apply their issues management process to all levels of problems, from low-level/trend-only issues to issues required to be reported to the DOE Occurrence Reporting and Processing System. Some sites use issues screening teams effectively to ensure appropriate grading of issues and assignment of responsibilities, and also use issues management metrics to effectively track performance. Some sites utilize advanced analytical techniques to address issues. For example, Nuclear Fuel Services, Inc. performed a failure mode, effects, and criticality analysis (an advanced analysis mechanism initially

developed by the U.S. military) to supplement a causal analysis to identify programmatic weaknesses and prioritize actions to resolve issues.

However, at four sites, not all LLW/MLLW-related non-compliances were entered into the site's issues management system. Some sites categorize issues as "recommendations" and "non-conforming conditions" instead of non-compliances, and as a result, those issues don't get entered into the issues management system. For example, at one site, identified performance deficiencies were designated as "recommendations"; these deficiencies included individuals not completing required training and 12 containers of waste with prohibited items. At another site, two prohibited articles were identified as "non-conforming" conditions and were not entered into the issues management system until questioned by the EA assessment team. These practices could inhibit the sites' ability to use performance information effectively for trending and identifying common weaknesses that deserve increased management attention. (**Recommendation**)

The sites are effective in using multiple feedback mechanisms, including performance metrics and lessons learned, to address issues within their waste management programs. For example, at Y-12, CNS Environmental Compliance maintains a suite of waste management performance metrics that are compiled and used by senior management to maintain awareness of overall organizational performance and focus additional management attention where needed. Lessons learned are used effectively to improve performance at several sites. For example, BEA developed, published, and distributed eight waste management-related lessons learned over the past year. In another example, NEPS recently used lessons learned from a waste bag seam separation due to a manufacturing defect and a surface abrasion due to an S-ring tie-down connector challenging the integrity of a soft-sided DOT-approved container to improve waste management performance. NEPS modified a packaging and shipping checklist to address these lessons learned.

2.4. Federal Oversight

Overall, DOE field element waste management program personnel are knowledgeable of their assigned areas and have met relevant technical qualification requirements. A few individuals had not completed the qualification standard due to competing job responsibilities, but actions are under way to address those few instances. Federal waste management personnel are also actively engaged in operational awareness activities. However, field elements at four sites have staffing challenges that impact the availability of personnel to adequately conduct waste management oversight due to competing job duties. (**Recommendation**)

The Headquarters Office of the Deputy Administrator for Naval Reactors (NA-30) has established an extensive oversight program that uses Headquarters and field office personnel to proactively maintain and/or improve FMP's already high record of performance. For example, NA-30 field office personnel perform extensive (and independent) technical reviews, audits, and assessments, as well as field observations of training, work performance, and packaging and storage of waste. Teams from the NA-30 Headquarters office assess performance at each contractor site at least every two years, including detailed reviews of radioactive waste management, to ensure that program principles and requirements are adequately implemented and that overall site performance improves. (**Best Practice**)

Field element oversight of LLW/MLLW management activities is adequate at most of the assessed sites, but important weaknesses were identified at five sites. For example, one of those five sites had not undergone a documented Federal oversight activity addressing the waste management program for over a year. The waste management-related assessment reports produced by the DOE field elements at these five sites showed limited detail and almost no focus on generator waste management performance at the point of waste origination, repackaging, or process changes. (**Recommendation**) Additionally, for these

five sites, DOE field element oversight reports focused on program status (e.g., status of activities and schedules), and did not adequately evaluate contractor compliance with DOE Manual 435.1-1. Further, many scheduled assessment activities that would have addressed aspects of waste management were not performed.

For Federal oversight of TRU waste management, CBFO has made multiple enhancements to the TRU waste characterization process since the WIPP drum overpressurization event in 2014. These improvements, such as establishing new requirements for creating the Interface Waste Management Documents List and proceduralizing chemical compatibility evaluations and assessments of oxidizers present in waste, support an enhanced AK process and are powerful tools to drive consistency in the characterization of TRU waste across the enterprise. (**Best Practice**)

CBFO, through its National TRU Program, and Federal field elements conduct oversight of sites that generate TRU waste. CBFO directs and defines requirements for conducting reviews and deploys personnel to each site to monitor and provide guidance and oversight of TRU waste certified program operations. At the time of this report, CBFO was formalizing the technical qualifications for the waste certification manager position and increasing the number of staff serving in this role. Prescribed requirements for oversight of TRU waste generators are adequate, with two exceptions. First, oversight does not currently include inspecting waste originator performance (the first line of defense). Second, CBFO has not specified requirements for managing non-compliances that are found during oversight activities (including generator site technical reviews (GSTRs), when used) which require specific actions by the site contractor, the Federal field element, NWP, and/or CBFO. **(Recommendation)**

For Federal oversight of LLW/MLLW, EM, through EM NV and its contractor NEPS, implements the RWAP. NEPS/RWAP personnel maintain the NNSS WAC; perform site waste profile reviews throughout the DOE complex, leading to recommending approval to EM NV; and assess generator sites' waste certification programs and implementation to ensure compliance with the NNSS WAC. RWAP audit and surveillance personnel are qualified, have the necessary security clearances, and use defined checklists effectively to ensure thorough site evaluations.

2.5. Directed Self-Assessments

The self-assessments that the field elements performed in response to the memoranda sent on July 16, 2019, and July 23, 2019, by the NNSA Chief of Staff and the EM Principal Deputy Assistant Secretary, respectively, were generally adequate. The direction provided by NNSA and EM was comprehensive in guiding broad evaluation of radioactive waste management practices across the DOE enterprise. All NNSA and EM sites performed the required self-assessments. Self-assessments at EM sites generally included one or more field-level reviews of radioactive waste management and related operations, including associated interviews and document reviews, and were effective in making valuable observations about the strengths and weakness of the program. In particular, the Savannah River Site and WIPP self-assessment approaches were unique in their rigor and comprehensiveness.

However, self-assessments by four sites were not fully responsive, in that they did not evaluate their most recent waste management performance by making new observations, but instead relied on previous assessment data. Further, participation in self-assessments by Federal field elements was variable. In many cases the self-assessment was conducted in a collaborative manner involving both the site contractor and the field element; in one instance, the field element shadowed the contractor self-assessment; and in others, the field element did not participate in assessing either contractor or field element performance. Per direction from SC, its laboratories established a common understanding of the lessons learned from the Y-12 incident to support continuous improvement, rather than performing a self-

assessment of their radioactive waste management program. The Waste Generator Services organization of NE's contractor, BEA, also provided lessons learned training on the Y-12 event to their staff.

2.6. Peer Reviews

The Secretary of Energy directed that a series of radioactive waste peer reviews be conducted. The peer reviews were jointly conducted by NNSA, EM, NE, and SC to identify best practices in radioactive waste governance and management and to support continuous improvement. This EA assessment examined the results of all 13 site peer reviews and the March 2020 Radioactive Waste Peer Review Executive Summary. EA site assessments and the peer reviews had different objectives and consequently focused on different aspects of the radioactive waste management program. The EA assessment addressed site performance of processes for characterizing, packaging, and shipping LLW, MLLW, and TRU waste for disposal, including related QA processes and Federal oversight. In contrast, peer reviews were conducted by small, short duration (typically two days) teams typically consisting of four Federal managers (one from each of the four participating program offices) and focused on governance, oversight, contractor assurance, and risk management. Where overlap occurred, EA assessments and peer reviews had similar conclusions. Both concluded that implementation of radiological waste management processes across the DOE complex is sound, and also identified that there are challenges that, if left uncorrected, would pose a risk to future performance.

3.0 Best Practices

Best practices are safety-related practices, techniques, processes, or program attributes observed during an assessment that may merit consideration for implementation by other DOE and contractor organizations because they substantially improve safety performance of a DOE operation, represent or contribute to superior performance, solve a problem or reduce the risk of a condition or practice that affects multiple DOE sites or programs, or provide an innovative approach or method to improve effectiveness or efficiency. This assessment identified 11 best practices, listed below. The organizations that demonstrated best practices are identified to facilitate exchange of information for interested organizations.

DOE

- One Headquarters program office integrates Headquarters and field office personnel in its oversight program for waste management performance, providing a more effective approach to oversight and resulting in notable improvements in the contractor's level of performance. (NA-30)

- One field office has made multiple enhancements to the TRU waste characterization process since the WIPP events of 2014 that could be applied to characterization of LLW and MLLW. Improvements include establishing new requirements for creating the Interface Waste Management Documents List and evaluation of chemical compatibility and oxidizers present in waste; collectively they support an enhanced acceptable knowledge process and are powerful tools to drive consistency in the characterization of TRU waste across the enterprise. (CBFO)

Contractors

- One contractor routinely applies real-time radiography to the waste characterization process for LLW and MLLW streams to visually verify waste container contents and provide a greater level of assurance of compliant waste shipments. (Fluor Idaho)

- One contractor applies conservative characterization estimates to container radiological contents based on the highest assay results to ensure that waste shipments do not exceed any WAC or DOT regulations. (NTESS)

- Three contractors use surrogate containers as a model to assist in estimating the potential error in isotope activity caused by waste geometries and shielding, which supplement a more accurate basis for the isotopic activity in LLW/MLLW packages. (Triad; FBP; CNS)

- One contractor established a culture focused on their waste generation program performance based on a unique set of guiding principles (know before do, cradle to grave, generators own the waste, minimize, and segregate) that has resulted in practices that have improved program performance. (FMP)

- One contractor developed a site procedure to guide LLW/MLLW generators in determining waste chemical compatibility based on EPA-600/2-80-076, *A Method for Determining the Chemical Compatibility of Hazardous Waste*. (Triad)

- Two contractors verify waste package compliance through a dual independent verification process that provides increased confidence that waste packages do not contain prohibited items. (Triad; Mission Support and Test Services, LLC)

- One contractor has fostered a mutual understanding of expectations for clean and compliant vehicles with its waste shippers that has resulted in the waste shippers dedicating certain known clean and compliant vehicles for the site's waste shipments. This practice efficiently and proactively ensures that trailers and transport rigs used for these shipments meet applicable shipping requirements and DOT regulations. (FMP)

- Two contractors implement a management self-assessment grading practice that provides feedback to the assessor to improve the quality of management assessments, resulting in the addition of more performance-based lines of inquiry. (FBP, CNS)

- One contractor incorporates periodic peer reviews, assist visits, and communities of practice into its assessment program that have resulted in significant waste management program performance improvements. (FMP)

4.0 Recommendations

The following recommendations are based on EA's analysis of site assessments, as discussed in Section 2.0 of this report. Although the underlying deficiencies and weaknesses from individual assessments do not apply to every assessed site, these recommendations are intended to provide insights for potential improvements at all DOE sites that conduct radioactive waste management activities. Consequently, DOE organizations and contractors should evaluate the applicability of the following recommendations to their respective facilities and/or organizations and consider them as suggestions for improving the effectiveness of their waste management programs.

DOE Program Offices

- Establish a group with membership from among Federal and contractor personnel associated with LLW/MLLW generators and disposal cells to periodically discuss and evaluate DOE complex-wide approaches to waste management programs and lessons learned.

- Ensure that field element waste management staffing levels, work priorities, and Federal oversight are sufficient to adequately evaluate contractor waste management performance.

DOE Office of Environmental Management

- During the next revision of DOE Manual 435.1-1:
  - Provide expectations for the site RWMB or equivalent documents to discuss the controls implemented to address uncertainties and vulnerabilities in a site's waste management program. Include expectations for actions to address compliance with reference to the statement "to the extent practical."
  - Provide expectations for waste stream control at the point of waste origination.
  - Require defined evaluation and control of potentially incompatible chemical combinations, oxidizers, or reactive chemicals, with consideration of consensus standards.
  - Incorporate a requirement for contractors to apply a documented change control process for changes in a site's waste management program and waste certification processes.
  - Clearly indicate expectations for field element and contractor oversight/assessment of radioactive waste management activities (including processes generating WRM for disposal) at the point of waste origination to ensure WAC compliance.

Field Elements

- During waste management assessments, provide additional focus on generator performance at the point of waste origination or repackaging (where the waste stream is most vulnerable to the introduction of prohibited items) and waste stream or process changes.

- For CBFO, establish a consistent and formal methodology for addressing issues identified when using the GSTR process. This methodology should identify the specific responsibilities of the site contractor, the Federal field element, the WIPP contractor, and CBFO regarding corrective action management.

- For EM-NV, convey the requirement that waste generators are to periodically assess the performance of waste management activities from waste planning through shipment to verify that waste streams are compliant with the approved waste profile for treatment, storage, or disposal. Specify criteria for NNSS and the waste generator sites to regain approval for waste shipments to NNSS after a suspension.

Contractors

NOTE: All recommendations for site contractors apply to LLW, MLLW, and TRU waste.

- Specify the radioactive waste training requirements for individuals who are intermittent generators, such as maintenance and radiological control personnel, to ensure that their training is commensurate with their responsibilities.

- Evaluate the practices for data entry into electronic waste tracking database systems to minimize free-form input, provide guidance on identification of optional and no-longer-used fields, and ensure performance of periodic verification of data quality/correctness.

- Minimize excessive or unnecessary waste container movements and handling to reduce risk of damaged containers or misplacement.

- During waste management assessments, provide additional focus on generator performance at the point of waste origination or repackaging (where the waste stream is most vulnerable to the introduction of prohibited items) and waste stream or process changes.

- Apply issues management processes to manage all unacceptable waste management conditions, not just identified non-compliances.

Appendix A
Supplemental Information

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Appendix B
Scope and Methodology

Scope and Methodology

The U.S. Department of Energy (DOE) independent oversight program is described in and governed by DOE Order 227.1A, *Independent Oversight Program*, which the Office of Enterprise Assessments (EA) implements through a comprehensive set of internal protocols, operating practices, assessment guides, and process guides. This report and the associated interim site reports use the terms "best practices, deficiencies, findings, and opportunities for improvement" as defined in DOE Order 227.1A.

This enterprise-wide assessment evaluated the implementation of radioactive waste management programs for packaging and shipping across multiple DOE sites and facilities. The sites and programs considered for assessment were prioritized through discussions with the DOE program offices that handle and dispose of radioactive materials, and through the use of 12 performance-related criteria pertinent to the scope of the radioactive waste management operations to be assessed. Examples of these criteria are past performance, waste volume packaged, specific activity of waste, and the potential for prohibited articles in waste streams. These considerations identified the waste management programs shown below as having the highest risk. In addition, oversight of waste generators performed by the Carlsbad Field Office was assessed. The sites/organizations evaluated during this assessment were:

- Carlsbad Field Office
- Hanford Site[1]
- Pacific Northwest National Laboratory
- Idaho Cleanup Project
- Idaho National Laboratory
- Knolls Atomic Power Laboratory and the Kesselring Site
- Lawrence Livermore National Laboratory
- Los Alamos National Laboratory (LANL)[2]
- LANL – Legacy Waste Management
- Nevada National Security Site (NNSS)
- Nuclear Fuel Services, Inc.
- Oak Ridge Office of Environmental Management
- Oak Ridge National Laboratory
- Portsmouth Site
- Sandia National Laboratories, New Mexico
- Savannah River Site
- Y-12 National Security Complex.

[1] Hanford Site and Pacific Northwest National Laboratory assessments conducted concurrently and results presented in one interim report.
[2] LANL was addressed in two site assessments. One addressed management of low-level waste and mixed low-level waste. The other addressed management of transuranic waste, and the scope included LANL and LANL – Legacy Waste Management.

EA discussed the scope of this assessment with DOE management representatives and stakeholders within the DOE Office of Environmental Management, the National Nuclear Security Administration, the DOE Office of Nuclear Energy, and the DOE Office of Science. Objectives and criteria from EA Criteria and Review Approach Document 31-33, Rev. 0, *Radioactive Waste Characterization, Packaging, and Transportation Criteria Review and Approach Document*, July 2019, were used to guide each site assessment.

The normal flow of requirements governing waste management packaging and shipping/transportation processes originates from applicable DOE directives and the waste acceptance criteria (WAC) for the intended treatment, storage, and disposal facility. Sites/organizations implement these requirements through their radioactive waste management basis (the controls and analyses used to comply with DOE Order 435.1, *Radioactive Waste Management*, and DOE Manual 435.1-1, *Radioactive Waste Management Manual*) or equivalent documents, and through their waste management programs. As waste is generated, it is disposed of through a waste stream established to meet the requirements of a "waste profile" that is developed, approved, and based on the WAC of the intended disposal facility. Multiple waste streams can be established and packaged under a single waste profile. However, to significantly reduce the likelihood of unwanted chemical reactions and minimize the volume of mixed waste, the waste from different profiles cannot be packaged in the same shipping container.

The waste activities observed by the EA assessment team began with waste characterization, which determines the composition, properties, and quantities of hazardous and radiological constituents within the waste. The procedures and practices for characterizing waste and documenting the basis for characterization are implemented through an evaluative process known as acceptable knowledge (AK). AK is established through process knowledge (PK) and direct sampling and analysis of the waste. PK evaluates the processes that generated the waste to establish estimates of the composition, properties, and quantities of the constituents of interest. Establishing waste estimates through PK is normally achieved through a thorough understanding of the activity-level process, starting with material inputs and ending with the final products. PK may be established through various means, including interviews with facility personnel, documentation reviews, evaluations of the mechanical actions and chemical reactions of the process, and mass balance estimates. Sampling and analysis is conducted to validate PK estimates of the constituents of interest using various activities, such as chemical evaluation of a direct sample of the waste by an analytical laboratory, sampling of gases in the container head space, or gamma spectroscopy to measure radiological constituents.

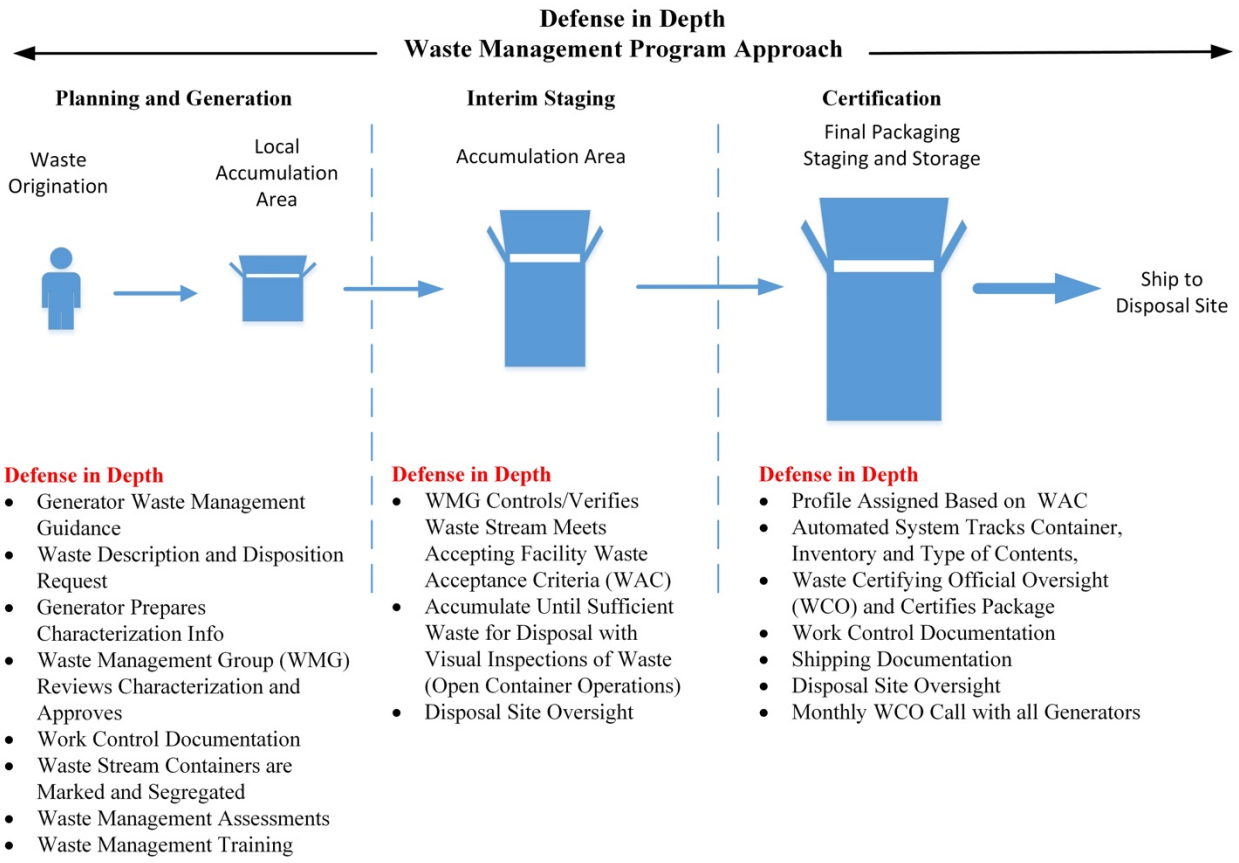
Once waste characterization is completed, a waste stream can be established for disposal and waste generation may begin. Examples of waste generation at the point of waste origination include discarding radioactively contaminated materials (e.g., from glovebox operations, maintenance activities, or laboratory research) and examining contents of a transuranic waste container (newly generated or retrieved from long-term waste stream control). Once the waste is introduced into a waste stream, it can pass through a series of processes before being certified for shipment to a disposal site; these typically include waste stream control, repackaging, final packaging, final verification of contents, and waste certification. (Sometimes the waste is placed in the final package at the point of waste origination, so several of the intermediate steps are not needed before waste certification.) Together, the processes from the point of waste generation through shipping constitute the waste certification process intended to ensure that the waste package meets the waste profile requirements and will meet the treatment, storage, and disposal facility WAC.

At each assessed site, the assessment team evaluated a representative sample of approximately 80% of the waste streams associated with approved waste profiles. If certain operations were not ongoing at a given site, the team evaluated processes and procedures for those operations by means of interviews, tabletop demonstrations, and review of documentation (e.g., analyses, logs, forms, and work products). The

assessment team also evaluated each site's implementation of the site's various engineered and administrative controls providing defense-in-depth – i.e., controls implemented to help ensure that when shipped, the waste meets the applicable WAC and that no prohibited items are accidentally introduced into waste streams. EA issued a site-specific interim report for each assessed site; hyperlinks for each interim report are provided in Appendix C of this report.

Description of Waste Control Defense-in-Depth General Approach

DOE Manual 435.1-1, *Radioactive Waste Management Manual*, defines defense-in-depth as "The practice of using physical systems and administrative systems in a structure of mutual reinforcement to avoid exposure of the public, the workforce, and the environment to nuclear radiation and to radioactive materials." The assessment team examined the implementation of defense-in-depth by observing the personnel in the facilities as they performed work, generated waste, or retrieved waste. As waste is collected and moves through the waste management processes, it can be stored until enough accumulates for final packaging and shipment. At various steps throughout the waste management process, the waste is characterized and verified to be appropriate for disposal in the approved waste stream. The assessment evaluated each of the waste management process steps to identify the defense-in-depth controls implemented to ensure a compliant waste stream and final waste package. The approach illustrated in the figure below lists the generic types of controls implemented at the sites that were assessed.



Appendix C
Radioactive Waste Management Interim Reports

Site/Organization (Hyperlinked to the associated EA Interim Report)	DOE Headquarters Program Office	Date of Onsite Assessment	Type of Waste*	Self-Assessment Conducted	Peer Review Conducted**
Carlsbad Field Office	Office of Environmental Management (EM)	August 2019	TRU	X	
Los Alamos National Laboratory	National Nuclear Security Administration (NNSA)	August 2019	LLW, MLLW	X	X
Lawrence Livermore National Laboratory	NNSA	August 2019	TRU	X	
Savannah River Site	EM	September 2019	LLW, MLLW, TRU	X	X***
Sandia National Laboratories New Mexico	NNSA	September 2019	LLW, MLLW	X	
Idaho National Laboratory	Office of Nuclear Energy	October 2019	LLW, MLLW		X
Los Alamos National Laboratory	NNSA and EM	October 2019	TRU	X	X
Idaho Cleanup Project	EM	November 2019	LLW, MLLW, TRU	X	X
Portsmouth Site	EM	December 2019	LLW, MLLW	X	
Oak Ridge National Laboratory	Office of Science (SC)	December 2019	LLW, MLLW, TRU		X
Y-12 National Security Complex	NNSA	January 2020	LLW, MLLW	X	X
Hanford Site and Pacific Northwest National Laboratory	EM and SC	January 2020	LLW, MLLW, TRU	X (Hanford Only)	X (PNNL Only)
Naval Nuclear Laboratory (Knolls Atomic Power Laboratory and Kesselring Site)	NNSA	January 2020	LLW, MLLW		
Nevada National Security Site	NNSA and EM	February 2020	LLW, MLLW	X	X***
Nuclear Fuel Services, Inc.	Commercial	February 2020	LLW, MLLW		
Oak Ridge Office of Environmental Management	EM	March 2020	LLW, MLLW, TRU	X	X

* TRU – Transuranic waste
LLW – Low-level waste
MLLW – Mixed low-level waste
** Peer review was conducted at Argonne National Laboratory; EA did not conduct an assessment there.
*** Separate peer reviews conducted for EM and NNSA operations