U.S. Department of Energy
Office of Environmental Management

Accident Investigation Report

Phase 2

Radiological Release Event at the Waste Isolation Pilot Plant, February 14, 2014

April 2015

Disclaimer

On February 14, 2014, an airborne radiological release occurred at the Department of Energy Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico. On March 4, 2014, an Accident Investigation Board (the Board) was appointed by Matthew Moury, Deputy Assistant Secretary, Safety, Security, and Quality Programs to determine the cause of the release. Because access to the underground was restricted following the event, the investigation was broken into two phases. The first phase, Phase 1, focused on how the radiological material was released into the atmosphere and the results were issued on April 22, 2014, in a Phase 1 investigation report.

On May 19, 2014, James Hutton, Deputy Assistant Secretary, Safety, Security, and Quality Programs, U.S. Department of Energy, Office of Environmental Management, appointed an Accident Investigation Board to complete the investigation (Phase 2). Phase 2 was performed once limited access to the underground was re-established and focused on how the radiological material was released. For both Phases, the Board was appointed to perform an accident investigation and to prepare an investigation report in accordance with Department of Energy Order 225.1B, *Accident Investigations*.

The discussion of the facts as determined by the Board and the views expressed in the report do not assume and are not intended to establish the existence of any duty at law on the part of the U.S. Government, its employees or agents, contractors, their employees or agents, or subcontractors at any tier, or any other party.

This Phase 2 report neither determines nor implies liability.

Release Authorization

On March 4, 2014, an Accident Investigation Board was appointed to investigate a radiological release event at the U.S. Department of Energy, Waste Isolation Pilot Plant site near Carlsbad, New Mexico, that occurred on February 14, 2014. The Board's responsibilities with respect to Phase 1 of the investigation, the radiological release to the atmosphere, were completed and a final report issued on April 22, 2014.

On May 19, 2014, James Hutton, Deputy Assistant Secretary, Safety, Security, and Quality Programs, U.S. Department of Energy, Office of Environmental Management appointed an Accident Investigation Board to continue Phase 2 of the investigation, focused on the radiological release from transuranic waste container 68660 at the Waste Isolation Pilot Plant site.

The analysis and the identification of the contributing causes, the root cause and the Judgments of Need resulting from this investigation were performed in accordance with DOE Order 225.1B, *Accident Investigations*.

The Phase 2 report of the Accident Investigation Board was accepted and the authorization to release this Phase 2 report was granted for general distribution on April 16, 2015.

[signature] 4/15/15

James Hutton
Deputy Assistant Secretary for
Safety, Security, and Quality Programs
Environmental Management

Date

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Acronyms

ADEP	Associate Directorate/Director of Environmental Programs
AK	Acceptable Knowledge
AKTSS	Acceptable Knowledge Tracking Spread Sheet
Am	Americium
ARF	Airborne Release Fraction
ARP	Accelerated Retrieval Project
Be	Beryllium
BIO	Basis for Interim Operation
CAM	Continuous Air Monitor
CAQ	Condition Adverse to Quality
CAR	Corrective Action Report
CAS	Contractor Assurance System
CBFO	Carlsbad Field Office
CCP	Central Characterization Program
CH	Contact-Handled
CIS	Characterization Information Summary
CON	Conclusion
Cs	Cesium
DL	Discard Limit
DOE	U.S. Department of Energy
DQO	Data Quality Objective
DSA	Documented Safety Analysis
DR	Damage Ratio
EM	Office of Environmental Management
EMCBC	Office of Environmental Management Consolidated Business Center
EMRTC	Energetic Materials Research and Testing Center
EPA	Environmental Protection Agency
EPO	Environmental Projects Office
ES	Energy*Solutions*, LLC
EWMO	Environmental and Waste Management Operations
FAS	Fixed Air Sampler
FGA	Flammable Gas Analysis
FTE	Full-time Equivalent
FTIR	Fourier Transform Infrared Analysis
GC-MS	Gas Chromatography-Mass Spectroscopy

HEPA	High Efficiency Particulate Air
HSS	Office of Health, Safety and Security (HSS)
HWFP	Hazardous Waste Facility Permit
IC	Ion Chromatography
ICP	Inductively Coupled Plasma
ICP-ES	Inductively Coupled Plasma Emission Spectrometry
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
JHA	Job Hazard Analysis
JON	Judgment of Need
K	Potassium
NA-LA	NNSA Los Alamos Field Office (formerly Los Alamos Site Office – LASO)
NMAC	New Mexico Administrative Code
LANL	Los Alamos National Laboratory
LANL-CO	Los Alamos National Laboratory Carlsbad Office
LANS	Los Alamos National Security, LLC
LLC	Limited Liability Company
LPF	Leakpath Factor
MP	Management Procedure
M&O	Management and Operating
MgO	Magnesium Oxide
MIN02	LANL Waste Stream LA-MIN 02-V.001, Mixed Inorganic
MST	Mountain Standard Time
NCR	Nonconformance Report
NaI	Sodium Iodide
NDA	Non-Destructive Assay
NMED	New Mexico Environment Department
NNSA	National Nuclear Security Administration
Np	Neptunium
NWP	Nuclear Waste Partnership LLC
ORPS	Occurrence Reporting and Processing System
Pa	Protactinium
Pb	Lead
PBI	Performance Based Incentive
PCB	Polychlorinated biphenyl

PE-Ci	^{239}Plutonium equivalent curies
PISA	Potential Inadequacy in the Safety Analysis
Po	Polonium
POP	Pipe Overpack
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
QAP	Quality Assurance Program
QAPD	Quality Assurance Program Document
QAPjP	Quality Assurance Program Project Plan
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RF	Respirable Fraction
RH	Remote Handled
Rn	Radon
RTR	Real-Time Radiography
SCG	Summary Category Group
SCWE	Safety Conscious Work Environment
SEM	Scanning Electron Microscopy
SME	Subject Matter Expert
SPM	Site Project Manager
SSSR	Sort, Segregate, and Size Reduction
SWB	Standard Waste Box
SWB	Standard Waste Box
TA	Technical Area
TAT	Technical Assessment Team
TDOP	Ten Drum Overpack
Th	Thorium
TOC/TIC	Total Organic/Inorganic Carbon Analysis
TRAMPAC	TRU Waste Authorized Methods for Payload Control
TRU	Transuranic
TRUPACT	Transuranic Package Transporter
TSDF	Treatment, Storage, and Disposal Facility
TSR	Technical Safety Requirement
U	Uranium
USQ	Unreviewed Safety Question
USQD	Unreviewed Safety Question Determination

VE	Visual Examination
WAC	Waste Acceptance Criteria
WAP	Waste Analysis Plan
WCG	Waste Characterization Glovebox
WCO	Waste Certification Official
WCRRF	Waste Characterization, Reduction, and Repackaging Facility
WCS	Waste Control Specialists, LLC
WDP	Waste Disposition Project
WDS	Waste Data System
WIPP	Waste Isolation Pilot Plant
WSPF	Waste Stream Profile Form
WTS	Washington TRU Solutions, LLC
WWIS	WIPP Waste Information System

Executive Summary

Accident Description

On February 14, 2014, there was a release of radioactive material from a transuranic (TRU) waste container emplaced in Panel 7 Room 7 of the Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) underground (Figure ES-1) near Carlsbad, New Mexico. The release was detected by a continuous air monitor (CAM) monitoring the Panel and an alarm activated on the Central Monitoring System in the Central Monitoring Room on the WIPP surface, which initiated a shift to filtration of the underground ventilation.

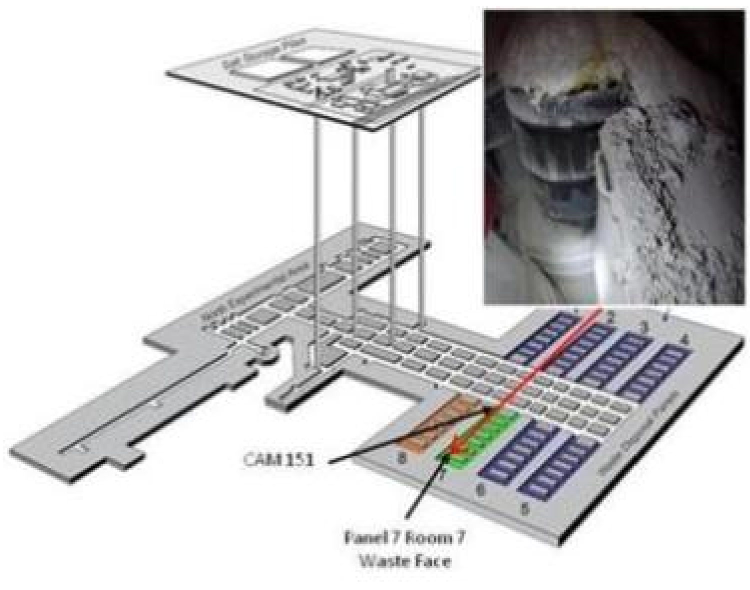

Figure ES-1: Location of the Accident

Because access to the underground was restricted following the radiological release and examination of the area and containers was not possible, the investigation was broken down into two phases. Phase 1 focused on the WIPP response to the alarm and associated radiological release to the atmosphere. On April 24, 2014, the results were published in a final report, *Phase 1, Radiological Release Event at the Waste Isolation Pilot Plant*. The Executive Summary of the Phase 1 report is provided in Attachment G of this report.

Once limited access to the underground was re-established, Phase 2 of the investigation was initiated. This phase of the investigation focused on the mechanism(s) of release from the waste containers in the underground and included entries, sampling, and additional forensics.

On February 19, 2014, the Carlsbad Field Office (CBFO) requested that the Los Alamos National Laboratory Carlsbad Office (LANL-CO) develop a list of potential source containers for the release. On February 20, 2014, the LANL-CO provided the list based on a comparison of isotopic ratios calculated from the Waste Data System (WDS) radionuclide data for each emplaced container in Room 7 of Panel 7 and isotopic ratios calculated from data obtained from analysis of WIPP Station A air filter samples. The list included containers from an Idaho - Rocky Flats waste stream and several drums containing nitrate salts from LANL. Subsequently, on May 1, 2014, CBFO declared a Potential Inadequacy in the Safety Analysis (PISA) regarding the potential for untreated nitrate salt waste being emplaced, which later prompted LANL to declare a PISA as well. On May 15, 2014, photographic evidence confirmed that a LANL-LA-MIN02-V.001 waste stream container (drum 68660) was in fact breached.

On May 19, 2014, James Hutton, Deputy Assistant Secretary, Safety, Security, and Quality Programs for the U.S. Department of Energy, Office of Environmental Management appointed a Phase 2 Accident Investigation Board (the Board) to complete the radiological release investigation and determine the cause of the TRU waste container(s) failure in accordance with DOE Order 225.1B, *Accident Investigations*.

The Board has completed the investigation and submitted this Phase 2 final report to the appointing official on March 31, 2015. Based upon the evidence gathered and analyzed during the investigation, the Board concluded that the release from the container(s) was preventable. If LANL had adequately developed and implemented repackaging and treatment procedures that incorporated suitable hazard controls and included a rigorous review and approval process, the release would have been preventable.

History of LANL Waste Generation and Treatment

On July 1, 1979, operations commenced at LANL Technical Area 55 (TA-55) (Figure ES-2) for the extraction and recovery of plutonium from residues and scraps generated from operations at various LANL facilities and other DOE sites in the defense complex. The scrap and residues were processed to recover as much plutonium as economically feasible. The recovered plutonium was converted into pure plutonium feedstock. This recovery process generated evaporator nitrate salt and bottom wastes.

Figure ES-2: LANL Technical Area 55

These nitrate salt wastes were vacuum-dried, packaged in double bags, and then placed in polyethylene liners within lead-lined 55-gallon drums. Filteraid® absorbent was added to absorb any moisture. The drums were then closed with a lid and a filter vent and placed into storage in the TA-55 Plutonium Facility Building 4 (PF-4). On November 12, 1985, parent drum S855793 was processed in this manner and placed into storage as contact handled (CH) TRU waste.

In late 2006 and early 2007, LANL conducted an expedited project to modify and upgrade an existing 30-year old glovebox facility to become the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) which was designed to support sampling, examination, characterization, size reduction, and repackaging of TRU waste, including the LANL Area TA-55 CH TRU waste. In April 2007, the Basis for Interim Operation (BIO) and Technical Safety Requirements (TSRs) for the WCRRF were issued and an Operational Readiness Review was performed in mid-2007 resulting in approval to begin operations at the WCRRF.

On May 23, 2007, LANL issued procedure EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations,* Revision 0. This procedure provided instructions for remediating TRU waste which did not meet WIPP WAC and Acceptable Knowledge (AK) requirements. The CH TRU nitrate salt wastes in storage at TA-55 since 1979 were within the scope of this procedure.

Remediation of nitrate salt drums at the WCRRF began on September 1, 2011. Remediation consisted of retrieving drums from storage and transporting them to the WCRRF where the drum contents were processed in the Waste Characterization Glovebox (Figure ES-3).

Figure ES-3: Waste Characterization Glovebox in WCRRF at LANL

Processing at that time included:

- Removal of the waste items from the drum;
- Adding WasteLock® 770 absorbent;
- Mixing the waste and absorbent;
- Placing the mixed waste into daughter drums; and
- Moving the remediated waste drums to storage in TA-54.

In February 2012, LANL issued a memorandum titled *Legacy TA-55 Nitrate Salt Wastes at TA-54, Potential Applicability of RCRA D001/D002/D003 Waste Codes.* This paper incorrectly concluded that nitrate salt drums did not meet the Environmental Protection Agency (EPA) ignitability or reactivity criteria, and that wastes containing free liquids must be remediated prior to shipment. The WIPP HWFP stated that:

> *"….the prohibition of liquid in excess of Treatment, Storage, and Disposal Facility Waste Acceptance Criteria limits and containerized gases prevents the shipment of corrosive, ignitable, or reactive wastes."*

The Board concluded that liquid prohibition alone was ineffective in preventing the shipment of ignitable wastes.

On March 8, 2012, processing of nitrate salt waste was put on hold due to concerns about the compatibility of the WasteLock® 770 absorbent with the nitrate salt waste matrix. Meetings between LANS, Energy*Solutions*, LLC (ES), a subcontractor to LANS, and the LANL-CO Difficult Waste Team were held in April 2012 to determine the path forward for the nitrate salt waste.

On May 8, 2012, the LANL-CO Difficult Waste Team issued a white paper titled Amount of Zeolite Required to Meet the Constraints Established by the EMRTC Report RF 10-13: Application of LANL Evaporator Nitrate Salts. This paper defined the amount of "Kitty Litter/Zeolite clay" to be added per volume of nitrate salts and was based on EMRTC Report RF 10-13 Results of Oxidizing Solids Testing, dated April 12, 2010.

In July 2012, LANS issued *Solution Package (SP) Report-72, Salt Waste (SP #72)* (Revision 1) to address the processing steps for nitrate salt drums. This document concluded that the glovebox procedure must be revised or replaced to ensure that the final waste mixture meets or exceeds 1.2:1 kitty litter/zeolite:nitrate salt as specified by May 8, 2012, LANL-CO white paper.

In response to SP #72, LANS prepared a major revision to the glovebox operations procedure. Section 10.6 was added to provide instructions for nitrate salt drum processing. Paragraph 10.6[3] stated "ensure an organic absorbent (Kitty Litter/Zeolite® absorbent) is added to the waste material at a minimum of 1.5 absorbent to 1 part waste ratio." The Board concluded that specifying the use of "organic" absorbent and the omission of the word "clay" in the WCRRF glovebox procedure was not consistent with the direction provided in the white paper.

On September 27, 2012, Swheat Scoop® kitty litter, an <u>organic</u> absorbent, was purchased and on October 1, 2012, ES personnel began remediation of nitrate salt waste drums previously remediated with WasteLock® 770, an organic compound.

Parent Drum S855793 Repackaging

On December 4, 2013, ES remediated parent drum S855793 in accordance with the glovebox operations procedure, producing daughter drums LA00000068660 (68660) and LA00000068685 (68685). Swheat Scoop® was added as the absorbent and pH was adjusted using KOLORSAFE® Liquid Acid Neutralizer. A tungsten lined glovebox glove was added as secondary waste to the waste/absorbent/neutralizer mixture. Drum 68660 was then closed with a lid and a filter vent.

On December 12, 2013, Central Characterization Program (CCP) personnel at LANL performed real-time radiography (RTR) on drum 68660.

On January 2, 2014, CCP personnel at LANL performed nondestructive assay (NDA) on drum 68660.

On January 3, 2014, CCP personnel at LANL performed flammable gas analysis (FGA) on drum 68660.

On January 21, 2014, based on RTR, NDA, FGA, and document review, CCP waste certification personnel certified drum 68660 as WIPP compliant.

On January 29, 2014, drum 68660 was shipped from LANL to WIPP with shipment LA140017. This shipment arrived and was accepted by WIPP. The WIPP receipt acceptance process included verification of the shipping manifest, performance of external surface radiological surveys, visual examination for physical damage (severe rusting, apparent structural defects, signs of pressurization, etc.) and leakage.

On January 31, 2014, drum 68660 was emplaced at Panel 7 Room 7, Row 16, Column 4 (R16:C4) in the WIPP underground.

On February 5, 2014, a salt haul truck caught on fire in another location in the WIPP underground. The fire was the subject of a DOE accident investigation.[1] The evacuation and subsequent investigation restricted access to the underground. There were no personnel in the underground at the time of the release event. The Board determined that the fire had no direct impact on waste stored in Panel 7.

Radiological Release Event

On February 14, 2014, an exothermic reaction involving the mixture of the organic materials (Swheat Scoop® absorbent and/or neutralizer) and nitrate salts occurred inside drum 68660. This exothermic reaction resulted in pressurization of the drum, failure of the drum locking ring, and displacement of the drum lid. The energetic release propelled TRU waste from the drum up into polypropylene magnesium oxide (MgO) super sacks on top of the containers and onto adjacent waste containers. The super sacks of MgO are an assurance feature to ensure that consistent and favorable chemical conditions are maintained in WIPP brines after final facility closure by reacting with any carbon dioxide produced by the decay of organic carbon in the waste and waste emplacement materials. WIPP HWFP states "Magnesium oxide (MgO) will be used as a backfill in order to provide chemical control over the solubility of radionuclides in order to comply with the requirements of 40 CFR §191.13."

At 2314, a CAM monitoring airflow in Panel 7 exhaust drift, where drum 68660 was stored, detected this release and an alarm was received on the Central Monitoring System in the Central Monitoring Room on the WIPP surface and automatically initiated a shift to filtration of the underground ventilation system. While the majority of the release was directed by the ventilation system through high efficiency particulate air (HEPA) filters, a small portion bypassed the HEPAs via leakage around the ventilation system dampers and exhausted directly to the atmosphere. The Phase 1 Department of Energy (DOE) Accident Investigation Board completed an investigation of the atmospheric release and the results were published on April 22, 2014, in the Phase 1 Accident Investigation Board report.

On May 19, 2014, James Hutton, Deputy Assistant Secretary, Safety, Security, and Quality Programs, U.S. Department of Energy, Office of Environmental Management appointed an Accident Investigation Board to begin Phase 2 of the investigation to determine the cause of the radiological release from container(s) in the WIPP underground.

[1] The Executive Summary of this report is found in Attachment G of this report. The full copy of this report can be found at http://www.wipp.energy.gov/wipprecovery/accident_desc.html.

Direct, Root, and Contributing Causes

Direct Cause: The immediate events or conditions that caused the accident.

The Board identified the direct cause of this accident to be an exothermic reaction of incompatible materials in LANL waste drum 68660 that led to thermal runaway, which resulted in over-pressurization of the drum, breach of the drum, and release of a portion of the drum's contents (combustible gases, waste, and wheat-based absorbent) into the WIPP underground.

The Board reached this conclusion based on post-event forensic and fire analyses that determined that:

- Isotopic ratios in air sample media analyzed post-event are consistent with drum 68660 which is unique from other drums in the area of the release.
- The contents of waste drum 68660 included incompatible materials which created the potential for an exothermic reaction.
- Waste drum 68660 was the only waste container with an identified breach.
- The visual evidence associated with the identified breach was consistent with an exothermic reaction within drum 68660. This reaction resulted in internal heating of the drum that led to internal pressure buildup of combustible gases within the drum which exceeded the drum venting capacity. The drum lid extruded beyond the lid retention ring, deflected the lid, and resulted in rapid release of the materials from the drum. The combustible gases and solids ignited which then spread to other combustible materials within the waste array, i.e., fiberboard and polyethylene slip sheets, reinforcement plates, stretch wrap, cardboard stiffeners and polypropylene super sack fabric.

Root Cause: Causal factors that, if corrected, would prevent recurrence of the same or similar accidents. Root causes can be local (specific to the one accident), and/or systemic (common to a broad class of similar accidents). For this accident, the Board identified both local and systemic root causes.

Local Root Cause: A specific deficiency that, if corrected, would prevent recurrence of the same accident.

The Board identified the local root cause of the radioactive material release in the WIPP underground to be the failure of LANS to understand and effectively implement the LANL Hazardous Waste Facility Permit and Carlsbad Field Office directed controls. Specifically, LANL's use of organic, wheat-based absorbent instead of the directed inorganic absorbent such as kitty litter/zeolite clay absorbent in the glovebox operations procedure for nitrate salts resulted in the generation, shipment, and emplacement of a noncompliant, ignitable waste form.

Systemic Root Cause: A deficiency in a management system that, if corrected, would prevent the occurrence of a class of accidents, e.g., operational accidents caused by procedural deficiencies.

The Board identified the systemic root cause as the Los Alamos Field Office (NA-LA) and National Transuranic Program/Carlsbad Field Office (CBFO) failure to ensure that LANL had adequately developed and implemented repackaging and treatment procedures that incorporated suitable hazard controls and included a rigorous review and approval process. NA-LA and CBFO did not ensure the adequate flow down of the Resource Conservation and Recovery Act and other upper tier requirements, including the WIPP Hazardous Waste Facility Permit, Attachment C, Waste Analysis Plan, WIPP Waste Acceptance Criteria, and the LANL Hazardous Waste Facility Permit requirements into operating procedures at LANL.

Contributing Causes: Events or conditions that collectively with other causes increased the likelihood or severity of an accident but that individually did not cause the accident.

The Board identified twelve contributing causes to the radiological release investigated in Phase 2:

1. Failure of Los Alamos National Security, LLC (LANS) to implement effective processes for procedure development, review, and change control. Execution of the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure resulted in a combination of incompatible materials and the generation of an ignitable, noncompliant waste.
2. Failure of Los Alamos National Security, LLC (LANS) to develop and implement adequate processes for hazard identification and control. As a result, an incompatible absorbent was specified and used during nitrate salt bearing waste processing.
3. Failure of the Los Alamos National Security, LLC (LANS) Contractor Assurance System (CAS) to identify weaknesses in the processes for operating procedure development; hazard analysis and control; and review that resulted in an inadequate glovebox operation procedure for processing the nitrate salt bearing waste.
4. Failure of the Central Characterization Program (CCP) to develop an Acceptable Knowledge (AK) for the mixed inorganic nitrate waste stream (LA-MIN02-V.001) that adequately captured all available information regarding waste generation and subsequent repackaging activities in order to prevent the generation, shipment, and emplacement of corrosive, ignitable, or reactive waste. Specifically, the AK Summary Report did not capture changes made to the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure. The addition of a secondary waste material was not adequately considered.
5. Failure of Los Alamos Field Office (NA-LA) and the National Transuranic (TRU) Program/Carlsbad Field Office (CBFO) to ensure that the CCP and LANS complied with Resource Conservation and Recovery Act (RCRA) requirements in the WIPP Hazardous Waste Facility Permit (HWFP) and the LANL HWFP, as well as the WIPP Waste Acceptance Criteria (WAC). Examples include the unapproved treatment (neutralization and absorption of liquids) and the addition of incompatible materials. As a result, waste containing incompatible materials was generated and sent to WIPP.
6. Failure of Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES), and the NNSA Los Alamos Field Office (NA-LA) to ensure that a strong safety culture existed within the Environmental and Waste Management Operations (EWMO) organization at the

Los Alamos National Laboratory (LANL). As a result, although there was a questioning attitude, there was a failure to adequately resolve employee concerns which could have identified the generation of noncompliant waste prior to shipment.

7. Failure of the execution of the LANL Unreviewed Safety Question (USQ) process to identify the lack of a hazard analysis of the proposed changes to the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox waste repackaging procedure (i.e., consistent with Integrated Safety Management (ISM) core functions]), and to recognize that an incompatible reactive nitrate salt bearing waste would be created by using "organic" absorbents. As a result, the Unreviewed Safety Question Determination (USQD) did not ensure that nuclear safety basis documents, including the WCRRF and Area G Basis for Interim Operation (BIO), were updated to evaluate hazards associated with material incompatibility in the nitrate salt-bearing waste stream and to specify preventive or mitigative controls.

8. Failure of NNSA Los Alamos Field Office (NA-LA) to establish and implement adequate line management oversight programs and processes in accordance with DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy*. As a result, weaknesses in Los Alamos National Security, LLC (LANS)/ Energy*Solutions*, LLC (ES) programs and waste operations procedures were not identified and corrected which allowed an ignitable, noncompliant nitrate salt-bearing waste to be generated, shipped, and emplaced at WIPP.

9. Failure of DOE Headquarters to perform adequate or effective line management oversight required by DOE Order 435.1, *Radioactive Waste Management*, dated July 9, 1999. As a result, waste containing incompatible materials was generated and sent to WIPP.

10. Failure of Nuclear Waste Partnership LLC (NWP) to ensure that the WIPP Fire Hazard Analysis (FHA) recognized the potential for a fire starting within the waste array as well as the potential for propagation within the array. As a result, fire protection controls focused on prevention of propagation to the array from external sources (e.g., vehicles) and did not consider the magnitude of the combustible material hazard.

11. Failure of Los Alamos National Security, LLC (LANS)/Energy*Solutions*, LLC (ES) to adequately train and qualify ES operators and supervisors in the identification and control of incompatible materials during waste processing. As a result, personnel did not question the instruction to add organic absorbent and other secondary waste items to the nitrate salt-bearing waste.

12. Failure of Energy*Solutions*, LLC (ES) operators and Los Alamos National Security, LLC (LANS)/ES supervisors to effectively execute the stop work process when unexpected conditions, including foaming reactions and smoke during waste processing, were encountered at Waste Characterization, Reduction, and Repackaging Facility (WCRRF). This resulted in waste containing incompatible materials being generated and sent to WIPP.

Conclusions and Judgments of Need

Based upon the evidence obtained during this accident investigation, the Board concluded that the release from the container(s) was preventable. If LANL had adequately developed and implemented repackaging and treatment procedures that incorporated suitable hazard controls and included a rigorous review and approval process, the release would have been preventable.

Table ES-1 summarizes the Conclusions (CONs) and Judgments of Need (JONs) determined by the Board. The conclusions are derived from the analytical results performed during this accident investigation for determining what happened and why it happened. Per DOE O 225.1B, *Accident Investigations*, the report must demonstrate that the Judgments of Need (JONs) are based on objective analysis and application of the core analytical techniques using the facts to develop the root and contributing causes. The report must also identify DOE and contractor management systems that, if corrected, could have prevented the accident so those systems can be addressed and corrected to prevent recurrence. Table D-2 in the body of the report provides more detail, including the causal factors, specific conditions related to the causal factors, and associated CONs and JONs.

Table ES-1: Conclusions and Judgments of Need

Conclusion (CON)	Judgments of Need (JON)
CON 1: Implementation of the characterization processes established in the Waste Isolation Pilot Plant (WIPP) Hazardous Waste Facility Permit (HWFP), Attachment C, Waste Analysis Plan (WAP) was not fully consistent with the criteria in 40 CFR 261.21, *Characteristic of Ignitability*. Specifically, characterization processes should have identified LA-MIN02-V.001 as ignitable because: • It is an oxidizer; and • Addition of the organic absorbent created conditions that made the waste capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burning so vigorously and persistently that it creates a hazard.	**JON 1**: The National Transuranic (TRU) Program needs to re-evaluate and strengthen the flow down of requirements regarding the compilation of Acceptable Knowledge (AK) in order to more clearly demonstrate that the WIPP HWFP, Attachment C, WAP waste characteristics prohibitions and chemical compatibility requirements are met consistent with 40 CFR 261.21.
CON 2: Execution of the National Transuranic (TRU) Program certification audit process for the LANL waste generator activities where Central Characterization Program (CCP) performs TRU waste characterization and certification failed to include key elements of waste packaging and characterization processes. In part, this was attributed to a lack of clear roles and responsibilities; and expectations. Specific elements include: • Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox treatment and repackaging operations;	**JON 2**: The National TRU Program needs to re-evaluate and strengthen the certification audit process across the DOE complex at all generator sites to include: • Evaluation of waste generator repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; • Verification that changes to processes are correctly incorporated into acceptable knowledge summary reports;

Conclusion (CON)	Judgments of Need (JON)
• Ensuring that TRU waste accepted for management and disposal at WIPP complies with the WIPP Hazardous Waste Facility Permit (HWFP), applicable laws, and regulations described in the Waste Acceptance Criteria (WAC); and • Verification that Los Alamos National Security, LLC (LANS) prepared implementation documentation and programs to meet the requirements and criteria of the WIPP Waste Acceptance Criteria (WAC) and that the CCP maintained an accurate and compliant Acceptable Knowledge Summary Report for the LA-MIN02-V.001waste stream.	• Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and • Evaluation of local site office oversight of TRU waste operations.
CON 3: The NNSA Los Alamos Field Office (NA-LA) oversight activities were ineffective in identifying weaknesses in the execution of waste packaging, characterization and certification of transuranic (TRU) waste at Los Alamos National Laboratory (LANL).	**JON 3**: NA-LA oversight of characterization and certification of TRU waste sites needs to be improved to include: • Waste Characterization, Reduction, and Repackaging Facility (WCRRF) repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; and • Verification that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit.
CON 4: Carlsbad Field Office (CBFO) oversight activities associated with the characterization and certification of transuranic (TRU) waste were ineffective in identifying programmatic weaknesses through the execution of certification audits and surveillances at LANL.	**JON 4**: The CBFO oversight of characterization and certification of TRU waste sites needs to be improved to include: • Waste generator repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; • Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and • Evaluation of local site office oversight of TRU waste operations.

Conclusion (CON)	Judgments of Need (JON)
	JON 5: CBFO needs to evaluate and restructure their organization such that objective oversight of the National TRU Program is evident and effective in ensuring that waste generator sites comply with requirements including appropriate separation of CBFO line management and oversight functions and responsibilities. **JON 6:** DOE Headquarters needs to review expectations documented in existing National TRU Program policy directives and take action necessary to clearly assert that CBFO, as the manager of the WIPP repository, has the authority to conduct oversight of waste generator site programs and processes necessary to provide assurance that any activities that could impact characterization and certification of waste are verified to be compliant.
CON 5: Implementation of requirements listed in CCP-PO-001, *CCP Transuranic Waste Characterization Quality Assurance Project Plan,* did not ensure that waste characterization methods and Acceptable Knowledge (AK) were effective in preventing the shipment of corrosive, ignitable, or reactive wastes.	**JON 7:** The Central Characterization Program (CCP) needs to improve implementation of requirements in CCP-PO-001 such that characterization methods are able to ensure that all WIPP Waste Acceptance Criteria (WAC) requirements are met.
CON 6: The preparation, review and approval of CCP-AK-LANL-006, *Acceptable Knowledge (AK)* summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of adding incompatible secondary waste items to the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.	**JON 8**: The CCP needs to improve the level of rigor in reviewing and approving AK summary reports for compliance with requirements.
CON 7: Los Alamos National Security, LLC (LANS) did not adequately evaluate the impact on the WIPP Waste Acceptance Criteria (WAC) or effectively control the addition of secondary job waste into transuranic (TRU) waste containers.	**JON 9**: LANS needs to improve the level of rigor in evaluating and controlling the addition of secondary job waste into TRU waste containers.
CON 8: Los Alamos National Security, LLC (LANS) did not adequately incorporate upper tier requirements into the development of repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF). Specifically: • The Carlsbad Field Office (CBFO) directed controls contained in the LANL-CO white	**JON 10**: LANS needs to strengthen the processes that ensure the flow down of upper tier requirements into their implementing procedures such that execution of work is compliant. **JON 11**: CBFO needs to conduct an extent of condition review of other waste generator sites to determine the adequacy of the flow down into the operating procedures and implementation

Conclusion (CON)	Judgments of Need (JON)

paper based on the Energetic Materials Research and Testing Center (EMRTC) Report RF 10-13; and
• The requirements associated with the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit (HWFP):
  • Nitrate salt-bearing wastes did not fully meet the LANL HWFP "special requirements" for managing ignitable wastes, including segregation and separation, and use of non-sparking tools;
  • Did not comply with the LANL HWFP requirement that the nitrate salt-bearing waste drums be labeled with all applicable Environmental Protection Agency (EPA) Hazardous Waste Numbers;
  • Placed incompatible wastes and materials in the same container and did not impose special precautions;
  • Did not label the nitrate salt-bearing waste prior to transport and remediation at the WCRRF; and
  • Did not label the unremediated nitrate salt-bearing waste drums which contained liquids as Resource Conservation and Recovery Act (RCRA) corrosive.
	of RCRA requirements contained in the WIPP Waste Acceptance Criteria (WAC) and hazardous waste permits regarding the treatment and repackaging of TRU waste.

CON 9: The preparation, review and approval of CCP-AK-LANL-006, Acceptable Knowledge (AK) summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of changes to EP-WCRR-WO-DOP-233 Glovebox Operations, on the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.	**JON 12**: The Central Characterization Program (CCP) needs to reevaluate and strengthen the process used to conduct review and approval of source documents that have an impact on Acceptable Knowledge.
CON 10: Los Alamos National Security, LLC (LANS) failed to provide sound technical basis for decisions regarding repackaging procedures and processes for the LA-MIN02-V.001 waste stream.	**JON 13:** LANS needs to strengthen documentation to include a detailed technical basis to justify decisions made regarding change control for procedures and processes for the LA-MIN02-V.001 waste stream.

Conclusion (CON)	Judgments of Need (JON)
CON 11: Los Alamos National Security, LLC (LANS) did not utilize a formal engineering change control process to develop modifications to repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF).	**JON 14:** LANS needs to implement an effective engineering change control process that includes defensible technical bases to justify process modifications.
CON 12: Los Alamos National Security, LLC (LANS) failed to ensure that there was sufficient detail provided in the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure to ensure safe, consistent, and compliant repackaging of waste and accurate documentation of the contents of the waste drums in the records.	**JON 15:** LANS needs to revise the WCRRF glovebox operations procedure to contain the necessary level of detail to ensure safe, consistent, and compliant remediation of nitrate salt bearing waste. **JON 16:** The glovebox operations procedure needs to be revised to require operators to document critical process steps in a quality record, e.g., initial pH, absorbent added, neutralizer used, adjusted pH. **JON 17**: Operators need to be adequately trained on the revised glovebox operations procedure.
CON 13: Available data indicated that oxidation was occurring in the Standard Waste Box (SWB) where sibling drum 68685 was stored, along with other similarly remediated waste drums.	**JON 18**: Los Alamos National Security (LANS) needs to investigate and determine the cause for oxidation in sibling drum 68685 and take action to mitigate the condition as well as prevent future nitrate salt bearing waste drums (remediated and unremediated) from oxidizing.
CON 14: The Waste Characterization, Reduction, and Repackaging Facility (WCRRF) Basis for Interim Operation (BIO) did not thoroughly describe or evaluate nitrate salt processing or waste storage activities.	**JON 19:** The WCRRF BIO needs to be revised to include more specificity in description of nitrate salt processing activities and then update the hazard analysis to include identification of all hazards and their evaluations. **JON 20**: LANS needs to review the Area G BIO in light of changes made to the WCRRF BIO and update accordingly. **JON 21**: LANS needs to conduct an extent of condition review for issues that are similar to nitrate salt bearing waste processing in WCRRF and Area G.
CON 15: The Los Alamos National Security, LLC (LANS) Unreviewed Safety Question (USQ) process was ineffective in ensuring that important procedure changes related to processing of nitrate salts were adequately evaluated for impacts to the safety basis.	**JON 22**: LANS needs to ensure that USQ evaluators are organizationally independent of line management. **JON 23**: LANS needs to conduct retraining of USQ process evaluators/approvers focused on implementation of the Unreviewed Safety Question Determination (USQD) process

Conclusion (CON)	Judgments of Need (JON)
	consistent with DOE Guide 424.1-1B, *Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements.* **JON 24**: The NNSA Los Alamos Field Office (NA-LA) needs to conduct an assessment of the LANS USQ program.
CON 16: The Los Alamos National Security, LLC (LANS) contractor assurance system was not effective in identifying weaknesses in the process for developing/changing procedures, analyzing and controlling hazards, performing work to repackage nitrate salt bearing wastes, and feedback mechanisms which resulted in the production and shipping of noncompliant waste drums to the Waste Isolation Pilot Plant and Waste Control Specialists, LLC (WCS).	**JON 25**: LANS Environmental and Waste Management Operations (EWMO) needs to develop and implement a fully integrated contractor assurance system that provides DOE and LANS confidence that work is performed compliantly, risks are identified, and control systems are effective and efficient. Specific areas to be addressed include: • Ensuring adequate scope and associated depth and breadth of self-assessments, independent assessments and management assessments; • Clarifying the oversight role of LANS EWMO with regard to subcontractors and waste processing/packaging operations; • Ensuring required environmental program oversight i.e., the Resource Conservation and Recovery Act (RCRA) (hazardous waste determination, upper tier requirements flow down into implementing procedures, waste determination, records); • Including the necessary rigor in implementation of the change control process (review and approval by subject matter experts); • Verifying that requirements are flowed down into implementing procedures, e.g., RCRA requirements, TRU Waste Authorized Methods for Payload Control, etc.; and • Evaluating and responding to feedback from Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations by LANS senior management, e.g., notification of reactions in the glovebox.
CON 17: The NNSA Los Alamos Field Office (NA-LA) oversight was ineffective in identifying weaknesses that contributed to this event.	**JON 26**: NA-LA needs to strengthen its oversight of Los Alamos National Security, LLC (LANS) Environmental and Waste Management Operations (EWMO) to ensure that:

Conclusion (CON)	Judgments of Need (JON)

	• Resource Conservation and Recovery Act (RCRA) oversight is performed;
	• Focus is placed on operational oversight in addition to budget/financial oversight;
	• On the ground operational oversight expands beyond that performed by the Facility Representatives to include adequate subject matter expertise;
	• NA-LA performs oversight of contractor activities related to waste certification in accordance with the WIPP Waste Acceptance Criteria (WAC);
	• Roles and responsibilities for oversight of Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations are made clear;
	• Staffing shortages are addressed, including:
	    • Facility Representatives, short three full-time equivalencies (FTEs);
	    • Senior Technical Safety Manager, short two FTEs;
	    • The staffing reduction in environmental compliance, down from five to three FTEs since 2011; and
	    • Senior technical advisor position has been vacant since 2008.
	    • Formal verification that there is an effective LANS Contractor Assurance System (CAS) in place for environmental compliance.
	JON 27: NA-LA needs to verify that LANS has developed and implemented a DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy* compliant CAS.

CON 18: The Federal roles, responsibilities and execution for oversight of the activities between the generator site transuranic (TRU) waste program (LANL) and the TRU Waste Central Characterization Program (CCP) were inadequate.	**JON 28**: The National TRU Program needs to clarify NA-LA and CBFO expectations and oversight roles and responsibilities between the generator site TRU waste program (LANL) and the TRU waste CCP. **JON 29**: NA-LA and CBFO needs to perform effective Federal oversight of CCP review and approval of waste management operating procedures/process changes, e.g., WCRRF

Conclusion (CON)	Judgments of Need (JON)
	glovebox operating procedure. **JON 30**: DOE Headquarters and CBFO need to conduct an extent of condition review of the overall Federal oversight across the DOE complex in all three key segments of the National TRU Program: the Generator Site TRU Waste Program, TRU Waste Certification Program, and the Disposal System Program (WIPP).
CON 19: DOE Headquarters did not perform DOE O 435.1, *Radioactive Waste Management,* oversight activities for implementation of requirements associated with the operational performance within the National Transuranic (TRU) Program.	**JON 31**: DOE Headquarters needs to develop and implement a DOE O 435.1 comprehensive oversight program for National TRU Program activities.
CON 20: Los Alamos National Security, LLC (LANS) existing processes governing the preparation, review, and approval of Environmental Programs procedures did not contain sufficient guidance related to hazard analysis and subject matter expert review necessary to ensure safe, consistent, and compliant execution of waste processing.	**JON 32**: LANS needs to review and revise EP-DIR-AP-10007, *Environmental Programs Procedure Preparation, Revision, Review, Approval, and Use,* to ensure that all procedures and procedure revisions contain: • The necessary level of detail to ensure the safe, consistent, and compliant performance of work, including process steps, materials, and material substitutions; • Explicit requirements and criteria regarding inclusion of appropriate subject matter experts and their review and concurrence with new and revised procedures; and • Requirements that a Job Hazard Analysis (JHA) is appropriately amended when new activities such as nitrate salt remediation that could introduce new hazards are incorporated into existing processes.
CON 21: The WIPP Fire Hazard Analysis (FHA) was ineffective in identifying and analyzing the potential for a fire starting within the waste array, as well as the potential for fire propagation within the array.	**JON 33**: Nuclear Waste Partnership LLC (NWP) needs to re-evaluate the quantities, type and form of exposed combustible emplacement materials used in the waste array and take action to minimize the fire ignition and propagation risks (e.g., eliminate unnecessary materials, and include fire retardant additives). **JON 34**: NWP needs to revise the waste array emplacement strategy to include criteria that limit the risk of fire propagation within the array, to include limiting the quantity of radiological waste that is at-risk from a single fire or

Conclusion (CON)	Judgments of Need (JON)
	explosion event. **JON 35**: NWP needs to revise the FHA to identify and address all credible fire and explosion scenarios initiated within the waste array underground. **JON 36**: NWP needs to reevaluate and revise the WIPP FHA to better characterize the fire risks associated with transuranic (TRU) waste packaging during handling and storage. This needs to include reevaluation of actions detailed in the WIPP Recovery Plan. **JON 37**: The Office of Environmental Management Headquarters needs to ensure that waste generator site's FHAs adequately characterize the fire risks associated with TRU waste packaging during handling and storage.
CON 22: Energy*Solutions*, LLC (ES) operators and supervisors were not adequately trained and qualified to process waste with regard to identification and control of incompatible materials.	**JON 38**: LANS needs to evaluate and strengthen the operator and supervisor training programs of LANS and their subcontractors to ensure adequate understanding of basic chemistry interactions and associated controls.
CON 23: Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) and NNSA Los Alamos Field Office (NA-LA) allowed the safety culture at the Los Alamos National Laboratory (LANL) to deteriorate within pockets of the organization as evidenced by the workers' feedback that they did not feel comfortable identifying issues that may adversely affect management direction, delay mission-related objectives, or otherwise affect cost or schedule. In addition, management failed to effectively respond to workers' issues regarding unexpected conditions, i.e., generation of smoke and foaming, encountered during waste processing activities. **CON 24**: Questioning attitudes were not welcomed by management and many issues and hazards did not appear to be readily recognized by site personnel.	**JON 39**: LANS and NA-LA need to develop and implement a more rigorous, effective integrated safety management system that embraces and implements the attributes of DOE G 450.4-1C, *Integrated Safety Management Guide,* including but not limited to: • Demonstrated leadership in risk-informed, conservative decision making; • Improved learning through error reporting and effective resolution of problems; • Line management encouraging a questioning attitude without fear of reprisal and following through to resolve issues identified by the workforce. • Consideration should also be given to some additional contract incentive associated with leading a culture change that fosters the desired work environment. The LANS, ES, and NA-LA stop work related processes need to ensure that response to issues raised by workers are based on sound, technical justification. **JON 40**: DOE Headquarters needs to engage safety culture expertise to provide training and

Conclusion (CON)	Judgments of Need (JON)
	mentoring to LANS, ES, and NA-LA management on the principles of a strong safety culture and take appropriate corrective action based on the outcome.

1.0 Introduction

1.1 Appointment of the Board

On May 19, 2014, an Accident Investigation Board (the Board) was appointed by James Hutton, Deputy Assistant Secretary, Safety, Security, and Quality Programs, U.S. Department of Energy (DOE) Office of Environmental Management (EM), to investigate Phase 2 of the radioactive release in the underground at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, that occurred on February 14, 2014. (Appendix A) This investigation had been broken into two phases because access to the WIPP underground was prohibited immediately following the radiological release. Phase 1 focused on how a small portion of radioactive material bypassed the WIPP effluent treatment system and was released into the atmosphere. The Executive Summary from the Phase 1 report is provided as Attachment G of this report. Phase 2 of the investigation was initiated once limited access to the underground was re-established and focused on how the radioactive material was released from the transuranic[2] (TRU) waste container(s).

Preliminary discoveries indicated that a Los Alamos National Laboratory (LANL) waste stream may have contributed to the radiological release. Based upon this discovery, the Board focused a significant amount of this Phase 2 investigation on the operations at LANL.

The Board's responsibilities have been completed with respect to this Phase 2 investigation. The analysis and the identification of the direct and contributing causes, the root causes (local and systemic), Conclusions, and associated Judgments of Need were performed in accordance with DOE Order (O) 225.1B, *Accident Investigations.*

This accident meets Accident Investigation Criteria 2.d.1 of DOE O 225.1B, Appendix A. The Board completed Phase 2 of the investigation on March 30, 2015, and submitted the report to the appointing official on March 31, 2015. The Phase 2 report covers the Board's conclusions on the cause of the container(s) failure that caused the release of TRU waste in the WIPP underground.

1.2 Waste Isolation Pilot Plant

WIPP, located in southeastern New Mexico near Carlsbad, was constructed to determine the efficacy of an underground repository for disposal of TRU waste (Figure 1-1). Disposal operations began in 1999.

[2] Transuranic waste (TRU) means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for (A) high-level radioactive waste; (B) waste that the DOE Secretary has determined, with the concurrence of the EPA Administrator, does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations. [Public Law 102-579 (1992)]

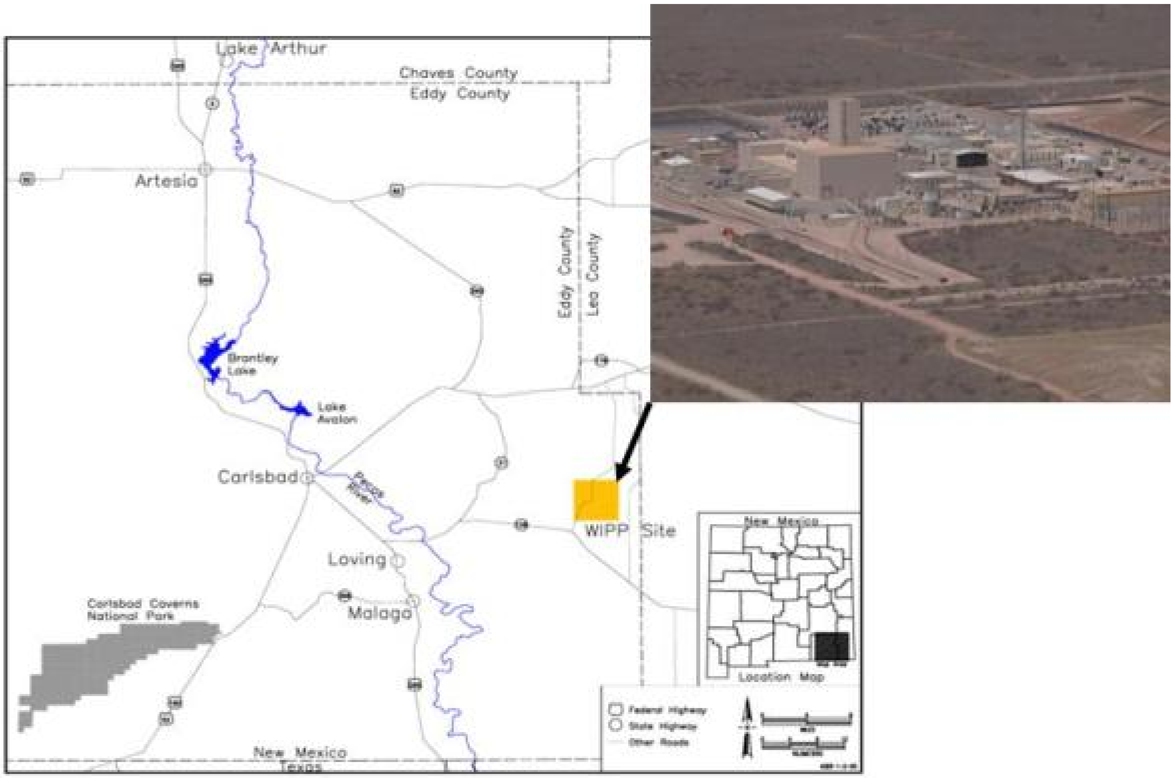

Figure 1-1: Waste Isolation Pilot Plant near Carlsbad, New Mexico

The WIPP facility is a deep geologic repository mined within a 2,000-foot-thick bedded-salt formation. The underground is 2,150 feet beneath the ground surface (Figure 1-2). TRU mixed waste management activities underground are confined to the southern portion of the 120-acre mined area.

Four shafts connect the underground area with the surface. The Waste Shaft headframe and hoist are located within the Waste Handling Building and are used to transport TRU mixed waste, equipment, and materials to the repository. The Waste Hoist can also be used to transport personnel. The Air Intake Shaft and the Salt Handling Shaft provide ventilation to all areas of the underground except for the Waste Shaft station. The Salt Handling Shaft is used to hoist mined salt to the surface and also serves as a personnel transport shaft. The Exhaust Shaft serves as a common exhaust air duct for all areas of the underground (Figure 1-3).

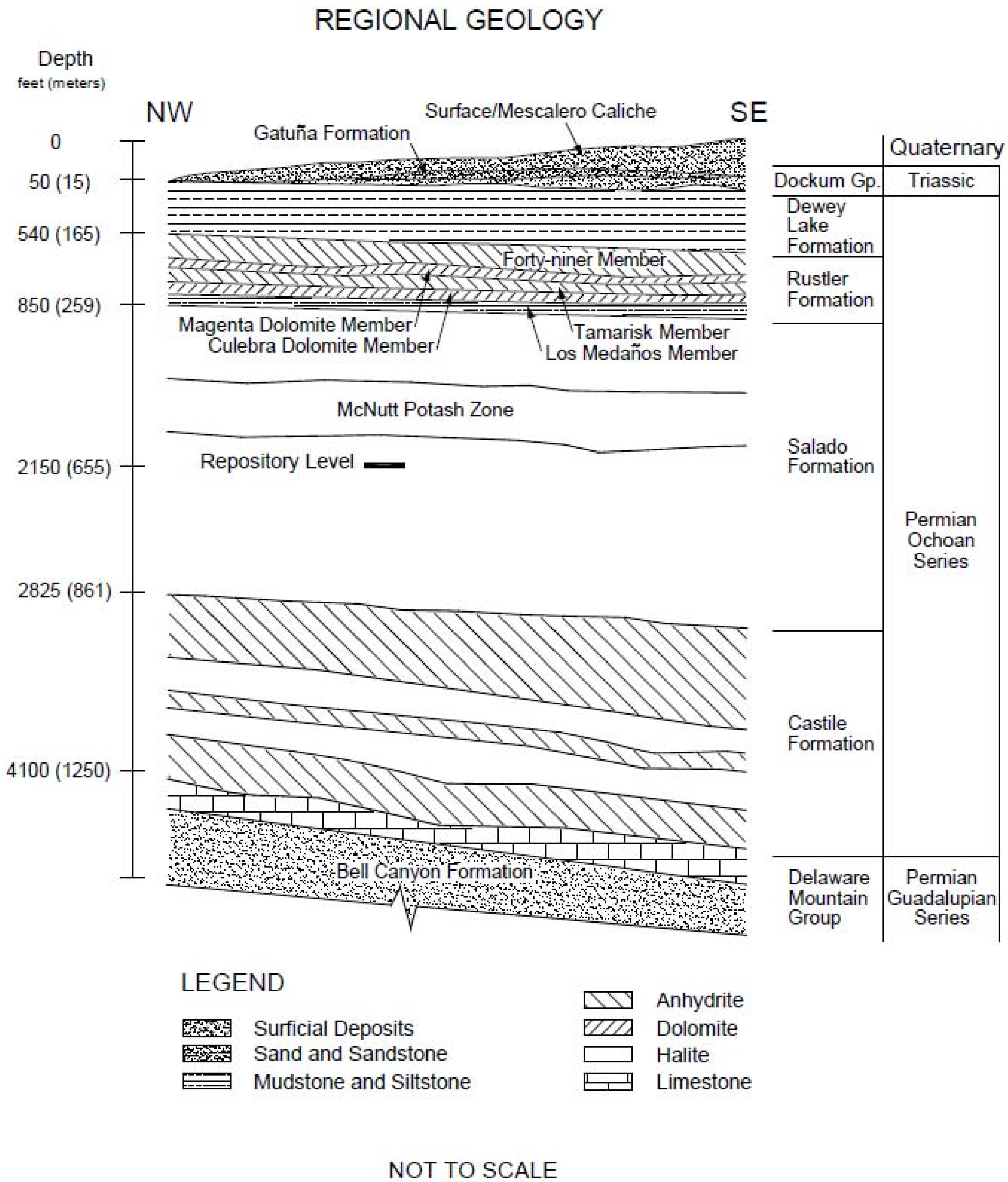

Figure 1-2: Regional Geology of the WIPP Area

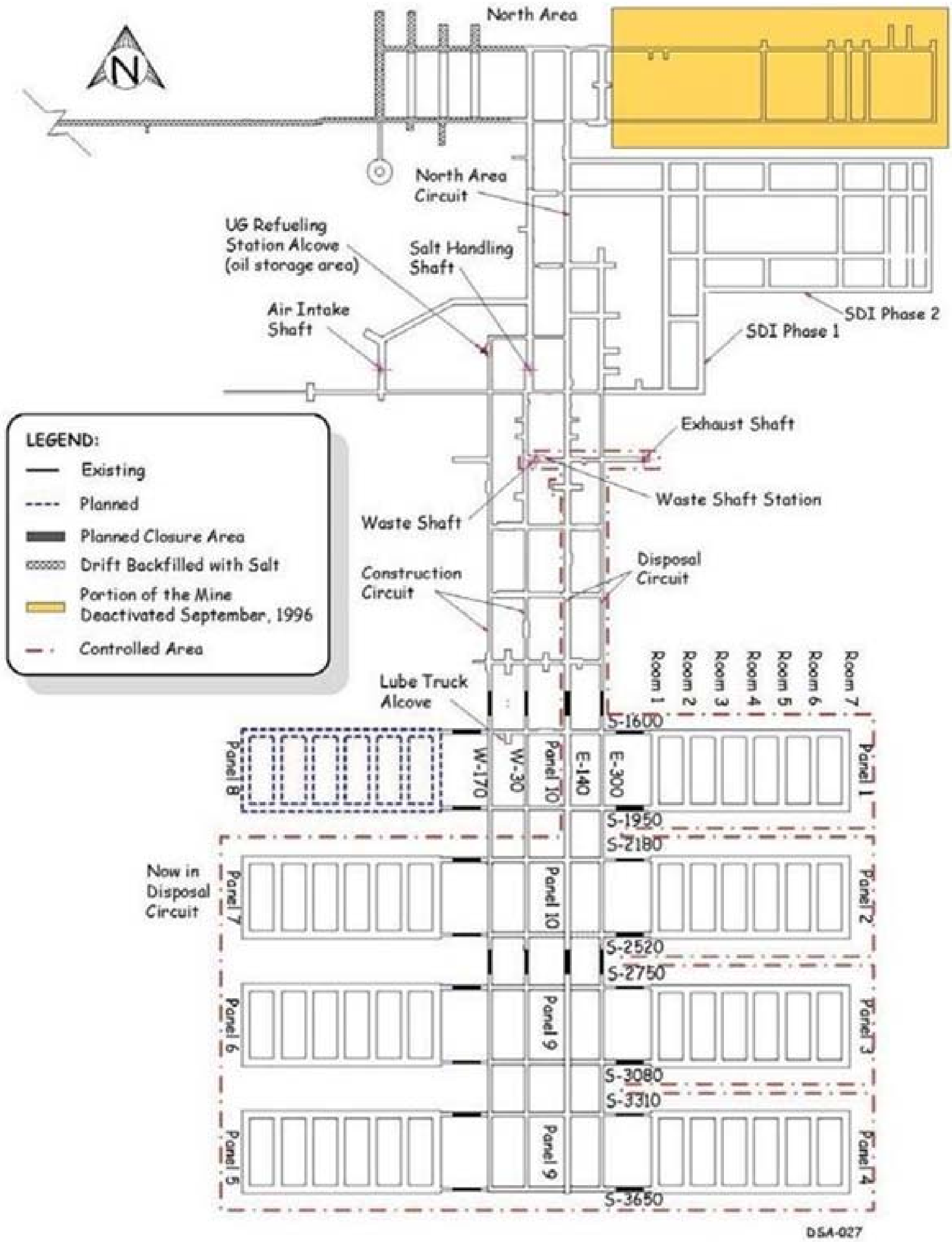

Figure 1-3: Underground Layout

The WIPP underground consists of the waste disposal area, construction area, north area, and Waste Shaft station area. The location of Panel 7 and continuous air monitor (CAM) 51 are shown in Figure 1-4.

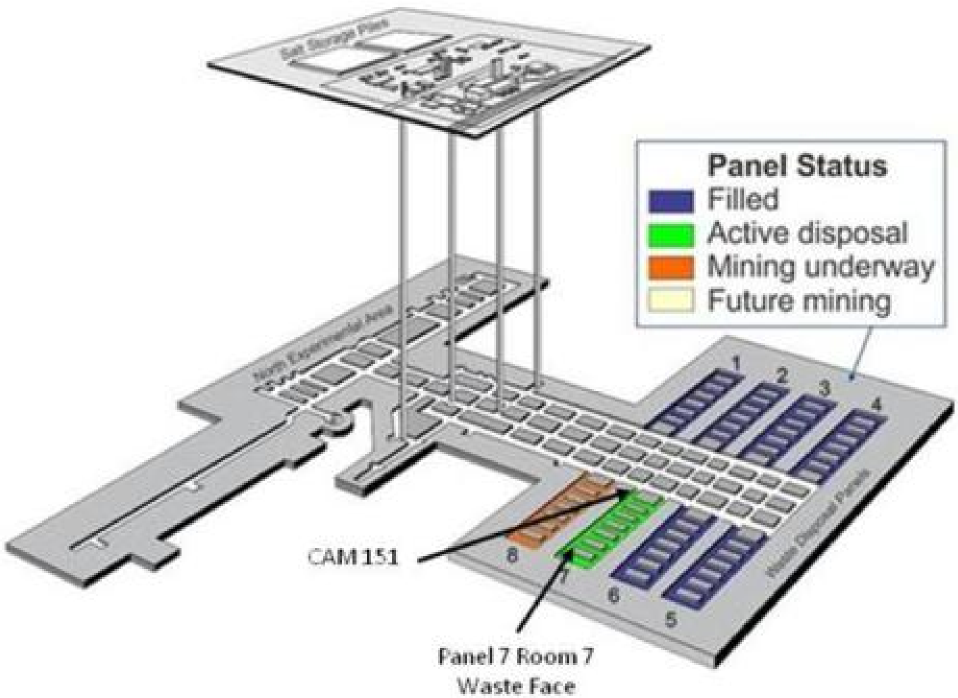

Figure 1-4: Location of Panel 7 and CAM 151

The principle contact-handled (CH) waste operations at the WIPP involve the receipt and disposal of TRU waste, and the mining of underground rooms in which the waste is emplaced. In the underground, the waste containers are removed from the waste hoist conveyance, placed on the underground transporter, and moved to a disposal room. In the disposal rooms, the CH waste containers are removed from the transporter and placed in the waste stack. The location of the container(s) involved in the radiological release in Panel 7, Room 7 is shown in Figure 1-5. Remote-handled (RH) waste in shielded containers is placed in boreholes in the walls (ribs) of the disposal rooms.

WIPP has been issued a Hazardous Waste Facility Permit (HWFP) by the New Mexico Environment Department for Resource Conservation and Recovery Act (RCRA) authorization as a Treatment, Storage, and Disposal Facility (TSDF). Some of these permit requirements are also found in DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant*.

The site has 55 permanent buildings and four temporary buildings (trailers) in operation, one temporary building (lab trailer) in excess status, and various connex boxes used for storage. The site buildings provide a total of 358,647 square feet of office and industrial space. Additional leased office space, the Skeen-Whitlock Building, is located in Carlsbad. Approximately 800 workers are assigned to WIPP, representing the Carlsbad Field Office (CBFO), the Management and Operating (M&O) contractor, the warehouse, the document services subcontractor, the information technologies subcontractor, the CBFO Technical Assistance Contractor, Los Alamos National Laboratory-Carlsbad, and Sandia National Laboratories-Carlsbad. Prominent features of the WIPP site include:

- **Air Intake Shaft**. The primary source of intake air for the underground ventilation and also used for emergency egress.
- **Waste Handling Building**. This structure provides a confinement barrier. Ventilation is operated to maintain a negative pressure with high-efficiency particulate air (HEPA) filtration.
- **Waste Hoist**. The Waste Hoist transports waste, material and personnel from the surface to the underground and is designed to prevent an uncontrolled fall or descent of the waste conveyance into the Waste Shaft.
- **Salt Handling Shaft Hoist**. This hoist transports mined salt to the surface; material and personnel between the surface and the underground.
- **Radiation Sampling and Monitoring**. Consists of CAMs, fixed air samplers (FAS), and other external radiation monitors.
- **Central Monitoring Room**. Provides a monitoring function and must be staffed and operational, with the ability to shift underground ventilation to filtration.
- **Underground Ventilation System**. Provides acceptable working conditions and a life-sustaining environment during normal operations and off-normal events, including waste handling events.
- **Exhaust Filter Building**. Contains the underground ventilation exhaust HEPA filtration equipment and is located north of the Exhaust Shaft.
- **Waste Handling Equipment**. Selected items are designated safety class or safety significant.
- **Emergency Services Bay**. Houses the ambulance, rescue truck, and fire engine.
- **Guard and Security Building**. Houses the security monitoring and alarm systems.
- **Parking Lot**. The east portion of the front parking lot is used for employee parking, and the two west rows of the lot are designated for trailer storage and staging of empty waste transporters for DOE carrier transport to the generator sites and trailer maintenance facility.

1.2.1 Panel 7 Room 7 Arrangement

Panel 7 consists of seven disposal rooms with an intake and an exhaust drift. Each room within the panel was approximately 33 feet wide by 13 feet high by 280 feet long. Room 7 was larger than the other six rooms, having a length of approximately 332.5 feet. The width and height measurements are the same. Each disposal room was separated from the adjacent room(s) by pillars of salt approximately 100 feet wide and 280 feet long. The panel intake drift was approximately 18 feet wide by 19 feet high, while the exhaust drift was approximately 20 feet wide by 9 feet high. These dimensions were taken from data provided by NWP. A layout of Panel 7 is shown Figure 1-5.

The waste array in Room 7 was approximately 33 feet wide, 87.1 feet long and 9.75 feet high. The space above the array was nominally 3.75 feet high.

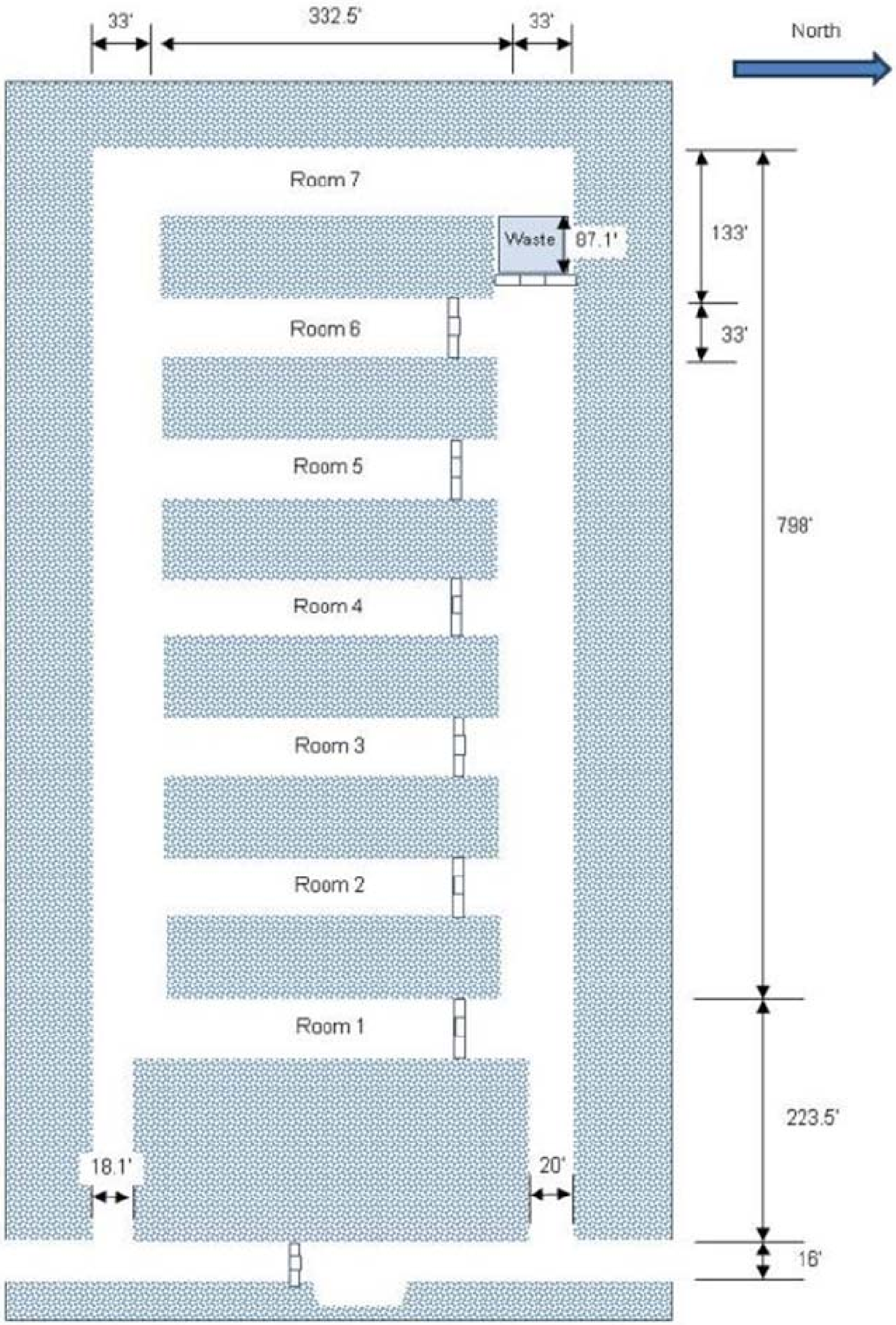

Figure 1-5: Layout of Panel 7 Room 7

1.2.2 Carlsbad Field Office

DOE created the Carlsbad Area Office in Carlsbad, New Mexico, in late 1993 to lead the nation's TRU waste disposal efforts. In September 2000, the office was elevated in status to become the CBFO. As a field office, CBFO has continued its primary mission of operating WIPP in conformance with the WIPP Land Withdrawal Act[3] (LWA). The LWA set aside the land for developing and building WIPP and assigns specific regulatory and enforcement roles to the US Environmental Protection Agency. CBFO is responsible for oversight of the M&O contract for the WIPP site and the National TRU Program.

1.2.3 Nuclear Waste Partnership LLC

Nuclear Waste Partnership LLC (NWP) is an URS Energy and Construction (URS)-led limited liability company (LLC) with partner Babcock and Wilcox Technical Services Group, Inc. (B&W), and major subcontractor AREVA Federal Services. NWP manages and operates the WIPP and supports the National TRU Program. NWP is primarily responsible for the Central Characterization Program (CCP). DOE awarded the contract to NWP on April 20, 2012. NWP assumed responsibility for management and operation of the WIPP facility on October 1, 2012, after a 90-day transition period. The contract, which has a five-year term, with an additional five-year option period, has a value of approximately $1.3 billion to the partnership over the full 10-year period. The prior contractor was Washington TRU Solutions, LLC (WTS). WTS was an entity comprised of URS and Weston Solutions, Inc.

1.3 Los Alamos National Laboratory

The Los Alamos National Laboratory[4] is located 35 miles northwest of Santa Fe, New Mexico, on 36 square miles of DOE-owned property (Figure 1-6). The primary responsibility of LANL is assuring the safety and reliability of the nation's nuclear deterrent. A rich variety of research programs directly and indirectly support LANL's basic mission: maintaining the safety, security, and reliability of the nation's nuclear deterrent without the need to return to underground testing.

One of LANL's main environmental duties is to investigate where hazardous chemical and/or radioactive materials may be present as a result of past Laboratory operations and to clean up sites where such materials are still found above acceptable levels.

Locations include sites of former Laboratory buildings, on hillsides, in canyon bottoms, and old landfills. These sites, called solid waste management units and areas of concern, are collectively called "potential release sites."

[3] Public Law 102-579 as amended by Public Law 104-201.

[4] Since preliminary discovery indicated that a Los Alamos National Laboratory (LANL) waste stream may have contributed to the radiological release, the Board focused a significant amount of this Phase 2 investigation on the operations at LANL to gain an understanding of why this occurred.

Figure 1-6: Los Alamos National Laboratory

About 2,100 cleanup sites were originally identified for action, ranging from small spills to large landfills known as "material disposal areas." Cleanup of about half of the sites has been completed, and an initial investigation of about 90 percent of the remaining areas has been performed. Continuing cleanup of these sites consists of activities such as:

- Removing contaminated soil and disposing of it in licensed disposal facilities;
- Closing landfills and demolishing unused buildings; and
- Removing containers of transuranic waste stored above ground.

Cleanup is achieved through the corrective actions process and follows the requirements of the Compliance Order on Consent from the New Mexico Environment Department (NMED).

1.3.1 Los Alamos Field Office

The National Nuclear Security Administration Los Alamos Field Office (NA-LA) is responsible for administering the LANL contract and managing Federal Activities. The NA-LA administers the M&O contract for Los Alamos Site activities. This includes:

- Overseeing and managing assigned NNSA and non-NNSA programs;
- Ensuring the safe, secure and environmentally responsible operation of facilities under the purview of NNSA;
- Overseeing and evaluating the work and business systems of the M&O contractor; and
- Planning for the long-term viability of the site.

The Environmental Projects Office (EPO) is led by NNSA and comprised of both EM and NNSA employees. The EPO provides day-to-day oversight of EM-funded projects related to Legacy Waste including planning, directing, establishing, coordinating and managing waste management site activities associated with the pre-1999 EM Legacy, and coordinating with the NNSA Enduring Waste Program at LANL to assure strict adherence to compliance and waste reduction in support of the overall LANL mission. EPO provides oversight of these environmental functions including management of the project baseline, authority of change control, establishing performance metrics and conducting performance evaluation. It performs line management day-to-day oversight of contractor's worker, public, and facility protection programs and regulatory deliverables. EPO interfaces with headquarters organizations and external organizations.

1.3.2 Los Alamos National Security, LLC

Los Alamos National Security, LLC (LANS) is a LLC formed by the University of California, Bechtel, Babcock & Wilcox Technical Services, and URS Energy and Construction. LANL is managed and operated by LANS under contract to the DOE's NNSA. LANS assumed direct management and operation of the Los Alamos National Laboratory on June 1, 2006.

The mission of LANS is to provide management of the LANL mission and provide science and technology, fundamental operations, and business programs to meet national security science needs.

LANL Carlsbad Office (LANL-CO) houses LANS employees that support the National TRU Program as scientific advisors for CBFO.

1.3.3 LANL Waste Characterization, Reduction, and Repackaging Facility Description

The Waste Characterization, Reduction, and Repackaging Facility (WCRRF) was constructed in 1979 and modified during the mid-1980s with an initial mission to sample, examine, characterize, reduce the volume, and repackage a variety of TRU wastes. Work activities at the WCRRF are managed by the LANS Environmental and Waste Management Operations (EWMO) Division. The WCRRF mission is identified as critical for NNSA and LANL to meet a

New Mexico Consent Order requirement to close Technical Area (TA)-54 as a TRU waste storage site.

The WCRRF is located in the northwest corner of TA-50 in the LANL complex. The facility is south of Pecos Drive, across from TA-55 and west of Building TA-50-37 (the Actinide Research and Technology Instructional Complex Facility). The WCRRF is comprised of Building TA-50-69 and a partially fenced, partially paved outside yard containing support facilities, equipment, and TRU waste container staging areas. Building TA-50-69 is a small, one-story building used primarily for waste remediation and repackaging activities, specifically in the waste characterization glovebox (WCG) (Figure 1-7). Another walk-in glovebox enclosure is also present in Building TA-50-69 and is under ventilation, although not utilized for TRU waste processing activities. A vehicle airlock is used to move waste containers and equipment to and from the building.

Figure 1-7: Waste Characterization Glovebox in WCRRF at LANL

At the WCG, parent drums are secured to an electronically operated drum lift fixture. The drum is clamped to the lift in an upright position. The lift rotates the drum to the horizontal position and lifts it to the entry port. A plastic sleeve that joins the drum to the glovebox establishes a contamination control barrier. Inside the WCG, workers use glove ports to manipulate hand tools (wrench, battery-operated drill, etc.) to loosen the drum lid retainer ring and remove the lid, exposing the container's contents. Examiners then lift the waste items from the open drum into the WCG for examination.

The TRU waste containers that do not comply with WIPP Waste Acceptance Criteria (WAC) requirements are remediated and repackaged at the WCRRF. Knowledge of specific noncompliance is obtained from generator records or from the waste characterization process. Repackaging involves opening drums in the WCG, separating the waste items, remediating noncompliant waste, placing the waste into one or more new drums (also called daughter drums), documenting the items placed in each drum, and closing and bagging out the newly packaged drums.

During remediation, items that are not in conformance with the WIPP WAC are removed. Items that cannot be brought into compliance are usually placed in drums and sent to another LANL facility for storage or further action. The remediation process also includes the opening of sealed and unsealed containers of various sizes. According to the WCRRF Basis for Interim Operation (BIO), the types of liquids that have been encountered include cleaning solutions and organic solvents such as ethanol and acetone. Other organic liquids, such as pump oil, which could be within a discarded pump, or paint, etc., have also been encountered. Aerosol cans with some residual contents that have not been punctured have also been removed from parent drums. A liquid absorbent may be added to these containers having liquids to absorb, including free or residual liquids, according to WIPP WAC requirements, or, if the containers with liquids cannot be remediated, they are separated for alternate disposal. Additionally, the pH of the liquids may be adjusted using acid or base neutralizers.

All waste matrices may be found in sealed or unsealed containers within the parent drum including but not limited to lead (Pb) shielding, liquids (both organic and aqueous), and combustibles. These waste matrices may be remediated, bagged out of the WCG, and segregated into daughter drums in accordance with WIPP WAC requirements.

1.3.4 LANL Technical Area-54, Area G

Technical Area 54 (TA-54), Area G is the primary site at LANL for the disposal of low level waste and tritium-contaminated waste, and for the storage of mixed low level waste, hazardous waste, tritium-contaminated waste, and TRU waste. The TA-54, Area G facilities, shown in Figure 1-8, are situated in the middle of TA-54 on Mesita del Buey. The low level waste to be disposed includes radiologically contaminated asbestos, bio-organics, beryllium, and small amounts of polychlorinated biphenyls (PCBs). The hazardous waste and mixed low level waste are stored in arrays that are easily inspected in a RCRA-permitted storage area, except for small amounts of tritium-contaminated low level waste and mixed low level waste that are stored in specific, commercially constructed steel chemical storage units on a RCRA-permitted pad. The TRU waste destined for WIPP is also stored in easily inspected arrays that allow for inspections of container integrity as well as RCRA-required inspections. Radiological wastes with significantly high dose rates that pose an unacceptably high exposure hazard to workers are placed in shafts for storage and/or disposal to meet *As Low as Reasonably Achievable* requirements.

Operations associated with waste management at TA-54, Area G include radiological waste receipt, handling, repackaging, storage, container inspection, decontamination, waste characterization/verification (both intrusive and non-intrusive), venting and purging, size reduction, disposal, retrieval of legacy waste, environmental monitoring, transport operations between the TA-54 Radioassay and Nondestructive Testing Facility, WCRRF, and Area G, as well as other operations to disposition the waste.

Figure 1-8: Technical Area 54, Area G

The low level waste, mixed low level waste, hazardous waste, tritium-contaminated waste, and TRU waste are managed according to applicable regulations. In accordance with RCRA, all mixed waste received is stored within RCRA permitted storage areas. Retrievably stored TRU wastes at Area G, if acceptable under the WIPP WAC, are prepared for eventual shipment to WIPP. TRU waste not meeting the WIPP WAC, and mixed low level waste with no treatment path, is held in storage at LANL until process activities are developed to treat or prepare this waste for acceptance at WIPP or another treatment, storage, and disposal facility.

1.4 Scope, Purpose and Methodology of the Accident Investigation

The Board was appointed on May 19, 2014, and completed Phase 2 of the investigation on March 31, 2015. The scope of the Board's investigation was to identify relevant facts; analyze the facts to determine the direct, contributing, and root causes of the event; develop conclusions; and identify Judgments of Need for actions that, when implemented, should prevent recurrence of the accident. The investigation was performed in accordance with DOE O 225.1B, using the following methodology:

- Facts relevant to the event were gathered through interviews and reviews of documents and other evidence, including photographs, videos, and other forensic evidence. The Board also established a hotline at both WIPP and LANL to allow personnel to communicate concerns or other related information to the Board.
- Facts were analyzed to identify the causal factors using event and causal factors analysis, barrier analysis, change analysis, root cause analysis, Integrated Safety Management (ISM) analysis, and Human Performance Improvement analysis.
- Judgments of Need for corrective actions to prevent recurrence were developed to address the causal factors of the event.

Figure 1-9 defines the accident investigation terminology used throughout this Phase 2 report.

Accident Investigation Terminology
A **causal factor** is an event or condition in the accident sequence that contributes to the unwanted result. There are three types of causal factors: direct cause(s), which is the immediate event(s) or condition(s) that caused the accident; root cause(s), which is the causal factor that, if corrected, would prevent recurrence of the accident; and the contributing causal factors, which are the causal factors that collectively with the other causes increase the likelihood of an accident, but which did not cause the accident. The **direct cause** of an accident is the immediate event(s) or condition(s) that caused the accident. **Root causes** are the causal factors that, if corrected, would prevent recurrence of the same or similar accidents. Root causes may be derived from or encompass several contributing causes. They are higher-order, fundamental causal factors that address classes of deficiencies, rather than single problems or faults. **Systemic root causes** involve a deficiency in a management system that, if corrected, would prevent the occurrence of a class of accidents. **Local root causes** involve a specific deficiency that, if corrected, would prevent recurrence of the same accident. **Contributing causes** are events or conditions that collectively with other causes increased the likelihood of an accident but that individually did not cause the accident. Contributing causes may be longstanding conditions or a series of prior events that, alone, were not sufficient to cause the accident, but were necessary for it to occur. Contributing causes are the events and conditions that "set the stage" for the event and, if allowed to persist or recur, increase the probability of future events or accidents. **Event and causal factors analysis** includes charting, which depicts the logical sequence of events and conditions (causal factors that allowed the accident to occur), and the use of deductive reasoning to determine the events or conditions that contributed to the accident. **Barrier analysis** reviews the hazards, the targets (people or objects) of the hazards, and the controls or barriers that management systems put in place to separate the hazards from the targets. Barriers may be physical or administrative. **Change analysis** is a systematic approach that examines planned or unplanned changes in a system that caused the undesirable results related to the accident. **Error precursor analysis** identifies the specific error precursors that were in existence at the time of or prior to the accident. Error precursors are unfavorable factors or conditions embedded in the job environment that increase the chances of error during the performance of a specific task by a particular individual, or group of individuals. Error precursors create an error-likely situation that typically exists when the demands of the task exceed the capabilities of the individual or when work conditions aggravate the limitations of human nature.

Figure 1-9: Accident Investigation Terminology

2.0 The Accident

2.1 Accident Description

2.1.1 Background

On February 14, 2014, at 2313, there was a release of radioactive material from one or more TRU waste container(s) emplaced in Panel 7 Room 7 of the WIPP underground. The release was detected by a CAM which was monitoring the Panel 7 exhaust drift and an alarm was received on the Central Monitoring System (CMS) in the Central Monitoring Room (CMR) at the WIPP surface which initiated a shift to filtration of the underground ventilation. The WIPP response to the alarm and associated radiological release to the atmosphere was investigated by a DOE Accident Investigation Board (the Board) and the results published in the final report, *Phase 1, Radiological Release Event at the Waste Isolation Pilot Plan on February 14, 2014*[5], on April 24, 2014. Because the underground was inaccessible following the event, the Phase 1 investigation was limited to evaluation of the radiological release to atmosphere and not the mechanism of release in the underground. The Board was subsequently chartered to conduct an additional investigation (Phase 2) to analyze and identify the physical mechanism that caused the TRU waste container failure. This report provides the results of the Phase 2 investigation.

2.1.2 Event Description

On February 14, 2014, at approximately 2300, there was a release of radiological materials from TRU waste container(s) in the WIPP underground. At 2314, a CAM monitoring Panel 7 detected this release and a "HI HI" CAM alarm was received on the Central Monitoring System (CMS) in the Central Monitoring Room (CMR) on the surface. While the majority of the release was directed by the ventilation system through HEPA filters on the WIPP surface, a small portion bypassed the HEPAs via leakage around the ventilation system dampers and exhausted directly to the atmosphere.

Five initial radiological surveys (direct and removable contamination) were performed at WIPP, Panel 7, in Rooms 7, 6, and 1 during the period April 23 through May 19, 2014. Surveys consisted of smears, quantitatively measuring removable contamination per 100 cm^2, as well as Masslinn cloth wipes, providing qualitative gross contamination. These surveys reported alpha

[5] The Executive Summary of this report is found at Attachment G. The full copy of this report can be found at http://www.wipp.energy.gov/wipprecovery/accident_desc.html.

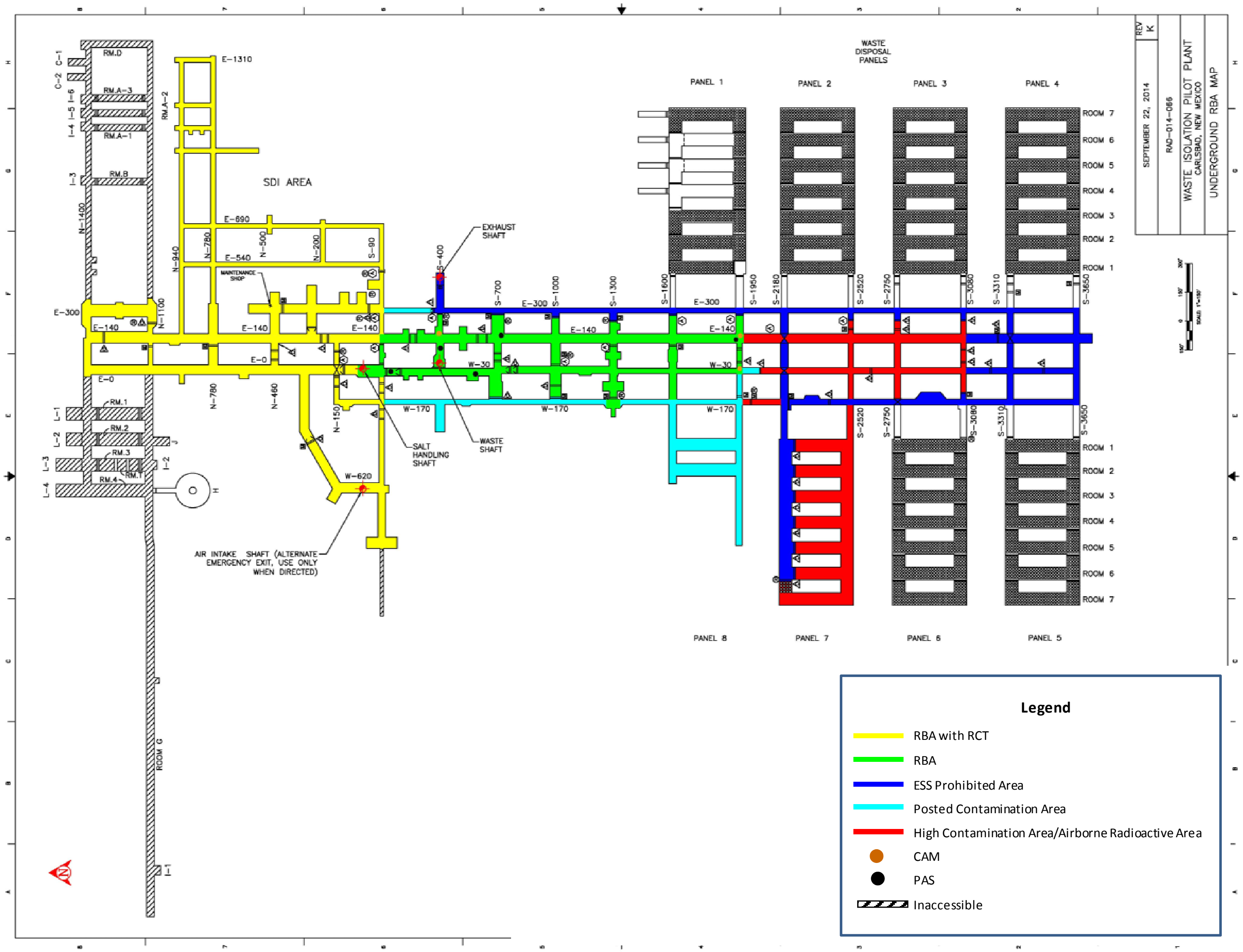

Figure 2-1: WIPP Underground RBA Map

activity contamination levels, with no beta or dose rate information collected. Radiological survey results of Panel 7 indicated that the general surface alpha contamination levels in Room 7 of 8,000 – 40,000 dpm, Room 6 of 10,000 – 20,000 dpm, and Room 1 of 6,000 – 28,000 dpm. More specific details are provided in Section 6.3, Radiological Forensics (Figure 2-1).

Photographic evidence of Panel 7 Room 7 from re-entries shows that 17 of the MgO super sacks were damaged. The super sack fabric and stiffener material (cardboard) was damaged or missing as illustrated in Figure 2-2, which allowed MgO to fall between waste stacks and left partial sloped piles of material on top of and between the waste stacks.

Figure 2-2: Missing Super Sacks Leaving Loose Piles of MgO on Waste Stacks

Photographic evidence from a May 15, 2014, entry identified a breached TRU waste drum (Figure 2-3) in the top tier, row 16, column 4 (R16:C4)[6]. It was subsequently determined that this drum was LANL drum 68660.

The ribs and back (roof) of Panel 7 Room 7 show some evidence of discoloration but no significant accumulations of soot on these surfaces. Based on the May 15, 2014, photos, NWP notified DOE to amend the categorization of the Occurrence Reporting and Processing System (ORPS) report on the radiological release (EM-CBFO--NWP-WIPP-2014-0006) to include that a fire had occurred in this waste container. Figure 2-4 illustrates the locations of the damaged 17 MgO super sacks, and locations of the LANL waste containers from the LA-MIN02-V.001 waste stream (MIN02).

[6] Hereafter referred to by row/column identifier, i.e., R16:C4.

On February 19, 2014, CBFO requested that the LANL Carlsbad Office (LANL-CO) develop a list of potential source containers for the release. On February 20, 2014, LANL- CO provided the list based on a comparison of isotopic ratios calculated from the Waste Data System (WDS) radionuclide data for each emplaced container in Room 7 of Panel 7 and isotopic ratios calculated from data obtained from WIPP Station A air filter samples. The list included containers from an Idaho - Rocky Flats waste stream and several drums containing nitrate salts from LANL. Of note, the isotopic ratios for the LANL drums were later determined to be in error. Subsequently, on May 1, 2014, NWP declared a Potential Inadequacy in the Safety Analysis (PISA) regarding the potential for untreated nitrate salt bearing waste being emplaced which subsequently prompted LANL to declare a PISA as well. On May 15, 2014, photographic evidence confirmed that a LANL - LA-MIN02-V.001 waste stream container (68660) was in fact breached.

Figure 2-3: Drum 68860 Lid Failure

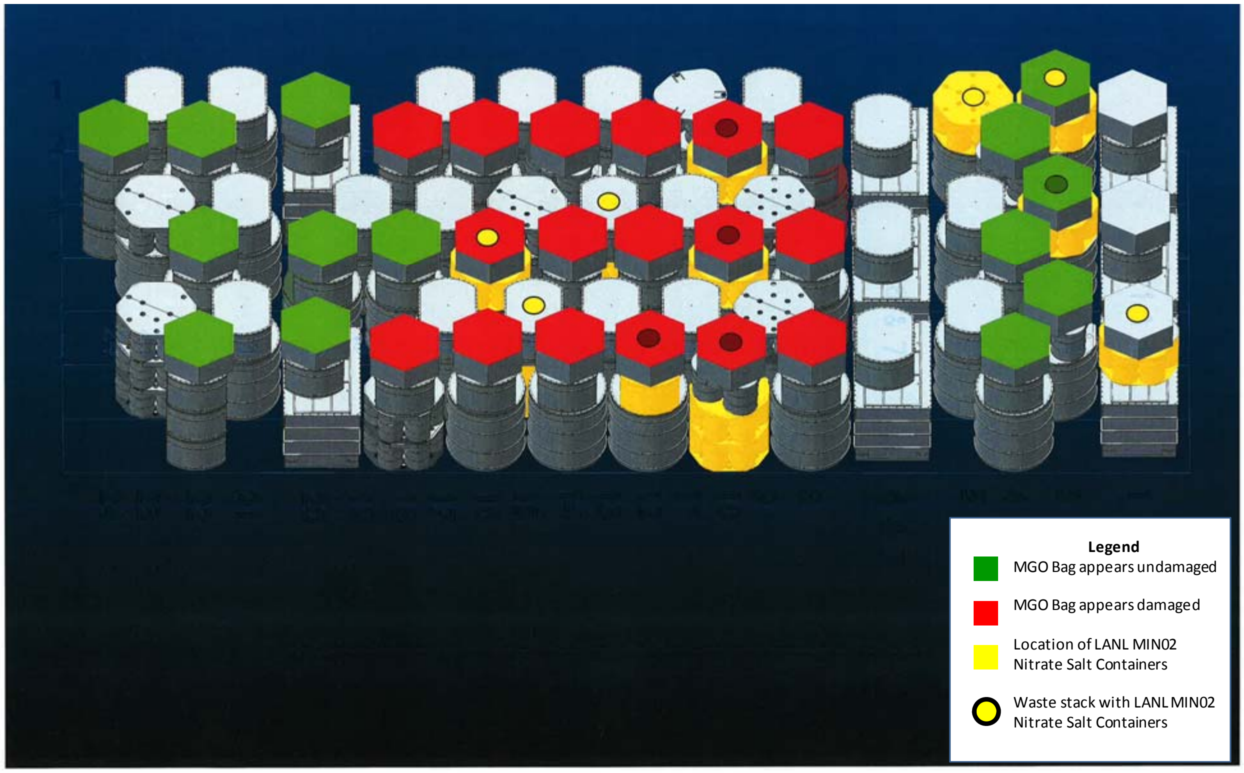

Figure 2-4: Panel 7, Room 7 Location of Damage from Event

2.1.3 Relevant LANL and WIPP History

On July 1, 1979, operations commenced at LANL Technical Area 55 (TA-55) for the extraction and recovery of plutonium from residues and scraps generated from operations at various LANL facilities and other DOE sites in the defense complex. The scrap and residues were processed to recover as much plutonium as economically feasible. The recovered plutonium was converted into pure plutonium feedstock. This recovery process generated evaporator nitrate salt and bottom wastes.

On July 6, 1984, LANL issued procedure MST-12 485-REC-R00, *Treatment of Evaporator "Bottoms"*. Per this procedure, the nitrate salts from the evaporator bottoms were vacuum-dried, packaged in double bags, and then placed in polyethylene liners within lead-lined 55-gallon drums. Filteraid® absorbent was then added to absorb any moisture. The drums were then placed into storage in the TA-55 plutonium facility Building 4 (PF-4). Parent drum S855793 was processed in this manner at TA-55 on November 12, 1985, and placed into storage at TA-54 Area G where it remained until December 4, 2013, when it was processed as part of the LANL campaign to ship 3,706 cubic meters of TRU waste to WIPP by June 30, 2014. Starting in late 1991, nitrate salt bearing wastes generated from the evaporator process were sent to cement fixation.

Consistent with requirements in the WAP, the CCP uses Acceptable Knowledge (AK) to initially characterize TRU waste. CCP-AK-LANL-006, *CCP Acceptable Knowledge Summary Report*, Revision 0, for CH TRU waste generated at LANL area TA-55 was issued by CCP on June 10, 2004. Waste generators are responsible for packaging wastes that are consistent with the AK, and CCP personnel perform document reviews, non-destructive examination (NDE) using real-time radiography (RTR) or visual examinations (VE), and non-destructive assay (NDA) to certify the waste as meeting WIPP requirements.

In late 2006 and early 2007, LANL conducted an expedited project to modify and upgrade an existing 30-year old glovebox facility from Hazard Category-3 to a Hazard Category-2 nuclear facility to become the WCRRF which was designed to support sampling, examination, characterization, size reduction, and repackaging of TRU waste.

On March 27, 2007, CCP-AK-LANL-006, Revision 6, was issued to include waste stream LA-CIN01.001, which was a cemented inorganic homogenous solid waste stream generated by the cement fixation process.

In April 2007, the BIO and Technical Safety Requirements (TSRs) for the WCRRF were issued and an Operational Readiness Review was performed in mid-2007 resulting in approval to begin operations at the WCRRF.

On May 23, 2007, LANL issued procedure EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations,* Revision 0. This procedure provided instructions for remediating TRU waste which did not meet WIPP WAC and AK requirements. The nitrate salt bearing wastes in storage since 1979 (both pre-cementation and post-cementation) are included in the scope of this procedure. In EP-WCRR-WO-DOP-0233, Revision 0, specific steps for nitrate salt processing were not included; operators were instructed to add a small amount of absorbent and then proceed with additional absorbent if they did not observe a reaction. Liquids were to be assessed qualitatively.

The glovebox procedure was revised again in Revision 3 on July 9, 2007, to add disposition of liquids and actions to be taken if actual or suspect oxidizers, flammable, or pyrophoric materials were encountered. Revision 3 also instructed operators to absorb any liquids removed from a parent drum into a new daughter drum.

On November 30, 2007, CCP-AK-LANL-006 was revised to include new waste stream LA-MIN 02-V.001[7] (MIN02), absorbed liquid homogenous solid waste stream.

On June 22, 2009, NCR-LANL-0509-09 was issued by the CCP AKE at LANL identifying 48 drums that were on the Acceptable Knowledge Tracking Spread Sheet (AKTSS) and had been identified as potentially containing non-cemented Evaporator Salts, which would require these drums to be re-assigned to a separate waste stream. The final disposition was obtained in December 2012 to remove the containers from the AKTSS. Drum S855793 was included in this population. These containers were subsequently reassigned to the LA-MIN02-V.001 waste stream.

[7] "LA" implies that the waste stream originated at LANL, and MIN represents mixed inorganic material.

The glovebox procedure was revised again on February 18, 2010. Revision 17 added pH measurement for corrosives using test strips but did not specify a brand or type. Revision 17 did specify that an "appropriate" absorbent was to be used. The procedure did not define what constituted an appropriate absorbent or how to gain approval for proposed absorbents.

On April 12, 2010, New Mexico Institute on Mining and Technology (New Mexico Tech), Energetic Materials Research and Testing Center (EMRTC) issued a technical paper *Results of Oxidizing Solids Testing, EMRTC Report FR 10-13* as part of WIPP's response to the discovery of nitrate salt bearing wastes during retrieval operations at the Idaho National Laboratory. The study was performed under contract to Washington TRU Solutions (then operator of WIPP) to determine the amount of inert material (zeolite clay and ground high strength grout) that must be mixed into the most reactive ratio of sodium nitrate and potassium nitrate in order to classify the mixture as a non-oxidizer. This study confirmed that nitrate salts mixed with inorganic absorbent material in a 1.2:1 ratio are non-oxidizing solids.

Revision 20 of EP-WCRR-WO-DOP-0233 was issued on July 8, 2010. This revision added a listing of required materials, including litmus paper (for pH measurement) and "absorbent". Wording was also changed in the body of the procedure from "absorbent" to "approved absorbing agent." Instructions on what an approved absorbent was, or how to gain approval were not defined.

From June 26 through July 3, 2011, the Las Conchas wildfire threatened the LANL facility, coming within 3.5 miles of Area G where TRU waste was stored. This created considerable concern and discussions between DOE and NMED on accelerating shipment of high risk TRU waste from LANL to WIPP.

Remediation of nitrate salt drums at the WCRRF began on September 1, 2011. Remediation consisted of retrieving drums from storage and transporting them to the WCRRF where the drum contents were processed in a glovebox. Processing at that time included:

- Removal of the waste items from the drum;
- Adding WasteLock® 770 absorbent;
- Mixing the waste and absorbent;
- Placing the mixed waste into daughter drum(s); and
- Then moving the remediated waste drums to storage in TA-54.

This was performed per procedure EP-WCRR-WO-DOP-0233, Revision 29, which had no specific steps for processing nitrate salts.

Discussions between DOE and the NMED concluded, and in January 2012, a Framework Agreement requiring LANL to ship 3,706 cubic meters of the highest risk, above ground TRU waste located in TA-54 to WIPP by June 30, 2014, was finalized.

In late 2011, LANL Environmental RCRA (ENV-RCRA) received a request from a LANL waste generating organization at TA-54 to review the RCRA characterization of 200 drums of legacy

TA-55 TRU wastes suspected of being unconsolidated nitrate salts (non-cemented waste evaporator salts and evaporator bottoms from multiple waste streams but not including MIN02). The ENV-RCRA was specifically asked to review new information and recent chemical/physical studies of similar wastes at other DOE sites and make a determination regarding the potential for these wastes to exhibit RCRA characteristics of ignitability, corrosivity, and/or reactivity. On February 29, 2012, LANL issued a memorandum titled *Legacy TA-55 Nitrate Salt Wastes at TA-54, Potential Applicability of RCRA D001/D002/D003 Waste Codes.* This memorandum incorrectly concluded that nitrate salt drums did not meet the Environmental Protection Agency (EPA) ignitability or reactivity criteria, and that wastes containing free liquids must be remediated prior to shipment. Additionally, the memorandum concluded that prior to certification for WIPP disposition the containers need to undergo a waste examination process which included determination if there were any free liquids. Any liquids identified by this examination were required to be managed as potentially RCRA corrosive (D002) waste (unless otherwise shown by pH testing) and remediated prior to shipment off-site.

On March 8, 2012, processing of nitrate salt bearing waste was put on hold in part due to concerns about the suitability of the WasteLock® 770 as an absorbent for use with the nitrate salt bearing waste matrix. Meetings between LANS, Energy*Solutions*, LLC (ES), a subcontractor to LANS, and the LANL-CO Difficult Waste Team were held in April 2012 to determine the path forward for the nitrate salt bearing waste.

On May 8, 2012, the LANL-CO Difficult Waste Team issued a white paper titled Amount of Zeolite Required to Meet the Constraints Established by the EMRTC Report RF 10-13: Application of LANL Evaporator Nitrate Salts. This paper defined the amount of "Kitty Litter/Zeolite clay" to be added per volume of nitrate salts and was based on the EMRTC RF 10-13.

In July 2012, LANS issued *Solution Package Scope Definition, Report 72, Salt Waste (SP #72)* (Revision 1) to address the processing steps for nitrate salt drums. This document concluded that EP-WCRR-WO-DOP-0233 must be revised or replaced to ensure that the final waste mixture met or exceeded 1.2:1 kitty litter/zeolite:nitrate salt as specified by May 8, 2012, LANL-CO Difficult Waste Team white paper and the April 2010 EMRTC study.

In response to SP #72, LANS prepared a major revision to EP-WCRR-WO-DOP-0233. A new section (10.6) was added to provide instructions for nitrate salt drum processing. Step 10.6[3] specified the addition of "an organic absorbent (Kitty Litter/Zeolite® absorbent)." LANS determined that no new hazards were introduced by this revision 36 as noted in the Document History file; therefore, a previous job hazard analysis (JHA) from revision 28 of this procedure was relied upon. Subject matter experts (SMEs) did not identify concerns with specification of the organic absorbent. Procedure revisions, including those that have an impact on AK are provided to AK personnel after issue for information rather than as part of the review and approval process. The draft was finalized and on August 1, 2012, Revision 36 of EP-WCRR-DOP-0233 was issued.

On September 27, 2012, Swheat Scoop® organic absorbent was purchased by ES and on October 1, 2012, ES personnel began remediation of nitrate salt bearing waste drums previously remediated with WasteLock® 770. In addition, KOLORSAFE® benchtop kits were used as the base neutralizer and Chemtex (dry) as the acid neutralizer.

In April 2013, LANS/ES switched to Pig Base® (dry) as the base neutralizer.

In September 2013, LANS/ES switched to KOLORSAFE® Acid Neutralizer, liquid formula as the acid neutralizer. The change to KOLORSAFE® was based on an employee concern regarding compatibility of Chemtex (dry) with metal nitrates.

On December 4, 2013, ES remediated parent drum S855793 producing daughter drums LA00000068660 (68660) and LA00000068685 (68685). Swheat Scoop® organic kitty litter was added as the absorbent and pH was adjusted using KOLORSAFE®. A tungsten lined glovebox glove was added to the waste/absorbent/neutralizer mixture as a secondary waste. A lid containing a filter vent was placed on Drum 68660.

Figure 2-5: Panel 7 Room 7 Waste Face

On December 12, 2013, CCP personnel at LANL performed RTR on drum 68660.

On January 2, 2014, CCP personnel at LANL performed NDA on drum 68660.

On January 3, 2014, CCP personnel at LANL performed flammable gas analysis (FGA) on drum 68660.

On January 21, 2014, based on RTR, NDA, FGA, and document review, CCP waste certification personnel certified drum 68660 as WIPP compliant.

On January 29, 2014, drum 68660 was shipped from LANL to WIPP on shipment LA140017. This shipment arrived and was accepted by WIPP. The WIPP receipt acceptance process includes verification of the shipping manifest, performance of external surface radiological surveys, and visual examination for physical damage: severe rusting, apparent structural defects, signs of pressurization, etc., and leakage.

On January 31, 2014, drum 68660 was emplaced at Panel 7 Room 7, Row 16, Column 4 (R16: C4) in the WIPP underground (Figure 2-5).

On February 5, 2014, a salt haul truck caught on fire in the WIPP underground resulting in evacuation of personnel. This event was the focus of a separate DOE accident investigation. However, in the Phase 2 investigation, the Board did evaluate the potential relationship between the salt haul truck fire and the radiological release on February 14, 2014.

2.2 Event Chronology

Table 2-1: Chronology of the Radiological Release

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
Los Alamos National Laboratory (LANL) began TA-55 Plutonium operations. Generated evaporator nitrate salt and bottom wastes.	07/01/1979	
LANL issued MST-12-485-REC-R00, *Treatment of Evaporator Bottoms*, Revision 0, to treat the TA-55 waste.	07/06/1984	
Mixed transuranic (TRU) waste drum S855793 is generated at TA-55 per MST-12-485-REC-R99.	11/12/1985	
	06/10/2004	Central Characterization Program (CCP) issued CCP-AK-LANL-006, *Acceptable Knowledge (AK) Summary for LANL TA-55 Mixed TRU Waste*, Revision 0.
LANL Waste Characterization, Reduction, and Repackaging Facility (WCRRF) upgraded to allow for sampling, examination, characterization, size reduction, and repackaging of TRU waste.	Late 2006 – Early 2007	
	03/27/2007	CCP issued CCP-AK-LANL-006, Revision 6, to include new cemented inorganic waste stream LA-CIN01.01 (CIN01).
WCRRF Basis for Interim Operation (BIO) and Technical safety requirements (TSRs), Revision 0, were issued.	04/2007	
LANL issued EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations*, Revision 0, to provide instructions for remediating TRU waste which did not meet WIPP WAC.	05/23/2007	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
WCRRF underwent DOE Operational Readiness Review and was approved to begin operations.	Mid 2007	
	11/30/2007	CCP issued CCP-AK-LANL-006, Revision 7, which included new absorbed liquid waste stream LA-MIN02-V.001, (MIN02).
Nonconformance Report (NCR) LANL-0509-09 issued by CCP on 48 non-cemented evaporator salt drums from TA-55 in CIN-01 waste stream. Drums removed from the AKTSS. Included parent drum S855793.	07/23/2009	
New Mexico Tech Energetic Materials Research and Testing Center (EMRTC) issued FR 10-13, *Results of Oxidizing Solids Testing* in response to discovery of nitrate salts at Idaho National Laboratory. Confirmed nitrate salts mixed with inorganic absorbent are non-oxidizing solids.	04/12/2010	
	05/04/2010	CCP issued AK, Revision 12 for LANL TA-55 Mixed TRU waste.
LANL issued EP-WCRR-WO-0233, Revision 28, for higher dose rate material, updated job hazard analysis (JHA).	08/10/2011	
LANL began remediation of nitrate salt parent drums with WasteLock® 770 absorbent.	09/01/2011	
WCRRF BIO and TSR, Revision 2.1, approved.	11/2011	
Framework agreement reached between DOE/NNSA and New Mexico Environment Department (NMED) to ship 3,706 cubic meters of TRU waste to WIPP.	01/05/2012	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
LANL issued evaluation of legacy TA-55 Nitrate salt bearing wastes at TA-54, Potential Applicability of Resource Conservation and Recovery Act (RCRA) D001/D002/D003 waste codes.	02/29/2012	
Processing of nitrate salt bearing waste put on hold by LANL due to concern about compatibility of WasteLock® 770 with nitrate salt bearing waste matrix.	03/08/2012	
	05/08/2012	Los Alamos National Laboratory Carlsbad Office (LANL-CO) Difficult Waste Team issued a white paper *Amount of Zeolite Required to Meet Constraints, established by the EMRTC Report RF 10-13 Application of LANL Evaporator Nitrate Salts*.
NA-LA directed LANS to repackage nitrate salt containers per May 8, 2012 LANL-CO white paper.	06/14/2012	
LANS issued *Solution Package Scope Definition, Report 72, Salt Waste (SP #72)* Revision 1, to address processing steps for nitrate salt drums as specified in May 8, 2014 LANL-CO white paper and April EMRTC study.	07/2012	
LANS issued EP-WCRR-WO-DOP-0233, Revision 36, to address nitrate salt bearing waste stream.	08/01/2012	
EP-WCRR-WO-DOP-0233, Revision 36, provided to CCP for information.	09/05/2012	
Initial purchase of Swheat Scoop® organic absorbent for nitrate salt remediation.	09/27/2012	
LANS/Energy*Solutions*, LLC (ES) began remediation of nitrate salt daughter drums previously remediated with WasteLock® 770 at the WCRRF.	10/01/2012	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
LANS/ES began remediation of salt bearing waste parent drums at the WCRRF.	02/01/2013	
LANS issued EP-WCRR-WO-DOP-0233, Revision 37. Section 10.3 added a step to neutralize the liquid, as necessary. Section 10.6 provided flexibility on amount of absorbent to be "added to the waste material at a minimum ratio of 3-parts absorbent to 1-part waste or at a ratio as directed by supervision."	03/20/2013	
LANS switched to Pig Base® (dry) as the base neutralizer.	04/2013	
NA-LA approved Area G BIO and TSR, Revision 2.	08/2013	
LANS changed to KOLORSAFE® (liquid) as the acid neutralizer.	09/12/2013	
LANL issued EP-AREAG-WO-DOP-1098 R0, TA-54 Area G TRU Waste Drum Sort, Segregate, and Size Reduction (SSSR) Activities.	09/30/2013	
Area G BIO implemented which allowed neutralization and absorbing liquids.	10/2013	
ES remediated parent drum S855793 at WCRRF producing daughter drums 68660 and 68685.	12/04/2013	
Drum 68660 was closed with a drum lid containing a filter vent.	12/04/2013	
LANL-CCP personnel performed real-time radiography (RTR) on drum 68660.	12/12/2013	
LANL-CCP personnel performed non-destructive assay (NDA) on drum 68660.	01/02/2014	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
LANL-CCP personnel performed flammable gas analysis (FGA) on drum 68660.	01/03/2014	
	01/21/2014	CCP certified drum 68660 for shipment to WIPP.
Drum 68660 was shipped from LANL to WIPP with shipment LA140017.	01/29/2014	Drum 68660 arrived and was accepted at WIPP.
	01/31/2014	Drum 68660 was emplaced at Panel 7 Room 7, Row 16, Column 4 (R16:C4) in the WIPP underground
	02/05/2014	Underground fire involving salt haul truck occurred at WIPP.
	02/07/2014	DOE Accident Investigation Board (the Board) appointed to investigate the underground fire.
	02/10/2014	DOE Accident Investigation Board arrived on site to investigate the underground fire.
	02/14/2014 (prior to 2314)	Radiological release from TRU waste container(s) in the WIPP underground.
	02/14/2014 2314	"HI HI" continuous air monitor (CAM) alarm from CAM 151.
	02/14/2014 2314	WIPP underground ventilation system initiated a shift to filtration mode.
	02/14/2014 ongoing	Nuclear Waste Partnership LLC (NWP) and Carlsbad Field Office (CBFO) responded to release and began developing and implementing response and recovery plans.
	03/04/2014	DOE Board appointed to investigate the radiological event. Phase 1 investigation, Radiological Release to the Environment from the underground began.
	03/11/2014	DOE Board final report on underground fire was issued.

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
Proposal developed to temporarily move LANL TRU waste to Waste Control Specialists, LLC (WCS) facility in Texas.	03/20/2014	
	03/21/2014	NWP finalized contract with WCS to temporarily store LANL TRU waste.
	04/01/2014	WIPP began TRU shipments from LANL to WCS facility in Texas.
	04/02/2014	First underground entry following the radiological event.
First TRU waste shipment from LANL arrived at WCS.	04/02/2014	
	04/04/2014	Underground entry to perform radiological surveys and extend boundary to W30/S1600.
	04/16/2014	Underground entry to survey Panel 7 and waste face.
	04/17/2014	WIPP recovery team assembled.
	04/23/2014	Underground entry to establish clean base of operations and examine Panel 7 Room 7.
	04/24/2014	DOE Board issued Phase 1 final report on the radiological release to the atmosphere.
	04/30/2014	Underground entry to continue surveys near Panel 7 and to take photos with cameras with telescopic extensions. Confirmed damage to MgO super sacks on top of Panel 7 waste.
	05/01/2014	NWP critique held to evaluate nuclear safety aspects of untreated nitrate salts.

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
	05/01/2014	NWP issued Potential Inadequacy in the Safety Analysis (PISA) in the Occurrence Reporting and Processing System (ORPS) on potential for presence of untreated nitrate waste salts in TRU waste packages (PISAD Number 14-0007).
	05/02/2014	DOE suspended WIPP's shipments of LANL waste to WCS.
LANL critique held as a result of NWP PISA. LANS discovered that an organic absorbent had been added to the nitrate salt bearing waste stream.	05/03/2014	
LANL completed consolidation of all MIN02 wastes in Dome 230 at Area G.	05/05/2014	
LANL began small scale testing of kitty litter.	05/07/2014	
LANL issued EP-AREAG-WO-DOP-1238, *Nitrate Salt Drum Sampling*, Revision 0.	05/07/2014	
	05/08/2014	WIPP issued AK sufficiency corrective action report to LANL.
LANL issued EP-WCRR-SO-1241, *Restrictions on Processing Nitrate Salt*, Revision 0.	05/08/2014	
	05/08/2014	Swipe samples, fixed air sampler filter, and CAM filter cartridge from Panel 7 underground sent to SRNL for radiological and chemical analysis.
LANL completed small scale testing of Swheat Scoop® mixed with nitrate.	05/09/2014	
	05/10/2014	Underground entry to continue surveys near Panel 7, performed thermal imagery and video. Found evidence of melted plastic and rubber on 55-gallon drums and standard waste boxes.

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
LANL issued EP-AREAG-SO-1242, *Restriction on Processing Nitrate Salt*, Revision 0.	05/13/2014	
LANL critique held on discovery that LANL drum(s) appeared to have breached at WIPP.	05/15/2014	Underground entry to examine Panel 7 Room 7. Confirmed breach of drum (later identified as 68660).
LANL declared a PISA on treated nitrate salt bearing waste and implemented immediate actions to overpack suspect drums at Area G, relocate drums to a facility with fire suppression system, and monitor temperature and pressure within the drums.	05/16/2014	
	05/19/2014	Underground entry to take photos between waste containers with rope camera. Found damaged slip sheets.
DOE Board was appointed to investigate the mechanism of the radiological release in the underground (Phase 2).	05/19/2014	DOE Board was appointed to investigate the mechanism of the radiological release in the underground (Phase 2).
NMED issued Administrative Order (AO) to DOE/LANS to submit a LANL Nitrate Salt Bearing Waste Container Isolation Plan to NMED by 2:00 pm on May 21, 2014.	05/19/2014	
	05/20/2014	NMED issued AO to DOE/NWP to submit a WIPP Nitrate Salt Bearing Waste Container Isolation Plan to NMED by 2:00 pm on May 30, 2014.
LANL issued an ORPS report on "PISA: TRU waste drums containing treated nitrate salts may challenge safety basis" (NA--LASO-LANL-WASTEMGT-2014-0004).	05/20/2014	
LANL sent Swheat Scoop® surrogate to lab for flammability testing.	05/20/2014	
LANL established a nitrate salt bearing waste remediation planning team.	05/20/2014	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
LANL submitted LA-UR-14-23605 *Nitrate Bearing Waste Container Isolation Plan* to NMED.	05/21/2014	
LANL issued EP-AREAG-SO-1237, *Area G Temperature Readings of Nitrate Salt Containers*, Revision 0.	05/22/2014	Underground entry to obtain additional video and photos of Panel 7 Room 7.
LANL critique held on NMED Administrative Order 05-20001.	05/22/2014	
LANL began moving Standard Waste Box (SWB) with remediated salt bearing waste drums into Dome 375 Permacon©.	05/22/2014	
	05/23/2014	NWP submitted Response Plan to DOE per Limiting Condition for Operations, LCO 3.7.1.
NMED issued conditional approval of LANL nitrate salt bearing waste container isolation plan contingent on submittal of additional requirements.	05/23/2014	
WCS loaded SWBs containing LA-MIN02-V.001 waste into casks (70 of 73).	05/23-28/2014	
LANL completed transfer of remediated nitrate salt drums to Area G Dome 375 Permacon©.	05/23/2014	
LANL issued ORPS NA--LASO-LANL-WASTEMGT-2014-0006 on receipt of the NMED Administrative Order.	05/23/2014	
WCS loaded suspect LANL waste stream boxes into modular concrete casks.	05/27/2014	
	05/28/2014	Underground entry to evaluate ground and radiological conditions, and make ventilation changes.
LANL submitted a revised nitrate salt bearing waste container isolation plan with additional requirements.	05/29/2014	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
LANL issued EP-AREAG-PLAN-1248 R0, *TA-54 Area G Nitrate-Salt Waste Container Response Instructions*.	05/29/2014	
LANL issued EP-AREAG-SO-1247 R0, *TA-54 Area G Domes TA-54-231 and 375 Permacon© Access Restrictions*.	05/29/2014	
LANL issued EP-AREAG-G-FO-DOP-124, *Nitrate Salt Bearing TRU Waste Container Monitoring*, Revision 0	05/29/2014	
LANL issued EP-DIV-SO-20222, Environmental and Waste Management Operations (EWMO) Legacy TRU Waste Pause, Revision 0.	05/30/2014	Underground entry to collect samples of magnesium oxide (MgO), material from the suspect drum; take additional video, evaluate ground control.
LANL completed transfer of un-remediated nitrate salt drums into Area G Dome 231 Permacon©.	05/30/2014	
	05/30/2014	DOE submitted WIPP nitrate salt bearing waste container isolation plan to NMED.
	06/06/2014	WIPP, LANL, SRNL, and the DOE Board worked on platform (Project Reach) to improve camera access to waste containers in Room 7 of Panel 7.
	6/10/2014	WIPP began high efficiency particulate air (HEPA) filter replacement. Underground entries suspended.
	6/20/2014	Filter replacement completed in first ventilation system filter unit.
	6/24/2014	Filter replacement activities were completed.
LANL (DOE/LANS) submitted addendum to the LANL HWFP regarding potential non-compliances regarding nitrate salt bearing waste drums.	07/02/2014	

Event	Date and Time (MST)	Event
Los Alamos National Laboratory	**Dates**	**Waste Isolation Pilot Plant**
	07/16/2014	CBFO issued memorandum to NA-LA and NWP suspending LANL certification and characterization activities associated with TRU waste disposition Summary Category Group S3000 and all waste processed at the WCRRF.
	07/18/2014	Underground entries resumed after ventilation system filter replacements. Performed radiological surveys, evaluated ground control, and tested power unit.
	07/30/2014	CBFO issued written notice to NMED regarding application of Environmental Protection Agency (EPA) hazardous waste code D001 to some nitrate salt bearing waste containers.
	08/2014	Underground entries to conduct surveys and take samples to reclassify areas for radiological control and specify personal protective equipment.
	08/15/2014	Underground entry to collect additional samples in support of the Board. Included materials surrounding drum 68660.
NMED approved the May 29, 2014, revised nitrate salt bearing waste container isolation plan.	08/29/2014	
	10/01/2014	DOE Inspector General (IG) released report regarding LANL's role in causing the WIPP radiological event.

3.0 National TRU Program

Sections 3.1 through 3.6 provide requirements and additional information from various source documents reviewed by the Board during the investigation. The information discussed in these sections serves as a basis for the analysis and conclusions relative to implementation.

The National TRU Waste Program was established to facilitate, with assistance from the CBFO Manager and Directors as well as TRU waste site personnel, the removal and disposal of TRU waste from sites across the country into the WIPP. DOE Order 435.1, *Radioactive Waste Management,* contains requirements and DOE responsibilities associated with the management of transuranic waste as outlined below.

3.1 Radioactive Waste Management

3.1.1 DOE Order 435.1, Chg. 1, Radioactive Waste Management

Section 3.1.1 contains excerpts from DOE O 435.1 that are relevant to the accident investigation. The information serves as a basis for the analysis and conclusions relative to implementation of the Order.

DOE O 435.1 Applicability:

This Order applies to all DOE elements including the NNSA, except as stated in item "d."

DOE O 435.1 Requirements:

a. DOE radioactive waste management activities shall be systematically planned, documented, executed, and evaluated.

b. Radioactive waste shall be managed to:

1. Protect the public from exposure to radiation from radioactive materials. Requirements for public radiation protection are in DOE 5400.5, *Radiation Protection of the Public and the Environment*.
2. Protect the environment. Requirements for environmental protection are in DOE 5400.1, *General Environmental Protection Program*, and DOE 5400.5, *Radiation Protection of the Public and the Environment*.
3. Protect workers. Requirements for radiation protection of workers are in 10 CFR Part 835, *Occupational Radiation Protection*; requirements for industrial safety are in DOE O 440.1A, *Worker Protection Management for DOE Federal and Contractor Employees*.
4. Comply with applicable Federal, State, and local laws and regulations. These activities shall also comply with applicable Executive Orders and other DOE directives.

c. All radioactive waste shall be managed in accordance with the requirements in DOE M 435.1-1, *Radioactive Waste Management Manual*.

d. DOE, within its authority, may impose such requirements, in addition to those established in this Order, as it deems appropriate and necessary to protect the public, workers, and the environment, or to minimize threats to property.

DOE O 435.1 Responsibilities:

All DOE elements as specified in 3.a (APPLICABILITY) are responsible for implementing the requirements of this Order. See DOE M 435.1-1, *Radioactive Waste Management Manual*, for specific responsibilities.

DOE M 435.1-1 further describes the requirements and establishes specific responsibilities for implementing DOE O 435.1, *Radioactive Waste Management*, for the management of DOE high-level waste, transuranic waste, low-level waste, and the radioactive component of mixed waste. The purpose of the Manual is to catalog those procedural requirements and existing practices that ensure that all DOE elements and contractors continue to manage DOE's radioactive waste in a manner that is protective of worker and public health and safety, and the environment.

3.1.2 DOE Manual 435.1-1, Radioactive Waste Management Manual

DOE M 435.1-1 Responsibilities:

Assistant Secretary for Environmental Management. The Assistant Secretary for Environmental Management is responsible for:

- **Complex-Wide Radioactive Waste Management Programs**. Establishing and maintaining integrated Complex-Wide Radioactive Waste Management Programs for high-level, transuranic, low-level, and mixed low-level waste. These programs shall use a systematic approach to planning, execution, and evaluation to ensure that waste generation, storage, treatment, and disposal needs are met and coordinated across the DOE complex.
- **Changes to Regulations and DOE Directives**. Ensuring changes to regulations and DOE directives are reviewed and, when necessary, incorporated into revisions of this Manual to ensure the basis for safe radioactive waste management facilities, operations, and activities is maintained.

Deputy Assistant Secretaries for Waste Management and Environmental Restoration (now Deputy Assistant Secretary for Site Restoration). The Deputy Assistant Secretary for Waste Management and the Deputy Assistant Secretary for Environmental Restoration are responsible for the following activities for facilities under their purview:

- **Disposal**. Reviewing and approving, along with EH-1, transuranic waste disposal facility performance assessments and other disposal documents as required in waste specific chapters for which DOE is responsible for making compliance determinations. Reviewing and approving performance assessments and composite analyses, or appropriate CERCLA documentation, for low-level waste disposal facilities, and issuing disposal authorization statements.

Assistant Secretary for Environment, Safety, and Health [currently this position has shared responsibility between the Office of Environment, Safety, Health and Security (EHSS) and Office of Independent Enterprise Assessments (IEA)]. The Assistant Secretary for Environment, Safety and Health is responsible for providing an independent overview of DOE radioactive waste management and decommissioning programs to determine compliance with DOE environment, safety, and health requirements and applicable EPA and state regulations, including:

- Advising the Secretary of the status of Departmental compliance with the requirements of DOE O 435.1, this Manual, and applicable provisions of other DOE Orders;
- Conducting independent appraisals and audits of DOE waste management programs; and
- Reviewing site Waste Management Plans with regard to compliance with DOE environment, safety, and health requirements.

Field Element Managers. Field Element Managers are responsible for:

1. **Site-Wide Radioactive Waste Management Programs**. Developing, documenting, implementing, and maintaining a Site-Wide Radioactive Waste Management Program. The Program shall use a systematic approach for planning, executing, and evaluating the site-wide management of radioactive waste in a manner that supports the Complex-Wide Radioactive Waste Management Programs and ensures that the requirements of DOE O 435.1, *Radioactive Waste Management*, are met.
2. **Radioactive Waste Management Basis**. Ensuring a radioactive waste management basis is developed and maintained for each DOE radioactive waste management facility, operation, and activity; and ensuring review and approval of the basis before operations begin. The Radioactive Waste Management Basis shall:
    a. Reference or define the conditions under which the facility may operate based on the radioactive waste management documentation;
    b. Include the applicable elements identified in the specific waste-type chapters of this Manual; and
    c. Be developed using the graded approach process.

DOE M 435.1-1 Requirements

Chapter III of the Manual contains transuranic waste requirements. Among those requirements are the following:

Section C. Complex-Wide Transuranic Waste Management Program. A complex-wide program and plan shall be developed as described under *Responsibilities*, 2.B and 2.D, in Chapter I of this Manual.

Section G. Waste Acceptance. The following requirements are in addition to those in Chapter I of this Manual.

3. **Technical and Administrative**. Waste acceptance requirements for all transuranic waste storage, treatment, or disposal facilities, operations, and activities shall specify, at a minimum, the following:
   a. Allowable activities and/or concentrations of specific radionuclides;
   b. Acceptable waste form and/or container requirements that ensure the chemical and physical stability of waste under conditions that might be encountered during transportation, storage, treatment, or disposal;
   c. Restrictions or prohibitions on waste, materials, or containers that may adversely affect waste handlers or compromise facility or waste container performance;
   d. Requirement to identify transuranic waste as defense or non-defense, and limitations on acceptance; and
   e. The basis, procedures, and levels of authority required for granting exceptions to the waste acceptance requirements, which shall be contained in each facility's waste acceptance documentation. Each exception request shall be documented, including its disposition as approved or not approved.
4. **Evaluation and Acceptance**. The receiving facility shall evaluate waste for acceptance, including confirmation that technical and administrative requirements have been met. A process for the disposition of non-conforming wastes shall be established.

3.2 Responsibilities

The responsibilities of organizations that developed and approved the WAC and of those that oversaw the implementation of the requirements defined in DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant,* are identified below.

3.2.1 DOE Headquarters

The Assistant Secretary for Environmental Management (EM-1) provides policy and guidance for DOE environmental management sites, facilities, and operations.

3.2.2 DOE Carlsbad Field Office

The CBFO is responsible for the day-to-day management and direction of strategic planning and related activities associated with the characterization, certification, transportation, and disposal of defense TRU waste. The CBFO holds the applicable permits, certifications, and records of decision necessary for the operation and closure of the WIPP facility.

The CBFO assists the sites in resolving issues about the management of TRU waste as requested. The CBFO provides policy and oversight direction for TRU waste program activities related to site certification of waste for disposal at WIPP. The CBFO is also responsible for the following:

- Ensuring that the sites prepare implementation documentation and programs to meet the requirements and criteria in the WAC;
- Overseeing activities associated with the:
  - characterization and certification of TRU waste;
  - proper use of approved transportation packaging; and
  - receipt, management, and disposal of TRU waste at WIPP.
- Providing a fleet of NRC-approved Type B transportation packaging for shipment of TRU waste from the sites to WIPP;
- Ensuring that TRU waste accepted for management and disposal at WIPP complies with the WIPP HWFP, applicable laws, and regulations as described in DOE/WIPP-02-3122;
- Reviewing and approving proposed revisions to the WAC to ensure that environmental impacts associated with any revision are bounded by existing WIPP National Environmental Policy Act (NEPA) documentation including the Final Environmental Impact Statement (Reference 19) and related supplements I (Reference 20) and II (Reference 21) of DOE/WIPP-02-3122;
- Reviewing and approving the sites' waste certification plans, site-specific TRAMPACs, QA plans, and Characterization Quality Assurance Program Project Plan (QAPjPs);
- Performing site certification audits and surveillances; and
- Granting transportation and waste certification authority to sites.

3.2.3 DOE Field Elements

Each DOE Field Element is responsible for overseeing the management of the site TRU waste program in compliance with established CBFO requirements, policies, and guidelines, and for providing liaison between the CBFO and the management and operating contractors.

3.2.4 TRU Waste Sites

Each participating site is responsible for developing and implementing site-specific TRU waste program documents (plans) that address applicable requirements and criteria pertaining to packaging, characterization, certification, and shipping of defense TRU waste to WIPP for disposal. Each participating site shall prepare the appropriate Waste Certification Plans, QA Plans, TRAMPACs, Appendix 4.10.2, "TRU Waste Payload Control for a 10-160B," of DOE/WIPP-02-3122, and QAPjPs, as applicable. Methods of compliance with each requirement and associated criterion to be implemented at the site shall be described or specifically referenced and shall include procedural and administrative controls consistent with the CBFO quality assurance project description (QAPD). TRU waste sites are required to submit these program documents to the CBFO for review and approval prior to their implementation (Figure 3-1). Sites will certify that each TRU waste payload container meets the waste acceptance criteria contained in this document.

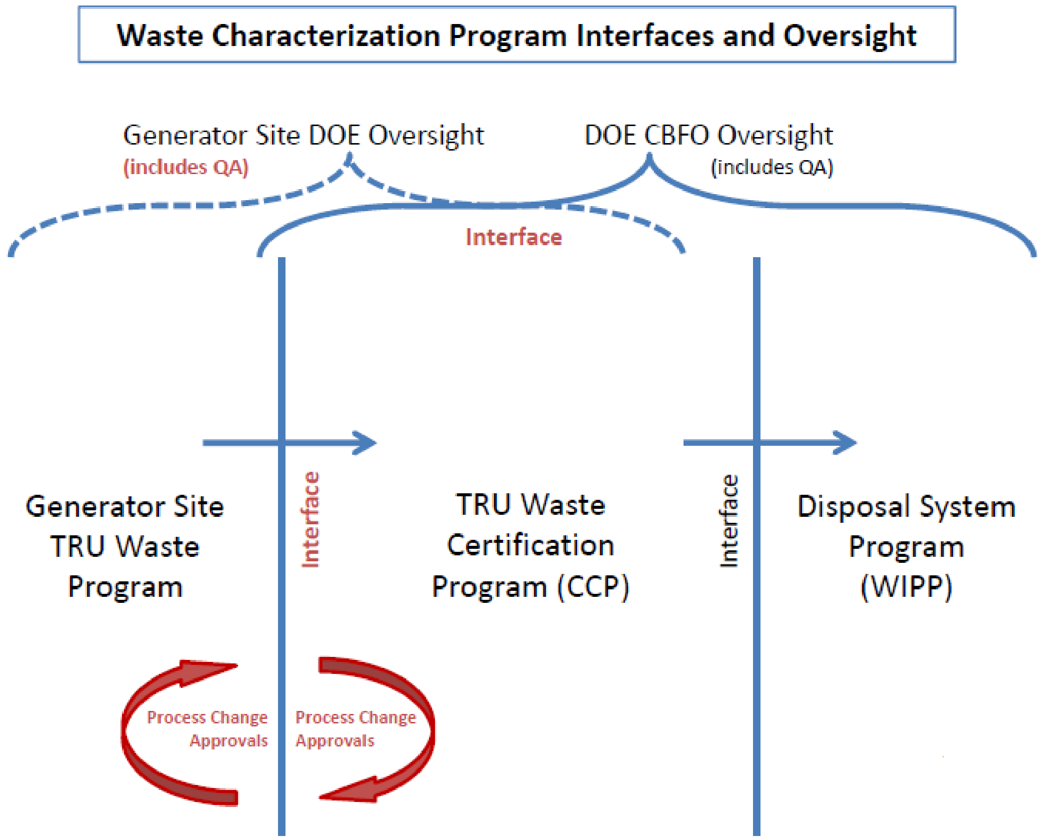

Figure 3-1: Waste Characterization Program Interfaces and Oversight

3.2.5 National Transuranic Waste Corporate Board

In May 2001, the CBFO, in coordination with DOE Headquarters, instituted a Corporate Board. The Corporate Board consisted principally of senior DOE and contractor representatives from those sites that were actively shipping TRU waste to the WIPP. Organized much like a private sector corporate board, this Corporate Board discussed major issues or concerns to the TRU waste complex and made consensus recommendations for improvements to operational efficiencies. In the By-Laws, the mission of the Corporate Board was described as follows:

> *The National TRU Program Corporate Board will serve as a consensus-building body to oversee an integrated DOE TRU Waste System. The Corporate Board will integrate the independently managed DOE sites into a single corporate entity to achieve, through consensus, best business practices, economy of scale, standardization, the appropriate use of Mobile/Modular systems and the use of Best Business Practices to minimize costs, optimize transportation logistics, and implement new policies or requirements.*

3.2.5.1 Corporate Board Executive Leadership Roles and Responsibilities:

Chief Executive Officer - CBFO Manager

- Has the final approval on all actions the Corporate Board undertakes;
- Serves as Corporate Board spokesperson;
- Summarizes or briefs EM-1 on the outcome of Corporate Board meetings;
- Provides Corporate Board recommendations to EM-1; and
- Approves members.

Chief Operating Officer - CBFO Deputy Manager

- Recommends and monitors the performance metrics for the National TRU Waste Management Plan;
- Serves as Chairperson of the Corporate Board in the absence of the Chair; and
- Monitors disposition and ensures closure of Corporate Board recommendations.

Chairperson - CBFO Director of the Office of the National TRU Program

- Integrates the TRU Waste Sites by communicating the National TRU Program priorities for work-off plans and resource utilization;
- Monitors the work of the Corporate Board Secretary to ensure that operations of the Board are consistent with the needs and requirements of the Corporate Board and the Chair;
- Tracks disposition of legacy TRU waste and reports to the Corporate Board;
- Implements and maintains the National TRU Waste Management Plan; and
- Ensures that action items assigned by the Corporate Board are implemented.

EM Headquarters – Office of Waste Management

- Includes Offices of Disposal Operations, Disposition Planning and Policy, and Packaging and Transportation;
- Headquarters representative that oversees the Corporate Board and that assists in carrying out the recommendations from the Corporate Board; and
- Oversees the integration of TRU Waste Sites and provides the priorities for DOE in the area of TRU Waste Management.

3.2.5.2 Corporate Board Members Roles and Responsibilities

- Implements site work off plans such that TRU waste entering the characterization process is maximized.
- Ensures that funding and scope priorities are consistent with integrated goals.

- Integrates Contractor Performance Based Incentives (PBIs) with the CBFO Contractor PBIs through the Executive Leadership.
- Informs and seeks assistance from Executive Leadership for emerging issues that affect or could affect implementation of TRU waste processing operations.
- Ensures that TRU waste site DOE staff and management incorporate TRU waste disposition performance elements into their Annual Performance Agreements.
- Offers solutions, ideas, and suggestions to address issues that affect the vision, mission, goals, and business initiatives of the National TRU Waste Complex.
- Makes commitments for their respective Sites.

3.3 Land Disposal Restriction Notice

With the initial shipment of a TRU waste stream, the CCP provided the permittees with a one-time written notice. The notice included the information listed below:

Land Disposal Restriction Notice Information

- EPA hazardous waste numbers and Manifest Numbers on first shipment of a mixed waste stream;
- Statement: "this waste is not prohibited from land disposal;" and
- Date the waste is subject to prohibition.

This information is the applicable information taken from column "268.7(a)(4)" of the "Generator Paperwork Requirements Table" in 20.4.1.800 New Mexico Administrative Code (NMAC), incorporating 40 CFR §268.7(a)(4). Note that item "5" from the "Generator Paperwork Requirements Table" is not applicable since waste analysis data are provided electronically via the WIPP Waste Information System (WWIS)/WDS and item "7" is not applicable since waste designated by the Secretary of Energy for disposal at WIPP is exempted from the treatment standards.

3.4 Waste Acceptance Criteria

The purpose of DOE/WIPP-02-3122 is to summarize the WAC applicable to the transportation, storage, and disposal of CH and RH TRU waste at WIPP. The WAC serves as DOE's primary directive for ensuring that CH and RH TRU waste is managed and disposed of in a manner that protects human health and safety and the environment. The WAC does not address the subject of waste characterization relating to a determination of whether the waste is hazardous; rather, the sites are referred to the WAP contained in the WIPP HWFP for details of the protocols to be used in determining compliance with the permit-required physical and chemical properties of the waste.

3.4.1 Summary of WIPP Authorization Basis

The requirements and associated criteria are organized under five major headings:

- Container Properties;
- Radiological Properties;
- Physical Properties;
- Chemical Properties; and
- Data Package Contents.

Additionally, site-specific plans and procedures shall contain details of the processes, controls, techniques, tests, and other actions to be applied to each TRU payload container, waste stream, and shipment. Methods of compliance with each requirement shall be described and the specific procedure cited. These methods of compliance shall include procedural controls, administrative controls, and waste generation process controls.

3.4.1.1 Container Properties

Payload containers shall meet U.S. Department of Transportation (DOT) Specification 7A, Type A, packaging requirements delineated in 49 CFR 173.465. Payload containers must be made of steel and be in good and unimpaired condition prior to shipment from the sites. A payload container in good and unimpaired condition:

1. Does not have significant rusting;
2. Is of sound structural integrity; and
3. Does not show signs of leakage.

Significant rusting is a readily observable loss of metal due to oxidation (e.g., flaking, bubbling, or pitting) that causes degradation of the payload container's structural integrity. Rusting that causes discoloration of the payload container surface or consists of minor flaking is not considered significant. A payload container is not of sound structural integrity if it has breaches or significant denting or deformation. Breaching is defined as a penetration in the payload container that exposes the internals of the container. Significant denting or deformation is defined as damage to the payload container that results in creasing, cracking, or gouging of the metal, or damage that affects payload container closure. Dents or deformations that do not result in creasing, cracking, or gouging or affect payload container closure are not considered significant. Sites report to the WWIS database the number and types of payload containers planned for shipment to the WIPP.

Additionally, Weight Limits and Center of Gravity, Assembly Configurations, Removable Surface Contamination, Identification/Labeling, Dunnage, and Filter Vent requirements are specified.

Method to Demonstrate Container Property Compliance

To demonstrate compliance with the requirement that payload containers be in good and unimpaired condition, the exterior of all payload containers shall undergo 100 percent visual inspection prior to loading into an authorized package. The results of this visual inspection shall be documented using the Payload Container Integrity Checklist. Newly purchased containers via a rigorous procurement process also demonstrate compliance.

Radiological Properties

Radiological properties identified within this section can be divided into two distinct groups:

The first group includes the activities and masses of the ten WIPP-tracked radionuclides (i.e., ^{241}Am, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{233}U, ^{234}U, ^{238}U, ^{90}Sr, and ^{137}Cs) and the TRU alpha activity concentration of the waste (i.e., >100 nCi/g of alpha-emitting TRU isotopes with half-lives greater than 20 years). This set of radiological properties is regulated by the EPA in accordance with 40 CFR Parts 191 and 194. Estimates of their activities and masses shall be derived from a system of controls certified by CBFO that includes AK, computations, measurements, sampling, etc. Appendix A of the WAC provides the methods and requirements by which to characterize the radiological composition of the CH TRU waste utilizing radioassay techniques.

The second group includes the remaining radionuclides contributing to the ^{239}Pu fissile gram equivalent (FGE), the ^{239}Pu equivalent curies (PE-Ci), and the decay heat of the payload container. This set of radiological data is regulated both by the NRC as specified in the CH TRU Waste Authorized Methods for Payload Control (TRAMPAC) and the TRUPACT-III TRAMPAC and by the CBFO as summarized by the WIPP Documented Safety Analysis (DSA). PE-Ci quantities shall be calculated for each payload container in accordance with Appendix B of the WAC.

Additionally, external radiation dose equivalent rate of individual payload containers shall be ≤200 milliroentgen equivalent man (mrem)/hour (hr) at the surface with the exception of the S100 and S300 pipe overpack (POP), which are limited to ≤179 mrem/hr and ≤155 mrem/hr, respectively, at the surface. Internal payload container shielding shall not be used to meet this criterion, except for authorized shielded payload container configurations such as the use of 55-gallon drums containing a pipe component or a shielded container. A decay heat component is also determined.

Method to Demonstrate Radiological Properties Compliance:

To demonstrate compliance, radio-assay is utilized as described in Appendix A of the WAC. External dose rate is measured with calibrated radiation monitoring devices. Decay heat is calculated using the radioassay results.

3.4.1.2 Physical Properties

Observable Liquid

From Section C7-1a of the WIPP HWFP WAP:

> *The prohibition of liquid in excess of TSDF-WAC limits and containerized gases prevents the shipment of corrosive, ignitable, or reactive wastes.*

From 40 CFR Part 261.21 Characteristic of Ignitability:

> *(a) A solid waste exhibits the characteristic of ignitability if a representative sample of the waste has any of the following properties:*
>
> *(1) It is a liquid, other than an aqueous solution containing less than 24 percent alcohol by volume and has flash point less than 60 °C (140 °F), as determined by a Pensky-Martens Closed Cup Tester, using the test method specified in ASTM Standard D 93-79 or D 93-80 (incorporated by reference, see § 260.11), or a Setaflash Closed Cup Tester, using the test method specified in ASTM Standard D 3278-78 (incorporated by reference, see § 260.11).*
>
> *(2) It is not a liquid and is capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard.*
>
> *(3) It is an ignitable compressed gas.*
>
> *(i) The term "compressed gas" shall designate any material or mixture having in the container an absolute pressure exceeding 40 p.s.i. at 70 °F or, regardless of the pressure at 70 °F, having an absolute pressure exceeding 104 p.s.i. at 130 °F; or any liquid flammable material having a vapor pressure exceeding 40 p.s.i. absolute at 100 °F as determined by ASTM Test D-323.*
>
> *(ii) A compressed gas shall be characterized as ignitable if any one of the following occurs:*
>
> *(A) Either a mixture of 13 percent or less (by volume) with air forms a flammable mixture or the flammable range with air is wider than 12 percent regardless of the lower limit. These limits shall be determined at atmospheric temperature and pressure. The method of sampling and test procedure shall be acceptable to the Bureau of Explosives and approved by the director, Pipeline and Hazardous Materials Technology, U.S. Department of Transportation (see Note 2).*
>
> *(B) Using the Bureau of Explosives' Flame Projection Apparatus (see Note 1), the flame projects more than 18 inches beyond the ignition source with valve opened fully, or, the flame flashes back and burns at the valve with any degree of valve opening.*

(C) Using the Bureau of Explosives' Open Drum Apparatus (see Note 1), there is any significant propagation of flame away from the ignition source.

(D) Using the Bureau of Explosives' Closed Drum Apparatus (see Note 1), there is any explosion of the vapor-air mixture in the drum.

(4) It is an oxidizer. An oxidizer for the purpose of this subchapter is a substance such as a chlorate, permanganate, inorganic peroxide, or a nitrate, that yields oxygen readily to stimulate the combustion of organic matter (see Note 4).

Liquid waste is not acceptable at WIPP. Observable liquid containing polychlorinated biphenyl (PCB) is prohibited at WIPP. Liquid in the quantities delineated below is acceptable:

- Observable liquid shall be less than 1 percent by volume of the outermost container at the time of radiography or VE.
- Internal containers with more than 60 milliliters or 3 percent by volume observable liquid, whichever is greater, are prohibited.
- Containers with Hazardous Waste Number U134 assigned shall have no observable liquid.
- Overpacking the outermost container that was examined during radiography or visual examination or redistributing untreated liquid within the container shall not be used to meet the liquid volume limits.

Additionally, for generator/storage sites that use VE, the detection of any liquid in non-transparent internal containers, detected from shaking the internal container, will be handled by assuming that the internal container is filled with liquid and adding this volume to the total liquid in the container being characterized using VE.

Sealed Containers

From the WAC, sealed containers that are greater than 4 liters (nominal) are prohibited except for solid inorganic waste (Waste Material Type II.2) packaged in a metal container.

Methods to Demonstrate Physical Property Compliance:

To demonstrate compliance with physical property requirements, radiography and/or VE (supplemented by AK) is performed as detailed in Appendix F and G respectively of the WAC, as summarized below:

- Appendix F of the WAC, *Radiography Requirements for Contact-Handled Transuranic Waste for EPA Compliance*, states the following regarding conduct of radiography examinations:

  To perform radiography, the waste container is scanned while the operator views the video monitor. An audio/video recording shall be made of the waste container scan and is maintained as a non-permanent record. A radiography data form shall also be used to document the Waste Matrix Code; verify there are no ignitable, reactive, or corrosive wastes present by verification that there is no observable *liquid in excess of the waste acceptance criteria limits and there are no compressed gases; and estimated waste material parameter weights of the waste.*

The estimated waste material parameter and weights for CH waste should be determined by compiling an inventory of waste items and packaging materials. The items on this inventory should be sorted by waste material parameter and combined with a standard weight look-up table to provide an estimate of waste material parameter weights.

- Appendix G of the WAC applies to VE requirements for CH waste. Contact-handled waste container contents may be verified directly by performing VE on the waste container contents. Visual examination may also be performed during packaging or repackaging of waste. Visual examination does not require audio/video recordings of the examination; the examination is documented on a data form and certified with signatures from two qualified VE operators. Visual examination shall be conducted to describe all contents of a waste container and includes estimated or measured weights of the contents. The description shall clearly identify all discernible waste items, packaging materials, and waste material parameters in the waste container. Visual examination activities shall be documented on VE data forms.

3.4.1.3 Chemical Properties (WAC)

Pyrophoric Materials

Radioactive pyrophoric materials shall be present only in small residual amounts (≤1 percent by weight) in payload containers and shall be generally dispersed in the waste. Radioactive pyrophorics in concentrations greater than 1 percent by weight and all nonradioactive pyrophorics shall be reacted (or oxidized) and/or otherwise rendered nonreactive prior to placement in the payload container. Non-radionuclide pyrophoric materials are not acceptable at WIPP.

Hazardous Waste

Hazardous wastes not occurring as co-contaminants with TRU wastes (non-mixed hazardous wastes) are not acceptable at WIPP. Each CH TRU mixed waste container shall be assigned one or more hazardous waste numbers as appropriate. Only EPA hazardous waste numbers listed as allowable in the HWFP may be managed at WIPP. Some of the waste may also be identified by unique state hazardous waste codes. These wastes are acceptable at WIPP as long as the TSDF WAC are met. Wastes exhibiting the characteristic of ignitability, corrosivity, or reactivity (EPA hazardous waste numbers of D001, D002, or D003) are not acceptable at WIPP.

Chemical Compatibility

TRU waste containing incompatible materials or materials incompatible with payload container and packaging materials, shipping container materials, other wastes, repository backfill, or seal and panel closure materials are not acceptable for transport in the TRUPACT-II, TRUPACT-III, and HalfPACT or for disposal at WIPP. Chemical constituents shall conform to the lists of allowable materials in Tables 4.3-1 through 4.3-8 of the CH TRAMPAC, and Tables 4.3-1 through 4.3-7 of the TRUPACT-III TRAMPAC, as applicable. Other chemicals or materials not identified in these tables are allowed provided that they meet the requirements as specified in Section 4.3.1 of the CH TRAMPAC and TRUPACT-III TRAMPAC.

Explosives, Corrosives, and Compressed Gases

Waste shall contain no explosives, corrosives, or compressed gases.

Headspace Gas Concentrations

The headspace gas of payload containers shall be determined in accordance with a site-specific TRAMPAC.

Polychlorinated Biphenyls

For TRU and TRU-mixed wastes containing PCBs meeting the conditions of approval in EPA Letter to DOE 2011-01-05, the payload container data entered into the WWIS database shall include the earliest date of waste generation (i.e., the date of removal from service for disposal), the date of waste certification for disposal, and the date the waste was sent to WIPP for disposal. Additionally, the estimated weight of the PCBs in kilograms (as recorded on the uniform hazardous waste manifest), and a description of the type of polychlorinated biphenyl (PCB) waste (e.g., PCB remediation waste, PCB bulk product waste, etc.) shall be entered into the WWIS database. Hanford, Idaho National Laboratory, Savannah River Site, Oak Ridge Reservation, Knolls Atomic Power Laboratory, and Los Alamos National Laboratory are authorized to ship their TRU and TRU-mixed wastes containing PCBs to WIPP.

Methods to Demonstrate Chemical Property Compliance:

To demonstrate compliance with chemical property requirements:

- AK is the primary avenue for determining the hazardous elements of a generator site's waste. Documentation of the chemicals used in the generation of the waste, testing performed by the generator site in support of the RCRA program, and application of codes assigned by the generator, conservative or otherwise, is the starting point for all the waste delivered to CCP for characterization. This information is compiled and reviewed, then summarized, to describe the chemical properties of the waste. When there is conflicting or incomplete information, the CCP AK process requires a discrepancy resolution to be worked that would resolve the issue for inclusion in a revision to the AK summary.
- Non-destructive examination (NDE) is performed on all containers. Verification of physical waste form is done to confirm the waste being examined conforms to the expected waste form from the AK Summary. The presence of free liquids is a key variable that NDE will look for, to confirm the code assignment from the AK is valid. Free liquids could be untreated chemicals. Free liquids present an issue for the assignment of D001, D002 and D003. Identification of metals such as lead and mercury are often made during NDE. When specific items are identified, the chemical makeup of those items can be determined and then validate that the code assignments for those elements are captured in the AK summary.

3.4.1.4 Data Package Contents

Characterization and Certification Data

Sites shall prepare a waste stream profile form (WSPF) for each waste stream. Each WSPF shall be approved by the permittees prior to the first shipment of that waste stream. Characterization and certification information for each payload container shall be submitted to the WWIS database and approved by the Data Administrator. Sites are required to estimate the cellulose, plastic, and rubber weights and report these estimates in the WWIS database on a payload container basis. Any payload container from a waste stream that has not been preceded by an appropriate certified WSPF is not acceptable at WIPP.

Shipping Data

Sites shall prepare either a bill of lading or a uniform hazardous waste manifest for CH TRU waste shipments as required by the transportation requirements. The land disposal restriction notification for CH TRU mixed waste shipments shall state that the waste is not prohibited from land disposal.

3.5 WIPP Certification Audits

As stated above, CBFO is responsible for performing site certification audits and surveillances. CBFO is also responsible for granting transportation and waste certification authority to sites. CBFO Management Procedure (MP) 5.2, *TRU Waste Site Certification/ Recertification*, is the CBFO Management Procedure that governs the conduct of WIPP Certification and Recertification Audits required by the WAP.

3.5.1 Audit and Surveillance Program

The WIPP HWFP states that DOE will approve lead auditors, auditors, and technical specialists based upon the expertise required for the functions being examined according to the audit scope. DOE will supply auditors/technical specialists with expertise in the RCRA requirements and knowledge of the testing and documentation methods required to verify the hazardous waste characterization performed by the sites. DOE shall identify all audit team members to NMED prior to the audit, and shall provide upon request the qualifications of all audit team members. Additionally, the permittees shall not manage, store, or dispose TRU mixed waste at WIPP from a generator/storage site until the following conditions have been met as necessary for the NMED Secretary to determine that the applicable characterization requirements of the Permit have been implemented:

- **Requirement to Audit** - DOE shall demonstrate to the Secretary that the generator/storage sites have implemented and complied with applicable requirements of the WAP by conducting audits as specified in the HWFP and as required by 20.4.1.500 NMAC (incorporating 40 CFR Part 264.13).
- **Observation of Audit** - The NMED Secretary may observe such audits as necessary to validate the implementation of and compliance with applicable WAP requirements at each generator/storage site. DOE shall provide the NMED Secretary with a current audit schedule

on a monthly basis and notify the NMED Secretary no later than 30 calendar days prior to each audit.

- **Final Audit Report** - DOE shall provide the NMED Secretary a final audit report as specified in the WIPP HWFP, post a link to the final audit report transmittal letter on the WIPP Home Page, and inform those on the e-mail notification list as specified in the WIPP HWFP. The final audit report shall include all information specified in WIPP HWFP, and:
  - A detailed description of all corrective actions and the resolution of any corrective action applicable to WAP requirements, including re-audits if required; and
  - All documentation necessary for the NMED Secretary to determine if the corrective action was resolved.

The NMED Secretary approves DOE's final audit report by written notification to DOE that the applicable characterization requirements of the WAP at a generator/storage site have been implemented.

3.5.2 WIPP Certification Audit Scope

From the WIPP HWFP, Attachment C6:

> *The Waste Isolation Pilot Plant (WIPP) Audit and Surveillance Program shall ensure that: 1) the operators of each generator/storage site (site) that plan to transport transuranic (TRU) mixed waste to the WIPP facility conduct testing of wastes in accordance with the current WIPP Waste Analysis Plan (WAP) (Permit Attachment C), and 2) the information supplied by each site to satisfy the waste screening and acceptability requirements of Section C-4 of the WAP is being managed properly. DOE will conduct these audits and surveillances at each site performing these activities in accordance with a standard operating procedure (SOP). NMED personnel may observe these audits and surveillances to validate the implementation of WAP requirements (Permit Attachment C) at each site. Only personnel with appropriate U.S. Department of Energy clearances will have access to classified information during audits. Classified information will not be included in audit reports and records. The audit SOP will contain steps for selecting audit personnel, reviewing applicable background information, preparing an audit plan, preparing audit checklists, conducting the audit, developing an audit report, and following up audit deficiencies. A deficiency is any failure to comply with an applicable provision of the WAP. The checklists for each site shall include, at a minimum, the appropriate checklists found in Tables C6-1 through C6-4 for the summary category groups undergoing audit.*

Table C6-1, Waste Analysis Plan (WAP) General Checklist for use at DOE's Generator/Storage Sites, consists of the following areas:

- Waste Stream Identification;
- Unacceptable Waste;
- Waste Acceptance Control;

- General Characterization Requirements;
- Data Generation, Verification, Validation, Documentation, and Quality Assurance;
- Data Transmittal;
- Records and Records Management; and
- Shipment.

Table C6-2 Acceptable Knowledge Checklist, consists of the following areas:

- General Requirements;
- Required and Additional Information;
- Training;
- Procedures;
- Re-evaluating AK;
- Criteria for Assembling an AK Record Delineating the Waste Stream; and
- Data Quality Requirements.

Table C6-3 Radiography Checklist, consists of the following areas:

- Quality Assurance Objectives;
- Characterization and System Requirements;
- Data Compilation;
- Training;
- Quality Assurance; and
- Data Validation, Review, Verification, and Reporting.

Table C6-4 Visual Examination (VE) Checklist, consists of the following areas:

- Training;
- Visual Examination Expert Requirements;
- Visual Examination Procedures; and
- Quality Assurance Objectives.

CBFO MP 5.2, states that it is the responsibility of the CBFO Director of the Office of the National TRU Program, to coordinate with the Director of the Office of Quality Assurance to develop detailed scope of audit requirements.

The WIPP HWFP states that audits will be conducted at least annually for each site involved in the waste characterization program. Both announced and unannounced audits will address the following:

- Results of previous audits;
- Changes in programs or operations;
- New programs or activities being implemented; and
- Changes in key personnel.

Annual certification audits address CH and RH waste characterization activities if the site has approval or is seeking approval for such wastes. At a minimum, the audit will evaluate AK documentation for CH and RH waste separately by Summary Category Group, as applicable.

3.5.3 WIPP Certification Audit Reports

CBFO audits, including Certification/Recertification Audits, are conducted in accordance with CBFO MP-10.3, *Audits*, and CBFO MP 5.2. During audits, the team may identify condition(s) adverse to quality (CAQ) and document each in a corrective action report (CAR). The following definitions are provided from CBFO MP 10.3:

Condition Adverse to Quality (CAQ) – An all-inclusive term used in reference to any of the following: failures, malfunctions, deficiencies, defective items, non-conformances, and technical inadequacies. A CAQ is considered significant when:

- if uncorrected, the condition adverse to quality could have a serious effect on safety, operability, waste isolation, TRU waste site certification, regulatory compliance demonstration, or effective implementation of the quality assurance (QA) program;
- the condition adverse to quality requires immediate notification of regulatory entities (e.g., 10 CFR Part 21, *Hazardous Waste Facility Permit* Part 1.7.13);
- the condition adverse to quality indicates a significant failure or breakdown in the implementation of QA Program requirements;
- repeated attempts to resolve a condition adverse to quality have been unsuccessful; and
- the condition adverse to quality is identified in items or activities important to safety or waste isolation and compromises the ability to prevent or mitigate the consequences of an accident, thereby presenting a significant hazard to safety and health of workers and/or the public.

Corrective Action Report (CAR) – A document used to identify and rectify CAQs and track the associated corrective actions. CARs address CAQs that are primarily programmatic in nature, as opposed to nonconformance reports (NCRs), which address CAQs relating to a specific item such as a piece of hardware or data. The category of CARs includes corrective action reports or corrective action requests, nonconformance corrective action reports, management corrective action reports, deficiency reports, process deficiency reports, audit findings, condition adverse to quality reports, etc.

Observation – Documentation of marginally acceptable conditions that, if not controlled, might later escalate into a deficiency. Observations are not deficiencies and do not require a response.

Recommendation – Suggestions that are directed toward identifying opportunities for improvement and enhancing methods of implementing process or quality program requirements.

For WAP-related audits, a final audit report shall be prepared after all WAP-related corrective actions are completed. The final audit report will then be reviewed, approved, and issued by the CBFO QA Director. One formal final audit report will be submitted to NMED in hard copy, but any additional copies may be submitted in electronic format. One copy is submitted to the WIPP managing and operating contractor for retention in the operating record. The report, at a minimum will include the following:

- The WAP-related portions of the audit report;
- Completed C6 checklists;
- WAP-related audited procedures;
- Documentation from all associated WAP-related CARs including the CAR, description of all corrective actions taken, and actions taken to close out the CAR;
- Documentation supporting all corrective actions taken on WAP-related CARs;
- Other applicable documents that provide evidence of WAP implementation;
- Procedure Revision Matrix (recertification audits only).

3.5.4 WIPP Certification Audit Reports for CCP/LANL

The initial certification audit (A-04-05) and the 2012 (A-12-12) and 2013 (A-13-23) recertification audits of the CCP at LANL were reviewed by the Board.

3.5.4.1 Carlsbad Field Office (CBFO) Audit A-04-05

CBFO Audit A-04-05 was conducted at LANL, April 26-30, 2004, to evaluate the CCP characterization and certification services that were contracted to the University of California and included evaluation of the CCP TRU waste characterization and certification activities related to Summary Category Group S3000 (homogeneous solid waste) and S5000 (debris waste). The audit team assessed the adequacy, implementation, and effectiveness of the technical and QA activities.

The audit scope included assessment of the physical characterization processes and activities being conducted on behalf of LANL. The activities evaluated included characterization with mobile RTR equipment; VE, including the VE technique; headspace gas sampling using sample canisters; headspace gas analysis on-site using an Entech-Agilent analysis system; and analysis off-site using an independent analysis laboratory. The process for developing AK documentation was also evaluated.

3.5.4.1 Carlsbad Field Office (CBFO) Audit A-12-12

CBFO Audit A-12-12 was conducted on July 24-26, 2012, to evaluate the adequacy, implementation, and effectiveness of LANL TRU waste characterization activities performed for LANL by WTS CCP. The audit was conducted relative to the requirements detailed in the WIPP HWFP, the *CBFO Quality Assurance Program Document* (QAPD), the *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (WAC), and the *Contact-Handled Transuranic Waste Authorized Methods for Payload Control* (CHTRAMPAC).

The CBFO audit team evaluated the continuing characterization processes for CH Summary Category Group (SCG) S3000 homogeneous solids and SCG S5000 debris wastes. The Office of the National TRU Program requested that the audit team also evaluate the characterization process for CH SCG S4000 soils/gravel waste for initial certification. As part of the audit, the National TRU Program requested a review of the extension of the calibration for the High-Efficiency Neutron Counter #1 (HENC #1) to include a population of lead-lined 55-gallon drums containing solidified materials, as well as a calibration extension of the high-resolution gamma spectrometry to 2.5 grams per cubic centimeter g/cc for the Super High-Efficiency Neutron Counter.

The CBFO audit team was unable to determine the adequacy, implementation and effectiveness of the characterization of CH SCG S4000 soils/gravel waste because the team was not provided with any completed S4000 characterization packages. The team reviewed the preliminary AK documentation, reviewed the RTR and NDA characterization of S4000 soils/gravel waste, and reviewed a random selection memo for LANL S4000 waste. All were deemed to be adequate.

3.5.4.2 Carlsbad Field Office Audit A-13-23

CBFO Audit A-13-23 was conducted on July 23-25, 2013, to evaluate the continued adequacy, implementation, and effectiveness of established programs for TRU waste characterization activities performed for LANL by NWP CCP. The audit team evaluated the programs, procedures and processes for characterizing and transporting CH SCG S3000 homogeneous solids, SCG S4000 soils/gravel, and SCG S5000 debris wastes. The audit was conducted relative to the requirements of the WIPP HWFP and the CBFO QAPD.

Audit activities were conducted at LANL facilities in Los Alamos, NM, and at the Skeen-Whitlock Building in Carlsbad, NM, July 23-25, 2013. Overall, the audit team concluded that the LANL/CCP technical and QA programs evaluated were adequately established for compliance with applicable upper-tier requirements, effectively implemented, and successful in achieving the desired results.

The audit team identified four concerns during the audit as described in the interim audit report. No Permit Waste Analysis Plan (WAP)-related conditions adverse to quality were identified.

As reported by the CBFO Quality Assurance Manager, three waste streams in CCP-AK-LANL-006 had been audited. The three waste streams were LA-MHD01.001, LA-CIN01.001, and LA-MIN04-S.001. At the time of the July 2013 recertification audit, LA-MIN02-V.001 was not an approved waste stream; therefore, it was not audited. The LA-MIN02-V.001 was to be audited during the 2014 recertification audit.

3.6 Los Alamos National Laboratory Carlsbad Office

In February of 2000, CBFO coordinated the establishment of a team of technical resources to address emerging issues across the DOE complex. The team was comprised of Los Alamos employees from the Los Alamos Technology Office at Rocky Flats. The office became known as the LANL-CO.

The tasking of the LANL-CO is contained in a Statement of Work (SOW) established by the CBFO and provided to the LANL-CO for execution. From the SOW, LANL-CO is to (1) serve the WIPP, National TRU Program and CBFO as Senior Technical Advisor to the Department of Energy for TRU Waste Characterization, Certification, and Shipping throughout the complex to ensure optimized, efficient and effective permanent disposal of TRU waste; (2) at the direction of the CBFO, support experimental activities and demonstrations for salt-based research and development, many specifically designed to confirm the suitability of salt as a disposal medium for heat-generating waste; and (3) assist the DOE in evaluating new and emerging wastes streams whose disposition paths have not yet been finalized through the integration of difficult waste, inventory and acceptable/process knowledge scope elements. This scope includes:

- Provide the WIPP program with the technical expertise to solve challenging waste issues in the packaging, certification, transportation, or emplacement of defense TRU Waste. Provide logistics planning for the packaging, certification, and transportation of challenging waste streams;
- Perform detailed characterization research on upcoming waste streams complex-wide using the container-specific inventory developed by LANL-CO inventory;
- Maintain AK qualifications in accordance with CCP procedures. Furnish compliant documentation and analyses to CCP for development into AK summary reports;
- Support the certification of TRU waste for the CCP by the research, development, and maintenance of acceptable and process knowledge of the waste, generator site missions, waste form analysis, chemical characterization, and historical sampling and analysis data;
- Ensure that all products produced by LANL-CO for CBFO meet regulatory requirements promulgated in the WIPP HWFP, the WIPP WAC, and the CH and RH TRAMPACs;
- Support the AK portion of CCP TRU waste certification audits; and
- Work with LANL-CO TRU Waste inventory and difficult waste groups to develop robust analyses and resolutions to difficult and challenging waste stream issues across the complex.

3.7 Analysis of Section 3.0 - National TRU Program

The Board reviewed the implementation of the National TRU Program with particular attention to the methods prescribed to demonstrate compliance with the WIPP HWFP Waste Analysis Plan (WAP). Section C7-1a of the WAP establishes the premise that if radiography or visual examination verifies that there are no liquids present that are in excess of the WAC limits, then waste streams will not exhibit ignitibility, corrosivity, or reactivity properties as defined by 40 CFR 261.21. The Board determined that the WAP premise is not consistent with 40 CFR 261.21 properties of ignitibility. The nitrate matrix, by nature of associated hazards, supported classifying the entire LA-MIN02-V.001 as ignitable because "*it is an oxidizer*" per (a)(4) of the regulation, unless additional waste stream testing and supporting analysis documentation was provided. Further, the use of an organic absorbent rendered the waste as ignitable per (a)(2) of the regulation where "*spontaneous chemical changes and, when ignited, burns so vigorously and persistently that it creates a hazard*." WIPP relies heavily on information provided by the generator site during development and revision of AK summary reports to meet these criteria since RTR and VE are only able to identify the absence of free liquid. Additionally, RTR of the LA-MIN02-V.001 waste stream was unable to distinguish between organic and inorganic materials.

The February 14, 2014, event and subsequent reclassification of the LA-MIN02-V.001 waste stream as ignitable by LANL proved that the "no liquid – no ignitability" premise was incorrect without additional control measures being implemented (neutralization of liquids and absorption with an inorganic material).

CON 1: Implementation of the characterization processes Implementation of the characterization processes established in the Waste Isolation Pilot Plant (WIPP) Hazardous Waste Facility Permit (HWFP), Attachment C, Waste Analysis Plan (WAP) was not fully consistent with the criteria in 40 CFR 261.21, *Characteristic of Ignitability*. Specifically, characterization processes should have identified LA-MIN02-V.001 as ignitable because

- It is an oxidizer; and
- Addition of the organic absorbent created conditions that made the waste capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burning so vigorously and persistently that it creates a hazard.

JON 1: The National Transuranic (TRU) Program needs to re-evaluate and strengthen the flow down of requirements regarding the compilation of Acceptable Knowledge (AK) in order to more clearly demonstrate that the WIPP HWFP, Attachment C, WAP waste characteristics prohibitions and chemical compatibility requirements are met consistent with 40 CFR 261.21.

The Board looked closely at the execution of the waste generator site certification and recertification audits on CCP conducted at LANL. While the audits provided a detailed evaluation of characterization efforts along with the data quality objectives in the waste certification process, there was a significant gap regarding activities such as waste repackaging performed by the host site. The Board determined that the certification audits of facilities where CCP conducts characterization and certification activities were focused only on CCP activities and did not look at the waste generator site as part of the process such as waste packaging. The CBFO and National TRU Program have relied on the oversight performed by the local site office to ensure that the waste generator is in compliance with their own RCRA permit. The Board's position is that certification and recertification audits should have also evaluated the adequacy of the local site office oversight of TRU waste operations, although not explicitly cited in the WAP.

Additionally, the Board reviewed the National TRU Program/CBFO certification audits conducted following the CBFO directed controls leading to the development of the LANS Solution Package #72. These audits are described in Section 3.5.4. CBFO Audit A-12-12 was conducted prior to implementation of procedure revisions to AK document CCP-AK-LANL-006, *Central Characterization Program, Acceptable Knowledge Summary Report for Los Alamos National Laboratory, TA-55 Mixed Transuranic Waste Streams: LA-MHD01.001, LA-CIN01.001, LA-MIN02-V.001, and LA-MIN04-S.001, by CCP; and* EP-WCRR-WO-DOP-0233, Revision 36, *WCRRF Waste Characterization Glovebox Operations*, by LANS. CBFO Audit A-13-23 was conducted a year afterwards. Neither of these recertification audits included evaluation of the implementation of the nitrate salt specific changes nor the potential impact of the errors contained within or between the documents. The Board concluded that the conduct of these audits represented missed opportunities to identify the inconsistencies between CBFO directed controls, Solution Package #72, AK Summary Report CCP-AK-LANL-006, and the EP-WCRRF glovebox operations procedure. These audits could have identified the improper use of an organic absorbent prior to the approval of the LA-MIN02-V.001waste stream profile form in August 2013. Given the amount of attention and correspondence related to issues regarding the disposition of nitrate salts in 2012, National TRU Program/CBFO should have ensured that resolution of those issues be included in the scope of recertification audits.

CON 2: Execution of the National Transuranic (TRU) Program certification audit process for the LANL waste generator activities where Central Characterization Program (CCP) performs TRU waste characterization and certification failed to include key elements of waste packaging and characterization processes. In part, this was attributed to a lack of clear roles and responsibilities; and expectations. Specific elements include:

- Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox treatment and repackaging operations;
- Ensuring that TRU waste accepted for management and disposal at WIPP complies with the WIPP Hazardous Waste Facility Permit (HWFP), applicable laws, and regulations described in the Waste Acceptance Criteria (WAC); and
- Verification that Los Alamos National Security, LLC prepared implementation documentation and programs to meet the requirements and criteria of the WIPP Waste Acceptance Criteria and that the CCP maintained an accurate and compliant Acceptable Knowledge Summary Report for the LA-MIN02-V.001waste stream.

JON 2: The National TRU Program needs to re-evaluate and strengthen the certification audit process across the DOE complex at all generator sites to include:

- Evaluation of waste generator repackaging operations that prepare TRU waste for characterization;
- Implementation of waste generator site processes as they relate to TRU waste management;
- Verification that changes to processes are correctly incorporated into acceptable knowledge summary reports;
- Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site RCRA permit; and
- Evaluation of local site office oversight of TRU waste operations.

Among other elements of National TRU Program management, the CBFO is also responsible for the following:

- Ensuring that the sites prepare implementation documentation and programs to meet the requirements and criteria in the WAC.
- Overseeing activities associated with the:
    - characterization and certification of TRU waste;
    - proper use of approved transportation packaging; and
    - receipt, management, and disposal of TRU waste at WIPP.

NA-LA is responsible, under the WIPP WAC, for overseeing the management of the site TRU waste program in compliance with established CBFO requirements, policies, and guidelines, and for providing liaison between the CBFO and the management and operating contractors. Although personnel interviewed indicated that there was routine oversight of WCRRF glovebox operations at LANL being conducted by NA-LA, this oversight did not result in the identification of inadequacies in repackaging procedures and operations. The RCRA non-compliances included unapproved treatment (neutralization of liquids and absorption with an organic material) and the addition of incompatible secondary waste items.

CBFO, through oversight of the National TRU Program certification audits, assumed that local oversight was being effectively conducted as prescribed in the responsibilities identified in the WAC. CBFO did not effectively ensure (1) that LANS prepared implementation documentation and programs that met the requirements and criteria in the WAC, and (2) that TRU waste accepted for management and disposal at WIPP complied with the WIPP HWFP, applicable laws, and regulations as described in the WAC. CBFO personnel associated with the National TRU Program indicated in interviews that they did not have the authority to conduct oversight of the waste generator site activities beyond the CCP-conducted characterization and certification processes, although the DOE Accident Investigation Board could find no evidence that such authority was limited. Key elements of the treatment and repackaging activities were not effectively evaluated during certification audits. Without effective oversight being conducted by the local field office, the gap in the oversight being performed by CBFO allowed fundamental flaws in the repackaging and treatment processes to continue unchecked. The Board also identified that since the advent of the CCP organization that, although meeting the stated requirements in the permit, certification audit scope had degraded in focus and did not take a critical look at waste generator activities that were important to the characterization process. Additionally, the National Transuranic Waste Corporate Board, while not having an assigned oversight role, represented a forum where the various senior leadership entities could discuss coordination of oversight activities aside from the role that was defined in the charter.

Additionally, the Office of Environmental Management (EM) and the Office of Health, Safety and Security (HSS)[8] did not effectively execute their roles and responsibilities as detailed in

[8] On May 4, 2014, the former Office of Health, Safety and Security (HSS) was reorganized into two separate organizations: the Office of Environment, Health, Safety and Security (EHSS) and the Office of Independent Enterprise Assessment (IEA).

DOE M 435.1-1, through National TRU Program implementation and programmatic oversight. The roles and responsibilities are described in Section 3.1.1. The Board could find no evidence of effective oversight being conducted that was specifically associated with the program performance or its implementation; reviewing and maintaining DOE O 435.1 current with major DOE organizational changes to ensure the basis for safe radioactive waste management facilities, operations, and activities; and conducting independent appraisals and audits of DOE waste management programs. Conclusions and judgments of need regarding the DOE headquarters roles and responsibilities are found in Section 9.0, "Federal Oversight."

CON 3: The NNSA Los Alamos Field Office (NA-LA) oversight activities were ineffective in identifying weaknesses in the execution of waste packaging, characterization and certification of transuranic (TRU) waste at Los Alamos National Laboratory (LANL).

JON 3: NA-LA oversight of characterization and certification of TRU waste sites needs to be improved to include:

- Waste Characterization, Reduction, and Repackaging Facility (WCRRF) repackaging operations that prepare TRU waste for characterization;
- Implementation of waste generator site processes as they relate to TRU waste management; and
- Verification that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit.

CON 4: Carlsbad Field Office (CBFO) oversight activities associated with the characterization and certification of transuranic (TRU) waste were ineffective in identifying programmatic weaknesses through the execution of certification audits and surveillances at the Los Alamos National Laboratory (LANL).

JON 4: The CBFO oversight of characterization and certification of TRU waste sites needs to be improved to include:

- Waste generator repackaging operations that prepare TRU waste for characterization;
- Implementation of waste generator site processes as they relate to TRU waste management;
- Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and
- Evaluation of local site office oversight of TRU waste operations.

JON 5: CBFO needs to evaluate and restructure their organization such that objective oversight of the National TRU Program is evident and effective in ensuring that waste generator sites comply with requirements including appropriate separation of CBFO line management and oversight functions and responsibilities.

JON 6: DOE Headquarters needs to review expectations documented in existing National TRU Program policy directives and take action necessary to clearly assert that CBFO, as the manager of the WIPP repository, has the authority to conduct oversight of waste generator site programs and processes necessary to provide assurance that any activities that could impact characterization and certification of waste are verified to be compliant.

4.0 Central Characterization Program

Sections 4.1 through 4.3 provide requirements and additional information from various source documents reviewed by the Board during the investigation. The information discussed in these sections serves as a basis for the analysis and conclusions relative to implementation.

The CCP is tasked with characterizing and certifying transuranic (TRU) waste for disposal at WIPP. Characterization consists of AK, radiography and VE. This work is conducted in accordance with the NWP *Quality Assurance Program Description* (QAPD) and CCP-PO-001, *Quality Assurance Project Plan* (QAPjP). Additionally, NDA and FGA are performed.

The WAP, within the QAPjP, is organized such that it specifies that the generator/storage sites conduct their own TRU waste characterization and certification, including their own data generation level and project level data validation and verification. However, many sites utilize the CCP to perform these functions. The CCP was established to assist these sites as well as to provide cost-effective TRU waste characterization, confirmation, and certification, including data generation level and project level data validation and verification.

The CCP may provide its services to a site by contracting directly with that site. If this is the case, the scope of services provided by CCP is specified in a Statement of Work (SOW) issued by the generator site. The SOW also specifies health and safety requirements, quality requirements, and other requirements specific to that site. A site-specific interface document may also be prepared which provides more detail on the site-CCP interface.

The generator site has general management oversight responsibility for work performed by the CCP at the site. The site is responsible for ensuring that CCP conducts its activities in compliance with site requirements.

4.1 Waste Characterization

Waste characterization is defined in Part 1 of the WIPP HWFP as the activities performed by the waste generator to satisfy the general waste analysis requirements of 20.4.1.500 NMAC (incorporating 40 CFR §264.13[a]) before waste containers have been certified for disposal at WIPP. The characterization techniques used by the CCP include AK and in the absence of an AK sufficiency determination, may also include as necessary, VE and/or radiography. Characterization activities are performed in accordance with CCP-PO-001. Table C-1, Summary of Parameters, Characterization Methods, and Rationale for Transuranic Mixed Waste, provides the parameters of interest for the constituent groupings and testing methodologies, including a summary of the characterization requirements for TRU waste.

Characterization requirements for individual containers of TRU waste are specified on a waste stream basis. The WAP defines a waste stream as waste materials that have common physical form, that contain similar hazardous constituents, and that are generated from a single process or activity. Waste streams are grouped by waste matrix code groups related to the physical and chemical properties of the waste (DOE 1995b). The CCP uses the characterization techniques described in this QAPjP to assign the appropriate waste matrix code groups to waste streams for WIPP disposal. The waste matrix code groups are solidified inorganics, solidified organics, salt bearing waste, soils, lead/cadmium metal, inorganic nonmetal waste, combustible waste, graphite, filters, heterogeneous debris waste, and uncategorized metal. Waste matrix code groups are grouped into three Summary Category Groups:

- S3000 (Homogeneous Solids) - Solid materials, excluding soil, that do not meet the NMED criteria for classification as debris. Included in the series of homogeneous solids are inorganic process residues, inorganic sludges, salt waste, and pyrochemical salt waste. Other waste streams are included in this Summary Category Group based on the specific waste stream types and final waste form. This Summary Category Group is expected to contain toxic metals and spent solvents. This category includes wastes that are at least 50 percent by volume homogeneous solids.
- S4000 Soil/Gravel - Waste streams that are at least 50 percent by volume soil/gravel. This Summary Category Group is expected to contain toxic metals.
- S5000 (Debris Waste) - Heterogeneous waste that is at least 50 percent by volume materials that meet the criteria specified in 20.4.1.800 NMAC (incorporating 40 CFR §268.2 [g]). Debris means solid material exceeding a 2.36 inch (in.) (60 millimeter [mm]) particle size that is intended for disposal and that is:
    1. a manufactured object, or
    2. plant or animal matter, or
    3. natural geologic material.

Particles smaller than 2.36 inches in size may be considered debris if the debris is a manufactured object and if it is not a particle of S3000 or S4000 material.

4.1.1 Acceptable Knowledge

Consistent with requirements in the WAP, CCP uses AK to initially characterize TRU waste. Section C4 of the QAPjP outlines the process used to characterize TRU waste using AK. AK documentation provides the basis for identifying the TRU waste eligible for WIPP disposal. The characterization process is based on the following:

- Waste considered for characterization is defense-related and has a TRU alpha activity greater than 100 nanocuries (nCi) per gram (g), and
- Resource Conservation and Recovery Act (RCRA) hazardous waste determinations are made initially using AK for TRU waste streams.

AK information for each waste stream is compiled in AK reports and supporting documentation. Based on AK, waste streams are delineated according to Summary Category Group, and waste matrix codes are assigned to each waste stream. The AK process is governed by CCP-TP-005, *CCP Acceptable Knowledge Documentation.* The *Waste Isolation Pilot Plant Hazardous Waste Facility Permit, Waste Analysis Plan* (WIPP-WAP), authorizes the use of AK in appropriate circumstances to delineate waste streams and to characterize hazardous waste. WIPP WAP AK requirements are addressed in CCP-PO-001, *CCP Transuranic Waste Characterization Quality Assurance Project Plan*, and implemented through CCP-TP-005. DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (WIPP WAC), AK requirements are addressed in CCP-PO-002, *CCP Transuranic Waste Certification Plan*.

Only CCP personnel trained in accordance with CCP-QP-002, *CCP Training and Qualification Plan,* will compile, evaluate, and document AK information in accordance with this procedure. Sites hosting the CCP may assist CCP personnel in the collection of AK information; however, CCP-TP-005 will be used by the CCP to generate the required AK in accordance with CCP-PO-001, CCP-PO-002, CCP-PO-003, and CCP-PO-505. CCP utilizes sub-contractor personnel to develop AK in accordance with these procedures.

EPA's 1994 Waste Analysis Guidance Manual broadly defines the term "acceptable knowledge" to include process knowledge, whereby detailed information on the wastes is obtained from existing published or documented waste analysis data or studies conducted on hazardous waste generated by processes similar to that which generated the waste; facility records of analysis performed before the effective date of RCRA; and sampling and waste analysis data obtained from generators of similar wastes that send their wastes off-site for treatment, storage, or disposal (EPA 1994a). If it is determined that AK alone is insufficient to accurately characterize a waste, radiography and/or VE may be used to complete the waste characterization process and satisfy the requirements of the WAP. AK is used in TRU waste characterization activities in the following five ways:

- To delineate TRU waste streams;
- To assess whether TRU mixed wastes comply with the TSDF-WAC;
- To assess whether TRU wastes exhibit a hazardous characteristic (New Mexico Hazardous Waste Management Regulations in 20.4.1.200 NMAC incorporating 40 CFR §261 Subpart C);
- To assess whether TRU wastes are listed (20.4.1.200 NMAC, incorporating 40 CFR §261 Subpart D); and
- To estimate waste material parameter weights.

AK includes any documentation that describes or verifies site history, mission, and operations, in addition to waste stream-specific information used to define the generating process, waste matrix, waste quantities and contaminants (radiological and chemical). At a minimum, the waste process information on each waste stream includes the following written information:

- Areas and buildings from which the waste stream was or is generated;
- The waste stream volume and time period of waste generation;
- Waste generating process described for each building (e.g., batch waste stream generated during decommissioning operations of gloveboxes), including processes associated with U134 waste generation, if applicable;
- Documentation regarding how the site has historically managed the waste, including the historical regulatory status of the waste (i.e., TRU mixed versus TRU non-mixed waste);

- Process flow diagrams. In the event that a process flow diagram cannot be created, a description of the waste generating process, rather than a formal process flow diagram, is used to satisfy this requirement. The use of the waste generating process description is justified, and the justification is placed in the AK record; and
- Material inputs or other information that identify the chemical content of the waste stream and physical waste form (e.g., glovebox materials and chemicals handled during glovebox operations; events or processes that may have modified the chemical or physical properties of the waste stream after generation; data obtained through VE of newly generated waste that later undergoes radiography; information demonstrating neutralization of ^{134}U [hydrofluoric acid] and waste compatibility).

Additionally, CCP collects information as appropriate to augment required information and provide any other information obtained to further delineate waste stream. Adequacy of the information is assessed by DOE during audits. CCP uses this information to compile the AK written record.

All additional specific, relevant AK documentation assembled and used in the AK process, whether it supports or contradicts any required AK documentation shall be identified and an explanation provided for its use (e.g., identification of a toxicity characteristic). Additional documentation may be used to further document the rationale for the hazardous characterization results. The collection and use of additional information shall be assessed by DOE during site audits to ensure that hazardous waste characterization is supported, as necessary, by such information. Similar to required information, if discrepancies exist between additional information and the required information, then CCP may consider applying all hazardous waste numbers indicated by the additional information to the subject waste stream, but must assess and evaluate the information to determine the appropriate hazardous waste numbers consistent with RCRA requirements. All information considered must be documented and placed in the auditable record, including applicable discrepancy resolution documentation. Additional AK documentation includes, but is not limited to, the following information:

- Process design documents (e.g., Title II Design);
- Standard operating procedures that may include a list of raw materials or reagents, a description of the process or experiment generating the waste, and a description of wastes generated and how the wastes are managed at the point of generation;
- Preliminary and final safety analysis reports and technical safety requirements;
- Waste packaging records;
- Test plans or research project reports that describe reagents and other raw materials used in experiments;
- Site databases (e.g., chemical inventory database for Superfund Amendments and Reauthorization Act Title III requirements);
- Information from site personnel (e.g., documented interviews);
- Standard industry documents (e.g., vendor information);

- Analytical data relevant to the waste stream, including results from fingerprint analyses, spot checks, routine verification sampling or other processes that collect information pertinent to the waste stream. This may also include new information which augments required information (e.g., VE not performed in compliance with the WAP, radiography screening for prohibited items);
- Material Safety Data Sheet, product labels, or other product package information;
- Sampling and analysis data from comparable or surrogate waste streams (e.g., residues, equivalent nonradioactive materials); and
- Laboratory notebooks that detail the research processes and raw materials used in an experiment.

Discussion of CCP development and approval of AK with respect to the LA-MIN02-V.001 waste stream is detailed in Section 6.0 of this report, “Forensic Analysis of Panel 7 Room 7”.

4.1.2 Radiography and Visual Examination

Radiography and VE are nondestructive qualitative and quantitative techniques used to identify and verify waste container contents. The CCP performs radiography or VE of all CH TRU waste containers in waste streams except for those waste streams for which the DOE approves a Determination Request. VE consists of either observing the filling of waste containers or opening full containers and physically examining their contents. Radiography and/or VE are used to examine a waste container to verify that the physical form of the waste matches its waste stream description as determined by AK. These techniques detect observable liquid in excess of TSDF-WAC limits and containerized gases which are prohibited for WIPP disposal. The prohibition of liquid in excess of TSDF-WAC limits and containerized gases prevents the shipment of corrosive, ignitable, or reactive wastes. If the physical form does not match the waste stream description, the waste is designated as another waste stream and assigned the preliminary hazardous waste numbers associated with that new waste stream assignment. If radiography and/or VE indicate that the waste does not match the waste stream description produced by AK characterization, an NCR is completed and the inconsistency resolved and the NCR dispositioned. The proper waste stream assignment is determined (including preparation of a new WSPF), the correct hazardous waste numbers are assigned, and the resolution is documented.

If CCP uses VE, the detection of any liquid in non-transparent internal containers, detected from shaking the internal container, is handled by assuming that the internal container is filled with liquid and adding this volume to the total liquid in the container being characterized using VE. The container being characterized using VE is then repackaged or rejected to exclude the internal container if it does not meet the requirements of the TSDF-WAC. When radiography is used or VE of transparent containers is performed, if any liquid in internal containers is detected, the volume of liquid is added to the total for the container being characterized using radiography or VE. Radiography, or the equivalent, is used as necessary on the existing or stored waste containers to verify the physical characteristics of the TRU waste corresponding with its waste stream identification and waste matrix code and to identify prohibited items.

4.2 Waste Stream Profile

After a complete AK record had been compiled and either a Determination Request had been approved by the DOE or the CCP had completed the applicable representative testing requirements specified in Section C1 of CCP-PO-001, the CCP would have completed a Waste Stream Profile Form (WSPF) and Characterization Information Summary (CIS) (T2). The requirements for the completion of a WSPF and a CIS were specified in Sections C3-6b(1) and C3-6b(2) respectively of CCP-PO-001. Specific instructions were provided in CCP-TP-002, CCP Reconciliation of Data Quality Objectives and Reporting Characterization Data.

The WSPF and the CIS for the waste stream resulting from waste characterization activities were transmitted to the permittees, who would have reviewed them for completeness, and screen them for acceptance before the CCP proceeded with payload assembly of TRU waste into the CH or RH Packaging. The review and approval process would have ensured that the submitted waste analysis information was sufficient to meet the data quality objectives (DQOs) for AK in Section C-4a(1) and allowed the permittees to demonstrate compliance with the requirements of the WIPP-WAP. Only TRU waste that met the characterization requirements of the WAP was certified by the CCP. Only waste certified that met the TSDF-WAC, specified in the WAP, was accepted at the WIPP facility for disposal in the permitted underground Hazardous Waste Disposal Unit (HWDU). DOE would have approved and provided NMED with copies of the approved WSPF and accompanying CIS prior to waste stream shipment. Upon notification of DOE’s approval of the WSPF, the CCP would have been authorized to ship waste to WIPP.

In the event that the permittees request detailed information on a waste stream, the CCP provided a Waste Stream Characterization Package, as described in Section C3-6b(3) of CCP-PO-001. For each waste stream, this package would have included the WSPF, the CIS, and the AK summary. The Waste Stream Characterization Package would have also included specific Batch Data Reports (BDRs), and raw data associated with waste container characterization as requested by the permittees.

4.3 Waste Certification

CCP-TP-030, *CCP CH TRU Waste Certification and WWIS/WDS Data Entry*, describes the steps the CCP uses for certifying CH TRU waste for disposal at WIPP. It also describes the process for entering data into the WWIS/WDS and reporting data on containers for disposal at the WIPP.

4.3.1 Responsibilities

Site Project Manager (SPM) or Designee

- Confirms that personnel performing CCP-TP-030 are trained and qualified in accordance with applicable requirements in CCP-QP-002.
- Prepares a list of candidate containers for certification and submits to the Waste Certification Official (WCO) and Waste Certification Assistant (WCA).
- Notifies the WCO and WCA of approved Waste Stream Profile Form (WSPF).
- Notifies the WCO and WCA of completed Lot CIS.

- Serves as focal point for resolution of data issues.

Quality Assurance (QA)

- Provides assistance in verifying data, completing documentation, and reviewing requirements and provides status of applicable Nonconformance Reports (NCRs).
- Confirms, individually and with an independent verification (does not have to be Quality Assurance [QA]), that there are no unresolved NCRs for containers to be certified when requested by the WCA or WCO.

Waste Certification Official (WCO) or Designee

- Confirms that WCOs and WCAs are granted access to the WWIS/WDS.
- Obtains a copy of the approved WSPF for applicable containers to be certified.
- Certifies the data for the container to be certified as identified on the WDS Spreadsheet.

Waste Certification Assistant (WCA)

- Works with the WCO to obtain access to the WWIS/WDS.
- Obtains copies of data for each container from CCP Records, item description code or the SPM that show data to be entered into the WDS Spreadsheet.
- Generates the WDS Spreadsheet and has a second WCA confirm the data are transferred correctly to the WDS Spreadsheet. The second data entry person verifies the information and places initials and date in the WDS Spreadsheet prior to certification by the WCO.
- Forwards the WDS Spreadsheet to the WCO for certification.
- Requests that QA confirm that NCRs associated with containers to be certified have been resolved, as appropriate, via electronic mail (E-mail).
- Submits the container data from the WDS Spreadsheet to the WWIS/WDS, as applicable.
- Submits data package to CCP Records Custodian in accordance with CCP-QP-008, *CCP Records Management.*

4.3.2 Process

Verifying WSPF in WWIS/WDS Tables and Listing Associated Containers

- Obtain the WSPF Number in accordance with CCP-TP-002, *CCP Reconciliation of DQOs and Reporting Characterization Data*;
- Request the DA establish the WSPF Number in the WWIS/WDS;
- Confirm that the WSPF Number is correct in the WWIS/WDS Reference Table upon notification that the DA has added the WSPF Number to the WWIS/WDS;
- Notify the WCO and WCA of the WSPF;

- Develop a list of containers for certification under the appropriate WSPF; and
- Review the list of containers for certification, revise as necessary, and submit the list to the WCO and WCA when the CIS is complete.

Entering and Verifying Characterization Data Using the WDS Spreadsheet

- Obtain, from CCP Records, integrated data center or the SPM, a copy of the appropriate WSPF, batch data reports, packaging records, AK summary report, AK tracking spreadsheet, and radiological survey data as applicable.
- Use copies of appropriate Batch Data Reports or other data source, from CCP Records, item description code or the SPM to enter characterization data for each container record used to support the WSPF.
- Enter DOE/WIPP-01-3194, CH TRU Waste Content Codes (CH TRUCON) or DOE/WIPP-11-3458, TRUPACT-III Content Codes (TRUCON-III), into the WWIS/WDS, as applicable.
- Enter shipping categories, if necessary.
- Enter initials and submit the completed WDS Spreadsheet to a second WCA for verification.
- The second WCA confirms the data entered for accuracy and completeness. If discrepancies are identified, corrections must be made by a WCA. Completed and verified WDS data sheets are submitted to the WCO.

Waste Certification (By Container of Waste)

- Using the appropriate WDS spreadsheet, confirm that the TRU alpha activity concentration is greater than 100 nanocuries per gram for each payload container.
- Confirm that the WDS spreadsheet contains accurate and complete information for each waste container by verifying that the WCA has completed their input and review.
- Verify that each container has no unresolved Nonconformance Report (NCR)s.
- Verify that the WDS Spreadsheet contains the correct WSPF Number for that container as listed in the AK tracking spreadsheet.
- Verify at least one TRU isotope is greater than the lower limit of detection for waste containers.
- Confirm that WCO waste certification requirements criteria are met.
- Confirm that waste containers meet methane and gas generation testing requirements.
- When container is considered certifiable, then sign and date the WDS spreadsheet and forward for submittal to the WWIS/WDS.

4.4 Analysis of Section 4.0 - Central Characterization Program

The AK process requirements listed in CCP-PO-001 includes the following information:

> *At a minimum, the waste process information on each waste stream includes the following written information:…Material inputs or other information that identify the chemical content of the waste stream and physical waste form (e.g., glove box materials and chemicals handled during glove box operations; events or processes that may have modified the chemical or physical properties of the waste stream after generation; data obtained through VE of newly generated waste that later undergoes radiography; information demonstrating neutralization of U134 [hydrofluoric acid] and waste compatibility).*

The Board determined that the upper tier requirements stated in CCP-PO-001 are satisfactory in describing the necessary content for development of AK documents. However, CCP and their subcontractor did not ensure that AK Summary Report CCP-AK-LANL-006 accurately represented the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.

A detailed evaluation of the revised WCRRF glovebox procedure should have identified the incorrect direction to use organic absorbent in that document instead of the addition of zeolite clay material specified in the CBFO-directed controls containing the LANL-CO Difficult Waste Team white paper and the EMRTC Report RF10-13.

However, CCP-PO-001 also states in Section C-3b, Radiography and Visual Examination, that:

> *The prohibition of liquid in excess of TSDF-WAC limits (and therefore the WIPP WAC) and containerized gases prevents the shipment of corrosive, ignitable, or reactive wastes. Radiography and/or VE are also able to verify the physical form of the waste matches its waste stream description.*

The Board concluded that these statements are not correct, as evidenced by the reclassification of the MIN02 waste stream. Although no free liquid was confirmed by RTR, the waste was later determined by LANS to be considered ignitable. The nitrate matrix, by nature of associated hazards, supported classifying the entire LA-MIN02-V.001 as ignitable per 40 CFR 261.21 because:

- it is an oxidizer; and
- the addition of the organic absorbent created conditions that made the waste capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, of burning so vigorously and persistently that it creates a hazard.

Additionally, personnel interviewed indicated that VE would most likely not have resulted in identifying the addition of the organic absorbent and its impact on the waste stream. The Board determined that AK Summary Report CCP-AK-LANL-006 was the only means to provide assurance that a given waste stream was not ignitable, corrosive or reactive since RTR and VE were only able to identify the absence of free liquid. Additionally, RTR of the LA-MIN02-V.001 waste stream was unable to distinguish between organic and inorganic materials. AK must include any packaging and process changes to ensure the AK remains accurate and relevant.

CON 5: Implementation of requirements listed in CCP-PO-001, *CCP Transuranic Waste Characterization Quality Assurance Project Plan,* did not ensure that waste characterization methods and Acceptable Knowledge (AK) were effective in preventing the shipment of corrosive, ignitable, or reactive wastes.

JON 7: The Central Characterization Program (CCP) needs to improve implementation of requirements in CCP-PO-001 such that characterization methods are able to ensure that all Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC) requirements are met.

5.0 LA-MIN02-V.001 Waste Stream

5.1 Origin of Nitrate Salt Waste Stream

All of the absorbed liquid waste originated from the recovery, fabrication, research and development, and associated maintenance operations in the TA-55, PF-4. Nitrate operations were conducted in order to recover plutonium from scrap and residues, and produce a purified plutonium oxide product, or for conversion into metal. The primary feed sources for the nitrate operations were plutonium residues from other recovery operations (e.g., chloride operations), metal preparation, metal fabrication, analytical laboratory operations, and residues from other DOE facilities. Nitrate operations consisted of the following six steps:

- Pretreatment;
- Dissolution;
- Purification and Oxide Conversion/Refinement;
- Americium Oxide Production;
- Evaporation; and
- Cement Fixation.

The Evaporator processed plutonium-poor liquids in order to re-concentrate plutonium, if possible, or to reduce the volume of liquid waste. These solutions were collected in tanks and sent to the evaporators in batches of up to 600 liters. The solution batches were then concentrated to approximately 25 liter volumes, called "bottoms." These cooled salts precipitated out as nitrate salts and settled on the bottom of cooling trays. After cooling, the bottoms were sent back to ion exchange if plutonium concentrations were above the discard limit (DL) or to cement fixation if concentrations were below the DL. Attempts were made to re-dissolve settled salts, but if this was not readily achievable, the salts were sent to dissolution if plutonium concentrations were above the DL or sent to cement fixation if concentrations were below the DL. Nitric acid was used in the evaporator to wash nitrate salts having a plutonium concentration above the DL.

Prior to 1992, nitrate salts below the DL were not sent to cement fixation for immobilization but were packaged as waste. These salts were washed, vacuum dried (to reduce, but not eliminate, moisture content), double- (or triple-) bagged, and placed in 55-gallon drums. There was no established moisture level in the vacuum drying process. The length of the drying process could vary greatly from as short as 15 minutes to as long as one weekend depending on production schedule demands.

5.2 Post Generation History

5.2.1 CCP-AK-LANL-006, Acceptable Knowledge Summary Report

Acceptable Knowledge document CCP-AK-LANL-006, *Central Characterization Program, Acceptable Knowledge Summary Report for Los Alamos National Laboratory, TA-55 Mixed*

Transuranic Waste Streams: LA-MHD01.001, LA-CIN01.001, LA-MIN02-V.001, and LA-MIN04-S.001, was prepared for the CCP for CH TRU waste generated at TA-55 of LANL. It was prepared in accordance with CCP-TP-005, *CCP Acceptable Knowledge Documentation*, to implement the AK requirements of the WIPP HWFP, WIPP WAP and the DOE/WIPP-02-3122, *Transuranic Waste Acceptance Criteria for the Waste Isolation Pilot Plant* (WIPP WAC). The WIPP-WAP AK requirements are addressed in CCP-PO-001, *CCP Transuranic Waste Characterization Quality Assurance Project Plan*. The WIPP WAC AK requirements are also addressed in CCP-PO-002, *CCP Transuranic Waste Certification Plan*. CCP-AK-LANL-006 provides the AK information required by CCP-PO-003, CCP *Transuranic Authorized Methods for Payload Control (CCP CHTRAMPAC).*

As documented in the Executive Summary of CCP-AK-LANL-006, the CCP is tasked with certification of CH TRU waste for transportation to and disposal at WIPP. CCP procedure CCP-TP-005, describes how AK is compiled and confirmed by the CCP. The CCP is responsible for collection, review, and management of AK documentation in accordance with CCP-TP-005 and reviews and approves the AK summary report. CCP maintains responsibility for the AK summary report.

5.2.1.1 CCP-AK-LANL-006, Revision 7

CCP-AK-LANL-006, Revision 7, released in November 2007, introduced the new absorbed liquid homogeneous solid waste stream number LA-MIN02-V.001. "LA" indicates that the waste stream originated at LANL, and MIN represents mixed inorganic material. Based on the evaluation of the materials contained in this waste stream and LANL waste management practices, waste stream LA-MIN02-V.001 is comprised of greater than 50 percent by volume absorbed liquid waste, since the population of containers at the time Revision 7 was issued consisted of 44 drums of absorbed liquid. Therefore, Waste Matrix Code S3110, inorganic particulate waste was assigned to waste stream LA-MIN02-V.001.

The waste material parameters for waste stream LA-MIN02-V.001 were estimated assuming approximately one gallon of TRU liquid absorbed by vermiculite was placed into either a 5-mil plastic bag or a 1-gallon can, and subsequently placed in a bag-out bag prior to being placed in the 55-gallon drum. A conservative approach was taken with respect to the absorbed liquid. Unless specified otherwise, the liquid absorbed by the vermiculite was assumed to be an organic matrix. Vermiculite is known to absorb approximately 250 percent of its weight in liquid; therefore, the vermiculite/organic matrix would be considered to be greater than 50 percent organic matrix. Average, minimum, and maximum waste material parameters weight percentages were calculated using this data. These calculations concluded that the relative waste weight percentages for organic waste materials (primarily organic liquid matrix absorbed in vermiculite and plastic bags) and inorganic waste materials (primarily steel cans and vermiculite saturated with inorganic matrix) for waste stream LA-MIN02-V.001 was 87.46 percent and 12.54 percent, respectively.

In Section 7.4.3.4, "Ignitables, Reactives, and Corrosives," the following information was provided:

- *D001 (ignitability) does not apply to the solid waste contaminated with aqueous and organic liquids because: (a) the solid waste is not liquid, and verification that there are no free liquids in the waste is performed prior to certification; (b) the solid waste does not spontaneously ignite at standard pressure and temperature through friction, absorption of moisture, or spontaneous chemical changes; (c) the solid waste is not an ignitable compressed gas; and (d) there are no oxidizers present.*
- *D002 (corrosivity) does not apply to the solid waste contaminated with aqueous acids and bases because the solid waste is not a liquid, and verification that there are no free liquids in the waste is performed prior to certification.*
- *D003 (reactivity) does not apply to the solid waste because it does not possess any of the reactivity properties listed in 40 CFR 261.23.*

This revision was dated nearly four years prior to any concerns being raised about nitrate salt because at that time organic liquid was discussed as being cemented as part of the CIN01 waste stream and therefore rendered inert. From the waste stream description in Revision 7:

> *"Waste stream LA-MIN02-V.001 consists of inorganic particulate waste generated during plutonium recovery, fabrication, R&D, facility and equipment operations, and maintenance processes. The waste is largely comprised of TRU liquids such as oils and solvents absorbed in vermiculite. Vermiculite is a hydrated magnesium-aluminum-iron silicate, it is lightweight, inorganic (noncombustible), compressible, highly absorbent, and non-reactive (compatible in many chemical compositions). TRU liquids absorbed in vermiculite are typically generated during fuel source fabrication, maintenance of equipment, metallography, and oil recovery activities and potentially contain high concentrations of actinides. Examples of absorbed liquids include carbon tetrachloride; ethylene glycol; kerosene; methylene chloride; silicone based liquids (e.g., silicone oil); tetrachloroethylene; trichloroethylene; and various types of oils including hydraulic, vacuum pump, grinding, and lapping (mixture of mineral oil and lard). The waste is also expected to contain heavy metals such as cadmium, chromium, and lead. Organic liquids not absorbed in vermiculite are often cemented and disposed of in waste stream LA-CIN01.001. Other types of absorbents which may be contained in this waste stream include Ascarite, diatomaceous earth, and zeolite. A small fraction of debris waste (mainly plastic and metal packaging) and metal fines may also be present. Any payload container consisting of more than 50 percent by volume of heterogeneous debris will be excluded from this waste stream."*

Section 7.4.4 addressed prohibited items. Prohibited items were not expected to be present. However, procedures allowed containers greater than four liters, sealed with tape, to be used for waste packaging until WIPP certification procedures were implemented. In addition, the potential for residual liquids due to dewatering was anticipated. Lead shielding was used to increase handling safety, and thick shielding can obscure RTR observations. Prohibited items were detected by RTR or VE and reported with the characterization results. Waste containers with prohibited items were to be segregated then dispositioned appropriately and/or repackaged, during which time liquids were absorbed, sealed containers greater than four liters were opened, and other items were removed and segregated if necessary prior to certification and shipment. Some secondary waste generated during remediation/repackaging activities may be added to the waste containers including the absorbent WasteLock® 770, rags and wipes containing Fantastik® used during decontamination, personal protective equipment, and rigid liner lids that have been cut into pieces.

Section 11 contained supplemental waste stream information. Included were:

- PLAN-WASTEMGT-002, *LANL Waste Acceptance Criteria*;
- Interview with the Team Leader of the Difficult Waste Team of TA-55 Nitrate Operations re: Draft AK Summary for TA-55 Nitrate Operations, January 19, 1999;
- EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations,* Revision 5;
- *Evaluation of LANL ^{238}Pu Waste Management Practices*;
- *Remediation/Repackaging Secondary Waste Disposition*;
- NMT7-WI3-HCP-TA-55-013, *Packing TRU Waste Containers*;
- DTP-00-001, *Waste Visual Examination and Packaging*; and
- 406-GEN, *Standard Operating Procedure for the Waste Management at TA-55*, Revision 0.

5.2.1.2 CCP-AK-LANL-006, Revision 8.

CCP-AK-LANL-006, Revision 8, was released in March of 2008. Among other changes, this revision addressed repackaging and Decontamination and Decommissioning operations. There were no significant changes related to the LA-MIN02-V.001 waste stream.

Section 11 continued to list EP-WCRR-WO-DOP-0233, Revision 5, *WCRRF Waste Characterization Glovebox Operations* although Revision 10 was released in January 2008.

5.2.1.3 CCP-AK-LANL-006, Revision 9

CCP-AK-LANL-006, Revision 9, was released in January of 2009. There were no significant changes related to the LA-MIN02-V.001 waste stream.

Section 11 continued to list EP-WCRR-WO-DOP-0233, Revision 5, *WCRRF Waste Characterization Glovebox Operations* although Revision 11 was released in March 2008.

5.2.1.4 CCP-AK-LANL-006, Revision 10

CCP-AK-LANL-006, Revision10, was released in May 2010. This revision added containers to the LA-MIN02-V.001 waste stream. Other than that, there were no significant changes related to the LA-MIN02-V.001 waste stream.

Section 7.4.4.2 was revised to read, "Some secondary waste generated during remediation and repackaging activities may be added to the waste containers, including but not limited to: absorbent (e.g., WasteLock® 770). Fantastik® bottles used during decontamination, miscellaneous hand tools, paper/plastic tags and labels, plastic/metal wire ties, PPE, rags and wipes (Kimwipes), rigid liner lids cut into pieces."

Section 11 continued to list EP-WCRR-WO-DOP-0233, Revision 5, WCRRF Waste Characterization Glovebox Operations although Revision 18 was released in March 2010.

5.2.1.5 CCP-AK-LANL-006, Revision 11

CCP-AK-LANL-006, Revision 11, was released in September of 2011. This revision deleted the Supplemental Waste Stream Information section. There were no significant changes related to the LA-MIN02-V.001 waste stream.

Section 11 continued to list EP-WCRR-WO-DOP-0233, Revision 5, WCRRF Waste Characterization Glovebox Operations although Revision 29 was released in August of 2011.

5.2.1.6 CCP-AK-LANL-006, Revision 12

CCP-AK-LANL-006, Revision 12, was released in December 2012. This revision expanded the waste stream description for LA-MIN02-V.001 and added TRUCON code LA226; to add new TA-54 repackaging facility description.

Section 7.4.1.2 was revised to update the discussion regarding the use of inorganic absorbent (e.g., kitty litter, zeolite). Additionally, previous reference to vermiculite was significantly reduced.

Section 7.4.3.4 was revised to reflect that the salts were to be remediated/repackaged in the WCRRF with an inert absorbent material (e.g., kitty litter, zeolite). The minimum inert absorbent material to nitrate salts mixture ratio was specified as 1.5 to 1. LANL determined that nitrate salts, when mixed with inert absorbent material, would further support the managing of the waste as non-ignitable. This determination was based on the results of oxidizing solids testing performed by the Energetic Materials Research and Testing Center. It further concluded that the materials in the LA-MIN02-V.001 waste stream were therefore not ignitable wastes.

Section 11, AK Source Documents contained a table of documents used in preparing the summary report. The following documents were included:

- *WCRRF Waste Characterization Glovebox Operations* (although there was no reference to procedure number or revision although this revision of the AK document occurred after a major rewrite of the WCRRF Glovebox Operations Procedure in Revision 37);

- *Solution Package Scope Definition, Report 72, Salt Waste (SP #72)* Revision 1;
- *Results of Oxidizing Solids Testing - EMRTC Report FR 10-13*; and
- *Amount of Zeolite Required to Meet the Constraints Established by the EMRTC Report FR 10-13: Application to LANL Evaporator Nitrate Salts*.

5.2.2 Los Alamos National Laboratory Reports of Non-Compliance to NMED

During the investigation, LANL formally reported several instances of noncompliance to the State of New Mexico Environment Department. As a result of reevaluating waste characterization information associated with the nitrate salt-bearing waste containers described in the *Central Characterization Project (CCP) Acceptable Knowledge Summary Report CCP-AK-LANL-006*, LANL reported the following instances of noncompliance:

On July 1, 2014:

- ES performed unpermitted treatment of the remediated nitrate salt-bearing wastes. Processing of nitrate salt-bearing waste drums was outside the permit exemptions for treatment activities required by NMED rules. The processing did not qualify for the elementary neutralization treatment permit exemption because the waste stream was assigned multiple EPA Hazardous Waste Numbers (D and F) and was not a hazardous waste solely due to the corrosivity characteristic (D002). In addition, the processing involved the addition of absorbents in locations that did not meet the permit exception that absorbent be added "the first time" the waste is placed in a "container."
- LANS failed to reevaluate the AK determination when pH results indicated the nitrate salt-waste was RCRA corrosive. During processing of nitrate salt-bearing waste, operators conducted pH tests and determined that some of the decanted liquids had a pH less than two and were RCRA corrosive. Based on these results, LANS should have reevaluated the unconsolidated nitrate salt-bearing waste to assess the accuracy of the initial characterization.

On September 5, 2014, in response to an NMED request for information, LANL:

- Explained the provisional application of the D001 waste code to the nitrate salt-bearing waste: LANL conservatively applied the D001 waste code to the nitrate salt-bearing waste pending the completion of a review of the characterization. Application of D001 was considered "provisional" until and unless re-characterization determined it was not applicable.
- Explained why D001 was assigned to both remediated and un-remediated nitrate salt-bearing waste containers: The un-remediated waste was tested and found to be an oxidizer. Samples of a surrogate of the remediated waste was tested and also found to be an oxidizer.
- Explained why LANL applied D002 to the un-remediated nitrate salt-bearing waste containers: LANL reviewed operating records associated with remediation of the nitrate salt-bearing waste and determined that a few of the parent containers had pH of two or less. LANL then evaluated the remaining un-remediated containers to identify those with free liquids (via high energy RTR). This testing identified 26 of 29 containers as having free liquids. As a conservative measure, LANL applied D002 to these containers.

- Provided an update on the plans and schedules for treatment and disposal of 57 remediated nitrate salt-bearing containers to remove the D001 (ignitability) and D002 (corrosivity) characteristics.

On October 21, 2014, LANL further identified to NMED that:

- LANS failed to conduct an adequate hazardous waste determination: Prior characterization of the nitrate salt-bearing waste did not properly characterize the waste as RCRA ignitable.
- LANS failed to comply with the LANL HWFP:
  - Nitrate salt-bearing wastes did not fully meet the LANL HWFP “special requirements” for managing ignitable wastes, including segregation and separation, and use of non-sparking tools;
  - Did not comply with the LANL HWFP requirement that the nitrate salt-bearing waste drums be labeled with all applicable EPA Hazardous Waste Numbers;
  - Placed incompatible wastes and materials in the same container and did not impose special precautions;
  - Did not label the nitrate salt-bearing waste prior to transport and remediation at the WCRRF; and
  - Did not label the unremediated nitrate salt-bearing waste drums which contained liquids as RCRA corrosive.
- LANS failed to package, label, and ship the nitrate salt-bearing waste to both WIPP and WCS as RCRA ignitable and in compliance with DOT regulations. LANS shipped the remediated nitrate salt-bearing waste drums to WIPP and WCS without packaging and labeling them appropriately for the RCRA D001 corrosivity characteristic. The presence of organic absorbent in some of the nitrate salt-bearing waste containers was not appropriate for the Type B package authorized for shipment and the drums were not labeled for the additional hazard class as required by DOE.

5.2.3 Idaho National Laboratory Accelerated Retrieval Project Nitrate Salts

Nitrate salt bearing waste from Idaho is relevant to the investigation since the identification of nitrate salt during excavation of targeted waste from the Accelerated Retrieval Project (ARP) led to the development of EMRTC Report FR 10-13, *Results of Oxidizing Solids Testing*, which served as the base document for decisions regarding the LA-MIN02-V.001 waste stream. The following discussion highlights the course of action that was developed and implemented to address the self-disclosed discovery at the Idaho National Laboratory.

Shortly after the opening of the ARP II area of the Radioactive Waste Management Complex at the Idaho National Laboratory, in August 2007, waste containing a material that looked like salt began to appear in trays of targeted waste. After a review of AK documentation and disposal records, it was concluded that the salt was from Rocky Flats Plant (RFP) Series 745 waste drums. Disposal records show that about 10,500 cubic feet of salt waste was disposed in areas processed as ARP II, ARP III, and ARP V.

During the fall of 2007, a series of meetings were held to address this issue. Participants included representatives from the Advanced Mixed Waste Treatment Plant (AMWTP), the CCP, and CH2M-WG Idaho, LLC (CWI), the waste generator. Within each organization, participant groups included waste operations, engineering, regulatory compliance, and program management. Consensus was reached that as long as trays of waste contain less than 40 percent by weight salt, the material is not considered ignitable. This was documented in EDF-8723, *Allowable Nitrate Salt Concentration in ARP Waste,* Revision 1, effective July 3, 2008.

EDF-8723, Revision 2, was approved June 29, 2010. The following paragraphs were taken from that revision:

> *According to cited records, the sludge contains about 60 percent sodium nitrate and 30 percent salts when mixed with other materials, a concern was raised that salt-contaminated waste might be ignitable or reactive under Resource Conservation and Recovery Act (RCRA) regulations. Studies were completed in 2003 and 2010 that address the oxidizing characteristics of targeted wastes combined with nitrate salts from non-targeted waste. It was determined that targeted waste containing relatively high concentrations of nitrate salt are oxidizers.*

A burn rate study, commissioned by Washington TRU Solutions, was performed at the New Mexico Institute of Technology in early 2010 (EMRTC Report FR 10-13, *Results of Oxidizing Solids Testing*, dated 4/12/2010). This study used two different types of waste surrogate. The first was potassium nitrate combined with zeolite, an aluminosilicate mineral. The second type of surrogate was potassium nitrate combined with powdered grout. The procedure used was EPA's Method 1040. However, tests were performed only at the 1:1 ratio with cellulose. No tests at the 4:1 ratio were conducted. The zeolite can be considered representative of ARP soil waste, but the grout surrogate does not represent any of the ARP waste streams. Unlike the 2003 study, which used a nitrate salt mixture that simulated evaporator salt from the Rocky Flats Plant, the 2010 study used 100 percent potassium nitrate salt. This is considered conservative, since potassium nitrate is somewhat more reactive than sodium nitrate. In this study, the 3:7 potassium bromate-cellulose standard was found to have a burn time of 191 seconds. Various mixtures of salt-grout and salt-zeolite were tested in an attempt to find the highest concentration of nitrate salt in the waste surrogates that would not cause the surrogate to be identified as an oxidizer. These results are summarized in the table below:

Table 5-1: Upper Limit of Nitrate Salt from 2010 EMRTC Study

Upper Limit of Nitrate from 2010 EMRTC Study				
Cellulose (%)	**KNO3 (%)**	**Zeolite (%)**	**Grout (%)**	**Percent of KNO3 in Surrogate**
50	33	18		65%
50	22.5		27.5	45%

Several useful observations were made from this study. First, the results for zeolite provided some evidence of the performance of a surrogate somewhat representative of ARP soil waste. A 2003 study used a surrogate representative of graphite debris waste. The inorganic surrogate appeared less likely to be an oxidizer at a given nitrate salt concentration than did the graphite. Second, the data showed that the burn time for the 3:7 potassium bromate-cellulose standard can vary significantly. While DOT lists a typical value of 100 seconds, this study demonstrated that the value could be much higher. A value of 191 seconds was reported. In a third study performed in 2010, the standard yielded a burn time of 112 seconds. Therefore, it is prudent to interpret burn rate data conservatively. Lastly, since no testing was performed at the 4:1 waste-to-cellulose ratio, the study results cannot be used to determine compliance with DOT oxidizer regulations. ARP waste with up to 65 percent nitrate salt could be an oxidizer, but the data did not allow for verification.

EDF-8723 and the associated referenced material, recommended that any waste packaged for shipment to WIPP be limited to 30 percent nitrate salt by weight (22 percent assumed maximum non-visible salt plus 8 percent maximum visible salt). Below this concentration, targeted sludge, soil, and graphite wastes are not considered ignitable. In addition, these wastes are not reactive according to RCRA definitions. The waste would also not be considered to be an oxidizer under DOT transportation regulations. Nitrate salt should be manually removed from targeted waste in trays to the extent practicable prior to drumming the waste.

While the results of the 2003 and 2010 studies could be used to argue for a higher concentration limit, there are four primary reasons for choosing a 30 percent total nitrate salt limit for ARP waste going to WIPP:

1. Only a limited number of waste surrogates were tested. Waste surrogates with oil, solvent, or fibrous material (i.e., filters) were not tested. It is expected that the surrogates tested are bounding for all ARP waste. Nevertheless, the available data should be interpreted conservatively to allow for uncertainty.
2. Relatively little data are available on the few waste forms that were tested. The test results from the 2010 study cannot be used for comparison with DOT requirements, and only a small number of nitrate salt concentrations were evaluated in the 2003 study. The presence of an outlier at 43.5 percent nitrate salt in the 2003 results cannot readily be explained, so the proposed limit was chosen to stay well away from suspect results.
3. The 3:7 potassium bromate-cellulose standard is not a constant value for comparison. The DOT "nominal" value is 100 seconds. However, the 2010 study reported burn times around 191 seconds for this standard. A recent study performed on low-level waste reported a burn time of 112 seconds for the 3:7 standard. This variability in the standard of comparison suggests that selection of a conservative nitrate salt limit is warranted. The proposed 30 percent nitrate salt limit in waste will be appropriate, even assuming a relatively fast burn time for the potassium bromate-cellulose standard of comparison, i.e., the 100-second nominal DOT value.
4. Over 700 drums of waste containing visible nitrate salt have been generated and stored during ARP operations. Of these, only two have been characterized with more than 8 percent visible salt. The overwhelming majority of the nitrate-bearing drums meet the proposed limit, and it is expected that future drums containing nitrate salt will also meet this

limit. The 30 percent total nitrate limit would not impose significant restrictions on ARP operations.

The EMRTC Report FR 10-13, *Results of Oxidizing Solids Testing*, dated April 12, 2010, cited in EDF-8723, Revision 2, is the same test report that later served as the basis for repackaging decisions regarding the LA-MIN02-V.001 waste stream.

5.2.4 Los Conchas Fire and Framework Agreement

On June 27, 2011, the Los Conchas wildfire came within 3.5 miles of TRU waste stored above ground in Area G of the Los Alamos National Laboratory. Driven by concerns about the threat of future wildfires to the above ground TRU waste, NMED entered into a nonbinding framework agreement with NNSA/DOE in January 2012, to reprioritize and expedite shipment of above ground TRU waste to WIPP. A target date of June 30, 2014, was established to ship 3706 cubic meters of waste from LANL.

5.3 Repackaging Operations

5.3.1 Early Repackaging Operations

Waste repackaging and prohibited item disposition was performed in two facilities outside of TA-55. The first facility was established in 1979 at TA-50 as the Size Reduction Facility to size reduce non-routine items such as decommissioned gloveboxes, ductwork, and process equipment to fit in 55-gallon drums or Standard Waste Boxes. A plasma torch was commonly used during size reduction activities to cut up these large items into manageable pieces. The SRF historically combined waste from multiple facilities and these containers were identified and characterized under a separate TA-50 waste stream. As LANL TRU waste characterization and certification activities increased, the mission of the SRF was expanded to include various operations to support TRU waste characterization. In 1993, the name of the SRF was changed to the Waste Characterization, Reduction, and Repacking Facility (WCRRF) to reflect the expanded remediation/repackaging mission. Size reduction operations at WCRRF were discontinued around 1997. The second remediation/repackaging facility was established in 2006 at the TA-54 Dome 231 Permacon and CCP personnel began observing these activities. Containers that fail to meet WIPP criteria are sent to the WCRRF or the Dome 231 Permacon to be safely remediated.

These outside facilities at LANL are used to perform VE, repackaging, and prohibited item dispositioning of TRU waste. VE is performed to provide information that is used to:

1. Confirm the results of RTR on a statistically selected number of the TRU waste container population;
2. Confirm the waste stream delineation by AK;
3. Ensure the absence of prohibited items; and
4. Characterize retrievably stored waste with inadequate AK, in lieu of RTR.

Waste containers with prohibited items are segregated then dispositioned appropriately and/or repackaged into new drums, during which time liquids are absorbed, sealed containers greater than four liters are opened, and other items removed and segregated if necessary prior to certification and shipment. Waste items with a dose rate greater than 190 mrem/hr may be repackaged into a POP container. Current repackaging procedures ensure that waste items placed into a new container originated from a single parent container. Therefore, if repackaging is necessary, the original TA-55 characterization is retained. Some secondary waste generated during remediation/repackaging activities may be added to the waste containers including the absorbent WasteLock® 770, rags and wipes containing Fantastik® used during decontamination, personal protective equipment, and rigid liner lids that have been cut into pieces.

5.3.2 3706 Related Repackaging Operations

Remediation of nitrate salts at the WCRRF, using glovebox procedure EP-WCRR-WO-DOP-233, *WCRRF Waste Characterization Glovebox Operations*, began in the fall of 2011, although the procedure contained no specific steps for processing nitrate salts. WasteLock® 770 was being used in an attempt to absorb free liquids with limited success. This was attributable to failure to adjust to a neutral pH in accordance with manufacturer's instructions. A significant amount of WasteLock® 770 was being used in an attempt to absorb free liquids. However, in July of 2011, LANL-CO personnel had become aware that there were a number of waste containers in the population that contained unsolidified nitrate salts that were representative of an oxidizer (ignitable) therefore, not acceptable at WIPP. On August 1, 2011, there was an e-mail communication from the LANL-CO Difficult Waste Team to ENV-RCRA at Los Alamos discussing the LANL nitrate salts and testing that had been conducted for a similar waste stream at the Idaho National Engineering Laboratory. Additionally the communication indicated that the current AK document was not sufficient and suggested "mixing the nitrate salts with kitty litter clay provides hard documentation in the WIPP AK to meet the WIPP WAC." LANL issued Memorandum, ENV-RCRA-12-0053, *Legacy TA-55 Nitrate Salt Wastes at TA-54 – Potential Applicability of RCRA D001/D002/D003 Waste Codes,* on February 29, 2012. This memorandum concluded with a high degree of confidence and after a thorough review that nitrate salt drums did not meet the Environmental Protection Agency (EPA) ignitability or reactivity definition and determined by the Board to be an incorrect conclusion. Additionally, the memorandum concluded that prior to certification for WIPP disposition that all containers need to undergo a waste examination process. Any liquids identified in the unconsolidated nitrate salt drums should be managed as potentially RCRA corrosive (D002) waste (unless otherwise shown by pH testing) and remediated prior to shipment off-site. *Solution Package Scope Definition, Report 72, Salt Waste (SP #72),* Revision 0, was developed to address the nitrate salt concern. In March 2012, LANL-CO Difficult Waste Team personnel discovered that WasteLock® 770, which contains sodium polyacrylate, had been used as described above. LANL-CO identified potential issues concerning the mixing of WasteLock® 770 (an organic) with nitrate salts (an oxidizer), which rendered the waste stream more dangerous because now an oxidizer was comingled with a fuel. This potential issue is supported by information obtained from EPA's Chemical Compatibility Chart regarding compatibility of chemical mixtures. The chart indicates that group 101, (Combustible and Flammable Materials, Miscellaneous) and group 104, (Oxidizing Agents, Strong) result in codes H, F, and G representing heat generation, fire, and innocuous and non-flammable gas generation, respectively. The chart also includes more specifically, that group 3 (Organic Acids, of which polyacrylates are an example) and group 104 (Oxidizing Agents, Strong) result in codes H, G, and T representing heat generation, fire and potentially toxic gas, depending on if the acid contains halogens or hetero atoms. This information indicates that the incompatibility of WasteLock® 770 with the nitrate salt bearing waste matrix extends beyond that of the nitric acid solution. All waste processing and characterization of nitrate salt bearing waste were put on hold until the CBFO request for treatment was resolved. In April 2012, meetings were held with LANL personnel, ES personnel and a LANL-CO Difficult Waste Team SME to discuss the processing of nitrate salts.

In May 2012, Revision 34 of procedure EP-WCRR-WO-DOP-233 was issued, but did not include changes related to the addition of absorbents to nitrate salts (processing of nitrate salts still on hold). LANL-CO Difficult Waste Team published report "Amount of Zeolite Required to Meet the Constraints Established by the EMRTC Report RF 10-13: Application to LANL Evaporator Nitrate Salts." The report was electronically transmitted to LANS via NA-LA and CBFO in June 2012. LANS produced SP #72, Revision 1 which was approved in July 2012. It identified the revised processing path and requirements for getting the nitrate salt drums shipped to WIPP. It stated, "Each liter of composite nitrate salt bearing waste is to be mixed with at least 1.2 liters of zeolite/kitty litter" as used in the LANL-CO Difficult Waste Team white paper.

EP-WCRR-WO-DOP-233, Revision 36 was issued in August 2012, which included a new Section 10.6, "Processing Nitrate Salt Drums." The Board identified that the procedure contained a long-standing (prior to Revision 28) precaution and limitation that stated, "Based on waste acceptance criteria, Class 1 oxidizers such as nitrates, and reactive flammables such as lithium metal or hydrides are prohibited items in the WCRRF." The words, "Ensure an organic absorbent (Kitty Litter/Zeolite® absorbent) is added to the waste material at a minimum of 1.5 absorbent to 1 part waste ratio" were added during the procedure revision process. The documented source of that direction was traced by the Board to an e-mail from an ES manager responsible for the glovebox operations. During a Board interview with the ES manager, the assertion was made that the word "organic" was specified due to personal notes taken during a meeting in May 2012. The manager recalled specific discussion related to that term during the meeting. The other party involved in the discussion disputed the ES manager's recollection. Regardless of the discussion, the Board noted that this direction conflicted with the CBFO-directed instructions for remediation of the nitrate salts. Subsequently, the procedure was revised per the e-mail without verifying that the selected absorbent was consistent with the absorbent prescribed in the CBFO-directed controls. The processing of SP #72, Revision 1, nitrate salts daughter drums that were previously treated with WasteLock® 770 was resumed utilizing this revision October 1, 2012. Processing of SP #72, Revision 1 parent drums commenced on February 1, 2013. Repackaging activities for nitrate salt bearing waste drums consisted of first decanting, then absorbing any free liquid in the parent container into smaller than 4 liter quantities in bags or other suitable containers within the glovebox. The pH of the solution was measured using litmus paper to estimate the pH of the free liquid.

According to personnel interviewed, that liquid was then neutralized using an unspecified quantity of KOLORSAFE® acid neutralizer. Some of the personnel interviewed indicated that neutralization was not achieved in some cases despite the addition of neutralizer over an hour's time. Once neutralized, the liquid was absorbed using Swheat Scoop®, an organic absorbent, in an unspecified ratio. The remaining nitrate salt bags were removed from the parent container per Section 10.6. Operators were directed to document the addition of any waste added to the daughter drum. Section 10.6 further directed that the nitrate salt material be absorbed and thoroughly mixed using the minimum ratio of 1.5 absorbent to 1 part waste. Substep [3] further states, "**ENSURE** an organic absorbent (Kitty Litter/Zeolite® absorbent) is added to the waste material at a minimum of 1.5 absorbent to 1 part waste ratio." The mixture was the added to the daughter drum. As a final step, the operators documented the volume of waste in the daughter container then closed the daughter drum.

WCRRF operations and support personnel that were interviewed also indicated that on occasion, during liquid neutralization activities, they would witness foaming and an orange or yellow colored smoke, that was evidence of the exothermic chemical reaction taking place between the acidic solution and the acid neutralizing agent, KOLORSAFE® Acid Reducer (liquid). The Board was informed that, in these situations, direction was given by supervisors to simply wait out the reaction and return to work once the foaming ceased and the smoke subsided. Subsequent revisions to the glovebox procedure did not indicate that any changes related to the reaction were made. This inappropriate management response to worker issues is further discussed in Section 11.3, Safety Culture Analysis.

EP-WCRR-WO-DOP-233, Revision 37 was issued in March 2013, which modified the specified ratio to 3-parts absorbent to 1-part waste or at a ratio as directed by supervision. Additionally, this revision proceduralized that neutralization activities were being performed, although the extent of the step was simply to *"neutralize the liquid, as necessary."* Revision 38 was released in August of 2013, but contained no changes applicable to processing nitrate salts.

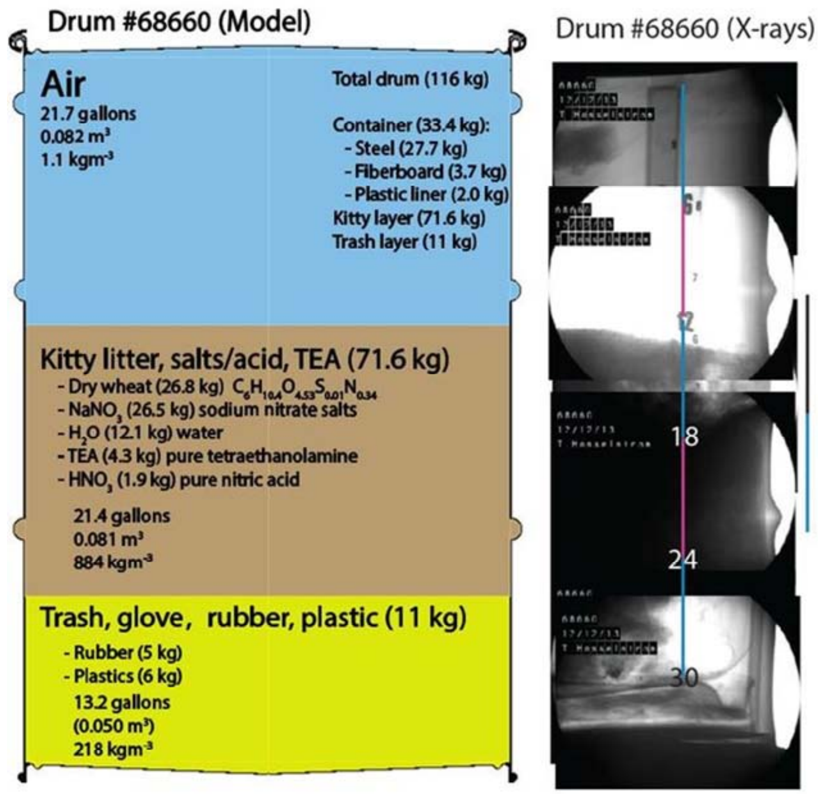

Figure 5-1: Drum 68660 Model Contents

On December 4, 2013, ES remediated parent drum S855793 in accordance with the glovebox procedure, producing daughter drums LA00000068660 (68660) and LA00000068685 (68685). Drum 68660 was repackaged by first adding some secondary waste including a tungsten-lined glovebox glove. Approximately two gallons of free liquid were decanted from the parent drum. The pH was measured and recorded to be 0 (zero). The pH was adjusted using KOLORSAFE® to an un-specified final pH. Swheat Scoop ® organic kitty litter was added as the absorbent and was placed in the drum. Additional bags of nitrate salt were absorbed and placed in the drum. See Figure 5-1 for a drum contents model.

5.4 Analysis of Section 5 – LA-MIN02-V.001 Waste Stream

Although clearly a potential source of introducing incompatible items into a waste stream, secondary waste generation was not strictly controlled. The AK summary report discusses some potential sources of secondary waste. Section 7.4.4.2 states:

> *Some secondary waste generated during remediation and repackaging operations may be added to the waste containers, including but not limited to: absorbent (e.g., WasteLock® 770), Fantastik® bottles used during decontamination, miscellaneous hand tools, paper/plastic tags and labels, plastic/metal wire ties, PPE, plastic sheeting used for contamination control, rags and wipes (Kimwipes), and original packaging material (e.g., plastic bags, plywood sheathing, rigid liner lids cut into pieces).*

Although not a finite list of all approved secondary wastes, it does identify several materials that are combustible, which are not compatible with this particular waste stream. The addition of combustible (organic) secondary waste items created conditions that made the waste capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, of burning so vigorously and persistently that it creates a hazard. These incompatible items were not identified by CCP when they reviewed and approved CCP-AK-LANL-006.

CON 6: The preparation, review and approval of CCP-AK-LANL-006, *Acceptable Knowledge (AK)* summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of adding incompatible secondary waste items to the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.

JON 8: The CCP needs to improve the level of rigor in reviewing and approving AK summary reports for compliance with requirements.

Additionally, the WCRRF glovebox procedure contains no specific direction to dispose of secondary waste other than for the placement of bag-off bag stubs into a daughter drum per section 8.1 step [17], although waste repackaging records and personnel interviewed indicated that secondary waste such as gloves, empty neutralizer containers, and room waste were placed into daughter drums. The lack of any specific process-based controls in the repackaging procedure resulted in poor decisions being made by operations personnel in the field regarding the addition of secondary waste materials into the LA-MIN02-V.001 waste stream. As a result, incompatible secondary waste items were introduced into the waste stream.

CON 7: Los Alamos National Security, LLC (LANS) did not adequately evaluate the impact on the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC) or effectively control the addition of secondary job waste into transuranic (TRU) waste containers.

JON 9: LANS needs to improve the level of rigor in evaluating and controlling the addition of secondary job waste into TRU waste containers.

Until Revision 37, EP-WCRR-WO-DOP-233 did not specify any neutralization process. The pH was measured, neutralization occurred outside of the procedure, and then the liquid was absorbed. Additionally, the procedure did not identify an acceptable range to achieve during neutralization or require further measurement of the liquid to verify neutralization had been achieved, although personnel interviewed stated that pH was measured post neutralization to verify success. On numerous occasions, the pH was recorded as less than two. A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5. Low pH measurements in that range should have triggered generation of a non-conformance report and been tagged for disposition. Both the adjustment of pH and absorption of free liquids should have been managed under the LANL HWFP as permitted treatment processes. The section for processing nitrate salt drums was added without regard to the existing precaution and limitation that prohibited introduction of this material in the WCRRF. Further, other waste generator sites across the DOE complex could be susceptible to similar RCRA or other upper tier requirements flow down inadequacies, and would benefit from a detailed extent of condition review. During the investigation, LANS disclosed several non-compliances with the LANL HWFP in three separate transmittal letters summarized in Section 5.2.2.

CON 8: Los Alamos National Security, LLC (LANS) did not adequately incorporate upper tier requirements into the development of repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF). Specifically:

- The Carlsbad Field Office (CBFO) directed controls contained in the Los Alamos National Laboratory- Carlsbad Office (LANL-CO) white paper based on the Energetic Materials Research and Testing Center (EMRTC) Report RF 10-13; and
- The requirements associated with the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit (HWFP):
  - Nitrate salt-bearing wastes did not fully meet the LANL HWFP "special requirements" for managing ignitable wastes, including segregation and separation, and use of non-sparking tools;
  - Did not comply with the LANL Hazardous Waste Facility Permit (HWFP) requirement that the nitrate salt-bearing waste drums be labeled with all applicable Environmental Protection Agency (EPA) Hazardous Waste Numbers;
  - Placed incompatible wastes and materials in the same container and did not impose special precautions;
  - Did not label the nitrate salt bearing waste prior to transport and remediation at the Waste Characterization, Reduction and Packaging Facility (WCRRF); and
  - Did not label the unremediated nitrate salt-bearing waste drums which contained liquids as Resource Conservation and Recovery Act (RCRA) corrosive.

JON 10: LANS needs to strengthen the processes that ensure the flow down of upper tier requirements into their implementing procedures such that execution of work is compliant.

JON 11: CBFO needs to conduct an extent of condition review of other waste generator sites to determine the adequacy of the flow down into the operating procedures and implementation of RCRA requirements contained in the WIPP Waste Acceptance Criteria (WAC) and hazardous waste permits regarding the treatment and repackaging of TRU waste.

The liquid absorption process prescribed in the transmittal from CBFO and updated in SP #72, Revision 1 was incorporated into CCP-AK-LANL-006, Revision 12, and released in December of 2012. The source document reference table in section 11 included the EP-WCRR-WO-DOP-0233, *Glovebox Operations*, although it was not specific to revision number. Revision 36 was released in August of 2012 and contained the addition of "organic absorbent (Kitty Litter/Zeolite® absorbent)" instead of the absorbent specified in the CBFO email direction to NA-LA. CCP and its sub-contractor failed to identify the error a year prior to the repackaging of drum 68660 that occurred in December 2013. The Board concluded that CCP and its subcontractor should have conducted a rigorous review of the WCCRF glovebox procedure and subsequent changes due to the potential impact on Acceptable Knowledge as required by CCP-TP-005, *CCP Acceptable Knowledge Documentation*.

CON 9: The preparation, review and approval of CCP-AK-LANL-006, *Acceptable Knowledge* (AK) summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of changes to EP-WCRR-WO-DOP-233 Glovebox Operations, on the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.

JON 12: The CCP needs to reevaluate and strengthen the process used to conduct review and approval of source documents that have an impact on Acceptable Knowledge.

The Board included a review of the technical basis documentation developed at the Idaho National Laboratory to disposition the nitrate salts identified at the Accelerated Retrieval Project. EDF-8723 was developed to document decision making based on the results of the EMRTC testing conducted to validate the ratios of nitrate salts to zeolite needed to render the matrix inert. The document clearly identified the technical basis for the final percentages and included a conservatism to ensure confidence that the waste would not present oxidizer properties. In contrast, ENV-RCRA-12-0053 was published at LANL in February 2012, which identified conclusions and provided recommendations based on limited objective evidence. The document downplayed any relationship between the Idaho National Laboratory waste and the LANL waste. Ultimately LANL was provided email direction from CBFO via NA-LA to incorporate the recommendations contained in the EMRTC report as amended in a LANL-CO white paper received in June 2012. The white paper specified the addition of 1.2 volumes of kitty litter/zeolite clay per volume of nitrate salts. When implemented by LANS via EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations*, the word clay was eliminated and a trademark applied next to zeolite. The procedure was issued with the word "organic" inserted as recommended by the ES subcontractor manager, due to personal notes taken during a meeting in May of 2012. The manager recalled specific discussion related to that term during the meeting. The other party involved in the discussion disputed the ES manager's recollection. Regardless of the discussion, the Board noted that this direction conflicted with the CBFO directed instructions for remediation of the nitrate salts. Subsequently, the procedure was revised per the e-mail without verifying that the selected absorbent was consistent with the absorbent prescribed in the CBFO directed controls. This lack of configuration management and supporting technical basis ultimately resulted in the procurement and use of the organic wheat-based Swheat Scoop® material contained in drum 68660 that was involved in the February 14, 2014, release accident at WIPP. LANS did not consider the reason for the suspending of waste processing using WasteLock® 770 when deciding to use an organic absorbent and an organic acid neutralizer. There was no evidence that any type of technical evaluation occurred regarding the compatibility of the agents with the waste stream. Subsequent adjustments to the ratio of absorbent material lacked any technical evaluation to support making the change. The procedure change process was not driven by an overarching engineering change control process that should have ensured the necessary rigor to have caught and dismissed the selection of the organic product.

CON 10: Los Alamos National Security, LLC (LANS) failed to provide sound technical basis for decisions regarding repackaging procedures and processes for the LA-MIN02-V.001 waste stream.

JON 13: LANS needs to strengthen documentation to include a detailed technical basis to justify decisions made regarding change control for procedures and processes for the LA-MIN02-V.001 waste stream.

CON 11: Los Alamos National Security, LLC (LANS) did not utilize a formal engineering change control process to develop modifications to repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF).

JON 14: LANS needs to implement an effective engineering change control process that includes defensible technical bases to justify process modifications.

The Board reviewed the content of EP-WCRR-WO-DOP-0233 and determined there were several instances where the details were not sufficient to ensure consistent and compliant execution. Steps in the procedure directed operators to add various secondary waste items into TRU waste containers. There was no evidence to support that these items had been evaluated for compatibility with the contents of the waste. Additionally, there was not a finite list of approved secondary items provided in the procedure. Prior to Revision 37, workers conducted neutralization activities without any procedural direction to do so. As a result, the chemicals used did not have a documented hazard analysis evaluation to implement the necessary controls to ensure safe execution of neutralization activities. The glovebox procedure did not require operators to document critical process steps, e.g., initial pH, type and amount of neutralizer used, adjusted pH, and type and amount of absorbent added.

Revision 37 added the step to perform neutralization, as necessary, but it still lacked the level of specificity and detail commensurate with compliant conduct of operations. There was not consistent direction to the operators as to what information important to the waste acceptance criteria needed to be documented in the provided attachment, which was and still is ultimately provided to the CCP in a package provided to support characterization activities.

CON 12: Los Alamos National Security, LLC (LANS) failed to ensure that there was sufficient detail provided in the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure to ensure safe, consistent, and compliant repackaging of waste and accurate documentation of the contents of the waste drums in the records.

JON 15: LANS needs to revise the WCRRF glovebox operations procedure to contain the necessary level of detail to ensure safe, consistent, and compliant remediation of nitrate salt bearing waste.

JON 16: The glovebox operations procedure needs to be revised to require operators to document critical process steps in a quality record, e.g., initial pH, absorbent added, neutralizer used, adjusted pH.

JON 17: Operators need to be adequately trained on the revised glovebox operations procedure.

6.0 Forensic Analysis of Panel 7 Room 7

The forensic analysis of the February 14, 2014, radiological release is segmented into three distinct segments (fire, chemical and radiological) based on the observed behaviors during the event. Sections 6.1 through 6.3 describe each analysis segment.

Fire Forensics

- Observed conditions within the array;
- Fire reconstruction of the February 14 radiological release event; and
- Fire reconstruction of the February 5 salt haul truck fire event.

Chemical Forensics

- Chemical analysis of ejected materials;
- Analysis of air filters and various swipes; and
- Comparison of the ejected materials chemical analysis results with the expected contents of drum 68660.

Radiological Forensics

- Isotopic analysis of ejected materials;
- Analysis of air filters and various swipes; and
- Comparison of the isotopic analysis results with the contents of drum 68660.

Section 6.4 is the collective analysis of all forensic data and conclusions of the February 14 event.

6.1 Fire Forensics

This section summarizes fire forensics based on the information found in the *Fire Forensic Analysis of the Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014*,[9] Revision 0 (Fire Forensic Analysis Report). This analysis was commissioned by the Board, compiled by the Board Fire Analysis Team, and was an informational report to the Board. The Fire Analysis Team examined visual evidence of the Panel 7 Room 7 waste array and conducted an evaluation of the potential impact from the February 5, 2014, salt haul truck fire event.

A fire and accompanying radiological release event occurred on February 14, 2014. The key observations by the fire analysis team included:

[9] The *Fire Forensic Analysis Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014* is available at http://energy.gov/ehss/downloads/accident-investigation.

- Based on fire evidence, the release was initiated by an exothermic reaction in LANL waste drum 68660 that contained what was described in characterization records as a nitrate salt waste stream (LA-MIN02-V.001).
- The exothermic reaction ignited exposed combustible materials (fiberboard and polyethylene slip sheets, reinforcement plates, stretch wrap, cardboard stiffeners and polypropylene super sack fabric) at the initiator location.
- The fire propagated within the array through ignition of the exposed combustibles within the array. Propagation mechanisms included direct flame impingement, thermal radiation heat transfer and ember transfer.
- The intensity of the overall fire was low to moderate and direct fire effects were primarily in Rows 8 through 18 of the array. Damage within the array was not uniform and there were multiple small fires that caused direct flame impingement on several waste packages. In some locations, the fire damage was significant.
- The greatest damage occurred at locations with the greatest quantities of exposed combustible material, e.g., polyethylene slip sheets and reinforcement plates associated with 3-pack and 7-pack drum assemblies.
- Flashover[10] in Panel 7 Room 7 did not occur. There was wide variation in local temperatures during the event that would have been dependent on local flaming behaviors. As such, local temperatures ranged from ambient to about 1,000°C (flame temperature). Temperatures near the Panel 7 Room 7 bulkhead did not exceed 135°C based on the undamaged polyethylene stretch wrap and MgO super sack polypropylene fabric.
- The fire self-extinguished without consuming all combustibles present. The precise time of fire extinguishment was not determined, but extinguishment did occur because the geometry of the combustibles did not facilitate continued combustion.
- The fire was not initiated or accompanied by a detonation. Movement of the MgO was dominated by gravity and none of the waste containers appeared to have been relocated from their original placement position. With the exception of the deflected lid on the LANL waste drum 68660, there was no evidence of container bulging, buckling or other permanent deformation.
- During the event an exothermic reaction of incompatible materials in LANL waste drum 68660 resulted in over-pressurization of the drum, breach of the drum, and release of a portion of the drum's contents into the WIPP underground (Figure 6-1).
- LANL waste drum 68660 contained a wheat-based combustible absorbent (Swheat Scoop®). This material is susceptible to spontaneous combustion when the moisture content is in the range of 15 and 50 percent. Drum 68660 was in this moisture range.

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[10] A flashover is "a transition phase in a "….compartment fire which surfaces exposed to thermal radiation reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space." [NFPA 921, pg 16]

- When LANL waste drum 68660 breached, it expelled a mixture of heated pyrolysis[11] gases and fine combustible particles. This mixture ignited on release creating an expanding flame front that caused secondary ignitions.
- The February 5, 2014, salt haul truck fire did not cause a localized MgO reaction and did not cause the February 14 release event.

6.1.1 Post-Fire Array Inspection

Visual inspections of the Panel 7 Room 7 waste array were conducted in two phases. Phase 1 occurred between April 23 and May 30, 2014. Phase 2 occurred in January 2015 using equipment capable of reaching all the locations in the array. These visual inspections provided a means to identify material discoloration, deformation, melting, and char. The inspections also allowed observation of container damage (e.g., with deformation, ejected material, and lid loss) but not container seal leakage or internal container damage. Cumulatively, these inspections resulted in a systematic and comprehensive evaluation of the array damage. The detailed results of these efforts are presented in the Fire Forensic Analysis Report and summarized below.

The visual inspections found evidence of slight localized discoloration of the Panel 7 Room 7 south rib (wall) that was the result of fire exposure. There were no such discolorations of the north rib, back (overhead), or bulkhead and no significant accumulations of soot on these three surfaces. This evidence indicates that flashover in Room 7 did not occur. The inspection demonstrated that the primary fire damage was intermittently dispersed in the array between Rows 8 through 18 (Figure 6-2). No physical damage was evident for waste containers in Rows 2 through 7 (yellow box in Figure 6-2), or Rows 19 through 24 (red box in Figure 6-2). The most significant damage occurred in the regions marked in blue on Figure 6-2.

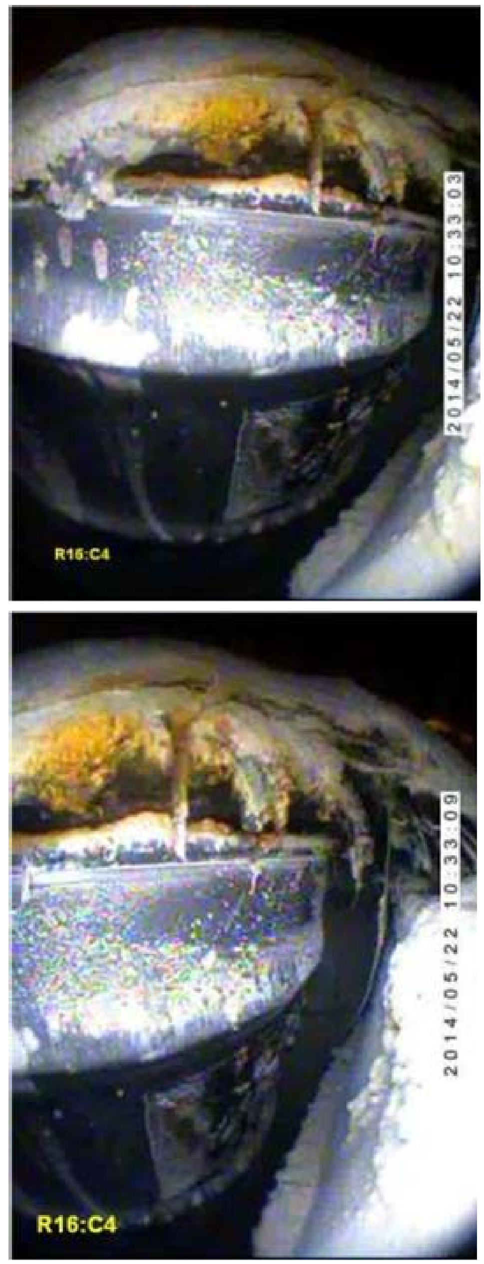
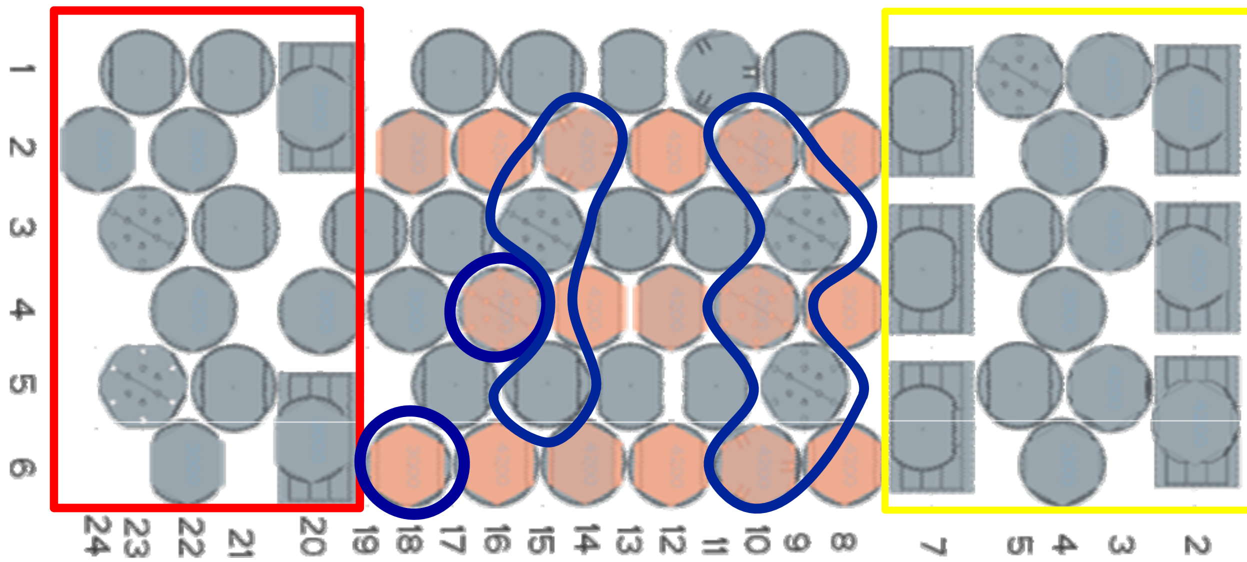


Figure 6-1: Drum 68660

[11] Pyrolysis - A process in which material is decomposed, or broken down, into simpler molecular compounds by effects of heat alone (NFPA 921:3.3.139).



NOTE: Significantly damaged MgO Super Sacks shown in peach.

Figure 6-2: Panel 7 Room 7 Array Arrangement

Visual damage within the waste array was most severe at, or near, locations with 55GD and 100GD. These were locations with higher quantities of combustibles external to the waste containers such as fiberboard and polyethylene slip sheets, reinforcement plates, stretch wrap, cardboard stiffeners and polypropylene super sack fabric (Figure 6-3). Evidence of both melting and ignition were identified at these locations. Polyethylene is categorized as an easy-to-ignite material and has a melting temperature range of 122 – 135°C (NFPA 921, pp 51) and the observed damage was consistent with this information.

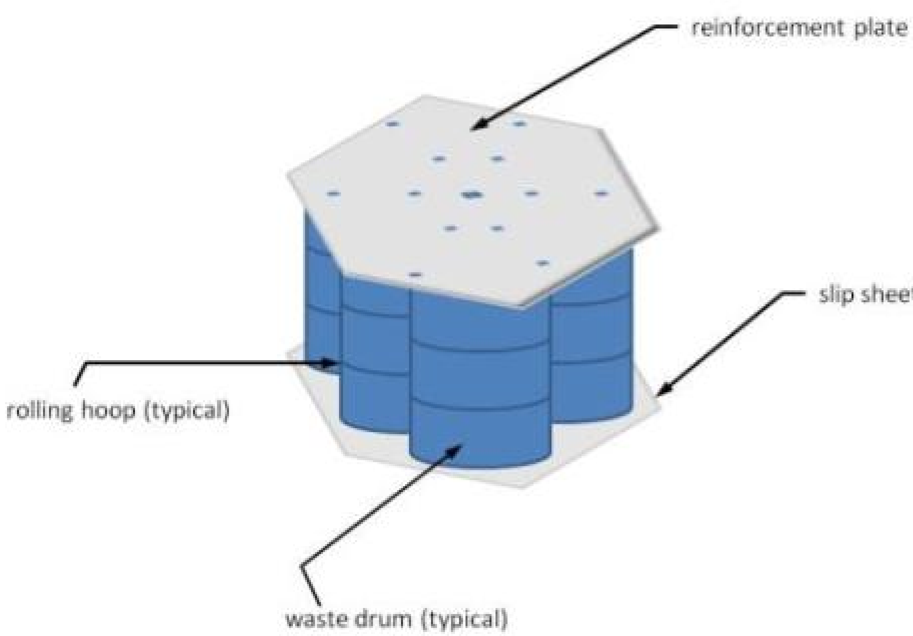


Figure 6-3: Drum Waste Assembly with Slip Sheet and Reinforcement Plate

The MgO super sacks from Rows 8 through 18 were damaged. The polypropylene fabric that formed the sacks was severely damaged or missing from most of these locations. The fabric damage could have been caused by melting or ignition (Figure 6-4). Polypropylene is categorized as an easy-to-ignite material with a melting temperature in the range of 160°-176°C. Evidence of both mechanisms was identified during the array inspections. When the fabric was damaged, the cardboard stiffeners collapsed, the MgO flowed and formed piles of loose material at the damaged MgO super sack locations. At most of these locations the angle of repose (e.g., slope) was very steep, almost 60°, indicating gravity was the dominant force acting on the MgO after the super sacks were consumed by the fire.

Figure 6-4: Panel 7 Room 7 Array, Columns 4 through 6

The cardboard stiffeners collapsed into multiple final orientations: hanging from a stack edge, cantilevered over the edge of a waste package, bridging between two stacks, or resting on the floor. Some of the locations where the stiffeners were cantilevered or bridging exhibited irregular edge surfaces (Figure 6-5). At R15:C5 there was a concave burn pattern in the portion of the cardboard that was cantilevered over the edge of the lid of a standard waste box (SWB) (Figure 6-6). The burn-pattern is typical of horizontal material exposed to a flame from below. Similar materials may burn as long as exposed to an external flame, but will likely self-extinguish once the flame is removed. There were also smaller cardboard remnants lying on the lid. These remnants display striations of the corrugated layer within the original cardboard matrix.

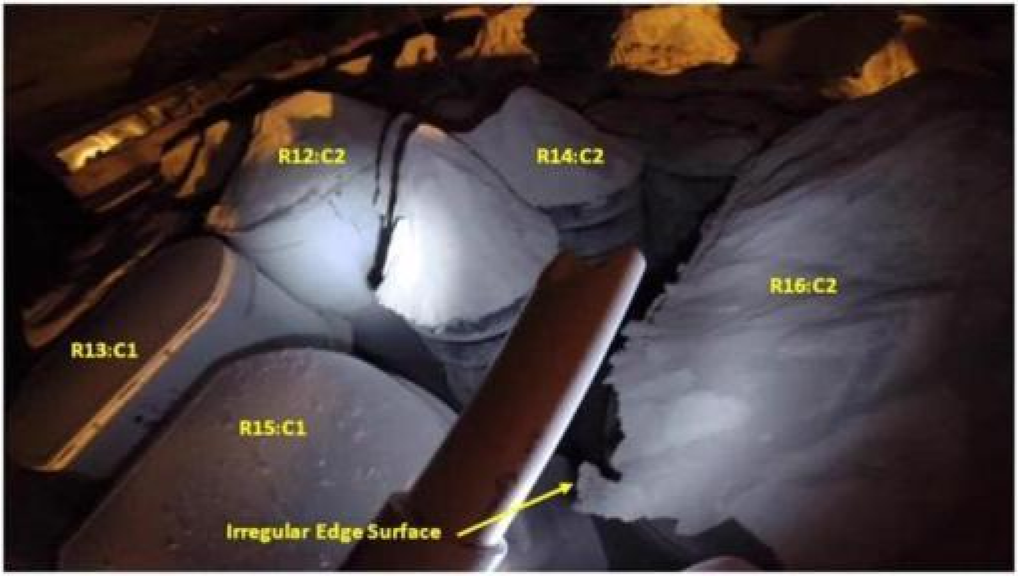


Figure 6-5: Evidence of Irregular Edge Surfaces at R16:C2

Figure 6-6: Evidence of Flaming Combustion Irregular Edge Surfaces at R15:C5

The array inspections and evidence evaluation identified just one location with a partially separated waste container lid, and no locations indicating other container deformation. The partially separated lid occurred at R16:C4 where the lid to waste drum 68660 was deflected upward from its original position as shown in Figure 6-1. There was no indication of waste container movement or significant horizontal displacement of the MgO during the release event. Additionally, there was no indication of bulged, buckled, dented, or torn waste containers, which suggests that a detonation did not occur during the event.

6.1.1.1 Rows 19 through 24

Rows 19 through 24 contained a mix of TDOPs, SWBs, 55GD assemblies, and Standard Large Box Type 2s. These rows were closest to the waste face. The inspection identified no fire-related damage in these rows. Row 20 was adjacent to Row 18, which contained the west-most damaged waste stacks. Row 20, combined with the single stack in Row 19, created a fire break in the array. The exposed combustibles in this fire break were limited to three MgO super sacks, three polyethylene slip sheets that were directly under the super sacks and fiberboard slip sheets that were almost completely covered by steel waste containers. As such, there were few locations available to promote ignition. Additionally, the ventilation provided air flow patterns across Rows 19 through 24 that prevented hot or burning embers from landing on the exposed combustibles in this region.

6.1.1.2 Rows 2 through 7

Rows 2 through 7 contained a mix of TDOPs, SWBs, 55GD assemblies, 100GD assemblies, and Standard Large Box Type 2s. These rows were closest to the bulkhead. The inspection identified no fire-related damage to the polyethylene stretch wrap or the polypropylene super sacks in these rows. The lack of damage to the polyethylene stretch wrap in these rows establishes that the bulk air temperature passing over the array was low, nominally below 135°C, which is the upper value of the melting temperature range of the polyethylene stretch wrap[12] (Figure 6-7, Figure 6-8 and Figure 6-9).

Figure 6-7: Undamaged Stretch Wrap at R5:C1

[12] The upper value melting temperature range for the polypropylene fabric used for the MgO super sacks is higher, 176°C.

Figure 6-8: Undamaged Stretch Wrap at R3:C5

Figure 6-9: Undamaged Stretch Wrap at R2:C6

As with Row 20, Row 7 created a fire break in the array with very limited exposed combustibles. Adjacent to Row 7 was Row 5. With the exception of R5:C1, which contained an undamaged 55GD assembly, the exposed combustibles in Row 5 were also very limited. These two rows prevented propagation to Rows 2, 3 and 4 which contained larger quantities of exposed polyethylene and polypropylene.

Ignition of a fiberboard slip sheet did occur at R7:C5. The fiberboard charred over a short region and self-extinguished (Figure 6-10). This region is adjacent to R8:C4, which had a fire-damaged MgO super sack, so ignition could have occurred by direct thermal heat transfer from the fire at R8:C4, from impact by burning material (cardboard or fabric) falling from R8:C4, or by embers generated elsewhere in the array. Damage to this fiberboard was identified as fire damage closest to the bulkhead.

Figure 6-10: Fiberboard Slip Sheet Damage at R7:C5

6.1.1.3 <u>Stack R18:C6</u>

The bottom and middle tiers at R18:C6 were 55GD assemblies with an SWB on top. A 3,000 pound MgO super sack was placed on the SWB. The damage at this location was typical of that observed in other regions between Rows 8 and 18. However, this location was unique in that the damage it incurred was closest to the waste face (i.e., upwind of most of the fire damage). In addition, the flames damaging this stack acted in isolation from other parts of the array since the majority of the damage to this stack faced away from the damaged region in the array.

Based on the orientation of the stack, the stack damage, and the ventilation direction, a hot or flaming ember is considered a plausible means of fire propagation to R18:C6. This ember landed on the fiberboard slip sheet that was below this SWB and caused ignition of the fiberboard. The fire consumed the exposed fiberboard above the two west drums (the drums on the face-side of the array, Figure 6-11). The reinforcement plate below the fiberboard burned and melted with the remaining material following the contour of the two west drums (Figure 6-12). The middle-tier stretch wrap on the west side was also damaged. There are streaks of polyethylene on the sides of the waste drums. The slip sheet and reinforcement plate between the middle and bottom 55GD assemblies appears to be intact although a variety of debris have accumulated on the top of the reinforcement plate. In some locations fallen material has combusted resulting in discoloration of a waste container. In one location sufficient flame exposure occurred to leave a clean burn pattern where all of the dirt, paint, and soot has burned away leaving a bright metal surface (Figure 6-13). The stretch wrap on the north-west corner of the lower tier was also damaged by flames (Figure 6-14). Except as noted, no other damage to the stretch wrap was identified in this stack.

Figure 6-11: Face Side (west) of R18:C6

Figure 6-12: Face Side (west) of R18:C6 Middle Tier

Figure 6-13: Face View (west) Base of Middle Tier Drum at R18:C6

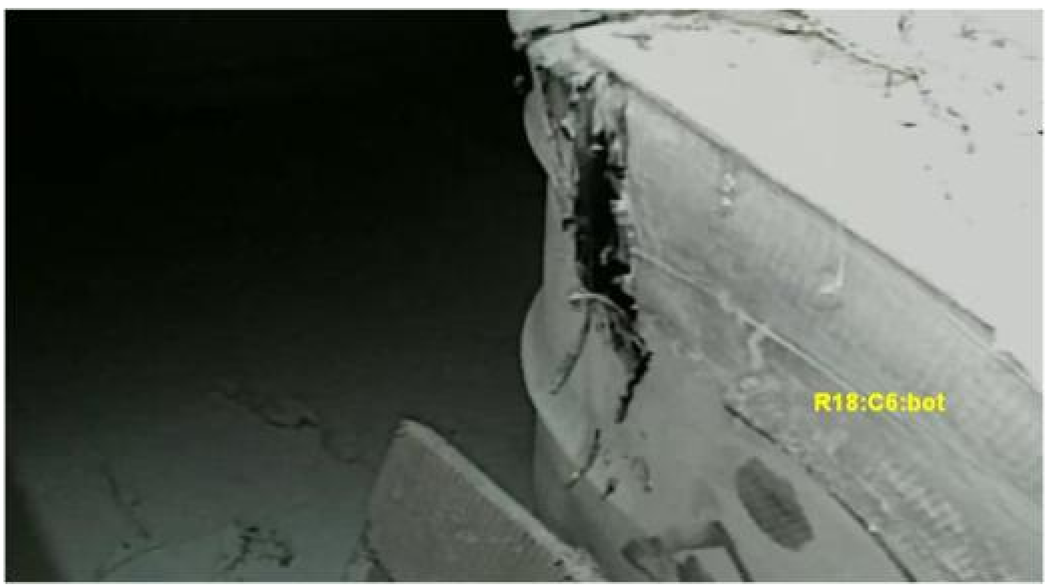


Figure 6-14: Face View (west) Stretch Wrap at Bottom Tier

The MgO super sack was damaged by the fire. The polypropylene fabric melted, burned or fell from all sides of the super sack. On the north side the cardboard stiffeners and fabric were trapped between the MgO and the SWB lid. The stiffener and fabric formed a cantilevered bridge that supported a pile of displaced MgO (Figure 6-15). On the west side, a stiffener fell to the floor where it was partially covered by MgO (Figure 6-16). The vertical edges of this stiffener were partially burned along with a hole through the stiffener. A stiffener on the south side bridges between the SWB and the rib. There was also evidence of flame impingement on the rib (Figure 6-17). The east (bulkhead side) stiffener fell and was not located. The SWB had vertical streaks created by melted polyethylene from the MgO super sack slip sheet flowing down the side and freezing (Figure 6-18). There was no evidence suggesting that any of the waste containers in this stack had an unfiltered release.

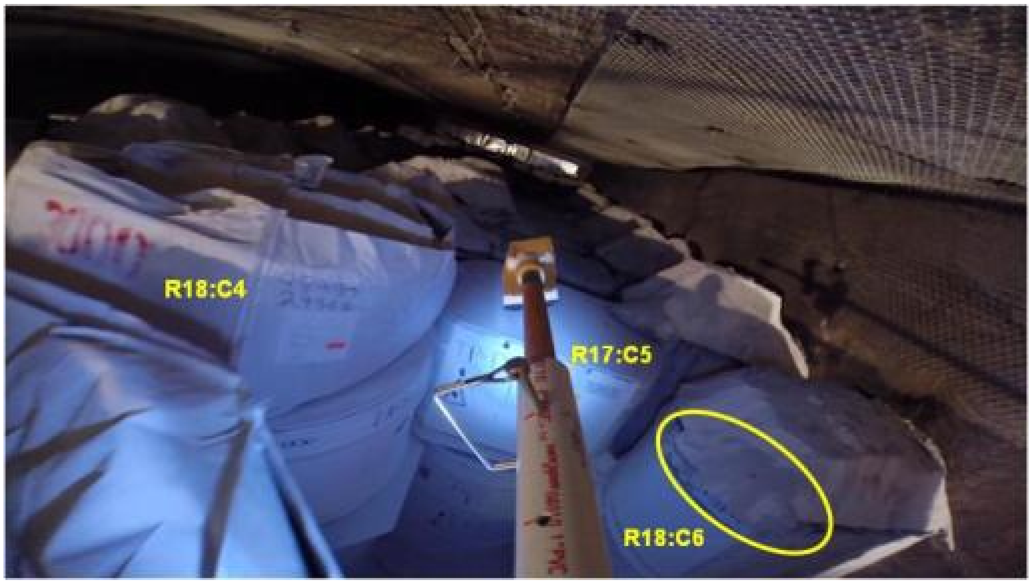


Figure 6-15: Cantilevered Bridge at R18:C6

Figure 6-16: Face View (west) – Debris at Base of R18:C6

Figure 6-17: Rib Damage near Rows 16 and 18

Figure 6-18: Bulkhead Side of R18:C6

6.1.1.4 Rows 9 and 10

R9:C1 contained a SWB placed on a TDOP. R10:C6 contained a 100GD assembly placed on two 55GD assemblies. The remaining stacks in Rows 9 and 10 contained a 55GD assembly placed on a TDOP. Each stack in Row 10 had a 4,200 pound MgO super sack. Although R9:C1 had no observable fire damage, stretch wrap at each of the other five stacks was damaged or missing. The 55GD assembly reinforcement plates at R9:C3 and R9:C5 melted, mixed with MgO, solidified on the drum lids, and cracked into pieces (Figure 6-19, Figure 6-20, Figure 6-21, Figure 6-22, Figure 6-23 and Figure 6-24). There was no evidence of reinforcement plate remaining between the drums. In some instances melting polyethylene formed streaks on the on the side of these drums. In addition, MgO slumped onto some of the drums in both locations.

Figure 6-19: Residual Polyethylene on Dunnage Drum at R09:C3

Figure 6-20: R9:C3 Bulkhead View (east)

Figure 6-21: R9:C3 West Side

Figure 6-22: Damage at R9:C5 and R10:C4

Figure 6-23: Damage at R9:C5

Figure 6-24: R10:C2, R9:C3 and R10:C4 East (Bulkhead) View

The MgO super sacks in Row 10 were damaged, with most of the fabric melted or gone (Figure 6-21, Figure 6-22, Figure 6-24, Figure 6-25, and Figure 6-26). The residual MgO formed conical piles consistent with the outline of the waste containers on the top tier at each stack. At R10:C6 the 100GD assembly slip sheet, the middle tier reinforcement plate and slip sheet, were partially damaged and conformed to the outline of the drums (Figure 6-27). Many locations had evidences of black discolorations on the sides of the waste drums. There was also evidence of flame impingement on the south rib (Figure 6-28).

While some of the TDOPs in Rows 9 and 10 exhibited streaks of melted plastic, none had substantive damage. In some instances the depth of the MgO at the floor was so deep that it obscured a substantial portion of the lower stack tier or the lower half of a TDOP.

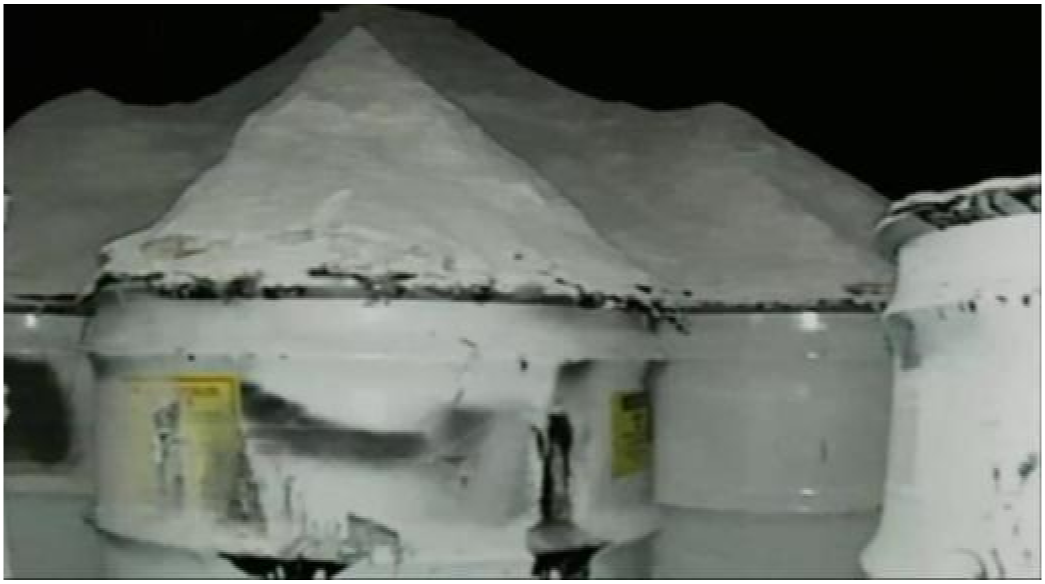


Figure 6-25: Discoloration and Residual MgO at R10:C4

Figure 6-26: R10:C2

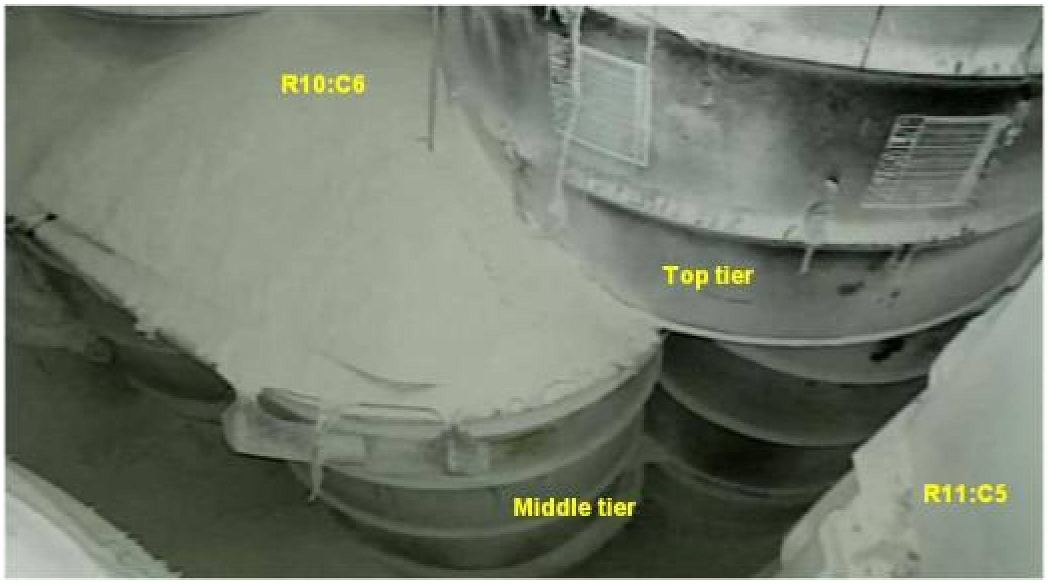


Figure 6-27: R10:C6

Figure 6-28: Flame Impingement Evidence on South Rib near Row 10

6.1.1.5 Rows 14 and 15

Rows 14 and 15 contained a mix of TDOPs, SWBs, 55GD assemblies, and 100GD assemblies. R14:C2 consisted of three tiers of 100 GD assemblies with a 4,200 pound MgO super sack. R15:C3 contained a 55GD assembly on a TDOP, and R15:C5 contained an SWB on two tiers of 55GD assemblies. With the exception of MgO super sack damage, these are the only stacks in Rows 14 and 15 that were severely damaged. The remaining stacks consisted of SWBs and TDOPs.

The exposed plastics (fiberboard and polyethylene slip sheets, reinforcement plates, stretch wrap, cardboard stiffeners and polypropylene super sack fabric) in stack R14:C2 were severely damaged. The polyethylene plastic burned and melted to the outline of the waste drums (Figure 6-29 and Figure 6-30). The MgO formed three conical piles on the three top-tier drums (Figure 6-31). The 100GDs were originally a glossy black, but were covered with a coating of fine white powder (Figure 6-32).

The reinforcement plate at R15:C3 was damaged. The missing plate material conformed to the outline of the seven drums, including the spaces between the drums (Figure 6-33). There was residual stretch wrap visible on some portions of the assembly and some of the drum labels were undamaged (Figure 6-34). The TDOP below the 55GD assembly was undamaged.

Figure 6-29: North View

Figure 6-30: West (face) View

Figure 6-31: R14:C2

Figure 6-32: R14:C2 (south)

Figure 6-33: Missing Reinforcement Plate at R15:C3

Figure 6-34: Drum in R15:C3 on Bulkhead Side Looking Southeast

The reinforcement plate and fiberboard slip sheet between the middle and top tiers of R15:C5 was severely damaged and partly burned on the west (face) and north sides. Much of the polyethylene stretch wrap was missing from these locations. There was discoloration indicative of overheat on the west side of the SWB near the seal (Figure 6-35). There was an inverted-cone pattern on the SWB was centered between the two west-most middle-tier drums (Figure 6-36). The fiberboard slip sheet had a U-shaped damage pattern (Figure 6-37). This is indicative of flame exposure to the fiberboard from below. When the flame exposure ceased, combustion of the horizontal fiberboard likely stopped. The fiberboard slip sheet and reinforcement plate were badly damaged below the north end of the SWB (Figure 6-38). Char from the slip sheet conformed to the middle tier 55GDs.

One 55GD on the middle tier of R15:C5 exhibited evidence of localized heat or flame exposure. Between the middle and upper rolling hoop there was one label that had charred, while a second label that showed no damage (Figure 6-39). In addition, there was a dark inverted-cone shaped pattern starting at the base of the drum that extended up the side of the drum about 12 inches. Around this region there was clumped MgO resting on the middle-tier slip sheet. While there was severe flame damage evidence on the west side of the SWB and the middle tier 55GD assembly, the lower tier stretch wrap appeared undamaged on the outer surface as viewed from the west side of the stack.

Figure 6-35: Discoloration of SWB at R15:C5

Figure 6-36: Side of SWB at R15:C5:top

Figure 6-37: Damage to Slip Sheet at R15:C5

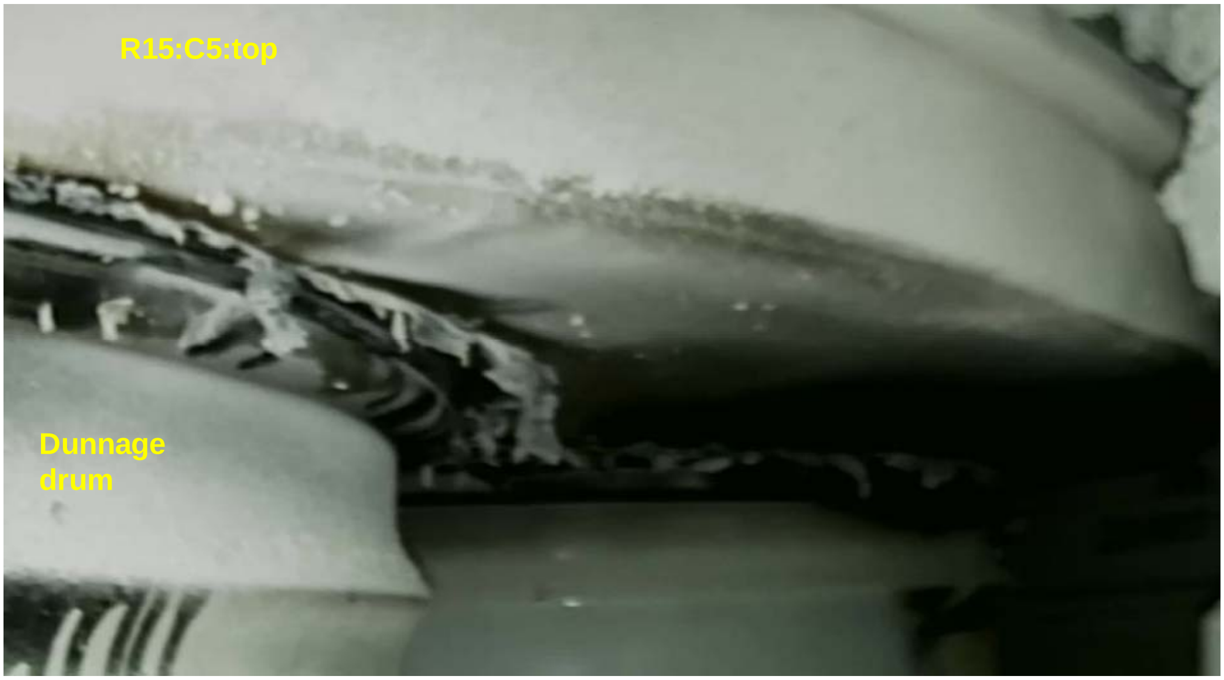


Figure 6-38: North View of R15:C5, Bottom of SWB on Top Tier

Figure 6-39: Charred Label at R15:C5

6.1.1.6 Stack R16:C4

A drum on the top tier of R16:C4 breached (Figure 6-40). This is waste container 68660; it is on the south side of the stack. The MgO super sack fabric on the top of the 55GD assembly is substantially gone. The MgO piles on 68660 and the neighboring drum to the west are short with a low angle of repose. This was potentially caused by movement of the lid. The cones on the other drums are similar to other stacks where the MgO super sacks have been damaged.

Figure 6-40: Drum 68660 at R16:C4

Drum 68660 experienced significant overheating and substantive damage. The material around the mouth of the breach was discolored. A "clean" burn region occurred on the south side of this drum between the lower and middle rolling hoop. The clean burn pattern is indicative of intense localized heat. As discussed in section 5.3.2 this was the region of the drum that contained nitrate salts, organic absorbents and absorbed free liquid. While much of the visible drum surface experienced a color change, there was a portion below the lower rolling hoop that had not changed color, consistent with the location that contained secondary waste items. There was a damaged label between the middle and upper rolling hoop. The label was partially charred, indicating that the exposure in this region was less severe than that near the clean burn.

There was a moderate quantity of clumped material and MgO spillover on the SWB lid at R15:C5 (Figure 6-41). The depth of this material was greatest on the northwest corner where the stack is in close proximity to R16:C4 (Figure 6-42). The north end of the lid had evidence of combusted cardboard stiffener material from the MgO bag that was placed on top of R16:C4. Additionally, there was a fallen cardboard stiffener lying on the north end of the lid. There were two spots on the southeast and southwest corners of the lid where white MgO was seen on top of the discolored material spread across the remainder of the lid. This suggests that the MgO sacks on R16:C6 and R14:C6 spilled their contents sometime after the clumped material dispersed across the lid surface.

Figure 6-41: R15:C5 SWB Lid from North Looking South

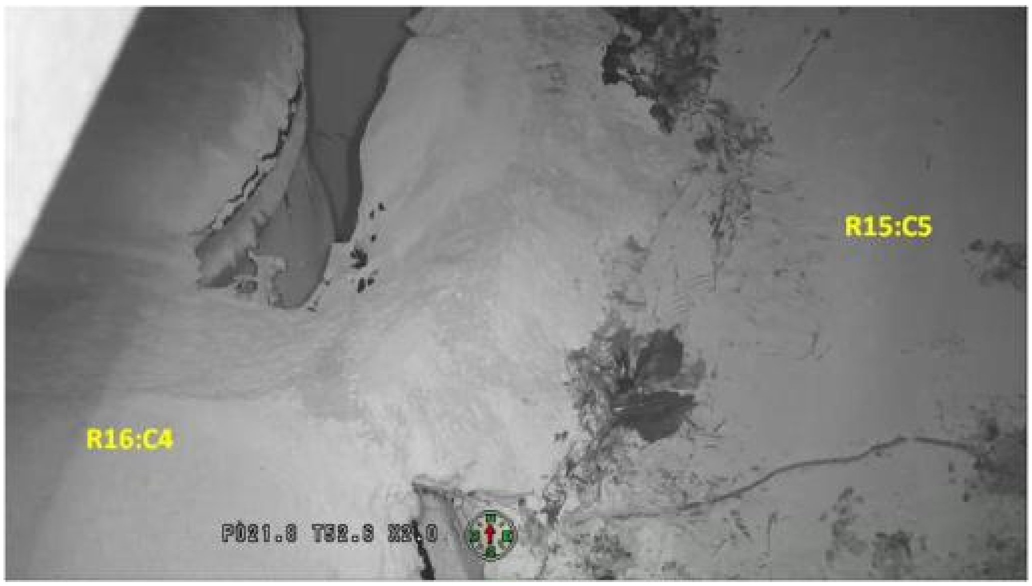


Figure 6-42: Bridge between the R15:C5 SWB Lid and R16:C4

6.1.2 Ignition Source

This section documents possible fire ignition sources, their credibility and proposes the most likely ignition causes. Ignition sources both inside and outside of the waste disposal array were evaluated. Review of the possible ignition sources coupled with the visual inspection have established that the ignition source was thermal runaway inside waste drum 68660.

The method used to establish the fire ignition source consisted of establishing a comprehensive list of possible ignition hazards in the underground, then systematically evaluating the credibility of each hazard consistent with the collected evidence. For simplicity the ignition hazards were arranged in three groups:

- Hazards existing outside of Panel 7 Room 7;
- Hazards existing inside Panel 7 Room 7, but outside of the waste array; and
- Hazards existing inside the Panel 7 Room 7 waste array.

6.1.2.1 Ignition from Outside of Panel 7 Room 7

Ignition hazards that are present in the underground outside of Panel 7 Room7 are:

- Lightning;
- Hot work;
- Fixed electrical systems;
- Diesel vehicle;
- Electric vehicle; and
- Portable electrical equipment.

Lightning was not considered a cause because the evening of February 14 was clear and not conducive to lightning strikes. Hot work was not considered a cause because no hot work had occurred since before the salt haul truck on February 5, 2014. (The possible effect of the salt haul truck fire is evaluated in Section 6.1.5.)

The remaining hazards require the propagation of flames, embers or pyrolysis gases to the waste array in Room 7. Ventilation velocities and directions in the North Ventilation Circuit, the Waste Shaft Intake Circuit, and the Construction Intake Circuit south of the Disposal Circuit Intake are sufficiently high that no credible ignition mechanisms exist that would cause ignition in Panel 7. The same is true of drifts associated with the underground exhaust.

Within the Waste Disposal Circuit and the Construction Intake Circuit north of the Waste Disposal Circuit, diesel equipment had not been operated since February 5. Electric vehicle operation was limited to personnel movement on February 13 and 14; the few vehicles were moved well away from Panel 7 prior to personnel exiting the underground on February 14. Operating electrical systems within the Disposal Circuit Intake functioning on February 14 were limited to lighting and instrumentation circuits (110 VAC or less).

Based on the above observations, no credible ignition source was identified outside of Panel 7 Room 7.

6.1.2.2 Ignition from Panel 7 Room 7, but Outside of the Waste Array

Ignition hazards that are present in the underground outside of Panel 7 Room7 are:

- Fixed electrical systems;
- Diesel vehicle;
- Electric vehicle;
- Portable electrical equipment; and
- Postulated liquid pool fire.

Fixed lighting systems were turned off prior to exiting Panel 7 on February 14. Visual inspection of these systems did not identify a credible source to ignite the February 14 fire.

Diesel, electric vehicles and portable electric equipment remaining in Panel 7 on February 14, with the exception of CAM 151 in the Panel 7 exhaust, had last been operated on February 5, 2014. Visual inspection of this equipment did not identify a credible source to ignite the February 14 fire.

Flammable and combustible liquids are readily absorbed into the salt floor. Visual inspection of the locations where combustible liquid spills were possible (e.g., mining vehicles) did not identify evidence of a combustible liquid fire in Room 7.

Based on the above observations, no credible ignition source was identified outside of the waste array within Panel 7 Room 7.

6.1.2.3 Ignition within the Waste Array

Eleven potential ignition hazards within the waste area were identified and evaluated:

- **Ignition of hydrogen created by chemical reaction**. Hydrogen produced by a chemical reaction can collect within a waste container if the vent is impaired. In sufficient quantity, this would result in an increase in the internal container pressure and subsequent seal failure. A rapid release, if ignited, could cause secondary ignitions. This mechanism is judged credible and fits within the release of combustible gas with ignition category.
- **Ignition of hydrogen created by radiolysis**. Hydrogen produced by radiolysis can collect within a waste container if the vent is impaired. In sufficient quantity, this would result in an increase in the internal container pressure and subsequent seal failure. A rapid release, if ignited, could cause secondary ignitions. This mechanism is judged credible and fits within the release of combustible gas with ignition category.
- **Ignition of a flammable gas**. A container with flammable gas contents could inadvertently be loaded into a waste container and not be identified through the RTR or visual examination process. If the container fails, it can release its contents as a rapid release, which if ignited, could cause secondary ignitions. While the likelihood of such a container being present is low, it will be evaluated as part of the combustible gas with ignition category.

- **Exothermic reaction involving contents of a waste container**. This cause, which includes spontaneous ignition and chemical reactions, is judged credible and fits within the exothermic reaction category.
- **Exothermic reaction involving MgO**. An exothermic reaction involving the MgO will not create elevated temperatures. Thus, this cause is judged not credible. See discussion in Section 6.1.5.3.
- **Exothermic reaction involving packaging external to waste containers**. No credible exposure to incompatible materials that would cause an exothermic reaction of the exposed emplacement combustibles has been identified, thus this ignition cause is judged not credible for the February 14 release event.
- **Overheat ignition of packaging external to waste containers.** An exothermic reaction within a drum will be hottest at the core of the susceptible material within the waste container. Surface temperature of the waste container will be close to ambient temperature. Ignition of the adjacent polyethylene will require surface temperatures in excess of 270°C. (NFPA 921, 2014) To produce such an external surface temperature would require an internal core temperature that would not be sustainable without thermal runaway.
- **Electrical ignition within waste container**. The presence of a battery in the waste stream would provide sufficient energy to cause ignition within a waste container. While this mechanism is credible, the radiographic inspection process or visual examination of waste container contents makes the likelihood sufficiently low that it is has not been further evaluated.
- **An internally generated spark ignition within waste container**. Some waste containers contained metals and similar materials with the potential to produce impact-generated sparks. While credible during movement, the waste containers had been in a stable configuration since before February 5. No mechanism has been identified to produce the needed impact within a waste container, thus this ignition cause is not credible for the February 14 release event.
- **Incompatible materials within waste container**. This cause is judged credible and fits within the exothermic reaction category. Evidence has identified incompatible materials within the waste container as detailed in Section 5.3.2.

Each hazard fits into one of two basic categories: exothermic reaction or release of a combustible gas with ignition.

Exothermic Reactions, Self-Heating and Spontaneous Combustion. Self-heating behaviors can occur through several mechanisms

- Exothermic chemical reactions;
- Biological metabolic reactions; and
- Heat-producing physical processes (e.g., water absorption).

One or a combination of these behaviors can result in ignition which is typically referred to as spontaneous combustion. The remainder of this subsection reviews specific aspects associated with some of the MIN02 waste stream which included the addition of Swheat Scoop® and KOLORSAFE® Liquid Acid Neutralizer.

Organic absorbent - Swheat Scoop® is a wheat-based cat litter that was used as an absorbent material in the MIN02 waste stream. Spontaneous combustion of grains has been studied since the 1700s, but quantitative modeling has provided limited results. (Babrauskas, Ignition Handbook, 2003, p. 867) Studies involving dry, clean, pure substances are of limited value since spontaneous combustion events typically do not occur where these conditions exist. Wheat with moisture content over 14.5 percent has been observed to spontaneously ignite during rail shipments. (Babrauskas, Ignition Handbook, 2003, p. 887) Moisture content exceeding 50 percent is recognized as preventing thermal runaway because of increased conductive cooling through some agricultural materials (e.g., hay). (Babrauskas, Ignition Handbook, 2003, p. 845) This region is not well studied because such high moisture contents equate to poor product quality. Precautions to avoid spontaneous heating of distiller's dried grains with no oil content are to maintain the moisture contents between 7 and 10 percent and cooling below 38°C prior to storage. (Babrauskas, Tables and Charts, 2008, pp. 6-288) Also, extremely low or high moisture content should be avoided when bulk feed materials are handled. (Babrauskas, Tables and Charts, 2008, pp. 6-289)

The salt-containing liquid components in the MIN02 waste stream, prior to the addition of the absorbent material, typically were a mixture of water, nitric acid and neutralizing agents. As such, the spontaneous combustion thresholds discussed in the previous paragraph must be extrapolated. Just as with plain water, low liquid concentrations will prevent spontaneous combustion because of low reaction rates and high liquid concentrations will prevent spontaneous combustion by ensuring good heat conduction through the waste material. In September 2013, LANS changed the quantity of absorbent used during the drum repackaging procedure. The quantity increased from a minimum ratio of 1.5:1 to a "minimum ratio of 3-parts absorbent to 1-part waste or at a ratio as directed by supervision." To quantitatively understand the impact of this change, consider that on a weight basis if all the liquid is treated as water, this equates to a moisture content reduction from 70 percent to well within the 15 to 50 percent range:

$$M_{1.5:1} = \frac{1 \text{ part water } \left(1000 \frac{\text{kg}}{\text{m}^3}\right)}{1.5 \text{ parts absorbent } \left(700 \frac{\text{kg}}{\text{m}^3}\right)} = 0.95$$

$$M_{3:1} = \frac{1 \text{ part water } \left(1000 \frac{\text{kg}}{\text{m}^3}\right)}{3 \text{ parts absorbent } \left(700 \frac{\text{kg}}{\text{m}^3}\right)} = 0.48$$

While these estimates do not account for the moisture in the as-delivered absorbent, the value is below 10 percent. As such, explicitly accounting for this moisture is unnecessary given the accuracy of the absorbent addition process used for treatment of waste drum 68660. In actuality, the liquid content was just part of the total waste component, thus prior to the procedure change the water content was likely already below 50 percent, thus having potential for spontaneous combustion. Following the procedure change, the moisture content was within the 15-50 percent range. While the water content approached 15 percent in portions of the waste matrix, exothermic reactions involving the other absorbed liquids likely created conditions favorable for thermal runaway. Therefore, the procedural change further increased the likelihood for self-heating behavior and the resulting thermal runaway.

<u>Nitrates</u> - The MIN02 waste stream included a variety of nitrates. Both sodium nitrate and magnesium nitrate mixed with cellulosic materials have been observed to ignite with limited heating. (Babrauskas, Ignition Handbook, 2003) Iron oxides, cobalt, copper, magnesium, lead carbonate, potassium carbonate, and lead acetate are recognized as increasing the self-heating behavior. It has been demonstrated that iron compounds can double the chemical oxidation rate of wet sawdust. (Babrauskas, Ignition Handbook, 2003, p. 966) Inorganic nitrates can melt under fire conditions, release oxygen, and intensify the fire severity. The "molten nitrates can react with organic materials with considerable violence." (Davenport, 2008)

<u>Acid neutralizer</u> - The KOLORSAFE® Liquid Acid Neutralizer, which was used during packaging of the MIN02, contains triethanolamine, alizarin and water. The MSDS for KOLORSAFE® identifies the material as having an NFPA health rating of 1, a flammability rating of 1 and a reactivity rating of 0. Thermal decomposition in a limited air supply will produce "carbon monoxide, carbon dioxide, ammonia, irritating aldehydes and ketones."

The DOW Chemical Company Triethanolamine Product Safety Assessment indicates that the product "can react exothermically (producing heat) with many other materials, including strong oxidizing agents, strong acids, strong bases, aldehydes, ketones, acrylates, organic anhydrides, organic halides, formates, lactones, oxalates, and copper and zinc metal alloys." The potential for exothermic reactions is not unique, and does not imply a significant hazard. In some of the cited cases, the other material represents the dominant hazard and exothermic reaction might occur with common combustible materials. The reaction hazard risk for triethanolamine has been established as negligible based on the National Fire Protection Association reactivity rating of 0. A reaction rating of 1 would be applied to (Standard System for the Identification of the Hazards of Materials for Emergency Response, 2012) "materials that in themselves are normally stable but that can become unstable at elevated temperatures and pressures."

Therefore, reactions attributable to triethanolamine were determined to have not directly initiated the exothermic reaction but may have served to increase the potential for such a reaction.

Combustible Gas Release with Ignition. The timing of the radiological release discussed later in Section 6.4.2, and the results of the visual inspection established that this mechanism did not occur. Based on characterization data (RTR and FGA), the potential for sufficient radiolysis gas generation or the inclusion of a significant quantity of compressed gas as necessary to initiate the fire has been reviewed for drum 68660 and judged not credible .

Summary

The Board concluded that the fire ignition occurred within the waste array. The most credible cause was an exothermic reaction initiated due to the presence of incompatible materials in the waste container [e.g., organic absorbent, nitrate salts, triethanolamine].

6.1.2.4 Secondary Ignition

To cause more than the initial flame condition, the credible ignition mechanisms discussed in Section 6.1.2.3 must ignite other materials in the array. These secondary items include the fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric.

The most common metric to evaluate if secondary ignition will occur is heat flux (i.e., energy transferred per unit area per unit time, kW/m^2). The threshold values are both flux and exposure time dependent. The longer the exposure the lower the threshold heat flux. For extended exposure most flames will impart a heat flux of above 35 kW/m^2. (Babrauskas, Ignition Handbook, 2003, p. 519) For short duration exposures such as might be created by a flash fire, the flux will be higher. While peak fluxes of 230 kW/m^2 have been measured these values lasted for less than 2 seconds. For evaluation purposes the short exposure threshold is taken as a composite of the 2 second value and 80 kw/m2 for 6 seconds. (Babrauskas, Ignition Handbook, 2003, p. 615)

Polypropylene is categorized as an easy-to-ignite material. The ignition time for thin, non-fire-retardant polypropylene (3 mm, 0.13") is 27 seconds for an exposure of 50 kW/m2 and 117 seconds for an exposure of 20 kW/m2 (Piloted Ignition of Solid Material Under Radiant Exposure, 2002, p. 45). Extrapolation of the published ignition flux data (*Piloted Ignition*, 2002, p. 45) demonstrates that a heat flux of 80 kW/m2 will produce an ignition time of 15 seconds in a 3 mm thick material. Thinner samples, such as the MgO super sacks, will have lower times to ignition for a given heat flux. As such, ignition of the polypropylene fabric is likely for any of the credible ignition sources that would produce a rapidly burning flame front similar to a flash fire.

Polyethylene is also categorized as easy-to-ignite, but requires a greater heat flux than polypropylene for ignition. Ignition of high-density polyethylene (6 mm, 0.23") occurs in 59 seconds at an exposure of 50 kW/m^2, and 422 seconds at an exposure of 20 kW/m^2. (*Piloted Ignition*, p. 38) Data for thinner samples (2 mm, 0.079"), is 54 and 257 seconds. (*Piloted Ignition*, p. 62) The polyethylene slip sheets and reinforcement plates are 3.8 mm (0.15") thick. Based on extrapolation of this information, an exposure of 80 kW/m^2 for 22 seconds (*Piloted Ignition*, p. 38) is necessary to ignite the polyethylene sheets within the array. As such, a flash fire is unlikely to cause direct widespread ignition of the polyethylene slip sheets and reinforcement plates. Rather, ignition must have resulted from exposure to sustained burning. A flash fire would be expected to ignite the stretch wrap.

Corrugated cardboard and fiber board are usually categorized as normally difficult to ignite based on the definition established in (Bukowski, Richard W, 1990). Corrugated cardboard ignites at a heat flux of 15 kW/m2. (Babrauskas, Ignition Handbook, 2003, p. 899) Fiberboard ignites spontaneously after 5 seconds when exposed to 52 kW/m2 (Guide for Fire & Explosion Investigations). Corrugated fiberboard (2.8 mm, 0.11") requires 4 seconds for ignition at an exposure of 81 kW/m2, 8 seconds at an exposure of 51 kW/m2, and 68 seconds at an exposure of 20 kW/m^2 (Wraight, H. *The Ignition of Corrugated Fibreboard ('Cardboard', 1974)* The ignition flux is not dependent on the thickness. Ignition is most likely to occur at the exposed edge of the material. Complete ignition would not be instantaneous and combustion may cease when the exposing flame is removed if the orientation of the fiberboard is horizontal or vertical with downward burning.

6.1.3 Ventilation

The ventilation flow rates and velocities associated with Panel 7 were characterized to support development of the release timing evaluation discussed in Section 6.4.2 and the evaluation of horizontal incremental fire propagation between waste stacks as discussed in Section 6.1.4. To establish the ventilation flow rates and velocities during the event the electronic data for the underground ventilation system was obtained from the WIPP Ventilation Data Records. This information included volumetric flows, pressure differentials, temperature, and humidity at instrumented locations. A comprehensive review of the records for February 14 and 15, 2014, was conducted for data published in 1-sample/minute increments. In addition, selective reviews were conducted using data published in 8-samples/minutes increments just prior to and just after, the detection of airborne contamination (Fire Forensic Analysis Report). This effort established that:

- Ventilation transient behavior was limited to the automatic shift to the filtration flow rate. (**Note**: Direction of flow to HEPA filters requires a manual action, but the flow rate change is automatic.) There was no measured transient established by fire or explosion behaviors;
- The flow rate through Room 7 prior to the release event was 42 kcfm;
- The total flow rate through Panel 7 prior to the release event was 90 kcfm;
- The flow rate through Room 7 after the transition to filtration mode was 4 kcfm;
- The total flow rate through Panel 7 after the transition to filtration mode was 4.4 kcfm;
- The flow velocity above the array prior to the release event was about 340 fpm; and
- The flow velocity above the array after the event was about 17 fpm.

6.1.4 Fire Propagation Mechanism

The visual inspection results (Section 6.1.1), the ignition source analysis (Section 6.1.2.3), the chemical forensic analysis (Section 6.2), and the radiological forensic analysis (Section 6.3) support the conclusion that an exothermic reaction within waste drum 68660 initiated the fire damage in the Panel 7, Room 7 waste array. The breach of drum 68660 ejected a mixture of pyrolysis gases and high-specific surface area organic material. This situation is unique and does not fit into the classical fire behavior terms used in NFPA 921 related to dust explosions, combustible gas ignitions, and flash fires. The high specific surface area of the waste matrix facilitated rapid combustion. Prior testing conducted by DOE involved ejected material that was more representative of job wastes such as sheets of plastic, cloth coveralls, paper. The rapidly combusting mixture created an expanding flame front that caused ignition of nearby combustibles and perturbed the ventilation flow.

While this initial fame front directly caused some of the observed damage described in Section 6.1.1, multiple fire propagation mechanisms likely occurred during the February 14 radiological release event. These included:

- Downward propagation from flaming droplets of burning plastic;
- Upward propagation by flame impingement on exposed combustibles within the same stack;
- Convective propagation associated with burning embers transported by air currents and landing on exposed combustibles;
- Incremental propagation by radiation heat transfer between a flame and a combustible in a nearby stack; and
- Incremental fire propagation between waste stacks by flame impingement.

Propagation by flaming droplets is a commonly observed phenomena associated with burning plastic. A heated thermoplastic, such as polyethylene, will tend to melt and flow when heated. When flaming, the material can drip and carry flames downward as burning tar-like drops. (Davenport, 2008, pp. V.1, Sec. 6, Chap. 13) When these flaming drops land on an exposed combustible material, ignition of the exposed combustible can occur.

Upward vertical propagation within a stack may occur if the middle or bottom tier combustibles are ignited and create a flame sufficiently tall to cause ignition of combustibles above the flames. These combustibles would include the vertical stretch wrap and reinforcement plates associated with 55GD and 100GD assemblies; the slip sheets and fabric associated with the MgO super sacks; and the fiberboard slip sheets that are under SWBs.

Propagation by burning or hot embers is a commonly observed mechanism that creates intermittent fire damage where two regions are badly fire damaged, but the intervening area is pristine. In such instances a fire in the first location releases a flaming or hot object that lands on an exposed combustible at the second location and the object ignites the exposed combustible. Migrated combustibles observed in the waste array included: the contents of 68660, polyethylene stretch wrap, polypropylene fabric, and cardboard stiffeners. Any of these materials have the potential to burn, migrate and cause ignition at a nearby waste stack.

This fire-propagation mechanism likely occurred at R18:C6, where the exposed MgO super sack fabric or a slip sheet ignited when the ventilation perturbation occurred following the failure of waste drum 68660 (Figure 6-12).

The incremental fire propagation mechanisms in the array were evaluated using computational fluid dynamics fire modeling, (Waste Isolation Pilot Plant - Fire Dynamics Simulator Modeling, 2015) and by comparison with prior waste drum array testing results. These efforts demonstrated that:

- The most severe fire damage would be expected to occur at locations with 55GD and 100GD assemblies;
- Vertical fire propagation between tiers can readily occur for 55GD and 100GD assemblies;
- Horizontal fire propagation between stacks can occur when 55GD and 100GD assemblies are separated by less than 10 cm, and may occur for greater separation distances where high forced ventilation flows, such as existed prior to the transition to filtered ventilation mode, are present; and

- While incremental propagation could have occurred within Rows 9 and 10, the mechanism would not account for the initial ignition in these rows.

6.1.5 Salt Haul Truck Fire Analysis

A fire reconstruction analysis was completed for the underground salt haul truck fire that occurred on February 5, 2014, and documented in the Fire Forensic Analysis Report. This reconstruction was developed from observed fire damage following the salt haul truck fire, ventilation flow measurements, and underground geometry. The analysis was segmented into three parts:

- Establish the fire conditions at the base of the Salt Handling Shaft;
- Demonstrate that the temperature increase in Panel 7 Room 7 was negligible; and
- Demonstrate that the fire combustion products did not damage the MgO super sacks.

6.1.5.1 Salt Handling Shaft Conditions

Conditions at the base of the Salt Handling Shaft on February 5, 2014, were estimated using simple thermodynamic and hydraulic models. Two approaches were used, one prior to the transition to filtration mode and the other during operation in the filtration mode.

The fire occurred at approximately 1048, when a salt haul truck caught fire in the E-0 drift at the intersection with N-300, which connects to the Air Intake Shaft. A majority of the flow through the Air Intake Shaft reaches this intersection, where it splits between the North Circuit Intake and the Construction circuits. At the beginning of the fire the combustion products were directed to each of these circuits.

At 1058, the Facility Shift Manager directed the Central Monitoring Room Operator to change ventilation from normal mode to filtration mode, believing this would reduce both the fire and smoke.[13] This change directed virtually all airflow through to the Construction Circuit, with no substantive flow through the North Circuit Intake. The base of the Salt Handling Shaft is connected to the drift between the salt haul truck fire and the remainder of the underground. As such, the fire-heated air at the base of the Salt Handling Shaft created a significant density gradient that caused the Salt Handling Shaft to upcast, which is a flow reversal with air traveling from the underground to the surface.

The energy release rate created by the burning salt haul truck during the intense portion of the fire was bracketed by 5 to 15 megawatts. This range was established based on comparison with design data for other vehicles *(Standard for Road Tunnels, Bridges, and Other Limited Access Highways*, 2014) and energy release rate for other items. (Babrauskas, Heat Release Rates, 2008)

During the early portion of the fire, before the shift to filtered mode, the energy release rate likely did not exceed 10 megawatts. As such, the temperature at the base of the Salt Handling Shaft, T_2, was estimated using a simple energy balance accounting for the energy release rate, $\dot{Q}$,

[13] *Underground Salt Haul Truck Fire at the Waste Isolation Pilot Plant February 5, 2014.* Washington, DC: Department of Energy, March 2014.

the mass flow through the drift, $\dot{m}$, the specific heat of air, c_p, and the air temperature entering the underground, T_1:

$$T_2 = \frac{\dot{Q}}{\dot{m}c_p} + T_1 = \frac{10\ \mathrm{kW}}{\left(142\ \frac{\mathrm{kg}}{\mathrm{s}}\right)\left(1.014\frac{\mathrm{kJ}}{\mathrm{kg}\cdot{}^{\circ}\mathrm{C}}\right)} - 0^{\circ}\mathrm{C} = 69.9^{\circ}\mathrm{C}$$

This temperature did not account for upcast flow induced by the fire in the Salt Handling Shaft, if it had been occurring. If the Salt Handling Shaft was upcasting during the earlier part of the fire, then the 69.9°C conservatively over predicts the temperature at the base of the Salt Handling Shaft.

Upcasting in the Salt Handling Shaft did occur following the change to filtered mode (Figure 6-43). This upcasting increased the airflow moving past the salt haul truck fire. The flow behavior in the Salt Handling Shaft was modeled by a Bernoulli's fluid equation, recognizing that the volumetric flow up the shaft was induced by the thermal gradient, and would create a friction flow resistance. Simultaneous solution of the flow equation, and the energy balance equation, as discussed for the early portion of the fire, demonstrated that the temperature at the based of the Salt Handling Shaft was about 82°C when the energy release rate was 15 megawatts.

Figure 6-43: Upcasting Observed at the Salt Shaft on February 5, 2014

6.1.5.2 Panel 7 Room 7 Conditions

The temperature at Panel 7 Room 7 was estimated using a heat transfer analysis that accounted for the energy loss to the drift walls as air traveled the 3,000 feet from the base of the Salt Handling Shaft to Room 7. The energy balance solution inputs included: the convective heat transfer coefficient for the salt that forms the exposed drift surfaces, the surface area of these surfaces, the temperature of these surfaces, the mass flow through the drift, $\dot{m}$, the specific heat of air, c_p, and the temperature at the base of the Salt Handling Shaft, T_2. Even for the 82°C prediction, the large heat transfer surface area ensured that the temperature increase in Panel 7 Room 7 during the salt haul truck fire was negligible.

6.1.5.3 MgO Response to Combustion Products

Possible reactions between the combustion products created during the salt haul truck fire and the MgO in Panel 7 Room 7 were evaluated to establish if these products could have caused the observed MgO damage or initiated the radiological release on February 14, 2014.

The transition to filtration mode did not occur prior to soot reaching Panel 7 Room 7. The flow rate through Panel 7 prior to the fire on February 5, 2014, was 66.1 kcfm. After the transition to filtration mode the flow rate was 38.5 kcfm. This relatively small flow transient would not be expected to result in significant soot deposition in Room 7. This was confirmed by visual inspection on February 14, just hours prior to the radiological release event. The lack of soot evidence indicates that soot-MgO interaction could not have occurred in Panel 7 Room 7.

In addition to soot, the other primary combustion products on February 5 were water (H_2O) and carbon dioxide (CO_2). The localized reaction between MgO and the primary combustion products (H_2O and CO_2) is very slow, with no discernible temperature increase and would not have caused the observed damage to the MgO super sacks prior to the February 14, 2014, radiological release event nor would it have created a localized MgO reaction that subsequently resulted in the February 14 release event.

6.2 Chemical Forensics

The following section provides a detailed summary of analytical chemistry results of various sample media. Chemical analyses were performed by three DOE national laboratories: Savannah River National Laboratory (SRNL), LANL, and Pacific Northwest National Laboratory (PNNL). In some cases, the DOE Headquarters-established Technical Assessment Team[14] (TAT) performed the chemical analyses in coordination with the Board, and in other cases the LANL performed the chemical analyses with TAT approval and in coordination with the Board, of the analysis protocols. In all cases, the Board reviewed the chemical analyses. The types of chemical analyses include:

[14] The Technical Assessment Team (TAT) was tasked to help determine the mechanism(s) and chemical reactions that resulted in the observed drum breach and release of material in WIPP in February 2014. The TAT represents the combined technical and scientific expertise of five national laboratories (Savannah River, Pacific Northwest, Sandia, Oak Ridge, and Lawrence Livermore National Laboratories). The TAT is closely coordinating its work with the DOE Accident Investigation Board, and the Los Alamos and Carlsbad Field Offices.

- Ion Chromatography (IC);
- Total Organic/Inorganic Carbon Analysis (TOC/TIC);
- Inductively Coupled Plasma (ICP) Emission Spectrometry (ICP-ES);
- Inductively Coupled Plasma Mass Spectrometry (ICP-MS);
- Gas Chromatography-Mass Spectroscopy (GC-MS);
- Fourier Transform Infrared Analysis (FTIR);
- X-Ray Diffraction;
- Scanning Electron Microscopy (SEM); and
- X-Ray Fluorescence.

6.2.1 Chemical Data Sources

Chemical data sources included the following:

- Radiological survey smears of removable surface contamination from Panel 7, Rooms 1-7 including exhaust drift samples;
- Air filters from the FAS 118 at the Panel 7 inlet and the CAM in the WIPP underground;
- Magnesium oxide samples from Panel 7 Room 7;
- Material samples parent drum S855793;
- FAS and CAM Filter Sample Results; and
- Analysis results of material ejected onto R15:C5.

6.2.2 Results of FAS 118, Station A FAS, Station B FAS, CAM Filter, Parent Drum, Debris and Deposited Material Analysis

The tables presented below summarize the results of chemical analyses of sample media collected after the event. These data support the chemical forensics summary discussion presented in Section 6.2.5.

The FAS 118 collected air samples from the inlet to Panel 7, CAM 151, directly sampled the airborne radioactivity in Room 7 Panel 7. The CAM provided continuous air monitoring of airborne radioactive particulates collected on a circular, 47-mm filter (Figure 6-44).

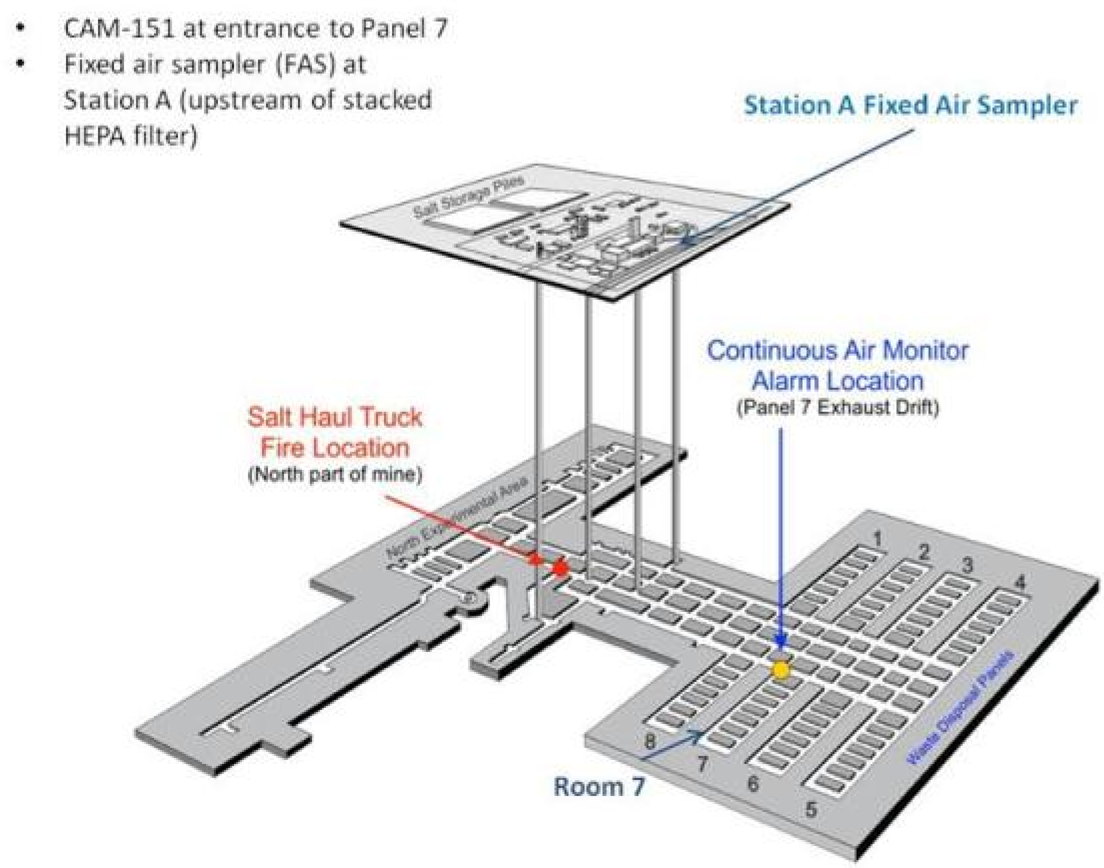


Figure 6-44: Effluent Monitoring Data

Chemical analysis of the FAS 118 and CAM 151 air samples identified actinides, metals, and organics. Results are consistent with the materials used in remediation actions to eliminate residual liquids from the waste for packaging drums, and the introduction of an organic-based absorbent to eliminate liquids. It should be noted that FTIR results provide evidence consistent with oxidation reactions involving an organic-based absorbent, by presence of cellulose and oxidized cellulose in the CAM 151 Filter #2 sample. The chemical analysis results of the FAS 118 filter and CAM filters are summarized in Table 6-1.

Table 6-1: Material Identified during Chemical Analysis of the FAS and CAM Filters

Analytical Method	Identified	Quantity/Notes
Ion Chromatography	Sulfate	252 – 892 µg/wipe
	Fluoride	1030 – 1480 µg/wipe
	Formate	512 – 1160 µg/wipe
	Chloride	3730 – 4510 µg/wipe
	Nitrate	197 – 2240 µg/wipe

Analytical Method	Identified	Quantity/Notes
	Sulfate	210 – 2920 µg/wipe
TOC/TIC	Inorganic Carbon Organic Carbon	39 – 1200 µg/swipe 1650 – 4760 µg/swipe
ICP-ES	Calcium Iron Magnesium Sodium Silicon	Qualitative measurement only.
ICP-MS	Strontium Lead Uranium Cadmium	Qualitative measurement only.
GC-MS	Hydrocarbons	Long chain hydrocarbons (C25 to C30), 0.79 to 0.97 mg/filter for CAM filters; 2.1 mg for FAS filter
FTIR	Hydroxide Groups Alkane Groups Nitrile Groups Carbonyl Group	Identifies presence of organic compounds. Evidence of cellulose and oxidized cellulose
X-Ray Diffraction	Sodium Chloride	Qualitative measurement only.
SEM	Sodium Chlorine Magnesium Potassium Lead	Lead was present at 1-10 micron diameter. Large presence of Lead overshadowed sulfur.
X-Ray Fluorescence	Chloride Iron Titanium Zinc Lead	XRF is not sensitive to elements with atomic number less than 13.

Samples of debris from the area of R15:C5 were collected and analyzed using the same test methodologies as for the FAS and CAM filters. The debris consisted of a mixture of MgO and material ejected from drum 68660. The chemicals identified are consistent with those for the

FAS and CAM filters. The results of the R15:C5 debris chemical analyses are summarized in Table 6-2.

Table 6-2: Chemicals Identified during Analysis of the Debris at R15:C5

Analytical Method	Identified	Quantity/Notes	
Ion Chromatography	Fluoride	<1460 mg/kg	
	Formate	<1460 mg/kg	
	Chloride	13100 mg/kg	
	Nitrite	13100 mg/kg	
	Bromide	<7300 mg/kg	
	Nitrate	34600 mg/kg	
	Phosphate	1610 mg/kg	
	Sulfate	3070 mg/kg	
	Oxalate	13100 mg/kg	
ICP-ES		#3 R15:C5 ug/g	#2 R15:C5 ug/g
	Sodium	6640	217000
	Magnesium	210000	130000
	Lead	5680	7740
	Potassium	1810, 8090 (14400-6310)	6660, 9140 (12300-3160)
	Calcium	5120, 5400 (11300-5900)	3260, 3370 (5900-25030)
	Aluminum	3130	2170
	Silicon	2470	1870
	Iron	1100	1160
	$^{235/238}U$	4.78%	6.05%
GC-MS and SPME GC-MS	No nitrated organics No triethanolamine or triethanolamine decomposition products.		
FTIR (ATR)	Carbonate Swheat Formates Oxalates	Qualitative measurement only. Did not identify nitro organics	

Analytical Method	Identified	Quantity/Notes
	Nitrates Nitriles	
FTIR Microscope	Sodium carbonate Sodium nitrate Sodium nitrate	Qualitative measurement only.
X-Ray Diffraction	NaNO3, MgO, and Trona Na3(CO3)(HCO3) 2H2O	
Energy-Dispersive Spectroscopy	All measurements show similar metals. The background particles contain mostly Mg, O, and Na with small amounts of K, Ca and Cl. In backscatter imaging, bright particles that show up contain mostly Pb, with small amounts of Al, P, Fe and occasionally Si.	Qualitative measurement only.

Materials deposited on the surfaces in Panel 7 were collected using multiple techniques, including Velcro backing, stick-tape and radiological smears. The samples were analyzed using the same test methodologies as the FAS and CAM filters and the R15:C5 debris. The chemicals identified are consistent with those for the FAS and CAM filters. The chemical analyses results of the surface-deposited materials are summarized in Table 6-3.

Table 6-3: Chemicals Identified during Analysis of Samples from Panel 7 Surfaces

Analytical Method	Identified	Quantity/Notes
Energy-Dispersive Spectroscopy	Magnesium Oxide particles Calcium Nitrate Iron Chromium Lead Tin Bismuth Barium Sulfate Plutonium	Qualitative measurement only. Note that many of the metals are also present in background materials in Panel 7. Some particle morphology is suggestive of rapid precipitation from gas phase.
Fluorescence Microscope	Fluorescence spectra consistent with Swheat.	Qualitative measurement only.
Raman Spectroscopy	Fluorescence spectra consistent with Swheat.	Qualitative measurement only. Did not identify nitro organics
ATR-FTIR	Dolomite Sodium Hydroxide	Unidentified organic residue observed on dolomite.
X-Ray Fluorescence	Lead	Abundant lead detected. Bismuth, lanthanum and tungsten were not detected.

Samples of material from the parent drum, S855793, included glass swipes and solid debris. The samples were analyzed using the same test methodologies as the FAS, CAM and R15:C5 samples. The analyses results indicate that the materials in the parent drum are consistent with its expected contents, increasing confidence that the parent drum manifested contents accurately reflect the actual parent drum contents with regard to chemical composition. The chemical analyses results of the parent drum materials are summarized in Table 6-4.

Table 6-4: Chemicals Identified during Analysis of Parent Drum Debris

Analytical Method	Quantity/Notes
Energy-Dispersive Spectroscopy	Debris contains predominantly Pb, with small amounts of Na, Mg, Al, K, Ca, and Fe
ICP-ES	No detectable metals (mixed acid & peroxide fusion)
ICP-MS	trace amounts of lead (372 µg/swipe)

Analytical Method	Quantity/Notes
Ion Chromatography	Mostly nitrate (12.6 wt%) and a trace of nitrite (<0.03 wt%) Small amount of oxalate (0.2 wt%) and acetate and formate (0.06 wt%) Trace amounts of chloride, fluoride, and sulfate (<0.1 wt%)
X-Ray Fluorescence	Predominantly Pb with very small amounts of Mg, Al, Cl, Ca, Fe, Cr, Mn, Ni, and Cu

6.2.3 Chemical Reactivity Sample Results

The purpose of chemical reactivity analysis is to understand how chemicals react when combined, specifically examining explosive and exothermic sensitivity. The following was identified through the DOE accident investigation:

- An organic based absorbent, Swheat Scoop®, was used to absorb free liquids and nitrate salt bearing waste in the process of waste remediation;
- The pH neutralizing agent, KOLORSAFE®, for the waste liquid contained triethanolamine;
- Glovebox gloves that contained the metals bismuth, lanthanum, and tungsten were added to the remediated waste stream (i.e., three drums in Panel 7); and
- Lead present in sample analysis likely originated from the lead liner of the parent drum, and was not indicative of lead being a constituent in the original waste stream.

At the request of the Board, LANL and the DOE TAT performed a series of small scale (e.g. bench top) chemical reactivity analyses. The chemical reactivity analyses were broken into three test series that varied the nitrate sources (e.g. potassium nitrate, sodium nitrate), the acid concentration (1 molar, 5 molar, none), neutralizing agent (e.g. KOLORSAFE®, triethanolamine), and addition of a metal source (e.g. lead, tungsten, none) with different forms of Swheat Scoop® (e.g. powdered, crushed).

The chemical reactivity analyses on the small scale samples concluded the following:

- Nearly all mixtures tested were insensitive to electrostatic discharge, impact, and friction. Only one mixture showed increased sensitivity to friction and impact. This is the nitrated Swheat Scoop® mixture consisting of Swheat Scoop® and sodium nitrate treated with 5M nitric acid.
- Nearly all samples have endothermic barriers around or above 130°C, and the onset of exothermicity beginning above 300°C.

- The physical characteristics of sample test materials also had an effect on results. Finely ground powders of Swheat Scoop® and potassium nitrate when mixed, exhibit lower exothermic temperature at around 178°C, which is lower than the exothermic temperature in excess of 300°C for other mixtures that are not ground. This is consistent with the expectation: materials with a higher specific surface area, i.e., small particulate, will require less initiating energy or lower temperature than those with lower specific surface area, i.e., bulk materials.
- Vacuum thermal stability test results on 200 mg samples indicated that nearly all mixtures were thermally stable. The single exception identified in testing was a nitrated Swheat Scoop® mixture; however, this mixture was not identified to be present in the event materials.
- KOLORSAFE® (triethanolamine solution) appears to reduce the onset of exothermicity by 100°C to around 240°C, as shown by DSC results. This is consistent with the expectation for a sensitizer.
- An exothermic reaction can occur from the mixture of cellulosic materials and the residual nitric acid catalyzed by metals (e.g. lead, tungsten).

Subsequent reactivity modeling and testing was conducted by Sandia National Laboratories (SNL). The SNL results differ from the results of the LANL testing, primarily with respect to initiation of drum self-heating being possible at onset temperatures below 100°C, leading to thermal runaway and over-pressurization of the drum. The results also indicate that the self-heating within the drum is strongly influenced by the metals present and the presence of water within the drum contents. The testing protocol and results of the SNL reactivity testing are presented in detail in the TAT investigation report and the SNL reactivity testing report. Key points are summarized below.

- Comparison with Los Alamos National Laboratory (LANL) results:
  - Extrapolation of low temperature exothermic reactions over a range of heating rates suggests these may occur near ambient temperature, with Swheat Scoop®, Mg nitrate, Na nitrate, Fe nitrate, and Ca nitrate.
  - Ca nitrate and Fe nitrate both have strong effects on thermal runaway temperatures. Fe nitrate has a significant role in low temperature reactions.
  - Pb, Cr, and oxalic acid have little effect on ignition of the dry mixtures.
  - Adding Mg and Na nitrates to Swheat and neutralized acid increases reactivity.
- A mixture of 3 volume parts Swheat Scoop® and 1 volume part 3.5 M HNO3 dried in air at room temperature overnight began reacting at 30°C, and continued to react until reaching 80°C when the reaction rate accelerated into thermal runaway
- A mixture of 3 volume parts Swheat Scoop and 1 volume part KolorSafe®-neutralized 3.5 M HNO3 began a sustainable self-heating reaction near 140°C.
- The heating of samples at 1°C/minute showed little exothermic behavior with Swheat Scoop® and water, but adding neutralized acid and nitrate salts resulted in significant

reactivity leading to thermal runaway. This behavior is suppressed by liquid water, and a thermal runaway occurs after the water has fully vaporized,

- Localized removal of water by hydrolysis reactions with carbohydrates and evaporation increased the concentration of nitric acid and increased the reactivity of the nitrate/organic mixtures.

- Thermal properties vary primarily with presence of moisture.
    - Addition of salts to Swheat has a lesser effect.
    - Neutralized acid and Swheat is more reactive than Swheat and water.
    - Temperatures were as high as 400-600°C in thermal runaway with mixtures that include liquid. Measured temperatures were as high as ~300°C in dry mixtures.
- Small-scale tests exhibit phenomena that may have occurred in drum 68660. Cook-off behavior may not be the same at larger scales.

6.2.4 Headspace Gas Sampling and Thermography Sample Results

Headspace sampling collected gas inside a standard waste box (SWB) in which the sibling drum 68685 is stored, along with other similar remediated drums that contained nitrate salt bearing waste. Gas was pulled out of the drum or SWB with a syringe that was inserted into the drum or SWB filter (Figure 6-45).

Figure 6-45: Syringe to Pull Gas from Drum or SWB via Sample Port on Filter

The purpose is to understand, if any, the chemical reactions occurring inside the drum or SWB. In addition to headspace gas sampling, drum and SWB thermography was also performed. Thermography measures the outside temperature of the drum or SWB. This is performed with a handheld device that is aimed at the drum or SWB and a temperature measurement is recorded.

Headspace gas sampling and thermography results of the SWB containing the sibling drum 68685, identified the following:

- No appreciable temperature change was occurring beyond normal environmental fluctuations;
- Oxidation was occurring; and
- Radiolytic generation was occurring, but at insufficient rates to account for the magnitude of gas generation being observed.

LANL conducted headspace gas sampling and thermography monitoring for the SWB containing drum 68685, the sibling drum of drum 68660. In addition, headspace gas sampling and thermography was performed for other remediated waste drums at LANL. The purpose of the gas sample analysis is to determine the presence and/or concentration of potential reaction products. The sampling was conducted via the vent port on the waste box, and thus is not able to directly sample the gases within the suspect drum, nor within any waste bags within the drum. The gases detected in the headspace gas sampling are consistent with oxidation. The headspace gas monitoring results are shown in Figure 6-46. The trend suggests that there is a chemical oxidation reaction occurring.

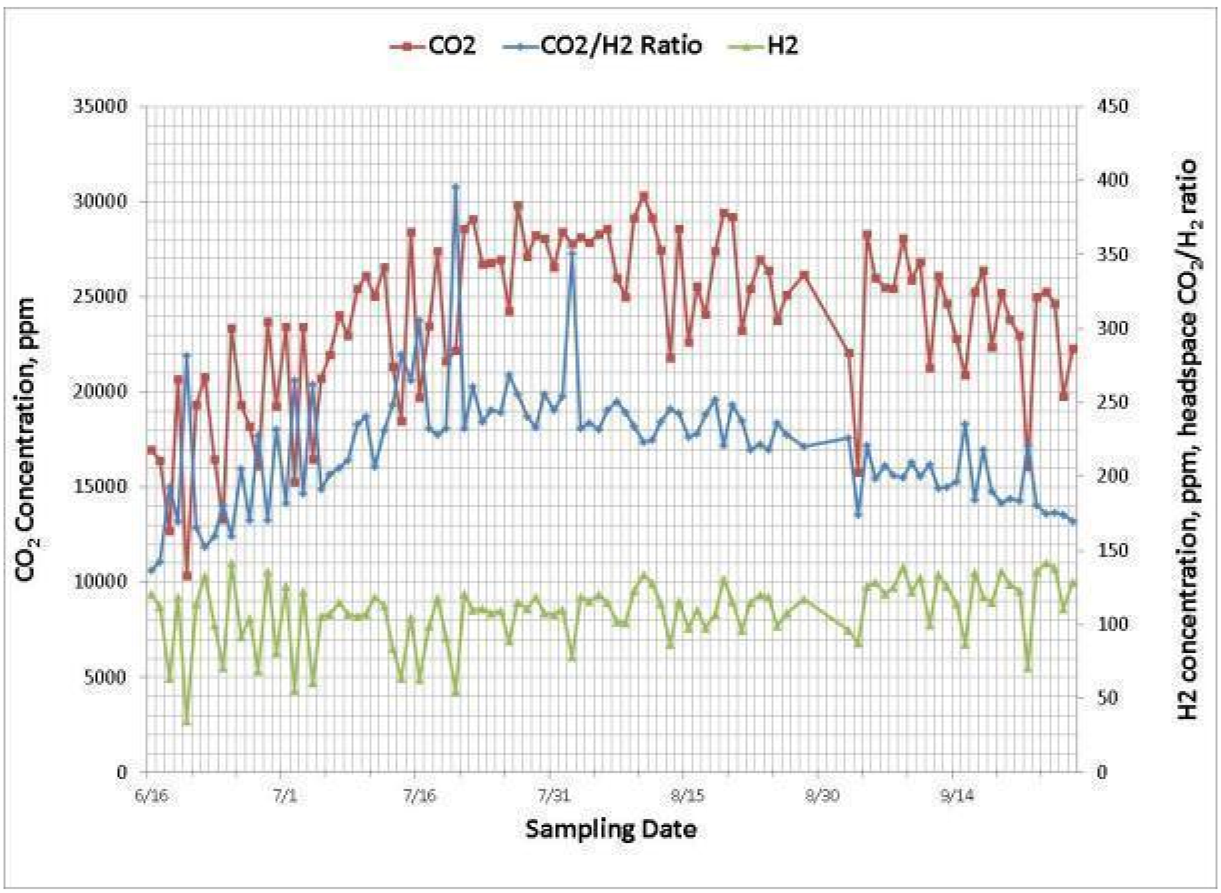


Figure 6-46: Headspace Sampling Results of CO_2 and H_2

6.2.5 Analysis of Section 6.2 – Chemical Forensics

Chemical analyses were conducted on a variety of sample media following the radiological event in Panel 7. Media collected and analyzed included the FAS 118 filter, CAM filters, magnesium oxide samples, debris from the vicinity of the breached drum, and materials from the parent drum S855793. The primary chemicals identified across the sample media are consistent with a transuranic waste profile, materials used in remediation activities, and materials in the vicinity of the event. The chemicals identified include organic and inorganic carbon, transuranic elements (actinides), and metals such as lead and magnesium. The analytical results suggest a fuel (organics) rich environment with limited quantities of oxidizers in the waste matrix. These results are consistent with the materials used in repackaging activities to neutralize the oxidative properties of the nitrate salts and/or eliminate residual liquids from the waste for packaging drums, and the introduction of an organic absorbent (Swheat Scoop®).

Headspace gas sampling and thermography of the SWB containing the sibling drum 68685 identified that oxidation was occurring; however, there have been no temperature fluctuations beyond those attributable to environmental influences. Chemical sensitivity testing of identified waste materials indicated that the materials were generally stable with regard to electrostatic discharge, impact, friction, and thermal stability, and had endothermic barriers around or above 130º C.

Evaluations conducted by the TAT and LANL, in coordination with the Board, as well as independent tests conducted by SNL, include the thermodynamics and reaction products of potential chemical reactions within the configuration and materials present in Panel 7 Room 7. The purpose of these evaluations was to determine the possibility for self-initiation of reactions within a drum (without external contributors), reaction rates, estimated drum temperatures, how much material needs to react to breach the drum, and resulting gases and drum internal pressures. The analyses also evaluated the sample media for metals (specifically MgO), organics, inorganics, and indications of an organic absorbent, e.g. Swheat.

Based on a review of the collective information from the parent drum, ejected materials and air filter analyses, the Board has made the following observations:

The materials in the parent drum are consistent with its expected contents, and are consistent with materials detected after the event. The primary chemicals identified across the sample media are consistent with a transuranic waste profile, materials used in remediation activities, including the Swheat Scoop® absorbent, and materials in the vicinity of the event. These observations indicate that the materials involved in the event are consistent with material originating in the parent drum, placed into drum 68660, materials from remediation, and materials in the vicinity of the event.

The materials detected are consistent with the source materials and with decomposition of the organic absorbent. No triethanolamine or triethanolamine decomposition products were detected. Nearly all mixtures of source materials tested were insensitive to electrostatic discharge, impact, and friction. Low temperature exothermic reactions over a range of heating rates may occur near ambient temperature under favorable conditions.

6.3 Radiological Forensics

The following section provides a detailed summary of laboratory radiological results of various sample media. Radiological analyses were performed at WIPP, and by three DOE national laboratories; Savannah River National Laboratory (SRNL), LANL, and Pacific Northwest National Laboratory (PNNL) in support of the accident investigation as part of the TAT.

The primary radiological analyses were performed with a high purity germanium detector that analyzed gamma energies. In addition, radiological smears were measured with a gas proportional counter. Additional radioanalyses were primarily performed by SRNL and PNNL.

6.3.1 Radiological Data Sources

Radiological data sources included the following:

- Non-destructive analysis of suspect drum 68660;
- Radiological survey smears of removable surface contamination from Panel 7, Rooms 1 – 7;
- Air filters from the FAS 118, FAS Station A, FAS Station B and CAM 151; and
- WIPP moderate efficiency filter.

6.3.2 Continuous Air Monitor Sample Results

The continuous air monitor, CAM 151 is located in the Panel 7 exhaust drift and monitors the air that flows out of Panel 7. CAM 151 provides continuous air monitoring of airborne radioactive particulates collected on circular, 47-mm filters. It performs alpha and beta measurements on each filter using a five Regions of Interest (ROI) analysis to evaluate the presence of long-lived alpha and beta emitters. Of the five ROIs, one is dedicated to beta emissions and gamma background, and the other four are dedicated to alpha emissions. The following ROI channels have been selected:

- ROI-1 for betas and background gamma;
- ROI-2 for long lived alphas;
- ROI-3 for ^{218}Po (^{222}Rn daughter) at 6.003 MeV peak;
- ROI-2 for ^{214}Po (^{222}Rn daughter) at 7.687 peak; and
- ROI-5 for ^{212}Po (^{220} Rn daughter) at 8.784 MeV peak.

The CAM cache records indicate that most of the radionuclide activity during the event was detected in ROI-2. This is consistent with the identification of ^{241}Am as indicated via the gamma pulse height analysis on other sample analyses results.

The time stamps recorded by the system computer are in error due to an improperly set CAM computer clock. However, when compared to the Central Monitoring Station (CMS) data, a benchmark was established for the first CAM alert. This alert occurred on December 29, 2013 at 2338:19 for the CAM and the equivalent alert occurred on February 14, 2014, at 2312:49 for the

CMS. Applying this differential of adding 47 days (minus 25 minutes and 30 seconds) to the CAM date and time stamp brings these two periods into correlation. This time correction, as well as an evaluation that the CAM functioned properly during the event, are documented in the Evaluation of CAM 151 Panel Exit Data and Comparison to Central Monitoring System data report.

Following the event, the CAM (Figure 6-47) filter housing was disassembled at SRNL. Each filter was assigned a specific number based on the order in which the filters were removed from the CAM cartridge, visually examined, and recorded. Each CAM filter was then screened by gamma pulse height analysis. The first six CAM filters were white and had low levels of activity; three of these are from routine monitoring before the event took place. The following 10 sample filters had various shades of black and brown, and had high levels of activity. Table 6-5 summarizes sampling start and stop time for each CAM filter and the DAC-hr value as recorded by the CAM, as well as total gamma emitting activity as measured by gamma pulse height analysis. CAM 151 filter papers are numbered and described in the order in which the filter paper was removed from the cartridge. The CAM 151 cartridge is loaded with filter papers with the earliest filters first. This means that the first filter used by the cartridge is the last filter paper to be removed. The CAM cache records indicate filter labeling as December 27, 2013 - 6 Filter 01 (Figure 6-48) through December 27, 2013 - 6 Filter 13 (Figure 6-49) during the period starting from February 12, 2014, 0304:43 through February 15, 2014, 0005:34 when the CAM shut down after the radiological event.

Figure 6-47: RADOS Continuous Air Monitor

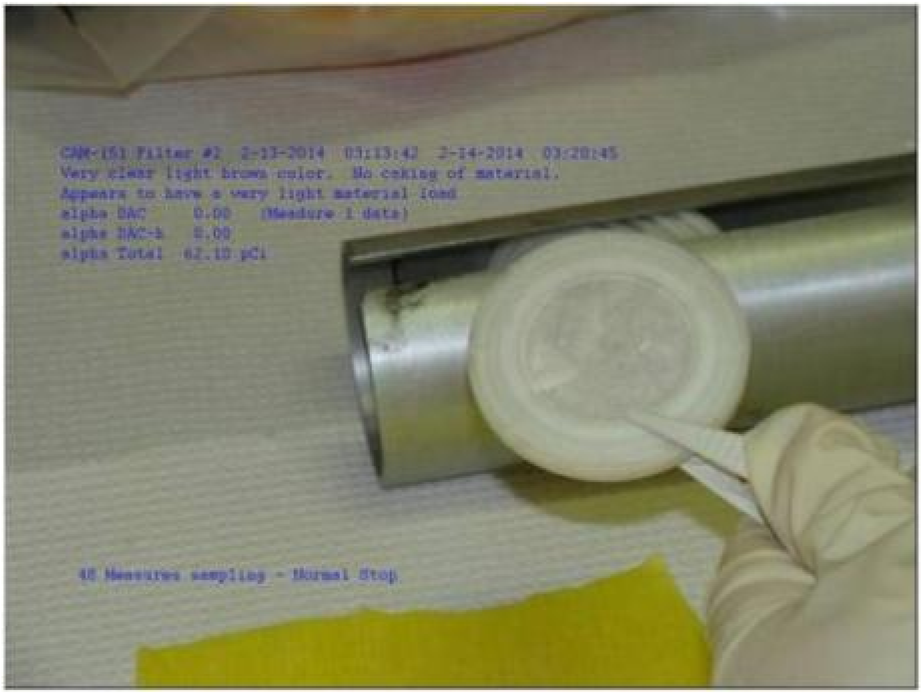


Figure 6-48: CAM 151 Filter #2

Figure 6-49: CAM 151 Filter #10

Table 6-5: CAM Filter Sample Results

CAM Filter (As Identified in CAM Output)	CAM Filter Start Time (24-hr format)	CAM Filter Stop Time (24-hr format)	DAC-hr	Filter time in CAM (hrs:mins:secs)	Beta Total (pCi)	Alpha Total (pCi)	Gamma Analysis total dpm/sample
1	2-12-2014 15:04:43	2-13-2014 15:11:48	N/A	24:07:05	677.70	487.62	3.48 E+05
2	2-13-2014 15:13:42	2-14-2014 15:20:45	91,474	24:07:03	82.35	62.10	7.50 E+06
3	2-14-2014 15:22:18	2-14-2014 23:15:54	92,529	07:53:36	51.03	46.17	6.65 E+06
4	2-14-2014 23:17:40	2-14-2014 23:18:49	178,319	00:01:09	1118.88	37671.21	8.73 E+06
5	2-14-2014 23:20:41	2-14-2014 23:24:26	112,384	00:03:45	246378.78	1266424.2	3.48 E+06
6	2-14-2014 23:26:38	2-14-2014 23:30:44	201,115	00:04:06	258244.20	1302337.4	6.98 E+06
7	2-14-2014 23:32:36	2-14-2014 23:35:42	163,899	00:03:06	241839.00	1330341.3	6.83 E+06
8	2-14-2014 23:37:34	2-14-2014 23:40:39	207,081	00:03:05	229820.49	1323391.2	7.37 E+06
9	2-14-2014 23:42:32	2-14-2014 23:43:40	163,899	00:01:08	2640.87	39017.70	5.97 E+06
10	2-14-2014 23:45:32	2-14-2014 23:50:38	105,478	00:05:06	313917.66	1405682.3	3.50 E+05
11	2-14-2014 23:52:30	2-14-2014 23:56:35	87,520	00:01:05	285111.09	1411371.0	5.80 E+06

CAM Filter (As Identified in CAM Output)	CAM Filter Start Time (24-hr format)	CAM Filter Stop Time (24-hr format)	DAC-hr	Filter time in CAM (hrs:mins:secs)	Beta Total (pCi)	Alpha Total (pCi)	Gamma Analysis total dpm/sample
12	2-14-2014 23:58:27	2-15-2014 00:02:33	210,722	00:04:06	259098.21	1401985.2	1.07 E+04
13	2-15-2014 00:04:25	2-15-2014 00:05:34	128,199	00:01:09	6093.26	55462.86	7.25 E+03

The total activity on each filter, expressed as DAC-hours, is related to the average air concentration over the entire period the filter was in use, and does not provide information about the fluctuation of real-time airborne concentrations during the time each filter is in use. As indicated in CAM log messages, the filter was rapidly clogging during the event, and required frequent filter changes at irregular intervals. However, as a filter is in use, the CAM is measuring the radioactivity on the filter at approximately 4-second intervals, and reporting the corresponding real-time concentration, which is then relayed to the CMS. The real-time DAC results are limited in their accuracy for quantitative results as the event progressed to later stages due to filter loading with ash/soot and potential alpha particle burial loss introducing measurement uncertainties; however the data are still appropriate for evaluating changes, trends, patterns, and timelines of the progression of airborne radioactivity concentrations. These real-time air concentrations as measured by CAM 151, along with the CAM flow rate, are presented in Figure 6-50.

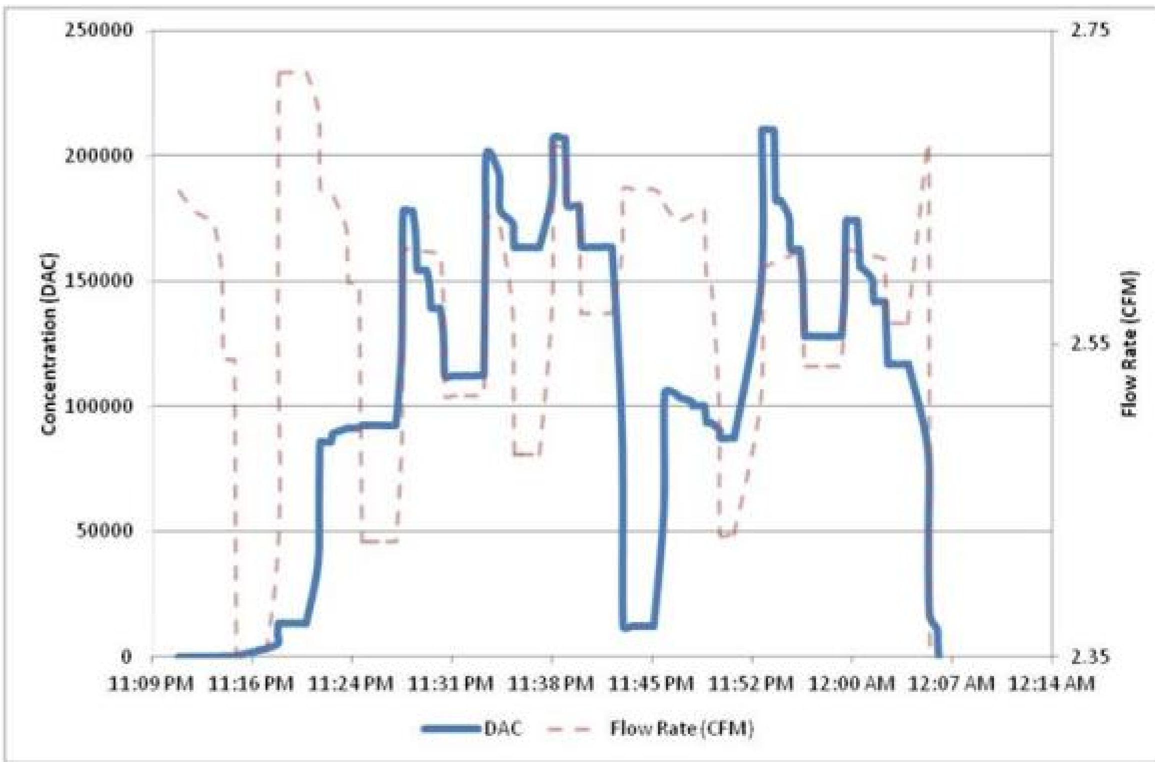


Figure 6-50: Real-Time Air Concentrations Measured By CAM 151 with the CAM Flow Rate

CAM airborne radioactivity data correlates with the timeline for the event initiation, progression, and termination. The data indicated rapid increases/decreases in airborne radioactivity concentration over the duration. Three CAM filters (2, 7, and 11) were selected for extended gamma assays and chemical analyses. Extended gamma assays on those three CAM filters measured an actinide signature similar to what was found on the FAS. Table 6-6 is summary of the results of the three selected CAM filters.

Table 6-6: CAM Filter Gamma Summary Results

Radionuclide	Filter 2		Filter 7		Filter 11	
	dpm/sample	percent of total	dpm/sample	percent of total	dpm/sample	percent of total
^{241}Am	7.15E+06	94.53%	6.66E+06	94.69%	5.80E+06	92.34%
^{243}Am	7.58E+02	0.01%	7.46E+02	0.01%	6.52E+02	0.01%
^{239}Pu	4.12E+05	5.45%	3.72E+05	5.29%	4.80E+05	7.64%
^{239}Np	7.17E+02	0.01%	7.58E+02	0.01%	7.57E+02	0.01%
^{237}Np/^{233}Pa	2.44E+01	<0.01%	2.75E+01	<0.01%	2.90E+01	<0.01%
^{212}Pb	4.33E+00	<0.01%	3.11E+00	<0.01%	Not Reported	N/A

Filter start time	2-13-2014 3:13:42	2-14-2014 11:32:36	2-14-2014 11:52:30
Filter stop time	2-14-2014 3:20:45	2-14-2014 11:35:42	2-14-2014 11:56:35

The CAM 151 analysis results indicate that the primary nuclides detected and the ratios between those nuclides remain consistent through the duration of the event.

6.3.3 Fixed Air Sampler Sample Results

FAS 118 sampled the airborne radioactivity at the inlet to Panel 7, upstream of CAM 151 and the event area. Radioactivity on the FAS 118 filter is likely due to a momentary back-pulse of airflow during the ventilation change and/or release of materials into the air flow. Prior to sectioning of the FAS, the air sample was analyzed by non-destructive gamma pulse height analysis. Visual analysis of the FAS is described as a "black-charcoal color." The gamma analysis indicated that the airborne activity was primarily ^{241}Am, followed by ^{241}Pu and ^{239}Pu. Table 6-7 summarizes the gamma pulse height analysis results. These results are consistent with the primary nuclides detected and the ratios between those nuclides on the CAM 151 filters.

Table 6-7: Fixed Air Sampler-118 Filter Results

Radioisotope	DPM/sample	1 Sigma % Uncertainty	pCi/sample
^{7}Be	4.72E+02	5 %	2.13E+02
^{40}K	4.35E+01	18.55 %	1.96E+01
^{137}Cs	1.15E+01	7.71 %	5.18E+00
^{208}Tl	2.10E+00	18.06 %	9.46E-01
^{212}Pb	2.79E+00	30.93 %	1.26E+00
^{237}Np/^{233}Pa	1.32E+01	9.57 %	5.95E+00
^{237}U	1.08E+02	5 %	4.86E+01
^{239}Np	3.14E+02	5 %	1.41E+02
^{243}Am	3.42E+02	5 %	1.54E+02
^{239}Pu	1.04E+05	7.29 %	4.68E+04
^{241}Am	2.74E+06	5 %	1.23E+06
^{241}Pu	4.42E+06	Calculated from ^{237}U	1.99E+06
^{232}Th	1.79E-02	from ICP-MS	8.06E-03
^{235}U	7.04E-01	(^{235}U enrichment 5.54%)	3.17E-01
^{238}U	1.87E+00	NA	8.42E-01

The Station A FAS sampled airborne radioactivity above ground in the exhaust shaft prior to the HEPA filters. The Station B FAS sampled airborne radioactivity in the exhaust shaft after filtration by the exhaust HEPA filters. The FAS Station A and B filters collected immediately after the event were analyzed by gamma spectroscopy, which identified ^{241}Am as a contaminant. Analysis for other nuclides was not performed due to the prohibitively high levels of radioactivity on the filters, which would have interfered with the analysis techniques. FAS Station A and B filters were collected over several weeks after the event, once levels had declined sufficiently to allow full analysis, and were sent to Sandia National Laboratories for radiological analysis. The Sandia analysis reported total activity on each Station A and Station B filter for the nuclides ^{238}Pu, ^{239}Pu and ^{241}Am. The results of the radiological analyses for Station A are summarized in Table 6-8, and the results for Station B filter are summarized in Table 6-9. The primary detected nuclides and the ratios of those nuclides are consistent between the FAS Station A and B filters and the CAM 151 filters.

Table 6-8: FAS Station A Results

Sample Start Date	Run Time (Min)	^{238}Pu Activity (dpm)	^{239}Pu Activity (dpm)	^{241}Am Activity (dpm) (Gamma spec)	^{239}Pu:^{238}Pu	^{241}Am:^{239}Pu
2/15/14	560	1.55E+02	3.58E+03	5.13E+04	2.31E+01	1.43E+01
2/16/14	480	3.93E+01	9.24E+02	1.22E+04	2.35E+01	1.32E+01
2/16/14	445	1.32E+01	2.89E+02	4.99E+03	2.19E+01	1.73E+01
2/17/14	485	5.96E+00	1.34E+02	1.75E+03	2.25E+01	1.31E+01
2/17/14	480	2.78E+00	6.13E+01	9.99E+01	2.21E+01	1.63E+00
2/17/14	470	1.88E-01	4.21E+00	7.02E+00	2.24E+01	1.67E+00
2/18/14	490	7.08E-01	1.71E+01	3.23E+01	2.41E+01	1.89E+00
2/18/14	465	1.05E+00	2.55E+01	2.62E+02	2.44E+01	1.03E+01
2/18/14	510	9.66E-01	2.37E+01	2.45E+02	2.45E+01	1.03E+01
2/19/14	468	2.29E-01	7.47E+00	8.09E+01	3.27E+01	1.08E+01
2/19/14	457	3.84E-01	8.86E+00	8.51E+01	2.31E+01	9.60E+00
2/19/14	498	4.19E-01	1.07E+01	1.03E+02	2.55E+01	9.64E+00
2/20/14	479	7.45E-01	2.00E+01	1.85E+02	2.68E+01	9.26E+00
2/20/14	487	2.66E-02	8.80E+00	9.53E+01	3.31E+02	1.08E+01
2/20/14	468	8.06E-01	2.00E+01	1.67E+02	2.48E+01	8.36E+00
2/21/14	513	1.06E+00	2.81E+01	2.72E+02	2.66E+01	9.69E+00
2/21/14	435	1.15E+00	1.90E+01	1.78E+02	1.65E+01	9.38E+00
2/21/14	930	1.31E+00	2.04E+01	1.81E+02	1.56E+01	8.88E+00
2/22/14	460	7.71E-01	1.15E+01	1.07E+02	1.49E+01	9.32E+00
2/22/14	495	6.17E-01	1.01E+01	9.78E+01	1.63E+01	9.71E+00
2/22/14	796	1.45E+00	1.99E+01	1.50E+02	1.37E+01	7.55E+00
2/23/14	499	8.55E-01	1.35E+01	1.07E+02	1.58E+01	7.94E+00
2/23/14	465	3.34E-01	5.69E+00	9.90E+01	1.70E+01	1.74E+01
2/23/14	250	4.52E-01	5.68E+00	4.68E+01	1.26E+01	8.25E+00
2/24/14	287	4.64E-01	5.95E+00	5.75E+01	1.28E+01	9.67E+00

Sample Start Date	Run Time (Min)	^{238}Pu Activity (dpm)	^{239}Pu Activity (dpm)	^{241}Am Activity (dpm) (Gamma spec)	^{239}Pu:^{238}Pu	^{241}Am:^{239}Pu
2/24/14	470	7.11E-02	2.62E+00	2.21E+01	3.69E+01	8.42E+00
2/24/14	423	1.54E-01	3.24E+00	2.64E+01	2.10E+01	8.15E+00
2/25/14	505	1.35E-01	4.29E+00	3.06E+01	3.17E+01	7.14E+00
2/25/14	478	1.23E-01	2.30E+00	1.76E+01	1.88E+01	7.64E+00
2/25/14	478	1.50E-01	3.58E+00	3.10E+01	2.38E+01	8.66E+00

	^{239}Pu:^{238}Pu	^{241}Am:^{239}Pu
Average Ratio	**3.22E+01**	**9.33E+00**

Table 6-9: FAS Station B Results

Sample Start Date	Run Time (Min)	^{238}Pu Activity (dpm)	^{239}Pu Activity (dpm)	^{241}Am Activity (dpm) (Alpha spec)	^{239}Pu:^{238}Pu	^{241}Am:^{239}Pu
2/19/14	475	7.08E-02	1.40E+00	1.39E+01	1.98E+01	9.90E+00
2/19/14	447	1.41E-01	2.46E+00	2.27E+01	1.75E+01	9.21E+00
2/19/14	508	9.38E-02	2.36E+00	2.40E+01	2.52E+01	1.02E+01
2/20/14	497	1.96E-01	5.41E+00	4.13E+01	2.76E+01	7.63E+00
2/20/14	482	4.07E-01	1.13E+01	8.52E+01	2.77E+01	7.55E+00
2/20/14	464	1.34E-01	3.43E+00	2.90E+01	2.55E+01	8.46E+00
2/21/14	462	1.13E-01	2.97E+00	2.35E+01	2.62E+01	7.91E+00
2/21/14	460	1.89E-01	3.72E+00	3.11E+01	1.97E+01	8.36E+00
2/22/14	471	1.12E-01	1.53E+00	1.30E+01	1.37E+01	8.48E+00
2/22/14	470	5.91E-03	1.75E+00	1.61E+01	2.96E+02	9.19E+00
2/22/14	741	3.29E-02	1.39E+00	1.42E+01	4.22E+01	1.02E+01
2/22/14	494	2.88E-02	1.21E+00	1.19E+01	4.20E+01	9.81E+00

Sample Start Date	Run Time (Min)	^{238}Pu Activity (dpm)	^{239}Pu Activity (dpm)	^{241}Am Activity (dpm) (Alpha spec)	$^{239}Pu:^{238}Pu$	$^{241}Am:^{239}Pu$
2/23/14	475	6.07E-02	1.35E+00	1.33E+01	2.22E+01	9.83E+00
2/23/14	250	1.00E-01	2.14E+00	1.38E+01	2.14E+01	6.44E+00
2/24/14	271	3.53E-02	1.15E+00	9.06E+00	3.26E+01	7.87E+00
2/24/14	469	3.41E-03	1.01E+00	NA	2.96E+02	0.00E+00
2/24/14	461	5.17E-02	7.80E-01	6.03E+00	1.51E+01	7.73E+00
2/25/14	438	4.06E-02	4.81E-01	5.22E+00	1.18E+01	1.09E+01
2/25/14	526	6.97E-02	8.99E-01	9.36E+00	1.29E+01	1.04E+01
2/25/14	470	2.05E-02	7.04E-01	6.07E+00	3.43E+01	8.62E+00
2/26/14	551	5.21E-02	1.23E+00	1.33E+01	2.36E+01	1.08E+01
2/26/14	415	0.00E+00	6.15E-01	6.26E+00	N/A	1.02E+01
2/26/14	494	1.44E-02	2.23E-01	3.77E+00	1.55E+01	1.69E+01
2/27/14	456	3.52E-02	1.29E-01	1.51E+00	3.66E+00	1.17E+01
2/27/14	966	4.67E-02	8.46E-01	7.17E+00	1.81E+01	8.48E+00
2/28/14	555	3.40E-02	5.85E-01	3.87E+00	1.72E+01	6.62E+00
2/28/14	458	-6.10E-03	3.34E-01	3.76E+00	N/A	1.13E+01
2/28/14	519	3.10E-03	2.85E-01	2.95E+00	9.19E+01	1.04E+01
3/1/14	451	9.00E-04	3.49E-01	2.49E+00	3.88E+02	7.14E+00
3/1/14	445	-2.77E-02	3.84E-01	4.24E+00	N/A	1.10E+01

	$^{239}Pu:^{238}Pu$	$^{241}Am:^{239}Pu$
Average Ratio	**5.88E+01**	**9.10E+00**

6.3.4 Moderate Filter Measurement Sample Results

In situ gamma pulse height analysis was conducted of the exhaust system moderate filter. Nuclide mixture ratios are consistent with those seen for the CAM and FAS air filters, and also surface contamination smears/Masselin. Moderate filter gamma measurement results as extracted from the In Situ Object Counting System (ISOCS™) report and are presented in Table 6-10.

Chemical analysis of the moderate filter was not performed.

Table 6-10: Moderate Filter Gamma Measurement Results

Nuclide	Mass g	Activity Ci	Act. Uncertainty (1-sigma) Ci	MDA Ci
^{90}Sr	<LLD	<LLD	0.00E+00	0.00E+00
^{137}Cs	<LLD	<LLD	0.00E+00	6.29E-09
^{237}Np	0.00E+00	0.00E+00	0.00E+00	1.29E-08
^{238}Pu	3.27E-07	5.60E-06	4.10E-06	6.45E-04
^{239}Pu	3.07E-03	1.90E-04	1.39E-04	5.27E-05
^{240}Pu	1.96E-04	4.46E-05	3.27E-05	1.75E-03
^{241}Am	6.84E-04	2.37E-03	1.74E-03	1.20E-07
^{241}Pu	6.55E-06	6.75E-04	4.94E-04	3.63E-03
^{242}Pu	6.55E-07	2.59E-09	1.89E-09	0.00E+00
^{243}Am	1.27E-06	2.53E-07	1.19E-07	3.08E-08
^{235}U	<LLD	<LLD	0.00E+00	1.03E-08
^{238}U	<LLD	<LLD	0.00E+00	9.42E-07
^{234}U	<LLD	<LLD	0.00E+00	0.00E+00

6.3.5 Surface Contamination Sample Results

Five radiological surveys (direct and removable contamination) were performed at WIPP, Panel 7, in Rooms 1, 6, and 7 during the period April 23, 2014, through May 19, 2014. Surveys consisted of smears, quantitatively measuring removable contamination per 100 cm^2, as well as Masselin cloth wipes, indicating qualitative gross contamination levels and order of magnitude. These surveys reported alpha activity contamination levels, with no beta or dose rate information. Selected smears from these surveys were sent to the SRNL for gamma analysis. The results identified ^{241}Am, which is consistent with other samples taken from the WIPP underground Panel 7. On May 30, 2014, another radiological survey was conducted of Panel 7. Table 6-11 provides a summary of results from the radiological surveys.

Table 6-11: Radiological Survey Results

Room Number	Smear Description	Activity by Alpha (WIPP analysis) (dpm)	Activity by Gamma (SRNL analysis) (dpm)
7	General Area	8,000 – 40,000	
	End of Room	27,000	
	Table and Chairs	26,000	105,000 (table) 24,300 (chair)
	Waste Face	8,000 – 40,000	61,000
	Waste Face Floor	30,000	
	Waste Face Slip Sheet by Drums	40,000	110,000
	Pink Spill Mat/Pigs	24,000	49,300 (pad) 119,000 (pigs) 32,500 (mat)
6	Slider at base	20,000	
	At end of room	16,000	
	H.E.R.E. machine	10,000 – 20,000	
	Floor in middle of room	8,000	
	I/S room on bulkhead	10,000 – 20,000	
	Other side of bulkhead	30,000	
	Vehicle (End of Room)	12,000	
	General Area	N/A	35,300
1	General Area	6,000 – 28,000	19,400
	End of Room	6,000	
	I/S room by slider	28,000	
	O/S room by slider	20,000	
	Exhaust Drift		4,840
May 30, 2014, Survey of Affected Area			
Affected	R-16, C-4, MgO	500	Sent to TAT for

Room Number	Smear Description	Activity by Alpha (WIPP analysis) (dpm)	Activity by Gamma (SRNL analysis) (dpm)
Area	R-15, C-5, SWB	> 1,000,000	analysis
	R-16, C-4, Lip	50,000	
	R-14, C-4, MgO	100	
	R-14, C-6, MgO	100	
	R-14, C-2, MgO	100	

6.3.6 Drum 68660 Radiological Summary Results

As part of repackaging of the parent drum, S855793, the contents of the bags of nitrate salt from the parent drum were emptied, mixed with Swheat, and placed into the daughter drum, 68660. Drum 68660 was packaged with the contents of multiple bags of nitrate salts, as well as approximately two gallons of free liquid (before addition of the absorbent) from the parent drum. Prior to transport to WIPP, CCP personnel at LANL measured the gamma-emitting nuclide inventory of drum 68660 using the Mobile In-Situ Objects Counting System Large Container Counter (MILCC) with two gamma-ray spectrometers. This initial data was used to determine the radiological constituents in the drum for acceptance at WIPP.

After the drum breach occurred at the WIPP, Canberra performed a re-evaluation of the MILCC data for drum 68660. A Canberra technical representative, via an interview, told the Board that the initial results were incorrect due to an "analyst error." The re-evaluation resulted in changes to several values, notably ^{241}Am. This corrected analysis was used to compare results of the radiological forensics with the drum contents. Upon investigation, 45 of 900 drums had to be reanalyzed resulting in a 5 percent error rate.

The Board concluded that the analytical error did not contribute to the drum breach at WIPP. The results of the Drum 68660 data reanalysis are summarized in Table 6-12 below.

Table 6-12: Drum 68660 NDA Corrected Results

Nuclide	Activity (Ci)
^{241}Am	2.20E+00
^{243}Am*	3.403E-04
^{237}Np	2.58E-05
^{238}Pu	2.08E-02

Nuclide	Activity (Ci)
^{239}Pu	4.63E-01
^{240}Pu	1.21E-01
^{241}Pu	2.00E+00
^{242}Pu	1.05E-05
^{234}U	4.63E-05
^{235}U	1.15E-06

* Drum 68660 NDA re-evaluation changed ^{243}Am from initial NDA results to non-detected, presumably due to very low levels. ^{243}Am retained from original data for purpose of comparison.

6.3.7 Comparison of Sample Analysis Results with Drum 68660 and Other Drums in the Vicinity of the Event

Drum 68660 and its sibling, 68685, were generated from the remediation of parent waste container S855793 packaged in 1985. Records indicate that the contents of S855793 included 14 individual bags of legacy salts produced from the processing of LANL process waste streams consisting of plutonium material types 52 and 53. The concentration of ^{240}Pu detected in samples is consistent with LANL MT52 and MT53 or mixtures of those materials. Additionally, MT-53 is more likely to contain higher levels of ^{241}Am than MT-52, likely resulting in the ^{241}Am:^{239}Pu ratios observed in samples being higher than would be attributable to MT-52 alone.

A unique ^{241}Am:^{243}Am signature existed for 68660 when compared to four MT-52 drums packaged in the same storage platform placed in Column 16, Row 4. Discussions with LANL indicate that, that in some instances, MT-56 would be added to material to meet MT-53 standards. MT-56 has an uniquely high ^{243}Am concentration compared to other material types, resulting in a significantly lower ^{241}Am:^{243}Am ratio than for drums that did not contain MT-53 or MT-56. The unique ^{241}Am:^{243}Am ratio in Drum 68660 compared to other drums in R16:C4 containing MT-52 is presented Table 6-13.

From the data shown, only drum 68660 contains salts with ^{241}Am/^{243}Am ratios consistent with the ratios measured on the CAM 151, FAS, FAS Station A, FAS Station B, and intermediate filter.

Table 6-13: ^{241}Am:^{243}Am Ratio in Drums Containing MT-52 in R16:C4

Drum	Parent Drum	Bags: MT-52:MT-53:MT--54	^{241}Am:^{243}Am Activity Ratio (Ci/Ci)
68333	S846107	8:0:0	1.77E+04
68607	S822952	2:0:0 (plus one bag MT42)	3.24E+05
68630	S818449	4:0:0	8.14E+05
68660	S855793	7:7:0	6.46E+03
68670	S832150	5:0:0 (plus one bag MT42)	1.33E+06

6.3.8 Analysis of Section 6.3 – Radiological Forensics

Radiological analyses were conducted on a variety of sample media following the radiological event in Panel 7. Media collected and analyzed included 12 CAM filters, the FAS 118, Station A and Station B filters, the exhaust system moderate filter, and numerous smears and Masselin wipes for surface contamination. The primary nuclides identified across the sample media are consistent with a transuranic waste profile (e.g. americium, plutonium, uranium, and neptunium). Ratios of key nuclides across data sets are presented in Table 6-14 below.

The nuclide mixtures observed across the sample data are not an identical match to the bulk NDA results for drum 68660**.** For example, the ^{241}Am to ^{239}Pu nuclide ratios vary between 4.75 in the Drum 68660 NDA re-evaluation, 12:1 and 17:1 for the CAM filters, 26:1 for FAS 118, 9:1 for FAS Station A, 9:1 for FAS Station B, and 12:1 for the moderate filter. Chemical and/or physical source differences may account for the differing ratios between nuclides. Drum 68660 NDA results represent the drum bulk activity, whereas the post-release material samples represent only the material that was ejected from the drum.

Factors that could contribute to differences in the results between the drum bulk contents and ejected material include ratio differences between the salts and the liquid added to a single drum, or anion exchange processes. Due to these confounding factors, the ratio of isotopes of the same element, such as ^{241}Am:^{243}Am or ^{240}Pu:^{239}Pu, are likely better indicators of material origin. These isotopic ratios are fairly consistent across drum 68660 and the various media samples, and are unique from other drums with MT-52 in R16:C4. A summary of the ratios between selected nuclides in the sample analyses are also presented in Table 6-14.

Based on this data, drum 68660 and the sample media share strong similarities in ratios of isotopes that would likely not be affected by chemical or physical differences between nuclides within the source. Drum 68660 contained a nuclide mixture that was consistent with the material released in the event. However, this data alone does not rule out possible lesser contributions from other source terms.

Table 6-14: Nuclide Ratios (Ci/Ci)

	CAM Filter* 2	CAM Filter* 7	CAM Filter* 11	Sum of CAMs	FAS 118	FAS Station A	FAS Station B	Moderate HEPA	Parent Drum, S855793**	68660 NDA Re-Eval
$^{241}Am:^{239}Pu$	1.74E+01	1.79E+01	1.21E+01	1.55E+01	2.63E+01	9.33E+00	9.10E+00	1.25E+01	1.84E+01	4.75E+00
$^{241}Am:^{243}Am$	9.43E+03	8.93E+03	8.90E+03	9.10E+03	8.01E+03	N/A	N/A	9.37E+03	7.39E+03	6.46E+03
$^{239}Pu:^{238}Pu$	N/A	N/A	N/A	N/A	N/A	3.22E+01	5.88E+01	3.39E+01	N/A	2.23E+01
$^{239}Pu:^{237}Np$	1.69E+04	1.35E+04	1.66E+04	1.56E+04	7.88E+03	N/A	N/A	N/A	N/A	1.80E+04

* CAM filters 2, 7 and 11 represent different times over the progression of the event. The nuclide ratios in the cumulative (summed) activity of filters 2, 7 and 11 estimate ratios in the total activity released in the event as measured by the CAM.

** Parent drum nuclide ratios are based on preliminary information from SRNL analysis, and are intended for qualitative comparison only.

6.4 Forensic Analysis Conclusions

This section blends the fire, chemical and radiological analyses to support the Board conclusion as to the cause of the radiological release. The material in this section is presented as three parts:

- Key analysis information that links with the conclusions;
- The most likely event sequence; and
- Supporting information in establishing the event sequence.

6.4.1 Analysis Summary

The radiological release that occurred at the WIPP site on February 14, 2014, resulted from an exothermic reaction that led to a thermal runaway in drum 68660, which was located on the top tier of R16:C4. The drum came from LANL and was part of the LA-MIN02-V.001 waste stream. The exothermic process involved organic materials (Swheat Scoop® absorbent, triethanolamine neutralizing agent and incompatible secondary waste items) and the nitrate salt matrix. Additionally, the reaction in drum 68660 could have occurred at any time after the December 4, 2013, repackaging activities established the conditions that allowed the reaction to occur.

The event on February 14 exhibited the following fire behaviors:

- Expanding flame front of material expelled from drum 68660;
- Ignition of exposed combustibles (packaging materials) within the waste array;
- Propagation within the waste array by flame impingement and ember transfer;
- Melting and burning of exposed plastics; and
- Convective movement of damaged stretch wrap consistent with air flow patterns.

As such, the combustion process observed in the waste array was complex.

During the release event, the combustibles external to the waste containers were ignited. The intensity of the fire was low to moderate and direct fire effects were limited to Rows 8 through 18 of the array. Damage within the array was not uniform and there were multiple small fires that caused direct flame impingement on several waste packages. The fire self-extinguished without consuming all combustibles present. The exact time of fire extinguishment was not able to be determined, but extinguishment occurred because the geometry of the combustibles did not facilitate continued combustion. The propagation of the fire within the waste array caused the migration of contamination throughout Panel 7, including areas that were upstream of the release location.

The significant fire damage in the waste array was centered on locations with the most exposed combustible materials. These areas included Rows 9 and 10; Rows 14 and 15, R16:C4 and R18:C6 (Figure 6-2). The extent of damage ranged from complete loss of exposed material (fiberboard and polyethylene slip sheets, reinforcement plates, stretch wrap, cardboard stiffeners and polypropylene super sack fabric) on multiple tiers such as at R14:C2, to a loss on just one face such as at R18:C6, where much of the polyethylene stretch wrap for the assemblies was undamaged. On top of the waste containers, there were 17 damaged MgO super sacks leaving loose MgO in a high angle of repose; however, there were no substantive soot deposits on the drift back, the ribs, or visible portions of the bulkhead. These observations, coupled with the non-uniform damage within the waste array, indicate that flashover in Panel 7 Room 7 did not occur. Thus, there would have been wide variations in local temperatures that would have been dependent on local flaming behaviors. As such, local temperatures ranged from ambient to flame temperature (~1,000°C). Temperatures near the Panel 7 Room 7 bulkhead did not exceed 135°C based on the undamaged polyethylene stretch wrap and MgO super sack polypropylene fabric.

During the event, a portion of the contents of drum 68660, a mixture of pyrolysis gases and high-specific surface area organic material, was ejected. This mixture partially burned upon release. The ejected materials were analyzed and found to be consistent with the expected materials in drum 68660.

The radiological contamination samples obtained from CAM 151, FAS 118, and the exhaust system prefilters had isotopic ratios consistent with the material types contained in drum 68660.

Based on the discussion in Section 6.1.4, the Board concluded that:

- The February 5 salt haul truck fire did not cause the widespread MgO super sack damage; and
- The February 5 salt haul truck fire did not cause a localized MgO reaction, and did not cause the February 14 release event.

The Board concluded that the forensic data presented in sections 6.1, 6.2, and 6.3 further support CON 6, CON 7, and CON 8 provided in Section 5.4.

6.4.2 Sequence of Release

The Board has identified the most likely event sequence associated with the radiological release on February 14, 2014. It is presented in Table 6-15. This sequence was established by combining the fire, chemical, and forensic analyses.

The initial radiological release from drum 68660 occurred at approximately 2308 and was detected at 2311:30 by CAM 151. The delay in detection was attributable to the transit time between the array and CAM 151 in the alternate ventilation mode at the time of the event. The release itself was a result of an exothermic process in drum 68660 that initiated a thermal runaway. A thermal runaway is characterized as a very rapid temperature rise within the container. The internal heating and pressure buildup resulted in venting of the reaction products through the waste container vent port. The combined thermal expansion rate and production rate of reaction products ultimately exceeded the waste container venting capacity. This led to failure of the lid gasket seal that vented some radiological material. At some point during this period, ignition of combustible gases and solids occurred in Panel 7 Room 7, as evidenced by the discoloration of Filter 3 retrieved from the CAM 151 cartridge. Sometime between 2311 and

2314 the pressure within waste drum 68660 was sufficient to extrude the drum lid past the lid retention ring. The unrestrained portion of the 68660 lid deflected, permitting a rapid release of combustible gases and combustible solids into the ventilation flow stream.

The high flow rate across the top of the array (~300 feet per minute, which equates to 10 feet of travel every two seconds) moved these materials towards the room bulkhead. Conditions were conducive to ignition of both the combustible gases and solids. While the high flow moved most of the released materials towards the room bulkhead, the expanding flame front would have modified the flow pattern. Eddies along the walls would be expected. These eddies transported flames and burning embers, which caused ignition of the exposed combustibles at R18:C2 and R18:C6 and damaged nearby polypropylene MgO super sacks. In addition to damaging the MgO super sacks, the release from 68660 ignited other exposed combustibles within that waste array (e.g., fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric). Damage within the array was not uniform and there were multiple small fires that caused direct flame impingement on several waste packages. The Board identified no indication of release from any other waste containers in the array.

Table 6-15: Derived Scenario Timing

Event	Timing
• Initial radiological release	2308
• Initial arrival of contamination at CAM 151 (Transit time in alternate flow mode is about 4 minutes).	2311:30
• Concentrations exceeding 100,000 DAC (calculated) at the bulkhead (time is best-estimate range)	2311 to 2313
• Hi alarm at CAM 151 (30 DAC)	2313
• Hi-Hi alarm at CAM 151 (50 DAC)	2314
• Filter 3 at CAM 151 change out started – filter demonstrated soot deposits from fire	2316
• Filter 4 at CAM 151 change out started	2319
• Airborne contamination levels at CAM 151 approach 100,000 DAC	2322

CON 13: Available data indicated that oxidation was occurring in the Standard Waste Box (SWB) where sibling drum 68685 was stored, along with other similarly remediated waste drums.

JON 18: Los Alamos National Security (LANS) needs to investigate and determine the cause for oxidation in sibling drum 68685 and take action to mitigate the condition as well as prevent future nitrate salt bearing waste drums (remediated and unremediated) from oxidizing.

7.0 Nuclear Safety Basis Evaluation

Due to the origin of the identified breached nitrate salt drum, the Board focused on investigating the LANL process used to remediate this waste stream for the Phase 2 investigation. The following sections provide an update to the Phase 1 investigation report discussion of potential accidents that could have caused the radiological release; evaluate the LANL hazard and accident analysis of nitrate salt remediation and drum storage; and review the LANL nuclear safety basis process, as well as oversight from the NNSA NA-LA as related to the nuclear safety basis.

7.1 Accident Scenarios and Source Term Evaluation

Section 2.1.2, "Event Description," summarizes the observed damage to Panel 7 Room 7, and the physical condition of LANL drum 68660 that is known to have been breached. Section 6.1, "Fire Forensics," summarizes the results of the fire analysis in the Fire Forensic Analysis Report. The efforts of the two LANL commissioned independent teams and the TAT as they relate to event initiation and radiological release is also considered in the following evaluation.

DOE has provided additional resources to support WIPP recovery activities and oversight, as has NWP including addressing the weaknesses in safety management programs discussed in the Phase 1 report. The Board has monitored nuclear safety approvals of recovery activities and additional declaration of a PISA since the Phase 1 report was issued, and determined that further investigation was not warranted.

7.1.1 Analysis of Section 7.1 - Accident Scenarios and Source Term Evaluation

The accidents published in the WIPP facility safety basis and others that could have created the magnitude of observed physical damage and release of radioactive materials are evaluated in this section and compared to the forensic results presented in Section 6 of this report.

In May 2014, LANL commissioned two independent teams to postulate hypothetical accidents that could have occurred or caused the observed damages and a radiological release. The teams prepared a combined summary of the WIPP hypotheses in June 2014. DOE also established the TAT to investigate possible release scenarios, working with a subgroup from the LANL teams and the Board. Chemical reactivity within the drum has received the most attention; however, other initiating events were postulated by LANL and were considered by LANL, the TAT, and the Board.

For the purposes of this Phase 2 report, different types of accident scenarios that could cause the observed damage are evaluated based on the LANL/TAT hypotheses; conclusions from the Section 6 forensic analysis of the photographic and analytical sampling evidence and the Fire Forensic Analysis Report; accident analysis described in the WIPP DSA that may be relevant; and opinions of the Board and advisors. Some accident scenarios will be eliminated as implausible.

The Board considered if a vapor cloud explosion due to the release of natural gas in the underground could cause the observed damage. Though natural gas pockets are experienced in the underground mining industry, a potential explosion was screened out in the WIPP underground due to its geology and location in the middle of the 2,000 foot-thick Permian Salado Formation (DSA Sections 4.4.10.2 and 4.4.10.4). The WIPP Hazardous Waste Permit[15], Appendix G1 (November 30, 2010), "Detailed Design Report for an Operation Phase Panel Closure System," states in Section 1.3.4:

> *The significance of small natural-gas occurrences within the WIPP repository is within the classification of Category IV for natural gas under the Mine Safety and Health Administration (30 CFR 57, Subpart T) (MSHA, 1987). These regulations include the hazards of methane gas and volatile dust. Category IV "applies to mines in which non-combustible ore is extracted and which liberate a concentration of methane that is not explosive nor capable of forming explosive mixtures with air based on the history of the mine or the geological area in which the mine is located.*

An event evaluated in the WIPP DSA hazard evaluation is a vapor cloud explosion in a closed panel that could cause melting/burning of the super sacks. However, a buildup of combustible/flammable gases in an active room could occur from venting of hydrogen due to radiolysis from waste containers, or possibly from a chemical reaction of incompatible materials. By process, a vent is installed in the waste containers before being sent to WIPP in order to reduce radiolysis gas buildup and the associated probability of a deflagration. However, Panel 7 Room 7 was under alternate ventilation mode which provided sufficient air movement to prevent a combustible gas mixture from forming.

The next scenario which could cause the observed damages to the 17 MgO super sacks as shown in the figures in Section 6, considered a detonation within a waste container that would result in high over-pressures that dissipate rapidly as a function of distance from the center of the explosion. This scenario was eliminated as the release initiator after visual inspection of the photographic evidence as described in Section 6.1 and the Fire Forensic Analysis Report. There was no observed damage to waste containers due to a detonation such as a "fishmouth" failure of a container caused by an internal explosion, crushing of nearby containers from the blast overpressure, or relocation of any containers from their original emplacement locations. In addition, there were no observations of physical damage to the Panel 7 Room 7 back, rib, or bulkhead from blast pressures.

An estimate of the source term released to the room from any type of accident associated with TRU waste containers can be made based on the known inventory of drum 68660 and accident modeling assumptions recommended in Section 4 of the DOE Standard DOE-STD-5506-2007, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, which was used for the development of the WIPP DSA and the LANL safety basis documents for WCRRF and Area G. This model of the initial material released into the room (i.e., "source term") is calculated using the "five-factor formula" as presented in the DOE-Handbook DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear*

[15] http://www.wipp.energy.gov/library/Information_Repository.htm

Facilities. Using this formula, a source term is the product of material at risk, airborne release fraction (ARF), respirable fraction (RF), damage ratio (DR) and leakpath factor (LPF).

The five factor source-term formula values of ARF*RF account for a respirable fraction of material released, however, for purposes of this report, only the ARF value of total airborne quantity is of interest considering the long travel distance from Panel 7 Room 7 to the Station A fixed air sampler. The DR value accounts for the fraction of material affected by accident energy. The LPF is an estimate that accounts for depletion of the airborne material during transit within a building or enclosure prior to release to the outside environment. It is numerically equivalent to a value resulting from the estimated fraction of material not deposited (i.e., fraction of material left in airborne plume following deposition during transit in the building/structure) and accounts for gravitational settling, impaction on surfaces, agglomeration of smaller particles, and other mechanisms that caused the detected contamination of the underground as the release traveled to the environment.

Modeling of ventilation flows and deposition (i.e., LPFs) to establish a conservative estimate for DSA accident analysis can be performed using computer models such as the DOE-recommended MELCOR code by applying the guidance from *MELCOR Computer Code Application Guidance for Leak Path Factor in Documented Safety Analysis* (DOE Office of Environment, Safety, and Health, May 2004). Due to the long travel distance from Panel 7 Room 7 to the surface, realistic estimates of LPFs are expected to be on the order of 0.1 to 0.01, i.e., 90 percent to 99 percent deposition within the underground, meaning that the source term at Station A should be 10 to 100 times lower than the source term in Panel 7 Room 7. These estimates are similar to results from an experiment performed in the WIPP underground of ventilation flows, as documented in a WIPP report, *Underground Flow Measurement and Particle Release Test* (Archer, J., R. Sanchez, and A. Strait, December 1998). This report concluded that an LPF of 0.05 would conservatively bound the experimental results, i.e., minimum 95 percent deposition within the underground, meaning that the source term at Station A should be 20 times lower than the source term in Panel 7 Room 7. This experiment was not designed for the purpose of establishing a conservative LPF credit for the accident analysis for the original Safety Analysis Report, but rather was for the purpose of locating CAMs. However, it has been included in the Board modeling results to provide a perspective on deposition within the underground as the aerosol exited through the exhaust path to the environment.

The estimated source-term can be compared to the radioactive material measured at the fixed air sampler at Station A at the surface prior to HEPA filtration. The analytical analysis of the FAS 118 samples as presented in Section 6.3.3, "Fixed Air Sampler Sample Results," are not representative to estimate the total activity at Station A because it measured activity in the ventilation supply in drift S-2520 at a location near Panel 7 Room 1, which is upstream of the airflow to Room 7, and is only a fraction of the contaminated airflow exiting Room 7. The analysis of the Station A samples reported in Section 6.3.3 is also not relevant, since it was taken approximately 24 hours after the initial release.

The Station A source term is estimated to be about 0.1 curies (Ci) of total activity, which is approximately 0.1 ^{239}plutonium equivalent curies (PE-Ci) since laboratory analysis showed that most of the activity was due to ^{241}Am. This estimate is based on the following considerations: (1) the initial reporting and laboratory analysis of dpm measurements for Station A converted to activity and adjusted by the ratio of the FAS flow with the total ventilation flow in the duct; (2) the Station B estimated 0.0005 PE-Ci used for the initial emergency response modeling of the release divided by the 0.005 leakage around the bypass dampers as determined by the ratio of dpm measurements between Station A and Station B; and (3) the single MOD filter analysis from Section 6.3.4, "Moderate Filter Measurement Sample Results," converted from dpm to PE-Ci and scaled up to represent 42 filters.

DOE-STD-5506-2007 Table 4.5-1, "ARF*RF Value Applicable to TRU Waste Accidents," recommends a bounding estimate of 1E-4 ARF (1.0 RF) for a drum over-pressurization without a fire. This value represents the respirable airborne fraction of material released. This release estimate, when applied to the CCP-revised drum inventory of 2.84 PE-Ci, results in an initial source term released to the room of 2.8E-4 PE-Ci. This estimate conservatively assumes no credit for DR (i.e., all material within the drum is affected by the release mechanisms). This release estimate from a drum over-pressurization without a fire is less than 1 percent of the 0.1 PE-Ci source term at Station A.

The chemical reaction resulting in over-pressurization of the drum described above is similar to the WIPP DSA hazard evaluation of a drum deflagration from hydrogen buildup from radiolysis which assumes burning of material expelled from the drum and a contained burning of material remaining within the drum. This results in a higher estimate of release as compared to an over-pressurization event. A drum deflagration could cause the observed damages to the super sack and cardboard stiffener via melting/burning, and would be consistent with observed damage to drum 68660 from an internal combustible gas deflagration (i.e., based on observations of drum damage from hydrogen deflagration test results summarized in Appendix B of DOE-STD-5506-2007). The presence of a 4,200-pound super sack likely prevented complete lid loss but permitted significant amount of ejected nitrate salts mixed with absorbent material. However, as discussed in Section 6.2, "Chemical Forensics," and Section 6.3, "Radiological Forensics," analytical sampling of material deposited outside the drum confirms that some fraction of waste was ejected, and is also consistent with the fixed air sampler and CAM air filters that identified presence of transuranic waste.

The WIPP DSA models three release mechanisms that contribute to the total airborne source term in accordance with recommendations in DOE Standard DOE-STD-5506-2007 that are based on past incidents and drum testing. DOE-STD-5506-2007, Appendix B recommends a bounding ARF*RF estimate of 5.4E-4 as the weighted product of various release mechanisms for a drum deflagration involving combustible contents. Eliminating the RF contribution in that calculation, the weighted ARF from a drum deflagration is 9E-4. This 9E-4 ARF release estimate when applied to the CCP-revised drum inventory of 2.84 PE-Ci results in an initial source term released to the room of 2.6E-3 PE-Ci. This release estimate from a drum deflagration is about 3 percent of the 0.1 PE-Ci source term at Station A. As a result, the actual amount of material released as measured at Station A was larger than the amount predicted using DOE-STD-5506-2007 by almost two orders of magnitude. This is further indication of a non-bounding DSA.

For either the drum over-pressurization or drum deflagration scenarios discussed above, a much greater airborne source term is possible if the nitrate salts behaved as a combustible dust ignited in air or if a greater fraction of material were ejected and burned. There is no experimental data in DOE-HDBK-3010-94 for dust cloud explosions that consume the substrate material releasing the radioactive contamination. An experiment involving the burning of lightweight combustible materials while suspended in air is determined by burning of tissue paper sprinkled with radioactive contamination in an updraft airflow which resulted in about 4E-1 ARF (1.0 RF) per DOE-HDBK-3010-94. The release estimate is about 8E-2 if the contamination were more substantially fixed to the substrate by air-drying a solution of radioactive material, a factor of five lower than loose contamination. These values compare to DOE-HDBK-3010-94 recommendation of 1E-2 ARF (1.0 RF) for uncontained burning of unpackaged, loosely strewn cellulosic materials (ordinary combustibles), which is also the ARF value for fires with reactive chemical (1E-3 RF).

These release fraction estimates only apply to the fraction of the drum contents expelled during the initial depressurization of the drum and before it falls from the suspended aerosol. Appendices B and C of DOE-STD-5506-2007 evaluated drum deflagration and fire experiments that at most ejected 30 percent to 40 percent of the drum contents. Assuming the higher 40 percent ejected fraction as a DR, the initial source term released to the room would be 0.45 PE-Ci (i.e., 2.84 PE-Ci x 40 percent DR x 4E-1 ARF). In order for a 0.1 PE-Ci source term at Station A if no other waste containers were breached, a maximum LPF is calculated to be 0.2 (i.e., 0.1 PE-Ci / 0.45 PE-Ci), or 80 percent of the initial source term could be deposited to the underground surfaces (i.e., 1- LPF). This magnitude of deposition and LPF is within realistic ranges, as discussed above for realistic modeling of LPFs using the MELCOR code and the results of the WIPP 1998 particle size experiment (i.e., more than 95 percent deposition occurred). Therefore, if only drum 68660 was breached, the magnitude of material ejected and burned while suspended in air under these assumptions was consistent with what was measured at Station A. However, application of the 4E-1 release fractions for the nitrate salt burning in air is recognized as a very conservative estimate, one that may not be based on physical reality of the Panel 7 Room 7 radiological release that is not well represented by the experiment of loose contamination on tissue paper burning in an updraft of air.

The 0.1 PE-Ci source term at Station A can be divided by the range of 0.01 to 0.05 LPFs (from the WIPP experiment) to estimate the range of source terms initially released in Panel 7 Room 7. This results in a range of 2 to 10 PE-Ci airborne in the room. Compared to the inventory in drum 68660 of 2.84 PE-Ci, the release parameters (ARF and fraction of drum expelled) would range from about 70 percent to 100 percent of the drum contents plus contributions from additional waste containers breached to total 10 PE-Ci. The 100 percent airborne release from drum 68660 is not likely, based on the experimental results summarized in DOE-HDBK-3010-94, and the lower 70 percent estimate requires a very energetic event. It is not known whether the LANL MIN02 waste constituents involving nitrate salts, organic kitty litter, and incompatible neutralizer that was applied to the free liquids, created an oxidant-fuel reaction that could cause this magnitude of radiological release.

For the propagating fire within the array described in Sections 6.1 and 6.4, the bounding ARF release estimate for contained burning of packaged wastes that is representative of combustibles in a drum is 5E-4 (1.0 RF) per DOE-STD-5506-2007, based on experiments evaluated in the DOE-HDBK-3010-94. If drum 68660 released a source term as modeled by conventional assumptions as described above, a significant number of waste containers would be expected to be breached to cause the 2 to 10 PE-Ci source term estimate in the room based on the range of deposition that may have occurred.

Based on the above estimates and calculations in considering various types of accidents, release fractions and deposition in the underground, indicated the release from drum 68660 alone was much larger than what would be modeled in accordance with the methodology described in DOE-HDBK-3010-94, DOE-STD-5506-2007, and the WIPP DSA. Therefore, the source term evaluation, using conventional release modeling assumptions, could not conclusively affirm that container 68660 was the sole contributor to the release.

7.2 LANL Safety Basis Documents

Existing Environmental Programs nuclear facility safety basis documentation does not thoroughly describe or evaluate nitrate salt processing or waste storage activities.

The Board focused on two facilities at LANL that are of interest to the WIPP radiological release. The WCRRF prepared the nitrate salt drums for compliance with the WIPP WAC, and the Area G, TA-54 facility provided staging or interim storage of TRU waste containers pending WAC certification after characterizing or remediating legacy wastes.

7.2.1 Waste Characterization, Reduction, and Repackaging Facility

The nitrate salt drums emplaced in WIPP Panel 7 Room 7 were processed at the LANL WCRRF. The nuclear safety basis required by Subpart B of 10 CFR 830, *Safety Basis Requirements,* is documented in the *WCRRF Basis for Interim Operation (BIO)*, Revision 2.1, and TSRs, Revision 2.1, dated November 2011.

BIO Section 2.5.7, "Remediation, Prohibited Item Disposition," describes the WCG process to remediate drums with free or residual liquids, as well as other WIPP WAC non-compliances. A "liquid absorbent" is added to material removed from a parent drum and placed in one or more daughter drums to comply with the WAC. This section does not distinguish between use of inorganic and organic absorbents. It also does not address that acidic liquids may need to be neutralized, as directed by Step 10.3 of the WCG procedure DOP-0233 Revision 36.[16]

The hazards associated with remediation of unspecified liquids are evaluated in the BIO Chapter 3 hazard and accident analysis. Identification of hazards is summarized in Section 3.3.2.1 based on a checklist included in Appendix 3A. Hazardous chemicals associated with TRU mixed waste were evaluated and considered to not be a significant hazard, other than as initiators of accidents that could result in a radiological release, e.g., spontaneous combustion as a result of reactions between various constituents in the waste, chemical reactions resulting in over-pressurization of a drum. Based on the WIPP WAC and waste container characterization studies, the BIO states in Sections 2.5.7 and 3.3.2.1.5 that Class I oxidizers such as nitrates are not expected. These sections do not acknowledge remediation of nitrate salt drums or their hazards. However, because of uncertainty in waste characterization, both of those sections note that

[16] The BIO Section 2.5.8.3, "Glovebox Operations and Maintenance Activities," acknowledges neutralization of decontamination solutions used to clean the WCG.

oxidizers, pyrophoric materials, and flammable liquids are considered as initiators to fire events during glovebox operations.

The qualitative hazard evaluation required by 10 CFR 830 is included in the BIO Appendix 3A that was based on the "What-If" hazard analysis methodology, and is summarized in Section 3.3.2.3, "Hazard Evaluation." For example, hazard scenario number HGB-3 evaluates a fire in the waste characterization glovebox and some of the causes noted are spontaneous combustion and ignition of oxidizer material. The BIO hazard evaluation also includes a hazard scenario HGB-2 deflagration in a drum when opened at the WCG, or hazard scenario number HHO-1 if it occurs in the outside staging area. A loss of confinement hazard scenario number HSO-26 considered container over-pressurization during staging that could be caused from chemical reactions of incompatible materials. All of these events would be representative of the type of release associated with the WIPP radiological release from nitrate salt drums. The BIO accident analysis further evaluates the fire and deflagration events as Design Basis Accidents (DBAs) in its Section 3.4, and together with the Section 3.3 "Hazard Evaluation," appropriate preventive and mitigative controls are identified and implemented (e.g., glovebox fire suppression system, use of fire blankets, verification of vents installed in drums prior to receipt, etc.).

However, as discussed in the USQD section of this report, a nuclear safety analysis of the nitrate salt process added to the DOP-0233 Revision 36 procedure was not performed. The hazard analysis for the BIO Revision 2.0 in effect in 2012 was not updated, which would have required identification and evaluation of hazards associated with the use of organic absorbents for the wet nitrate salts. Like the lack of updating the JHA discussed in Section 11.1 of this report, this was another missed opportunity where substitution with an inorganic absorbent could have been reasonably been expected had the appropriate SMEs been involved in the BIO update.

The WCRRF BIO was implemented in 2007 when the facility was commissioned. The most recent annual update is Revision 3.0 that was submitted to NA-LA in April 2012, but not yet approved at the time of the Board investigation. NA-LA and LANL have been engaged in an iterative process of comment resolutions and BIO/TSR re-submittals. This delay in DOE approval of the BIO Revision 3 was determined by the Board to not be a contributing cause to the radiological release event at WIPP.

A BIO was selected as the "safe harbor methodology" due to the limited life of WCRRF whose purpose is to process Area G legacy waste to comply with the WIPP WAC. Its mission was expected to be completed in 2012 according to the 2011 BIO, and currently with the completion of the Area G 3706 campaign by June 2014, now delayed due to the WIPP accident. The BIO was prepared per the DOE Standard DOE-STD-3011-2002, which also relies on a graded-approach application of the DOE Standard DOE-STD-3009-94. Application of a BIO instead of a Standard 3009 *Documented Safety Analysis* was determined by the Board to not be a contributing cause to the radiological release event at WIPP. Either 10 CFR 830 safe harbor methodology can be used to establish a nuclear safety basis for the duration to process the remaining 3706 campaign, and any other legacy waste remaining at Area G that cannot be processed in sort, segregate, size reduction, and repackaging activities (SSSR).

7.2.2 Area G

Remediated TRU waste drums, such as nitrate salts with absorbents, are normally returned to Area G for staging (storage) until they can be transferred to the Radioassay and Nondestructive Testing facility for loading into DOT Type B shipping containers to ship to WIPP. The nuclear safety basis required by Subpart B of 10 CFR 830 is documented in the Area G BIO, Revision 2.3, and TSRs, Revision 2.3, dated January 2014.

The Area G BIO Section 2.5.5.4, "TRU Sort, Segregate, Size Reduction, and Repackaging Activities (SSSR)," describes a process similar to the WCRRF WCG remediation of free liquids removal or absorption. Like the WCRRF BIO, it does not distinguish between inorganic and organic absorbents. Neutralization of liquids is not specifically mentioned. One significant difference between Area G SSSR and the WCRRF WCG is that SSSR has a much smaller inventory limit established in its TSRs. As discussed in the procedure review section of this report, the SSSR procedure DOP-1084 does not specifically address remediation of nitrate salt drums with absorbents, and there is no evidence that any unremediated nitrate salt drums were processed at SSSR.

Like the WCRRF BIO, the Area G BIO Section 2.5.2.1 acknowledges that Class I oxidizers such as nitrates are not expected; however, they are considered in the hazard analysis, also restated in the BIO Section 3.3.2.1.4 "Combustible/Flammable Materials." The hazard identification checklist in Appendix 3H did not identify the presence of nitrates as an explosive hazard, but did identify nitric acid and organics, and uncontrolled chemical reactions.

The Area G BIO Appendix 3A documents the selection of Chapter 3 DBAs from the Appendix 3H Consolidated Hazards Analysis (CHA) of over 600 hazard scenarios. This includes drum deflagrations and fires. Related to the WIPP release, the CHA includes hazard scenario BLDG412-1-016, BLDG412-1-008 and AGTRU-1-054 (among others) that identified "chemical incompatibility w/ absorption material" and "chemical reaction" – both occur during SSSR repackaging, rather than during storage. These are bounded by the DBA-3 large fire scenario per the BIO Appendix 3A DBA selection process. Regarding a drum deflagration, the CHA hazard scenarios are represented by DBA-4A and DBA-4C, and include chemical reactions or incompatible chemicals as a cause. Preventive and mitigative controls are identified for these events. Although the Area G BIO hazard and accident analysis evaluated drum deflagration and fires, it did not specifically evaluate the hazards associated with the nitrate salts and organic absorbents.

On May 2, 2014, WIPP declared a PISA (PISAD Number 14-0007, "PISA Determination for Occurrence Report EM-CBFO-NWP-WIPP-2014-0006") based on photographic observations from the entries occurring in late April which indicated that there was a potential energetic release and consumption of the MgO super sacks on top of the emplaced waste columns in Room 7 of Panel 7. Based on waste characterization information, one LANL waste stream, LA-MIN02-V.001, was identified of concern because it matched the radiological release profile and contained cellulosic material that could support combustion. Occurrence report EM-CBFO-NWP-WIPP-2014-0006, "Potential for the presence of untreated nitrate waste salts in TRU waste containers," was revised on May 16, 2014, to include that a fire event had occurred in a waste container based on photographs from the previous day's re-entry to the underground and identification of the breached LANL drum 68660.

Based on WIPP filing an occurrence report and the latest photographic evidence, LANL declared a PISA for the Area G BIO on May 16, 2014, because the likelihood of the fire or deflagration involving a TRU waste drum containing treated nitrate salts increased, and further, it was concluded that the credited controls established in the BIO may not be adequate given the new information. Appropriate interim operational restrictions were established and NA-LA was notified, and subsequently occurrence report NA--LASO-LANL-WSTEMGT-2014-0004, "PISA: TRU Waste Drums Containing Treated Nitrate Salts May Challenge the Safety Analysis," was filed on May 20, 2014. These operational restrictions were reviewed by the Board and the Board determined that NA-LA oversight of the LANL PISA process was sufficient. Similar efforts were undertaken for nitrate salt containers at the Waste Control Specialists' facility in Texas, which was being tracked by CBFO and LANL. Therefore, no further investigation of operational restrictions at LANL or Texas was deemed necessary by the Board.

Based on interviews with personnel from NA-LA and LANS, NA-LA questioned why a PISA should not be declared for WCRRF, and accepted LANS's argument that the nitrate salt hazard is associated with staging/storage of the sealed drum as a function of time and temperature, not during the repackaging process. Hazards and controls related to remediating the liquid and use of absorbent for the nitrate salts were already evaluated in the BIO. The daughter drum was believed to be compliant with the WIPP WAC when it was sealed and transferred to Area G for staging, and the deflagration or fire hazard associated with the nitrate salt and organic absorbent did not exist at WCRRF. The duration of staging daughter drums at WCRRF was fairly short until onsite transfer can be scheduled.

CON 14: The Waste Characterization, Reduction, and Repackaging Facility (WCRRF) Basis for Interim Operation (BIO) did not thoroughly describe or evaluate nitrate salt processing or waste storage activities.

JON 19: The WCRRF BIO needs to be revised to include more specificity in description of nitrate salt processing activities and then update the hazard analysis to include identification of all hazards and their evaluations.

JON 20: Los Alamos National Security, LLC (LANS) needs to review the Area G BIO in light of changes made to the WCRRF BIO and update accordingly.

JON 21: LANS needs to conduct an extent of condition review for issues that are similar to nitrate salt bearing waste processing in WCRRF and Area G.

7.3 LANL Unreviewed Safety Question Process

LANS procedure SBP-112-3-R1.1, *Unreviewed Safety Question (USQ) Process*, has been approved by NA-LA as compliant with the DOE's Nuclear Safety Rule, 10 CFR Part 830.203, *Unreviewed Safety Question Process* and DOE G 424.1-1B, *Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements*. In accordance with this procedure, a USQD worksheet (WCRRF-12-625-D) was prepared in July 2012 for Revision 36 of EP-

WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations*. This revision of the WCRRF procedure added new steps for treatment of nitrate salt bearing wastes.

The USQD (WCRRF-12-625-D) was negative, meaning that the USQ preparer concluded that proposed nitrate salt processing steps were adequately addressed in the WCRRF BIO (ABD-WFM-005, Revision 2.1). Section 2.5.7 of this BIO discusses the use of an absorbent being added to containers having liquids, but does not specify the use of organic or inorganic material. Because it is not specific, it was assumed Step 10.6[3] (i.e., referring to "organic absorbent (Kitty Litter/Zeolite® absorbent)" was within the scope of activities and hazards analyzed in the USQD. Based on interviews with LANL personnel, it was assumed that appropriate safety analysis was performed on proposed changes to the WCRRF procedure change prior to initiation of the USQ process. However, no such additional analysis was performed, or discovered by the USQ evaluator as needing to be performed. As a result, the USQD failed to recognize that an incompatible reactive nitrate salt bearing waste would be created by using "organic" absorbents as permitted by Step 10.6[3] of the procedure, and appropriate compensatory or remedial actions were not taken, nor was the associated BIO's hazard analysis revised.

7.4 Analysis of Section 7.0 – Nuclear Safety Basis Evaluation

The LANS Unreviewed Safety Question (USQ) process was ineffective in capturing changes related to processing of nitrate salts as they could impact the safety basis.

The Board noted that LANS procedure SBP-112-3-R1.1 requires that positive USQDs must be approved by the Facility Operations Director prior to submittal to DOE/NNSA. Additionally, the Facility Operations Director is responsible for approving and maintaining a list of personnel who are qualified to prepare or review USQ documents at their facility. Although no evidence was found that this contributed to the results of the negative conclusion in USQD WCRRF-12-625-D, the team did determine that there was significant production pressure and urgency related to approval of Revision 36 of the WCRRF glovebox procedure. Additionally, the roles and responsibilities of the Facility Operations Director related to the USQ process could result in additional undue pressure to process a procedure change with a negative USQD conclusion when the change may actually pose an unreviewed safety question. NA-LA nuclear safety management has acknowledged concerns with the Facility Operations Director's role with respect to the USQ process, and is seeking organizational changes in near term USQ procedure updates planned by LANS.

The Board found evidence that NA-LA has performed assessments of the LANS' USQ process, although the most recent assessment was performed in May 2012. Numerous USQDs were reviewed, and some weaknesses were found and documented in a formal assessment report. However, the last assessment preceded the USQD WCRRF-12-625-D. NA-LA indicated another formal assessment is planned in the upcoming year, and it is advised that the USQD in question be further reviewed as part of that assessment.

CON 15: The Los Alamos National Security, LLC (LANS) Unreviewed Safety Question (USQ) process was ineffective in ensuring that important procedure changes related to processing of nitrate salts were adequately evaluated for impacts to the safety basis.

JON 22: LANS needs to ensure that USQ evaluators are organizationally independent of line management.

JON 23: LANS needs to conduct retraining of USQ process evaluators/approvers focused on implementation of the Unreviewed Safety Question Determination (USQD) process consistent with DOE Guide 424.1-1B, *Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements*.

JON 24: The NNSA Los Alamos Field Office (NA-LA) needs to conduct an assessment of the LANS USQ program.

8.0 LANL Contractor Assurance System

8.1 Overview

The LANL Contractor Assurance System (CAS) is described in LA-UR 10-04565, *Los Alamos National Laboratory Contractor Assurance System Description Document, System Description 320*, Revision 3.0. The CAS includes the required elements of the Contractor Requirements Document in DOE O 226.1B, *Implementation of Department of Energy Oversight Policy*. The LANL CAS consists of:

- a performance-based continuous improvement cycle;
- a process for governance and oversight;
- mechanisms to ensure system sustainability; and
- tools to manage risk, optimize performance, and improve safety and security.

The CAS is designed in accordance with Section H of the Management and Operating Contract for Los Alamos National Laboratory, specifically clauses H-3 and H-4. The CAS is also designed to meet the requirements of NNSA Supplemental Directive 226.1B, *NNSA Line Oversight and Contractor Assurance System*.

The LANS CAS includes a variety of methods for validating effectiveness, including self-assessment, independent assessment, and management assessments. An annual self-assessment of the CAS is also performed and the results published in an annual fiscal year CAS self-assessment. LANL is also a Voluntary Protection Program site and publishes an annual Voluntary Protection Program report. Oversight is based on a risk register which drives the integrated assessment schedule which is intended to address and evaluate potentially high consequence activities. With regard to this investigation, the risk register includes the following risk areas:

- Radcon glovebox issues;
- Sustaining safety culture;
- WIPP operational delay;
- Waste compliance;
- RCRA permit appeal;
- Product accepted trouble free;
- Conduct of operations;
- Conduct of engineering;
- DSA/TSR continuous improvement;
- Drive consistent work control processes; and

- Nuclear safety.

LANL utilizes a Performance Feedback and Continuous Improvement Tracking System to manage program and performance deficiencies (individually and collectively). The Performance Feedback and Continuous Improvement Tracking System is capable of categorizing the significance of issues based on risk and priority and other appropriate factors which enables LANS to evaluate and correct issues on a timely basis. Issues management includes causal analysis for higher risk deficiencies and concerns, and effectiveness reviews to assess the effectiveness of corrective action/plan implementation and results in preventing recurrences.

LANL uses a desktop network application “dashboard” of performance measures for key systems and their supporting processes. With regard to this investigation, key performance measures include:

- Safety analysis implementation and safety systems performance, and
- Environmental non-compliance rates

LANS issues an annual assurance letter per the direction of the Contracting Officer. This letter describes overall compliance, operational performance, and areas for CAS improvement. The letter is based on the results of the annual CAS assessment.

Additional key elements of a CAS include the Quality Assurance/Quality Control (QA/QC) program and implementing procedures and contractor oversight and control of their subcontractors.

The LANL CAS incorporates the principles of QA and is integrated with other LANL management systems, including the Integrated Safety Management System (ISMS) and Integrated Safeguards and Security Management. LANL trends QA system performance as part of the trending and analysis process.

Appendix B, Requirements and Drivers of the LANL CAS crosswalks how the principles of the LANL QA program are incorporated in the CAS to assure that LANL products and services meet or exceed customer requirements.

Appendix B of the LANL CAS also crosswalks how LANL ensures comprehensive gathering of operational and other appropriate data, adequate causal analysis, risk analysis, trending, comparison to metrics (including leading and lagging indicators), dissemination of operational data, measures both worker and subcontractor performance and identifies and corrects negative performance/compliance before they become significant issues.

The LANL CAS also includes provisions for continuous feedback and improvement, including worker feedback mechanisms (e.g., employee concerns programs, telephone hotlines, employee suggestions forms, labor organization input) improvements in work planning and hazard identification activities and lessons learned programs.

8.2 Analysis of Section 8.0 – LANL Contractor Assurance System

The Board reviewed program documents, procedures, assessment schedules, self-assessments, independent assessments, lessons learned documentation, trending data, ISMS and Voluntary Protection Program data, occurrence reports, management observation verifications, and other metrics related to the implementation of the CAS.

While the LANL/LANS CAS and NNSA/NA-LA oversight processes appear to be compliant with applicable DOE Headquarters and NNSA requirements, execution of oversight is less than adequate. The Board noted significant deficiencies with regard to work planning and control within Environmental Projects at LANL. The procedure change process was not driven by an overarching engineering change control/management process that would have ensured appropriate SME involvement to provide the necessary technical evaluation to establish specifications regarding type of neutralizer and absorbent added to the waste. LANS did not adequately consider or share the basis for suspending waste processing using WasteLock® 770 when deciding the on the appropriate absorbent (organic vs. inorganic) and neutralizers to use. In addition, there was no evidence that any type of technical evaluation occurred regarding the compatibility of the agents planned to be added to the waste stream. Although the procedure change process specified review by selected SMEs, this process lacked the detail and focus that would have been provided in a more formal engineering design package. In addition, as a part of the LANL change control process, the negative USQD performed for the WCRRF glovebox procedure change to use organic absorbent was based on an incorrect assumption that the scope of the change was bounded by the existing safety analysis, and as a result, the USQD failed to identify or recognize that an incompatible reactive nitrate salt bearing waste would be created by using "organic" absorbents as permitted by Step 10.6[3] of the procedure. This resulted in appropriate compensatory or remedial actions (e.g., identifying the correct absorbent) not being taken, nor was the associated WCRRF BIO's hazard analysis revised. Additional issues include:

- There were insufficient and/or ineffective contractor and DOE third party audits (see Section 9, "Federal Management and Oversight"), peer reviews, and independent assessments of the process for procedure development/revision, hazard analysis and control, and waste processing/packaging operations;
- There were inadequate LANS self-assessment and improvement activities with regard to waste processing and packaging;
- There were inadequate worker feedback mechanisms and lessons learned with regard to previous issues regarding incompatible waste absorbents. If such feedback/lessons learned were gathered and appropriately evaluated, the specification of Swheat Scoop® could have been avoided;
- The LANL QA/QC program and procedures did not effectively encompass waste processing operations (such as inadequate implementation of the HWFP); and
- LANS oversight of waste operations conducted by Energy*Solutions*, LLC was lacking both in the frequency and depth of oversight.

Under CCP-PO-012, *CCP/Los Alamos National Laboratory (LANL) Interface Document*, the CCP is responsible for maintenance of the AK document. Step 4.27.2 of CCP-PO-012 states, "The host site has primary responsibility to notify CCP when there are changes to policies, processes, or procedures that may affect CCP characterization activities or operations." LANS provided changes to CCP regarding changes to the WCRRF glove box procedure as required. However, there was no context provided indicating the changes that may affect AK and there was no evidence that CCP reviewed those changes effectively.

The Board reviewed documentation and interviewed personnel related to oversight activities. While there were diverse topics assessed across LANL, there was inadequate depth and breadth of assessments related to waste management operations, and procedures as evidenced by the failure of LANS to identify the deficiencies uncovered by the Board during the accident investigation. The focus of CAS assessments of waste management operations was primarily on compliance with facility Technical Safety Requirements, operability of vital safety systems, conduct of operations, and general procedure compliance, but not development of waste operation procedures. As a result, the weaknesses in the facility operating procedures were not identified.

The Board also learned during interviews that independent RCRA Self-Assessments at LANL were suspended during several months in FY2013. LANL established the RCRA Self-Assessment Program in 1996. From 1996 through 2012, the program was staffed at a level of effort of two to three full time equivalencies, conducting approximately 1,200 site visits/inspections per year. In FY2013, LANL general and administrative funding was eliminated and independent self-assessments were suspended.

The program had consistently been managed for NA-LA by the LANS organization currently titled Associate Directorate for Environment, Safety, and Health and funded as an institutional general and administrative program. Even though regular RCRA compliance inspections occurred as required, these independent contractor self-assessments were relied upon by NA-LA for demonstration of RCRA compliance since NA-LA had not been staffed to perform this level of oversight.

The requirements flow down into LANL procedure EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations*, did not occur. This represented a failure in the CAS to adequately flow down requirements from the DOE/LANL HWFP, the TRAMPAC and the WIPP WAC into implementing procedures, specifically. The requirements were referenced but not incorporated allowing the introduction of incompatible wastes.

Based on review of past LANS documentation, lessons were not learned from a previous use of an organic based absorbent, i.e., WasteLock® 770. Such feedback/lessons learned should have identified that specification of the Swheat Scoop® organic absorbent was inappropriate. Specifically, lessons learned were not effectively implemented from the comprehensive assessment performed by the HSS Office of Enforcement and Oversight "Independent Oversight Review of the Facility Centered Assessment of the Los Alamos National Laboratory Waste Disposition Project" dated September 2011 that included "shadowing" by Federal oversight. Examples include:

- Inappropriate assignment of hazard category to identified work. WDP had graded the hazard level of many operations non-conservatively and not in accordance with P-300, *Integrated Work Management*, Attachment B, "Hazard Grading Table."
- Failure to ensure the appropriate rigor of hazard analysis based on the hazard category. LANL actions within the WDP to complete and close the DOE Office of Health, Safety and Security (HSS) Finding C-9 were not effective in ensuring comprehensive and appropriate hazard analyses for moderate and high hazard activities within the WDP. In addition, documented hazard analyses, as required by P300 and P315, *Conduct of Operations Manual*, were not documented or otherwise made available to the FCA team. For example, radiological hazard analysis and mitigation for the WCRR high dose drum campaign was not performed for its imminent startup in 2011.

Through interviews with workers and environmental program management, the Board also determined that worker feedback from WCRRF operations did not get acted upon by the senior level management. Workers indicated that there were abnormal reactions such as foaming and orange/yellow smoke during neutralization of waste in the glovebox and brought this to the attention of the first line supervisor of the WCRRF facility. After conditions cleared, the workers were instructed by the first line supervisor to continue operations. These actions were not brought to the attention of LANS and NA-LA.

CON 16: The Los Alamos National Security, LLC (LANS) contractor assurance system was not effective in identifying weaknesses in the process for developing/changing procedures, analyzing and controlling hazards, performing work to repackage nitrate salt bearing wastes, and feedback mechanisms which resulted in the production and shipping of noncompliant waste drums to the Waste Isolation Pilot Plant and Waste Control Specialists, LLC (WCS).

JON 25: LANS Environmental and Waste Management Operations (EWMO) needs to develop and implement a fully integrated contractor assurance system that provides DOE and LANS confidence that work is performed compliantly, risks are identified, and control systems are effective and efficient.

Specific areas to be addressed include:

- Ensuring adequate scope and associated depth and breadth of self-assessments, independent assessments and management assessments;
- Clarifying the oversight role of LANS EWMO with regard to subcontractors and waste processing/packaging operations;
- Ensuring required environmental program oversight i.e., the Resource Conservation and Recovery Act (RCRA) (hazardous waste determination, upper tier requirements flow down into implementing procedures, waste determination, records);
- Including the necessary rigor in implementation of the change control process (review and approval by subject matter experts);
- Verifying that requirements are flowed down into implementing procedures, e.g., RCRA requirements, TRU Waste Authorized Methods for Payload Control, etc.; and
- Evaluating and responding to feedback from Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations by LANS senior management, e.g., notification of reactions in the glovebox.

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9.0 Federal Management and Oversight

9.1 DOE/NNSA Program and Oversight Facts

The NA-LA Environmental Projects Office provides primary oversight to the site contractor LANS and its subcontractors. Day-to-day oversight of project activities at the site is mostly completed by the Environmental Projects Office staff in the Waste Management group. The Environmental Projects Office organization is made up of a mix of DOE employees that are predominantly DOE Environmental Management (EM) employees, but a few, including the Assistant Manager, are NNSA employees. The Environmental Projects Office Assistant Manager reports to the NA-LA Manager. The Environmental Projects Office is also supported by other NNSA employees from NA-LA. Project management and waste management oversight is conducted by the Environmental Projects Office Waste Management employees. Field oversight of waste management activities is conducted primarily by the Facility Representatives. The Facility Representatives report to the NA-LA Assistant Manager for Field Operations.

The Environmental Projects Office and NA-LA project management and oversight staff members include a diverse set of skills and backgrounds including: experienced waste management staff, qualified facility representatives, project managers, regulatory compliance staff, engineering, waste operations, safety basis staff, and safety operations. The Environmental Projects Office and NA-LA develop an annual integrated evaluation plan that is used to plan and track evaluations and assessments across many project-related areas. The Board reviewed several integrated evaluation plans from past years.

The Environmental Projects Office and NA-LA have several policies and procedures that address oversight activities such as QA audits, surveillances, and other project verifications. NA-LA is required to implement an oversight program in accordance with DOE O 226.1B. The Environmental Projects Office and NA-LA also implement a Technical Qualification Program (TQP) in accordance with DOE O 426.1, *Federal Technical Capability.* The Board reviewed the WIPP WAC that provides roles and responsibilities for all parties involved in waste generation, including waste generating sites and field offices.

The Board interviewed the Environmental Projects Office and NA-LA management and oversight staff and reviewed supporting documentation during the course of this investigation. The Environmental Projects Office management indicated that staffing and resources were adequate to safely conduct environmental project activities. However, the Board reviewed a staffing analysis performed by NA-LA in support of the Federal Technical Capabilities Program that indicated staffing shortages in the areas of facility representatives, Senior Technical Safety Managers, and environmental compliance.

9.2 DOE Headquarters

DOE Headquarters provides support to LANL and NA-LA in the form of policies, DOE orders, resources (budget and human capital), mission support, emergency management, quality assurance, nuclear safety, and security. Periodically, oversight is also performed by DOE Headquarters to ensure safe and compliant operations at the facility.

The Office of the Chief of Defense Nuclear Safety led a biennial review of LASO's (predecessor organization to NA-LA) oversight of nuclear operations at the LANL in June 2012. It concluded that LASO's efforts resulted in significant improvement in overall performance since the last review in 2009, and that the strong NA-LA performance provided a high degree of assurance that NA-LA was aware of nuclear safety issues and was effecting positive change in contractor performance. There were observed weaknesses in contractor performance, indicating that NA-LA must maintain its strong presence/oversight until LANS performance improves and the LANS Contractor Assurance System matures.

Under the Voluntary Protection Program, HSS has conducted performance-based assessments on a periodic basis. At the time of the investigation, the last assessment for LANL was conducted June 3-13, 2013. The assessment recommended that LANL continue at DOE- Voluntary Protection Program Merit level while it addresses the specific improvements in the Worksite Analysis and Hazard Prevention and Control tenets. The assessment recommended that LANL continue walking down procedures with a team of "hands-on" workers and SMEs to ensure that procedures are workable, remove ambiguous language, clarify assumptions, and resolve the outstanding conduct of operations issues.

9.3 National TRU Program

The National TRU Waste Program was established to facilitate, with assistance from the CBFO Manager and Directors as well as TRU waste site personnel, the removal and disposal of TRU waste from sites across the country into the WIPP.

The CBFO is responsible for the day-to-day management and direction of strategic planning and related activities associated with the characterization, certification, transportation, and disposal of defense TRU waste. The CBFO holds the applicable permits, certifications, and records of decision necessary for the operation and closure of the WIPP facility. The CBFO assists the sites in resolving issues about the management of TRU waste as requested.

Each DOE Field Element is responsible for overseeing the management of the site TRU waste program in compliance with established CBFO requirements, policies, and guidelines, and for providing liaison between the CBFO and the management and operating contractors.

The Board noted that there has been no external oversight of the adequacy of implementation of the National TRU Program.

9.4 NNSA/NA-LA Oversight

The clauses found in Section H of the LANS Prime Contract, along with DOE O 226.1B and NNSA Supplemental Directive 226.1B, define the approach to NA-LA oversight of LANS. Primary responsibility for oversight rests with the NNSA/NA-LA Site Manager. The LANL Contractor Assurance Officer works with the NNSA Site Manager to integrate CAS with NNSA oversight activities in accordance with direction from the NNSA Administrator to continuously improve the performance of mission and mission support organizations.

The CAS enables the NNSA oversight of LANL performance by providing or facilitating the following types of information:

- LANL performance indicators;
- LANL internal performance reviews;
- LANL management and independent assessments;
- various third-party assessments;
- shadowing LANL assessments;
- observing LANL Management Review Boards (MRBs);
- transactional oversight data for nuclear operations and security;
- feedback from operational oversight by facility representatives; and
- audits by NNSA, DOE, and other governmental agencies.

The Contract Management Plan, which includes the Performance Evaluation Plan, documents the processes and associated performance objectives, performance incentives, award-term incentives, and associated measures and targets by which contractual performance will be evaluated. The Oversight Plan defines the NA-LA process and procedures for oversight of LANL, including the use of CAS. NNSA will continue to conduct transactional operational awareness for high-hazard and nuclear activities, as well as for security.

The Environmental Operations Integration Team was created to centralize and enhance project oversight and integration of Environmental Projects Office's cross-cutting functions and activities, non-traditional environmental programs and initiatives. It works closely with the Environmental Projects Office Team Leads and staff to assure that these programs and initiatives are coordinated with and integrated into the traditional environmental management efforts in an efficient and effective manner. Specific functions include project controls management support functions such as baseline validation and review, estimating, planning, scheduling, and project performance assessment; the Co-Deputy Designated Federal Officer function for the Northern New Mexico Citizen Advisory Board; DOE Oversight Bureau, Environmental Justice coordination with NA-LA; and DOE O 458.1, *Radiation Protection of the Public and the Environment*.

9.5 Analysis of Section 9.0 - Oversight

The Environmental Projects Office and NA-LA organization share resources in the management and oversight of LANL operations. The DOE staff is a mix of EM and NNSA employees.

The Board reviewed the Environmental Projects Office and NA-LA Spreadsheets that list external assessments, LASO assessments, and LASO field observations from 2010 to present. While EPO and NA-LA perform many diverse oversight activities throughout the year, the Board did not find objective evidence of adequate assessments in the areas of RCRA compliance, WCRRF operations, or WCRRF procedure change control.

Results from the interviews and document reviews confirm that much of the oversight related to the 3706 shipping campaign was focused on budget, financial and schedule performance versus operational oversight.

It was noted that NA-LA had scheduled an assessment of RCRA compliance in 2011; however, the Integrated Evaluation Plan shows that no oversight of RCRA was completed. Facility Representative operational awareness assessments included RCRA elements, e.g., one report noted failure to use bermed pallets for drums with liquids. But there was no RCRA oversight of the WCRRF glovebox repackaging operation as related to the changes with neutralization and absorbent materials to process the nitrate salts.

On the ground operational oversight has been limited to Facility Representatives oversight, which lacks support from other subject matter expertise. DOE O 226.1B requires that each DOE field element establish an effective contractor oversight program. The Board identified that NA-LA relies substantially on the DOE Facility Representatives to provide contractor operational oversight. While it is the primary job of the DOE Facility Representatives to provide contractor oversight, there was no identification of a DOE SME in the area of waste remediation or CCP also performing contractor operational oversight. During interviews with the Facility Representatives and review of the NA-LA organizational chart, there was no identification of a DOE expert in this area for the Facility Representatives to reach out to for support.

While roles and responsibilities were clearly defined in the WIPP WAC, the failure of NA-LA to identify problems associated with the event at WIPP indicates that there is inadequate translation and implementation of those requirements in the LANL waste management policies and procedures. Specifically, LANL failed to adequately implement controls that demonstrated compliance with the WIPP WAC and incorrectly certified that those requirements were met.

Related to nuclear safety, NA-LA is comprised of at least twelve engineers and SMEs. Environmental Projects Office utilized this expertise from the NA-LA organization. Similarly, eleven facility representatives provide coverage for all of LANL. With respect to EWMO operations, the Environmental Projects Office utilized three facility representatives from NA-LA, but utilization of dedicated resources in engineering and SMEs was not evident. The safety oversight program had been reviewed several times over the last few years.

Deficiencies identified during these reviews included:

- Inadequate staffing;
- Procedures that are incomplete and not used;
- No structured surveillance/oversight program; and
- No clear mechanism being used to communicate issues to management and the contractor.

Specifically related to the EWMO operations, the Board reviewed evidence of the performance of NA-LA Facility Representatives oversight. This revealed frequent coverage by Facility Representatives often focused on compliance with the Technical Safety Requirements. However, interviews with ES and LANS staff and management responsible for WCRRF and Area G operations indicated only sporadic oversight coverage by other NA-LA SMEs.

The 2013 FTCP analysis developed by NA-LA identified staffing shortfalls for Facility Representatives, Senior Technical Safety Managers, and Environmental Compliance SMEs. Based upon review of the NA-LA staffing analysis, shortages include:

- Facility Representatives, short three full-time equivalents (FTEs) after being consistently two short since at least 2010;
- Senior Technical Safety Manager, short two FTEs consistently since 2011; and
- The staffing reduction in environmental compliance, down from five to three FTEs since 2011.

Since NA-LA failed to identify weaknesses in WCRRF operations, the Board determined that execution of WIPP WAC roles and responsibilities by NA-LA in providing oversight was inadequate. During interviews, NA-LA personnel indicated there is an over-reliance on the LANS Contractor Assurance System for environmental compliance oversight due to the lack of resources for the Environmental Projects Office to perform this oversight. As WCRRF glovebox operations started to process nitrate salts in 2012, the lack of NA-LA oversight was not consistent with the NNSA 2011 biennial review observation that stated, since the LANS CAS program was still maturing, a strong NA-LA oversight presence should continue.

The NA-LA senior technical advisor position has been vacant since 2008; this position would be expected to review reports and white papers such as the 2010 New Mexico Tech report and the LANL-CO Difficult Waste Team zeolite white paper for applicability and field office awareness. Additionally, there is no organic chemistry expertise available at NA-LA or through contractor support at LANL, thus the existing skill mix is not conducive to adequate technical reviews in this area.

CON 17: The NNSA Los Alamos Field Office (NA-LA) oversight was ineffective in identifying weaknesses that contributed to this event.

JON 26: NA-LA needs to strengthen its oversight of Los Alamos National Security, LLC (LANS) Environmental and Waste Management Operations (EWMO) to ensure that:

- Resource Conservation and Recovery Act (RCRA) oversight is performed;
- Focus is placed on operational oversight in addition to budget/financial oversight;
- On the ground operational oversight expands beyond that performed by the Facility Representatives to include adequate subject matter expertise;
- NA-LA performs oversight of contractor activities related to waste certification in accordance with the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC);
- Roles and responsibilities for oversight of Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations are made clear;
- Staffing shortages are addressed, including:
- Facility Representatives, short three full-time equivalencies (FTEs);
- Senior Technical Safety Manager, short two FTEs;
- The staffing reduction in environmental compliance, down from five to three FTEs since 2011; and
- Senior technical advisor position has been vacant since 2008.
- Formal verification that there is an effective LANS Contractor Assurance System (CAS) in place for environmental compliance.

JON 27: NA-LA needs to verify that LANS has developed and implemented a DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy* compliant CAS.

Based upon interviews and the review of pertinent documentation, the Board noted that there is a gap in Federal oversight performance between CBFO National TRU Program and NA-LA of waste site activities. The Board observed that NA-LA oversight focused more on budget and schedule performance versus operational oversight.

The Board also noted a lack of clearly defined Federal interface roles and responsibilities, and expectations between the LANL/generator site TRU waste program and the TRU waste certification program (CCP) as illustrated in Figure 9-1. Additionally, the Board identified inadequate CCP review and approval of waste management operating procedures/process changes, e.g., WCRRF glovebox operating procedure and inadequate Federal oversight of those processes.

Based upon interviews and the review of pertinent documentation associated with the National TRU Program, the Board noted the following:

- CBFO oversight of the LANL TRU waste programs did not verify compliance with all permit requirements relying on confidence of past evidence of compliant performance. As stated in Section 3.7, prior to the advent of the CCP organization, there was more detailed

Federal oversight of the waste generator operations but this has evolved into annual certification reviews of CCP and occasional informal spot checks.

- Inadequate separation of oversight and line management responsibilities within the CBFO National TRU Program was acknowledged by CBFO during the investigation.
- Lack of external/Headquarters oversight of all three key segments illustrated in Figure 9-1 of the National TRU Program including the generator site (LANL) TRU waste program, TRU waste certification program (CCP), and the disposal system program (WIPP).

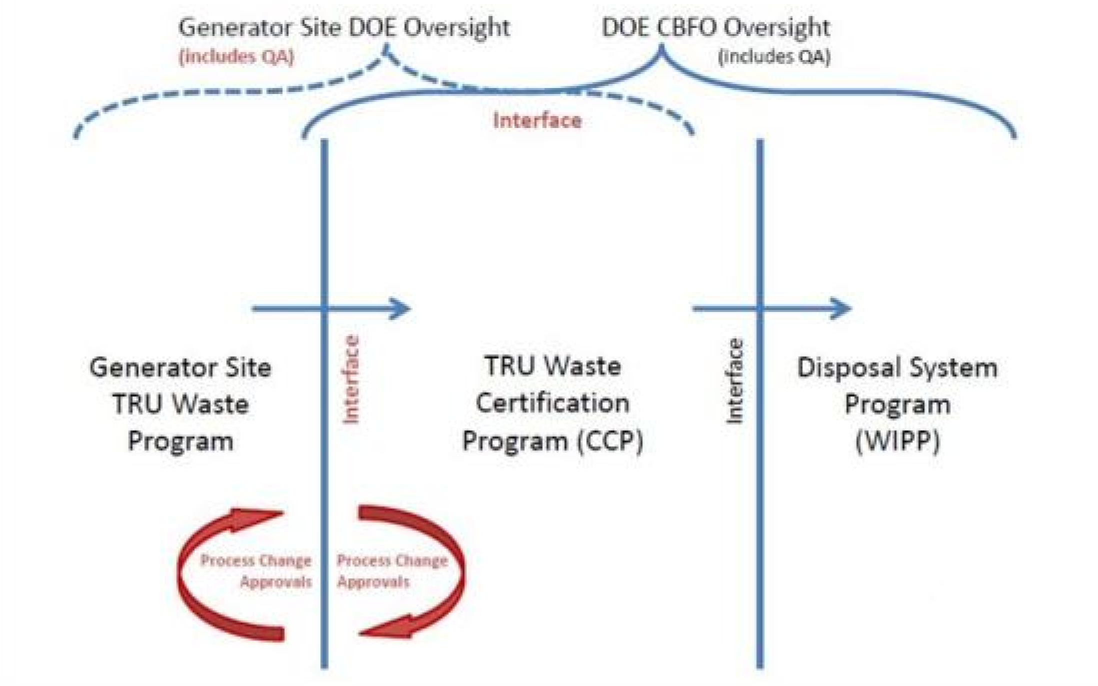


Figure 9-1: Waste Characterization Program Interfaces and Oversight

CON 18: The Federal roles, responsibilities and execution for oversight of the activities between the generator site transuranic (TRU) waste program (LANL) and the TRU Waste Central Characterization Program (CCP) were inadequate.

JON 28: The National TRU Program needs to clarify NA-LA and Carlsbad Field Office (CBFO) expectations and oversight roles and responsibilities between the generator site TRU waste program (LANL) and the TRU waste CCP.

JON 29: NA-LA and CBFO needs to perform effective Federal oversight of CCP review and approval of waste management operating procedures/process changes, e.g., WCRRF glovebox operating procedure.

JON30: DOE Headquarters and CBFO need to conduct an extent of condition review of the overall Federal oversight across the DOE complex in all three key segments of the National TRU Program: the Generator Site TRU Waste Program, TRU Waste Certification Program, and the Disposal System Program (WIPP).

The Board interviewed several DOE Headquarters management and support staff to gain an understanding of roles and responsibilities related to line management and support of the environmental projects at LANL.

During a Voluntary Protection Program assessment that was conducted June 3-13, 2013, one of the opportunities for improvement identified in the assessment stated that "LANL needs to continue walking down procedures with a team of “hands-on" workers and SMEs to ensure procedures are workable, remove ambiguous language, clarify assumptions, and resolve the outstanding conduct of operations issues.” The Board noted that implementation of this opportunity may have identified the issues identified in the EP-WCRR-WO-DOP-0233 procedure detailed in Section 5.4. The report also noted that in relation to the 3706 campaign the team's observation of work at times appeared "harried", particularly as problems arose, i.e., encountering higher activity waste materials, but workers and managers did not stop or pause work as questions or problems arose.

As discussed in Section 3.7, the Board found no objective evidence of DOE Headquarters oversight activities for implementation of DOE O 435.1 requirements associated with the operational performance within the National TRU Program.

CON 19: DOE Headquarters did not perform DOE O 435.1, *Radioactive Waste Management,* oversight activities for implementation of requirements associated with the operational performance within the National transuranic (TRU) Program.

JON 31: DOE Headquarters needs to develop and implement a DOE O 435.1 comprehensive oversight program for National TRU Program activities as identified by the Office of Environmental Management.

The Board looked closely at the execution of the waste generator site certification and recertification audits on CCP conducted at LANL. While the audits provided a detailed evaluation of characterization efforts along with the data quality objectives in the waste certification process, there was a significant gap regarding activities such as waste repackaging efforts that are performed by the host site. Certification audits of facilities where CCP conducts characterization and certification activities were focused only on CCP activities and did not look at the waste generator site as part of the process. Additionally, the CBFO and National TRU Program rely on the oversight performed by the local site office to ensure that the waste generator is in compliance with the LANL HWFP (see CON 2/JON 2, Section 3).

Specifically, CBFO Audit A-12-12 was conducted immediately following the development of a path forward related to the WasteLock® 770 compatibility issue that was resolved via SP #72, Revision 1, but prior to implementation of procedure revisions to AK document CCP-AK-LANL-006, *Central Characterization Program, Acceptable Knowledge Summary Report for Los Alamos National Laboratory, TA-55 Mixed Transuranic Waste Streams: LA-MHD01.001, LA-CIN01.001, LA-MIN02-V.001, and LA-MIN04-S.001,* by CCP and EP-WCRR-WO-DOP-0233, Revision 36, *WCRRF Waste Characterization Glovebox Operations*, by LANS. However, CBFO Audit A-13-23 was conducted the following year. As stated in Section 3.7, neither of these recertification audits included evaluation of the implementation of these changes nor the potential impact of the errors contained within or between the documents.

Among other elements of National TRU Program management, the CBFO is also responsible for the following:

- Ensuring that the sites prepare implementation documentation and programs to meet the requirements and criteria in the WAC.
- Overseeing activities associated with the:
    - Characterization and certification of TRU waste;
    - Proper use of approved transportation packaging; and
    - Receipt, management, and disposal of TRU waste at WIPP.

NA-LA is responsible, under the WIPP WAC, for overseeing the management of the site TRU waste program in compliance with established CBFO requirements, policies, and guidelines, and for providing liaison between the CBFO and the management and operating contractors. Although personnel interviewed indicated that there was routine oversight of WCRRF glovebox operations at LANL being conducted by NA-LA, it did not result in the identification of inadequacies in repackaging operations. CBFO, through oversight of the National TRU Program certification audits, incorrectly assumed that local oversight was being effectively conducted as prescribed in the responsibilities laid out in the WAC. The National Transuranic Waste Corporate Board, while not having an assigned oversight role, represents a forum where the various senior leadership entities could discuss coordination of oversight activities aside from the role that is lined out in the charter (see CON 3/JON 3; and CON 4/JON 4,JON 5, JON 6, Section 3).

10.0 Safety Programs

10.1 Integrated Safety Management System

The Board's review of the radiological release event in the context of the Integrated Safety Management System (ISMS) as related to WIPP is provided in the Phase 1 report. This section is related to the LANS ISMS except for specific discussion regarding the WIPP Fire Hazard Analysis.

Background

LANS is contractually required to implement a Safety Management System in accordance with 48 CFR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*. It is also LANS responsibility to flow these requirements down through their sub-contractors in their execution of LANS scope. The requirement states that in performing work, the contractor shall perform work safely, in a manner that ensures adequate protection for employees, the public, and the environment, and shall be accountable for the safe performance of work. The contractor shall exercise a degree of care commensurate with the work and the associated hazards. The contractor shall ensure that management of ES&H functions and activities becomes an integral but visible part of the contractor's work planning and execution processes. This contract clause identifies the guiding principles and core functions that are expected to be integrated into the work planning and execution processes. Those expectations are reviewed in this section.

LANS developed LANL P300, *Integrated Work Management*, to establish the Laboratory Integrated Work Management (IWM) expectations for doing work in a manner that protects people, the environment, property, and the security of the nation. At the facility level, LANS has established safety management programs with the intent of integrating safety into operations while focusing on continuous improvement, consistent with the guiding principles of Integrated Safety Management (ISM). The nuclear safety program has been established and maintained and is implemented through the establishment and maintenance of an approved "safety basis" which provides the foundation for ensuring that the appropriate hazards and accidents are identified, evaluated, and controlled. Tailoring hazard controls to the work being performed through identification of safety structures, systems and components (SSCs) and administrative controls provides a basis upon which the facility is designed, operated and maintained to protect against bounding accident scenarios.

The Board did not conduct a complete review of the LANL ISMS from the perspective of overall program implementation. The Board evaluated the LANL ISMS only to the extent necessary to determine if it caused or contributed to this accident. The following analysis represents the Phase 2 investigation, and references other sections of this report where appropriate.

Analysis

The ISMS Core Functions (CF) and associated Guiding Principles (GP) are provided in boxes preceding each respective section. The Board identified the following in the context of the ISMS.

Define the Scope of Work (CF-1)
Line Management is Responsible for Safety (GP-1)
Competence Commensurate with Responsibilities (GP-3)
Balanced Priorities (GP-4)
Identification of Safety Standards and Requirements (GP-5)

EP-DIR-AP-10007, *Environmental Programs Procedure Preparation, Revision, Review, Approval, and Use, Revision 2.1* established requirements for defining the scope of work in operating procedures. Section 6.2 states, "In accordance with P300, *Integrated Work Management*, work components and processes must be defined in sufficient detail to enable the hazards and the situations or circumstances in which they could cause harm to be identified and analyzed." EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations,* Revision 36, was made effective on August 1, 2012. The scope of the revision listed in the Document Action Request stated,

> *"Revised procedure to incorporate EP-SO-1708, and add steps to clarify the amount of absorbent needed when processing Nitrate Salts. Also, added Appendix 6 Administrative Control Lock Log Sheet. No additional hazards were identified during this revision. Revision bars in the left column display location of changes in the procedure."*

The same statement was found repeated in the document Revision History. However, the revision did not result in a change to the scope of the document itself, in Section 2.0 of the document, even though a completely new section (10.6) was added pertaining to nitrate salts.

EP-SO-1708, *WCRRF Waste Characterization Glovebox Operations* was a Standing Order developed in response to an increase in the frequency of continuous air monitor (CAM) alarms that were occurring during glovebox operations in the WCRRF. It prescribed actions to be taken to reduce the probability of future radiological contamination releases during glovebox operations. The Board reviewed the original document and its revision. The content of the standing order had no specific relation to the repackaging activity in the context of the investigation.

The Board reviewed records associated with Revision 36 of EP-WCRR-WO-DOP-0233 and determined the scope of work for the waste repackaging operation also included incorporation of ERID 214637, P2010-3345, *Solution Package Scope Definition, Report 72, Salt Waste (SP #72),* Revision 1, July 2012. The report identified groupings of similar waste forms and documented the overall disposition strategy and paths for each grouping for compliance with the WIPP WAC. The disposition strategy stated, "In May 2012 the LANL Carlsbad Office Difficult Waste Team authored a white paper *(Amount of Zeolite Required* to *Meet the Constraints Established by the EMRTC Report RF 10-13: Application* to *LANL Evaporator Nitrate Salts,* May 08, 2012), agreed to by the DOE June 14, 2012, that established the requirement that a minimum of 1.2 volumes of kitty litter/zeolite must be mixed with 1.0 volume of nitrate salts (in existing parent and daughter containers) in order for the WIPP to affirm that the final mixture of LANL nitrate salts can be considered a non-oxidizing solid." For the non-cemented nitrate salts, it defined remediation of the legacy TA-55 evaporator bottoms at the WCRRF process that already addressed neutralization and use of absorbents for free liquids. SP #72 also indicated that revising EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations,* would be the procedural means to implement the controls to mix kitty litter/zeolite and nitrate salts.

The Board concluded that LANS execution of EP-DIR-AP-10007 and P300 to develop and revise the glovebox procedure was inadequate with regard to ISMS CF-1. The revision did not correctly incorporate the description of work from SP #72 as prescribed by P300.

Identify and Analyze the Hazards Associated with the Work (CF-2)

Identification of Safety Standards and Requirements (GP-5)

Hazard controls tailored to work performed (GP-6)

EP-DIR-AP-10007, *Environmental Programs Procedure Preparation, Revision, Review, Approval, and Use*, Revision 2.1, was reviewed to determine if it contained sufficient requirements for the identification of hazards. EP-DIR-AP-10007 required a documented hazard analysis of activities and steps contained in new procedures or major revisions of existing procedures in accordance with P300. Section 6.2, "Format/Content" of EP-DIR-AP-10007 stated that:

> *Major Revisions require a review of the existing hazard analysis document (e.g., JHA tool) against the changes to the activity in order to make a determination as to whether any associated hazards or controls are affected by the activity changes.*

This procedural step was not specific as to what was expected by a review of the hazard analysis and who was responsible for performing the review. There was also no linkage to a specific hazard analysis process and/or reference to another procedure; only a statement that a JHA tool was one example that may be used. Finally, the hazard analysis review that applied to major revisions did not have a "shall" statement to perform this step. That was only required for new technical procedures. The absence of clear hazard analysis requirements and guidance may have contributed to the failure to identify organic absorbent hazards.

Consistent with ISMS principles, LANL procedure EP-DIR-AP-10007 also required that subject matter expertise be integrated into the review of new procedures or major procedure revisions.

Weaknesses were identified in related procedural steps in Section 6.3, "Procedure Review and Concurrence Process," that required SME reviews:

Reviews shall be conducted on new and revised procedures per the Document/Review Approval Matrix (Appendix 1).

The procedure also did not contain objective criteria for determining which SMEs to involve. For example, it stated that Industrial Hygiene experts should be involved when the procedure “concerns issues associated with industrial hygiene and occupational safety.” Involvement of the appropriate SME(s) in the review and approval of the revision could have identified the incorrect specification of an organic absorbent.

The Board reviewed the Document History File associated with Revision 36 of EP-WCRR-WO-DOP-0233 and determined that a new hazard analysis was not developed for the nitrate salt processing steps added in Section 10 of the procedure that was approved on August 1, 2012. Similarly, the WCRRF BIO hazard analysis, hazard identification and hazard evaluation, was not updated (see Section 7.2, LANL Safety Basis Documents for details). The Revision 36 Document History File stated “add steps to clarify the amount of absorbent needed when processing Nitrate Salts. No additional hazards were identified during this revision.” This may have pre-disposed the operations, support, SME reviewers, and the USQD evaluator, that no new hazards were being introduced.

Prior to the event, there had been no JHA review of the glovebox procedure performed since Revision 28. Interviews and a review of documentation indicated that the procedure writer started with direction from ES operations to specify adding “organic absorbent” for nitrate salt processing in Step 10.6[3] since Step 10.3[5][C] only required “appropriate absorbing agent” for disposition of all free liquids (including any in a nitrate salt drum), but the review process added more specificity that resulted in adding “organic absorbent (Kitty Litter/Zeolite® absorbent)” in Step 10.6[3]. The LANL Carlsbad Difficult Waste Team issued *Amount of Zeolite Required to Meet the Constraints Established by the New Mexico Tech Energetic Materials Research and Testing Center (EMRTC) Report RF 10-13, "Application to LANL Evaporator Nitrate Salts”* (May 8, 2012) that specified use of zeolite/kitty litter such that the nitrate salts would not exhibit oxidizer properties. The direction provided in this paper was not correctly incorporated into the WCRRF procedure Revision 36. In the Document History File for Revision 36, it was not recognized during the review process that the change introduced chemical incompatibility and impacted the combustible loading in the glovebox. The subject matter expert reviews missed an opportunity to identify the incorrect specification of organic absorbent where zeolite/kitty litter had been prescribed. Additionally, as discussed in Section 7, Nuclear Safety Basis Evaluation, development and revisions to contractor packaging/characterization procedures were not reviewed by CCP, which would have represented another opportunity to prevent the use of organic kitty litter and incompatible neutralizer with the nitrate salts. As a result, the hazard associated with adding a combustible absorbent was not considered.

An evaluation of hazards was documented in a February 29, 2012, LANL memo ENV-RCRA-12-0053, regarding potential applicability of RCRA codes D001 (ignitability), D002 (corrosivity), and D003 (reactivity), where it was concluded that the nitrate salts as prepared for shipment to WIPP would not need to be assigned those characteristics. Hazards associated with processing nitrate salts were considered by LANL prior to development of the Revision 36 procedure. Specifically, the use of WasteLock® 770 was recognized to be unsuitable which resulted in the suspension of WCRRF glovebox processing after 33 nitrate salt drums were initially processed in 2011, as detailed in Section 5.3.2 and analyzed in Section 5.4. The issuance of SP #72, Revision 1, on July 17, 2012, incorporated the minimum 1.2 absorbent ratio by volume, as recommended in the LANL-CO Difficult Waste Team (zeolite white paper, May

2012) that was developed from the New Mexico Tech test report EMRTC FR-10-13, *Results of Oxidizing Solids Testing* (April 12, 2010), to ensure the nitrate salt "oxidizer" characteristics are rendered safe and not classified as an oxidizer. The CCP AK summary report, CCP-AK-LANL-006 Revision 12 (December 12, 2012) summarized the RCRA waste code determinations and described in Section 7.4.3.4 that nitrate salts are "remediated/ repackaged in the WCRR Facility with an inert absorbent material (e.g., zeolite, kitty litter) … ratio is 1.5 to 1." This error in the AK was attributable to relying on LANS to incorporate the correct controls rather than verifying so by reviewing the revision to the WCRRF glovebox procedure. Consequently, these upper tier documents were not correctly incorporated into Revision 36, of the WCRRF glovebox procedure that specified use of an "organic" absorbent.

Revision 28 of EP-WCRR-WO-DOP-0233 was reviewed. The associated JHA was the latest JHA and focused on hazards associated with operational activities (e.g., chemical contact and inhalation) and identification of controls to protect the operators (e.g., glovebox confinement, room ventilation, respirators, personal protective equipment). The Board found that it did not include applicable code and regulatory compliance considerations. Specifically, it evaluated handling of acidic and caustic liquids, and disposition of liquids from a personal safety perspective, and recognized potential flammable/combustible gases and "explosive/ pyrophoric/thermal energy/smoke/fire/bubbling chemicals," along with identifying control measures. Additionally, there were no comments from the "Safety" or "fire protection" reviewers included in the Document History File for this Revision 28 JHA.

The next JHA revision did not occur until the update to the glovebox operations procedure issued on March 13, 2014, as EP-WCRR-WO-DOP-1198, Revision 1. This JHA update also failed to recognize the chemical incompatibility or increased combustible loading hazard.

In summary, the Board concluded that the waste repackaging operation was insufficiently scoped and controlled (CF-1) and as a result the hazard of combining incompatible materials were not identified (CF-2). Additionally requirements specified in the CBFO directed controls were not correctly incorporated into the work scope, when organic absorbent was prescribed in the revision rather than the zeolite/kitty litter from the CBFO directed controls. Therefore, appropriate controls and safety requirements to prevent this combination were not identified and tailored (GP-5).

CON 20: Los Alamos National Security, LLC (LANS) existing processes governing the preparation, review, and approval of Environmental Programs procedures did not contain sufficient guidance related to hazard analysis and subject matter expert review necessary to ensure safe, consistent, and compliant execution of waste processing.

JON 32: LANS needs to review and revise EP-DIR-AP-10007 and other documents governing the procedure development process to ensure that all procedures and procedure revisions contain:

- The necessary level of detail to ensure the safe, consistent, and compliant performance of work, including process steps, materials, and material substitutions;
- Explicit requirements and criteria regarding inclusion of appropriate subject matter experts and their review and concurrence with new and revised procedures; and
- Requirements that a Job Hazard Analysis (JHA) is appropriately amended when new activities such as nitrate salt remediation that could introduce new hazards are incorporated into existing processes.

It should be noted that the Area G BIO also authorizes remediation of liquids with absorbents, and could have allowed processing of nitrate salts, although it is not believed that nitrate salts were processed at Area G. Remediating liquids is performed in the SSSR glovebox using procedure EP-AREAG-WO-DOP-1084, Revision 0, issued September 30, 2013, (new procedure number replaces EP-AREAG-WO-DOP-0216 originally issued November 20, 2009). Its Section 6[47] is similar to the WCRRF DOP-0233 pre-Revision 37 procedure Section 10.3 processing of free liquids, which required a pH test but not neutralization. Revision 37 became effective March 30, 2013. The Area G procedure does not include the specific WCRRF steps for processing nitrate salts. The SSSR glovebox also has a low plutonium equivalent-curie (PE-Ci) TSR that limits which containers could be processed.

WIPP Fire Hazards

With respect to recognition of the fire hazards, WIPP implements a fire protection program based on the requirements in DOE O 420.1C, *Facility Safety*. The program included the preparation of written fire protection criteria and procedures for the use and storage of combustible materials, and the preparation of Fire Hazard Analyses (FHA) for Hazard Category 2 Nuclear Facilities.

The use of exposed combustible emplacement materials (e.g., fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric) in the array was not fully evaluated, nor was the quantity used fully understood. An evaluation of the combustible emplacement material mass based on fabrication documentation concluded that the actual mass of combustible materials in the array was 40 percent higher than was represented in the Waste Data System. NWP missed an opportunity to recognize and correct this error in 2011 when the Defense Nuclear Facilities Safety Board issued a letter dated June 24, 2011, to the Assistant Secretary for Environmental Management (sir_2011624_12300_18) with the attached Staff Issue Report, dated May 2, 2011, that identified the hazard associated with the MgO super sacks and other interstitial materials.

The *Fire Hazard Analysis for the Waste Isolation Pilot Plant WIPP-023* (FHA), Revision 5A, of record on February 14, 2014, recognized the potential for a fire involving a waste array; there were weaknesses in the results.

- It was assumed that an external fire exposure was necessary to ignite the waste array;
- The fire propagation hazard created by the combustible emplacement materials (e.g., fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric, etc) was not recognized;
- The presence of radiological contamination in the exhaust drift was not considered a hardship since "it is normally considered contaminated, with access restricted." (Note: The exhaust drift, E-300, is a secondary evacuation route for evacuation of the underground. Radiological contamination in this route interferes with its use as an evacuation route.);
- The possibility that following a radiological release, ventilation through the underground would be limited to the capacity of the HEPA filters was not recognized.
- The possible presence of noncompliant waste in the array was not recognized; and
- The need for an extended outage following a waste array fire was not recognized.

Because the fire ignition hazards within the array were overlooked, the fire protection program, features and procedural controls focused on ensuring there were no unnecessary fire exposures to waste being transported (FHA, page 109).

The FHA suggests that because the super sack material has been demonstrated to have "flammability classification of horizontal burning (HB) based on the HB test specified in" UL 94, Standard for Safety – Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, it would require "20 minutes to burn from one side of the super sack to the other" (FHA, page 72). Such a burning behavior did not occur on February 14; the MgO super sacks were damaged over a period of seconds to minutes. The evidence demonstrated that the technical basis was incorrect. The HB category is the lowest categorization in the standard and demonstrates that a horizontal sample is subjected to impingement by a 20mm long flame for 30 seconds or less. Such an exposure is inconsistent with most unwanted fires. In addition, the conclusion neglects that much of the MgO super sack surface is vertical, a position that is more susceptible to fire propagation.

DOE O 420.1C establishes the objective to "minimize the consequence of a fire-related event affecting the public, workers, environment, property and missions." It also requires the preparation of an FHA for all hazard category 1, 2, and 3 nuclear facilities; and facilities that represent unique fire safety risks, as such an FHA is required for WIPP. The WIPP FHA asserted that "A fire involving electrical services underground or a vehicle fire in a waste disposal room that is not extinguished with a handheld extinguisher and burns to fuel exhaustion or ventilation extinguishment could require a recovered interval of one month from the initial fire." WIPP has not received waste for over a year. The FHA did not recognize the potential for a fire starting in the waste array and spreading contamination into the exhaust drift. DOE-STD-1066-2012 provides guidance to address evaluation of public, worker, environment and property but does not provide guidance on evaluating mission protection. The mission-related risk decisions related to the processing and handling of TRU waste were not recognized or documented in a form that allowed informed decisions.

The Board recognizes that WIPP has developed a recovery plan. The recovery plan has implied assumptions related to minimum adequate ventilation and combustible control limits that will be reviewed when the FHA is updated to reflect actual experience that exceeded prior damage expectations for any credible fire event.

CON 21: The WIPP Fire Hazard Analysis (FHA) was ineffective in identifying and analyzing the potential for a fire starting within the waste array, as well as the potential for fire propagation within the array.

JON 33: Nuclear Waste Partnership LLC (NWP) needs to re-evaluate the quantities, type and form of exposed combustible emplacement materials used in the waste array and take action to minimize the fire ignition and propagation risks (e.g., eliminate unnecessary materials, and include fire retardant additives).

JON 34: NWP needs to revise the waste array emplacement strategy to include criteria that limit the risk of fire propagation within the array and to include limiting the quantity of radiological waste that is at-risk from a single fire or explosion event.

JON 35: NWP needs to revise the FHA to identify and address all credible fire and explosion scenarios initiated within the waste array underground.

JON 36: NWP needs to reevaluate and revise the WIPP FHA to better characterize the fire risks associated with transuranic (TRU) waste packaging during handling and storage. This needs to include reevaluation of actions detailed in the WIPP Recovery Plan.

JON 37: The Office of Environmental Management Headquarters needs to ensure that waste generator site's FHAs adequately characterize the fire risks associated with TRU waste packaging during handling and storage.

Develop and Implement Hazard Controls (CF-3)

Identification of Safety Standards and Requirements (GP-5)

Hazard controls tailored to work performed (GP-6)

Operations authorized (GP-7)

The Board did not find evidence of integrated safety management related to identification of appropriate hazard controls and their incorporation into work processes, as related to the WIPP radiological release event. This was due to the failure to update the WCRRF JHA and BIO hazard analysis as discussed above in CF-2, and in Sections 7.2, 7.3, and 7.4 of this report.

The issuance of SP #72 by LANS incorporated the minimum 1.2 absorbent to waste ratio of "kitty litter/zeolite" to implement the CBFO directed controls based on the LANL-CO Difficult Waste Team (zeolite white paper) that specified a minimum 1.2:1 ratio of "Kitty Litter/Zeolite clay" referencing the New Mexico Tech test report EMRTC FR-10-13, *Results of Oxidizing Solids Testing* (April 12, 2010), which identified a minimum amount of inert material (zeolite clay and ground high strength grout) that must be mixed into the most reactive ratio of sodium nitrate and potassium nitrate in order to classify the mixture as a Category IV (non-oxidizer) to ensure the nitrate salt mixture is considered a non-oxidizing solid. See Section 5.4, "Analysis of Section 5 – LA-MIN02-V.001 Waste Stream," regarding CON 8 with JON 10 and JON 11 related to flowdown of upper tier requirements into implementing procedures.

Revision 36 of EP-WCRR-WO-DOP-0233 specified an inappropriate type of absorbent (i.e., organic vs. inorganic) for the moist waste material after neutralizing free liquids, and did not contain the necessary level of detail to ensure safe, consistent, and compliant remediation of nitrate salt bearing waste. See Section 5.4, "Analysis of Section 5 – LA-MIN02-V.001 Waste Stream," regarding CON 12 with JON 15, JON 16 and JON 17 related to ensuring sufficient detail was provided in the WCRRF glovebox procedure. The glovebox procedure did not require operators to document critical process steps, e.g., initial pH, quantity of absorbent added, neutralizer used, and adjusted pH. Records produced during execution of the glovebox waste procedure did not contain enough information to accurately describe the contents of the waste drums. Specifically, the procedure required the use of organic absorbent when zeolite/kitty litter had been prescribed.

The Board found that LANS did not adequately scope and limit the waste repackaging evolution and therefore could not identify associated hazards (CF-2) and develop and implement corresponding controls (CF-3 and GP-5).

Perform Work within Controls (CF-4)

Clear Roles and Responsibilities (GP-2)

Competence commensurate with responsibilities (GP-3)

Operations authorized (GP-7)

There were inadequate performance measures and indicators in place to evaluate how safely the waste processing/packaging work was being performed and verified.

The Board concluded that readiness and authorization (GP 7) to begin waste repackaging following implementation of SP #72 was not assured by verifying that controls were adequate to mitigate the hazard of incompatible materials in the waste containers, and that these controls were implemented prior to commencement of work.

Work control processes during waste processing/packaging did not include continuous identification of hazards nor stopping work to re-evaluate these hazards and controls, and therefore did not result in work package changes to address the incompatible material hazard.

Personnel were accustomed to performing steps that were outside of the detailed instructions as evidenced by the neutralization of acidic liquids when no such steps were in the WCRRF glovebox procedure prior to revision 37. Additionally, when abnormal situations occurred in the glovebox (e.g. foaming or yellow smoke during neutralization) LANS did not procedurally address these conditions and document a path forward.

The Board reviewed training and qualification records and interviewed ES personnel involved in waste processing and packaging to assess the adequacy (breadth and depth) of training, the adequacy of qualification standards, and personnel understanding of waste processing and packaging procedures and expectations.

Based upon interviews and review of LANL and ES documentation, the Board concluded that current training and qualification of ES operators and their supervisors was ineffective (GP 3). Training to follow procedures is a minimum expectation. However, for this event the glovebox operations procedure was deficient. Operator and supervisor training and qualification must be supported by a basic understanding of the waste composition and associated waste processing/packaging materials, e.g., absorbents, neutralizers, etc., compatibility of secondary wastes, and critical hazards and associated precautions and controls.

CON 23: Energy*Solutions*, LLC (ES) operators and supervisors were not adequately trained and qualified to process waste with regard to identification and control of incompatible materials.

JON 38: Los Alamos National Security, LLC (LANS) needs to evaluate and strengthen the operator and supervisor training programs of LANS and their subcontractors to ensure adequate understanding of basic chemistry interactions and associated controls.

Feedback and Improvement (CF-5)

Line Management is Responsible for Safety (GP-1)

The LANL waste operations consist of EM funded activities at NNSA facilities with mostly EM employees that results in some blurring of responsibilities and reduced oversight from a Headquarters perspective.

The NA-LA senior technical advisor position has been vacant since 2008. This position would be expected to review reports and white papers such as the 2010 New Mexico Tech report and the LANL-CO zeolite white paper for applicability and field office awareness. Additionally, there was no organic chemistry expertise available at NA-LA or through contractor support at LANL, thus the existing skill mix was not conducive to adequate technical reviews in this area.

Regarding process improvements, uncertainty existed in pH measurements. Color change on the litmus paper was read through two glass windows of the glovebox – leaded glass and inner glass.

Drum 68660 was logged as neutralized by the operators, but no post neutralization measurements were documented on Attachment 1 of the WCRRF glovebox procedure.

The Board concluded that there was inadequate line, independent contractor, and DOE oversight (self-assessment, independent, and management assessment) of the waste processing/packaging operation, as discussed in Sections 8 and 9 (CF-5). As a result, inadequacies in procedure content and detail, as well as hazard identification and control were not proactively identified, corrected, and effectiveness verified.

Feedback, including worker input, and lessons learned from previous use of an organic based absorbent were not solicited or otherwise obtained. Such feedback/lessons learned would have clearly indicated that specification of the organic absorbent (Swheat Scoop®) was inappropriate.

In summary, the Board concluded that the waste repackaging operation at WCRRF was insufficiently scoped and controlled in accordance with ISMS core functions. The LANS procedure development process as executed to prepare and implement Revision 36 of EP-WCRR-WO-DOP-0233 did not ensure the appropriate identification of organic absorbent hazards, were not sufficiently detailed with appropriate steps and controls, did not adequately limit the work evolution, and did not adequately address SP #72 (i.e., use of organic vs. inorganic absorbent) (CON 17/JON 25 and JON 26).

10.2 Human Performance Improvement

The goal of Human Performance Improvement (HPI) is to facilitate the development of a facility structure that recognizes human attributes and develops defenses that proactively manage human error and optimize the performance of individuals, leaders, and the organization. The Department's *Human Performance Improvement Handbook*, Volumes 1 and 2 (DOE-HDBK-1028-2009), describe the HPI tools available for use at DOE sites. Human error is not a cause of failure alone, but rather the effect or symptom of deeper trouble in the system. A review of Human Performance is a review of an individual's abilities, tasks, and operating environment to determine if the organization supports them for success.

The significance, or severity, of a particular event lies in the consequences suffered by the physical plant or personnel, not the error that initiated the event. The error that causes a serious accident and the error that is one of hundreds with no consequence can be the same error that has historically been overlooked or uncorrected. In most cases, for a significant event to occur, multiple breakdowns in defenses must first occur. Whereas human error may trigger an event, it is the number and extent of flawed defenses that dictate the severity of the event. The existence of many flawed defenses is directly attributable to weaknesses in the organization or management control systems. The Anatomy of an Event Model (Figure 10-1) illustrates the elements that exist before an event occurs and is a very useful model to guide the analysis of an event from an HPI perspective. The elements analyzed are the flawed defenses that allowed the event to occur or did not mitigate the consequences of the event; the error precursors that existed; the latent organizational conditions that allowed those to be in existence; and finally the vision, beliefs and values of management and workers.

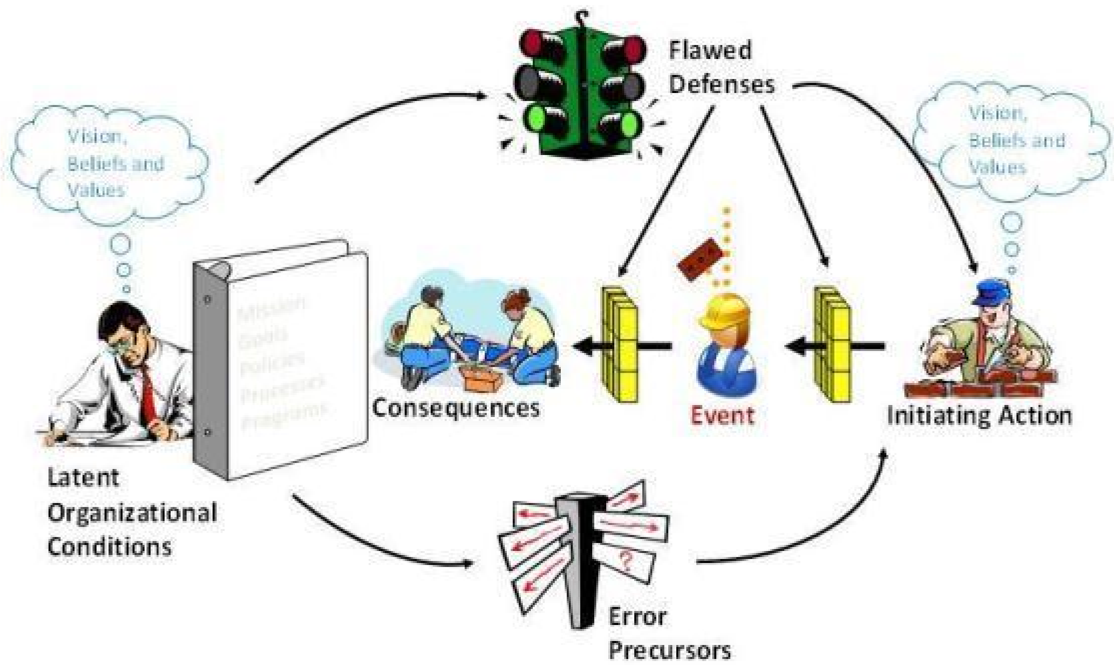


Figure 10-1: Anatomy of an Event Model

Error precursors are unfavorable conditions that increase the probability for error during a specific action and create what are known as error-likely situations. An error-likely situation typically exists when the demands of the task exceed the capabilities of the individual or when work conditions exceed the limitations of human nature. Human nature comprises all mental, emotional, social, physical, and biological characteristics that define human tendencies, abilities, and limitations. For instance, humans tend to perform poorly under high stress and undue time pressure. Error-likely situations such as these are also known as error traps. Error precursors exist in the work place before the error occurs, and thus are manageable. If identified before or during the performance of work, the conditions can be changed or managed to reduce the chance for error(s) to lead to an event.

Error precursors (conditions) associated with Human Performance attributes (Figure 10-2) were analyzed by the Board to identify specific conditions that may have provoked error and led to the accident.

HUMAN PERFORMANCE ATTRIBUTES

Task Demands. Specific mental, physical, and team requirements to perform an activity that may either exceed the capabilities or challenge the limitations of human nature of the individual assigned to the task; for example, excessive workload, hurrying, concurrent actions, unclear roles and responsibilities, or vague standards.

Individual Capabilities. Unique mental, physical, and emotional abilities of a particular person that fail to match the demands of the specific task; for example, unfamiliarity with the task, unsafe attitudes, level of education, lack of knowledge, unpracticed skills, personality, inexperience, health and fitness, poor communication practices, or low self-esteem.

Work Environment. General influences of the workplace, organizational, and cultural conditions that affect individual behavior; for example, distractions, awkward equipment layout, complex tagout procedures, at-risk norms and values, work group attitudes toward various hazards, or work control processes.

Human Nature. Generic traits, dispositions, and limitations of being human that may incline individuals to err under unfavorable conditions; for example, habit, short-term memory, fatigue, stress, complacency, or mental shortcuts.

Figure 10-2: Human Performance Attributes

Human Performance also describes three modes in which errors occur. The three modes, progressing from most familiar to the task to the least familiar to the task are: skill based, rules based, and knowledge based. Errors will most likely occur in the knowledge based performance mode. The performance mode in which an error occurs is based on the individual's familiarity with the task being performed.

The Board did not look at HPI from the perspective of overall program implementation. The Board evaluated HPI to determine if it played a part in this accident. Much of the information provided in this section is based on the analysis of the events, conditions, processes, and barrier information presented in this report, Phase 2 of the investigation.

10.2.1 Analysis of Section 10.2 – Human Performance Improvement

This analysis identified the likely human performance mode, and provided an error precursor analysis, which considered task demands, individual capabilities, work environment, and human nature.

Human Performance Mode

Based upon interviews with staff, the Board concluded that the likely dominant human performance mode for which these errors occurred is the knowledge based mode. Knowledge-based activities require diagnosis and problem-solving. There are considerable demands on the information-processing capabilities of the individual that are necessary when a situation has to be evaluated from first principles.

During the waste remediation process, unclear and/or unspecific requirements existed in ES operator procedures. In many cases, the operator had to make a decision on what step to do next. The main ES operator procedure for waste remediation activities underwent several revisions that inserted new requirements, did not identify requirements, and also could not be executed as written because it provided no step-out requirements.

The allowed condition for adding an organic neutralizer and absorbent also occurred in the knowledge base mode. Knowledge base mode points to a situation where the organization/individual did not fully understand what they were doing. ES, LANS, and NA-LA did not recognize that adding organics created both a combustible and a chemical incompatibility hazard.

Error Precursor Analysis

The Board conducted an Error Precursor analysis based on the information obtained from documents and interviews as documented throughout this Phase 2 report. The results of this analysis are presented in Table 10-1. The following is a discussion of some of the more dominant error precursors.

The dominant Error Precursors the Board identified are Inaccurate Risk Perception, Inaccurate Mental Picture (Assumptions), Lack of or Unclear Standards, and Unclear Roles and Responsibilities. There were several conditions throughout the waste remediation process that increased the likelihood for a waste drum to be packaged noncompliant with the WIPP WAC. These include:

- The addition of an organic absorbent and neutralization agent was not a recognized risk;
- Waste repackaging procedures did not identify hazards, and allowed the use of inadequately evaluated materials, e.g. absorbing materials, neutralizer agents, and potentially incompatible materials such as room trash, glovebox gloves;
- Waste processing procedures did not specify desired results for use of log books, record keeping, and departures from normal operations;
- Incorrect non-destructive analysis algorithm was applied for validating waste drum profile;
- Inaccurate assumption that non-destructive analysis of waste drums validated them as WIPP WAC compliant;
- Unclear roles and responsibilities between LANS and ES; and between NNSA and EM operations within NA-LA; and
- High-load work schedule to complete the waste remediation campaign.

The following is a discussion of the four categories of error precursors: Task Demands, Work Environment, Individual Capabilities, and Human Nature.

Table 10-1: Error Precursors

TASK DEMANDS			INDIVIDUAL CAPABILITIES		
X[17]	1	Time Pressure (In a hurry)	X	1	Unfamiliarity with Task/First time
XX	2	High Workload (large memory)	XX	2	Lack of Knowledge (faulty mental model)
	3	Simultaneous, Multiple Tasks	X	3	New Technique Not Used Before
	4	Repetitive Actions/Monotony	XX	4	Imprecise Communications
	5	Irreversible Acts	XX	5	Lack of Proficiency/Inexperience
X	6	Interpretation Requirements		6	Indistinct Problem-solving Skills
XX	7	Unclear Goals, Roles, or Responsibilities		7	"Unsafe" Attitudes
XX	8	Lack of or Unclear Standards		8	Illness/Fatigue (general health)
WORK ENVIRONMENT (WE)			**HUMAN NATURE (HN)**		
	1	Distractions/Interruptions		1	Stress
	2	Changes/Departure from Routine		2	Habit Patterns
	3	Confusing Displays/Controls	XX	3	Assumptions (inaccurate mental picture)
	4	Work-Arounds		4	Complacency/Overconfidence
	5	Hidden System/Equipment Response		5	Mindset (intentions)
	6	Unexpected Equipment Conditions	XX	6	Inaccurate Risk Perception
X	7	Lack of Alternative Indication		7	Mental Shortcuts (biases)
	8	Personality Conflicts		8	Limited Short-term Memory

17 X = single occurrence, XX = multiple occurrences.

Task Demands. There were several examples of high workload and time stress to accomplish the Area G 3706 Campaign by June 2014. While workers never explicitly identified this as an issue, the Board identified this unrecognized error precursor. In addition, there was a lack of clear standards and interpretation of requirements regarding the neutralization process using litmus paper and making a qualitative determination. The Board was unable to determine whether the drum 68660 was adequately neutralized as it needed to be due to its initial low pH of 0, or whether it was over-neutralized and required addition of a basic solution as had been reported in the past experience of operators.

Work Environment. Operators perform waste remediation operations in a relatively confined glovebox. The glovebox essentially only had room for the operators, and is not set up for radiological control coverage, and therefore restricted access for CCP to perform oversight in accordance with the interface agreement, CCP-PO-012. In addition, the glovebox is equipped with a thick lead glass window that was cracked and repaired with tape. As such, visibility through the glovebox window was challenging. Operators are required to read a litmus paper to interpret the pH of the drum liquid. This is accomplished by comparing the color on the litmus paper with the color on the litmus container to determine the pH level. Reading the litmus paper through the thick lead glass window may hinder the interpretation of the pH value.

Individual Capabilities. There were indications related to individual capabilities in the area of proficiency, first-time use, and lack of knowledge for the intended task. The neutralization and use of absorbents was a new process developed specifically to render the nitrate salts as a non-oxidizer, and also to remediate an error that occurred with the use of the organic-based neutralizer, WasteLock® 770. Although LANL had been neutralizing free liquids and using absorbents previous to 2012, changes were necessary to process the non-cemented nitrate salts to use an inorganic absorbent material, and over time, the ratio of absorbent material to waste was changed based on individual capabilities.

Human Nature. There was Inaccurate Risk Perception error precursor for not recognizing chemical incompatibility of using an organic-based kitty litter as the choice of absorbent material to render the nitrate salt as a non-oxidizer. In addition, the hazard associated with adding a combustible absorbent was not considered. This was inherent in the development of the WCRRF glovebox procedure that included the failure of the SME review process. This went unrecognized by the LANS and ES management including the NA-LA.

11.0 LANL Safety Culture

11.1 Departmental Safety Culture Expectations

The Department of Energy has increased focus on establishing and maintaining a strong safety culture and a Safety Conscious Work Environment (SCWE), recognizing that to be successful in safely accomplishing our mission, we must foster an environment of trust, a questioning attitude and a receptiveness to raising issues. Jeffrey Kupfer, Acting Deputy Secretary, issued a memo on January 16, 2009, to the Under Secretaries for Nuclear Security, Energy, and Science, *Taking Integrated Safety Management to the Next Level: Strengthening Safety Culture*, that stated, "… we know that increasing emphasis on building a strong safety culture is perhaps the most important area we can focus on at this time to take ISM to the next level."

The Secretary of Energy and Deputy Secretary of Energy issued a memo titled, "Personal Commitment to Health and Safety through Leadership, Employee Engagement, and Organizational Learning," dated September 20, 2103. The memo, applicable to Federal, laboratory and contractor employees, states the "Department's Integrated Safety Management policy is the foundation of our approach to safety and health."

Figure 11-1 depicts information from DOE G 450.4-1C, *DOE Integrated Safety Management Guide,* Attachment 3, ISM Overview, which specifically discusses the various levels within the organizational culture.

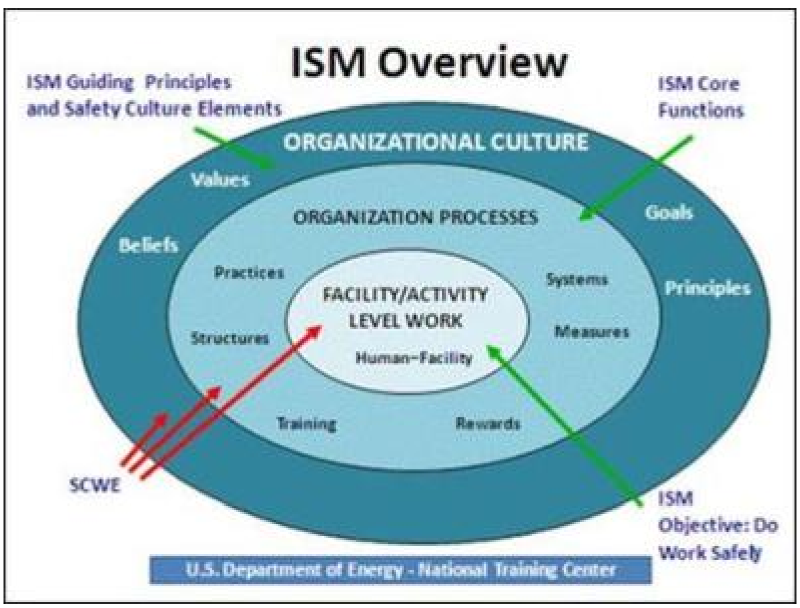


Figure 11-1: ISM Overview

- **Organizational Culture** - This outer level represents the environment within which the work takes place. This level is most influenced by the ISM principles and the supplemental safety culture elements.
- **Organization Processes** - This is *the process level,* where management systems are defined to direct behaviors. This level is most influenced by the ISM core functions.
- **Facility/Activity Level Work -** The innermost level is the *activity level*, where operational work is actually performed. This work represents the direct interaction between people and the physical facility and is mostly performed by DOE contractors (except at government-owned, government-operated facilities). The Facility/Activity Level is where organizations can measure ultimate performance results and determine whether the ISM system objectives have been realized. Performance measures at other levels show how effectively the process and culture support the desired safety objectives. Showing work at the innermost level does not mean that work is not required at the other levels; work activities are required at the other levels to develop work processes and highly reliable, error-tolerant work environments.

Organizations are systems. It is important that the organization be measured at all three levels of the ISM (organizational culture, organization processes, and facility/activity level) as the concepts of Safety Culture and SCWE affect all three levels of ISM.

Included in Figure 11-2 are DOE's Elements of Culture, which provides DOE's definitions for Organizational Culture,[18] Safety Culture,[19] and SCWE.[20]

[18] Organizational Culture: A set of commonly shared beliefs, expectations, and values that influence and guide the thinking and behavior of organization members, and are reflected in how work is carried out.

[19] Safety Culture: An organization's values and behaviors modeled by its leaders and internalized by its members, which serve to make safe performance of work the overriding priority to protect the workers, the public, and the environment.

[20] Safety Conscious Work Environment (SCWE): A work environment in which employees feel free to raise safety concerns to management (or a regulator) without fear of retaliation.

Figure 11-2: DOE's Elements of Culture

Although it may appear that SCWE and safety culture are subsets of organizational culture, they are actually interdependent. It is recognized that it is not really possible to have a strong SCWE if the overall organizational culture is weak, and it is not possible to have a strong Safety Culture if the concept of SCWE is not implemented in the organization. Therefore DOE has begun to focus on shifting behaviors that support positive attributes for SCWE, Safety Culture and Organizational Culture.

DOE issued additional Safety Culture Focus Areas and Associated Attributes in September 2011, based on experience and research conducted over the past decade.

This document was based on information developed by the Energy Facilities Contractor's Operating Group between 2007 and 2010. DOE G 450.4-1C, Attachment 10, builds upon the existing ISM and applies to all organizations with DOE/NNSA and the DOE/NNSA contractors. Attachment 10 focuses on three Safety Focus Areas: Leadership, Employee Engagement, and Organizational Learning. Under each Safety Focus Area is a list of attributes followed by behavioral elements.

The identified supplemental safety culture *behavioral* elements are intended to provide a useful tool to leaders, as well as employees, to focus attention and action in the right areas to create the desired ISM environment(s). These elements describe behavioral attributes (for example, what a positive SCWE should *look like* and *feel like*) and also promote a shift from mere compliance toward excellence. These elements emphasize continuous improvement and long-term performance, and they are entirely consistent with the original intents of ISM. In other words, these are not new concepts. These behaviors are further emphasized in the Secretary's Personal Commitment.

11.2 Safety Culture at LANL

The Board previously assessed the safety culture at the WIPP site as documented in Accident Investigation reports entitled, *Underground Salt Haul Truck Fire at the Waste Isolation Pilot Plant, February 5, 2014*, dated March 2014, and *Phase 1 Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014*, dated April 2014.[21]

Upon arrival at LANL, the Board reviewed recent employee surveys and assessments, interviewed Federal, contractor, and subcontractor employees (management staff and workers), and reviewed site policies and procedures to determine the maturity and effectiveness of the safety culture.

The Board reviewed available information from the following reports:

- LA-UR-13-27299, *LANL Safety Conscious Work Environment (SCWE) Self-Assessment*, September 20, 2013;
- *Evaluation of Organizational Safety Culture at the U.S. Department of Energy National Nuclear Security Administration*, July 2, 2013; and
- Los Alamos National Laboratory Associate Directorate of Environmental Programs (ADEP), Occupational Health & Safety Program Assessment Executive Feedback, Los Alamos, New Mexico, dated June 5, 2013.

In addition, the Board also conducted numerous interviews with LANL site management and staff.

11.2.1 LANL Safety Conscious Work Environment Self-Assessment

On September 20, 2013, LANL issued its Safety Conscious Work Environment (SCWE) Self-Assessment findings in LA-UR-13-27299, *LANL Safety Conscious Work Environment (SCWE) Self-Assessment*. The LANL SCWE Self-Assessment utilized the DOE *Safety Conscious Work Environment (SCWE) Self-Assessment Guidance*, Revision G, and the DOE G 450.4-1C, Attachment 10, *Safety Culture Focus Areas and Associated Attributes*. The methodology/approach included the distribution and analysis of a safety culture survey; work observations; interviews; focus groups; a review of SCWE related processes; and a review of performance measures and contract incentives. The LANL SCWE Self-Assessment included approximately 2,800 survey participants, 30 focus groups (~250 participants), 65 interviews, 17 critique observations, eight work procedure revision sessions, nine Worker Safety and Security Teams and three senior management meetings and a critique process self-assessment. The overall assessment conclusions indicated several strengths including:

- Progress towards a strong safety culture: LANL is perceived to have made great strides towards improving the establishment of a Lab-wide safety culture.

[21] Copies of these reports can be found at http://www.wipp.energy.gov/wipprecovery/accident_desc.html.

- Employees are interested and engaged in strengthening the LANL safety culture: Employees care, are invested in, and have positive expectations for LANL's continued journey towards building an even stronger safety culture.
- Pockets of excellence: Named managers were mentioned again and again as being exceptional in creating a safe work environment where a questioning attitude is encouraged and nobody feels retaliated against.
- Employees caring for employees: There is good trust and communication peer-to-peer.
- High trust with FLM and immediate supervisors: Local management received many positive comments for creating a strong safety culture.
- Communication: The habit of starting each meeting with a safety share seems to be widespread and well perceived.

However, the report also indicated some critical observations. Here are several examples:

- There is a lack of trust and respect for senior leadership across the organization;
- There is a reluctance to report safety concerns to higher management;
- There is a tendency to address safety issues with a procedural change or additional training which seldom addresses the root cause; and
- There is a historic attitude of "get it done at all costs" that can lead to personnel taking safety risks that are unacceptable.

The report also identified a number of Opportunities for Improvement and Recommendations, as follows:

Opportunities for Improvement:

- Excess requirements are diluting what really needs to be done. Reduce bureaucratic requirements and paperwork;
- A review of Lab requirements should be done using a risk-based approach;
- Replace old facilities and equipment;
- Improve communication: it does not flow smoothly and clearly from upper management down toward the lower management and staff;
- Address the tendency to handle safety issues with procedural change or additional training which seldom addresses the root cause;
- Address reluctance to report safety concerns to a higher management; and
- Change the historic attitude of "get it done at all costs" which can lead to personnel taking safety risks that are unacceptable.

Recommendations:

- Provide timely and professional feedback to employee requests and suggestions;
- Achieve a better balance between benefit and risk that is appropriate for a research and development environment;
- Simplify the critique process;
- Improve infrastructure to help instill pride in the workplace; and
- Leadership should demonstrate they have heard the concerns expressed in this assessment and are addressing them.

11.2.2 Los Alamos National Laboratory Associate Directorate of Environmental Programs DuPont Sustainable Solutions Assessment[22]

LANL's ADEP initiated a DuPont Sustainable Solutions Assessment in June 2013 that focused on Occupational Health & Safety Program including assessment of the waste management activities that support the WIPP, as performed by ES. The assessment identified positive observations regarding messages of safety importance being regularly communicated in routine meetings, visual media and publications, robust participation in the Management Observation Verification program, support of the Worker Safety and Security Teams, an Integrated Safety Management System that contained the nucleus of functional and value - based ideals and a commitment that line management is responsible for safety.

However, the report also indicated some critical observations. Here are several examples:

- Incident reporting is inconsistent;
- Evidence that some incidents were attempted to be hidden by a major contractor;
- Safety communications do not flow down to subcontractors effectively;
- Incident investigations fail to derive accurate root causes and corrective action implementation;
- The subcontractor culture for incident reporting is negative; and
- ADEP's safety values were not clearly demonstrated by subcontractor management ranks, subcontractors believe that execution trumps safety, and subcontractors avoid reporting "near misses" for fear of retaliation.

11.2.3 Board Interviews

The Board interviewed Federal and contractor managers and staff, workers and subcontractors to gain a better understanding of the maturity of the safety culture at the site. During interviews with various levels of LANS and ES management and staff, there was a distinct difference in responses related to safety culture and the willingness of workers to bring issues forward

[22] *Los Alamos National Laboratory Associate Deputy of Environmental Programs (ADEP), Occupational Health & Safety Program Assessment Executive Feedback, Los Alamos, New Mexico*, dated June 5, 2013.

(SCWE). Most of the management staff stated that the safety culture was being adequately implemented; however, several of the workers and a few hotline calls indicated that some of the managers at LANL were not receptive to bad news and would retaliate in response to reported issues. One or more interviewees:

- Expressed concern that workers were brought in with little or no experience and rushed through a training program that was not adequate.
- Described what they perceived as production and schedule pressure to get the job done during the 3706 campaign.
- Expressed a concern over occurrences or situations where pH neutralization may not have been fully accomplished because the neutralization process was not happening fast enough so absorbent was added to the waste prior to complete neutralization.
- Identified a concern to management about the change to the WCRRF procedure that added the word “organic” to the procedure when describing the absorbent used in the glovebox. That employee stated that when they questioned the logic of this change, they were told to focus on their area of expertise and not to worry about other areas of the procedure.

Interview results also identified that several of the managers and workers involved in the processing of the waste did not fully understand the complexities or hazards associated with the waste they were handling. It was not evident to the Board that these types of issues were openly discussed during senior management or work planning meetings. Facility management did not effectively respond to worker questions when presented with unexpected issues during the process (e.g. foaming of waste, orange/yellow smoke in the glovebox, or adding items to the waste stream such as glovebox gloves). Lastly, interviewees did not understand the limits imposed upon their operations in the LANL HWFP.

The Environmental Projects Office Federal staff expressed frustration related to areas of excessive workload and the adverse impact on their ability to provide adequate oversight. This is especially evident in the areas of waste management and RCRA compliance. It is not clear that these concerns have been expressed to DOE management.

11.3 Analysis of Section 11.0 – LANL Safety Culture

The Board analyzed the various survey results coupled with several of the interviews and hotline feedback and perceived that LANL, NA-LA, and ES management did not welcome critical feedback, lacked credibility with the workforce, did not fully understand the complexities and hazards related to waste processing, did not effectively flow down expectations, and have fostered a culture where employees do not feel comfortable raising safety issues to management. As a contributing factor, WCRRF management did not effectively respond to worker questions when presented with unexpected issues during the process (e.g. foaming of waste, orange/yellow smoke in the glovebox, or adding items to the waste stream such as glovebox gloves).

Interview results also identified that several of the managers and workers involved in the processing of the waste did not fully understand the complexities or hazards associated with the waste they were handling. (See CON 17/JON 25 and JON 26) It was not evident to the Board that these types of issues were openly discussed during senior management or work planning meetings. Significant changes to the processes for MIN02 repackaging (changes in the use of absorbents and neutralizing agents) were not adequately discussed or considered at these forums. This represents a lost opportunity to use the resources at LANL to address issues before they became problems.

The Board perceived a reluctance of the Federal staff to identify areas of excessive workload to management and the adverse impact on their ability to provide adequate oversight. This is especially evident in the areas of waste management and RCRA compliance.

Both LANL and the ADEP issued action plans and safety objectives for 2014 in response to their respective SCWE assessments. The Board reviewed those plans and objectives (some of the actions are still in progress) and found them to be moving in the right direction. However, from the results of the interviews and document reviews, there are still opportunities for improvement.

Additionally, when workers informed supervisors of unexpected conditions during waste processing, supervisors failed to engage knowledgeable resources to investigate and develop appropriate process changes to mitigate the problem. Further, workers accepted less than adequate management responses and returned to work without addressing the issue.

CON 24: Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) and NNSA Los Alamos Field Office (NA-LA) allowed the safety culture at the Los Alamos National Laboratory (LANL) to deteriorate within pockets of the organization as evidenced by the workers' feedback that they did not feel comfortable identifying issues that may adversely affect management direction, delay mission-related objectives, or otherwise affect cost or schedule. In addition, management failed to effectively respond to workers' issues regarding unexpected conditions encountered during waste processing activities.

CON 25: Questioning attitudes were not welcomed by management and many issues and hazards did not appear to be readily recognized by site personnel.

JON 39: LANS and NA-LA need to develop and implement a more rigorous, effective integrated safety management system that embraces and implements the attributes of DOE G 450.4-1C, *Integrated Safety Management Guide,* including but not limited to:

- Demonstrated leadership in risk-informed, conservative decision making;
- Improved learning through error reporting and effective resolution of problems;
- Line management encouraging a questioning attitude without fear of reprisal and following through to resolve issues identified by the workforce.
- Consideration should also be given to some additional contract incentive associated with leading a culture change that fosters the desired work environment. The LANS, ES, and NA-LA stop work related processes need to ensure that response to issues raised by workers are based on sound, technical justification.

JON 40: DOE Headquarters needs to engage safety culture expertise to provide training and mentoring to LANS, ES, and NA-LA management on the principles of a strong safety culture and take appropriate corrective action based on the outcome.

12.0 Analysis

12.1 Identification of the Accident

Based upon the evidence obtained during this accident investigation, the Board concluded that the release from the container(s) was preventable. If LANL had adequately developed and implemented repackaging and treatment procedures that incorporated suitable hazard controls and included a rigorous review and approval process, the release would have been preventable.

12.2 Barrier Analysis

After a basic chronology of events was developed, the Board performed a barrier analysis of the accident. To start the barrier analysis, the Board chose a target (the person or item to be protected) and the hazard (what the person or item is to be protected from). The Board chose the workers and the public as the target and the release of mixed TRU waste as the hazard.

Fifty three barriers were identified and analyzed by the Board.

The barrier analysis is presented in Attachment B.

12.3 Change Analysis

To further support the development of causal factors, the Board performed a change analysis of the accident, examining the planned and unplanned changes that caused the undesired results or outcomes related to the event.

Twenty-four changes were identified and analyzed by the Board.

The change analysis is presented in Attachment C.

12.4 Event and Causal Factors Analysis

After performing the barrier and change analyses, the Board assigned the results of the various analyses to the conditions that were related to or caused the events in the chronology. Correlating these conditions with events resulted in the events and causal factors chart provided in Attachment D. When the correlation was complete, the Board examined the chart to determine which events were significant, i.e., which events played a role in causing the accident. The Board then assessed the significant events and the conditions of each, to determine the causal factors of the accident.

The causal factors that resulted are described below.

Direct, Root, and Contributing Causes

Direct Cause: The immediate events or conditions that caused the accident.

The Board identified the direct cause of this accident to be an exothermic reaction of incompatible materials in LANL waste drum 68660 that led to thermal runaway, which resulted in over-pressurization of the drum, breach of the drum, and release of a portion of the drum's contents (combustible gases, waste, and wheat-based absorbent) into the WIPP underground.

The Board reached this conclusion based on post-event forensic and fire analyses that determined that:

- Isotopic ratios in air sample media analyzed post-event are consistent with drum 68660 which is unique from other drums in the area of the release.
- The contents of waste drum 68660 included incompatible materials which created the potential for an exothermic reaction.
- Waste drum 68660 was the only waste container with an identified breach.
- The visual evidence associated with the identified breach was consistent with an exothermic reaction within drum 68660. This reaction resulted in internal heating of drum that led to internal pressure buildup of combustible gases within the drum which exceeded the drum venting capacity. The drum lid extruded beyond the lid retention ring, deflected the lid, and resulted in rapid release of the materials from the drum. The combustible gases and solids ignited which then spread to other combustible materials within the waste array, i.e., fiberboard and polyethylene slip sheets, reinforcement plates, stretch wrap, cardboard stiffeners and polypropylene super sack fabric.

Root Cause: Causal factors that, if corrected, would prevent recurrence of the same or similar accidents. Root causes can be local (specific to the one accident, and/or systemic (common to a broad class of similar accidents). For this accident, the Board identified both local and systemic root causes.

Local Root Cause: A specific deficiency that, if corrected, would prevent recurrence of the same accident.

The Board identified the local root cause of the radioactive material release in the WIPP underground to be the failure of LANS to understand and effectively implement the LANL Hazardous Waste Facility Permit and Carlsbad Field Office directed controls. Specifically, LANL's use of organic, wheat-based absorbent instead of the directed inorganic absorbent such as kitty litter/zeolite clay absorbent in the glovebox operations procedure for nitrate salts resulted in the generation, shipment, and emplacement of a noncompliant, ignitable waste form.

Systemic Root Cause: A deficiency in a management system that, if corrected, would prevent the occurrence of a class of accidents, e.g., operational accidents caused by procedural deficiencies.

The Board identified the systemic root cause as the Los Alamos Field Office (NA-LA) and National Transuranic Program/Carlsbad Field Office (CBFO) failure to ensure that LANL had adequately developed and implemented repackaging and treatment procedures that incorporated suitable hazard controls and included a rigorous review and approval process. NA-LA and CBFO did not ensure the adequate flow down of the Resource Conservation and Recovery Act and other upper tier requirements, including the WIPP Hazardous Waste Facility Permit, Attachment C, Waste Analysis Plan, WIPP Waste Acceptance Criteria, and the LANL Hazardous Waste Facility Permit requirements into operating procedures at LANL.

Contributing Causes: Events or conditions that collectively with other causes increased the likelihood or severity of an accident but that individually did not cause the accident.

The Board identified twelve contributing causes to the radiological release investigated in Phase 2:

1. Failure of Los Alamos National Security, LLC (LANS) to implement effective processes for procedure development, review, and change control. Execution of the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure resulted in a combination of incompatible materials and the generation of an ignitable, noncompliant waste.
2. Failure of Los Alamos National Security, LLC (LANS) to develop and implement adequate processes for hazard identification and control. As a result, an incompatible absorbent was specified and used during nitrate salt bearing waste processing.
3. Failure of the Los Alamos National Security, LLC (LANS) Contractor Assurance System (CAS) to identify weaknesses in the processes for operating procedure development; hazard analysis and control; and review that resulted in an inadequate glovebox operation procedure for processing the nitrate salt bearing waste.
4. Failure of the Central Characterization Program (CCP) to develop an Acceptable Knowledge (AK) for the mixed inorganic nitrate waste stream (LA-MIN02-V.001) that adequately captured all available information regarding waste generation and subsequent repackaging activities in order to prevent the generation, shipment, and emplacement of corrosive, ignitable, or reactive waste. Specifically, the AK Summary Report did not capture changes made to the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure. The addition of a secondary waste material was not adequately considered.
5. Failure of the Los Alamos Field Office (NA-LA) and National Transuranic (TRU) Program/Carlsbad Field Office (CBFO) to ensure that the CCP and LANS complied with Resource Conservation and Recovery Act (RCRA) requirements in the WIPP Hazardous Waste Facility Permit (HWFP) and the LANL HWFP, as well as the WIPP Waste Acceptance Criteria (WAC). Examples include the unapproved treatment (neutralization and absorption of liquids) and the addition of incompatible materials. As a result, waste containing incompatible materials was generated and sent to WIPP.
6. Failure of Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES), and the NNSA Los Alamos Field Office (NA-LA) to ensure that a strong safety culture existed within the Environmental and Waste Management Operations (EWMO) organization at the

Los Alamos National Laboratory (LANL). As a result, although there was a questioning attitude, there was a failure to adequately resolve employee concerns which could have identified the generation of noncompliant waste prior to shipment.

7. Failure of the execution of the LANL Unreviewed Safety Question (USQ) process to identify the lack of a hazard analysis of the proposed changes to the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox waste repackaging procedure [i.e., consistent with Integrated Safety Management (ISM) core functions], and to recognize that an incompatible reactive nitrate salt bearing waste would be created by using "organic" absorbents. As a result, the Unreviewed Safety Question Determination (USQD) did not ensure that nuclear safety basis documents, including the WCRRF and Area G Basis for Interim Operation (BIO), were updated to evaluate hazards associated with material incompatibility in the nitrate salt-bearing waste stream and to specify preventive or mitigative controls.

8. Failure of NNSA Los Alamos Field Office (NA-LA) to establish and implement adequate line management oversight programs and processes in accordance with DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy*. As a result, weaknesses in Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) programs and waste operations procedures were not identified and corrected which allowed an ignitable, noncompliant nitrate salt-bearing waste to be generated, shipped, and emplaced at WIPP.

9. Failure of DOE Headquarters to perform adequate or effective line management oversight required by DOE Order 435.1, *Radioactive Waste Management*, dated July 9, 1999. As a result, waste containing incompatible materials was generated and sent to WIPP.

10. Failure of Nuclear Waste Partnership LLC (NWP) to ensure that the WIPP Fire Hazard Analysis (FHA) recognized the potential for a fire starting within the waste array as well as the potential for propagation within the array. As a result, fire protection controls focused on prevention of propagation to the array from external sources (e.g., vehicles) and did not consider the magnitude of the combustible material hazard.

11. Failure of Los Alamos National Security, LLC (LANS)/Energy*Solutions*, LLC (ES) to adequately train and qualify ES operators and supervisors in the identification and control of incompatible materials during waste processing. As a result, personnel did not question the instruction to add organic absorbent and other secondary waste items to the nitrate salt-bearing waste.

12. Failure of Energy*Solutions*, LLC (ES) operators and Los Alamos National Security, LLC (LANS)/ES supervisors to effectively execute the stop work process when unexpected conditions, including foaming reactions and smoke during waste processing, were encountered at Waste Characterization, Reduction, and Repackaging Facility (WCRRF). This resulted in waste containing incompatible materials being generated and sent to WIPP.

The events and causal factors chart is presented in Attachment E.

13.0 Conclusions and Judgments of Need

Conclusions (CONs) are significant deductions derived from the investigation's analytical results. They are derived from and must be supported by the facts plus the results of testing and the various analyses conducted.

Judgments of Need (JONs) are the managerial controls and safety measures determined by the Board to be necessary to prevent or minimize the probability or severity of a recurrence. These JONs are linked directly to the causal factors, which are derived from the facts and analysis. They form the basis for corrective action plans that must be developed by line management. The Board's conclusions and JONs are listed below in Table 13-1.

Figure 13-1: Conclusions and Judgments of Need

Conclusion (CON)	Judgments of Need (JON)
CON 1: Implementation of the characterization processes established in the Waste Isolation Pilot Plant (WIPP) Hazardous Waste Facility Permit (HWFP), Attachment C, Waste Analysis Plan (WAP) was not fully consistent with the criteria in 40 CFR 261.21, *Characteristic of Ignitability*. Specifically, characterization processes should have identified LA-MIN02-V.001 as ignitable because: • It is an oxidizer; and • Addition of the organic absorbent created conditions that made the waste capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burning so vigorously and persistently that it creates a hazard.	**JON 1**: The National Transuranic (TRU) Program needs to re-evaluate and strengthen the flow down of requirements regarding the compilation of Acceptable Knowledge (AK) in order to more clearly demonstrate that the WIPP HWFP, Attachment C, WAP waste characteristics prohibitions and chemical compatibility requirements are met consistent with 40 CFR 261.21.
CON 2: Execution of the National Transuranic (TRU) Program certification audit process for the LANL waste generator activities where Central Characterization Program (CCP) performs TRU waste characterization and certification failed to include key elements of waste packaging and characterization processes. In part, this was attributed to a lack of clear roles and responsibilities; and expectations. Specific elements include: • Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox treatment and repackaging operations; • Ensuring that TRU waste accepted for management and disposal at WIPP complies	**JON 2**: The National TRU Program needs to re-evaluate and strengthen the certification audit process across the DOE complex at all generator sites to include: • Evaluation of waste generator repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; • Verification that changes to processes are correctly incorporated into acceptable knowledge summary reports; • Verification of effective implementation

Conclusion (CON)	Judgments of Need (JON)
with the WIPP Hazardous Waste Facility Permit (HWFP), applicable laws, and regulations described in the Waste Acceptance Criteria (WAC); and • Verification that Los Alamos National Security, LLC (LANS) prepared implementation documentation and programs to meet the requirements and criteria of the WIPP Waste Acceptance Criteria (WAC) and that the CCP maintained an accurate and compliant Acceptable Knowledge Summary Report for the LA-MIN02-V.001waste stream.	documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and • Evaluation of local site office oversight of TRU waste operations.
CON 3: The NNSA Los Alamos Field Office (NA-LA) oversight activities were ineffective in identifying weaknesses in the execution of waste packaging, characterization and certification of transuranic (TRU) waste at Los Alamos National Laboratory (LANL).	**JON 3**: NA-LA oversight of characterization and certification of TRU waste sites needs to be improved to include: • Waste Characterization, Reduction, and Repackaging Facility (WCRRF) repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; and • Verification that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit.

<table>
<tr><th>Conclusion (CON)</th><th>Judgments of Need (JON)</th></tr>
<tr><td>CON 4: Carlsbad Field Office (CBFO) oversight activities associated with the characterization and certification of transuranic (TRU) waste were ineffective in identifying programmatic weaknesses through the execution of certification audits and surveillances at LANL.</td><td>JON 4: The CBFO oversight of characterization and certification of TRU waste sites needs to be improved to include:
• Waste generator repackaging operations that prepare TRU waste for characterization;
• Implementation of waste generator site processes as they relate to TRU waste management;
• Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and
• Evaluation of local site office oversight of TRU waste operations.
JON 5: CBFO needs to evaluate and restructure their organization such that objective oversight of the National TRU Program is evident and effective in ensuring that waste generator sites comply with requirements including appropriate separation of CBFO line management and oversight functions and responsibilities.
JON 6: DOE Headquarters needs to review expectations documented in existing National TRU Program policy directives and take action necessary to clearly assert that CBFO, as the manager of the WIPP repository, has the authority to conduct oversight of waste generator site programs and processes necessary to provide assurance that any activities that could impact characterization and certification of waste are verified to be compliant.</td></tr>
<tr><td>CON 5: Implementation of requirements listed in CCP-PO-001, CCP Transuranic Waste Characterization Quality Assurance Project Plan, did not ensure that waste characterization methods and Acceptable Knowledge (AK) were effective in preventing the shipment of corrosive, ignitable, or reactive wastes.</td><td>JON 7: The Central Characterization Program (CCP) needs to improve implementation of requirements in CCP-PO-001 such that characterization methods are able to ensure that all WIPP Waste Acceptance Criteria (WAC) requirements are met.</td></tr>
</table>

Conclusion (CON)	Judgments of Need (JON)
CON 6: The preparation, review and approval of CCP-AK-LANL-006, *Acceptable Knowledge (AK)* summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of adding incompatible secondary waste items to the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.	**JON 8**: The CCP needs to improve the level of rigor in reviewing and approving AK summary reports for compliance with requirements.
CON 7: Los Alamos National Security, LLC (LANS) did not adequately evaluate the impact on the WIPP Waste Acceptance Criteria (WAC) or effectively control the addition of secondary job waste into transuranic (TRU) waste containers.	**JON 9**: LANS needs to improve the level of rigor in evaluating and controlling the addition of secondary job waste into TRU waste containers.

CON 8: Los Alamos National Security, LLC (LANS) did not adequately incorporate upper tier requirements into the development of repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF). Specifically:
• The Carlsbad Field Office (CBFO) directed controls contained in the LANL-CO white paper based on the Energetic Materials Research and Testing Center (EMRTC) Report RF 10-13; and
• The requirements associated with the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit (HWFP):
    • Nitrate salt-bearing wastes did not fully meet the LANL HWFP "special requirements" for managing ignitable wastes, including segregation and separation, and use of non-sparking tools;
    • Did not comply with the LANL HWFP requirement that the nitrate salt-bearing waste drums be labeled with all applicable Environmental Protection Agency (EPA) Hazardous Waste Numbers;
    • Placed incompatible wastes and materials in the same container and did not impose special precautions;
    • Did not label the nitrate salt-bearing waste prior to transport and remediation at the WCRRF; and
    • Did not label the unremediated nitrate salt-bearing waste drums which contained liquids as Resource Conservation and
	JON 10: LANS needs to strengthen the processes that ensure the flow down of upper tier requirements into their implementing procedures such that execution of work is compliant.
	JON 11: CBFO needs to conduct an extent of condition review of other waste generator sites to determine the adequacy of the flow down into the operating procedures and implementation of RCRA requirements contained in the WIPP Waste Acceptance Criteria (WAC) and hazardous waste permits regarding the treatment and repackaging of TRU waste.

Conclusion (CON)	Judgments of Need (JON)
Recovery Act (RCRA) corrosive.	
CON 9: The preparation, review and approval of CCP-AK-LANL-006, Acceptable Knowledge (AK) summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of changes to EP-WCRR-WO-DOP-233 Glovebox Operations, on the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.	**JON 12**: The Central Characterization Program (CCP) needs to reevaluate and strengthen the process used to conduct review and approval of source documents that have an impact on Acceptable Knowledge.
CON 10: Los Alamos National Security, LLC (LANS) failed to provide sound technical basis for decisions regarding repackaging procedures and processes for the LA-MIN02-V.001 waste stream.	**JON 13:** LANS needs to strengthen documentation to include a detailed technical basis to justify decisions made regarding change control for procedures and processes for the LA-MIN02-V.001 waste stream.
CON 11: Los Alamos National Security, LLC (LANS) did not utilize a formal engineering change control process to develop modifications to repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF).	**JON 14:** LANS needs to implement an effective engineering change control process that includes defensible technical bases to justify process modifications.
CON 12: Los Alamos National Security, LLC (LANS) failed to ensure that there was sufficient detail provided in the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure to ensure safe, consistent, and compliant repackaging of waste and accurate documentation of the contents of the waste drums in the records.	**JON 15:** LANS needs to revise the WCRRF glovebox operations procedure to contain the necessary level of detail to ensure safe, consistent, and compliant remediation of nitrate salt bearing waste. **JON 16:** The glovebox operations procedure needs to be revised to require operators to document critical process steps in a quality record, e.g., initial pH, absorbent added, neutralizer used, adjusted pH. **JON 17**: Operators need to be adequately trained on the revised glovebox operations procedure.
CON 13: Available data indicated that oxidation was occurring in the Standard Waste Box (SWB) where sibling drum 68685 was stored, along with other similarly remediated waste drums.	**JON 18**: Los Alamos National Security (LANS) needs to investigate and determine the cause for oxidation in sibling drum 68685 and take action to mitigate the condition as well as prevent future nitrate salt bearing waste drums (remediated and unremediated) from oxidizing.
CON 14: The Waste Characterization, Reduction, and Repackaging Facility (WCRRF) Basis for Interim Operation (BIO) did not thoroughly describe or evaluate nitrate salt processing or waste storage activities.	**JON 19:** The WCRRF BIO needs to be revised to include more specificity in description of nitrate salt processing activities and then update the hazard analysis to include identification of all hazards and their evaluations.

Conclusion (CON)	Judgments of Need (JON)
	JON 20: LANS needs to review the Area G BIO in light of changes made to the WCRRF BIO and update accordingly. **JON 21**: LANS needs to conduct an extent of condition review for issues that are similar to nitrate salt bearing waste processing in WCRRF and Area G.
CON 15: The Los Alamos National Security, LLC (LANS) Unreviewed Safety Question (USQ) process was ineffective in ensuring that important procedure changes related to processing of nitrate salts were adequately evaluated for impacts to the safety basis.	**JON 22**: LANS needs to ensure that USQ evaluators are organizationally independent of line management. **JON 23**: LANS needs to conduct retraining of USQ process evaluators/approvers focused on implementation of the Unreviewed Safety Question Determination (USQD) process consistent with DOE Guide 424.1-1B, *Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements.* **JON 24**: The NNSA Los Alamos Field Office (NA-LA) needs to conduct an assessment of the LANS USQ program.
CON 16: The Los Alamos National Security, LLC (LANS) contractor assurance system was not effective in identifying weaknesses in the process for developing/changing procedures, analyzing and controlling hazards, performing work to repackage nitrate salt bearing wastes, and feedback mechanisms which resulted in the production and shipping of noncompliant waste drums to the Waste Isolation Pilot Plant and Waste Control Specialists, LLC (WCS).	**JON 25**: LANS Environmental and Waste Management Operations (EWMO) needs to develop and implement a fully integrated contractor assurance system that provides DOE and LANS confidence that work is performed compliantly, risks are identified, and control systems are effective and efficient. Specific areas to be addressed include: • Ensuring adequate scope and associated depth and breadth of self-assessments, independent assessments and management assessments; • Clarifying the oversight role of LANS EWMO with regard to subcontractors and waste processing/packaging operations; • Ensuring required environmental program oversight i.e., the Resource Conservation and Recovery Act (RCRA) (hazardous waste determination, upper tier requirements flow down into implementing procedures, waste determination, records); • Including the necessary rigor in implementation of the change control process (review and approval by subject matter

Conclusion (CON)	Judgments of Need (JON)
	experts); • Verifying that requirements are flowed down into implementing procedures, e.g., RCRA requirements, TRU Waste Authorized Methods for Payload Control, etc.; and • Evaluating and responding to feedback from Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations by LANS senior management, e.g., notification of reactions in the glovebox.

CON 17: The NNSA Los Alamos Field Office (NA-LA) oversight was ineffective in identifying weaknesses that contributed to this event.	**JON 26**: NA-LA needs to strengthen its oversight of Los Alamos National Security, LLC (LANS) Environmental and Waste Management Operations (EWMO) to ensure that:
	• Resource Conservation and Recovery Act (RCRA) oversight is performed;
	• Focus is placed on operational oversight in addition to budget/financial oversight;
	• On the ground operational oversight expands beyond that performed by the Facility Representatives to include adequate subject matter expertise;
	• NA-LA performs oversight of contractor activities related to waste certification in accordance with the WIPP Waste Acceptance Criteria (WAC);
	• Roles and responsibilities for oversight of Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations are made clear;
	• Staffing shortages are addressed, including:
	    • Facility Representatives, short three full-time equivalencies (FTEs);
	    • Senior Technical Safety Manager, short two FTEs;
	    • The staffing reduction in environmental compliance, down from five to three FTEs since 2011; and
	    • Senior technical advisor position has been vacant since 2008.
	    • Formal verification that there is an effective LANS Contractor Assurance System (CAS) in place for environmental

Conclusion (CON)	Judgments of Need (JON)
	compliance. **JON 27**: NA-LA needs to verify that LANS has developed and implemented a DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy* compliant CAS.
CON 18: The Federal roles, responsibilities and execution for oversight of the activities between the generator site transuranic (TRU) waste program (LANL) and the TRU Waste Central Characterization Program (CCP) were inadequate.	**JON 28**: The National TRU Program needs to clarify NA-LA and CBFO expectations and oversight roles and responsibilities between the generator site TRU waste program (LANL) and the TRU waste CCP. **JON 29**: NA-LA and CBFO needs to perform effective Federal oversight of CCP review and approval of waste management operating procedures/process changes, e.g., WCRRF glovebox operating procedure. **JON 30**: DOE Headquarters and CBFO need to conduct an extent of condition review of the overall Federal oversight across the DOE complex in all three key segments of the National TRU Program: the Generator Site TRU Waste Program, TRU Waste Certification Program, and the Disposal System Program (WIPP).
CON 19: DOE Headquarters did not perform DOE O 435.1, *Radioactive Waste Management,* oversight activities for implementation of requirements associated with the operational performance within the National Transuranic (TRU) Program.	**JON 31**: DOE Headquarters needs to develop and implement a DOE O 435.1 comprehensive oversight program for National TRU Program activities.
CON 20: Los Alamos National Security, LLC (LANS) existing processes governing the preparation, review, and approval of Environmental Programs procedures did not contain sufficient guidance related to hazard analysis and subject matter expert review necessary to ensure safe, consistent, and compliant execution of waste processing.	**JON 32**: LANS needs to review and revise EP-DIR-AP-10007, *Environmental Programs Procedure Preparation, Revision, Review, Approval, and Use,* to ensure that all procedures and procedure revisions contain: • The necessary level of detail to ensure the safe, consistent, and compliant performance of work, including process steps, materials, and material substitutions; • Explicit requirements and criteria regarding inclusion of appropriate subject matter experts and their review and concurrence with new and revised procedures; and • Requirements that a Job Hazard Analysis (JHA) is appropriately amended when new activities such as nitrate salt remediation that

Conclusion (CON)	Judgments of Need (JON)
	could introduce new hazards are incorporated into existing processes.
CON 21: The WIPP Fire Hazard Analysis (FHA) was ineffective in identifying and analyzing the potential for a fire starting within the waste array, as well as the potential for fire propagation within the array.	**JON 33**: Nuclear Waste Partnership LLC (NWP) needs to re-evaluate the quantities, type and form of exposed combustible emplacement materials used in the waste array and take action to minimize the fire ignition and propagation risks (e.g., eliminate unnecessary materials, and include fire retardant additives). **JON 34**: NWP needs to revise the waste array emplacement strategy to include criteria that limit the risk of fire propagation within the array, to include limiting the quantity of radiological waste that is at-risk from a single fire or explosion event. **JON 35**: NWP needs to revise the FHA to identify and address all credible fire and explosion scenarios initiated within the waste array underground. **JON 36**: NWP needs to reevaluate and revise the WIPP FHA to better characterize the fire risks associated with transuranic (TRU) waste packaging during handling and storage. This needs to include reevaluation of actions detailed in the WIPP Recovery Plan. **JON 37**: The Office of Environmental Management Headquarters needs to ensure that waste generator site's FHAs adequately characterize the fire risks associated with TRU waste packaging during handling and storage.
CON 22: Energy*Solutions*, LLC (ES) operators and supervisors were not adequately trained and qualified to process waste with regard to identification and control of incompatible materials.	**JON 38**: LANS needs to evaluate and strengthen the operator and supervisor training programs of LANS and their subcontractors to ensure adequate understanding of basic chemistry interactions and associated controls.
CON 23: Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) and NNSA Los Alamos Field Office (NA-LA) allowed the safety culture at the Los Alamos National Laboratory (LANL) to deteriorate within pockets of the organization as evidenced by the workers' feedback that they did not feel comfortable identifying issues that may adversely affect management direction, delay mission-related objectives, or otherwise affect cost or schedule. In	**JON 39**: LANS and NA-LA need to develop and implement a more rigorous, effective integrated safety management system that embraces and implements the attributes of DOE G 450.4-1C, *Integrated Safety Management Guide,* including but not limited to: • Demonstrated leadership in risk-informed, conservative decision making; • Improved learning through error reporting

Conclusion (CON)	Judgments of Need (JON)
addition, management failed to effectively respond to workers' issues regarding unexpected conditions, i.e., generation of smoke and foaming, encountered during waste processing activities. **CON 24**: Questioning attitudes were not welcomed by management and many issues and hazards did not appear to be readily recognized by site personnel.	and effective resolution of problems; • Line management encouraging a questioning attitude without fear of reprisal and following through to resolve issues identified by the workforce. • Consideration should also be given to some additional contract incentive associated with leading a culture change that fosters the desired work environment. The LANS, ES, and NA-LA stop work related processes need to ensure that response to issues raised by workers are based on sound, technical justification. **JON 40**: DOE Headquarters needs to engage safety culture expertise to provide training and mentoring to LANS, ES, and NA-LA management on the principles of a strong safety culture and take appropriate corrective action based on the outcome.

14.0 Board Signatures

Theodore A. Wyka
DOE Accident Investigation Board Chairman
U.S. Department of Energy, Office of Environmental Management

Roger Claycomb
DOE Accident Investigation Deputy Board Chairman
U.S. Department of Energy, Office of Environmental Management
Idaho Operations Office

Todd N. Lapointe
DOE Accident Investigation Board Member
U.S. Department of Energy, Office of Environmental Management

Jason Armstrong
DOE Accident Investigation Board Member
U.S. Department of Energy, Office of Environmental Management

Steven Calvert
DOE Accident Investigation Board Member
National Nuclear Security Administration

15.0 Board Members, Advisors and Consultants

Board Members

Theodore A. Wyka	Board Chair, EM-40 Chief Nuclear Safety Advisor
Roger Claycomb	Board, ID, Trained Accident Investigator
Jason Armstrong	Board, Oak Ridge EM
Todd N. Lapointe	Board, EM-41, Safety Management Director
Steven L. Calvert	Board, NNSA, NA-SH-70

Team Advisors/Consultants

Advisor/Consultant	T.J. Jackson Board Deputy Chair, EMCBC Trained Accident Investigator
Advisor/Consultant	Kaniah Konkoly-Thege Attorney-Advisor, EMCBC
Advisor/Consultant	Elizabeth C. Rose Attorney-Advisor, EMCBC
Advisor/Consultant	William Weaver CNS-EM-40, DOE HQ, Chief of Nuclear Safety
Advisor/Consultant	Julie Goeckner EM-40, Senior Advisor on Nuclear Safety Culture
Advisor/Consultant	Jack Zimmerman Deputy Manager, Idaho Cleanup Project
Advisor/Consultant	Jeff Woody Link Technologies, Inc.
Advisor/Consultant	Terry Foppe Link Technologies, Inc.
Advisor/Consultant	D. Allan Coutts, PE (SC), PhD, FSFPE AECOM, Aiken, SC
Advisor/Consultant	Matthew Buchholz, CHP Dade Moeller & Associates
Analyst/Advisor	Jack Gerber MJW Technical Services

Administrative Assistant	Heidi Lowe, ATA Services, Inc. Accident Investigation Board/Fire Forensic Team
Administrative Coordinator/ Technical Writer	Susan M. Keffer, Project Enhancement Corporation Trained Accident Investigator

Additional Visual Surveillance Analysis Team Members (not previously listed)

Analyst	John Vandekraats, NWP
Analyst	Craig Suggs, NWP
Analyst	Curtis Chester, NWP
Analyst	Tim Burns, LANL-Carlsbad Operations
Analyst	Roger Allan Nelson, DOE CBFO
Analyst	Kerry Watson, DOE CBFO
Analyst	James Landmesser, DOE HQ
Analyst	John Young, SRNS/SRNL
Analyst	Neil Robert Sorensen, SNL
Analyst	David Funk, LANL
Analyst	Kirk Viers, LANL

Attachment A. Appointment of the Accident Investigation Board

Department of Energy
Washington, DC 20585
May 19, 2014

MEMORANDUM FOR THEODORE A. WYKA
BOARD CHAIRPERSON
CHIEF NUCLEAR SAFETY ADVISOR

FROM: JAMES HUTTON
ACTING DEPUTY ASSISTANT SECRETARY FOR SAFETY, SECURITY, AND QUALITY PROGRAMS
ENVIRONMENTAL MANAGEMENT

SUBJECT: Phase 2 Accident Investigation of the February 14, 2014 Radiological Incident at the Waste Isolation Pilot Plant

In accordance with the requirements of the Department of Energy (DOE) Order 225.1B, *Accident Investigations*, I am tasking the Accident Investigation Board (AIB) to investigate Phase 2 of the February 14, 2014, Radiological Incident that occurred at the Waste Isolation Pilot Plant (WIPP). The AIB was originally established on February 27, 2014. This Phase 2 investigation will complete the overall accident investigation that was initiated and documented in the Accident Investigation Report, *"Phase 1 - Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014"* dated April 22, 2014. The Phase 1 investigation identified and documented results related to the airborne radioactivity escaping to the environment downstream of the High Efficiency Particulate Air (HEPA) filters. Due to restrictions on access to the underground following the event, it was decided that a Phase 2 accident investigation would be conducted to identify the physical mechanism of container(s) failure that caused the radiological incident.

You are appointed as the Accident Investigation (AI) Chairperson. In a revision to my previous direction, the AI will be composed of the following members:

- Theodore A. Wyka – Office of Environmental Management – Chairperson
- Timothy Jay Jackson – EMCBC – Deputy Chairperson
- John P. Zimmerman – PPPO – Board Member
- Roger M. Claycomb – ID – Board Member
- Todd Lapointe – Office of Environmental Management – Board Member
- Steven Calvert – NNSA – Board Member

The Board is encouraged to utilize appropriate advisors and consultants with specialized expertise as deemed necessary, including site contractor expertise.

All members of the AI team, by this memorandum, are released from their normal regular duty assignment to serve on the AIB, during the period the AI is convened.

The scope of the AI's investigation is to include, but not be limited to, identifying all relevant facts, determining direct, contributing, and root causes of the event, developing conclusions, and determining the judgments of need to prevent recurrence. The scope of the investigation is to include DOE programs and oversight activities.

The AI is expected to provide my office periodic reports on the status of the investigation. Please submit draft copies of the factual portion of the investigation report to me, the Office of Environment, Health, Safety and Security, Carlsbad Field Office, and the affected contractor for factual accuracy review prior to finalization. The final report should be provided to me within 30 days of the date of this memorandum, or identify additional time required to complete the investigation and report. Discussion of the investigation and copies of the draft report will be controlled until I authorize release of the final report.

If you have any further questions please contact me, at (202) 586-0975.

cc: Don Nichols, NNSA
Michael Garcia, NNSA
Ralph Holland, EMCBC (Acting)
Jose Franco, CBFO
Kim Davis Lebak, LAFO
David Moody, SR
William Murphie, PPPO
Richard Provencher, ID
Matthew Moury, AU-1 (Acting)
Donald Lentzen, AU-20
Colette Broussard, AU-33
David Huizenga, EM-1 (Acting)
James Owendoff, EM-2 (Acting)
Mark Whitney, EM-2
Jack Craig, EM 2.1 (Acting)
Candice Turmmell, EM-3
Mark Gilbertson, EM-10
Kenneth Picha, EM-20
Frank Marcinowski, EM-30

Department of Energy
Washington, DC 20585
JUN 1 6 2014

MEMORANDUM FOR THEODORE A. WYKA
BOARD CHAIRPERSON
CHIEF NUCLEAR SAFETY ADVISOR

FROM: JAMES HUTTON
ACTING DEPUTY ASSISTANT SECRETARY FOR
SAFETY, SECURITY, AND QUALITY PROGRAMS
ENVIRONMENTAL MANAGEMENT

SUBJECT: AMENDED: Phase 2 Accident Investigation of the February 14, 2014 Radiological Incident at the Waste Isolation Pilot Plant Addendum Replacing Board Member

On May 19, 2014, I appointed an the Accident Investigation Board (AIB) to investigate Phase 2 of the February 14, 2014, Radiological Incident that occurred at the Waste Isolation Pilot Plant (WIPP) in accordance with the requirements of the Department of Energy (DOE) Order 225.1 B, *Accident Investigations.* With the selection of Jack Zimmerman as DOE's next cleanup chief for the Idaho site, I am naming Jason Armstrong as a Board member to complete the Phase 2 investigation.

The AI will be composed of the following members:

- Theodore A Wyka - Office of Environmental Management - Chairperson
- Timothy Jay Jackson - EMCBC - Deputy Chairperson
- Roger M. Claycomb - ID - Board Member
- Todd Lapointe - Office of Environmental Management - Board Member
- Steven Calvert -NNSA - Board Member
- Jason Armstrong – EMOR – Board Member

The Board is encouraged to utilize appropriate advisors and consultants with specialized expertise as deemed necessary, including site contractor expertise.
All members of the AI team will continue to be released from their normal regular duty assignment to serve on the AIB, during the period the AI is convened.

If you have any further questions please contact me, at (202) 586-0975.

cc: Don Nichols, NNSA
Michael Garcia, NNSA
Ralph Holland, EMCBC (Acting)
Jose Franco, CBFO
Kim Davis Lebak, LAFO
David Moody, SR
William Murphie, PPPO
Richard Provencher, ID
Matthew Moury, AU-1 (Acting)
Donald Lentzen, AU-20
Colette Broussard, AU-20
David Huizenga, EM-1 (Acting)
James Owendoff, EM-2 (Acting)
Mark Whitney, EM-2
Jack Craig, EM 2.1 (Acting)
Candice Trummell, EM-3
Mark Gilbertson, EM-10
Kenneth Picha, EM-20
Frank Marcinowski, EM-30

Department of Energy
Washington, DC 20585

November 14, 2014

MEMORANDUM FOR THEODORE A.WYKA
BOARD CHAIRPERSON
CHIEF NUCLEAR SAFETY ADVISOR

FROM: JAMES HUTTON
ACTING DEPUTY ASSISTANT SECRETARY FOR SAFETY, SECURITY, AND QUALITY PROGRAMS
ENVIRONMENTAL MANAGEMENT

SUBJECT: AMENDED: Phase 2 Accident Investigation of the February 14, 2014 Radiological Incident at the Waste Isolation Pilot Plant Addendum Replacing the Board Deputy Chairperson

On May 19, 2014, I appointed an Accident Investigation Board (AIB) to investigate Phase 2 of the February 14, 2014, Radiological Incident that occurred at the Waste Isolation Pilot Plant (WIPP) in accordance with the requirements of the Department of Energy Order 225 .1 B, *Accident Investigations.* With the retirement of Timothy Jackson, I am naming Roger Claycomb as the Board Deputy Chairperson to complete the Phase 2 investigation.

The AI will be composed of the following members:

- Roger Claycomb - ID - Deputy Chairperson
- Todd Lapointe - Office of Environmental Management - Board Member
- Steven Calvert - NNSA - Board Member
- Jason Armstrong - EMOR - Board Member

The Board is encouraged to utilize appropriate advisors and consultants with specialized expertise as deemed necessary, including site contractor expertise. All members of the AI team will continue to be released from their normal regular duty assignment to serve on the AIB, during the period the AI is convened.

If you have any questions please contact me, at (202) 586-0975.

cc: Don Nichols, NNSA
Michael Garcia, NNSA
Ralph Holland, EMCBC (Acting)
Jose Franco, CBFO
Kim Davis Lebak, LAFO
David Moody, SR
William Murphie, PPPO
Richard Provencher, ID

Printed with soy ink on recycled paper

Matthew Moury, AU-1
Colette Broussard, AU-20
Gary Staffo, AU-20
Mark Whitney, EM-1 (Acting)
Colin Jones, EM-1
Monica Regalbuto, EM-2.1
Candice Trummell, EM-3
Mark Gilbertson, EM-10
Kenneth Picha, EM-20
Frank Marcinowski, EM-30

Attachment B. Barrier Analysis

Barrier analysis is based on the premise that hazards are associated with all tasks. A barrier is any means used to control, prevent, or impede a hazard from reaching a target, thereby reducing the severity of the resultant accident or adverse consequence. A hazard is the potential for an unwanted condition to result in an accident or other adverse consequence. A target is a person or object that a hazard may damage, injure, or fatally harm. Barrier analysis determines how a hazard overcomes the barriers, comes into contact with a target (e.g., from the barriers or controls not being in place, not being used properly, or failing), and leads to an accident or adverse consequence. The results of the barrier analysis are used to support the development of causal factors. This Phase 2 report covers the Board's analysis and conclusion for the release of TRU from the underground to the environment, as updated based on continued investigations after the Phase 1 report was issued without repeating that barrier analysis of WIPP activities and conditions.

Table B-1: Barrier Analysis

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
B.1	Confinement of waste in container.	Failed.	The rate of pressure rise in the drum exceeded the venting capability and caused the drum lid to be extruded past the locking ring.	Resulted in release of radioactive material from the drum.	HPI: N/A ISMS: N/A
B.2	Inspection of the container.	Inspections were performed prior to addition of treated waste and upon receipt at Waste Isolation Pilot Project (WIPP).	Did not fail.	No effect. Inspection of the drum, lid, vent, lock ring would not provide information that waste was improperly processed.	HPI: N/A ISMS: N/A
B.3	Adequacy of Central Characterization Program (CCP) waste characterization program to comply with Waste Acceptance Criteria	Failed.	Insufficient information in waste data package for CCP personnel to determine if waste was compliant. Methods to	Processed waste was not in compliance with the Resource Conservation and Recovery	HPI: HN3 ISMS: CF1, CF2, CF3, GP5, GP6

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
	(WAC).		demonstrate compliance lack the level of rigor needed to certify with high confidence that TRU waste conforms to the WAC.	Act (RCRA) permit, WAC, and Acceptable Knowledge (AK).	
B.4	Intact back/rib.	Back/rib were intact (cannot see all rib surfaces due to waste placement).	Did not fail.	No effect.	HPI: N/A ISMS: N/A
B.5	Intact roof bolt.	Unknown (cannot see obvious penetration by a roof bolt).	Unknown – no current evidence of penetration.	Unknown.	HPI: N/A ISMS: N/A
B.6	Protection on top of waste.	Not applicable.	Not designed to provide protection.	No effect.	HPI: N/A ISMS: N/A
B.7	Ground control program.	No apparent issues with ground control (cannot see underneath the containers).	Did not fail.	No effect.	HPI: N/A ISMS: N/A
B.8	Fall of waste container (stability of three tier stacking).	It does not appear that any containers fell.	Did not fail.	No effect.	HPI: N/A ISMS: N/A
B.9	Penetration during handling, e.g., puncture by forklift tine.	Unknown. No apparent damage from penetration but cannot see all container surfaces.	Unknown – no current evidence of puncture.	Unknown.	HPI: N/A ISMS: N/A
B.10	Flooding of containers.	There was no flooding.	Did not fail.	No effect.	HPI: N/A ISMS: N/A

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
B.11	Protection from explosion, e.g., battery, methane, refueling station, etc.	Unknown. No known explosions from external sources in the underground.	Unknown – no current evidence of explosion.	Unknown.	HPI: N/A ISMS: N/A
B.12	Completed Panel closure system (Panel 1, 2, and 5).	Not applicable.	Not applicable.	No effect.	HPI: N/A ISMS: N/A
B.13	In-process Panel closure (Panels 3 and 4).	Not applicable.	Not applicable.	No effect.	HPI: N/A ISMS: N/A
B.14	In-process Panel closure (Panel 6), next to Panel 7 door between Panels or Rooms 6 and 7 may be open.	Not applicable.	Not applicable.	No effect.	HPI: N/A ISMS: N/A
B.15	WIPP Hazardous Waste Facility Permit (HWFP).	States that prohibition of free liquid prevents shipment of corrosive, ignitable, or reactive wastes.	Inconsistency between WIPP HWFP and 40 CFR 261.21.	After absorbent was added to drum 68660, the waste was still a RCRA characteristic (ignitable) waste.	HPI: TD6, TD8 ISMS: CF1, CF2, GP5, GP6
B.16	LANL Hazardous Waste Facility Permit (HWFP).	Failed.	• Nitrate salt-bearing wastes did not fully meet the LANL HWFP "special requirements" for managing ignitable wastes, including segregation and separation, and use of non-sparking tools. • Did not comply	Generation of a noncompliant waste (ignitable, reactive), subsequent emplacement at WIPP, and resulted in the release TRU waste in the WIPP underground.	HPI: TD6, TD8 ISMS: CF1, CF2, GP5, GP6

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			with the LANL HWFP requirement that the nitrate salt-bearing waste drums be labeled with all applicable Environmental Protection Agency (EPA) Hazardous Waste Numbers. • Placed incompatible wastes and materials in the same container and did not impose special precautions. • Did not label the nitrate salt-bearing waste prior to transport and remediation at the WCRRF. • Did not label the unremediated nitrate salt-bearing waste drums which contained liquids as RCRA corrosive.		
B.17	WIPP WAC.	Provides criteria for waste acceptance.	Did not fail.	No effect.	HPI: N/A ISMS: N/A
B.18	Compliance with the WIPP WAC.	Failed.	Inadequate glovebox operating procedure did not adequately	Emplacement of noncompliant	HPI: HN3, HN6 ISMS:

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			control processing/packaging.	(ignitable, reactive) waste and release of transuranic (TRU) waste in the underground.	CF2, CF3, GP5, GP6
B.19	CCP site certification (approval to ship to WIPP).	Failed.	Did not recognize weaknesses in LANS glovebox procedure and processing records.	Organic absorbent was prescribed to be added to nitrate salt bearing waste. Processing records did not reflect addition of organic absorbent and neutralization agent.	HPI: IC2, IC5, HN3, HN6 ISMS: GP-1, CF-5, GP-7
B.20	Drum/wasteboxes and packaging.	Failed.	Not designed to withstand the overpressures of this incident.	Allowed release of drum waste contents.	HPI: HN3, HN6 ISMS: CF2, CF3, GP5, GP6
B.21	Drum/wastebox vents.	Unknown. Vents are covered with magnesium oxide (MgO), or not observable within the waste stack.	Unknown – not designed for rapid over-pressurization.	Unknown	HPI: N/A ISMS: N/A
B.22	LANL WCRRF glovebox procedure.	Failed.	Incorrect process step related to nitrate salt processing, i.e., use of organic absorbent. Contrary to AK, LANL-CO white paper, WAC, etc. – specified use of inert	Allowed addition of incompatible materials (absorbent, neutralizer, tungsten glove) and creation of	HPI: IC2, HN3, HN6 ISMS: CF2, CF3, GP5. GP6

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			(inorganic) material. Flow down of upper tier requirements inadequate. Vagueness on key process steps, e.g., neutralization process, pH measurement, addition of waste, etc. No caution or verification at step 10.6[3] of the WCRRF to ensure compatibility of any additional waste to the drum. Failed to consider the requirements of the LANL HWFP in repackaging activities in the WCRRF.	noncompliant ignitable, reactive waste.	
B.23	Acceptable Knowledge (AK)	Failed.	CCP did not ensure that AK was maintained such that it accurately reflected repackaging in the WCRRF, e.g., lead liner, absorbent, neutralizer, addition of tungsten glovebox gloves to MIN02 waste, or other incompatible materials. Section 7.4.4.2 of the AK included items that should have been recognized as incompatible with the nitrate salt matrix.	Allowed addition of incompatible materials and creation of noncompliant waste.	HPI: TD7, TD8, HN3, HN6 ISMS: CF2, CF3, GP5, GP6

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
B.24	AK personnel competency	Failed	Inattention to detail.	Allowed addition of incompatible materials and creation of noncompliant waste.	HPI: HN6, HN7 ISMS: GP5, CF5
B.25	Implementation of the QAPjP	Failed	The MIN02 waste stream AK was not compliant with CCP TRU Waste QAPjP. The MIN02 waste stream AK was not compliant with CCP TRU Waste QAPjP. Requirements in CCP-PO-001 did not ensure that waste characterization methods prevent the shipment of RCRA non-compliant waste CCP and LANL did not evaluate impact of secondary waste on MIN02 waste stream when reviewing/ approving CCP-AK-LANL-006.	A WAC noncompliant waste stream was generated and shipped to WIPP.	HPI: N/A ISMS: N/A
B.26	CCP waste certification process	Failed.	CCP documentation, e.g., Batch Data Report, incorrectly described the waste stream as inorganic matrix. CCP is not directly involved or observant of WCRRF glovebox operations. Unknown how certification process	Certified a noncompliant waste.	HPI: TD7, TD8, IC2, IC5, HN3, HN6 ISMS: CF2, CF3, GP5, GP6

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			could identify process changes.		
B.27	CCP personnel competency	Failed.	Approved an AK document that was deficient. Used wrong algorithm to identify isotope quantity in drum 68660 and others.	Contributed to release of mixed TRU waste. Error did not contribute to release of mixed TRU waste.	HPI: IC2, IC5 ISMS: GP3
B.28	Compliance with CCP requirements	CCP personnel appeared to have followed CCP procedures.	Did not fail.	No effect.	HPI: N/A ISMS: N/A
B.29	Documents used for waste acceptance at WIPP	Failed.	Documents provided by LANL for waste certification do not provide all materials added to the waste, e.g., organic absorbent, type of neutralizer.	Did not identify that a noncompliant waste was shipped for disposal.	HPI: TD7, IC2, IC5, HN3, HN6 ISMS: CF2, CF3, GP5, GP6
B.30	WIPP receipt personnel competency.	Adequate	Did not fail	No effect	HPI: N/A ISMS: N/A
B.31	WIPP conduct of operations.	Adequate.	Did not fail.	No effect.	HPI: N/A ISMS: N/A

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
B.32	Training and qualification of ES operators.	Ineffective.	Training and qualification of ES operators was ineffective. Qualifications are inadequate to ensure understanding and controlling of critical waste processing activities, e.g., compatibility of waste and additives, addition of secondary wastes, etc.	Produced a noncompliant, ignitable waste which was emplaced at WIPP.	HPI: TD7, TD8 ISMS: GP2
B.33	Training and qualification of ES supervisors.	Ineffective.	Qualifications are inadequate to ensure understanding and controlling of critical waste processing activities, e.g., compatibility of waste and additives, addition of secondary wastes, etc.	Did not identify procedure and training and qualification weaknesses that resulted in production of a noncompliant, ignitable waste which was emplaced at WIPP.	HPI: TD7, TD8 ISMS: GP2
B.34	Stop work process.	Failed.	Supervision did not engage correct resources to resolve conditions identified by workers. Workers accepted an ineffective resolution.	Waste repackaging continued without changes being made.	HPI: TD7, TD8 ISMS: CF2, CF3, CF5
B.35	LANS oversight of ES.	Failed.	Inadequate frequency and depth of LANS oversight of ES waste processing activities (ES Supervisors and Operators). Uncertain roles and	Did not identify procedure and training and qualification weaknesses that resulted in production of a	HPI: TD7, TD8, HN3, HN4, HN6 ISMS: GP1, GP2, GP7, CF5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			responsibilities for Subcontract Technical Representative (STR) position; STR inadequately staffed (period where the position was not staffed, training and qualification effectiveness).	noncompliant, ignitable waste which was emplaced at WIPP.	
B.36	Subject matter expert (SME) review of processes.	Failed.	Did not identify addition of organic absorbent. Did not identify ambiguity, e.g., neutralization, pH measurement, etc. Did not include a chemist. In at least one case, feedback directly relevant to the incorrect specification of the organic absorbent was provided by a subject matter expert but not acted upon.	Did not discover that this would create a noncompliant waste stream.	HPI: TD8, IC2, IC5, HN3, HN6 ISMS: CF2, CF3, GP5, GP6
B.37	Job hazard analysis (JHA) process.	Failed.	Did not perform a JHA for Revision 36 of 0233 for nitrate salt bearing waste processing steps as required by EP-DIR-AP-10007, *Environmental Programs Procedure Preparation, Revision, Review, Approval, and Use.* Sufficient detail	Did not identify incompatibility of organic absorbent with nitrate salts.	HPI: TD8, HN6 ISMS: CF3, GP5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			regarding the hazard analysis of new/revised procedure not adequately addressed by EP-DIR-AP-10007		
B.38	EP-DIR-AP-10007 procedure development and change process.	Failed.	Execution of procedure revision review process of EP-DIR-AP-10007 did not result in identification of the compatibility hazard/issue. Did not ensure involvement of all necessary SME/hazard reviews (e.g., chemist).	Did not identify incompatibility of organic absorbent with nitrate salts.	HPI: TD8, HN6 ISMS: CF2, CF3, GP5, GP6
B.39	LANS/ES Contractor Assurance System (self-assessment, management assessment, independent internal assessment, worker feedback, issues management, lessons learned, performance indicators/measures).	Failed.	Inadequate depth and breadth of self-assessment and oversight. Limited environmental program oversight i.e., RCRA (hazardous waste determination, upper tier requirements flow down, waste determination, records). Did not identify lack of rigor in implementation of the change control process (review and approval). Did not identify that upper tier requirements were	Did not identify the weaknesses identified in this investigation.	HPI: TD7, TD8 ISMS: CF1, CF5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			not flowed down into implementing procedures, e.g., RCRA requirements, TRAMPACT, etc. Worker feedback from WCRRF operations did not get acted upon by senior management, e.g., notification of reactions in the glovebox. Did not ensure that lessons learned from previous organic absorbent use were addressed.		
B.40	LANS Subcontract Technical Representative.	Failed.	Uncertain roles and responsibilities. Subcontract Technical Representative position inadequately staffed (period where the position was not staffed, training and qualification - competence).	Did not identify the weaknesses identified in this investigation.	HPI: TD7, TD8 ISMS: GP2
B.41	LANS/ES Conduct of operations.	Failed.	Procedures are not specific enough to ensure consistent results, e.g., procedure detail, record keeping, logs, etc.	Did not identify the weaknesses identified in this investigation.	HPI: TD8 ISMS: CF1, CF2
B.42	LANS/ES safety culture.	Failed.	Worker feedback that they are not comfortable raising issues, questioning attitudes not	Did not adequately question concerns such as the addition of organic	HPI: IC7, HN5 ISMS: GP4, CF5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			welcomed.	absorbent the uncertainties in the neutralization process, or ambiguity in the procedure.	
B.43	LANL nuclear safety basis – WCRRF Basis for Interim Operation (BIO).	Failed.	Weakness in the hazard evaluation – was not revised to address the nitrate salt processing hazard. The Waste Characterization, Reduction, and Repackaging Facility (WCRRF) BIO does not thoroughly describe or evaluate nitrate salt processing or waste storage activities.	Did not drive typical safety analysis process to identify safety preventive controls (e.g., hazard elimination through substitution with inorganic absorbent).	HPI: TD8, HN3, HN6 ISMS: CF1, CF2, CF3, GP5, GP6
B.44	LANL nuclear safety basis – Area G BIO.	Failed.	Increased likelihood of previously analyzed accident scenarios for drums containing treated nitrate salts for which adequate controls may not be in place.	Did not prevent the drum from entering storage and being shipped to WIPP.	HPI: TD8, HN3, HN6 ISMS: CF1, CF2, GP5, GP6
B.45	LANL nuclear safety basis – Unreviewed Safety Question Determination (USQD)/ Potential Inadequacy in the Safety Analysis (PISA).	Failed.	USQD for EP-WCRR-WO-DOP-00233, Revision 36 change was negative.	Did not drive an update to the hazard analysis.	HPI: TD8, HN3, HN6 ISMS: CF1, CF2, CF3, GP5, GP6
B.46	LANS change control process	Failed.	Did not ensure appropriate SME involvement and/or technical evaluation	Allowed creation of incompatible	HPI: TD8, HN3, HN6 ISMS:

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			of specification of change to an organic absorbent. In addition, changes to neutralizers also were not sufficiently controlled.	waste drum.	CF1, GP2
B.47	WIPP Fire Hazard Analysis performed by NWP.	Failed	Did not recognize the potential for a fire starting and propagating within a waste array.	Combustible materials stored in waste array at WIPP.	HPI: N/A ISMS: N/A
B.48	LANS/ES quality assurance program.	Failed.	Inadequately implemented.	Quality assurance (QA)/Quality Control (QC) checks and balances, including oversight did not identify weaknesses identified in this report.	HPI: TD8, HN3, HN6 ISMS: CF5
B.49	CCP quality assurance program.	Failed.	Inadequately implemented.	Quality Assurance/ Quality Control checks and balances, including oversight did not identify weaknesses identified in this report.	HPI: TD8, HN3, HN6 ISMS: CF5
B.50	NA-LA oversight.	Failed.	Did not perform RCRA oversight. Focused on budget/financial oversight versus	Did not identify the weaknesses identified in this investigation or ensure closure	HPI: TD8, HN3, HN6 ISMS: CF5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			operational oversight. On the ground operational oversight limited to Facility Representative; lacks subject matter expertise. Roles and responsibilities for oversight of WCRR operations unclear. Short on Facility Representatives [three full time equivalents (FTE)] and Senior Technical Safety Manager (two FTE). Since 2011, staffing reduction in environmental compliance from five to three FTEs. Reliance on the LANS Contractor Assurance System (CAS). Certification process failed to ensure that LANS is compliant with the WIPP WAC.	of previously identified issues.	
B.51	National TRU program.	Failed.	National TRU program oversight limited to recertification audits, relied on local Federal oversight. Did not ensure that RCRA requirements for ignitability are adequately addressed in the WIPP WAC and waste	Unknown.	HPI: TD8, HN3, HN6 ISMS: CF5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			processing/packaging methods. Lack of understanding of the quality, depth and breadth of local Federal oversight of the waste generator processing and packaging processes. Assumed that sites complied with their RCRA permits. Overly reliant on site Federal oversight and CAS on oversight of pre-characterization activities. Recertification audits did not cover the breadth of oversight responsibilities.		
B.52	National TRU Corporate Board	Failed	Failed to ensure that LANS prepared implementation documentation and programs to meet the requirements in the WAC and that CCP maintained an accurate and compliant AK summary report for the mixed inorganic nitrate waste stream (LA-MIN02-V.001) waste stream.	Did not discover and ensure correction of deficiencies in procedures and approach to repackaging TRU waste.	HPI: TD6, TD7, HN3, HN5, HN6 ISMS: CF5
B.53	DOE Headquarters oversight.	Failed.	No oversight of the national TRU program was performed. DOE O 435.1,	Did not identify the weaknesses identified in this investigation or	HPI: TD8, HN3, HN6 ISMS: CF5

Hazard: Release of Mixed TRU Waste			Target: Workers and the Public		
No.	**Barriers**	**How did barrier perform?**	**Why did barrier fail?**	**How did barrier affect accident?**	**Context: HPI/ISMS**
			Radioactive Waste Management, lacks adequate waste packaging requirements for remediation activities, including the addition of absorbents and neutralization agents.	ensure closure of previously identified issues.	

Attachment C. Change Analysis

Change is anything that disturbs the "balance" of a system from operating as planned. Change is often the source of deviations in system operations. Change can be planned, anticipated, and desired, or it can be unintentional and unwanted. Change analysis examines the planned or unplanned disturbances or deviations that caused the undesired results or outcomes related to the accident. This process analyzes the difference between what is normal (or "ideal") and what actually occurred. The results of the change analysis are used to support the development of causal factors. This Phase 2 report covers the Board's analysis and conclusion for the release of TRU from the underground to the environment, as updated based on continued investigations after the Phase 1 report was issued without repeating the change analysis of WIPP activities and conditions.

Table C-1: Change Analysis

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
Components/Materials				
C.1	Fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric disappeared.	Fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric in-place.	Fiberboard and polyethylene slip sheets, polyethylene reinforcement plates, polyethylene stretch wrap, cardboard stiffeners and polypropylene super sack fabric did not exist as designed.	Implies that an energetic event occurred, whether by heat or blast pressure.
C.2	Shrink wrap disappeared.	Shrink wrap in-place.	Shrink wrap did not exist as designed.	Implies that an energetic event occurred, whether by heat or blast pressure.
C.3	Container vents covered with magnesium oxide (MgO).	Vents free.	Vents were covered.	Unknown.
C.4	Container lid was not secure.	Lid is in-place.	Lid was not secured as designed.	Loss of waste confinement.
C.5	Container lid locking ring was not intact.	Retaining ring is in-place.	Retaining ring not in-place as designed.	Loss of waste confinement.
C.6	MgO super sacks damaged.	MgO super sacks intact/in-place.	MgO super sacks not in-place as designed.	Implies that an energetic event

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
				occurred, whether by heat or blast pressure.
C.7	Glovebox procedure allowed combination of incompatible materials (too vague, did not adequately describe the scope of work, hazard identification, hazard controls).	Glovebox procedure sufficiently detailed, prohibits addition of incompatible materials, types, quantities, measurement.	Drum(s) contained incompatible materials.	Contributed to a reaction that resulted in loss of waste confinement.
C.8	Incorrect decisions were made due to schedule pressure to meet the June 30, 2014, framework agreement deadline.	Appropriate decisions were made to meet the framework agreement deadline.	Expedited safety reviews were performed, workers felt pressured.	Unknown.
C.9	The waste characterization process did not identify noncompliant waste stream.	The waste characterization process clearly identifies a noncompliant waste stream and issues a nonconformance report.	A drum was packaged containing incompatible materials for shipment to Waste Isolation Pilot Plant (WIPP).	Noncompliant waste was emplaced in the WIPP underground.
C.10	The waste certification process did not identify noncompliant waste stream.	The waste certification process clearly identifies a noncompliant waste stream and issues a nonconformance report	A drum containing incompatible materials was shipped to WIPP.	Noncompliant waste was emplaced in the WIPP underground.
C.11	Lessons learned from previous WasteLock® 770 concerning organic incompatibility was not recognized when specifying an organic absorbent in Revision 36 of EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations* for	Lessons learned were appropriately disseminated and utilized when specifying use of absorbents in procedures.	An incompatible absorbent was used in the remediation of MIN02 waste.	Noncompliant waste was emplaced in the WIPP underground. Possibly contributed to a reaction that resulted in loss of waste confinement.

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
	waste remediation.			
C.12	Glovebox procedure allowed/did not prevent use of incompatible neutralizers to adjust the pH of MIN02 waste during remediation.	Glovebox procedure specified a compatible neutralizer for pH adjustment.	An incompatible neutralizer was used in the remediation of MIN02 waste.	Noncompliant waste was emplaced in the WIPP underground. Possibly contributed to a reaction that resulted in loss of waste confinement.
C.13	Allowed addition of unanalyzed waste material, e.g., tungsten glovebox glove, lead drum liners, etc. to MIN02 waste during remediation.	Controlled the addition of waste to ensure only compatible items are added to MIN02 waste during remediation.	An incompatible material was added to MIN02 waste during remediation.	Possibly contributed to a reaction that resulted in loss of waste confinement.
C.14	The Central Characterization Program (CCP) transuranic (TRU) Characterization Quality Assurance Program Project Plan (QAPjP) did not drive the level of detail necessary for the generator site to accurately account for waste contents.	The QAPjP requires sufficient detail necessary for generator sites to accurately account for waste contents.	Addition of incompatible materials was not clearly annotated on the paperwork submitted for characterization.	Possibly contributed to a reaction that resulted in loss of waste confinement.
Processes				
C.15	A JHA was not performed on a revision to the glovebox procedure which added an organic absorbent.	The JHA is performed on all steps of a new/revised procedure, includes worker and subject matter expert (SME) involvement, and identifies the incompatible	The hazard of adding an organic absorbent to nitrate salts in a revision to the glovebox procedure was not identified or controlled.	Noncompliant waste was emplaced in the WIPP underground. Contributed to a reaction that resulted in loss of waste confinement

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
		absorbent.		
C.16	Los Alamos National Security, LLC (LANS) Unreviewed Safety Question (USQ) process did not ensure safety basis documents Waste Characterization, Reduction, and Package Facility (WCRRF) and Area G addressed material incompatibility in the waste stream.	LANS safety basis identifies, evaluates, and controls all hazards associated with planned operations as well as changes to these operations.	Process did not ensure changes to operations were adequately evaluated in safety basis documents.	Negative Unreviewed Safety Question Documentation (USQD) did not prevent the use of incompatible materials or identification of appropriate compensatory or remedial actions.
Conduct of Operations Program				
C.17	LANS/Energy*Solutions*, LLC (ES) procedure content and compliance contributed to inadequate procedure development/change procedure, inadequate waste remediation procedure, inadequate logs were maintained.	Conduct of Operations Program effective. System is compliant with DOE O 422.1, *Conduct of Operations*, and is fully implemented.	A drum was packaged containing incompatible materials for shipment to WIPP.	Noncompliant waste was emplaced in the WIPP underground.
C.18	Work was stopped by operators but did not result in identification and effective resolution of the problem situation.	Work gets stopped by the correct people and a safe and compliant course of action is implemented.	A drum was packaged containing incompatible materials for shipment to WIPP.	Noncompliant waste was emplaced in the WIPP underground.
Nuclear Safety (DSA, TSR, USQD)				
C.19	LANS nuclear safety basis process did not ensure safety basis documents (WCRRF and Area G) addressed material incompatibility in the waste stream.	Clearly defines program requirements and expectations that ensure records generated and certified accurately reflect compliance with the Waste Acceptance Criteria and associated	The WCRRF and Area G Basis for Interim Operation did not thoroughly describe or evaluate nitrate salt processing or waste storage activities.	Noncompliant waste was emplaced in the WIPP underground. Contributed to a reaction that resulted in loss of waste confinement.

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
		permits.		
Safety Culture				
C.20	A safety conscious work environment did not exist. Safety culture inhibits frank worker feedback and questioning attitude.	There is a safety conscious work environment at LANL that complies with ISMS Guide DOE G 450.4-1C, *Institutional Controls Implementation Guide for Use with DOE P 454.1, Use of Institutional Controls Institutional Controls*.	Reluctance by some personnel to raise issues and/or issues raised was discounted.	Nonconforming condition was not identified and corrected – incompatible materials were mixed in the drum.
LANS/ES Contractor Assurance System				
C.21	The LANS Environmental and Waste Management Operations (EWMO) Contractor Assurance System (CAS) (including QA program/procedures) did not identify precursors.	The LANS CAS is fully compliant with DOE O 226.1B, *Implementation of Department of Energy Oversight Policy*, and effectively implemented. Weaknesses in waste processing, packaging, and/or certification are identified and corrected prior to waste being shipped and emplaced at WIPP.	Could have identified program/procedure inadequacies that contributed to or caused this event.	Did not identify precursors to this incident.
NA-LA Oversight				
C.22	NNSA Los Alamos Field Office (NA-LA) oversight did not identify	The NA-LA oversight program is fully compliant	Could have identified weaknesses in the	Did not identify precursors to this

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
	inadequacies in the LANS Environmental and Waste Management Operations (EWMO) Contractor Assurance System (CAS) or precursors.	with DOE O 226.1B, and effectively implemented. Weaknesses in the LANS EWMO CAS and/or waste processing, packaging, and/or certification are identified and corrected prior to waste being shipped and emplaced at WIPP.	LANS EWMO CAS that contributed to, or caused this event.	incident.
NWP/CBFO Oversight of LANL				
C.23	Nuclear Waste Partnership, LLC (NWP) Central Characterization Program (CCP)/Carlsbad Field Office (CBFO) (National TRU Program) did not identify inadequacies in LANS Environmental and Waste Management Operations (EWMO) programs/procedures regarding waste processing, packaging, and certification.	NWP/CBFO is conducting effective oversight of LANL waste processing, characterization, record keeping. Weaknesses in waste processing, packaging, and/or certification are identified and corrected prior to waste being shipped and emplaced at WIPP.	Could have identified program/procedure inadequacies that contributed to, or caused this event.	Did not identify precursors to this incident.
DOE Headquarters Oversight				
C.24	DOE Headquarters did not perform oversight of the National TRU Program.	The DOE Headquarters oversight program is fully compliant with DOE O 226.1B, and effectively implemented. Weaknesses in waste processing, packaging, and/or	Could have identified program/procedure inadequacies that contributed to, or caused this event.	Did not identify precursors to this incident.

Accident Situation		Prior, Ideal, or Accident-Free Situation	Difference	Evaluation of Effect
		certification are identified and corrected prior to waste being shipped and emplaced at WIPP.		

Attachment D. Causal Factors and Related Conditions

Table D-1: Causal Factors and Related Conditions

Causal Factor		Related Conditions
CC1	Los Alamos National Security, LLC (LANS) processes for procedure development, review, and change were inadequate in ensuring that operating procedures had the sufficient detail and controls necessary for the consistent production of safe and compliant waste.	LANS procedure EP-WCRR-WO-DOP-0233, Revision 36, *WCRRF Waste Characterization Glovebox Operations:* • Did not adequately control processing/repackaging. • Contained incorrect process step related to nitrate salt processing, i.e., use of organic absorbent. • Did not result in waste that was compliant with the Acceptable Knowledge (AK), LANL-CO white paper, WIPP WAC, etc. • Did not address critical upper tier requirements. • Was vague on key process steps, e.g., neutralization process, pH measurement, addition of waste, etc. • Did not include a caution or verification at step 10.6[3] (Repackaging Activities) of the WCRRF to ensure compatibility of any additional waste to the drum. • Failed to consider the requirements of the LANL Hazardous Waste Facility Permit (HWFP) in repackaging activities in the WCRRF. • Did not ensure that AK characteristics were maintained during repackaging, e.g., lead liner, absorbent, neutralizer, addition of tungsten glovebox gloves, to the mixed inorganic nitrate waste. • Generated records that did not adequately describe all materials added to the waste, e.g., organic absorbent, type of neutralizer. • Was not reviewed by all necessary SME reviewers (e.g., chemist) and the review did not ensure appropriate SME involvement and/or technical evaluation of specification of change to an organic absorbent. • Did not adequately evaluate and control changes to neutralizers.

Causal Factor		Related Conditions
CC2	LANS processes for the identification of hazards, selection of standards and hazard controls, and application of these standards and controls were inadequate to ensure the consistent production of safe and compliant waste.	• LANS subject matter experts did not identify the addition of an organic absorbent, ambiguity, e.g., neutralization, pH measurement, etc., and did not include a chemist. In at least one case, feedback directly relevant to the incorrect specification of the organic absorbent was provided by a subject matter expert but discounted. • LANS did not perform an adequate Job Hazard Analysis (JHA) for Revision 36 of the glovebox operating procedure for nitrate salt bearing waste processing steps as required by EP-DIR-AP-10007*, Environmental Programs Procedure Preparation, Revision, Review, Approval, and Use.* • Sufficient detail regarding the hazard analysis of new/revised procedure was not adequately addressed by EP-DIR-AP-10007. • LANS execution of the procedure revision review process of EP-DIR-AP-10007 did not result in identification of the compatibility hazard/issue nor evaluate the impact of secondary waste on the mixed inorganic nitrate waste stream (LA-MIN02-V.001). • Hazard review did not ensure involvement of all necessary SME/hazard reviews (e.g., chemist). • The WIPP Fire Hazards Analysis did not recognize the potential for a fire starting and propagating within a waste array. • LANS allowed use of incompatible neutralizers to adjust the pH of MIN02 waste during remediation. • LANS allowed addition of unanalyzed waste material, e.g., tungsten glovebox glove, lead drum liners, etc., to MIN02 waste during remediation. • LANS Unreviewed Safety Question (USQ) process did not ensure safety basis documents Waste Characterization, Reduction, and Package Facility (WCRRF) and Area G addressed material incompatibility in the waste stream.

Causal Factor		Related Conditions
CC3	The LANS Contractor Assurance System (CAS) was inadequate to ensure the necessary level of line-management self-assessment, independent assessment, subcontractor oversight, and feedback/lessons learned of operations. The CAS failed to identify weaknesses in the processes for procedure development and review, and in the identification and control of hazards in operating procedures.	• Inadequate depth and breadth of self-assessment and oversight. • Limited environmental program oversight i.e., RCRA (hazardous waste determination, upper tier requirements flow down, waste determination, records). • Did not identify inadequacies in the procedure development process or lack of rigor in implementation of the change control process (review and approval). • Did not identify that upper tier requirements were not flowed down into implementing procedures, e.g., RCRA requirements, TRAMPACT, etc. • LANS Subcontract Technical Representative role/responsibilities were unclear and the position was inadequately staffed (period where the position was not staffed, training and qualification - competence). • Waste characterization process did not identify noncompliant waste stream. • Lessons learned from previous WasteLock® 770 concern regarding organic incompatibility was not recognized when specifying an organic absorbent in Revision 36 of EP-WCRR-WO-DOP-0233, *WCRRF Waste Characterization Glovebox Operations* for waste remediation. • The LANS Environmental and Waste Management Operations (EWMO) CAS did not identify precursors.
CC4	The Central Characterization Program (CCP) failed to develop an AK for the mixed inorganic nitrate waste stream (LA-MIN02-V.001) that adequately captured all available information regarding waste generation and subsequent repackaging activities in order to prevent the generation, shipment, and emplacement of corrosive, ignitable, or reactive waste.	• CCP site certification did not recognize weaknesses in the LANS glovebox procedure and resultant processing records. • The LA-MIN02-V.001 waste stream Acceptable Knowledge was not compliant with CCP-PO-001, *Quality Assurance Project Plan* (QAPjP). • Did not evaluate the potential impact of changes to the LANS glovebox operating procedure when the AK summary report was revised. • Requirements in the QAPjP did not ensure that waste characterization methods prevent the shipment of RCRA characteristic waste. • The QAPjP did not drive the level of detail

Causal Factor		Related Conditions
		necessary for the generator site to accurately account for waste contents. • CCP did not evaluate impact of secondary waste on the LA-MIN02-V.001 waste stream when reviewing/approving CCP-AK-LANL-006, CCP, AK summary report for Los Alamos National Laboratory, TA-55 Mixed TRU Waste Streams: LA-MHD01.001, LA-CIN01.001, LA-MIN02-V.001, and LA-MIN04-S.001 • CCP documentation, e.g., batch data report incorrectly described the waste stream as inorganic matrix. • CCP is not directly involved or observant of WCRRF glovebox operations. • Unknown how certification process could identify process changes. • Did not identify inadequacies in LANS EWMO programs/procedures regarding waste processing, packaging, and certification.
CC5	The National Transuranic (TRU) Program/Carlsbad Field Office (CBFO) and Los Alamos Field Office (NA-LA) did not ensure that the Central Characterization Program (CCP) and the Los Alamos National Security, LLC (LANS) complied with all Resource Conservation and Recovery Act (RCRA) requirements in the WIPP HWFP and the LANL HWFP, as well as the WIPP Waste Acceptance Criteria (WAC).	• Oversight limited to recertification audits which do not cover the breadth of oversight responsibilities. • Lack of understanding of the quality of depth and breadth of local Federal oversight of the waste generator processing and packaging processes. • Certification process did not evaluate LANS/ES repackaging operations and compliance with the LANL HWFP permit. • Certification process did not ensure that CCP maintained an accurate and compliant AK summary report for the mixed inorganic nitrate waste stream (LA-MIN02-V.001). • Assumed that sites complied with their RCRA permits. • Did not discover that RCRA properties of ignitability and/or reactivity were not demonstrated by methods employed under the WIPP WAC. • Overly reliant on site Federal oversight and CAS.
CC6	LANS, Energy*Solutions*, LLC (ES), and the National Nuclear Security Administration Los Alamos Field Office	• Worker feedback that they did not feel comfortable identifying issues.

	Causal Factor	Related Conditions
	(NA-LA) allowed the safety culture at the Los Alamos National Laboratory (LANL) to deteriorate.	
CC7	LANL nuclear safety and change management processes did not ensure that the nuclear safety basis documents, Waste Characterization, Reduction, and Repackaging Facility (WCRRF) and Area G Basis for Interim Operation (BIO), were revised to evaluate hazards associated with material incompatibility in the nitrate salt bearing waste stream and to specify preventive or mitigative controls. Integrated Safety Management (ISM) core functions, including the need to ensure that hazards are appropriately identified and analyzed and controls established to mitigate these hazards, did not support recognition of the material incompatibility. The LANL Unreviewed Safety Question Determination (USQD) failed to recognize the lack of the ISM hazard analysis of the proposed changes to the WCRRF glovebox waste repackaging procedure, and did not recognize that an incompatible reactive nitrate salt bearing waste would be created by using "organic" absorbents; therefore, the USQD did not drive the need to update the WCRRF BIO hazard analysis for the changes in neutralization and stabilization materials to repackage the nitrate salts.	LANL nuclear safety basis – WCRRF BIO: • Had weakness in the hazard evaluation – was not revised to address the nitrate salt processing hazard. • Did not thoroughly describe or evaluate nitrate salt processing or waste storage activities. LANL nuclear safety basis – Area G BIO: • Did not identify the increased likelihood of previously analyzed accident scenarios for drums containing treated nitrate salts and that adequate controls may not be in place. LANL nuclear safety basis – Unreviewed Safety Question Determination (USQD)/ Potential Inadequacy in the Safety Analysis (PISA) • USQD for the proposed glovebox procedure change specifying use of organic absorbent was negative and therefore did not drive an update to the hazard analysis. • Was not effectively executed such that important procedure changes related to processing of nitrate salts were not adequately evaluated for impacts to the safety basis. The LANS Unreviewed Safety Question (USQ) process did not ensure safety basis documents for WCRRF and Area G addressed material incompatibility in the waste stream. The LANL nuclear safety basis process did not ensure safety basis documents (WCRRF and Area G) addressed material incompatibility in the waste stream.
CC8	Execution of NNSA Los Alamos Field Office (NA-LA) oversight in accordance with DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy* was ineffective. NA-LA failed to establish and implement adequate line management oversight programs and processes and hold personnel accountable.	• Did not perform effective RCRA oversight. • Focused on budget/financial oversight versus operational oversight. • On the ground operational oversight limited to Facility Representative(s) who lack subject matter expertise. • Roles and responsibilities for oversight of WCRR operations unclear. • Short on Facility Representatives [three full time equivalents (FTE)] and Senior Technical

Causal Factor		Related Conditions
		Safety Manager (two FTE). Since 2011, staffing reduction in environmental compliance from five to three FTEs. • Reliance on the LANS Contractor Assurance System (CAS). • Certification process failed to ensure that LANS is compliant with the WIPP WAC. • Did not identify inadequacies in the LANS EWMO CAS or precursors.
CC9	DOE Headquarters line management oversight regarding DOE Order 435.1, Chg. 1, *Radioactive Waste Management*, dated July 9, 1999, was inadequate/ineffective.	• No oversight of the National TRU program has been performed. • The National Transuranic Waste Corporate Board represents a missed opportunity to share lessons learned and safety issues related to processing TRU waste across the generator sites.
CC10	The WIPP Fire Hazard Analysis (FHA) did not recognize the potential for a fire starting within the waste array, nor did it recognize the potential for fire propagation within the array.	• Nuclear Waste Partnership LLC (NWP) needs to re-evaluate the quantity, type, and form of exposed combustible emplacement materials used in the waste array and take action to minimize the fire ignition risk (e.g., eliminate unnecessary materials, and include fire retardant additives). • NWP needs to revise the waste array emplacement strategy to include criteria that limit the risk of fire propagation within the array and limit the quantity of radiological waste that is at-risk from a single fire or explosion event. • NWP needs to revise the FHA to identify and address all credible fire and explosion scenarios initiated within the waste array underground.
CC11	Energy*Solutions*, LLC (ES) operators and supervisors were not adequately trained and qualified to process waste with regard to identification and control of incompatible materials.	• Training and qualification of ES operators and supervisors was ineffective. • Qualifications of ES operators and supervisors were inadequate to ensure understanding and controlling of critical waste processing activities, e.g., compatibility of waste and additives, addition of secondary wastes, etc.
CC12	Energy*Solutions*, LLC (ES) operators and LANS/ES supervisors did not effectively execute the stop work process when unexpected conditions were encountered at Waste Characterization, Reduction,	• WCRRF management did not effectively respond to worker feedback regarding notification of reactions in the glovebox. • Supervision did not engage correct resources to

Causal Factor		Related Conditions
	and Repackaging Facility (WCRRF).	resolve conditions identified by workers. • Workers accepted an ineffective resolution.

Table D-2: Causal Factors as Related to Conclusions and Judgments of Need

Causal Factor	Conclusion	Judgment of Need
Local Root Cause: The Board identified the local root cause of the radioactive material release in the WIPP underground to be the failure of LANS to understand and effectively implement the LANL Hazardous Waste Facility Permit and Carlsbad Field Office directed controls. Specifically, LANL's use of organic, wheat-based absorbent instead of the directed inorganic absorbent such as kitty litter/zeolite clay absorbent in the glovebox operations procedure for nitrate salts that resulted in the generation, shipment, and emplacement of a noncompliant, ignitable waste form.	**CON 7:** Los Alamos National Security, LLC (LANS) did not adequately evaluate the impact on the WIPP Waste Acceptance Criteria (WAC) or effectively control the addition of secondary job waste into transuranic (TRU) waste containers.	**JON 9**: LANS needs to improve the level of rigor in evaluating and controlling the addition of secondary job waste into TRU waste containers.
	CON 8: Los Alamos National Security, LLC (LANS) did not adequately incorporate upper tier requirements into the development of repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF). Specifically: • The Carlsbad Field Office (CBFO) directed controls contained in the Los Alamos National Laboratory- Carlsbad Office (LANL-CO) white paper based on the Energetic Materials Research and Testing Center (EMRTC) Report RF 10-13; and • The requirements associated with the Los Alamos National Laboratory (LANL) Hazardous Waste Facility Permit (HWFP): ◦ Nitrate salt bearing wastes did not fully meet the LANL HWFP "special requirements" for managing ignitable wastes, including segregation and separation, and use of non-	**JON 10:** LANS needs to strengthen the processes that ensure the flow down of upper tier requirements into their implementing procedures such that execution of work is compliant. **JON 11**: CBFO needs to conduct an extent of condition review of other waste generator sites to determine the adequacy of the flow down into the operating procedures and implementation of RCRA requirements contained in the WIPP Waste Acceptance Criteria (WAC) and hazardous waste permits regarding the treatment and repackaging of TRU waste.

Causal Factor	Conclusion	Judgment of Need
	sparking tools; • Did not comply with the LANL HWFP requirement that the nitrate salt-bearing waste drums be labeled with all applicable Environmental Protection Agency (EPA) Hazardous Waste Numbers; • Placed incompatible wastes and materials in the same container and did not impose special precautions; • Did not label the nitrate salt bearing waste prior to transport and remediation at the Waste Characterization, Reduction and Packaging Facility (WCRRF); and • Did not label the unremediated nitrate salt bearing waste drums which contained liquids as Resource Conservation and Recovery Act (RCRA) corrosive.	
	CON 10: Los Alamos National Security, LLC (LANS) failed to provide sound technical basis for decisions regarding repackaging procedures and processes for the LA-MIN02-V.001 waste stream.	**JON 13:** LANS needs to strengthen documentation to include a detailed technical basis to justify decisions made regarding change control for procedures and processes for the LA-MIN02-V.001 waste stream.
	CON 11: Los Alamos National Security, LLC (LANS) did not utilize a formal engineering change control process to develop modifications to repackaging activities in the Waste Characterization, Reduction and Packaging Facility (WCRRF).	**JON 14**: LANS needs to implement an effective engineering change control process that includes defensible technical bases to justify process modifications.
Systemic Root Cause: The Board identified the systemic root cause as the Los Alamos Field Office (NA-LA) and National Transuranic Program/Carlsbad Field Office (CBFO) failure to ensure that LANL had	**CON 1**: Implementation of the characterization processes established in the Waste Isolation Pilot Plant (WIPP) Hazardous Waste Facility Permit (HWFP), Attachment C, Waste Analysis Plan (WAP) was not fully consistent with the criteria in 40 CFR 261.21, *Characteristic of Ignitability*. Specifically, characterization	**JON 1**: The National Transuranic (TRU) Program needs to re-evaluate and strengthen the flow down of requirements regarding the compilation of Acceptable Knowledge (AK) in order to more clearly demonstrate that the WIPP HWFP, Attachment C, WAP waste characteristics prohibitions and

Causal Factor	Conclusion	Judgment of Need
adequately developed and implemented repackaging and treatment procedures that incorporated suitable hazard controls and included a rigorous review and approval process. NA-LA and CBFO did not ensure the adequate flow down of the Resource Conservation and Recovery Act and other upper tier requirements, including the WIPP Hazardous Waste Facility Permit, Attachment C, Waste Analysis Plan, WIPP Waste Acceptance Criteria, and the LANL Hazardous Waste Facility Permit requirements into operating procedures at LANL.	processes should have identified LA-MIN02-V.001 as ignitable because: • It is an oxidizer; and • Addition of the organic absorbent created conditions that made the waste capable, under standard temperature and pressure, of causing fire through friction, absorption of moisture or spontaneous chemical changes and, when ignited, burning so vigorously and persistently that it creates a hazard.	chemical compatibility requirements are met consistent with 40 CFR 261.21.
	CON 5: Implementation of requirements listed in CCP-PO-001, *CCP Transuranic Waste Characterization Quality Assurance Project Plan,* did not ensure that waste characterization methods and Acceptable Knowledge (AK) were effective in preventing the shipment of corrosive, ignitable, or reactive wastes.	**JON 7:** The Central Characterization Program (CCP) needs to improve implementation of requirements in CCP-PO-001 such that characterization methods are able to ensure that all WIPP Waste Acceptance Criteria (WAC) requirements are met.
Contributing Causes (CC)		
CC1: Failure of Los Alamos National Security, LLC (LANS) to implement effective processes for procedure development, review, and change control. Execution of the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure resulted in a combination of incompatible materials and the generation of an ignitable, noncompliant waste.	**CON 12:** Los Alamos National Security, LLC (LANS) failed to ensure that there was sufficient detail provided in the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure to ensure safe, consistent, and compliant repackaging of waste and accurate documentation of the contents of the waste drums in the records.	**JON 15:** LANS needs to revise the WCRRF glovebox operations procedure to contain the necessary level of detail to ensure safe, consistent, and compliant remediation of nitrate salt bearing waste. **JON 16:** The glovebox operations procedure needs to be revised to require operators to document critical process steps in a quality record, e.g., initial pH, absorbent added, neutralizer used, adjusted pH. **JON 17**: Operators need to be adequately trained on the revised glovebox operations procedure.
	CON 20: Los Alamos National Security, LLC (LANS) existing processes governing the preparation, review, and approval of	**JON 32**: LANS needs to review and revise EP-DIR-AP-10007 to ensure that all procedures and procedure revisions contain:

Causal Factor	Conclusion	Judgment of Need
	Environmental Programs procedures did not contain sufficient guidance related to hazard analysis and subject matter expert review necessary to ensure safe, consistent, and compliant execution of waste processing.	• The necessary level of detail to ensure the safe, consistent, and compliant performance of work, including process steps, materials, and material substitutions, and • Explicit requirements and criteria regarding inclusion of appropriate subject matter experts and their review and concurrence with new and revised procedures. • Requirements that a Job Hazard Analysis (JHA) is appropriately amended when new activities such as nitrate salt remediation that could introduce new hazards are incorporated into existing processes.
CC2: Failure of Los Alamos National Security, LLC (LANS) to develop and implement adequate processes for hazard identification and control. As a result, an incompatible absorbent was specified and used during nitrate salt bearing waste processing.	**CON 13**: Available data indicates that oxidation was occurring in the Standard Waste Box (SWB) where sibling drum 68685 was stored, along with other similarly remediated waste drums.	**JON 18**: Los Alamos National Security (LANS) needs to investigate and determine the cause for oxidation in sibling drum 68685 and take action to mitigate the condition as well as prevent future nitrate salt bearing waste drums (remediated and unremediated) from oxidizing.
CC3: Failure of the Los Alamos National Security, LLC (LANS) Contractor Assurance System (CAS) to identify weaknesses in the processes for operating procedure development; hazard analysis and control; and review that resulted in an inadequate glovebox operation procedure for processing the nitrate salt bearing waste.	**CON 16**: The Los Alamos National Security, LLC (LANS) contractor assurance system was not effective in identifying weaknesses in the process for developing/changing procedures, analyzing and controlling hazards, performing work to repackage nitrate salt bearing wastes, and feedback mechanisms which resulted in the production and shipping of noncompliant waste drums to the Waste Isolation Pilot Plant and Waste Control Specialists, LLC (WCS).	**JON 25**: LANS Environmental and Waste Management Operations (EWMO) needs to develop and implement a fully integrated contractor assurance system that provides DOE and LANS confidence that work is performed compliantly, risks are identified, and control systems are effective and efficient. Specific areas to be addressed include: • Ensuring adequate scope and associated depth and breadth of self-assessments, independent assessments and management

Causal Factor	Conclusion	Judgment of Need
		assessments; • Clarifying the oversight role of LANS EWMO with regard to subcontractors and waste processing/packaging operations; • Ensuring required environmental program oversight i.e., the Resource Conservation and Recovery Act (RCRA) (hazardous waste determination, upper tier requirements flow down into implementing procedures, waste determination, records); • Including the necessary rigor in implementation of the change control process (review and approval by subject matter experts); • Verifying that requirements are flowed down into implementing procedures, e.g., RCRA requirements, TRU Waste Authorized Methods for Payload Control, etc.; and • Evaluating and responding to feedback from Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations by LANS senior management, e.g., notification of reactions in the glovebox.
CC4: Failure of the Central Characterization Program (CCP) to develop an Acceptable Knowledge (AK) for the mixed inorganic nitrate waste stream (LA-MIN02-V.001) that adequately captured all available information regarding waste generation and subsequent repackaging activities in order to	**CON 6**: The preparation, review and approval of CCP-AK-LANL-006, *Acceptable Knowledge (AK)* summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of adding incompatible secondary waste items to the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.	**JON 8**: The CCP needs to improve the level of rigor in reviewing and approving AK summary reports for compliance with requirements.
	CON 9: The preparation, review and	**JON 12**: The CCP needs to

Causal Factor	Conclusion	Judgment of Need
prevent the generation, shipment, and emplacement of corrosive, ignitable, or reactive waste. Specifically, the AK Summary Report did not capture changes made to the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox procedure. The addition of a secondary waste material was not adequately considered.	approval of CCP-AK-LANL-006, Acceptable Knowledge (AK) summary report revisions by the Central Characterization Program (CCP) was not effective in identifying the potential impact of changes to EP-WCRR-WO-DOP-233 Glovebox Operations, on the LA-MIN02-V.001 waste stream, in part due to poor communications between LANS and CCP.	reevaluate and strengthen the process used to conduct review and approval of source documents that have an impact on Acceptable Knowledge.
CC5: Failure of the Los Alamos Field Office (NA-LA) and the National Transuranic (TRU) Program/Carlsbad Field Office (CBFO) to ensure that the CCP and LANS complied with Resource Conservation and Recovery Act (RCRA) requirements in the WIPP Hazardous Waste Facility Permit (HWFP) and the LANL HWFP, as well as the WIPP Waste Acceptance Criteria (WAC). Examples include the unapproved treatment (neutralization and absorption of liquids) and the addition of incompatible materials. As a result, waste containing incompatible materials was generated and sent to WIPP.	**CON 2**: Execution of the National Transuranic (TRU) Program certification audit process for the LANL waste generator activities where Central Characterization Program (CCP) performs TRU waste characterization and certification failed to include key elements of waste packaging and characterization processes. In part, this was attributed to a lack of clear roles and responsibilities; and expectations. Specific elements include: • Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox treatment and repackaging operations, • Ensuring that TRU waste accepted for management and disposal at WIPP complies with the WIPP Hazardous Waste Facility Permit (HWFP), applicable laws, and regulations described in the Waste Acceptance Criteria (WAC), and • Verification that Los Alamos National Security, LLC (LANS) prepared implementation documentation and programs to meet the requirements and criteria of the WIPP Waste Acceptance	**JON 2**: The National TRU Program needs to re-evaluate and strengthen the certification audit process across the DOE complex at all generator sites to include: • Evaluation of waste generator repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; • Verification that changes to processes are correctly incorporated into acceptable knowledge summary reports; • Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and • Evaluation of local site office oversight of TRU waste operations.

Causal Factor	Conclusion	Judgment of Need
	Criteria and that the Central Characterization Program (CCP) maintained an accurate and compliant Acceptable Knowledge Summary Report for the LA-MIN02-V.001waste stream.	
	CON 4: Carlsbad Field Office (CBFO) oversight activities associated with the characterization and certification of transuranic (TRU) waste were ineffective in identifying programmatic weaknesses through the execution of certification audits and surveillances at Los Alamos National Laboratory (LANL).	**JON 4**: The CBFO oversight of characterization and certification of TRU waste sites needs to be improved to include: • Waste generator repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; • Verification of effective implementation documentation and programs to ensure that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit; and • Evaluation of local site office oversight of TRU waste operations. **JON 5**: CBFO needs to evaluate and restructure their organization such that objective oversight of the National TRU Program is evident and effective in ensuring that waste generator sites comply with requirements including appropriate separation of CBFO line management and oversight functions and responsibilities. **JON 6:** DOE Headquarters needs to review expectations documented in existing National TRU Program policy directives and take action necessary to clearly assert that CBFO, as the manager of the WIPP repository, has the authority to conduct oversight of waste generator

Causal Factor	Conclusion	Judgment of Need
		site programs and processes necessary to provide assurance that any activities that could impact characterization and certification of waste are verified to be compliant.
	CON 18: The Federal roles, responsibilities and execution for oversight of the activities between the generator site transuranic (TRU) waste program (LANL) and the TRU Waste Central Characterization Program (CCP) were inadequate.	**JON 28**: The National TRU Program needs to clarify NA-LA and CBFO expectations and oversight roles and responsibilities between the generator site TRU waste program (LANL) and the TRU waste CCP. **JON 29**: NA-LA and CBFO need to perform effective Federal oversight of CCP review and approval of waste management operating procedures/process changes, e.g., WCRRF glovebox operating procedure. **JON 30**: DOE Headquarters and CBFO need to conduct an extent of condition review of the overall Federal oversight across the DOE complex in all three key segments of the National TRU Program: the Generator Site TRU Waste Program, TRU Waste Certification Program, and the Disposal System Program (WIPP).
CC6: Failure of Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES), and the NNSA Los Alamos Field Office (NA-LA) to ensure that a strong safety culture existed within the Environmental and Waste Management Operations (EWMO) organization at the Los Alamos National Laboratory (LANL). As a result, although there was a questioning attitude, there was a failure to adequately resolve employee concerns which	**CON 23**: Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) and NNSA Los Alamos Field Office (NA-LA) allowed the safety culture at the Los Alamos National Laboratory (LANL) to deteriorate within pockets of the organization as evidenced by the workers' feedback that they did not feel comfortable identifying issues that may adversely affect management direction, delay mission-related objectives, or otherwise affect cost or schedule. In addition, management failed to effectively respond to workers' issues regarding unexpected conditions encountered during waste processing activities.	**JON 39**: LANS and NA-LA need to develop and implement a more rigorous, effective integrated safety management system that embraces and implements the attributes of DOE G 450.4-1C, *Integrated Safety Management Guide*, including but not limited to: • Demonstrated leadership in risk-informed, conservative decision making; • Improved learning through error reporting and effective resolution of problems; • Line management encouraging a questioning attitude without fear of reprisal and following through to resolve issues

Causal Factor	Conclusion	Judgment of Need
could have identified the generation of noncompliant waste prior to shipment.	**CON 24**: Questioning attitudes were not welcomed by management and many issues and hazards did not appear to be readily recognized by site personnel.	identified by the workforce. • Consideration should also be given to some additional contract incentive associated with leading a culture change that fosters the desired work environment. The LANS, ES, and NA-LA stop work related processes need to ensure that response to issues raised by workers are based on sound, technical justification. **JON 40**: DOE Headquarters needs to engage safety culture expertise to provide training and mentoring to LANS, ES, and NA-LA management on the principles of a strong safety culture and take appropriate corrective action based on the outcome.
CC7: Failure of the execution of the LANL Unreviewed Safety Question (USQ) process to identify the lack of a hazard analysis of the proposed changes to the Waste Characterization, Reduction, and Repackaging Facility (WCRRF) glovebox waste repackaging procedure [i.e., consistent with Integrated Safety Management (ISM) core functions], and did not	**CON 14**: The Waste Characterization, Reduction, and Repackaging Facility (WCRRF) Basis for Interim Operation (BIO) did not thoroughly describe or evaluate nitrate salt processing or waste storage activities.	**JON 19**: The WCRRF BIO needs to be revised to include more specificity in description of nitrate salt processing activities and then update the hazard analysis to include identification of all hazards and their evaluations. **JON 20**: LANS needs to review the Area G BIO in light of changes made to the WCRRF BIO and update accordingly. **JON 21**: LANS needs to conduct an extent of condition review for issues that are similar to nitrate salt bearing waste processing in WCRRF and Area G.

Causal Factor	Conclusion	Judgment of Need
recognize that an incompatible reactive nitrate salt bearing waste would be created by using "organic" absorbents. As a result, the Unreviewed Safety Question Determination (USQD) did not ensure that nuclear safety basis documents, including the WCRRF and Area G Basis for Interim Operation (BIO), were updated to evaluate hazards associated with material incompatibility in the nitrate salt-bearing waste stream and to specify preventive or mitigative controls.	**CON 15**: The Los Alamos National Security, LLC (LANS) Unreviewed Safety Question (USQ) process was ineffective in ensuring that important procedure changes related to processing of nitrate salts were adequately evaluated for impacts to the safety basis.	**JON 22**: LANS needs to ensure that USQ evaluators are organizationally independent of line management. **JON 23**: LANS needs to conduct retraining of USQ process evaluators/approvers focused on implementation of the Unreviewed Safety Question Determination (USQD) process consistent with DOE Guide 424.1-1B, *Implementation Guide for Use in Addressing Unreviewed Safety Question Requirements*. **JON 24**: The NNSA Los Alamos Field Office (NA-LA) needs to conduct an assessment of the LANS USQ program.
CC8: Failure of NNSA Los Alamos Field Office (NA-LA) to establish and implement adequate line management oversight programs and processes in accordance with DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy*. As a result, weaknesses in Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) programs and waste operations procedures were not identified and corrected which allowed an ignitable, noncompliant nitrate salt-bearing waste to be generated, shipped, and emplaced at WIPP.	**CON 3**: The NNSA Los Alamos Field Office (NA-LA) oversight activities were ineffective in identifying weaknesses in the execution of waste packaging, characterization and certification of transuranic (TRU) waste at Los Alamos National Laboratory (LANL).	**JON 3**: NA-LA oversight of characterization and certification of TRU waste sites needs to be improved to include: • Waste Characterization, Reduction, and Repackaging Facility (WCRRF) repackaging operations that prepare TRU waste for characterization; • Implementation of waste generator site processes as they relate to TRU waste management; and • Verification that waste generator activities comply with the generator site Resource Conservation and Recovery Act (RCRA) permit.
	CON 17: The NNSA Los Alamos Field Office (NA-LA) oversight was ineffective in identifying weaknesses that contributed to this event.	**JON 26**: NA-LA needs to strengthen its oversight of Los Alamos National Security, LLC (LANS) Environmental and Waste Management Operations (EWMO) to ensure that: • Resource Conservation and

Causal Factor	Conclusion	Judgment of Need
		Recovery Act (RCRA) oversight is performed; • Focus is placed on operational oversight in addition to budget/financial oversight; • On the ground operational oversight expands beyond that performed by the Facility Representatives to include adequate subject matter expertise; • NA-LA performs oversight of contractor activities related to waste certification in accordance with the WIPP Waste Acceptance Criteria (WAC); • Roles and responsibilities for oversight of Waste Characterization, Reduction, and Repackaging Facility (WCRRF) operations are made clear; • Staffing shortages are addressed, including: • Facility Representatives, short three full-time equivalencies (FTEs); • Senior Technical Safety Manager, short two FTEs; • The staffing reduction in environmental compliance, down from five to three FTEs since 2011; and • Senior technical advisor position has been vacant since 2008. • Formal verification that there is an effective LANS Contractor Assurance System (CAS) in place for environmental compliance. **JON 27**: NA-LA needs to verify that LANS has developed and implemented a DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy* compliant CAS.

Causal Factor	Conclusion	Judgment of Need
CC9: Failure of DOE Headquarters to perform adequate or effective line management oversight required by DOE Order 435.1, *Radioactive Waste Management*, dated July 9, 1999. As a result, waste containing incompatible materials was generated and sent to WIPP.	**CON 19**: DOE Headquarters did not perform DOE O 435.1, *Radioactive Waste Management*, oversight activities for implementation of requirements associated with the operational performance within the National Transuranic (TRU) Program.	**JON 31**: DOE Headquarters needs to develop and implement a DOE O 435.1 comprehensive oversight program for National TRU Program activities as identified by the Office of Environmental Management.
CC10: Failure of Nuclear Waste Partnership LLC (NWP) to ensure that the WIPP Fire Hazard Analysis (FHA) recognized the potential for a fire starting within the waste array as well as the potential for propagation within the array. As a result, fire protection controls focused on prevention of propagation to the array from external sources (e.g., vehicles) and did not consider the magnitude of the combustible material hazard.	**CON 21**: The WIPP Fire Hazard Analysis (FHA) was ineffective in identifying and analyzing the potential for a fire starting within the waste array, as well as the potential for fire propagation within the array.	**JON 33**: Nuclear Waste Partnership LLC (NWP) needs to re-evaluate the quantities, type and form of exposed combustible emplacement materials used in the waste array and take action to minimize the fire ignition and propagation risks (e.g., eliminate unnecessary materials, and include fire retardant additives). **JON 34**: NWP needs to revise the waste array emplacement strategy to include criteria that limit the risk of fire propagation within the array and to include limiting the quantity of radiological waste that is at-risk from a single fire or explosion event. **JON 35**: NWP needs to revise the FHA to identify and address all credible fire and explosion scenarios initiated within the waste array underground. **JON 36**: NWP needs to reevaluate and revise the WIPP FHA to better characterize the fire risks associated with transuranic (TRU) waste packaging during handling and storage. This needs to include reevaluation of actions detailed in the WIPP Recovery Plan. **JON 37**: The Office of Environmental Management Headquarters needs to ensure that waste generator site's FHAs adequately characterize the fire risks

Causal Factor	Conclusion	Judgment of Need
		associated with TRU waste packaging during handling and storage.
CC11: Failure of Los Alamos National Security, LLC (LANS)/ Energy*Solutions*, LLC (ES) to adequately train and qualify ES operators and supervisors in the identification and control of incompatible materials during waste processing. As a result, personnel did not question the instruction to add organic absorbent and other secondary waste items to the nitrate salt-bearing waste.	**CON 22**: Energy*Solutions*, LLC (ES) operators and supervisors were not adequately trained and qualified to process waste with regard to identification and control of incompatible materials.	**JON 38**: LANS needs to evaluate and strengthen the operator and supervisor training programs of LANS and their subcontractors to ensure adequate understanding of basic chemistry interactions and associated controls.
CC12: Failure of Energy*Solutions*, LLC (ES) operators and Los Alamos National Security, LLC (LANS)/ES supervisors to effectively execute the stop work process when unexpected conditions, including foaming reactions and smoke during waste processing, were encountered at Waste Characterization, Reduction, and Repackaging Facility (WCRRF). This resulted in waste containing incompatible materials being generated and sent to WIPP.	**CON 23**: Los Alamos National Security, LLC (LANS), Energy*Solutions*, LLC (ES) and NNSA Los Alamos Field Office (NA-LA) allowed the safety culture at the Los Alamos National Laboratory (LANL) to deteriorate within pockets of the organization as evidenced by the workers' feedback that they did not feel comfortable identifying issues that may adversely affect management direction, delay mission-related objectives, or otherwise affect cost or schedule. In addition, management failed to effectively respond to workers' issues regarding unexpected conditions encountered during waste processing activities. **CON 26**: Questioning attitudes were not welcomed by management and many issues and hazards did not appear to be readily recognized by site personnel.	**JON 39**: LANS and NA-LA need to develop and implement a more rigorous, effective integrated safety management system that embraces and implements the attributes of DOE G 450.4-1C, *Integrated Safety Management Guide,* including but not limited to: • Demonstrated leadership in risk-informed, conservative decision making; • Improved learning through error reporting and effective resolution of problems; • Line management encouraging a questioning attitude without fear of reprisal and following through to resolve issues identified by the workforce. • Consideration should also be given to some additional contract incentive associated with leading a culture change that fosters the desired work environment. The LANS, ES, and NA-LA stop work related

Causal Factor	Conclusion	Judgment of Need
		processes need to ensure that response to issues raised by workers are based on sound, technical justification. **JON 40**: DOE Headquarters needs to engage safety culture expertise to provide training and mentoring to LANS, ES, and NA-LA management on the principles of a strong safety culture and take appropriate corrective action based on the outcome.

Attachment E. Event and Causal Factor Analysis

An events and causal factors analysis was performed in accordance with the DOE Workbook, Conducting Accident Investigations. The events and causal factors analysis requires deductive reasoning to determine those events and/or conditions that contributed to the accident. Causal factors are the events or conditions that produced or contributed to the accident, and they consist of direct, contributing, and root causes. The direct cause is the immediate event(s) or condition(s) that caused the accident. The contributing causes are the events or conditions that, collectively with the other causes, increased the likelihood of the accident, but which did not solely cause the accident. Root causes are the events or conditions that, if corrected, would prevent recurrence of this and similar accidents. The causal factors are identified in Figure E-1: Events and Causal Factors Analysis.

To ensure full understanding of events and conditions leading up to, during, and following the event, timelines and events and causal factors were developed for nuclear safety, ground control, ventilation, continuous air monitors, and DOE Headquarters oversight in addition to the overall radiological release timeline.

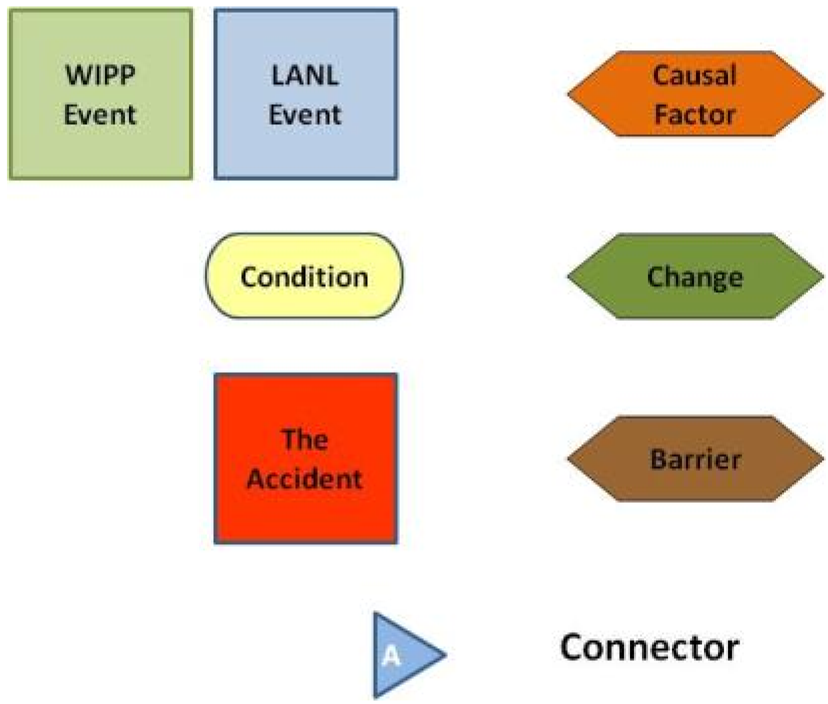
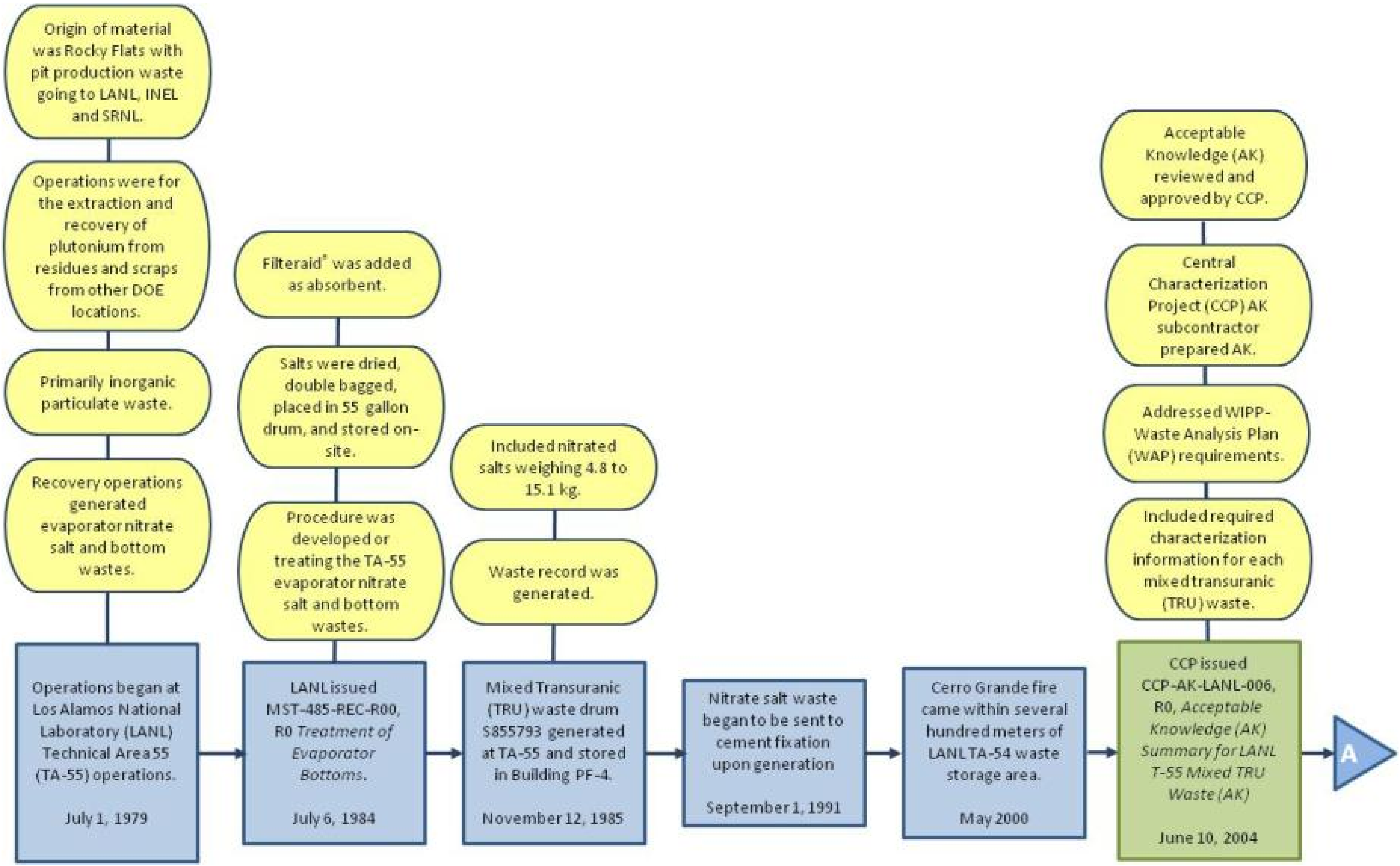
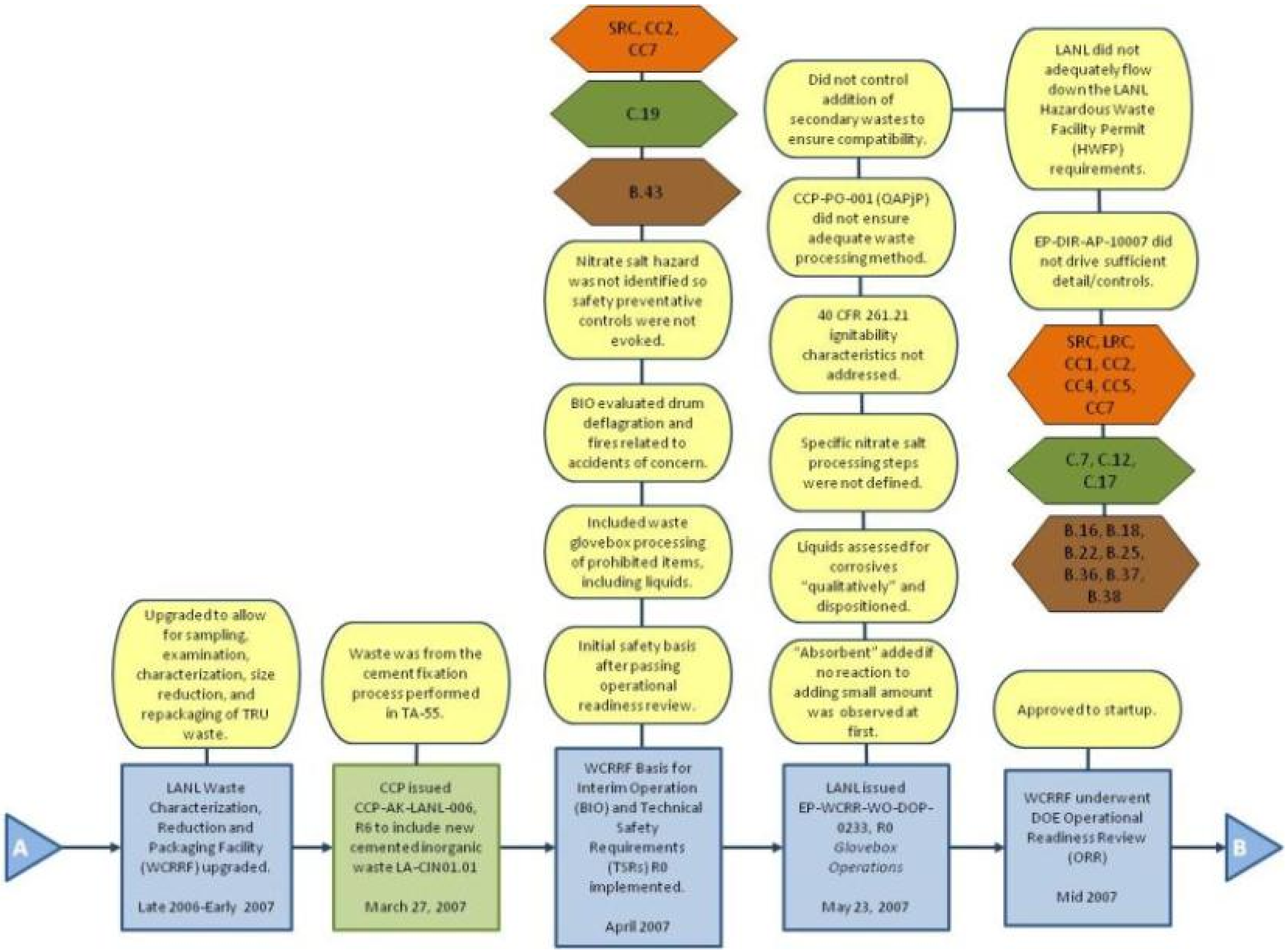
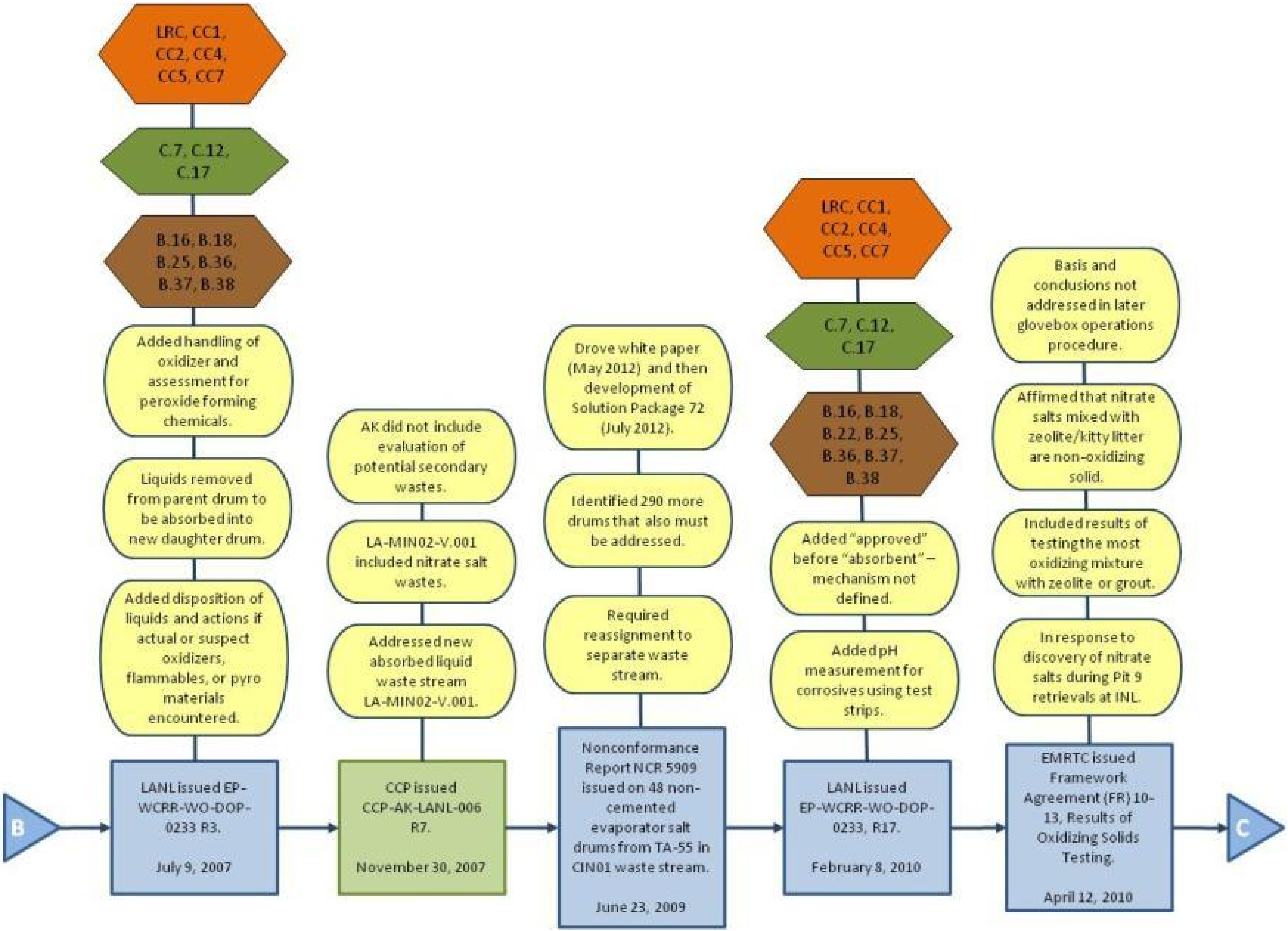
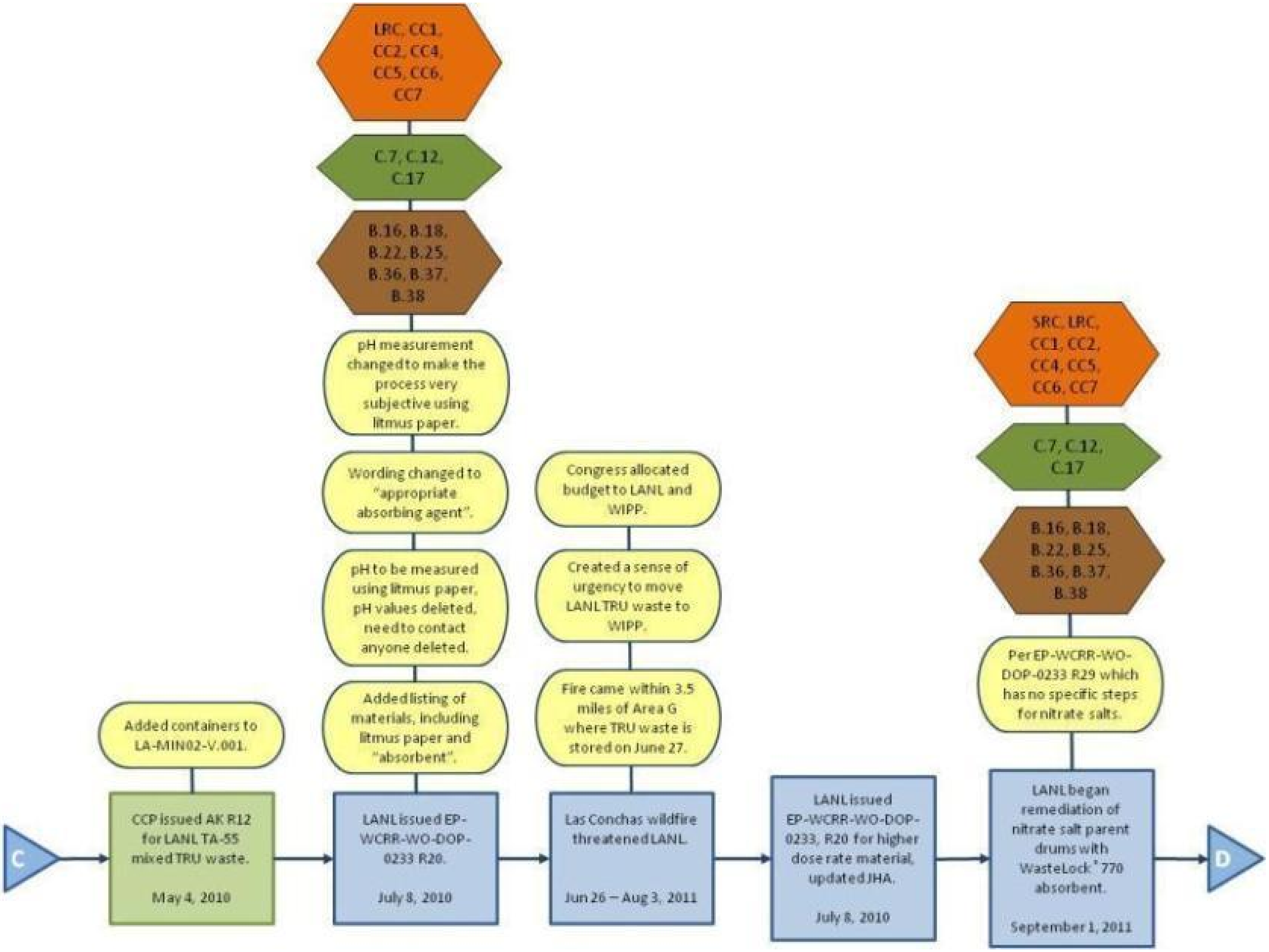


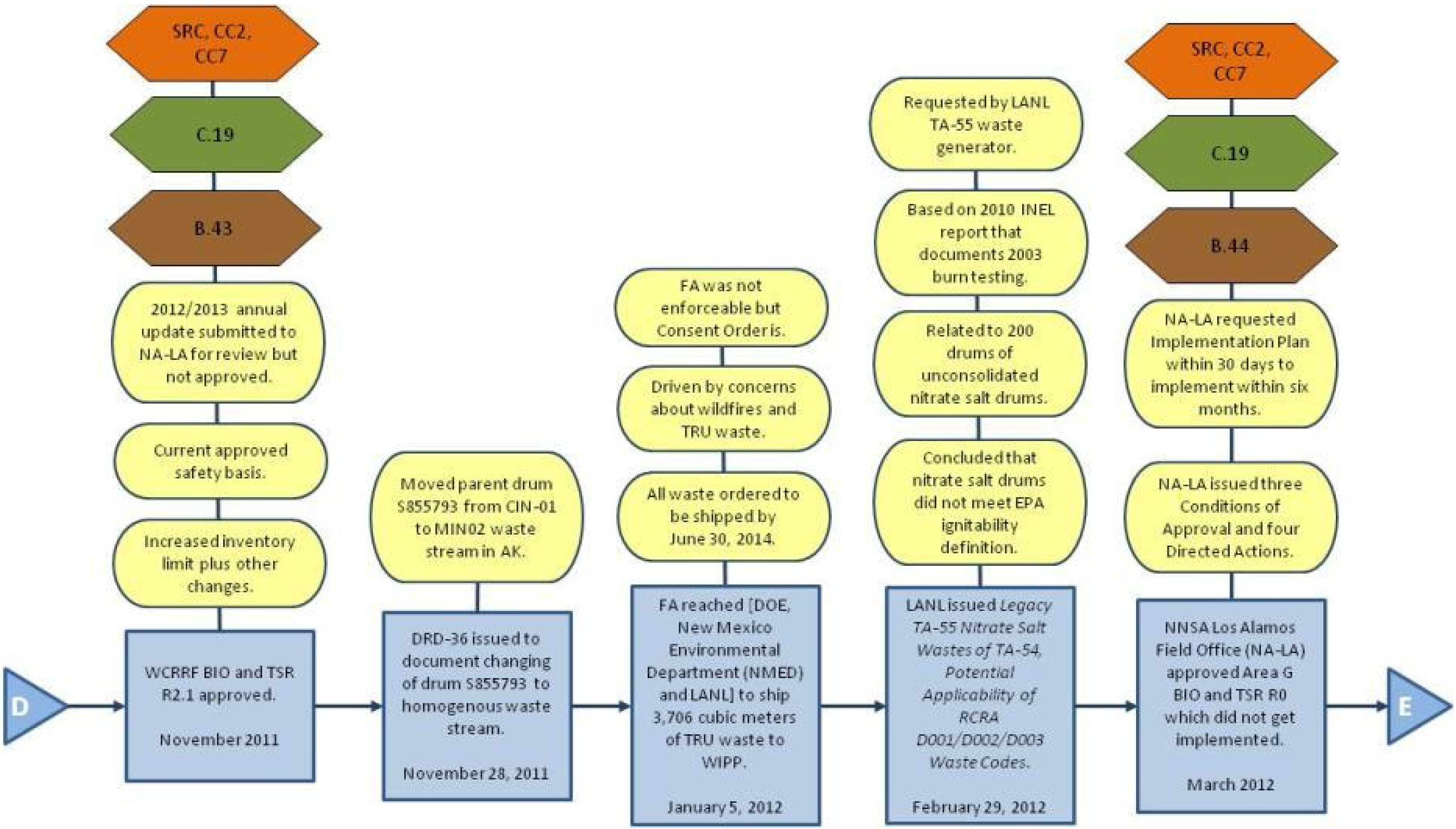
Table E-1: Event and Causal Factors Analysis

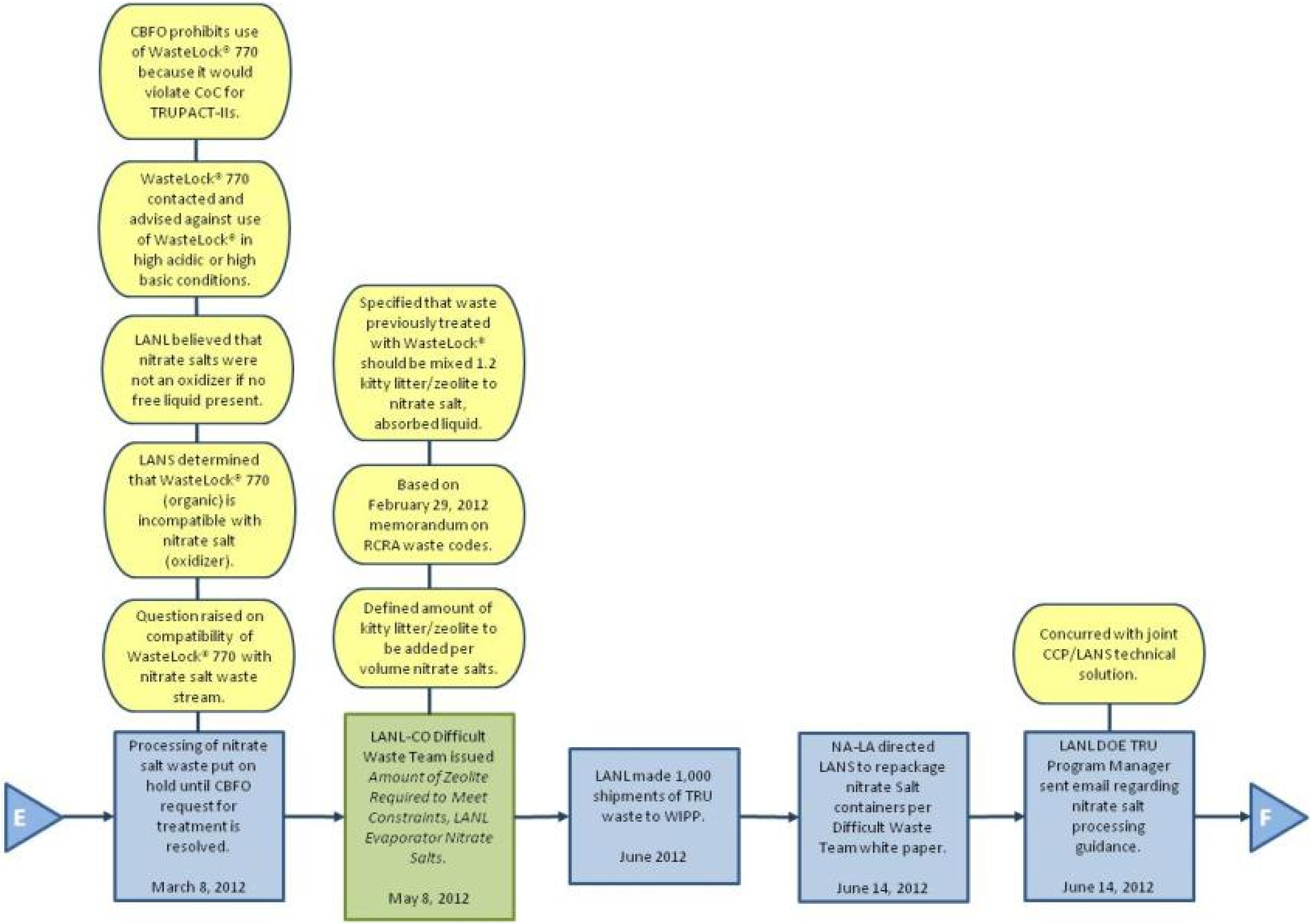


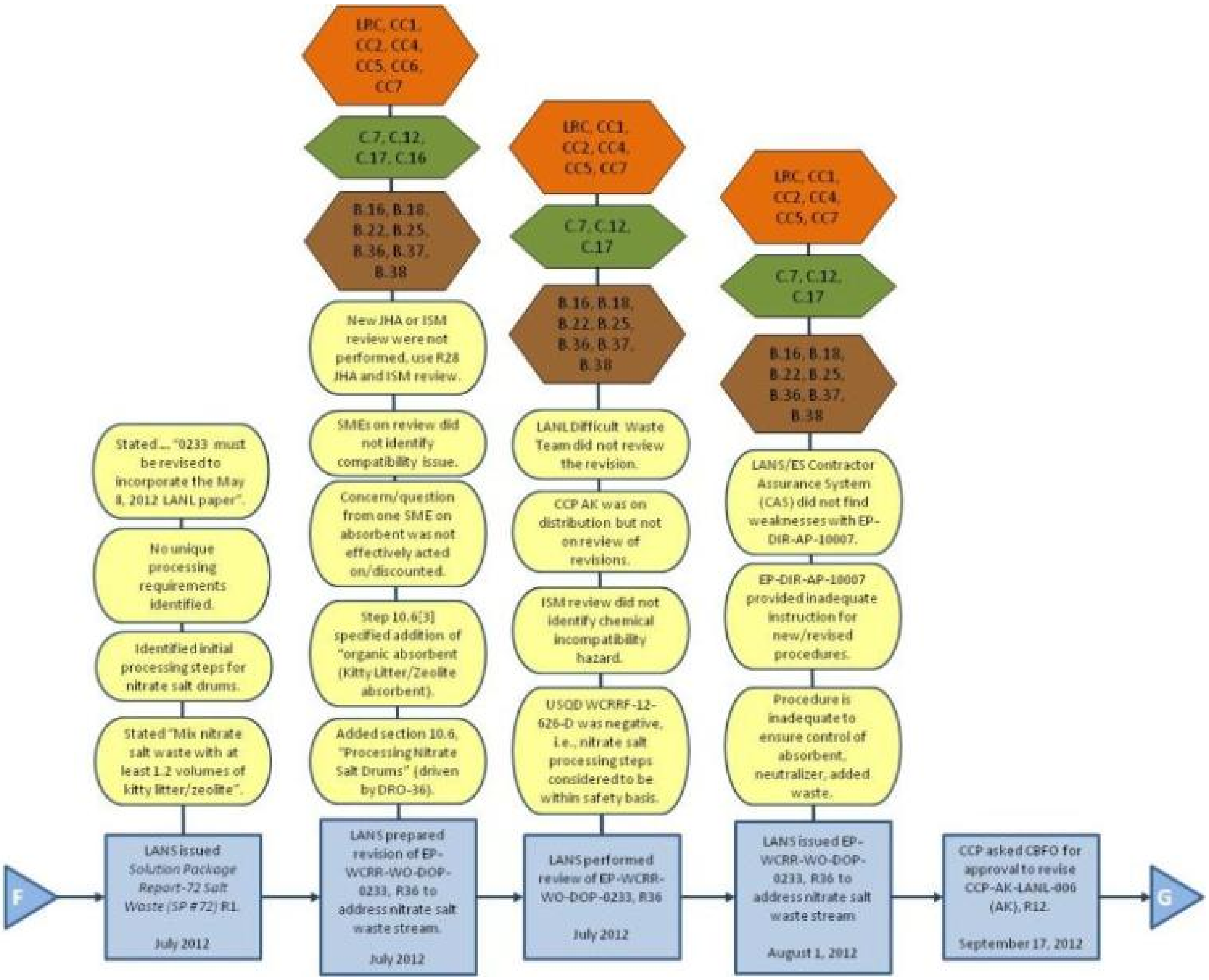

A
LANL Waste Characterization, Reduction and Packaging Facility (WCRRF) upgraded.
Late 2006-Early 2007
Upgraded to allow for sampling, examination, characterization, size reduction, and repackaging of TRU waste.
CCP issued CCP-AK-LANL-006, R6 to include new cemented inorganic waste LA-CIN01.01
March 27, 2007
Waste was from the cement fixation process performed in TA-55.
WCRRF Basis for Interim Operation (BIO) and Technical Safety Requirements (TSRs) R0 implemented.
April 2007
Initial safety basis after passing operational readiness review.
Included waste glovebox processing of prohibited items, including liquids.
BIO evaluated drum deflagration and fires related to accidents of concern.
Nitrate salt hazard was not identified so safety preventative controls were not evoked.
B.43
C.19
SRC, CC2, CC7
LANL issued EP-WCRR-WO-DOP-0233, R0 Glovebox Operations
May 23, 2007
"Absorbent" added if no reaction to adding small amount was observed at first.
Liquids assessed for corrosives "qualitatively" and dispositioned.
Specific nitrate salt processing steps were not defined.
40 CFR 261.21 ignitability characteristics not addressed.
CCP-PO-001 (QAPjP) did not ensure adequate waste processing method.
Did not control addition of secondary wastes to ensure compatibility.
LANL did not adequately flow down the LANL Hazardous Waste Facility Permit (HWFP) requirements.
EP-DIR-AP-10007 did not drive sufficient detail/controls.
SRC, LRC, CC1, CC2, CC4, CC5, CC7
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
WCRRF underwent DOE Operational Readiness Review (ORR)
Mid 2007
Approved to startup.
B

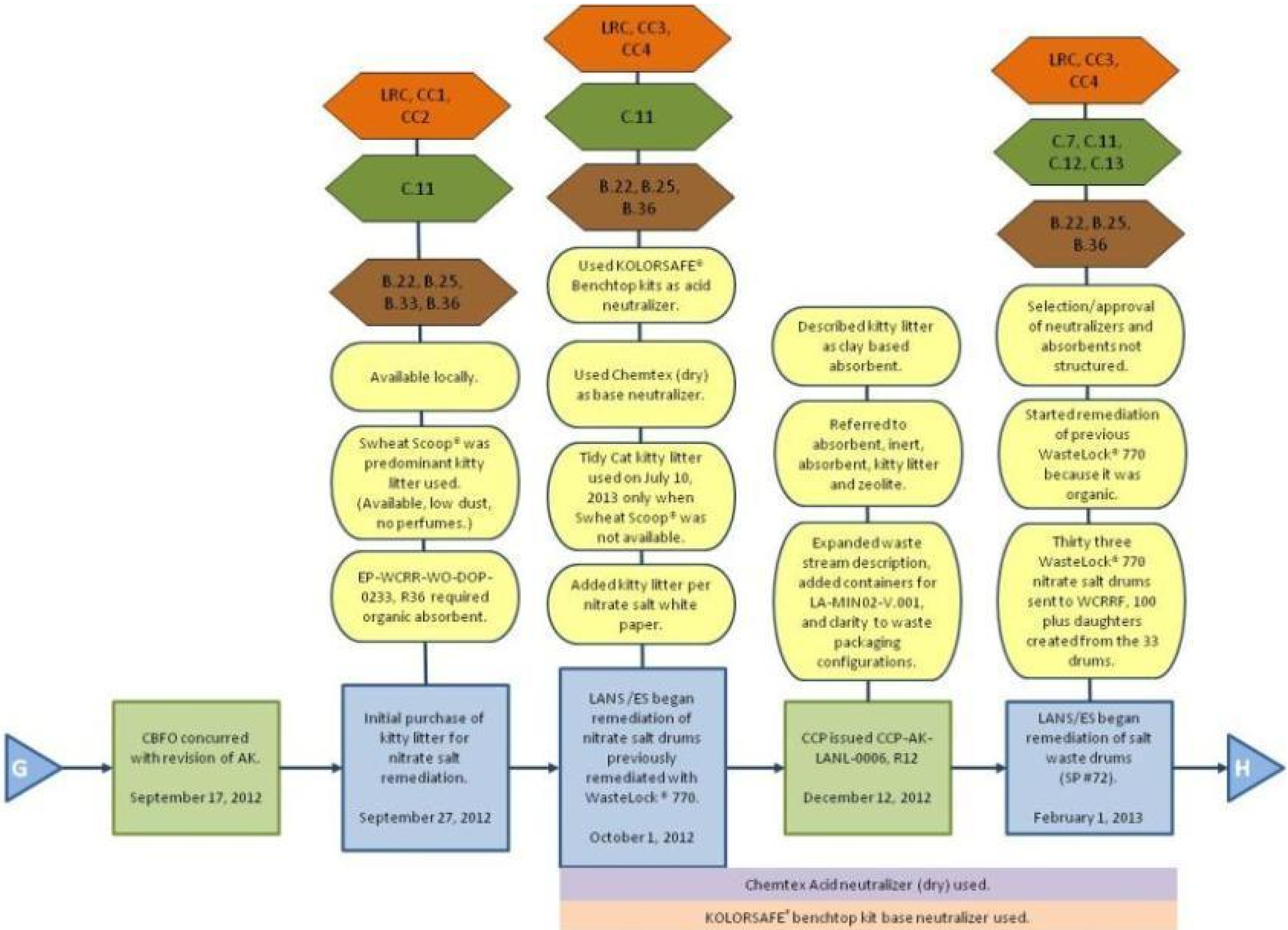

B
LRC, CC1, CC2, CC4, CC5, CC7
C.7, C.12, C.17
B.16, B.18, B.25, B.36, B.37, B.38
Added handling of oxidizer and assessment for peroxide forming chemicals.
Liquids removed from parent drum to be absorbed into new daughter drum.
Added disposition of liquids and actions if actual or suspect oxidizers, flammables, or pyro materials encountered.
LANL issued EP-WCRR-WO-DOP-0233 R3.
July 9, 2007
AK did not include evaluation of potential secondary wastes.
LA-MIN02-V.001 included nitrate salt wastes.
Addressed new absorbed liquid waste stream LA-MIN02-V.001.
CCP issued CCP-AK-LANL-006 R7.
November 30, 2007
Drove white paper (May 2012) and then development of Solution Package 72 (July 2012).
Identified 290 more drums that also must be addressed.
Required reassignment to separate waste stream.
Nonconformance Report NCR 5909 issued on 48 non-cemented evaporator salt drums from TA-55 in CIN01 waste stream.
June 23, 2009
LRC, CC1, CC2, CC4, CC5, CC7
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
Added "approved" before "absorbent" – mechanism not defined.
Added pH measurement for corrosives using test strips.
LANL issued EP-WCRR-WO-DOP-0233, R17.
February 8, 2010
Basis and conclusions not addressed in later glovebox operations procedure.
Affirmed that nitrate salts mixed with zeolite/kitty litter are non-oxidizing solid.
Included results of testing the most oxidizing mixture with zeolite or grout.
In response to discovery of nitrate salts during Pit 9 retrievals at INL.
EMRTC issued Framework Agreement (FR) 10-13, Results of Oxidizing Solids Testing.
April 12, 2010
C

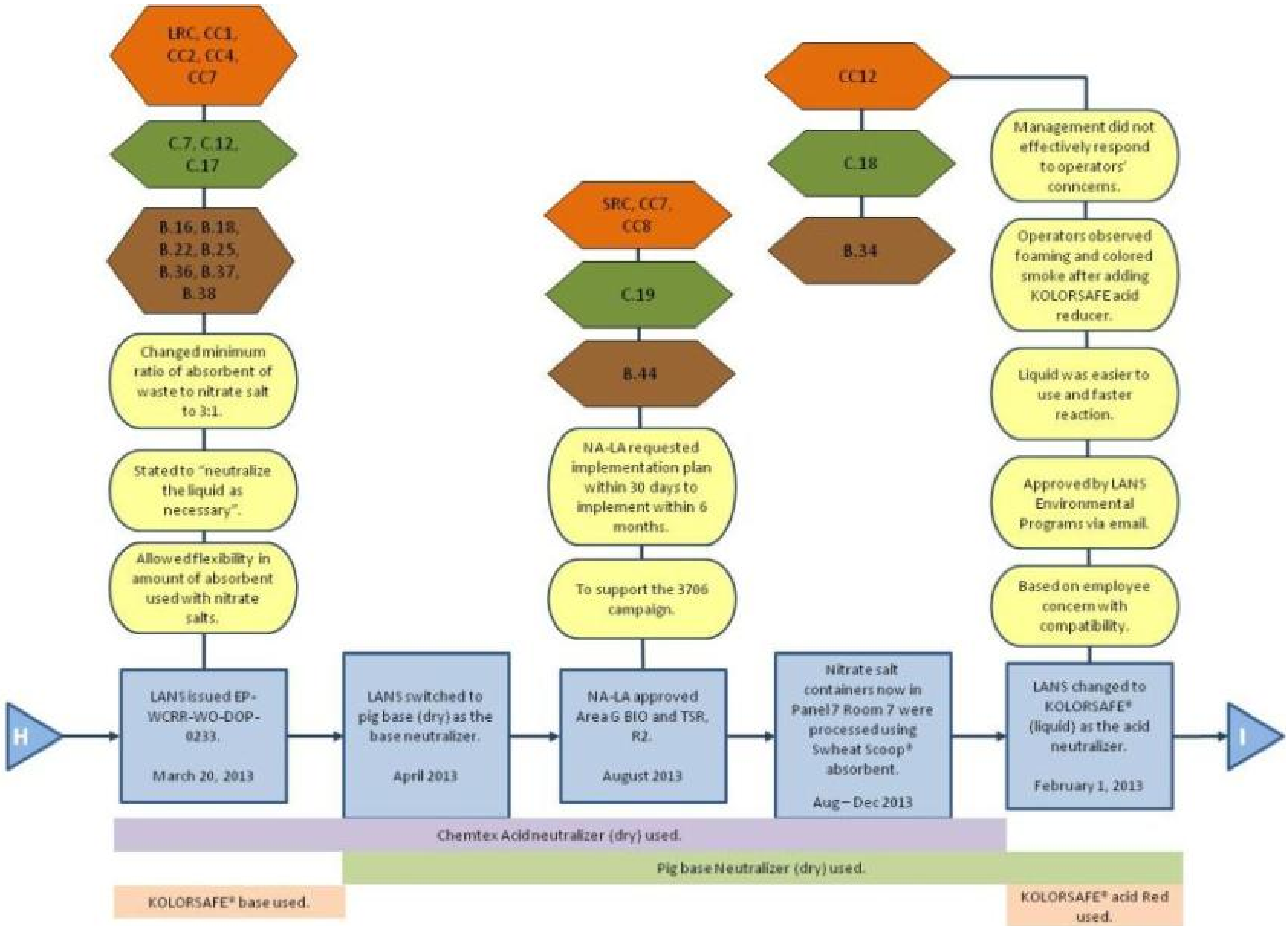

LRC, CC1, CC2, CC4, CC5, CC6, CC7
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
pH measurement changed to make the process very subjective using litmus paper.
Wording changed to "appropriate absorbing agent".
pH to be measured using litmus paper, pH values deleted, need to contact anyone deleted.
Added listing of materials, including litmus paper and "absorbent".
Added containers to LA-MIN02-V.001.
Congress allocated budget to LANL and WIPP.
Created a sense of urgency to move LANL TRU waste to WIPP.
Fire came within 3.5 miles of Area G where TRU waste is stored on June 27.
SRC, LRC, CC1, CC2, CC4, CC5, CC6, CC7
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
Per EP-WCRR-WO-DOP-0233 R29 which has no specific steps for nitrate salts.
C
CCP issued AK R12 for LANL TA-55 mixed TRU waste. May 4, 2010
LANL issued EP-WCRR-WO-DOP-0233 R20. July 8, 2010
Las Conchas wildfire threatened LANL. Jun 26 – Aug 3, 2011
LANL issued EP-WCRR-WO-DOP-0233, R20 for higher dose rate material, updated JHA. July 8, 2010
LANL began remediation of nitrate salt parent drums with WasteLock® 770 absorbent. September 1, 2011
D

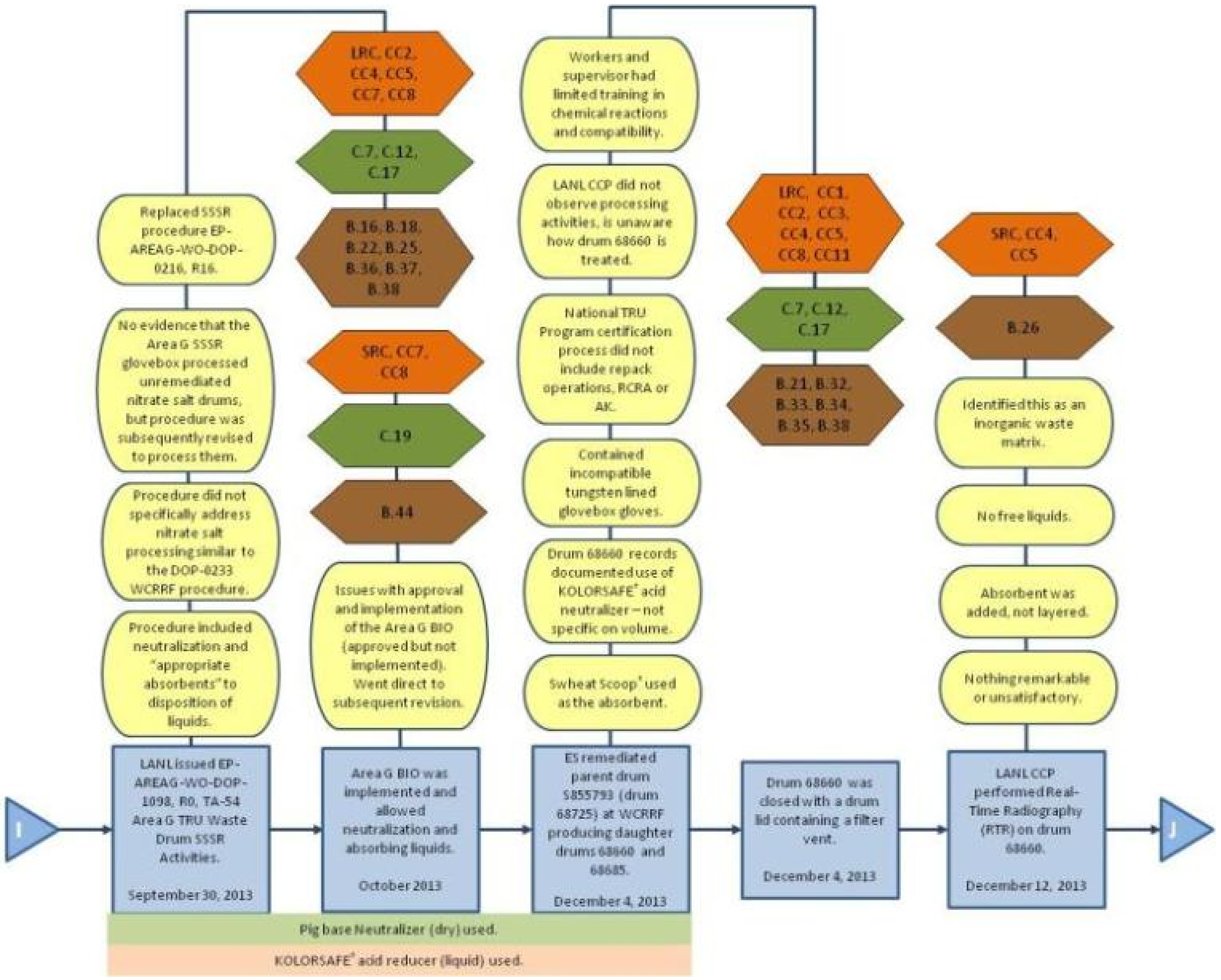

SRC, CC2, CC7
C.19
B.43
2012/2013 annual update submitted to NA-LA for review but not approved.
Current approved safety basis.
Increased inventory limit plus other changes.
D
WCRRF BIO and TSR R2.1 approved.
November 2011
Moved parent drum S855793 from CIN-01 to MIN02 waste stream in AK.
DRD-36 issued to document changing of drum S855793 to homogenous waste stream.
November 28, 2011
FA was not enforceable but Consent Order is.
Driven by concerns about wildfires and TRU waste.
All waste ordered to be shipped by June 30, 2014.
FA reached [DOE, New Mexico Environmental Department (NMED) and LANL] to ship 3,706 cubic meters of TRU waste to WIPP.
January 5, 2012
Requested by LANL TA-55 waste generator.
Based on 2010 INEL report that documents 2003 burn testing.
Related to 200 drums of unconsolidated nitrate salt drums.
Concluded that nitrate salt drums did not meet EPA ignitability definition.
LANL issued Legacy TA-55 Nitrate Salt Wastes of TA-54, Potential Applicability of RCRA D001/D002/D003 Waste Codes.
February 29, 2012
SRC, CC2, CC7
C.19
B.44
NA-LA requested Implementation Plan within 30 days to implement within six months.
NA-LA issued three Conditions of Approval and four Directed Actions.
NNSA Los Alamos Field Office (NA-LA) approved Area G BIO and TSR R0 which did not get implemented.
March 2012
E

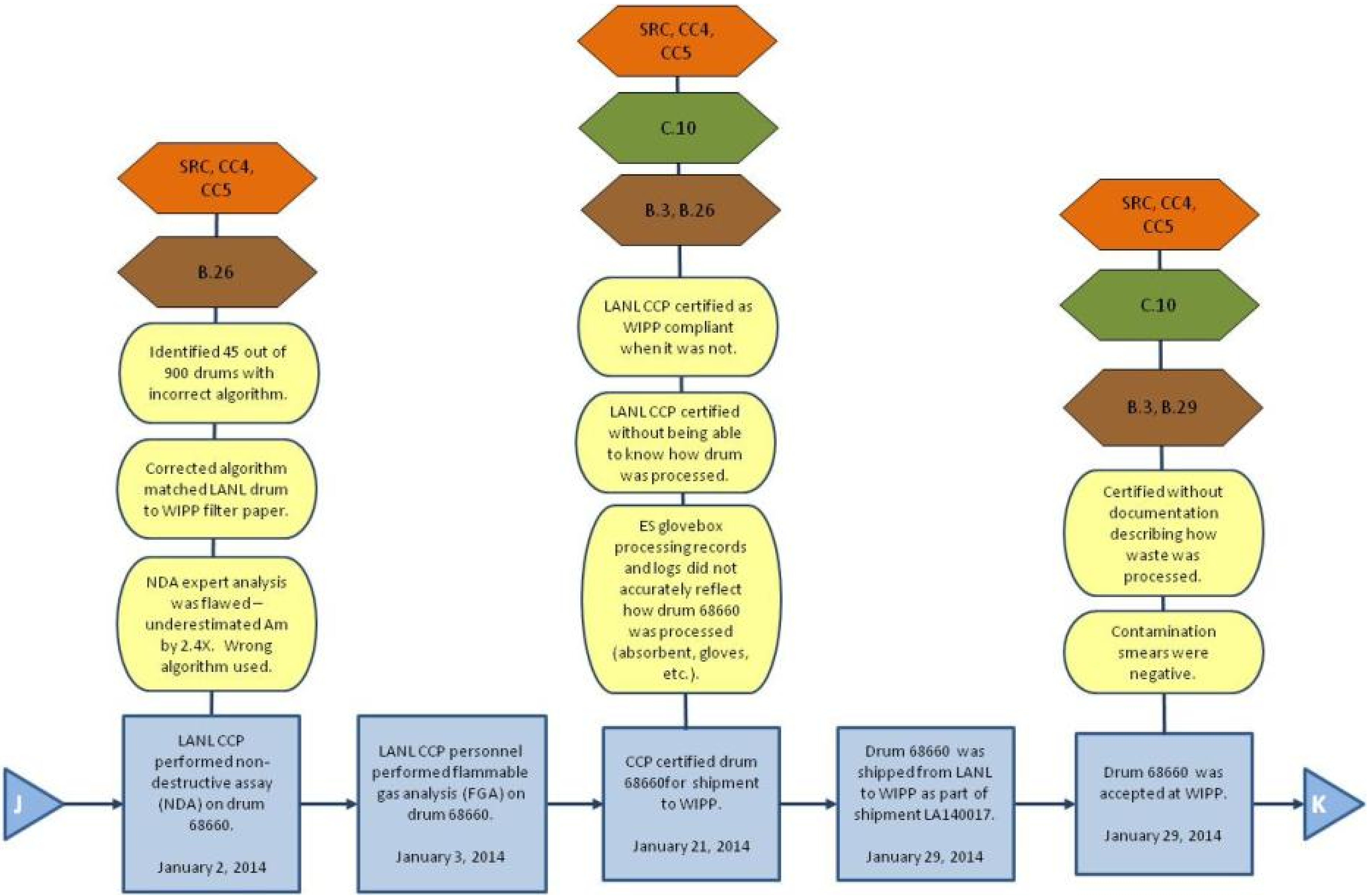

E
CBFO prohibits use of WasteLock® 770 because it would violate CoC for TRUPACT-IIs.
WasteLock® 770 contacted and advised against use of WasteLock® in high acidic or high basic conditions.
LANL believed that nitrate salts were not an oxidizer if no free liquid present.
LANS determined that WasteLock® 770 (organic) is incompatible with nitrate salt (oxidizer).
Question raised on compatibility of WasteLock® 770 with nitrate salt waste stream.
Processing of nitrate salt waste put on hold until CBFO request for treatment is resolved. March 8, 2012
Specified that waste previously treated with WasteLock® should be mixed 1.2 kitty litter/zeolite to nitrate salt, absorbed liquid.
Based on February 29, 2012 memorandum on RCRA waste codes.
Defined amount of kitty litter/zeolite to be added per volume nitrate salts.
LANL-CO Difficult Waste Team issued Amount of Zeolite Required to Meet Constraints, LANL Evaporator Nitrate Salts. May 8, 2012
LANL made 1,000 shipments of TRU waste to WIPP. June 2012
NA-LA directed LANS to repackage nitrate Salt containers per Difficult Waste Team white paper. June 14, 2012
Concurred with joint CCP/LANS technical solution.
LANL DOE TRU Program Manager sent email regarding nitrate salt processing guidance. June 14, 2012
F

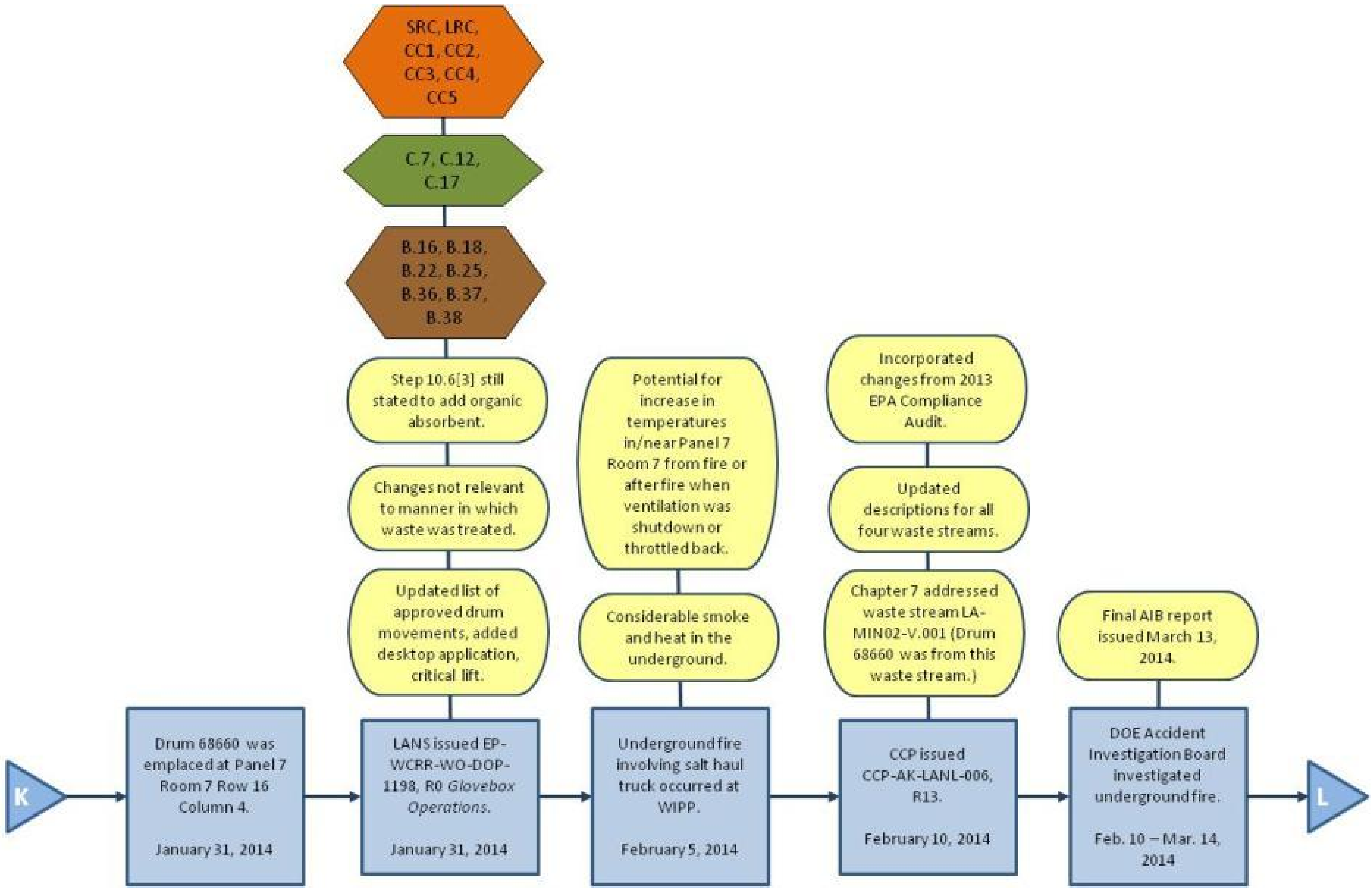

F
LANS issued Solution Package Report-72 Salt Waste (SP #72) R1. July 2012
Stated "Mix nitrate salt waste with at least 1.2 volumes of kitty litter/zeolite".
Identified initial processing steps for nitrate salt drums.
No unique processing requirements identified.
Stated ... "0233 must be revised to incorporate the May 8, 2012 LANL paper".
LANS prepared revision of EP-WCRR-WO-DOP-0233, R36 to address nitrate salt waste stream. July 2012
Added section 10.6, "Processing Nitrate Salt Drums" (driven by DRO-36).
Step 10.6[3] specified addition of "organic absorbent (Kitty Litter/Zeolite absorbent).
Concern/question from one SME on absorbent was not effectively acted on/discounted.
SMEs on review did not identify compatibility issue.
New JHA or ISM review were not performed, use R28 JHA and ISM review.
B.16, B.18, B.22, B.25, B.36, B.37, B.38
C.7, C.12, C.17, C.16
LRC, CC1, CC2, CC4, CC5, CC6, CC7
LANS performed review of EP-WCRR-WO-DOP-0233, R36 July 2012
USQD WCRRF-12-626-D was negative, i.e., nitrate salt processing steps considered to be within safety basis.
ISM review did not identify chemical incompatibility hazard.
CCP AK was on distribution but not on review of revisions.
LANL Difficult Waste Team did not review the revision.
B.16, B.18, B.22, B.25, B.36, B.37, B.38
C.7, C.12, C.17
LRC, CC1, CC2, CC4, CC5, CC7
LANS issued EP-WCRR-WO-DOP-0233, R36 to address nitrate salt waste stream. August 1, 2012
Procedure is inadequate to ensure control of absorbent, neutralizer, added waste.
EP-DIR-AP-10007 provided inadequate instruction for new/revised procedures.
LANS/ES Contractor Assurance System (CAS) did not find weaknesses with EP-DIR-AP-10007.
B.16, B.18, B.22, B.25, B.36, B.37, B.38
C.7, C.12, C.17
LRC, CC1, CC2, CC4, CC5, CC7
CCP asked CBFO for approval to revise CCP-AK-LANL-006 (AK), R12. September 17, 2012
G

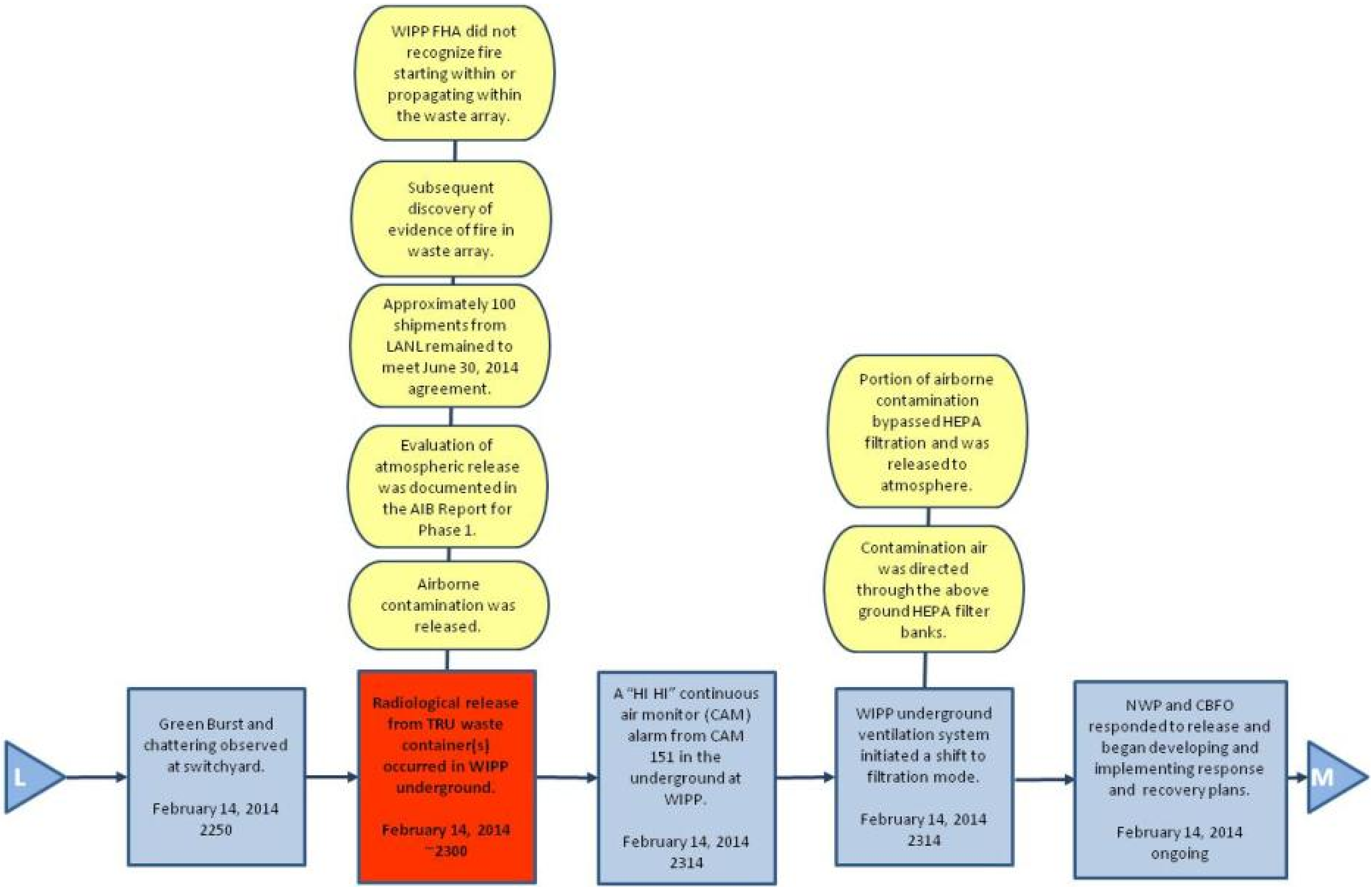

G
CBFO concurred with revision of AK.
September 17, 2012
LRC, CC1, CC2
C.11
B.22, B.25, B.33, B.36
Available locally.
Swheat Scoop® was predominant kitty litter used. (Available, low dust, no perfumes.)
EP-WCRR-WO-DOP-0233, R36 required organic absorbent.
Initial purchase of kitty litter for nitrate salt remediation.
September 27, 2012
LRC, CC3, CC4
C.11
B.22, B.25, B.36
Used KOLORSAFE® Benchtop kits as acid neutralizer.
Used Chemtex (dry) as base neutralizer.
Tidy Cat kitty litter used on July 10, 2013 only when Swheat Scoop® was not available.
Added kitty litter per nitrate salt white paper.
LANS/ES began remediation of nitrate salt drums previously remediated with WasteLock® 770.
October 1, 2012
Described kitty litter as clay based absorbent.
Referred to absorbent, inert, absorbent, kitty litter and zeolite.
Expanded waste stream description, added containers for LA-MIN02-V.001, and clarity to waste packaging configurations.
CCP issued CCP-AK-LANL-0006, R12
December 12, 2012
LRC, CC3, CC4
C.7, C.11, C.12, C.13
B.22, B.25, B.36
Selection/approval of neutralizers and absorbents not structured.
Started remediation of previous WasteLock® 770 because it was organic.
Thirty three WasteLock® 770 nitrate salt drums sent to WCRRF, 100 plus daughters created from the 33 drums.
LANS/ES began remediation of salt waste drums (SP #72).
February 1, 2013
H
Chemtex Acid neutralizer (dry) used.
KOLORSAFE® benchtop kit base neutralizer used.

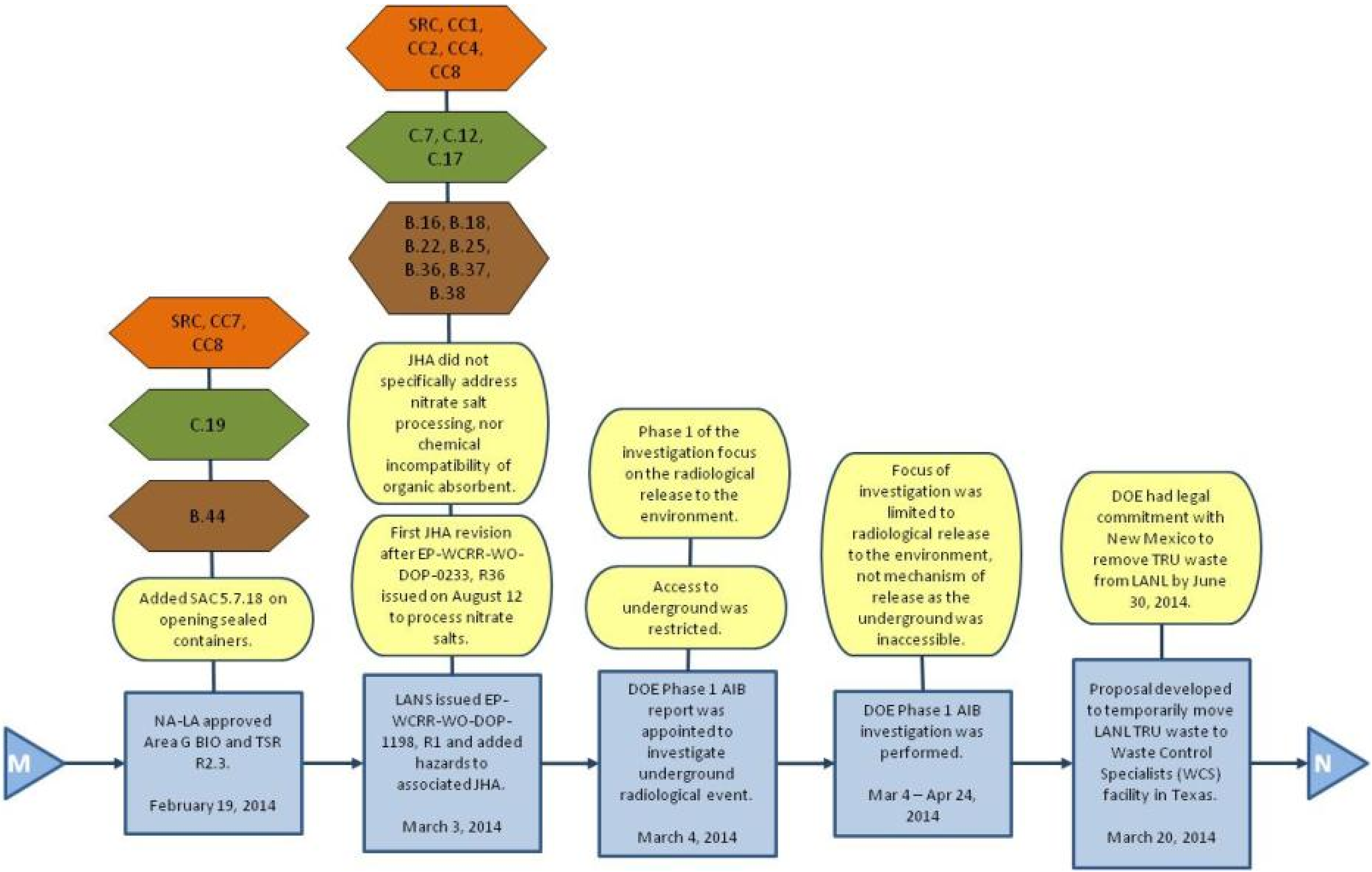

LRC, CC1, CC2, CC4, CC7
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
Changed minimum ratio of absorbent of waste to nitrate salt to 3:1.
Stated to "neutralize the liquid as necessary".
Allowed flexibility in amount of absorbent used with nitrate salts.
SRC, CC7, CC8
C.19
B.44
NA-LA requested implementation plan within 30 days to implement within 6 months.
To support the 3706 campaign.
CC12
C.18
B.34
Management did not effectively respond to operators' conncerns.
Operators observed foaming and colored smoke after adding KOLORSAFE acid reducer.
Liquid was easier to use and faster reaction.
Approved by LANS Environmental Programs via email.
Based on employee concern with compatibility.
H
LANS issued EP-WCRR-WO-DOP-0233. March 20, 2013
LANS switched to pig base (dry) as the base neutralizer. April 2013
NA-LA approved Area G BIO and TSR, R2. August 2013
Nitrate salt containers now in Panel 7 Room 7 were processed using Swheat Scoop® absorbent. Aug – Dec 2013
LANS changed to KOLORSAFE® (liquid) as the acid neutralizer. February 1, 2013
I
Chemtex Acid neutralizer (dry) used.
Pig base Neutralizer (dry) used.
KOLORSAFE® base used.
KOLORSAFE® acid Red used.

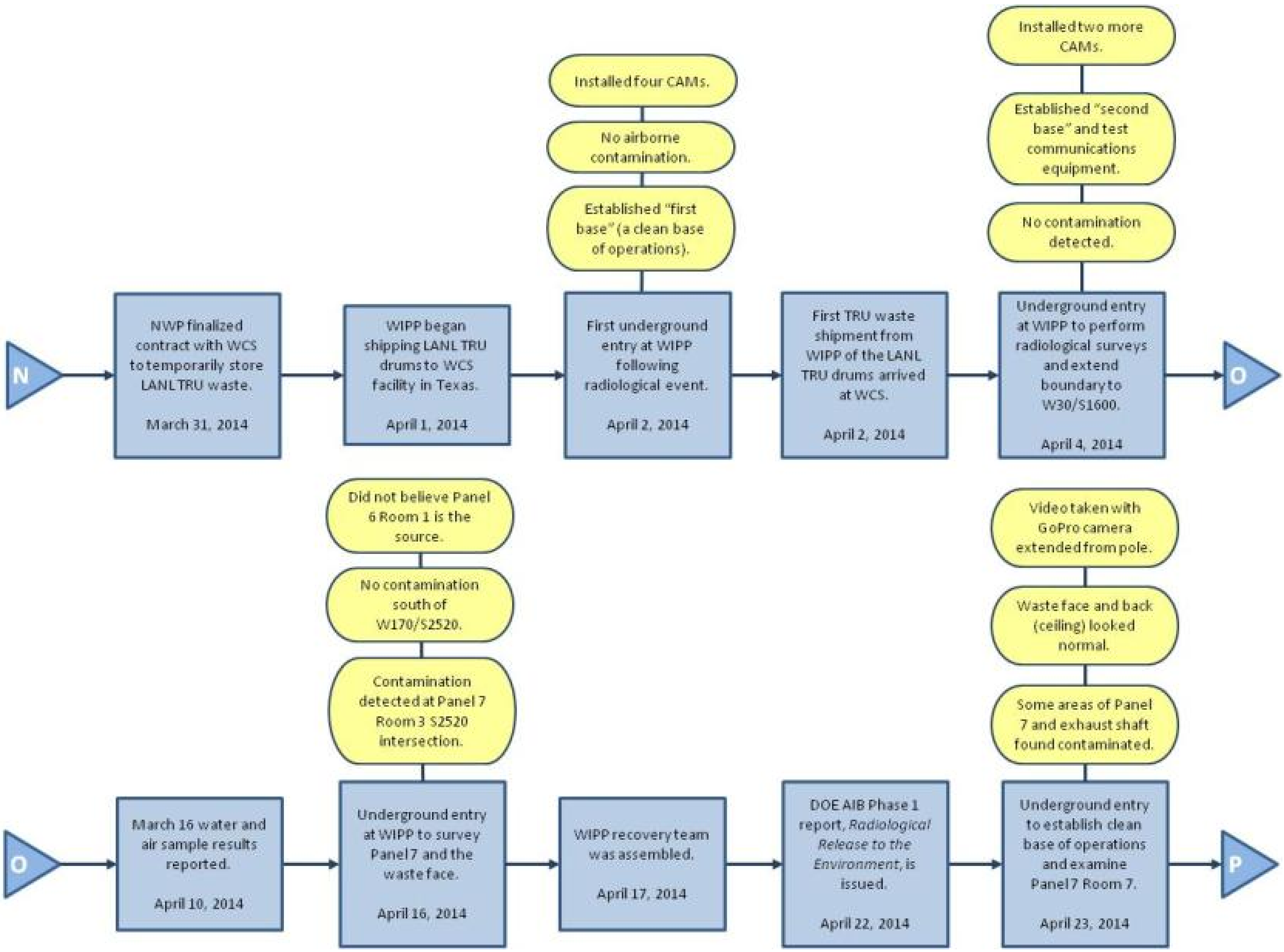

I
LANL issued EP-AREAG-WO-DOP-1098, R0, TA-54 Area G TRU Waste Drum SSSR Activities.
September 30, 2013
Procedure included neutralization and "appropriate absorbents" to disposition of liquids.
Procedure did not specifically address nitrate salt processing similar to the DOP-0233 WCRRF procedure.
No evidence that the Area G SSSR glovebox processed unremediated nitrate salt drums, but procedure was subsequently revised to process them.
Replaced SSSR procedure EP-AREAG-WO-DOP-0216, R16.
LRC, CC2, CC4, CC5, CC7, CC8
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
SRC, CC7, CC8
C.19
B.44
Issues with approval and implementation of the Area G BIO (approved but not implemented). Went direct to subsequent revision.
Area G BIO was implemented and allowed neutralization and absorbing liquids.
October 2013
Workers and supervisor had limited training in chemical reactions and compatibility.
LANL CCP did not observe processing activities, is unaware how drum 68660 is treated.
National TRU Program certification process did not include repack operations, RCRA or AK.
Contained incompatible tungsten lined glovebox gloves.
Drum 68660 records documented use of KOLORSAFE® acid neutralizer – not specific on volume.
Swheat Scoop® used as the absorbent.
ES remediated parent drum S855793 (drum 68725) at WCRRF producing daughter drums 68660 and 68685.
December 4, 2013
Pig base Neutralizer (dry) used.
KOLORSAFE® acid reducer (liquid) used.
LRC, CC1, CC2, CC3, CC4, CC5, CC8, CC11
C.7, C.12, C.17
B.21, B.32, B.33, B.34, B.35, B.38
Drum 68660 was closed with a drum lid containing a filter vent.
December 4, 2013
SRC, CC4, CC5
B.26
Identified this as an inorganic waste matrix.
No free liquids.
Absorbent was added, not layered.
Nothing remarkable or unsatisfactory.
LANL CCP performed Real-Time Radiography (RTR) on drum 68660.
December 12, 2013
J

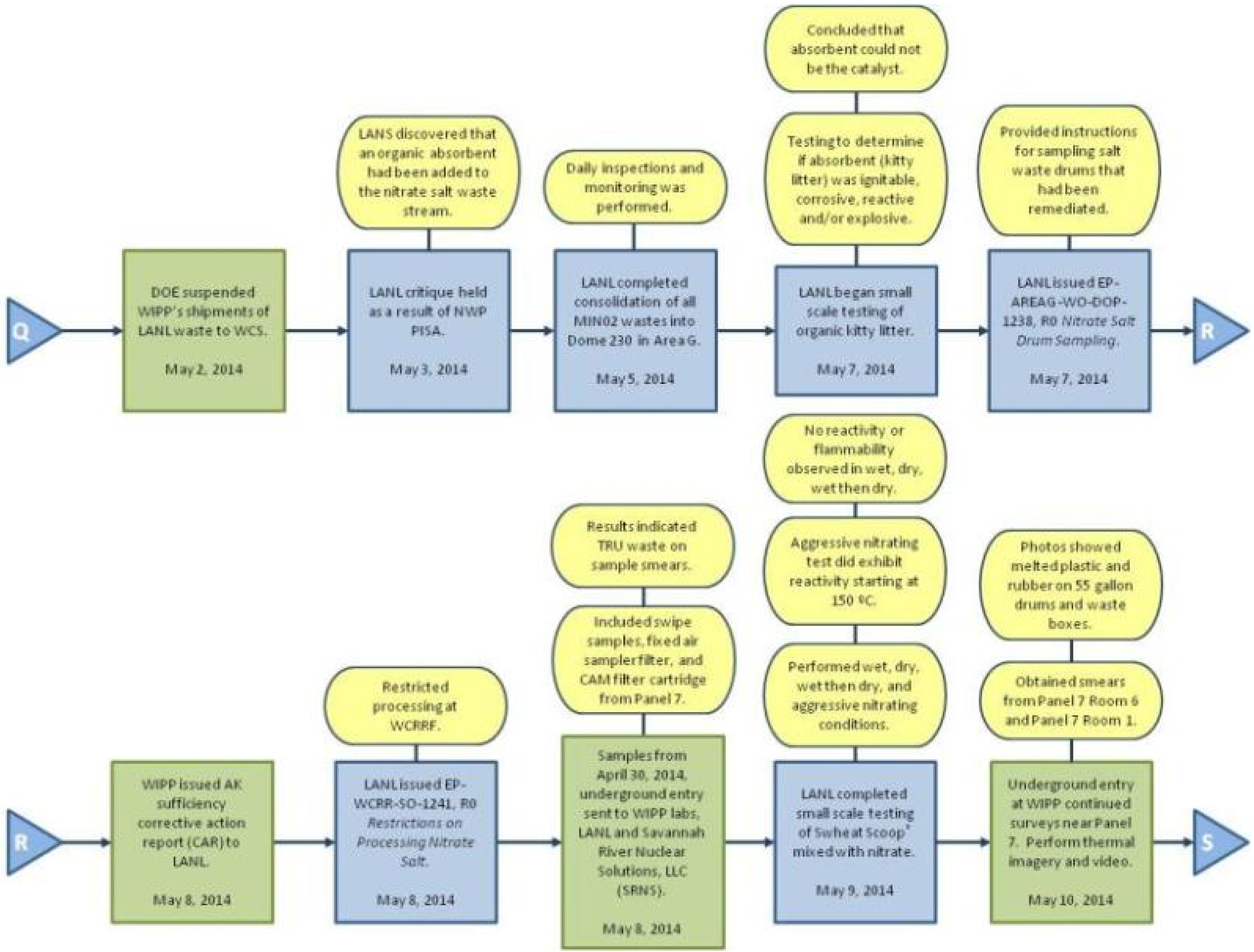

SRC, CC4, CC5
B.26
Identified 45 out of 900 drums with incorrect algorithm.
Corrected algorithm matched LANL drum to WIPP filter paper.
NDA expert analysis was flawed – underestimated Am by 2.4X. Wrong algorithm used.
SRC, CC4, CC5
C.10
B.3, B.26
LANL CCP certified as WIPP compliant when it was not.
LANL CCP certified without being able to know how drum was processed.
ES glovebox processing records and logs did not accurately reflect how drum 68660 was processed (absorbent, gloves, etc.).
SRC, CC4, CC5
C.10
B.3, B.29
Certified without documentation describing how waste was processed.
Contamination smears were negative.
J
LANL CCP performed non-destructive assay (NDA) on drum 68660.
January 2, 2014
LANL CCP personnel performed flammable gas analysis (FGA) on drum 68660.
January 3, 2014
CCP certified drum 68660for shipment to WIPP.
January 21, 2014
Drum 68660 was shipped from LANL to WIPP as part of shipment LA140017.
January 29, 2014
Drum 68660 was accepted at WIPP.
January 29, 2014
K

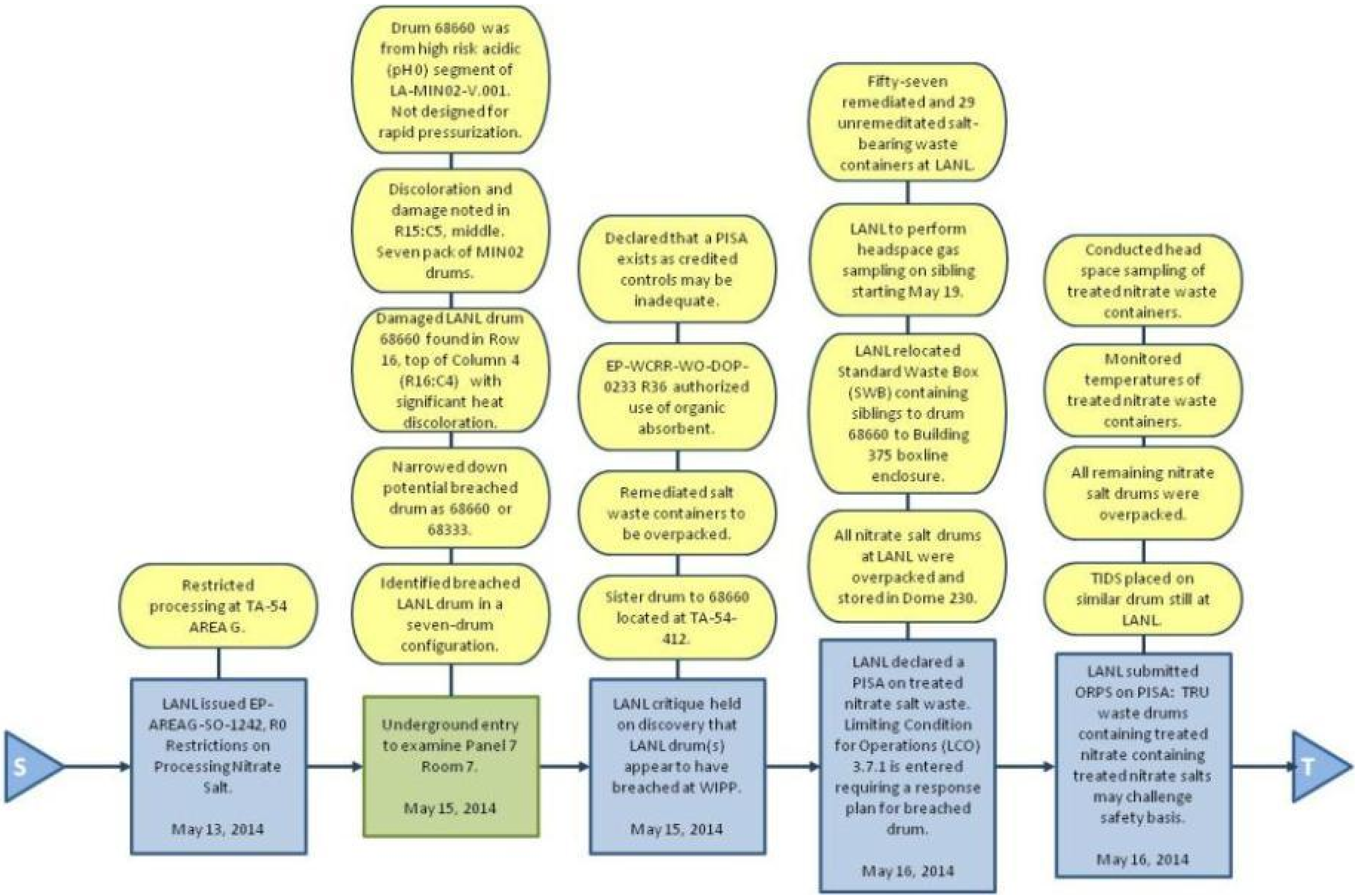

SRC, LRC, CC1, CC2, CC3, CC4, CC5
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
Step 10.6[3] still stated to add organic absorbent.
Changes not relevant to manner in which waste was treated.
Updated list of approved drum movements, added desktop application, critical lift.
Potential for increase in temperatures in/near Panel 7 Room 7 from fire or after fire when ventilation was shutdown or throttled back.
Considerable smoke and heat in the underground.
Incorporated changes from 2013 EPA Compliance Audit.
Updated descriptions for all four waste streams.
Chapter 7 addressed waste stream LA-MIN02-V.001 (Drum 68660 was from this waste stream.)
Final AIB report issued March 13, 2014.
K
Drum 68660 was emplaced at Panel 7 Room 7 Row 16 Column 4.
January 31, 2014
LANS issued EP-WCRR-WO-DOP-1198, R0 Glovebox Operations.
January 31, 2014
Underground fire involving salt haul truck occurred at WIPP.
February 5, 2014
CCP issued CCP-AK-LANL-006, R13.
February 10, 2014
DOE Accident Investigation Board investigated underground fire.
Feb. 10 – Mar. 14, 2014
L

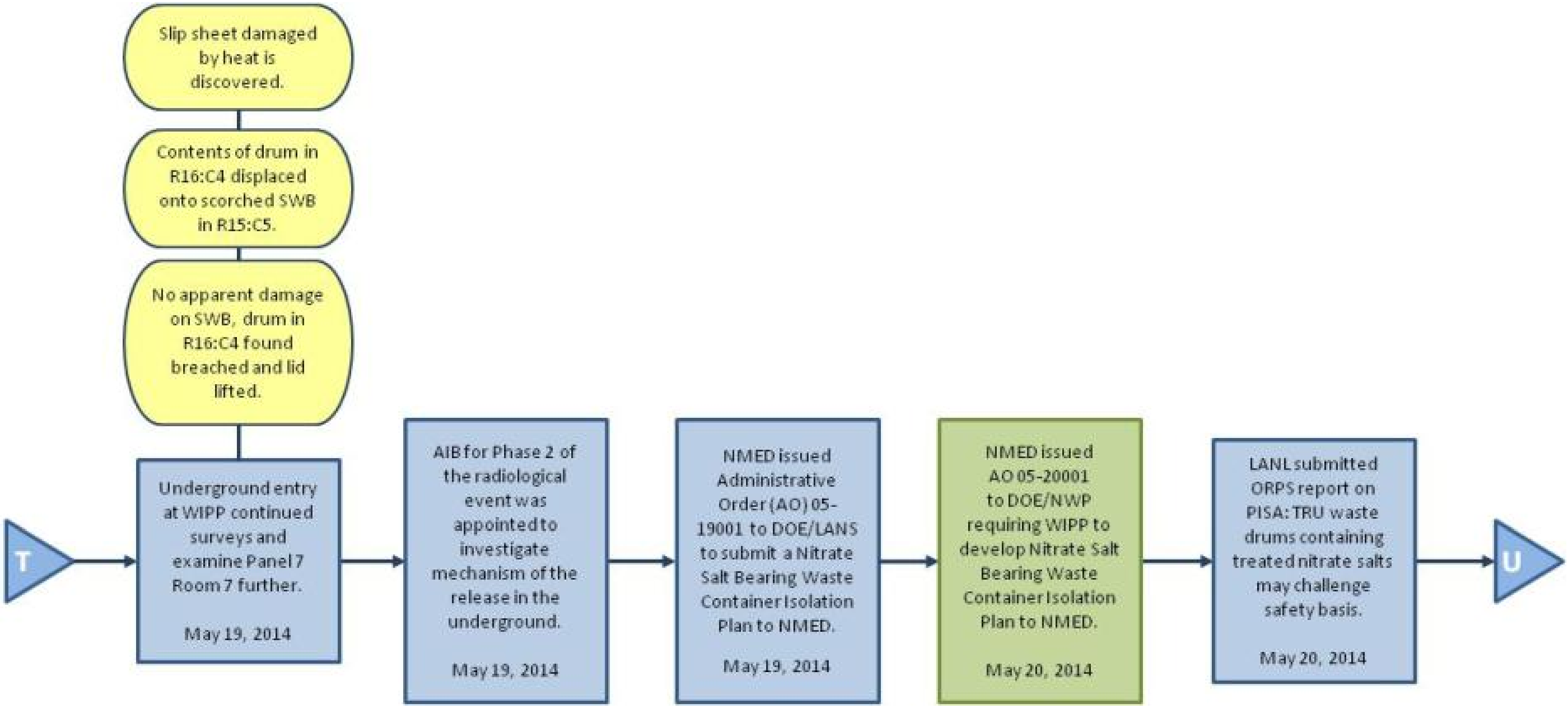

WIPP FHA did not recognize fire starting within or propagating within the waste array.
Subsequent discovery of evidence of fire in waste array.
Approximately 100 shipments from LANL remained to meet June 30, 2014 agreement.
Evaluation of atmospheric release was documented in the AIB Report for Phase 1.
Airborne contamination was released.
L
Green Burst and chattering observed at switchyard. February 14, 2014 2250
Radiological release from TRU waste container(s) occurred in WIPP underground. February 14, 2014 ~2300
A "HI HI" continuous air monitor (CAM) alarm from CAM 151 in the underground at WIPP. February 14, 2014 2314
Portion of airborne contamination bypassed HEPA filtration and was released to atmosphere.
Contamination air was directed through the above ground HEPA filter banks.
WIPP underground ventilation system initiated a shift to filtration mode. February 14, 2014 2314
NWP and CBFO responded to release and began developing and implementing response and recovery plans. February 14, 2014 ongoing
M

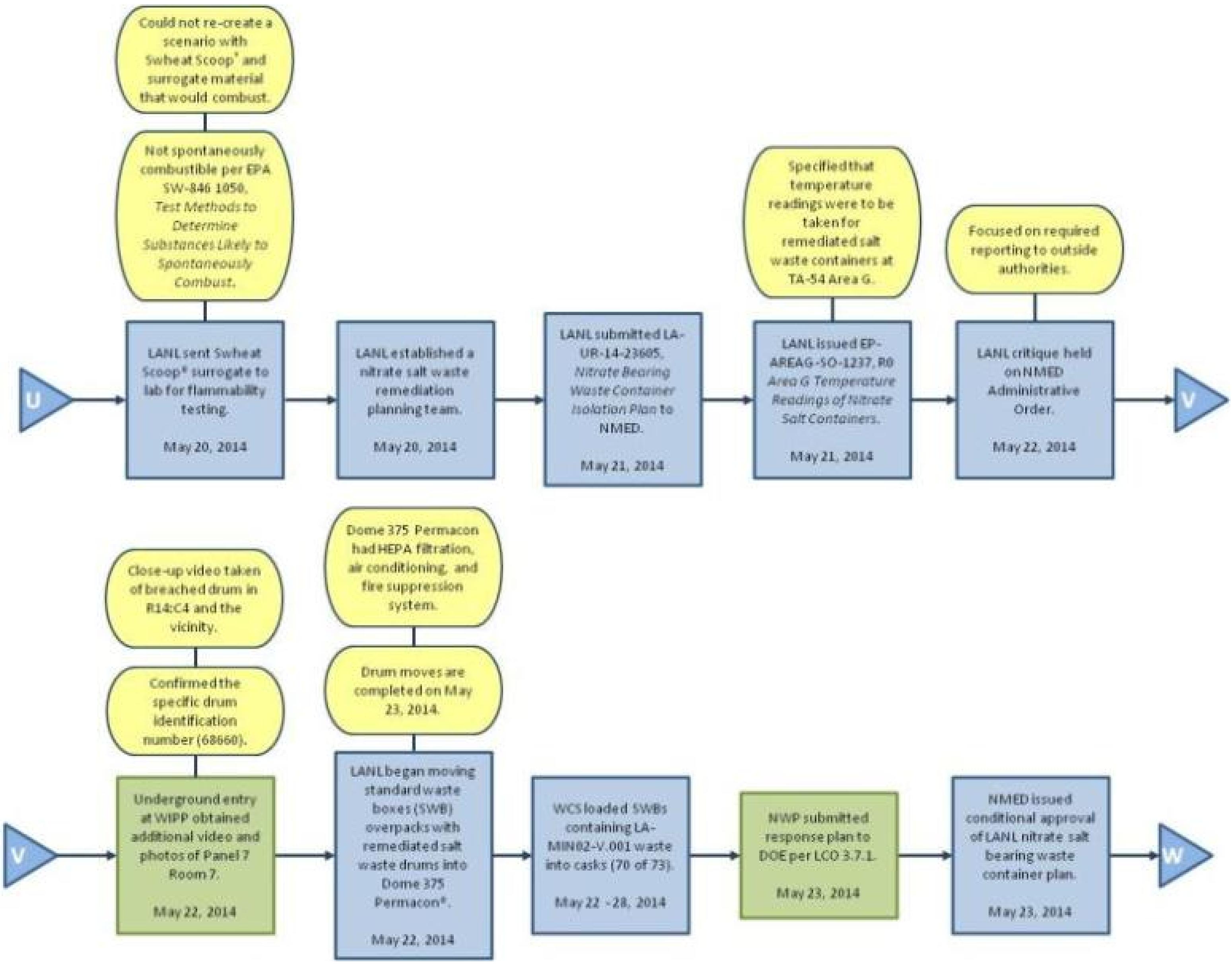

SRC, CC1, CC2, CC4, CC8
C.7, C.12, C.17
B.16, B.18, B.22, B.25, B.36, B.37, B.38
JHA did not specifically address nitrate salt processing, nor chemical incompatibility of organic absorbent.
First JHA revision after EP-WCRR-WO-DOP-0233, R36 issued on August 12 to process nitrate salts.
SRC, CC7, CC8
C.19
B.44
Added SAC 5.7.18 on opening sealed containers.
Phase 1 of the investigation focus on the radiological release to the environment.
Access to underground was restricted.
Focus of investigation was limited to radiological release to the environment, not mechanism of release as the underground was inaccessible.
DOE had legal commitment with New Mexico to remove TRU waste from LANL by June 30, 2014.
M
NA-LA approved Area G BIO and TSR R2.3.
February 19, 2014
LANS issued EP-WCRR-WO-DOP-1198, R1 and added hazards to associated JHA.
March 3, 2014
DOE Phase 1 AIB report was appointed to investigate underground radiological event.
March 4, 2014
DOE Phase 1 AIB investigation was performed.
Mar 4 – Apr 24, 2014
Proposal developed to temporarily move LANL TRU waste to Waste Control Specialists (WCS) facility in Texas.
March 20, 2014
N

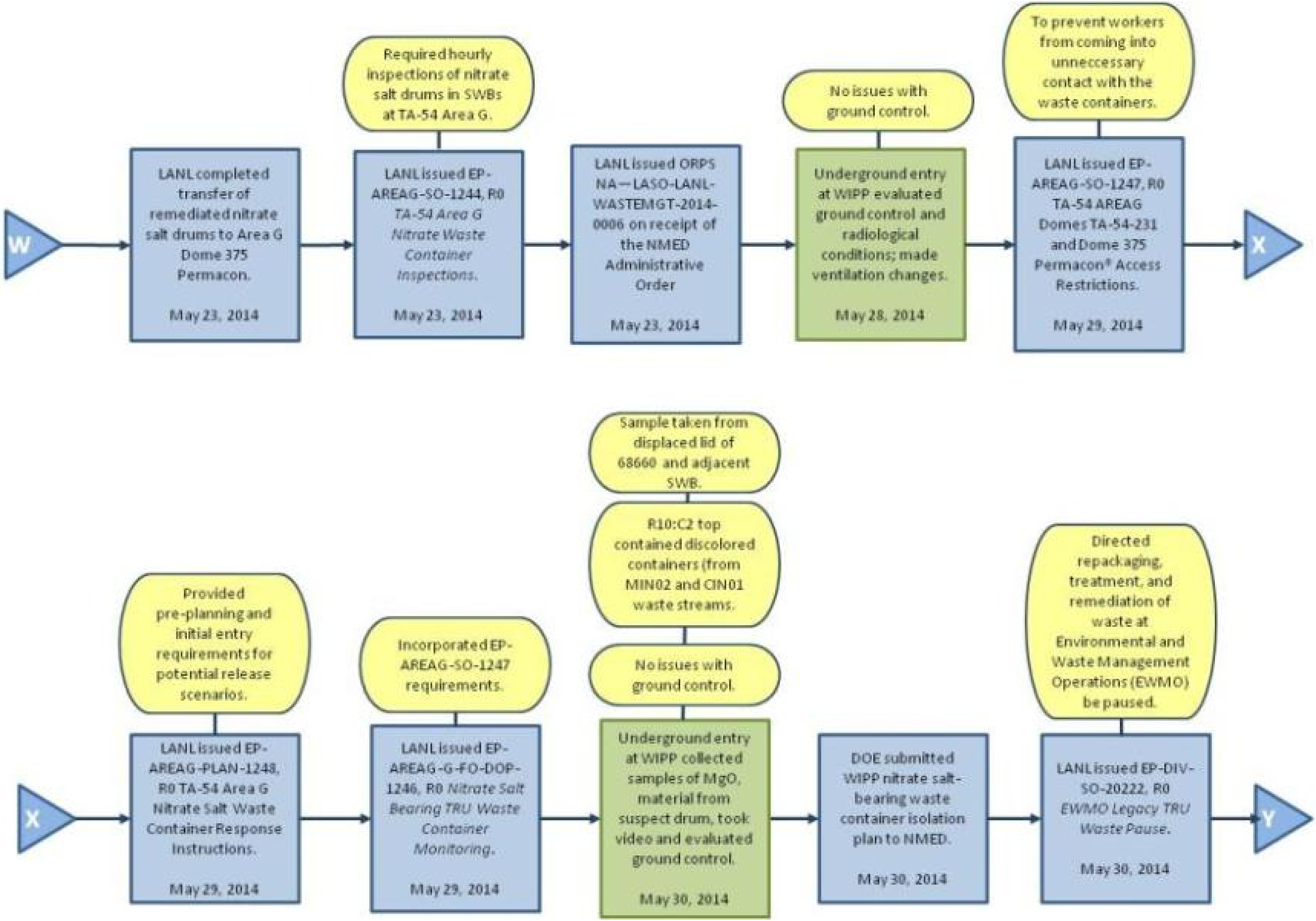

N
NWP finalized contract with WCS to temporarily store LANL TRU waste. March 31, 2014
WIPP began shipping LANL TRU drums to WCS facility in Texas. April 1, 2014
First underground entry at WIPP following radiological event. April 2, 2014
Established "first base" (a clean base of operations).
No airborne contamination.
Installed four CAMs.
First TRU waste shipment from WIPP of the LANL TRU drums arrived at WCS. April 2, 2014
Underground entry at WIPP to perform radiological surveys and extend boundary to W30/S1600. April 4, 2014
No contamination detected.
Established "second base" and test communications equipment.
Installed two more CAMs.
O
O
March 16 water and air sample results reported. April 10, 2014
Underground entry at WIPP to survey Panel 7 and the waste face. April 16, 2014
Contamination detected at Panel 7 Room 3 S2520 intersection.
No contamination south of W170/S2520.
Did not believe Panel 6 Room 1 is the source.
WIPP recovery team was assembled. April 17, 2014
DOE AIB Phase 1 report, Radiological Release to the Environment, is issued. April 22, 2014
Underground entry to establish clean base of operations and examine Panel 7 Room 7. April 23, 2014
Some areas of Panel 7 and exhaust shaft found contaminated.
Waste face and back (ceiling) looked normal.
Video taken with GoPro camera extended from pole.
P

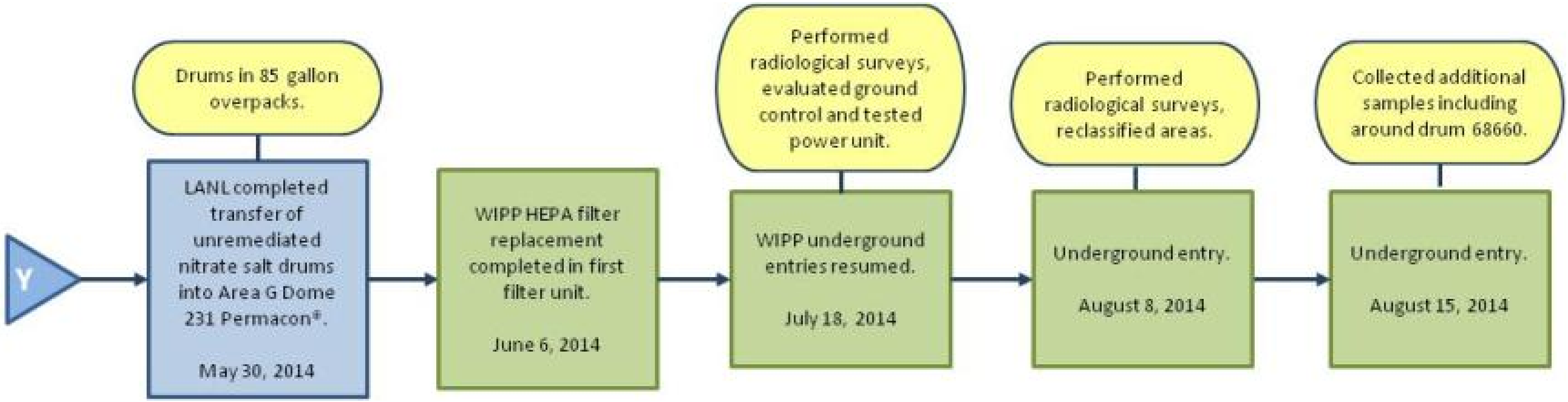

Q
DOE suspended WIPP's shipments of LANL waste to WCS. May 2, 2014
LANS discovered that an organic absorbent had been added to the nitrate salt waste stream.
LANL critique held as a result of NWP PISA. May 3, 2014
Daily inspections and monitoring was performed.
LANL completed consolidation of all MIN02 wastes into Dome 230 in Area G. May 5, 2014
Concluded that absorbent could not be the catalyst.
Testing to determine if absorbent (kitty litter) was ignitable, corrosive, reactive and/or explosive.
LANL began small scale testing of organic kitty litter. May 7, 2014
Provided instructions for sampling salt waste drums that had been remediated.
LANL issued EP-AREAG-WO-DOP-1238, R0 Nitrate Salt Drum Sampling. May 7, 2014
R
R
WIPP issued AK sufficiency corrective action report (CAR) to LANL. May 8, 2014
Restricted processing at WCRRF.
LANL issued EP-WCRR-SO-1241, R0 Restrictions on Processing Nitrate Salt. May 8, 2014
Results indicated TRU waste on sample smears.
Included swipe samples, fixed air sampler filter, and CAM filter cartridge from Panel 7.
Samples from April 30, 2014, underground entry sent to WIPP labs, LANL and Savannah River Nuclear Solutions, LLC (SRNS). May 8, 2014
No reactivity or flammability observed in wet, dry, wet then dry.
Aggressive nitrating test did exhibit reactivity starting at 150 ºC.
Performed wet, dry, wet then dry, and aggressive nitrating conditions.
LANL completed small scale testing of Swheat Scoop® mixed with nitrate. May 9, 2014
Photos showed melted plastic and rubber on 55 gallon drums and waste boxes.
Obtained smears from Panel 7 Room 6 and Panel 7 Room 1.
Underground entry at WIPP continued surveys near Panel 7. Perform thermal imagery and video. May 10, 2014
S


S
Restricted processing at TA-54 AREA G.
LANL issued EP-AREAG-SO-1242, R0 Restrictions on Processing Nitrate Salt. May 13, 2014
Drum 68660 was from high risk acidic (pH 0) segment of LA-MIN02-V.001. Not designed for rapid pressurization.
Discoloration and damage noted in R15:C5, middle. Seven pack of MIN02 drums.
Damaged LANL drum 68660 found in Row 16, top of Column 4 (R16:C4) with significant heat discoloration.
Narrowed down potential breached drum as 68660 or 68333.
Identified breached LANL drum in a seven-drum configuration.
Underground entry to examine Panel 7 Room 7. May 15, 2014
Declared that a PISA exists as credited controls may be inadequate.
EP-WCRR-WO-DOP-0233 R36 authorized use of organic absorbent.
Remediated salt waste containers to be overpacked.
Sister drum to 68660 located at TA-54-412.
LANL critique held on discovery that LANL drum(s) appear to have breached at WIPP. May 15, 2014
Fifty-seven remediated and 29 unremeditated salt-bearing waste containers at LANL.
LANL to perform headspace gas sampling on sibling starting May 19.
LANL relocated Standard Waste Box (SWB) containing siblings to drum 68660 to Building 375 boxline enclosure.
All nitrate salt drums at LANL were overpacked and stored in Dome 230.
LANL declared a PISA on treated nitrate salt waste. Limiting Condition for Operations (LCO) 3.7.1 is entered requiring a response plan for breached drum. May 16, 2014
Conducted head space sampling of treated nitrate waste containers.
Monitored temperatures of treated nitrate waste containers.
All remaining nitrate salt drums were overpacked.
TIDS placed on similar drum still at LANL.
LANL submitted ORPS on PISA: TRU waste drums containing treated nitrate containing treated nitrate salts may challenge safety basis. May 16, 2014
T


Slip sheet damaged by heat is discovered.
Contents of drum in R16:C4 displaced onto scorched SWB in R15:C5.
No apparent damage on SWB, drum in R16:C4 found breached and lid lifted.
T
Underground entry at WIPP continued surveys and examine Panel 7 Room 7 further. May 19, 2014
AIB for Phase 2 of the radiological event was appointed to investigate mechanism of the release in the underground. May 19, 2014
NMED issued Administrative Order (AO) 05-19001 to DOE/LANS to submit a Nitrate Salt Bearing Waste Container Isolation Plan to NMED. May 19, 2014
NMED issued AO 05-20001 to DOE/NWP requiring WIPP to develop Nitrate Salt Bearing Waste Container Isolation Plan to NMED. May 20, 2014
LANL submitted ORPS report on PISA: TRU waste drums containing treated nitrate salts may challenge safety basis. May 20, 2014
U


Could not re-create a scenario with Swheat Scoop® and surrogate material that would combust.
Not spontaneously combustible per EPA SW-846 1050, *Test Methods to Determine Substances Likely to Spontaneously Combust*.
U
LANL sent Swheat Scoop® surrogate to lab for flammability testing. May 20, 2014
LANL established a nitrate salt waste remediation planning team. May 20, 2014
LANL submitted LA-UR-14-23605, *Nitrate Bearing Waste Container Isolation Plan* to NMED. May 21, 2014
Specified that temperature readings were to be taken for remediated salt waste containers at TA-54 Area G.
LANL issued EP-AREAG-SO-1237, R0 *Area G Temperature Readings of Nitrate Salt Containers*. May 21, 2014
Focused on required reporting to outside authorities.
LANL critique held on NMED Administrative Order. May 22, 2014
V
Close-up video taken of breached drum in R14:C4 and the vicinity.
Confirmed the specific drum identification number (68660).
V
Underground entry at WIPP obtained additional video and photos of Panel 7 Room 7. May 22, 2014
Dome 375 Permacon had HEPA filtration, air conditioning, and fire suppression system.
Drum moves are completed on May 23, 2014.
LANL began moving standard waste boxes (SWB) overpacks with remediated salt waste drums into Dome 375 Permacon®. May 22, 2014
WCS loaded SWBs containing LA-MIN02-V.001 waste into casks (70 of 73). May 22 -28, 2014
NWP submitted response plan to DOE per LCO 3.7.1. May 23, 2014
NMED issued conditional approval of LANL nitrate salt bearing waste container plan. May 23, 2014
W


W
LANL completed transfer of remediated nitrate salt drums to Area G Dome 375 Permacon.
May 23, 2014
Required hourly inspections of nitrate salt drums in SWBs at TA-54 Area G.
LANL issued EP-AREAG-SO-1244, R0 TA-54 Area G Nitrate Waste Container Inspections.
May 23, 2014
LANL issued ORPS NA—LASO-LANL-WASTEMGT-2014-0006 on receipt of the NMED Administrative Order
May 23, 2014
No issues with ground control.
Underground entry at WIPP evaluated ground control and radiological conditions; made ventilation changes.
May 28, 2014
To prevent workers from coming into unneccessary contact with the waste containers.
LANL issued EP-AREAG-SO-1247, R0 TA-54 AREAG Domes TA-54-231 and Dome 375 Permacon® Access Restrictions.
May 29, 2014
X
X
Provided pre-planning and initial entry requirements for potential release scenarios.
LANL issued EP-AREAG-PLAN-1248, R0 TA-54 Area G Nitrate Salt Waste Container Response Instructions.
May 29, 2014
Incorporated EP-AREAG-SO-1247 requirements.
LANL issued EP-AREAG-G-FO-DOP-1246, R0 Nitrate Salt Bearing TRU Waste Container Monitoring.
May 29, 2014
Sample taken from displaced lid of 68660 and adjacent SWB.
R10:C2 top contained discolored containers (from MIN02 and CIN01 waste streams.
No issues with ground control.
Underground entry at WIPP collected samples of MgO, material from suspect drum, took video and evaluated ground control.
May 30, 2014
DOE submitted WIPP nitrate salt-bearing waste container isolation plan to NMED.
May 30, 2014
Directed repackaging, treatment, and remediation of waste at Environmental and Waste Management Operations (EWMO) be paused.
LANL issued EP-DIV-SO-20222, R0 EWMO Legacy TRU Waste Pause.
May 30, 2014
Y


Y
Drums in 85 gallon overpacks.
LANL completed transfer of unremediated nitrate salt drums into Area G Dome 231 Permacon®.
May 30, 2014
WIPP HEPA filter replacement completed in first filter unit.
June 6, 2014
Performed radiological surveys, evaluated ground control and tested power unit.
WIPP underground entries resumed.
July 18, 2014
Performed radiological surveys, reclassified areas.
Underground entry.
August 8, 2014
Collected additional samples including around drum 68660.
Underground entry.
August 15, 2014

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Attachment G. Executive Summary - Phase 1 Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014

U.S. Department of Energy
Office of Environmental Management

Accident Investigation Report

Phase 1
Radiological Release Event at the Waste Isolation Pilot Plant on February 14, 2014

April 2014

Radiological Release Event at the Waste Isolation Pilot Plant

Radiological Release Event at the Waste Isolation Pilot Plant

Acronyms

ABSTA	Authorization Basis Senior Technical Advisor
AEOC	Alternate Emergency Control Center
AC	Administrative Control
ALARA	As Low as Reasonably Achievable
ASME	American Society of Mechanical Engineers
CAR	Corrective Action Report
CAS	Contractor Assurance System
CBFO	Carlsbad Field Office
CFM	Cubic Feet Per Minute
CH	Contact Handled
CHAMPS	Computerized History and Maintenance Planning System
CMR	Central Monitoring Room
CMRO	Central Monitoring Room Operator
CMS	Central Monitoring System
CON	Conclusion
CONOPS	Conduct of Operations
CTAC	Carlsbad Technical Assistance Contractor (Portage)
DBA	Design Basis Accident
DF	Design Feature
DOE	U.S. Department of Energy
dP	Differential Pressure
DPTA	diethylenetriamine pentaacetate
DPM	Disintegrations per Minute
DNFSB	Defense Nuclear Facilities Safety Board
DSA	Documented Safety Analysis
EAL	Emergency Action Level
EMCBC	DOE-EM Office of Environmental Management Consolidated Business Center
EOC	Emergency Operations Center
EPA	U.S. Environmental Protection Agency
ERO	Emergency Response Organization
EXO	Enriched Xenon Observatory
FR	Facility Representative
FSM	Facility Shift Manager
GCAP	Ground Control Annual Plan
HEPA	High-Efficiency Particulate Air

Radiological Release Event at the Waste Isolation Pilot Plant

HSS	DOE Office of Health, Safety and Security
HQ	Headquarters
IC	Incident Commander
ICS	Incident Command System
IEP	Integrated Evaluation Plan
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
ITS	Important to Safety
JON	Judgments of Need
JIC	Joint Information Center
LCO	Limiting Condition for Operations
M&O	Management and Operations
MACCS	MELCOR Accident Consequence Code Systems
NRB	Nuclear Review Board
NWP	Nuclear Waste Partnership LLC
MSHA	Mine Safety and Health Administration
MST	Mountain Standard Time
NaI	Sodium Iodide
OE	Operational Emergency
OH/IS	Occupational Health/Industrial Safety
ORPS	Occurrence Reporting and Processing System
PA	Public Address
PAC	Programmatic Administrative Control
PE-Ci	plutonium$^{239/240}$ equivalent curies
PISA	Potential Inadequacy in the Safety Analysis
QA	Quality Assurance
QAP	Quality Assurance Program
QAPD	Quality Assurance Program Document
RH	Remote Handled
RCDM	Radiological Control and Dosimetry Manager
RCM	Radiological Control Manager
RCRA	Resource Conservation and Recovery Act
RCT	Radiological Control Technician
REMS	Radiological Effluent Monitoring System
RPP	Radiation Protection Program
SAC	Specific Administrative Control

Radiological Release Event at the Waste Isolation Pilot Plant

SC	Safety Class
SCFM	Standard Cubic Feet Per Minute
SER	Safety Evaluation Report
SigCat	Significance Category
SLA	Service Level Agreement
SME	Subject Matter Expert
SMP	Safety Management Program
SS	Safety Significant
SSC	Structures, Systems, and Components
STA	Senior Technical Advisor
TIM	Training Implementation Matrix
TQP	Technical Qualification Program
TRU	Transuranic
TRUPACT	Transuranic Package Transporter
TSR	Technical Safety Requirement
U/G	Underground
USGS	United States Geologic Service
USQ	Unreviewed Safety Question
USQD	Unreviewed Safety Question Determination
UVS	Underground Ventilation System
WIPP	Waste Isolation Pilot Plant
WTS	Washington TRU Solutions, LLC

Radiological Release Event at the Waste Isolation Pilot Plant

Radiological Release Event at the Waste Isolation Pilot Plant

Executive Summary

At approximately 2314 Mountain Standard Time (MST) on Friday, February 14, 2014, there was an incident in the underground repository at the Department of Energy (DOE) Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, which resulted in the release of americium and plutonium from one or more transuranic[1] (TRU) waste containers into the environment. The WIPP is a deep geologic repository, mined out of a thick bed of salt, for the disposal of defense TRU waste generated primarily from the cleanup of DOE sites. The release was detected by an underground (U/G) continuous air monitor (CAM) and then directed through high-efficiency particulate air (HEPA) filter banks located in the surface exhaust building. However, a measurable portion bypassed the HEPA filters via design leakage through two ventilation system dampers and was discharged directly to the environment from an exhaust duct. No personnel were determined to have received external contamination; however, 21 individuals were identified through bioassay to have initially tested positive for low level amounts of internal contamination as of March 28, 2014. Trace amounts of americium and plutonium were detected off-site.

This accident meets the criteria in Appendix A to DOE Order (O) 225.1B, *Accident Investigations*. On February 27, 2014, Matthew Moury, Deputy Assistant Secretary for Safety, Security, and Quality Programs, U.S. Department of Energy, Office of Environmental Management, formally appointed an Accident Investigation Board (the Board) to investigate the radiological release in accordance with DOE Order 225.1B. The appointment letter was modified on March 4.

The Board began the investigation on March 3, 2014, completed Phase 1 of the investigation on March 28, 2014, and submitted the report to James Hutton, Acting Deputy Assistant Secretary for Safety, Security, and Quality Programs, U.S. Department of Energy, Office of Environmental Management on April 1, 2014. This report covers the Board's conclusions for the release of TRU from the U/G to the environment, which is considered to be Phase 1 of the investigation. Based upon the evidence gathered in this accident investigation, the Board concluded that the unfiltered above-ground release identified in Phase 1 of the investigation was preventable.

The Board concludes that a thorough and conservatively considered hazard analysis, coupled with a robust, tested and well maintained HEPA filter capable exhaust ventilation system could have prevented the unfiltered above ground release that occurred on February 14, 2014.

Originally, a large release from the underground that would have required crediting the HEPA filtered ventilation system to mitigate was not assumed to occur. Dating back to 2005, the safety basis documents designated the U/G confinement ventilation system (CVS) as a Safety Significant (SS) system based on directing airflow away from facility workers emplacing waste. However, the above ground systems including the exhaust High Efficiency Particulate Air (HEPA) filtration and bypass isolation valves were not credited because the safety controls at the

[1] Transuranic waste (TRU) means waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for (A) high-level radioactive waste; (B) waste that the DOE Secretary has determined, with the concurrence of the EPA Administrator, does not need the degree of isolation required by the disposal regulations; or (C) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with part 61 of title 10, Code of Federal Regulations. [Public Law 102-579 (1992)]

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time consisted of a credited Technical Safety Requirement (TSR) control that required weekly ground control inspections to ensure changing conditions were promptly identified, evaluated and addressed. When the existing Contact-Handled (CH) and Remote-Handled (RH) TRU safety basis documents were combined in September of 2008, the new Documented Safety Analysis (DSA) reduced the classification of the U/G CVS to "Balance of Plant," meaning that it was no longer credited for worker protection from accidents identified in the DSA. Among the bounding accidents identified in this version of the DSA was a roof fall accident in an active panel (Event 030-CH/RH-UG), which resulted in an anticipated frequency with low consequences to facility workers, high consequences to co-located workers (100 meter receptor), and moderate consequences to public.

The primary safety basis control established for the roof fall accident was related to the ground control program. As a result, the release from a roof fall accident was assumed to be adequately prevented by the ground control program, and only relatively smaller releases in the U/G from events such as waste handling accidents were judged to be credible. The ground control program preventive controls were determined to be sufficient, and safety related mitigative controls for the larger releases in the U/G were not deemed necessary. As a result, the HEPA ventilation system and its associated bypass isolation dampers were not designated as credited safety related equipment. Because the isolation dampers were not nuclear safety system credited, the damper design was not required to meet requirements in the nuclear industry ventilation code, ASME AG-1-2012, *Code on Nuclear Air and Gas Treatment*. This decision resulted in the HEPA bypass isolation damper configuration not being equally efficient to the HEPA filters or suitable as a containment boundary, and resulted in the unfiltered release to the environment. The nuclear safety basis is more thoroughly discussed in Chapter 3, Nuclear Safety Program.

The U/G ventilation system originally consisted of three 860 series fans, each rated at 60,000 cfm, capable of providing normal unfiltered airflow to support early mining operations. The system also provided the capability to realign airflow through two banks of HEPA filters using a single 860 series fan to provide the rated airflow for waste emplacement activities. However, in order to align for filtration, two bypass isolation dampers that represent a pathway of unfiltered exhaust into the environment must be closed. These isolation dampers have a design leak rate of up to 1000 cfm. The radiological event that occurred on February 14 with the leakage past the isolation dampers was less than the National Emission Standards for Hazardous Air Pollutants (NESHAP) guidelines for the public and below the limits established by DOE and WIPP for site workers.

As mining activities were increased, the existing fans were no longer able to provide the necessary airflow to support the additional fossil fueled vehicle emissions. Two larger 700 series fans each rated at 260,000 cfm were installed, later followed by a third, that discharged upstream of the 860 series fans and significantly improved air flow capabilities. The ability to use the 860 fans to supplement unfiltered airflow was maintained for flexibility, although the addition of the new fans represented an opportunity to evaluate and improve the overall efficiency of the HEPA filtered system by eliminating the bypass dampers, which would have prevented the unfiltered release. However, since these systems were not credited as safety related, modifications were not subjected to the same level of scrutiny as would have occurred for modifications to credited safety systems. Additionally, there was significant degradation in the material condition of several ventilation system components identified that were not being aggressively pursued.

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Since the HEPA ventilation system was not designated as a credited safety system, the CAMs in the U/G whose purpose is to detect a release in the U/G and cause an automatic switch of the ventilation system to filtration mode, were also not credited. The U/G ventilation system is more thoroughly discussed in Chapter 7, NWP Maintenance Program, Chapter 8, Radiation Protection Program and Chapter 9, Underground Ventilation.

The Board also determined that weaknesses in oversight by the contractor, CBFO, Headquarters, and outside organizations missed opportunities to identify inadequacies in the safety basis, as well as the configuration management and maintenance of the U/G ventilation system at WIPP. For example, the accident involving the roof fall in an active panel was removed in error from the latest revision to the DSA. This change was not identified by CBFO during their review, and therefore, the basis for the change was not provided in the DSA or DOE's Safety Evaluation report (SER). Oversight is more thoroughly discussed in Chapter 11, NWP Contractor Assurance System and Chapter 12, DOE Programs and Oversight.

Inability of the Board to access to the U/G following the incident also prohibited definitive determination of the physical cause of the waste container(s) breach/failure. Nuclear Waste Partnership LLC (NWP) and the DOE Carlsbad Field Office (CBFO) will be implementing a detailed recovery plan to systematically reenter the U/G and make an absolute determination as to cause. The Board presumes either the penetration of a waste container or multiple containers by a roof bolt, or partial collapse of the back (roof) and/or ribs (walls) caused the breach and release of contamination. This will be investigated in Phase 2. Phase 2 of the Board investigation will occur after reentry into the U/G and a cause of the release within the U/G is able to be determined.

Accident Description

On Friday, February 14, 2014, at approximately 2314, a "HI HI" radiation alarm was received in the Central Monitoring Room (CMR) at the DOE WIPP facility approximately 27 miles east of Carlsbad, New Mexico. The alarm was triggered from a CAM (Figure ES-1) in the U/G which was monitoring airborne radioactivity levels in air exhausting from Panel 7, an active waste panel where TRU waste was being emplaced for disposal.

Figure ES-1: RADOS Continuous Air Monitor

The underground ventilation system (UVS) automatically switched to HEPA filtration mode when the airborne radiation alarmed the CAM and the 860 fan vortex damper was manually opened and adjusted to achieve designated airflow. This directed contaminated air from the U/G up through

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the U/G exhaust shaft, through the HEPA filter banks, and then to the environment from an exhaust duct. There were no employees working in the U/G at the time, but 11 personnel were working on the surface. After receiving the alarm, the Central Monitoring Room Operator (CMRO) notified the Operations and Radiological Control Manager (RCM also known as the Radiological Controls and Dosimetry Manager) and the DOE Facility Representative (FR), who responded to the site early the next morning. At 2342, the CMRO logged, "Disabled U/G CAM-151," which was the only in-service CAM in the U/G, due to a malfunction indication, suspected due to filter plugging. Ventilation continued to run in filtration mode through the HEPA filters, and Radiological Control Technicians (RCTs) collected filters from upstream and downstream effluent sample stations for radiological counting. There were no other CAMs in the U/G or on the surface monitoring the exhaust. The Board determined that there should have been additional CAMs operating. However, the CAMs currently in U/G active disposal panels possess the lowest functional safety classification, Balance of Plant, and can be taken out of service without prior DOE or NWP Nuclear Safety approval, leaving no real-time monitoring capability.

On Saturday, February 15, 2014, the filters were counted at 0715; the RCM reported 4.4 million disintegrations per minute (dpm) alpha contamination on the filters from the effluent sample station upstream from the HEPA filters (Station A) (Figure ES-2). Preliminary data indicated the presence of TRU materials.

Figure ES-2: Exhaust Air Shaft and Effluent Sample Station A

Results from analysis of filters from the effluent sample station downstream of the HEPA filters (Station B) and at the discharge point to the atmosphere (Figure ES-3) were reported at 0915 and indicated 28,000 dpm alpha and 5,900 dpm beta contamination. This was the first indication that there was a release of contamination downstream of the HEPA filters to the environment.

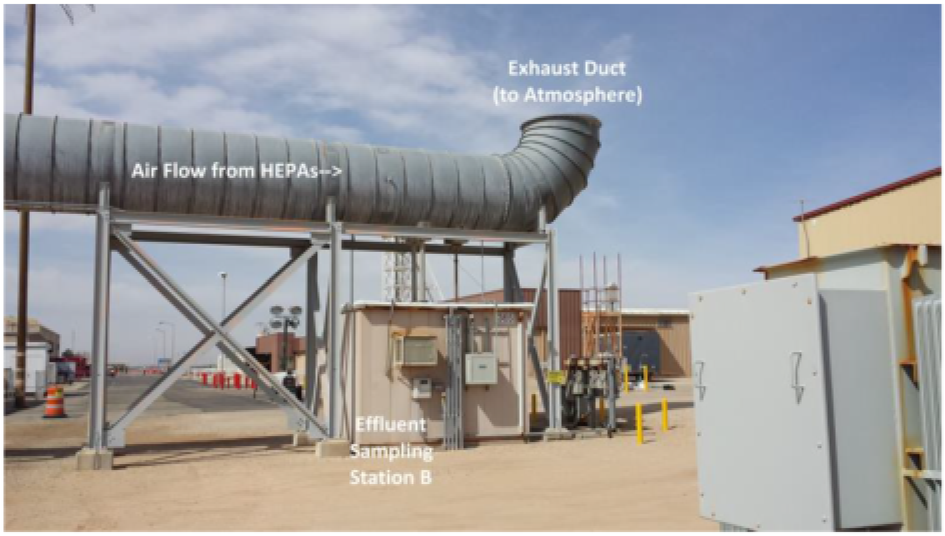

Figure ES-3: Station B and Exhaust Duct

On-site personnel were directed to shelter-in-place at 0934. On-site and off-site surveys were initiated and portable air samplers were installed in selected site areas. A total of 153 people were working on the surface that day, including the backshift personnel and those on-site during the morning and afternoon. No personnel were working in the U/G. The Operations Assistance Team (OAT), Alternate Emergency Operations Center (AEOC) and Joint Information Center (JIC) were activated and at 1449 the AEOC at the CBFO facility in Carlsbad was declared operational.

At 1557, it was reported that site surveys were negative for radiological contamination and at 1612 preliminary analysis of the initial Station A and Station B filters indicated the presence of plutonium$^{239/240}$ (Pu) and americium^{241}(Am). The UVS was still in HEPA filtration mode with no on-site or off-site contamination above background detected at that time. The site parking lot and vehicles were surveyed and found clean at 1557. At 1635, the shelter-in-place order was lifted and non-essential personnel were systematically released, building by building, via surveyed and controlled egress routes. Before they exited the guard gate, personnel underwent whole body radiological surveys (frisk). Radiological data from site surveys, effluent monitoring, portable air samplers and low volume off-site sampling continued to be collected with no indication of a detectable release to the environment. Site access was then restricted to essential personnel only.

The emergency event was terminated at 1917 on February 16, when the JIC and AEOC were deactivated. Bioassay was subsequently performed on approximately 150 personnel to determine if there was any intake of airborne contamination from the event. As of March 28, 2014, 21 personnel were found to have positive bioassay results.

On February 19, radiological results from the Carlsbad Environmental Monitoring and Research Center (CEMRC) high volume air sampling station located approximately 0.6 miles northwest of the site on the WIPP access road were reported. CEMRC is affiliated with New Mexico State University and provides independent monitoring of the WIPP facility. The filter that was counted had been installed at the station prior to the event, on Tuesday, February 11, and was removed on Sunday, February 16. The levels detected at this sampling station indicated a small release of radioactive particles from the WIPP site.

On February 24, DOE reported additional environmental monitoring data from samples collected by WIPP radiological and environmental personnel on February 17 and 18 at numerous locations on and around the site. These results also indicated slightly elevated levels of airborne radioactive concentrations consistent with the waste disposed of at WIPP. These concentrations were well below a level of public or environmental hazard.

On March 6, two ventilation system dampers that were known to have design leakage, and allowed a portion of the radioactive material to bypass the HEPA filters were sealed with a high-density foaming material.

On March 7 and 8, radiological and air quality instruments were lowered into the U/G to check for airborne radioactivity and to determine air quality. The preliminary sample results indicated no detectable radioactive contamination in the air or on the air quality instruments.

On March 18, new air sample data were reported via a DOE press release and indicated a very small radiation release occurred on March 11, but with no expected health impact to the workers, public and environment. A series of workforce and public meetings were held following the February 14 radiological event to communicate what was known about the incident, provide monitoring results, and to provide status on recovery planning. These actions are ongoing, and site access continues to be limited to essential personnel only. Manned entry into the U/G to collect samples and assess conditions is being planned but has not yet been authorized.

Direct, Root, and Contributing Causes

Direct Cause – the immediate events or conditions that caused the accident.

The Board identified the direct cause of this accident to be the breach of at least one TRU waste container in the U/G which resulted in airborne radioactivity escaping to the environment downstream of the HEPA filters. Due to restrictions on access to the U/G following the event, the exact mechanism of container failure, e.g., back or rib fall, puncture by a failed roof bolt, off-gassing, etc., is unknown at this time and must be determined once access to the U/G is restored. This will be investigated in Phase 2.

Root Cause – causal factors that, if corrected, would prevent recurrence of the same or similar accidents.

The Board identified the root cause of Phase 1 of the investigation of the release of radioactive material from underground to the environment to be NWP's and CBFO's management failure to fully understand, characterize, and control the radiological hazard. The cumulative effect of inadequacies in ventilation system design and operability compounded by degradation of key safety management programs and safety culture resulted in the release of radioactive material from the underground to the environment, and the delayed/ineffective recognition and response to the release.

With regard to ventilation system design and operability: the filtration portion of the ventilation system has two HEPA filter bypass isolation dampers that provide a pathway of unfiltered exhaust into the environment. These isolation dampers are not suitable as a containment boundary and reduce the overall efficiency of the HEPA filter system. This is discussed further in Chapter 9, Underground Ventilation. This condition was never identified by the contractor, CBFO, or Headquarters in any of the revisions and updates to the WIPP safety basis documentation.

Contributing Causes – events or conditions that collectively with other causes increased the likelihood or severity of an accident but that individually did not cause the accident. For the purposes of this investigation, contributing causes include those related to the cause of the radiological release to the environment as well as those related to the subsequent response.

The Board identified eight contributing causes to the radiological release to the environment investigated in Phase 1, or resultant response:

1. Implementation of the NWP Conduct of Operations Program is not fully compliant with DOE O 422.1, *Conduct of Operations*, and impacted the identification of abnormal conditions and timely response.
2. NWP does not have an effective Radiation Protection Program in accordance with 10 Code of Federal Regulations (CFR) 835, *Occupational Radiation Protection*, including but not limited to radiological control technician training, qualification and requalification, equipment and instrumentation, and audits.
3. NWP does not have an effective maintenance program. The condition of critical equipment and components, including continuous air monitors, ventilation dampers, fans, sensors, and the primary system status display were degraded to the point where the cumulative impact on overall operational readiness and safety was not recognized or understood.
4. NWP does not have an effective Nuclear Safety Program in accordance with 10 CFR 830 Subpart B, *Safety Basis Requirements*. There has been a reduction in the conservatism in the Documented Safety Analysis (DSA) hazard/accident analysis and corresponding Technical Safety Requirement (TSR) controls over time, commencing with EM Headquarters delegation of safety basis approval authority (SBAA) in late 2009. For example, 15 of 22 design basis accidents were removed from the latest revision without any clear justification, including the elimination of a roof/rib fall event in an open waste panel. Several other examples are provided in Chapter 3, Nuclear Safety Program. In addition, the DSA and TSRs contain errors, there is a lack of DSA linkage to supporting hazard analysis information, and there is confusion over the back fall accident description in a closed versus open panel.
5. NWP implementation of DOE O 151.1C, *Comprehensive Emergency Management System*, was ineffective. Personnel did not adequately recognize, categorize, or classify the emergency and did not implement adequate protective actions in a timely manner.

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6. The current site safety culture does not fully embrace and implement the principles of DOE Guide (G) 450.4-1C, *Integrated Safety Management Guide*. There is a lack of a questioning attitude, reluctance to bring up and document issues, and an acceptance and normalization of degraded equipment and conditions. This is supported by the 2012 Safety Conscious Work Environment (SCWE) survey results which indicated a reluctance to report issues to management, indicating a chilled work environment. Execution of the NWP Contractor Assurance System (CAS) in accordance with DOE O 226.1B, *Implementation of Department of Energy Oversight Policy,* was ineffective. Execution of the CAS did not identify precursors to this event or the unacceptable conditions and behaviors documented in this Phase 1 report.
7. Execution of CBFO oversight in accordance with DOE O 226.1B was ineffective. CBFO failed to establish and implement adequate line management oversight programs and processes and hold personnel accountable.
8. DOE Headquarters (HQ) line management oversight was ineffective. DOE HQ failed to ensure that CBFO was held accountable for correcting repeated identified issues involving radiological protection, nuclear safety, Integrated Safety Management (ISM), maintenance, emergency management, work planning, and control and oversight.

Conclusions and Judgments of Need

Based upon the conclusions of this accident investigation, the Board concluded that the unfiltered above ground release identified in Phase 1 of the investigation was preventable. The ventilation system has High Efficiency Particulate Air (HEPA) filter bypass isolation dampers that represent a pathway of unfiltered exhaust into the environment. These isolation dampers are not suitable as a containment boundary and reduce the overall efficiency of the HEPA filter system.

Table ES-1 summarizes the Conclusions (CONs) and Judgments of Need (JONs) determined by the Board. The conclusions are derived from the analytical results performed during this accident investigation for determining what happened and why it happened. Also listed are JONs determined by the Board as managerial controls and safety measures necessary to prevent or minimize the probability or severity of a recurrence of this type of accident. Table 4-1 in the body of the report provides more detail, including the causal factors, specific conditions related to the causal factors, and associated CONs and JONs.

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Table ES-1: Conclusions and Judgments of Need

Conclusion (CON)	Judgments of Need (JON)
CON 1: The direct cause of the transuranic mixed waste container release could not be definitively determined during Phase 1 of the investigation due to the inability for personnel to access the underground, collect information, and inspect the waste panels/rooms.	**JON 1**: Nuclear Waste Partnership LLC (NWP) and the Carlsbad Field Office (CBFO) need to implement a detailed recovery plan to systematically reenter the underground, collect data and information, and make an absolute determination as to the mechanism of the transuranic waste release. **JON 2**: During Phase 2, the DOE Accident Investigation Board needs to evaluate the data and information collected and provided by NWP and CBFO to determine the mechanism of release and determine the related conditions and causal factors, reach conclusions, and identify additional judgments of need.
Nuclear Safety Program	
CON 2: There has been a reduction in conservatism in the Documented Safety Analysis hazard/accident analysis and Technical Safety Requirement safety controls within safety basis revisions occurring since 2010, i.e., *Documented Safety Analysis/ Technical Safety Requirement*, Revision 1 to Revision 4. This is not consistent with DOE-Standard (STD)-3009, *Preparation Guidance for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis* and DOE-STD-5506, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities.*	**JON 3**: NWP needs to revise the hazard and accident analyses to comply with DOE-Standard-3009, *Preparation Guidance for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis* and DOE-STD-5506, *Preparation of Safety Basis Documents for Transuranic (TRU) Waste Facilities*, regarding not crediting administrative controls in the unmitigated analysis. In particular, some initial assumptions/initial conditions, e.g., compliance with 30 CFR 57, *Safety and Health Standards Underground Metal and Nonmetal Mines* ground control program requirements, should be preventive or mitigative controls derived by the mitigated analysis and should be evaluated for the need for protection with Technical Safety Requirement controls.

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Conclusion (CON)	Judgments of Need (JON)
CON 3: The Documented Safety Analysis and Technical Safety Requirement have several errors or omissions that are indicative of lack of rigorous contractor internal review and independent peer-review processes for the development of the safety basis, e.g., quality issues include Documented Safety Analysis and Technical Safety Requirement errors, lack of Documented Safety Analysis linkage to supporting hazard analysis information, confusion over back fall accident description in closed vs. open panel.	**JON 4**: NWP needs to commission an independent assessment of the Documented Safety Analysis/Technical Safety Requirement Revision 4 through corporate assistance or other recognized external resources, and corrective actions implemented that establish appropriate hazard controls and functional classifications.
CON 4: Technical Safety Requirements are not effective in ensuring facility configurations that provide contribution to defense-in-depth for radiological events. The function of the Documented Safety Analysis as articulated in 10 CFR 830, *Nuclear Safety Management Rule,* Appendix A, Section G.4 is as follows: "Technical Safety Requirements establish limits, controls and related actions necessary for the safe operation of a nuclear facility."	**JON 5**: NWP needs to re-evaluate the importance of the suite of available preventive and mitigative controls, e.g., continuous air monitors and underground ventilation system, in the supporting hazards analysis report and the Documented Safety Analysis, Section 3.3 hazard evaluation, and whether they should be considered as major contributors to defense in depth. This may require upgrading of some Structures, Systems, and Components functional classifications.
CON 5: Since neither the CAMs nor the underground ventilation system are pedigreed, i.e., Safety Class, Safety Significant, Important to Safety Structures, Systems, and Components, their importance has not been acknowledged within the Technical Safety Requirements, e.g., no Limiting Conditions for Operation/ Surveillance Requirements. In addition, neither Documented Safety Analysis Safety Management Programs, (Chapter 7 Radiation Protection Program), nor the Technical Safety Requirement Programmatic Administrative Controls consider whether CAMs may provide protection for the facility worker who may be in the exhaust drift.	**JON 6**: NWP needs to re-evaluate the classification of continuous air monitors and the underground ventilation system consistent with the outcome of the revised hazard analysis and develop Technical Safety Requirement controls consistent with that classification.

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Conclusion (CON)	Judgments of Need (JON)
CON 6: The Technical Safety Requirement documentation is not being controlled with the rigor normally associated with a Hazard Category 2 nuclear facility.	**JON 7**: NWP needs to revise the Technical Safety Requirements to align with changes to the Documented Safety Analysis, e.g., continuous air monitor and underground ventilation system, correct current errors in the Technical Safety Requirements, and ensure that implementing procedures clearly support consistent interpretations.
CON 7: The NWP Unreviewed Safety Question Determination procedure does not clearly communicate the actions required to evaluate situations that could involve a Potential Inadequacy in the Safety Analysis. In addition, NWP's implementation of Unreviewed Safety Question procedure requirements indicates a lack of recognition that some proposed recovery activities associated with the radiological release event were outside the analyzed safety basis. This is evident from NWP's Unreviewed Safety Question's evaluations or lack there-of, related to impacts on previously analyzed accidents or safety controls; identifying equipment that is important to safety; and completeness of identifying accidents of a new type not previously analyzed.	**JON 8**: NWP needs to commission an independent assessment of the Unreviewed Safety Question process through corporate assistance or other recognized external resources, and implement corrective actions that ensure effectiveness. **JON 9:** NWP needs to strengthen the Unreviewed Safety Question Determination procedure to clarify Potential Inadequacy in the Safety Analysis guidance, including the appropriate timeliness for entrance into the process and decision making.
CON 8: There is an observed lack of robustness in the CBFO technical review of Documented Safety Analysis/Technical Safety Requirement changes/annual updates, e.g., lack of documentation of the technical basis for approval to support development of a Safety Evaluation Report. While the Safety Evaluation Reports are consistent with the format per DOE-Standard-1104, *Review and Approval of Nuclear Facility Safety Basis and Safety Design Basis Documents,* the conclusions do not include adequate rationale for acceptance of the proposed changes.	**JON 10**: CBFO needs to revise Management Procedure 4.11, *Safety Basis Review Procedure,* to require adequate documentation of the technical basis supporting approval of changes to the WIPP Document Safety Analysis or Technical Safety Requirements, consistent with DOE Standard 1104, e.g., regulatory compliance, justification for initial assumptions/initial conditions, reduced conservatisms of the hazards and accident analysis. **JON 11**: CBFO and DOE HQ need to commission an independent assessment of the CBFO safety basis review and approval process and implement corrective actions that ensure effective implementation.

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Conclusion (CON)	Judgments of Need (JON)
CON 9: CBFO has insufficient nuclear safety management/staffing since the 2010 timeframe and the retirement of Authorization Basis Senior Technical Advisor and existing Nuclear Safety Specialist staff responsible for multiple subject matter expertise.	**JON 12**: CBFO needs to perform a critical federal staffing analysis focused on Nuclear Safety e.g., Nuclear Safety Specialist, nuclear safety qualified Senior Technical Advisor and supporting CBFO Subject Matter Experts and determine whether existing resources are adequate. **JON 13**: CBFO and DOE HQ need to arrange for temporary DOE senior nuclear safety resources to mentor existing CBFO nuclear safety and supporting resources, and assist as necessary.
Emergency Management	
CON 10: Compensatory measures were not put in place to mitigate issues identified immediately following the February 5, 2014, underground fire event with respect to emergency management. **CON 11**: The emergency management program was not adequately structured and implemented such that personnel did not recognize, categorize, or classify the emergency and implement protective actions in a timely manner. **CON 12**: The Waste Isolation Pilot Plant (WIPP) (NWP and CBFO) emergency management program is not fully compliant with DOE Order 151.1C, *Comprehensive Emergency Management System*, e.g., activation of the Emergency Operations Center, classification and categorization, emergency action levels, implementation of the Incident Command System, training, drills and exercises, etc. Weaknesses in classification, categorization, and emergency action levels were previously identified by both external review and in the response to the underground fire and the radiological release events.	**JON 14**: NWP needs to immediately develop and implement interim compensatory measures to ensure prompt identification, categorization, classification, and response to operational emergencies, e.g., corporate reach-back, training, Senior Management Watch in the Central Monitoring Room, etc. **JON 15**: CBFO needs to take prompt action to fully integrate trained Federal management resources into the emergency response organization and take action to bring their emergency management program into compliance with DOE Order 151.1C, *Comprehensive Emergency Management System.* **JON 16**: NWP needs to correct their activation, notification, classification, and categorization protocols to be in full compliance with DOE Order 151.1C, *Comprehensive Emergency Management System*, Resource Conservation and Recovery Act Contingency Plan and then provide training and drills for all applicable personnel. **JON 17**: NWP needs to revise Emergency Response Organization training to include

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Conclusion (CON)	Judgments of Need (JON)
	more supervised hands-on training and drills to enhance the effectiveness of the Emergency Response Organization's response. **JON 18**: NWP needs to fully integrate the Resource Conservation and Recovery Act Contingency Plan activation criteria within the site Emergency Action Levels and to train the applicable personnel to ensure implementation of the Resource Conservation and Recovery Act Contingency Plan. **JON 19**: NWP needs to take prompt action to correct longstanding deficiencies from previous reviews. **JON 20**: CBFO needs to ensure that NWP completes prompt action to correct longstanding deficiencies from previous reviews. **JON 21**: NWP needs to improve the content of site-specific Emergency Action Levels to expand on the information provided in the standard Emergency Action Levels contained in DOE Order 151.1C, *Comprehensive Emergency Management System*. **JON 22**: NWP needs to develop and implement an Incident Command System for the Emergency Operations Center/Central Monitoring Room that is compliant with DOE O 151.1C and is capable of assuming command and control for all anticipated emergencies. **JON 23**: DOE Headquarters (HQ) needs to conduct an effectiveness review of the NWP and CBFO emergency management program implementation within six months of completion of the corrective actions for the Emergency Management Judgments of Need.

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Conclusion (CON)	Judgments of Need (JON)
Safety Culture	
CON 13: NWP and CBFO have allowed the safety culture at the WIPP project to deteriorate as evidenced by the workers feedback that they do not feel comfortable identifying issues that may adversely affect management direction, delay mission related objectives, or otherwise affect cost or schedule. Questioning attitudes are not welcomed by management and many issues and hazards do not appear to be readily recognized by site personnel.	**JON 24**: NWP and CBFO need to develop and implement an effective integrated safety management system that embraces and implements the principles of DOE G 450.4-1C, *Integrated Safety Management Guide,* including but not limited to: • Demonstrated leadership in risk-informed, conservative decision making • Improved learning through error reporting and effective resolution of problems • Line management encouraging a questioning attitude without fear of reprisal and following through to resolve issues identified by the workforce • Reinforcing the mechanisms, e.g., WIPP Forms, "Notes to Joe," employee concern program, differing professional opinions, and protocols for communicating issues to NWP and CBFO leadership. **JON 25**: DOE HQ needs to engage external safety culture expertise in providing training and mentoring to NWP and CBFO management on the principles of a strong nuclear safety culture and implement any recommendations from these experts.

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Conclusion (CON)	Judgments of Need (JON)
CON 14: DOE has exacerbated the safety culture problem by referring to numbers of ORPS reports and other deficiency reporting documents, rather than the significance of the events, as a measure of performance by Source Evaluation Boards during contract bid evaluations, and poor scoring on award fee determinations. Directly tying performance to the number of occurrence reports drives the contractor to non-disclosure of events in order to avoid the poor score. This practice is contrary to the Department's goals of the development and implementation of a strong safety culture across our projects.	**JON 26**: DOE HQ needs to clearly specify the use of performance reporting results, e.g., Occurrence Reporting and Processing System and non-conformance reports in Past Performance Evaluations, to encourage conservative reporting and communication of Lessons Learned.
Conduct of Operations	
CON 15: Key elements of the NWP Conduct of Operations program were ineffective in driving safe and compliant operation of a Hazard Category 2 nuclear facility.	**JON 27**: NWP needs to strengthen execution of the Conduct of Operations program to be compliant with DOE O 422.1, *Conduct of Operations*. Specific areas of focus must include (but not limited to): • Establishing and reinforcing expectations conveyed in WP 04-CO.01, *Conduct of Operations* series procedures. • Initiate a mentoring program, e.g., senior supervisor watch that provides real time feedback to first and second line supervisors as to their responsibilities regarding compliant execution of operations activities. • Strengthen the structure, content and flow of abnormal response procedures to ensure immediate actions do not require judgment calls prior to execution. • Consider the addition of real time surveillance capability, e.g., video of the active waste panels/rooms. • Establish and execute an operational drill program that evaluates operator

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Conclusion (CON)	Judgments of Need (JON)
	response to upset conditions. • Establish a process that heightens awareness and requires deliberate action to reduce the quantity and length of time key pieces of equipment are out of service. **JON 28**: CBFO needs to take an active role towards improving NWP conduct of operations through implementation of a structured DOE O 226.1B, *Implementation of Department of Energy Oversight Policy*, oversight process that includes mechanisms for identifying, reporting, and transmitting issues that tracks corrective actions to effective closure. Specific areas of focus must include, but are not limited to: • Develop and conduct routine oversight of contractor implementation of the WP 04-CO.01, *Conduct of Operations* series procedures. Oversight needs to include detailed oversight plans that contain specific criteria and lines of inquiry to effectively assess compliance with DOE O 422.1. • Oversight of the NWP mentoring program e.g., senior supervisor watch that provides real time feedback to first and second line supervisors as to their responsibilities regarding compliant execution of operations activities in order to provide feedback on effectiveness. • Oversight of procedure development in order to strengthen the structure, content and flow of abnormal response procedures to ensure immediate actions do not require judgment calls prior to execution. • Overseeing execution of the NWP operational drill program that evaluates operator response to upset conditions.

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Conclusion (CON)	Judgments of Need (JON)
	Additionally, DOE HQ Office of Environmental Management needs to coordinate an extent of condition review at other EM sites and take action based on the outcome of that review.
Radiation Protection Program	
CON 18: NWP does not have an effective Radiation Protection Program in accordance with 10 Code of Federal Regulations (CFR) 835, *Occupational Radiation Protection*, including but not limited to radiological control technician training, qualification and requalification, equipment and instrumentation, and audits.	**JON 33**: NWP needs to evaluate the current state of the radiological control program including the current radiological conditions and implement compensatory measures to support recovery and current activities. **JON 34**: NWP needs to perform an extent of condition review of the training program incorporating the results of this event and implement actions to improve radiological control management, Radiological Control Technician, and rad worker proficiency in dealing with contamination, and airborne radioactive material. **JON 35**: NWP needs to perform an extent of condition review for identified weaknesses in the radiological control program and implement corrective actions to fully implement 10 CFR 835. **JON 36**: CBFO needs to determine the effectiveness of the radiation protection program within three months of completion of NWP's corrective actions.

Conclusion (CON)	Judgments of Need (JON)
CON 19: There is an inadequate technical basis for the existing ventilation and airborne monitoring systems. It is unclear that they adequately provide protection to the underground workers, the co-located worker, the public, and the environment from the transuranic mixed waste or hazardous constituents, e.g., reliability of a single CAM to initiate an automatic shift to filtration, acceptability of leakage past the bypass dampers and automatic shift to filtration that now requires manual operation of 860 fan vortex dampers.	**JON 37**: NWP needs to develop a technical basis to implement continuous and reliable/redundant real-time air monitoring with appropriate automatic shift to filtration to protect the workers, the public and the environment. This needs to take into consideration the different ventilation modes, protection of workers in the underground, and release of contaminants to the environment. The technical basis must also consider the hazardous constituents in the transuranic mixed waste, e.g., reliability of a single CAM to initiate an automatic shift to filtration, acceptability of leakage past the bypass dampers and automatic shift to filtration that now requires manual operation of 860 fan vortex dampers.
NWP Contractor Assurance System	
CON 20: NWP has not fully developed an integrated contractor assurance system that provides assurance that work is performed compliantly, risks are identified, and control systems are effective and efficient.	**JON 38**: NWP needs to develop and implement a fully integrated contractor assurance system that provides DOE and NWP confidence that work is performed compliantly, risks are identified, and control systems are effective and efficient.
CON 21: NWP failed to adequately establish and implement line management oversight programs and processes to meet the requirements of DOE O 226.1B, *Implementation of Department of Energy Oversight Policy*, and hold personnel accountable for implementing those programs and processes. **CON 22**: NWP failed to identify weaknesses in conduct of operations, maintenance, radiological protection, nuclear safety, emergency management, and safety culture. **CON 23**: NWP failed to adequately complete corrective actions from prior assessments to prevent or minimize recurrence. **CON 24**: Comprehensive self-assessments are	**JON 39**: NWP needs to establish and implement line management oversight programs and processes that: • Meet the requirements of DOE O 226.1B, *Implementation of Department of Energy Oversight Policy*, and hold personnel accountable for implementing those programs and processes. • Implement effective contractor assurance processes to emphasize conduct of operations, maintenance, radiological protection, nuclear safety, emergency management, and safety culture. • Implement a Contractor Assurance System to ensure that actions from prior

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Conclusion (CON)	Judgments of Need (JON)
not being performed by knowledgeable, qualified subject matter experts within the various safety management programs. Contractor Assurance System is implemented primarily through the Quality Assurance program.	assessments are implemented to prevent or minimize recurrence of identified deficiencies. • Include self-assessments by knowledgeable, qualified subject matter experts within the various safety management programs.
CBFO Oversight	
CON 25: CBFO failed to adequately establish and implement line management oversight programs and processes to meet the requirements of DOE Order 226.1B, *Implementation of Department of Energy Oversight Policy*, and hold personnel accountable for implementing those programs and processes. **CON 26**: CBFO failed to identify weaknesses in oversight processes, conduct of operations, maintenance, radiological protection, nuclear safety, emergency management, and safety culture. **CON 27**: CBFO is lacking adequate qualified staffing in numerous areas related to line management, technical disciplines and oversight functions. **CON 28**: CBFO failed to adequately complete corrective actions from prior assessments to prevent or minimize recurrence.	**JON 40**: CBFO needs to establish and implement line management oversight programs and processes such that CBFO: • Verifies that NWP has developed and implemented a DOE Order 226.1B compliant Contractor Assurance System. • Meets the requirements of DOE Order 226.1B and hold personnel accountable for implementing those programs and processes. • Implements effective oversight processes to ensure emphasis on conduct of operations, maintenance, radiological protection, nuclear safety, emergency management, and safety culture. **JON 41**: CBFO needs to develop and implement an effective issues management process to document, disposition (including extent of condition), close, track/trend issues, and ensure effectiveness of corrective actions. The process shall also ensure that actions from prior assessments are implemented to prevent or minimize recurrence of identified deficiencies. **JON 42**: The CBFO Site Manager needs to institutionalize and communicate expectations for a strong safety culture and the identification, documentation, reporting, and correction of issues without fear of reprisal. **JON 43**: CBFO needs to evaluate the

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Conclusion (CON)	Judgments of Need (JON)
	current organizational structure, identify specific staffing needs related to line management, technical discipline and oversight functions, submit those staffing needs to DOE HQ, and effectively manage their resources such that qualified personnel are effectively performing those functions.
DOE Headquarters Oversight	
CON 29: DOE HQ failed to ensure that CBFO was held accountable for correcting repeated identified issues involving radiological protection, nuclear safety, Integrated Safety Management System, maintenance, emergency management, work planning and control and oversight.	**JON 44**: DOE HQ needs to develop and implement a process to ensure repeatedly identified issues related to the safety management programs are confirmed, closed and validated by the local DOE office in a timely manner.
CON 30: DOE HQ management has failed to ensure that adequate resources, full time employees, technical expertise, travel money, adequate budget, etc., are provided to support the WIPP project. **CON 31**: DOE HQ management and staff failed to adequately define and execute roles and responsibilities related to line management, oversight, safety and balanced priorities.	**JON 45**: DOE HQ needs to re-evaluate priorities and allocate the resources, i.e., funding, staffing, infrastructure, etc., applied to the WIPP project to ensure those resources effectively address safety, programmatic, and operational considerations. **JON 46**: DOE HQ needs to better define and execute their roles and responsibilities in order to improve line management ownership, oversight, safety, and resources to ensure site implementation of the radiological protection, nuclear safety, ISMS, maintenance, emergency management, work planning and control and oversight policies and requirements are consistent and effective. **JON 47**: DOE HQ needs to perform an effectiveness review on all corrective actions completed in response to this investigation.

Attachment H.
Photographs of CAM 151 Filters #2 through #13

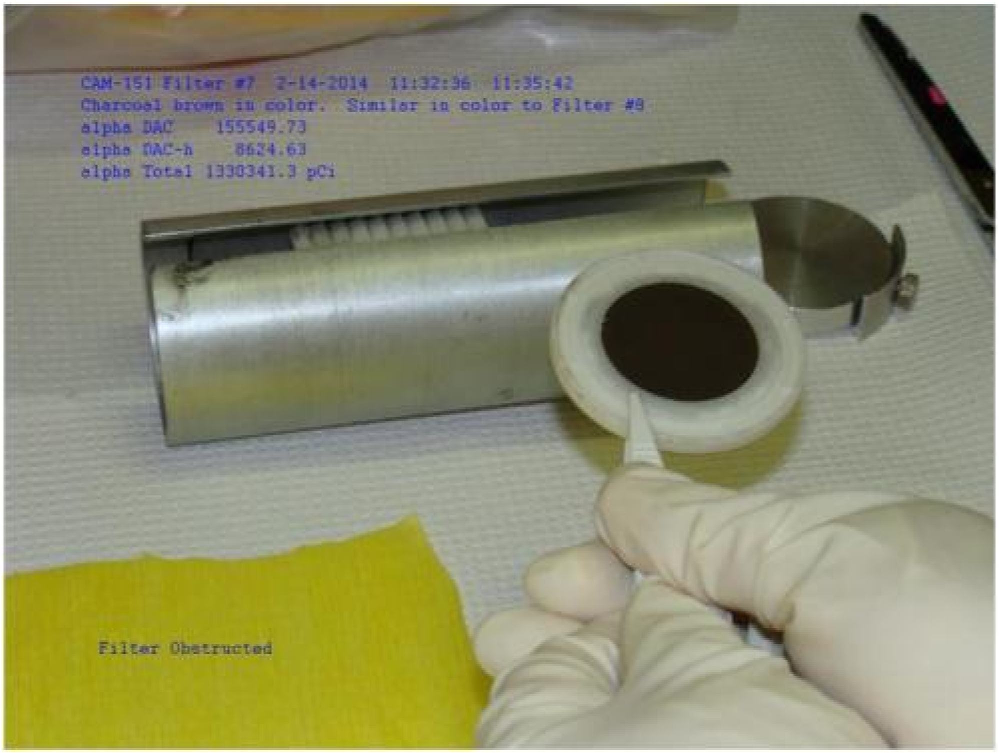
CAM 151 Filter #2

CAM 151 Filter #3

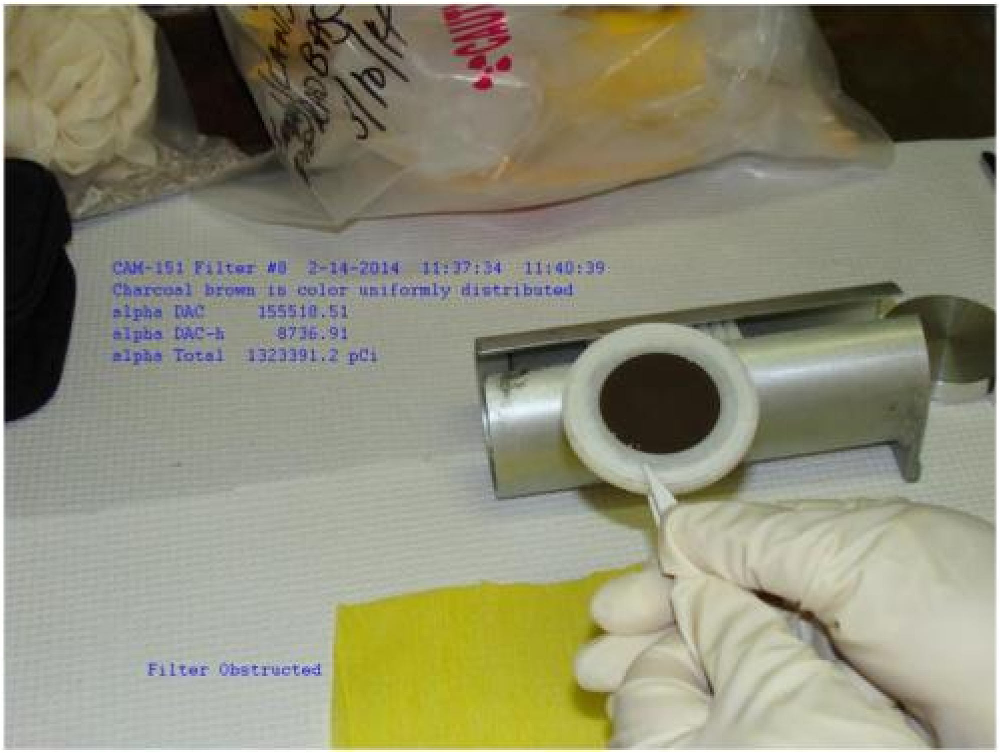
CAM 151 Filter #4

CAM 151 Filter #5

CAM 151 Filter #6



CAM 151 Filter #7



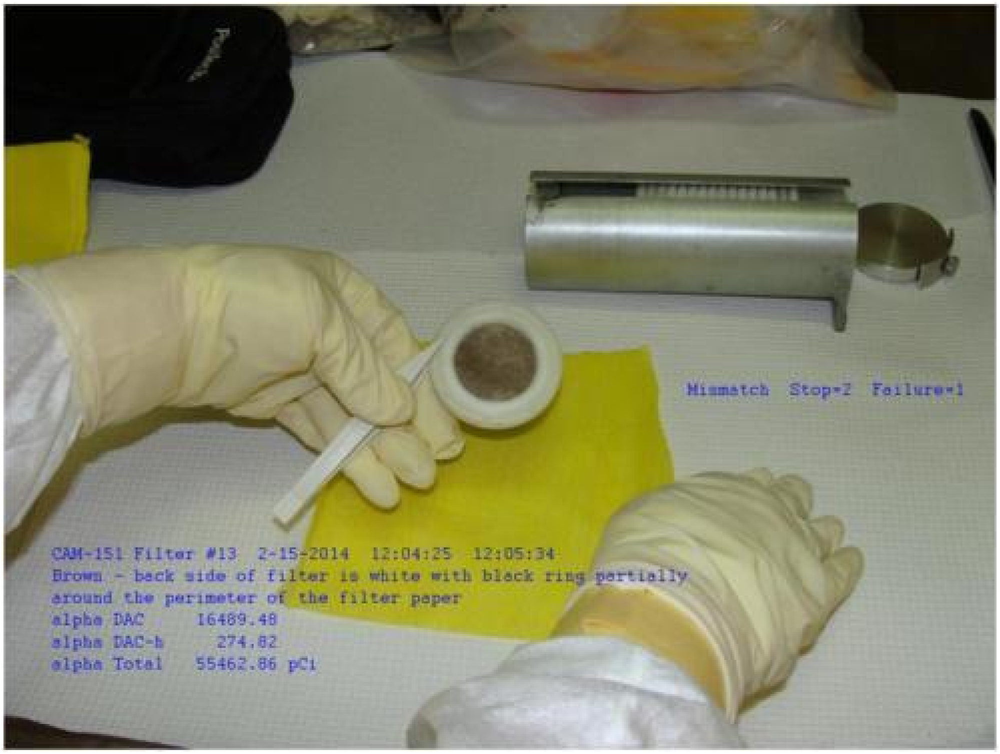
CAM 151 Filter #8

CAM 151 Filter #9

CAM 151 Filter #10

CAM 151 Filter #11

CAM 151 Filter #12



CAM 151 Filter # 13

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