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Carlsbad Field Office
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SEP 2 5 2015

Mr. Jonathan D. Edwards, Director
Radiation Protection Division
U.S. Environmental Protection Agency
1200 Pennsylvania Ave, NW - MC 6608T
Washington, D.C. 20460

Subject: Response to the U.S. Environmental Protection Agency Letters Dated February 27, 2015 and June 5, 2015 Regarding the 2014 Compliance Recertification Application

Dear Mr. Edwards:

The U.S. Department of Energy (DOE) Carlsbad Field Office (CBFO) is providing responses to six of the U.S. Environmental Protection Agency (EPA) completeness questions on the 2014 Compliance Recertification Application from the EPA letters dated February 27, 2015 and June 5, 2015. The DOE will continue to submit phased responses to the EPA to ensure questions are answered in a timely manner.

With this submittal, the DOE is providing responses to all of the EPA's completeness questions from the February 27, 2015 letter. The DOE has previously provided responses to all of the EPA's completeness questions from the December 17, 2014 letter. Responses for the remaining questions in the EPA's June 5, 2015 and July 30, 2015 letters will be submitted at a later date, yet to be determined. This submittal includes three enclosures:

- Enclosure 1 is a hardcopy of six of the EPA's comments and the DOE's responses;
- Enclosure 2 (on compact disc) provides the electronic version of the references as noted in each response. Copyrighted references, marked with an asterisk in "References" of Enclosure 1, are not provided in Enclosure 2. If there are specific copyrighted references the EPA needs, the DOE will work to obtain a copy;
- Enclosure 3 is the "Status Report of DOE Responses to EPA Completeness Questions." The Table shows the status of responses to the EPA comments received on December 17, 2014, February 27, 2015, June 5, 2015, and July 30, 2015.

If you have any questions, please contact Mr. Russ Patterson at (575) 234-7457.

Sincerely,

DCBryson

Dana C. Bryson, Acting Manager
Carlsbad Field Office

Enclosures

cc: w/enclosures

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*ED denotes electronic distribution

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CBFO:EPD:RP:MN:15-2220:UFC 5486.00

EPA Comment

2-46-1 CCA Appendix WRAC Waste Removal Documentation Needs Updating.

The cited removal plan is basically the same as that given during the 1996 CCA and does not reflect updates and modifications to the repository design and waste characteristics. The Agency found discrepancies between what was used as the removal plan listed in 1996 CCA Appendix WRAC, "Waste Removal after Closure," with the current 2014 repository design, waste, and container characteristics. Please assure that 40 CFR 194.46 requirements "Removal of Waste" still comply and are aligned with expected repository conditions at the time of closure, and that removal of waste remains feasible.

- *The repository is no longer mined on one contiguous level [CCA Appendix WRAC page WRAC-7], the southern portion of the mine was moved up to the Clay Seam G level.*
- *The waste containers have changed. The CCA assumed two principal types of containers (55-gallon drums and standard waste boxes) [CCA Appendix WRAC, page WRAC-8] but with the introduction of large waste boxes, shielded RH-TRU containers, pipe over packs, and super-compacted waste, these assumptions are no longer valid.*
- *The waste characteristics have changed with the introduction of nitrate waste potentially subject to exothermic reactions.*
- *The run-of-mine salt panel closure replaced the original concrete-based Option D panel closure design, which can no longer be used "as markers for locating panels and drifts" [CCA Appendix WRAC, Section WRAC.6.4].*
- *Given the use of shielded containers CH and RH wastes no longer must be segregated in the waste panels [CCA Appendix WRAC, Sections WRAC.4.3, WRAC.6, WRAC.6.4] and can no longer be removed using separate retrieval operations where the RH shielded containers are comingled with CH waste containers.*
- *CCA Appendix WRAC refers to performance assessment (PA) modeling to predict future characteristics of repository waste rooms. The PA assumptions, models, parameters, and inventory have changed since the CCA. Please include these changes in the waste removal reevaluation.*
- *CCA Appendix WRAC, Section WRAC.4.3 takes credit for the effectiveness of active and passive controls to deter human intrusion for up to 700 years after closure. However, this credit was denied by EPA because of difficulty predicting the future. This should be removed from the waste removal reevaluation.*

References:

U.S. Department of Energy (DOE). 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant (October). CCA Appendix WRAC, Waste Removal After Closure". DOE/CAO-1996-2184. Carlsbad, NM: Carlsbad Area Office.

U.S. Department of Energy (DOE). 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant (October). CCA Chapter 7.0, "Assurance Requirements". DOE/CAO-1996-2184. Carlsbad, NM: Carlsbad Area Office.

U.S. Department of Energy (DOE). 2004. Title 40 CFR Part 191 Compliance Recertification Application for the Waste Isolation Pilot Plant (March). CRA-2004 Chapter 7.0, "Assurance Requirements". DOE/WIPP 2004-3231. Carlsbad, NM: Carlsbad Field Office.

U.S. Department of Energy (DOE). 2009. Title 40 CFR Part 191 Compliance Recertification Application for the Waste Isolation Pilot Plant (March). CRA-2009 Section 46, "Removal of Waste" DOE 09-2434. Carlsbad, NM: Carlsbad Field Office.

DOE Response

The CCA Appendix WRAC has been revised to address the specific bullets listed in EPA's comment. The original CCA Appendix WRAC was slightly modified to reflect changes in the repository design and container types, and new information that is relevant to waste removal after closure. No changes have occurred since the first EPA certification decision in May of 1998 that impact the conclusion that removal of waste after closure remains feasible. The revised Appendix WRAC is included as Attachment A. The locations within the revised Appendix WRAC that addresses the EPA comments are provided under each bulleted item below.

- *The repository is no longer mined on one contiguous level [CCA Appendix WRAC page WRAC-7], the southern portion of the mine was moved up to the Clay Seam G level.*

  See revisions to Section WRAC-5.0, page WRAC-5, lines 22-25.

- *The waste containers have changed. The CCA assumed two principal types of containers (55-gallon drums and standard waste boxes) [CCA Appendix WRAC, page WRAC-8] but with the introduction of large waste boxes, shielded RH-TRU containers, pipe over packs, and super-compacted waste, these assumptions are no longer valid.*

  See revisions to Section WRAC-5.0, page WRAC-8, lines 7-15, and Tables WRAC-1 and WRAC-2. See also Figure WRAC-5, Section WRAC-5.3, page WRAC-14, lines 13-17, and Section WRAC-7.0, page WRAC-18, lines 1-11.

- *The waste characteristics have changed with the introduction of nitrate waste potentially subject to exothermic reactions.*

  See revisions to Section WRAC-5.3, page WRAC-14, lines 18-20.

- *The run-of-mine salt panel closure replaced the original concrete-based Option D panel closure design, which can no longer be used "as markers for locating panels and drifts" [CCA Appendix WRAC, Section WRAC.6.4].*

  See revisions to Section WRAC-5.0, page WRAC-8, lines 19-23; text concerning the Option D closure has been deleted. See also Figure WRAC-6.

- *Given the use of shielded containers CH and RH wastes no longer must be segregated in the waste panels [CCA Appendix WRAC, Sections WRAC.4.3, WRAC.6, WRAC.6.4] and can no longer be removed using separate retrieval operations where the RH shielded containers are comingled with CH waste containers.*

  See revisions to Section WRAC-5.3, page WRAC-14, lines 13-17, and Section WRAC-7.0, page WRAC-18, lines 4-11.

- *CCA Appendix WRAC refers to performance assessment (PA) modeling to predict future characteristics of repository waste rooms. The PA assumptions, models, parameters, and inventory have changed since the CCA. Please include these changes in the waste removal reevaluation.*

  See revisions to Section WRAC-5.1, page WRAC-10, lines 14-25, Section WRAC-5-2, page WRAC-12, lines 21-24, and Section WRAC-5.3, page WRAC-15, lines 6-11.

- *CCA Appendix WRAC, Section WRAC.4.3 takes credit for the effectiveness of active and passive controls to deter human intrusion for up to 700 years after closure. However, this credit was denied by EPA because of difficulty predicting the future. This should be removed from the waste removal reevaluation.*

  See revisions to Section WRAC-5.3, page WRAC-15, lines 6-11.

Note: The revised Appendix WRAC was reformatted to be consistent with the current CRA format. As such, the sections of the appendix were renumbered and do not match those of the original appendix. The sections referenced in the DOE response are those of the new appendix, while the sections referenced in the EPA's comments are those of the original CCA appendix.

Attachment A

Title 40 CFR Part 191
Subparts B and C
Compliance Recertification Application 2014
for the
Waste Isolation Pilot Plant

Appendix WRAC-2014
Waste Removal After Closure

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Field Office
Carlsbad, New Mexico

Compliance Recertification Application 2014
Appendix WRAC-2014

NOTE

This Appendix is a revised version of the Compliance Certification Application (CCA) Appendix WRAC (DOE 1996). The revision to Appendix WRAC was made in response to Environmental Protection Agency (EPA) completeness comments on the 2014 Compliance Recertification Application (EPA 2015).

Table of Contents

List of Tables

Acronyms and Abbreviations

CAG	Compliance Application Guidance
CFR	Code of Federal Regulations
CH	contact-handled
DOE	Department of Energy
DRZ	disturbed rock zone
EPA	U.S. Environmental Protection Agency
HEPA	high efficiency particulate air
HSLA	high-strength low alloy
LWA	Land Withdrawal Act
MB	marker bed
MgO	magnesium oxide
RH	remote-handled
SWB	standard waste box
TRU	transuranic
WHS	waste handling shaft
WIPP	Waste Isolation Pilot Plant

WRAC-1.0 Introduction

This Appendix is a revised version of the Compliance Certification Application (CCA) Appendix WRAC (DOE 1996). This revision was made in response to Environmental Protection Agency (EPA) completeness comments on the 2014 Compliance Recertification Application (EPA 2015). The analysis discussed in this appendix documents the techniques that could be applied in removing transuranic (TRU) waste from the Waste Isolation Pilot Plant (WIPP) repository after disposal. Title 40 Code of Federal Regulations (CFR) § 191.02(l) defines disposal of waste in a mined geologic repository as occurring ". . .when all of the shafts to the repository are backfilled and sealed." This report will serve to document compliance with the requirement in 40 CFR § 191.14(f) that the disposal system not preclude ". . .removal of most of the waste . . .for a reasonable period of time after disposal." The removal discussion is based on currently available technologies. The reasoning for waste removal is not considered relevant except that it is assumed the packaging, transportation mechanism and destination for the removed waste will be known. Transportation methods, end use, and destinations of the removed waste are not considered in this analysis.

WRAC-2.0 WIPP Mission Description

The WIPP is a research and development facility of the U.S. Department of Energy (DOE) designed to demonstrate the safe transportation, handling, and disposal of defense-generated TRU radioactive waste. The facility is located 26 miles (42 kilometers) east of Carlsbad, New Mexico. The repository is located in a salt deposit, 2,150 feet (655 meters) below ground. The waste is shipped to the facility from numerous generator sites around the United States and placed in the underground repository for disposal. Figure WRAC-1 details the WIPP location and Figure WRAC-2 contains a diagram of the WIPP surface and underground facilities. The facility began disposal operations in 1999. A comprehensive description of the WIPP disposal system and its operations is presented in Chapters 2.0 and 3.0 of the Compliance Certification Application (CCA: DOE 1996). A description of the operations and planned closure of the facility is in Chapter 3.0 of the CCA. The waste was originally described in Chapter 4.0 of the CCA, but the current waste information and important waste-related parameters used in performance assessment (PA) can be found in Section 24 of the CRA-2014 (DOE 2014a).

WRAC-3.0 Analytical Scope

This analysis examines the feasibility of removing emplaced waste from the WIPP repository after closure. The regulatory and technical bases for removal are discussed. The emplacement and closure scenarios are defined to describe the condition of the repository and waste after closure. The sequence of steps for removal is described in this Appendix and includes a detailed discussion of their implementation. Assuming that the technology and equipment used today to mine materials deposited millions or billions of years ago will be available in the future, it is technically feasible to remove the waste any time during the regulatory time frame. The feasibility of waste removal is demonstrated by describing a method for waste removal.

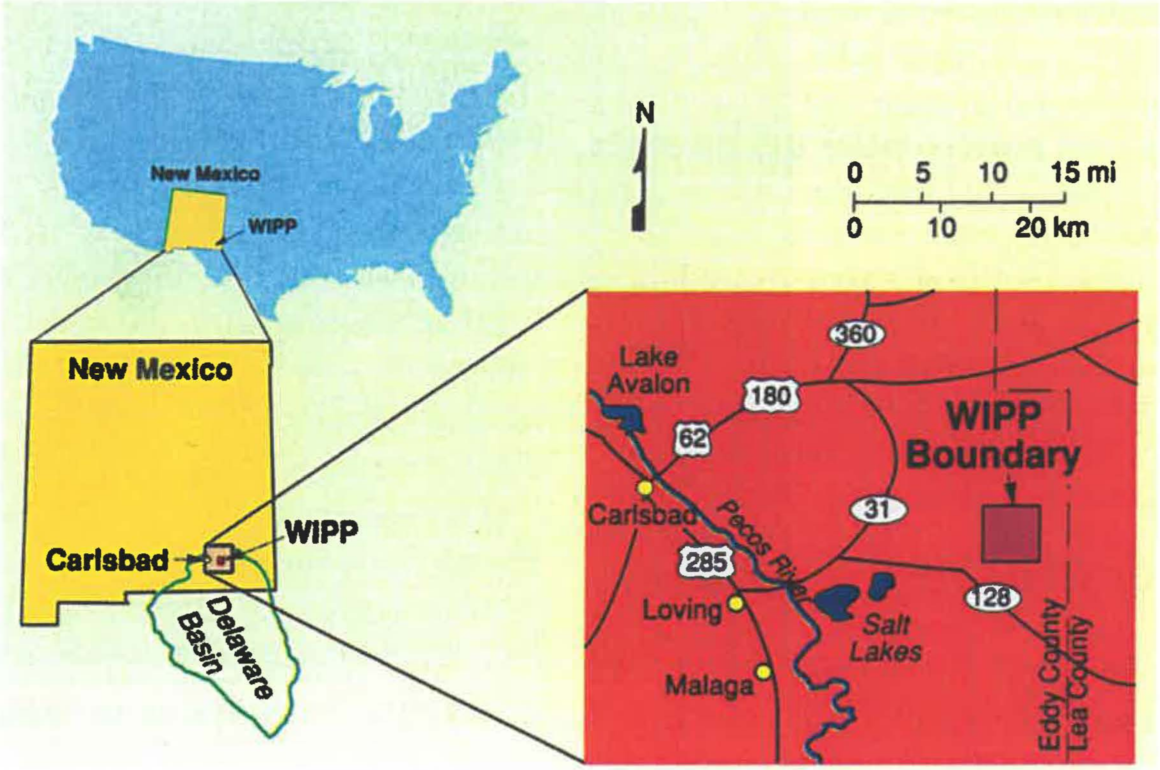


Figure WRAC-1. General Location of the WIPP Facility

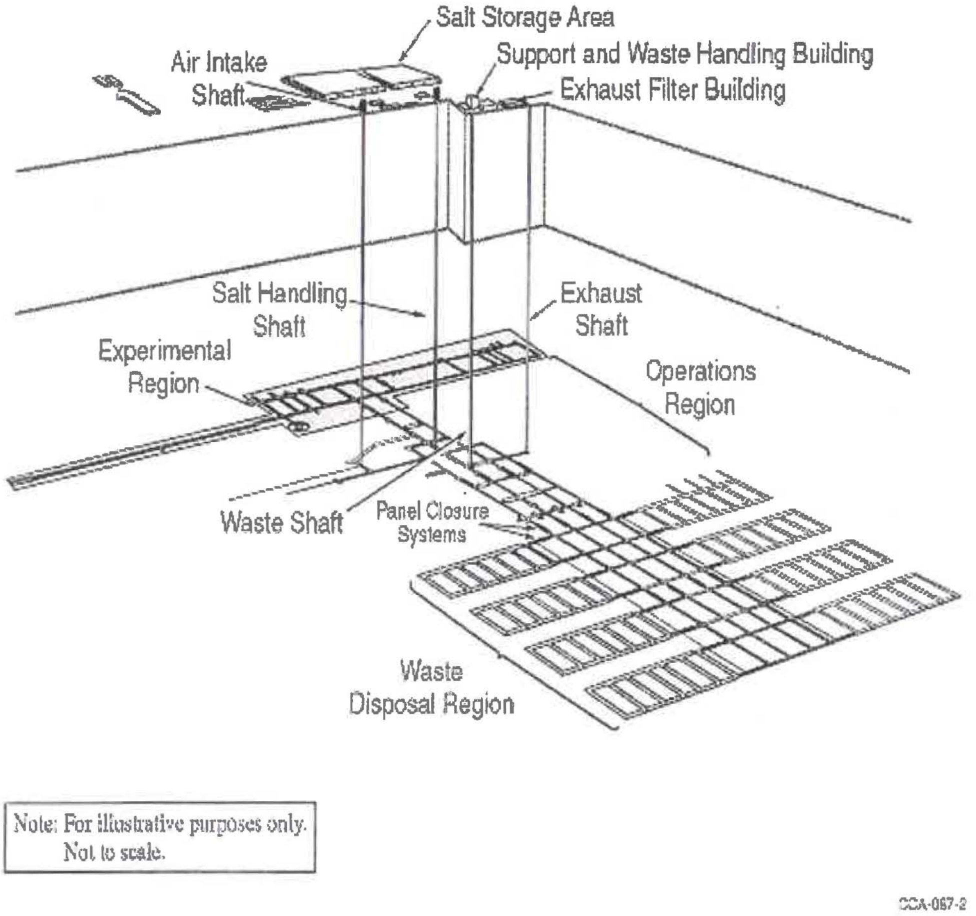


Figure WRAC-2. WIPP Surface and Underground Facilities

For the purposes of this feasibility analysis, it is important to distinguish the difference between waste removal and waste retrieval. Waste removal differs from waste retrieval in that removal refers to actions taken after the repository is closed and sealed. Retrieval, which is essentially the reverse of emplacement, refers to recovering the waste prior to repository closure. This analysis specifically deals with waste removal.

WRAC-4.0 Regulations Applicable to This Feasibility Analysis

As an assurance requirement in 40 CFR Part 191, waste removal is one of several cautious steps that are to be taken to reduce uncertainties inherent in the long-term predictions of disposal system performance. The EPA believes that recovery of the waste, though not necessarily easy or inexpensive, should not be precluded in the event some future discovery or insight made it clear that the wastes needed to be removed. The EPA provides specific insights regarding the implementation of this requirement as well as criteria in 40 CFR Part 194 for judging the adequacy of the DOE's demonstration of compliance to this requirement. Each is discussed below.

WRAC-4.1 40 CFR Part 191 Requirements

40 CFR § 191.14(f) states, "Disposal systems shall be selected so that removal of most of the waste is not precluded for a reasonable period of time after disposal". With respect to the recovery of waste after disposal, the preamble to 40 CFR Part 191 (50 *Federal Register* (FR) 38082) states that

...any current concept for mined geologic repository meets this requirement without any additional procedures or design features. For example, there is no intent to require that the repository shafts be kept open to allow future recovery. To meet this assurance requirement, it only need be technically feasible (assuming current technology levels) to be able to mine the sealed repository and recover the waste - albeit at substantial cost and occupational risk" (EPA 1985).

WRAC-4.2 40 CFR Part 194 Certification Criteria

40 CFR § 194.36 states that

Any compliance application shall include documentation which demonstrates that removal of waste is feasible for a reasonable period of time after disposal. Such documentation shall include an analysis of the technological feasibility of mining the sealed disposal system, given technology levels at the time a compliance application is prepared.

By way of guidance for the requisite analysis referenced in the criterion, the EPA has provided a specific list of expectations in its Compliance Application Guidance (CAG) (EPA 1996). In the CAG, the EPA states:

EPA expects the required analysis to include:

- *a sequence of procedures or steps which would need to be accomplished in order for waste to be removed from the disposal system after closure;*

- *a discussion of how the sequence described above could be implemented, including descriptions of how currently available equipment and technologies could be utilized; and*
- *an estimate of how long after disposal it would be technologically feasible to remove the waste, based on the disposal system design and closure, and using the system and equipment described in the application. (EPA 1996, 66)*

The following feasibility analysis examines and addresses this criterion and the implementation guidance. Background information is provided as part of the feasibility analysis. This background information includes a description of the disposal system and the waste at the time of disposal and the assumed condition at the time of removal (to the practicable extent to which this condition can be anticipated).

WRAC-5.0 WIPP Repository Description

The WIPP disposes TRU waste in rooms 2,150 feet (655 meters) below the surface. These rooms are mined in a bedded halite (salt) layer known as the Salado Formation (hereafter referred to as the Salado). The Salado is approximately 2,000 feet (610 meters) thick at the repository location. Figure WRAC-3 shows the general geologic cross section of the WIPP site. The underground repository is mined on three general levels, the north area and two waste areas. The northern most area includes mined areas that were used for early experiments and is mined at a level above the shaft landings and disposal areas. The north area is used today for operations and includes areas for ongoing experiments. Waste is emplaced in the disposal areas, which are comprised of eight panels, each panel composed of seven rooms, and the inter-connecting access entries (drifts) which are identified as Panels 9 and 10. The rooms are mined to the initial dimensions of 300 feet long by 33 feet wide by 13 feet high (91 meters by 10 meters by 4 meters). Half of the disposal area is mined at a higher horizon. Panels 3, 4, 5 and 6 are mined approximately six feet higher than the other panels. The access drifts include ramps connecting the two levels. The repository layout is shown in Figure WRAC-4. A complete technical description of the repository including its geotechnical performance is found in annual Geotechnical Analysis Reports or GARs (DOE 2014b).

The waste is composed of radioactive and hazardous waste materials generated by the DOE's nuclear weapons programs. The materials are primarily laboratory and production equipment such as glassware, solidified spent solvents, cleaning rags, laboratory clothing, solidified sludges, metal tools, pipes, plastics, and paper. TRU waste is defined as waste contaminated with alpha emitting radionuclides having atomic numbers greater than 92, half-lives greater than 20 years, and a specific activity greater than 100 nanocuries per gram. Some of the waste to be disposed of at WIPP will contain hazardous constituents as defined by the Resource Conservation and Recovery Act (RCRA). This waste is referred to as TRU mixed waste. The waste is currently generated or stored at numerous sites in the United States. Current waste emplacement volumes are reported on an ongoing basis in the WIPP Waste Data System.

There are two classifications for the TRU waste, contact-handled (CH) TRU and remote-handled (RH) TRU. The CH-TRU waste is defined as TRU waste packaged in containers whose maximum surface dose rate does not exceed 200 millirem per hour. Surface dose rates greater than 200 millirem per hour are classified as RH-TRU waste. For emplacement into the WIPP the RH-TRU surface dose rates cannot exceed 1,000 rems per hour with a maximum total of five percent of the canisters exceeding 100 rems per hour. The total maximum activity for RH-TRU waste at WIPP cannot exceed 5.1 million curies. These limits including a maximum TRU waste volume of 6,200,000 cubic feet (175,588 cubic meters) are established by the Land Withdrawal Act (LWA). The actual emplaced volumes, waste stream information and waste emplacement locations are kept as long-term records and will be available for an appreciable period of time after closure which will aid in waste removal activities. This information includes the specific locations of all CH and RH containers and includes the location of a few shielded containers that are planned to be emplaced within the areas used to emplace CH waste.

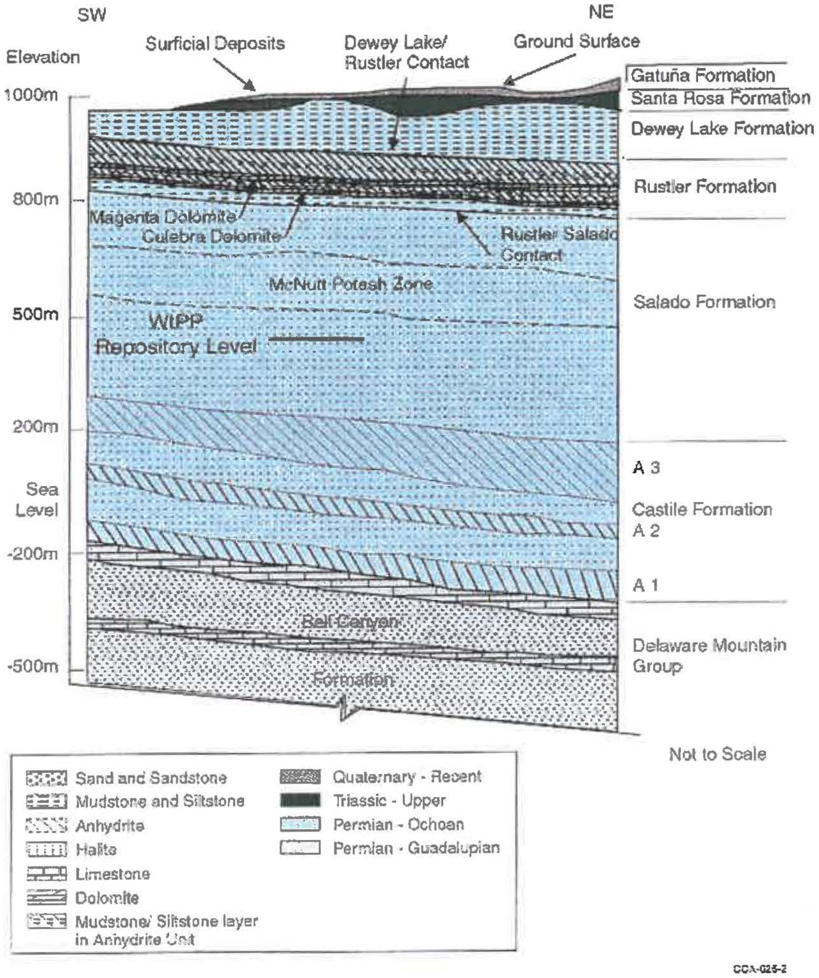
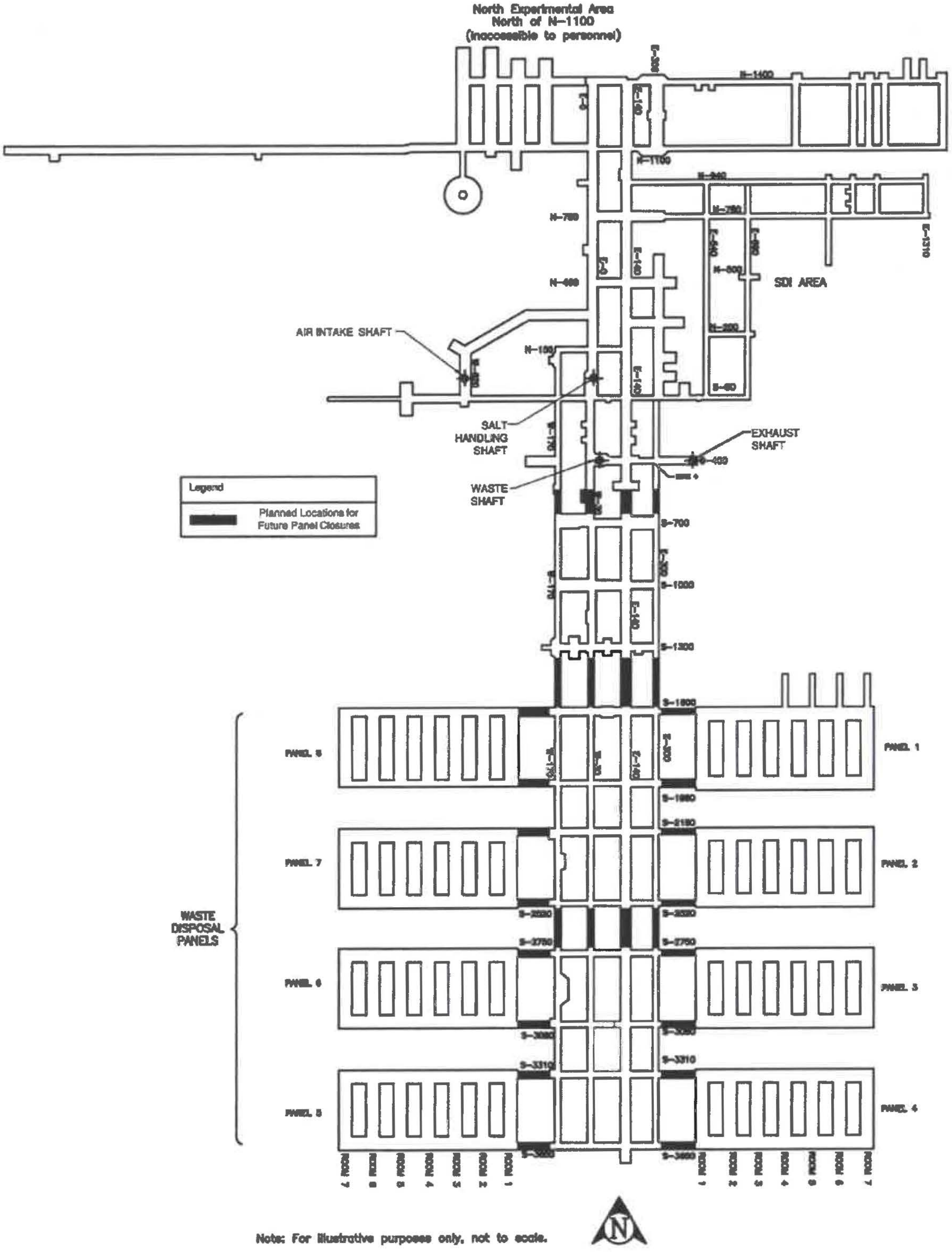


Figure WRAC-3. Generalized Geologic Cross Section



Note: For illustrative purposes only, not to scale.

Figure WRAC-4. Repository Layout

The high radiation associated with RH-TRU waste is due to the presence of isotopes of cesium, strontium, barium, plutonium, and yttrium. The longest half-life among these isotopes is 30.0 years. Therefore, after about 300 years, the isotopes will have gone through a minimum of 10 half-lives and their radioactivity, relative to the longer lived isotopes associated with the CH-TRU waste, will be significantly diminished. For this reason, in discussion of the removal of waste after 300 years, the DOE does not distinguish between the RH-TRU and CH-TRU types.

The majority of CH-TRU waste has been shipped to the WIPP in either 55-gallon (208-liter) drums or standard waste boxes (SWBs). The 55-gallon drums are wrapped together in an arrangement of seven drums called seven-packs. A list of the waste containers used in the repository is shown in Table WRAC-1. A list of the emplaced waste volumes is shown in Table WRAC-2. The waste container is the outermost container and may include other overpacked containers, such as 55-gallon drums or pipe overpacks. The waste containers are shown in Figure WRAC-5. Rows of containers are placed in the rooms, generally three high, with a bag of magnesium oxide placed on top of most of the stacks to achieve the quantity needed to meet the regulatory requirements of an engineered barrier. The waste will also be emplaced in the panel access entries.

Table WRAC-1. Container Types and Emplaced Waste Volumes (As of 2/28/2015; DOE 2015)[1]

Emplaced Waste Containers	Number of Containers in Repository
55-Gallon Drum	116,955
Standard Waste Box	12,846
Ten-Drum Overpack	6,047
85-Gallon Drum (short and tall)	5
100-Gallon Drum	34,255
Standard Large Box 2S	228
Removable Lid 72-B RH Canisters	701
Fixed Lid 73-B RH Canister	18
Shielded Containers	9

Table WRAC-2. Emplaced Waste Volumes (As of 2/28/2015; DOE 2015)[2]

Emplaced Waste	Volume (m^3)
CH Container Volume	90,627
RH Container Volume	357
Total Waste Volume	90,984

After a panel is filled, a closure system is constructed to isolate the waste from further operations. The original closure system design used a block wall and called for a large concrete monolith. Block walls have only been constructed in Panels 1, 2 and 5. Steel bulkheads have been emplaced in the entryways to Panels 3, 4 and 6. The concrete closure design has been

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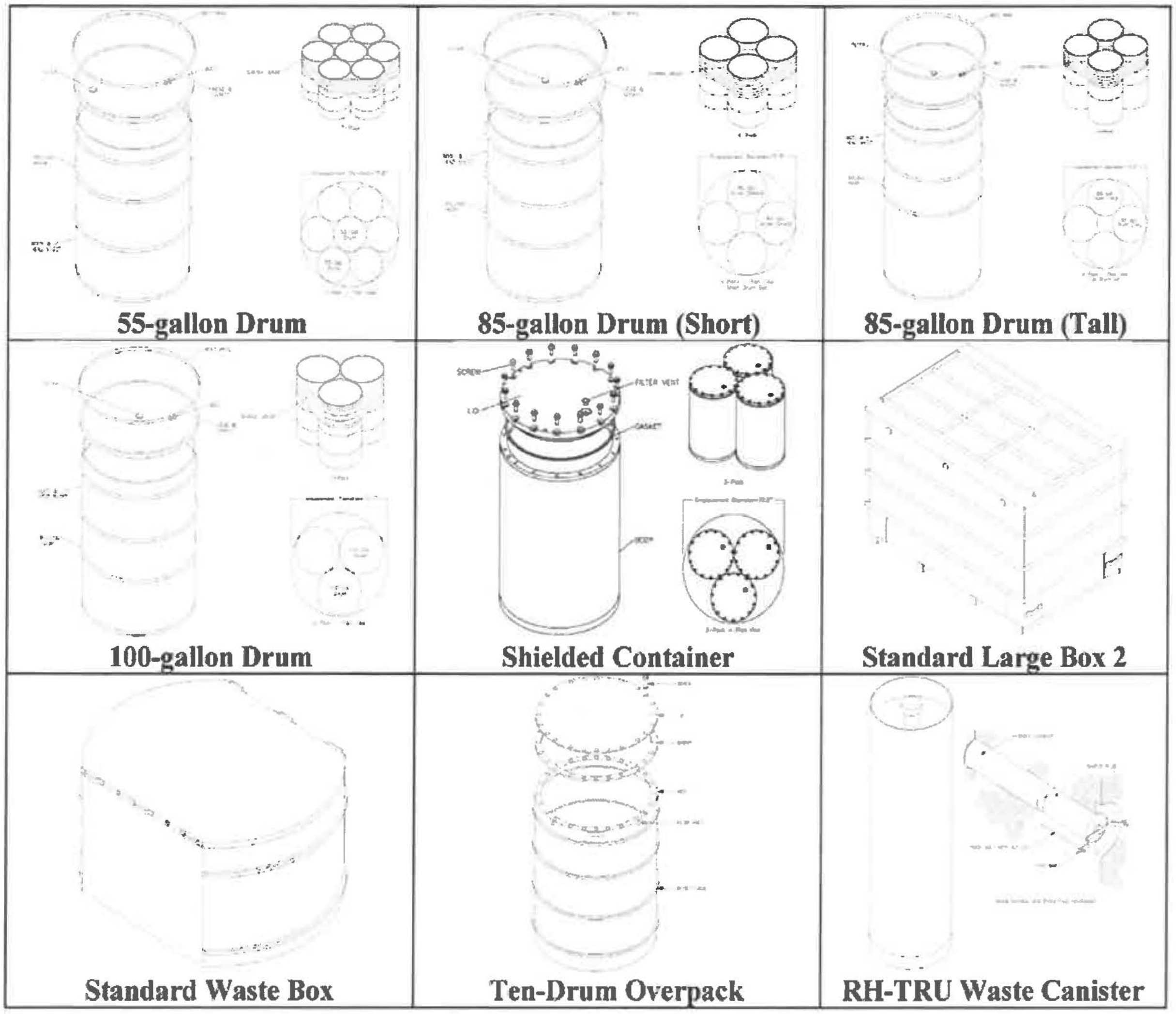
[1] The date for this information is more current than that of the CRA-2014 and may differ from the information in the CRA-2014.

[2] The date for this information is more current than that of the CRA-2014 and may differ from the information in the CRA-2014.

replaced with a 100 foot run-of-mine-salt-based panel closure design that will be emplaced in all of the panel entries prior to repository closure. The closure design is shown in Figure WRAC-6 and described in CRA-2014 Appendix PA, Section PA-4.2.8 (DOE 2014a).



55-gallon Drum
85-gallon Drum (Short)
85-gallon Drum (Tall)
100-gallon Drum
Shielded Container
Standard Large Box 2
Standard Waste Box
Ten-Drum Overpack
RH-TRU Waste Canister

Figure WRAC-5. SWB and Seven-Pack Configurations

An engineered barrier consisting of magnesium oxide (MgO) is placed over the containers of CH-TRU waste. The MgO is emplaced in 3,000-lb or 4,200-lb super sacks on top of the waste stack (see CRA-2014 Appendix MgO for more detailed information on MgO emplacement). The MgO super sacks are intended to burst as the room creeps closed, allowing the granular materials to be exposed to the room environment. Alkaline earth oxides (such as MgO) are known to readily react with water to form hydroxides. These hydroxides are free to react with carbonic acid that may form in the disposal room. The reaction buffers the brine to a pH which serves to reduce the amount of actinides in solution.

The RH-TRU waste canisters are constructed of painted carbon steel, 26 inches (66 centimeters) in diameter with a maximum length of 121 inches (307.3 centimeters). The maximum weight of a filled canister is 8,000 pounds (3628.7 kilograms) (DOE 1991). In order for personnel to handle the RH-TRU waste, the RH waste canisters must be shielded to reduce radiation levels to allowable limits. The shielded facility cask is used to transport RH-TRU waste to the underground. The RH-TRU waste canisters are emplaced in the disposal room walls prior to CH-TRU waste emplacement in that room. The waste canister is pushed out of the facility cask and into a horizontal borehole in a disposal room wall. The borehole is then closed with a shield plug. The shield plug is a cylinder 29 inches (73.7 centimeters) in diameter and 70 inches (177.8 centimeters) long with a wall thickness of 1.5 inches (3.8 centimeters). The bottom of the plug is constructed from a 5-inch (12.7-centimeter) thick plate. The 3-inch (7.6-centimeter) thick top plate also has a standard waste handling pintle. The total weight of the plug is approximately 4,200 pounds (1,905 kilograms). Currently, RH waste has not been emplaced in every room of the repository that has CH waste. Some RH waste has been emplaced in shielded containers along with the CH waste, and not in the disposal room walls. As is done for the CH waste, all emplaced RH-TRU waste locations are recorded and retained as a permanent record.

WRAC-5.1 Repository Configuration at the Time of Closure

The anticipated final configuration of the repository at the time of closure is shown in Figure WRAC-6. This is the configuration that is used as input to the conceptual model developed to predict repository performance. The model geometry used in PA is shown in CRA-2014 Appendix PA, Figure PA-12 (DOE 2014a). The important regions include the waste disposal panel, panel closures, the panels and access drifts in the North and South rest-of-the repository area, the shaft region, the operations region, and the experimental region at the north end of the excavation. In addition, the repository geometry conceptual model described in Appendix PA incorporates the stratigraphic units surrounding the repository into the model as discrete regions. These include the Salado Formation outside the disposal region, MB138, Anhydrite Layers A and B, the disturbed rock zone and MB139. Parameter values have been assigned to important properties (such as porosity and permeability) of these various regions. Initial values and value ranges used in the CRA-2014 PA are summarized in Kicker and Herrick 2013.

The LWA limits the total disposed TRU waste to 6,200,000 cubic feet (175,600 cubic meters). After waste emplacement is complete, the surface structures will be decontaminated and decommissioned. This will include decontaminating the surface facilities and dismantling the aboveground structures. TRU waste generated by these activities will be emplaced in the repository and the last waste panel will be closed. The four shafts will be sealed using crushed Salado salt in combination with other materials such as concrete, cementitious grout, clay, and asphalt. CCA Appendix SEAL details the shaft seal design (DOE 1996).

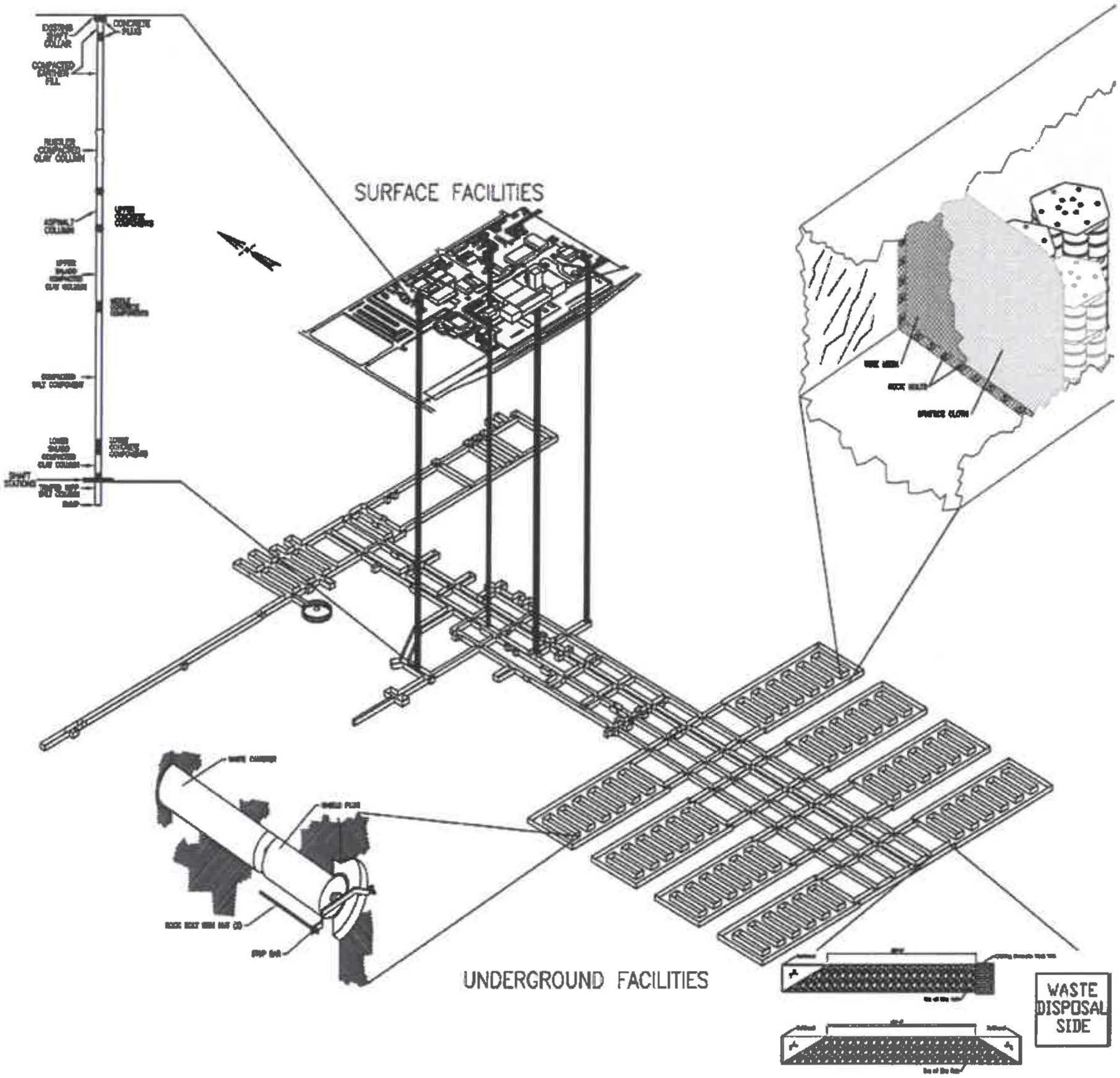


Figure WRAC-6. WIPP Repository at Time of Closure

WRAC-5.2 Repository Condition at Time of Removal

The requirement to remove the waste does not specify when or if removal would occur; only that removal not be precluded. The condition of the repository is time dependent with respect to salt reconsolidation, waste compaction and decay. For the purposes of this analysis, the DOE assumes that the reason for removal is the result of a discovery or insight gained by a future generation and not the result of an event that necessitates removal. As the result of this assumption, there are no time or cost limits imposed on the removal process in this analysis. Radioactive waste within the disposal region can be removed at whatever rate is necessary to safely manage occupational and public exposure.

Additional assumptions include the following.

- The reason for waste removal is known and what will be done with the waste is unimportant for this analysis. This analysis need only demonstrate removal feasibility.
- The length of time the repository has been closed at the time of removal is known to those planning the removal and the anticipated conditions of the waste panels and panel closure can be determined for use in designing removal systems (see CRA-2014 Appendix PA, Section PA-4.2.3 [DOE 2014a] for a discussion of rock creep and porosity and permeability values assumed for performance assessment).
- The waste containers have been breached.
- Removal of most of the waste means that all waste within the disposal region will be removed, however any contamination that may have migrated into the marker beds and may have moved out of the disposal region will not be removed.

Numerical calculations performed for the repository are focused on predictions of performance over a 10,000-year period. In the shorter term, the configuration of the excavation and waste within the repository is changing as it reaches a steady state configuration. As steady state is reached, the brine inflow rate is affected by the potential increasing pressure in the repository caused by gas generation and creep closure. These three phenomena are related in the numerical modeling that is detailed in CRA-2014 Appendix PA. All of these phenomena and the various associated states of the excavation need to be considered in evaluating the feasibility of removal. In no case, however, are conditions expected to render removal impossible. The repository was originally mined for disposal operations and the area can be mined again. The last PA run prior to repository closure will be included in archived records (see CCA Appendix PIC [DOE 1996]). This information can be used to help predict the conditions in the repository at the specific time of waste removal.

Gas generation affects pressure within the excavation, which in turn is an important mechanism in creep closure. The computer simulation of this process uses an average-stoichiometry model to estimate the potential for gas generation in the waste disposal region. Modeling shows that gas pressure in the disposal room can range from slightly above atmospheric to near lithostatic over the 10,000-year period. The model assumes that interbed fracturing occurs at high pressures thereby limiting pressure buildup. If the agency removing the waste in the future anticipates that high pressures are present, techniques are available to detect and safely relieve such pressures. Such techniques are currently in use in the WIPP to prevent dangerous pressure blowouts from localized pressurized zones ahead of mining. The technique involves drilling small diameter probe holes into the rock ahead of the mining machine.

The DOE conceptualizes the Salado as a porous medium composed of several rock types arranged in layers, through which fluid flow occurs according to Darcy's Law. This model was chosen because it can be simulated using standard numerical techniques and because it is the most conservative of the three mechanisms in that it predicts the maximum rate and cumulative volume of brine inflow. Two rock types, impure halite and anhydrite, are used to represent the intact Salado. Near the repository, the disturbed rock zone (DRZ) has increased permeability compared to intact rock and offers limited resistance to flow between anhydrite interbeds and the repository. Except for the DRZ and anhydrite interbeds, under certain circumstances, this simulation assumes spatially constant properties for Salado rock. The inference is that there is little variation in large-scale averages of rock or flow properties across the disposal system. Assumptions about Salado flow in general are presented in CRA-2014 Appendix PA, Section PA-4.2 and CRA-2014 Appendix MASS, Section MASS-5 and 6 (DOE 2014a).

In the computer simulation, brine flows from the Salado and into the repository in response to fluid potential gradients that form over time. Because of the low permeability of the impure halite and relatively small surface area of the excavation, direct brine flow between the impure halite and the repository is limited. The interbeds, however, can serve as conduits for brine flow between the impure halite and the repository. Conceptually, brine flows laterally along higher-permeability interbeds towards or away from the repository and vertically between the interbeds and the lower-permeability halite (DRZ).

Alternatively, in the modeling for the disturbed case, brine could flow into the repository as the result of a drilling intrusion that connects a disposal panel with postulated brine reservoir in the Castile Formation. In such a case, a portion or all of the excavation could be saturated with brine. Removal feasibility should consider a range of brine saturation from dry to fully saturated.

Creep closure of the excavation is the focus of a computer model that implements the repository processes associated with rock properties in the repository rooms and the shafts. The amount of waste consolidation resulting from creep closure, and the time it takes to consolidate the waste, are governed by properties of the waste (waste strength), properties of the surrounding rock, the dimensions and location of the room, and the quantities and pressure of fluids present in the room. Creep closure of waste disposal areas will cause their volume to decrease as the Salado deforms to consolidate and encapsulate the waste, changing waste porosity and permeability. Waste strength and fluid pressure may act to resist creep closure. The conceptual model implementing creep closure is discussed in CRA-2014, Appendix PA, Section PA-4-2-3 and CRA-2014 Appendix MASS, Section MASS-5 and 6 (DOE 2014a).

Fluids that could affect closure are (1) brine that may enter the repository from the Salado and is present in the repository when it is sealed, and (2) gas produced by reactions occurring during waste degradation. Closure and consolidation slowed by fluid pressure in the repository can be quantified according to the principle of effective stress:

$$\sigma_T=\sigma_e+p \tag{1}$$

where σ_T is the stress caused by the weight of the overlying rock and brine (an essentially constant value), p is the pressure of the repository pore fluid, and σ_e is the stress that is applied to the waste matrix. As the waste matrix pore pressure increases, an increasing amount of overburden stress is supported by pore fluid pressure, and less overburden stress is supported by the strength of the waste matrix. Because of the strength, waste consolidation can cease even if pore fluid pressures do not reach lithostatic. If gas and brine quantities in the repository stabilize, creep closure will act to establish a constant pressure and void volume.

Creep closure becomes an important consideration for the removal process since it determines, to a major extent, the dimensions of the excavation that is needed to remove the waste and the condition of the rock that must be mined. Conditions where the creep has been minimal also indicate the situations where brine content or gas pressure are highest and represent the most hazardous pressure-related conditions.

WRAC-5.3 Summary of Conditions to be Anticipated for Removal Feasibility

Based on the descriptions in the preceding sections, there are five potentially hazardous conditions that should be anticipated in preparing for the removal of disposed waste. These are radioactivity, hazardous constituents, gas, brine, and rock integrity.

The amount of radioactivity depends on the time at which removal is initiated. Within the first 300 years of disposal, it may be necessary to consider treating (removing) RH-TRU and CH-TRU waste differently, because of higher radioactivity of the RH waste. Beyond 300 years, all the waste can be managed as CH-TRU waste because the inventory of Cs-137 and Sr-90 has decayed to very low levels. Regardless of when removal is initiated, the inventory of the waste documentation that will be accumulated by the DOE during operations and archived after closure will contain sufficient information to determine rather precisely the radioactivity levels to be anticipated and the locations of any containers of waste that may pose higher radioactivity hazards (i.e., shielded containers with RH waste).

Archived waste information would be available that could be analyzed to determine if there are potentially hazardous chemical waste properties, reactions or interactions that would need to be addressed during removal activities. With regard to the hazardous constituents in the waste, the volatile organics do not occur in sufficient quantities to pose a hazard as long as adequate ventilation is provided in areas that will be occupied by workers. Non-volatile hazardous constituents only pose threats if they are released during the removal process. Here, as with both the volatile components and the radioactive contaminants, proper ventilation control will be needed to provide adequate protection to workers, the public, and the environment. If environmental protection laws are the same at the time of removal as they are today, the planning for removal will require that the agency implementing removal provide detailed plans for controlling hazardous constituent contamination.

Gas pressures can range from one atmosphere (14.7 pounds per square inch or 0.101 megapascals) to pressures near 2,000 pounds per square inch (13 megapascals). Experience with mining in halite indicates that in virgin rock, high pressure zones are maintained because of the low permeability of the rock. Therefore, current mining activities are conducted in anticipation of pressure in areas where such pressures are known to exist. Due to the nature of the disposal operations and the panel closure practices, future pressures could vary from panel to panel.

Brine quantities can vary from little to no brine, caused by brine consuming processes such as corrosion, hydration of MgO and microbial degradation, to panels full of brine as the result of a borehole that connects the repository with a potential brine reservoir in the Castile Formation. As with gas, the quantity of brine can be different from one panel to the next because of the anticipated efficiency of the panel closures.

The amount of pore space in a disposal panel can be used to represent the degree of consolidation that has occurred due to creep closure. While brine and gas can act to maintain rather large pore volumes in a sealed panel, this condition is considered unlikely since creep closure acts fairly rapidly and it is unlikely that sufficient brine and subsequent gas will be available to support large pore volumes without an external source such as an intrusion involving a Castile brine reservoir. Because active controls are expected to deter human intrusion for at least 100 years after closure, an encounter with such a brine source is not expected during this time period. Although PA does not take credit for passive controls in the release calculations, the DOE believes passive controls will likely reduce human intrusions beyond 100 years. Consequently, without human intrusion, the repository is expected to reach its maximum closure before large quantities of brine are available.

Each of the factors above represents variable conditions that the removal planning activity must evaluate prior to actually removing the waste from the repository. None of these are expected to create conditions that will render the waste impossible to remove. However, the hazards imposed by the ranges of possible future conditions dictate careful hazard mitigation evaluations and appropriate planning prior to initiating waste removal.

WRAC-6.0 Sequence of Steps to Remove Waste

The DOE has identified a sequence of five phases for implementing removal:

Phase 1 —	planning and permitting.
Phase 2 —	initial aboveground setup and shaft sinking.
Phase 3 —	underground excavation and facility setup of underground ventilation, radiation control, packaging areas, decontamination areas, maintenance, remote control center, and personnel support rooms.
Phase 4 —	waste location and removal operations, including mining waste removal, packaging, package surveying and decontamination, transportation to surface, staging for off-site transportation, and off-site transportation.
Phase 5 —	closure and D&D of the facility.

Each of the five phases is summarized below and described in detail in Section WRAC-7.0.

WRAC-6.1 Planning and Permitting

A decision to remove waste will initiate the planning and permitting phase. Permitting requirements will be based on governing regulations at the time removal is authorized. The planning and permitting program will identify all permits and research the available technologies at that time to determine available removal techniques and the condition of the repository. After initial research is completed, a plan will be drafted to itemize and schedule all removal activities. It is at this stage that initial estimates of the condition of the waste will be made. These will be based on the performance assessment results, the record of reassessments that may have been done as the facility was filled, the records of the waste that was actually placed in the facility, and any other information that may be useful in determining the status with regard to pressure, water content, contamination movement, and disposal room configuration. Strategies for evaluating the conditions in the repository and adjacent host rock will be developed. These may include surface drilling or drilling from within an initial excavation adjacent to the waste areas. Appropriate geophysical techniques and other remote sensing measures will be identified for determining the condition of the waste and adjacent areas in a manner that minimizes the hazards and chance for radiation exposure.

WRAC-6.2 Initial Aboveground Setup and Shaft Sinking

Aboveground support buildings will house the exhaust fans and any radiation control equipment such as HEPA filters, administration facilities, operations and engineering facilities, training facilities, safety facilities, maintenance support facilities, control center, waste staging and decontamination areas, container shipment loading and dock areas, warehouses (waste containers and maintenance), laboratories, and others as deemed necessary. Initial estimates of the amount of mining necessary will be made based on the results of the planning phase. The amount of mining will dictate the size and capacity of the surface support facilities and tailings piles.

WRAC-6.3 Underground Excavation and Facility Setup

After the shafts are completed, drifts will be run and ventilation paths will be established using conventional mine ventilation techniques. During shaft sinking, provision will be made to test the muck prior to its release to the surface to detect radioactive or hazardous constituent contamination. If such contamination is found, shaft muck will be isolated for future disposition. If contamination is minor, this material will likely be isolated from the environment by placing it back into the facility at the time of closure. Underground support and service areas will be excavated. The location of the shafts and initial excavations will be determined based on the anticipated brine and gas conditions. These areas will have sufficient intact salt between them and the waste areas that seepage or blowout of contaminated brine or gas into the shafts and service areas will be precluded. There are not expected to be any limitations on the amount of distance that can be specified between the wastes and the service areas. Support rooms will be excavated for maintenance, control, and packaging. Air locks will be constructed to provide the necessary level of ventilation control and separation between contaminated and non-contaminated areas. All equipment required for removal, packaging, and related support equipment will be installed.

Excavation will be in two stages. Initial excavation will not contact waste and will provide for mine support rooms, haulage drifts, ventilation, and access to the waste. The second stage will remove the waste.

WRAC-6.4 Waste Location and Removal Operations

The waste removal will be performed in discrete operations depending on the anticipated level of radioactivity. The waste will be removed by mining the area where the waste was emplaced. The mined waste will be transported to the packaging areas. The waste can be removed many ways using standard equipment. Section WRAC-7.2 contains a brief description and describes the feasibility of using various mining techniques for waste removal. An appropriate level of radiological controls will be used depending upon the radioactivity of the mined waste.

WRAC-6.5 Closure and D&D of the Facility

After waste is removed from the repository, the facility will be decommissioned according to the current regulations at that time.

WRAC-7.0 Removal Implementation

To support the requirement that waste removal is not precluded, a system for waste removal is described using available mining technologies. This description includes standard shaft sinking practices and drift excavations. Since the salt is a good radiation barrier, standard mining techniques may be used until contamination or radiation is reached that exceeds the current personnel safety limits. In these contaminated areas, currently available remote controlled mining equipment or equipment modified with off-the-shelf systems may be used. Where practical or necessary, removal operations will be performed remotely. All support, radiation and air quality monitoring, and geotechnical surveying will be performed remotely in the contaminated areas. The clean and contaminated areas will be segregated from each other and maintained using separate air intake paths and ventilation control structures.

The excavated waste and materials will be placed in appropriately designed waste containers. Appropriate air locks and bag out operations will be used to limit container contamination. The container surfaces will be decontaminated if necessary prior to being transported aboveground. Aboveground facilities will include a control center where any necessary remote waste handling and packaging operations are coordinated, and a decontamination area where waste containers will undergo any necessary additional decontamination or overpacking. The waste containers (including overpacks) will be staged aboveground for transportation. A control center in the underground will provide the interface between the aboveground control center and the underground operational activities.

The mining and waste removal operations will be designed to reduce the amount of contamination and exposure to allow limited human access for assessments, equipment retrieval, and equipment repairs. Operations will be designed to reduce human involvement to the extent practicable. Radiological work will be performed using standard industry practices and approved procedures.

The mining operations will use standard equipment to sink the shafts and excavate the drifts and support rooms. After the underground support areas are completed, the waste will be removed. Smaller scale mining equipment will be used to perform the removal. Modifications to the equipment will enable the vehicles and support equipment to be remotely monitored and controlled. The length of time since disposal will determine whether or not the RH-TRU and CH-TRU wastes will be retrieved in separate operations. It is currently anticipated that the radioactivity level of RH will decay to CH levels within 300 years after disposal (DOE 1995). Thus if removal is conducted subsequent to 300 years after disposal, a single mining operation may remove CH and RH simultaneously. However, removal prior to that time may require separate waste handling and packaging operations. Because RH wastes may pose a greater radiation hazard, RH-TRU removal activities may be more complex and possibly involve remote handling equipment in order to limit the exposure to personnel. RH-TRU waste should be removed in as intact a condition as possible. Some RH waste has been emplaced in shielded containers with the CH waste. These containers may require special consideration during removal. To aid removal operations, archived records will contain waste stream information, container type and location of the waste containers. The various types of waste containers will degrade at different rates due to their material composition and mechanical properties. Some containers, such as the pipe overpacks, have thicker containers walls than other containers and are expected to endure longer than less robust containers (container types are shown in Figure WRAC-5). Depending on the amount of time after closure the waste is retrieved, some containers may be more intact than others.

The preamble to 40 CFR Part 191 states that waste removal must be feasible but would likely incur great cost and overall occupational hazard. No time limit is specified. The removal approach will include measures that reduce the overall hazards but will require a long time period to complete. No time limits or cost estimates are included in this study.

The removal requirement states that removal of most of the waste will not be precluded but does not quantify the term most. This study assumes that the quantity removed shall be the amount that can be removed practically. No quantitative figure for this amount is specified because removal is speculative. The amount that practically can be removed using the technologies available at the time of removal shall be achieved. Since today's equipment is very effectively used to mine materials deposited millions or billions of years ago, this same equipment technology would provide for the feasibility to remove the waste any time during the regulatory time frame.

WRAC-7.1 Planning and Permitting (P&P)

The need to remove the waste would initiate the planning and permitting phase. By definition (40 CFR § 191.02[l]), waste removal does not occur until after disposal. The permitting requirements will be based on governing regulations at the time removal is authorized. The planning and permitting program will identify all required permits. This program will also research the available technologies to determine the appropriate removal techniques, the waste conditions, and the repository conditions (see Chapter 6.0 of the CCA for performance assessment assumed conditions after repository closure). After the initial research is completed, a plan will be drafted to itemize and schedule all removal activities.

The following considerations would be included in the planning and permitting process for the WIPP. These are necessarily general since the actual activities are solely dependent on the conditions at the time removal is deemed necessary. It should be noted that technologically, removal could be accomplished without any of the steps in this section. Such brute force approaches would meet the requirement of describing feasible techniques for removal; they are not, however, considered to be prudent.

Availability of Records. Available records will be collected to determine the location of waste containers, the nature of the waste placed in the facility, the underground excavation conditions during operations and at the time of closure, the location of seals and panel closures, and the amount and nature of backfill materials. Since the DOE plans to place records in numerous locations, records should be readily available for needed evaluations. Additionally, WIPP will also have complete inventories of the contents and locations of both the CH and RH containers.

Location of the Site. Records and markers will be used to identify site locations such as the previous shaft locations, the area of the disposal region footprint, previously drilled boreholes, location of monitoring activities, and other features that will aid in delineating the areas for new excavation and new surface structures.

Background Environmental Conditions. A baseline of environmental conditions will be established prior to any surface disturbing activity in order to get an accurate assessment of pre-operational conditions. Background measurements will be compared with environmental data stored in the site archives to determine any changes in conditions since the closure of the facility.

Time Since Disposal. This will be used to determine the expected condition of the disposal rooms, the amount of radioactivity and hazardous constituents that need to be dealt with, the amount of migration outside the disposal zone that may have occurred, and the presence of potential hazardous conditions such as pressurized gas and brine.

Facility Design. Initial facility designs will be prepared so that appropriate technologies can be identified and so that environmental impacts can be assessed. Release and exposure pathways will be identified and risk analyses performed to ensure appropriate environmental protection measures are taken. Design will be in accordance with applicable commercial and regulatory standards in effect at the time. Regulations such as those promulgated by the Occupational Safety and Health Administration and the Mine Safety and Health Administration will be given due consideration in designing systems that are protective of human health and the environment. Final facility design will be appropriately reviewed and approved by the implementing agency and appropriate regulatory organizations.

Permitting. Current environmental regulations governing releases to environmental media and protection of the public from exposure to noise, gases, dust, hazardous waste, radioactivity, and other potentially harmful substance will be identified and appropriate permits studies and impact statements will be obtained in the time frames dictated by the regulations.

Radiological Controls. The removal process will require a comprehensive assessment of the facilities and the precautions necessary to ensure the safety of workers and the public during the entire removal operation from initial coring until final closure and decommissioning of the facility. The facilities will include appropriate areas for washing and decontamination of containers and equipment and separate areas for the decontamination of personnel should such requirements arise. Decontamination areas and washing areas will be designed and constructed both in the underground and on the surface. Special areas will also be constructed on the surface and in the underground for storage of material and/or containers having high radiation levels. Such areas will be shielded to permit operational activities nearby without undue risk to personnel. Rigorous radiation and hazardous material monitoring of all activities from initial borehole drilling and coring to actual removal will be required until such time as removal activity experience provides sufficient information to understand the actual conditions existing in the repository and permit formulation of appropriate monitoring policy.

WRAC-7.2 Aboveground Setup and Shaft Sinking

Existing geological characterization data will be supplemented with new characterization data at the site. During all boring, shaft sinking, and mining activities in the vicinity of the waste panels careful monitoring will be conducted to ensure early determination of the presence of any hazardous or radioactive material. An initial shaft location sufficiently distant from the waste will be identified and excavated. Coring in the vicinity of the repository horizon will be performed in order to identify horizons that may contain radioactive contamination caused by brine migration through marker beds. The level of contamination will be assessed and appropriate precautions taken to protect personnel, the public, and the environment from contamination. Such precautions are used today in cleanup activities in which contamination is kept within well-defined barriers and entrance and egress is carefully controlled and monitored. Emphasis will be placed on avoiding the areas that were originally mined for the repository. The DOE currently believes that, for the WIPP, the best approach to the waste is from the south because this area avoids the existing shafts and mined areas.

Use of the intact portion of the formation instead of using previous shafts and tunnels minimizes potential ground control problems. Additional geological studies would be conducted to determine the adequacy of the rock south of the repository.

Aboveground support buildings will be constructed to house the exhaust fans and any radiation control equipment such as HEPA filters, administration facilities, operations and engineering offices, training facilities, safety facilities, maintenance support facilities, control center, waste staging and decontamination areas, loading/shipping docks and warehouses (waste containers and maintenance), laboratories and others as deemed necessary. Portable and/or temporary structures such as trailers could be used for miscellaneous activities. Power and water distribution network shelters will be required.

Where practicable, aboveground support facilities should be designed for later disassembly and removal to facilitate decommissioning. Removal facilities would closely resemble those currently in use at the WIPP and described in Chapter 3.0 of the CCA with some additional radiological control facilities and decontamination facilities.

A shielded area for the protection of personnel from higher levels of radiation, similar in construction to the shielded storage room currently located in the Waste Handling Building (see Appendix D&D of the CCA), may be required to handle and store the RH-TRU canisters and their containers prior to off-site shipment. This area will contain all the equipment necessary to transfer the RH-TRU waste into suitable waste containers and load shielded shipping casks. If necessary, remote operations can be used for any removed waste that exceeds CH-TRU safe handling limits.

Security fencing will be required around the facilities. The extent of the security devices required will be governed by the regulatory requirements at that time.

A control center will be located aboveground that houses the personnel and equipment that controls the remote mining equipment and all other remote operations.

At least three shafts will be constructed. The number and size of the shafts will be based on waste removal throughput requirements, airflow requirements, and mining regulations at that time. The underground ventilation requirement should be lower than the original ventilation system assuming a reduction in both manpower and diesel equipment usage (if used). To reduce the discharge of hazardous and radioactive particulate contamination, the removal working area and packaging areas will be provided with separate HEPA filtration systems. This precaution will reduce migration of particulate material from the mining areas.

The three shaft concept would include two intake shafts and an exhaust shaft. The current WIPP shaft designs would be adequate, although technology improvements may make operations more efficient and reliable.

Each shaft will include a hoisting system. The waste handling shaft (WHS) and hoist will be fully enclosed and will allow air intake without backflow. The WHS will be an air intake shaft that ventilates the maintenance, packaging, and contaminated work areas of the mine.

The ventilation exhaust system for the removal of the waste will be significantly more complex than the system supporting waste emplacement. Because of the likelihood of the production of hazardous and radioactive particulate material during the remote removal of waste material, the ventilation system will require local systems within the underground that include the appropriate exhaust fans, monitoring, and HEPA filtration systems used to filter the exhaust air during removal operations. The levels of dust in a potentially highly contaminated environment will present a significant maintenance challenge. Maintenance of these systems will require high degrees of redundancy of system components, system configurations, or flow paths. Flexibility of operation will be a major operational requirement of the ventilation system design in order to ensure that removal operations remain within the regulatory and safety limitations imposed for workers and the general public. The system design must permit remaining within the allowable limits at all times. Since the potential for hazardous or radioactive material contamination will exist, once waste removal begins, filtration of all exhaust air will be required. Self-cleaning or roughing pre-filters may be used to increase HEPA filter life and reduce down time for filter change-out.

After the first shaft (no particular order) is completed, the others may be excavated from the bottom up using a drill and ream system similar to the system used at WIPP to excavate the existing air intake shaft. This will require access entries (drifts) to be excavated to the base of each shaft and drilling to this area. An ore transfer station will also be installed to facilitate removal of excavated salt (uncontaminated) from drift and support area mining.

WRAC-7.3 Underground Excavation and Facility Setup

After the shafts are completed, drifts will be excavated using commercially available equipment such as continuous miners, roadheaders, scalers, and ventilation paths will be established using air control regulators. Support rooms for use as maintenance areas, control rooms, and packaging areas will be excavated. Air locks will be constructed to isolate the clean areas from the contaminated areas by use of differential pressure. All equipment required for removal, packaging, and related support activities will be installed.

Excavation will be in two phases. The initial excavation will not contact waste but will mine support rooms and haulage drifts that provide ventilation and access to the waste panels. A barrier pillar will be maintained. The size of the barrier pillar depends on the anticipated conditions in the waste panels. The barrier pillar will provide protection from blowout or flooding due to pressurized gas or brine. The second phase will remove the waste. Conceptual layout of removal operations is shown in Figure WRAC-7.

Air locks will be used to allow travel between air circuits while maintaining the isolation of contaminated areas from the clean areas. Lined sumps may be used to manage liquids if conditions involving flowing brine are encountered.

The following support areas may be required:

Control Centers. Rooms that contain the remote control support interface between the surface control center and the equipment supporting the underground ventilation, mining, packaging, and transportation operations.

Maintenance Rooms. Shop areas where all maintenance and repairs are performed, including wash bay and parts warehouse for support equipment.

Personnel Support. Lunch room, lockers, washrooms, and facilities.

Container Warehouse. Storage for clean, empty waste containers, and decontamination supplies.

Packaging Area. Waste emplacement into containers, container filling, and container sealing area.

Decontamination Area. Container radiation survey and decontamination area.

Ore Transfer Station. Virgin salt transfer and removal station at base of shaft.

Container Staging Area. Lower hoist loading area with staging area (clean area) located in clean intake air feeding contamination area; final radiation survey area.

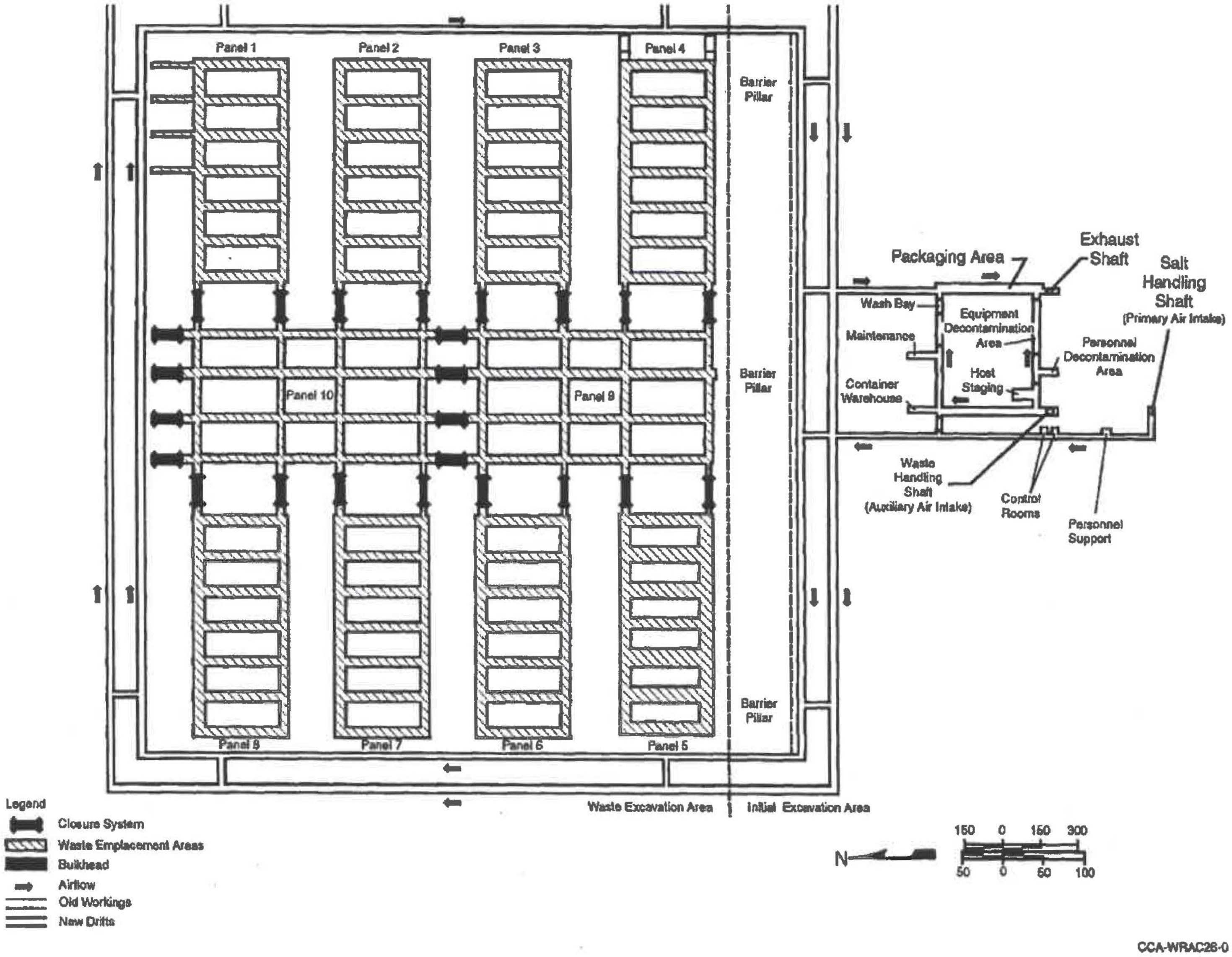


Figure WRAC-7. Repository Removal Operations Layout

WRAC-7.4 Waste Location and Removal Operations

A single drift should be excavated around the waste panels. This drift will provide ventilation that will be used during removal operations. After the support, ventilation, and access drifts are completed, the first panel can be entered to remove the waste. Panel 9, the panel closest to the exhaust shaft should be excavated first to reduce initial contamination. An entrance and exit will be excavated, dust and moisture control systems installed, and isolation bulkheads erected. The location of the panel closures should be available from the detailed information at record centers and archives. To determine the relative position of the waste, ground penetrating impulse radar technology could be used. Impulse radar technology has been successfully tested in salt mines and has demonstrated the capability of locating metallic targets up to ten meters away (Cook 1982). Other geotechnical techniques that identify variations in the host rock (such as sonic velocity or electromagnetic measurements) could be used to distinguish previously mined areas and potentially the waste. The access entries could be completed and the entrances to each panel could be located by the panel closure systems and radar. Radar and gamma detectors could be used to help locate the RH-TRU waste. The gamma detectors should be effective during the first few hundred years after disposal prior to extensive decay of the RH radioactivity.

Initially, each waste panel will be evaluated using a small diameter probe hole drilled from the access drifts. The hole will be used to investigate the conditions within the panel. Of particular interest will be the porosity (degree of consolidation), pressure, and moisture content. In addition, gasses will be tested for explosive or flammable constituents.

For conditions that would require the CH-TRU and RH-TRU waste removal operations be performed in separate operations, the CH-TRU waste will be removed by mining the area where this waste was emplaced. The CH-TRU waste and surrounding rock will be removed and transported to the packaging areas without disturbing the RH-TRU waste. The RH-TRU waste will be removed by excavating the rock salt around the waste and removing it in as intact a condition as possible. This waste may be placed in a waste container at the work face and then transported to the packaging area. The waste container may be the shipping container if sealing and decontamination are possible underground or it may be over-packed at the packaging area prior to decontamination.

The CH-TRU waste can be removed many ways using standard mining equipment. The waste could be mined out using large-scale continuous miners such as those used to originally mine the underground excavations. However, this method does have the potential to spread excessive amounts of particulate contamination and could be difficult to control particularly with respect to the RH-TRU wastes. A more practical approach would be to use small-scale mining equipment such as road headers, scalers, hydraulic breakers, small loaders, and excavators. A small head continuous miner or a roadheader (telescopic boom miner) could be used to excavate a large portion of the waste. The other extraction equipment would be used to remove the most difficult waste such as large metallic items.

A practical approach to CH-TRU removal is to excavate an area approximately three feet high directly below the waste and then, using a hydraulic breaker/scaler system similar to the Fletcher diesel powered scaler capable of being equipped with either an Alpine No Gap cutting head, a percussion scaling hammer, or a scaling claw attachment devices to dislodge the waste above.

Similar scaling devices have been successfully utilized at WIPP and other mines in the Delaware Basin. Appendix WRAC, Section 6 of the CCA detailed specific mining equipment discussed above (DOE 1996).

The CH-TRU waste will be excavated behind bulkheads separating the mining area from normal ventilation. After removing a predetermined amount of excavated materials, loaders will transport the waste materials to the packaging area.

The CH-TRU waste will be transferred to the waste handling and packaging system which packages the waste into containers. Bulk material handling equipment may be used to transfer the waste from the loaders to the waste containers. The container will move into the decontamination area where it is automatically surveyed and decontaminated. The container is then moved into the hoist underground staging area where it is surveyed again and transported to the surface. The container will be warehoused until transported off site.

The CH-TRU waste containers will be selected using the regulatory requirements at that time. Currently available containers will be researched to determine their suitability, and if none are found, new containers will be built and certified.

An aboveground decontamination area will be used if any contamination is found during the off-site container loading and transportation operations.

RH-TRU waste will be removed after the CH-TRU waste is excavated past the shield plugs to allow equipment access. The equipment will be set up to remove and excavate the materials around the waste. The waste will be loaded into a container and moved to the packaging area.

There, the container may be decontaminated, if possible, or overpacked prior to shipment aboveground. After completion of any necessary decontamination, the RH-TRU waste will be transported to the surface and then warehoused in a shielded area prior to off-site shipping. Radiation surveying and decontamination procedures will be similar to the CH-TRU operations.

The waste will be removed from the panel and its original access entries. After the initial panel's waste is removed, all other panels will be excavated.

If the removal of waste is not initiated until hundreds of years after disposal and the RH radioactivity has decayed to near the activity levels of the CH waste, the decision may be made to remove the RH waste in conjunction with CH waste removal. Under these conditions, evaluation of the probable condition of the RH containers should be made. The heavier wall thickness of the RH containers may provide an opportunity to remove the RH waste intact provided that corrosion has not yet destroyed the containers' integrity. Under these conditions, RH removal should be conducted in a manner similar to that described above. That is, CH removal within a given panel should proceed until sufficient clearance is obtained to permit installation of equipment to excavate the rock salt around the RH container and then remove the container in as intact a condition as possible. Under conditions in which the RH container has lost its integrity, removal of RH waste would be accomplished using the procedures applicable to CH waste removal.

WRAC-7.5 Closure

After the waste is removed from the repository, the facility will be decommissioned in accordance with the regulatory requirements applicable at that time. Closure may include partial backfilling of the mine and support areas. The mine may be used for disposal of both contaminated and uncontaminated muck. The shafts will be sealed (see CCA Appendix SEAL for the details of what a seal may look like) and the surface facilities will be decontaminated and decommissioned (see CCA Appendix D&D for an outline of a decontamination and decommissioning program). All decontamination wastes could be packaged and shipped in the same fashion as the removed waste.

WRAC-8.0 Currently Available Removal Technologies

As part of the feasibility demonstration, the DOE has identified technologies that are available today that could be used to facilitate removal. These are divided into mining technologies (Section WRAC-8.1) and remote removal technologies (Section WRAC-8.2).

WRAC-8.1 Mining Techniques for Waste Removal

Waste removal can be accomplished in many ways using available technologies. Mining techniques are the most plausible since they must be used initially to provide access to and locate the waste. Methods used to extract salt and potash were briefly evaluated to determine the capable removal techniques. Since the waste is hazardous and radioactive, the techniques used must limit the spread of contamination to the environment and exposure to facility personnel. The condition of the waste at the time of removal will be unknown and is related to the amount of time the waste was exposed to repository conditions.

Removal processes should be performed with as little direct human interaction as possible. Limited contamination is acceptable provided that the exhaust from these areas is controlled and filtered. Roughing filters and HEPA filters can be used to control contamination. Limiting the air throughput in the work areas will minimize the spread of contamination.

Mining techniques that were evaluated include the following:

- continuous mining,
- drill and blast,
- solution mining and mechanical extraction, and
- mechanical excavation techniques.

WRAC-8.1.1 Continuous Mining

Continuous mining was used to excavate most of the WIPP facility. A continuous miner is used to mechanically excavate materials by ripping, milling, or boring the rock from the work face. Rotary drums and heads with cutting bits attached to the surface cut the rock. The miner mechanically removes the loose material and transports it away from the face onto a conveyor where it can be transferred to haulage equipment or transported by belting to other areas. Continuous mining equipment can precisely remove rock and hold tolerances in the order of a few inches. The equipment is available in a wide variety of styles and sizes. Remote controlled continuous miners are commercially available from manufacture such as Joy, Caterpillar and Bucyrus.

The waste contains some metallic items (for example, cadmium, lead, silver) and the containers are steel. Continuous mining heads can be made with bits utilizing various steel alloys. Examples of these alloys include high-strength low alloy (HSLA) ordnance-grade steels such as AISI 4140 chromium molybdenum steel and AISI 8650 nickel chromium molybdenum steels; molybdenum or tungsten-based high speed tool steels such as M2 or T6; and the powder-metallurgy-produced sintered tungsten carbide steel groups such as the six percent cobalt group 2 alloy. All of these alloys are frequently used for various mining, petroleum production drilling, ordnance, and tooling applications such as drilling, mining, and cutting through metals, ores, and hardened rock. The equipment may be further modified by changing the cutting head configuration and sizing to efficiently handle the metallic substances by altering the cutting surface, speed, and bit angles. The need to address cutting through metals, particularly the metal containers, will be dependent upon the time after disposal that removal is initiated (see CCA Chapter 6.0 for performance assessment assumptions regarding metal persistence; DOE 1996).

Large-scale continuous mining of the waste is possible but is impractical because of the potential for spreading contaminated material. Excessive amounts of dust are generated during continuous mining. Water is generally used for dust control which may increase the spread of contamination. Water will transport the contamination into the fractures of the surrounding rock.

Small-scale continuous mining of the waste is practical if electric equipment is used and the area is isolated during mining operations. To control contamination, bulkheads can be placed close to the mining face that isolates the mining activities from normal mine ventilation. Ventilation in the mining area can be reduced or eliminated since remote controlled electrical equipment would be used and no diesel equipment or personnel are required. Suspended particles can be effectively removed from the air during mining and loading operations using local HEPA filtered systems with prefiltering capability to reduce the maintenance of HEPA filters.

WRAC-8.1.2 Drill and Blast

This method excavates by drilling holes in a rock face and filling the holes with explosives. The explosion fractures and loosens the rock material. Other equipment is then used to remove the debris and the cycle starts again.

This method could also be used to remove the waste. However, this method generally requires personnel to drill and load and would be difficult to perform remotely. The dust and fumes caused after the explosives are detonated must be ventilated and would cause a contamination problem. Isolating the working areas with bulkheads would be difficult because of the large pressures produced by the blast. Thus, while this method could possibly be used to remove the waste, the associated problems of personnel in the vicinity, ventilation, contamination, and blast side-effects make this method impractical.

WRAC-8.1.3 Solution Mining

Solution mining uses a solvent to extract the material of interest. In salt solution mining, water is injected into the formation and saturated brine is pumped out.

A modified version of this technique could possibly be used to remove the salt from around the waste at the repository level. After the salt is removed, remote controlled mechanical equipment would remove the exposed waste. Hence, both standard mechanical mining methods and solution mining would be required. However, this method would require large amounts of water and would require a system to be designed to recycle the water. Water treatment would also be required to extract salt and any contaminated material. These processes involved add significant complexity to the system and the salt, and probably the water, would still be contaminated and would have to be packaged along with the waste. Additionally, this method would produce a large volume of contaminated material and would spread contaminants into the fractures of the surrounding rock. Therefore, based on the problems of the systems' complexity and of the likely ineffectiveness of those systems, in general, this method is impracticable.

WRAC-8.1.4 Small Scale Mechanical Excavation Techniques

Smaller-scale mechanical excavation techniques can be used and are the most favorable. One method uses roadheaders, hydraulic breakers, and scalers to dislodge material from the face by scaling or cleaving the material. This method is extremely slow and precise. It produces the least amount of dust and can be performed remotely.

Additionally, other forms of mechanical excavation equipment such as skid-steer loaders with various small backhoes, manipulators, and earth moving and cutting attachments exist and would also be used to dislodge, move, cut, and crush the waste. These types of equipment will be required to support any method used.

WRAC-8.1.5 Remote Mining

Two examples of remote mining operations include work in Australia and France. Australia removed 198,334 tons of coal from a McQueen Company mine using a remote controlled flexible conveyor train, a continuous miner, and roof-bolting machines between 1985 and 1987 (McQueen 1988). The French have been actively pursuing remote coal mining since 1972. In 1983, 93 percent of French coal shearers were remotely controlled and monitored (Boutonnat 1986).

In 1986, the U.S. Bureau of Mines initiated research to develop technology to enable the relocation of workers from hazardous areas (Schnakenberg 1993). Such work includes developing computer assisted operation of continuous miners, roof bolters, and haulage systems (Schnakenberg 1993).

In addition to remote mining techniques, mining has included automation to increase productivity and reduce human resources in remote or high hazard mines. Recent mining has been performed using autonomous load/haul equipment. Such techniques are used in Australia by Rio Tinto Ltd. in their iron ore operations (Rio Tinto 2015). This technology has been successfully used along with other remote techniques at this mine since 2008. Autonomous technologies have also been used in other mining operations in Chile, Australia, Queensland and the United States (Brundrett 2014).

Remote and automated mining technologies are continuing to progress making the likelihood of their success in any future removal operations highly probable.

WRAC-8.2 Remote Removal

On April 27, 1992, a retrieval demonstration took place that successfully retrieved SWBs from a WIPP storage room. This demonstration simulated a cave-in or roof fall condition with salt and metal roof support materials piled on top of the SWBs. All retrieval operations were performed using remote controlled equipment.

The equipment used for this demonstration consisted of two remote controlled skid-steer loaders, a remote controlled freestanding portable television camera, a WILD TM 3000 automatic laser survey station, a portable beta-gamma radiation detector, and an ANDROS Mark VA hazardous duty robot. One remote-controlled skid-steer loader used a backhoe attachment and the other used a manipulator, front loader bucket, hydraulic breaker, or grapple bucket attachment. The attachments were changed out when required. The equipment used both radio and tethered cable remote control methods.

The demonstration used the robot to survey the areas using television cameras and laser ranging equipment. The condition and location of the SWBs were determined using the robot's data. The robot also set up equipment and surveyed the areas for radioactive contamination.

In order to remove the SWBs, the salt and metal materials were removed and boxed in containers using the remote controlled equipment. The SWBs were successfully removed from the room.

Although the retrieval demonstration was performed on a small scale, it proved that remote controlled equipment could be used to remove salt and metal materials from around a waste container, package the excess material, and remove the waste container. The removal of waste from a consolidated salt condition will involve a more complex set of circumstances. However, current technological capabilities permit remote operation of current equipment and will permit these complexities to be solved operationally. Thus, no new technology will be required.

Current technology exists and is in operation in mines throughout the world to excavate materials using remote controlled machinery. Remote coal mining has been performed for many years by countries including Australia, France, Austria, Canada, Russia, and the United States. Remote controlled continuous miners, rock bolters, drills, haulage, road headers, loaders, and locomotives are examples of the equipment used at these mines (Naunkovic 1986).

WRAC-9.0 Conclusion

The requirement for waste removal after closure originates in 40 CFR § 191.14(f). Specifically, 40 CFR § 191.14(f) states that WIPP disposal systems will be selected so that removal of the waste is not precluded for a reasonable period of time after disposal (EPA 1993). Removal of the waste after the repository is sealed is possible. Because access to the repository was accomplished using standard mining practices, access to the waste after closure can be accomplished using the same mining technologies supplemented by a more extensive use of remote controlled and robotic equipment. The degree of robotic and remote controlled technology required to successfully remove the waste is not only available but also has been used in mining and industrial packaging activities around the world. The accessibility for waste removal has no operational time limit assuming use of today's technology. 40 CFR § 194.46 states that the analysis of the technological feasibility of removing the waste use ". . .technology levels at the time a compliance application is prepared." Locating and removing the waste is feasible using currently available equipment modified to operate remotely. Packaging the removed waste and decontaminating the containers can be safely accomplished by using established techniques. The concept of sealing and decommissioning the facility will have been demonstrated prior to waste removal.

As stated in the preamble to 40 CFR Part 191, with respect to the waste removal requirement:

Any current concept for mined geologic repository meets this requirement without any additional procedures or design features. For example, there is no intent to require that the repository shafts be kept open to allow future recovery. To meet this assurance requirement, it only need be technically feasible (assuming current technology levels) to be able to mine the sealed repository and recover the waste - albeit at substantial cost and occupational risk.

The WIPP is a mined geologic repository and, as such, meets the removal requirement without any additional design requirements since current technology can be used to remove the waste if the need arises. Examples of the necessary mining equipment are in existence today, are readily available, and have been effectively used for mining applications. Thus, it is logical to conclude that since the necessary equipment not only exists in off the shelf forms but also has been effectively used in a variety of mining applications, then waste removal utilizing this equipment is feasible. Partial proof of this concept has already been demonstrated by retrieving waste containers from under salt and metal roof support materials using remote controlled equipment (DOE 1993).

WRAC-10.0 References

(*Indicates a references that has not been previously submitted.)

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EPA Comment

3-C-2 Boron Species in WIPP Brine. *The Compliance Certification Application (CCA) and CRA-2004 refer to the presence of boric acid* [$B(OH)_3$] *in WIPP brine. However, the CRA-2009 (Appendix SOTERM, Table SOTERM-2) and CRA-2014 (Appendix SOTERM, Table SOTERM-4) indicate that "boron species will be present in brine as boric acid, hydroxyl polynuclear forms* ($B_3O_3(OH)_4^-$)*, and/or borate forms (e.g.,* $B_4O_7^{2-}$)*." Borkowski et al. (2010a) indicates that Tetraborate is present in WIPP brine and Borkowski et al. (2010b) determined the stability complex and Pitzer coefficients for the neodymium(III)-tetraborate aqueous species. Lucchini (2013) refers to Tetraborate in WIPP brines during comparisons of measured and modeled brine compositions. Consequently, there appears to have been an evolution in the assumed boron species in WIPP brines since the CCA. Because complexation by Tetraborate has been identified as important for actinide(III) speciation in WIPP brines (Borkowski et al. 2010b), DOE must identify all expected chemical constituents that contain boron species in WIPP brines. The basis for that determination must be included.*

Borkowski, M., J.-F. Lucchini, M.K. Richmann and D.T. Reed. 2010a. Actinide(III) Solubility in WIPP Brine: Data Summary and Recommendations. Los Alamos National Laboratory, LCO-ACP-08, Rev 0.

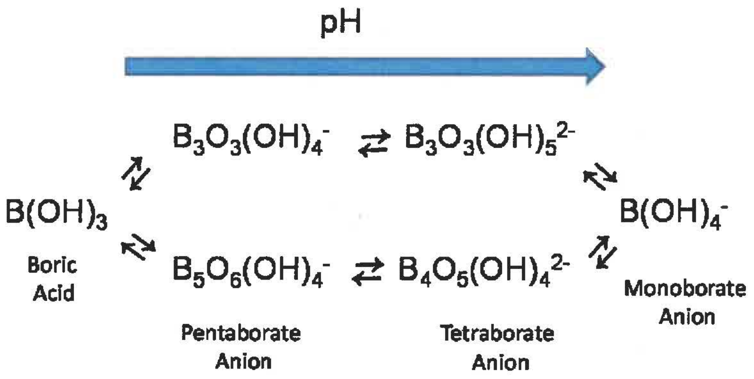
Borkowski, M., M. Richmann, D. Reed and Y. Xiong. 2010b. Complexation of Nd(III) with Tetraborate Ion and Its Effect on Actinide(III) Solubility in WIPP Brine. Radiochimica Acta 98:577-582.

Lucchini, J.-F. 2013. WIPP Actinide-Relevant Brine Chemistry. Los Alamos National Laboratory, LCO-ACP-15, Rev. 0.

DOE Response

Borate, which has a relatively complex chemistry, is indigenous to WIPP brine and is naturally present at concentrations that range from 62 to 166 mM (Lucchini et al. 2013). It is correctly noted by the EPA that there has been an evolution in our understanding of the nature and relevance of this borate chemistry in WIPP brine since the CCA, although the WIPP model has always included two polyborate species (tetraborate and the tri-borate mono-anionic species). The linkage of borate chemistry to actinide solubilities is a direct result of the research that was done for the WIPP project (EPA references provided above) and continues to be an active area of research (post CRA-2014 data cutoff) both within and outside the WIPP project (Xiong et al. 2013; Hinz et al. 2015; Wang et al. 2011; Polinski et al. 2012; Schott et al. 2014; and Schott et al. 2015). For this reason, our understanding of the underlying borate speciation and its potential impacts on actinide speciation and solubility in brine continues to evolve.

The borate species that are potentially present in WIPP, based on the speciation scheme developed by Anderson et al. (1964), are given below. In the WIPP model, only the higher concentration polyborate species are present. Additional species beyond this are also possible (for example, higher-order polyborates and calcium/magnesium borate complexes), but the current effects on actinide chemistry are sufficiently explained by the role and influence of tetraborate. The overall speciation diagram for these species is given in Figure 1. This shows the tetraborate species to be predominant in the pH range of interest to the WIPP ($pC_{H+} \sim 9.4$).



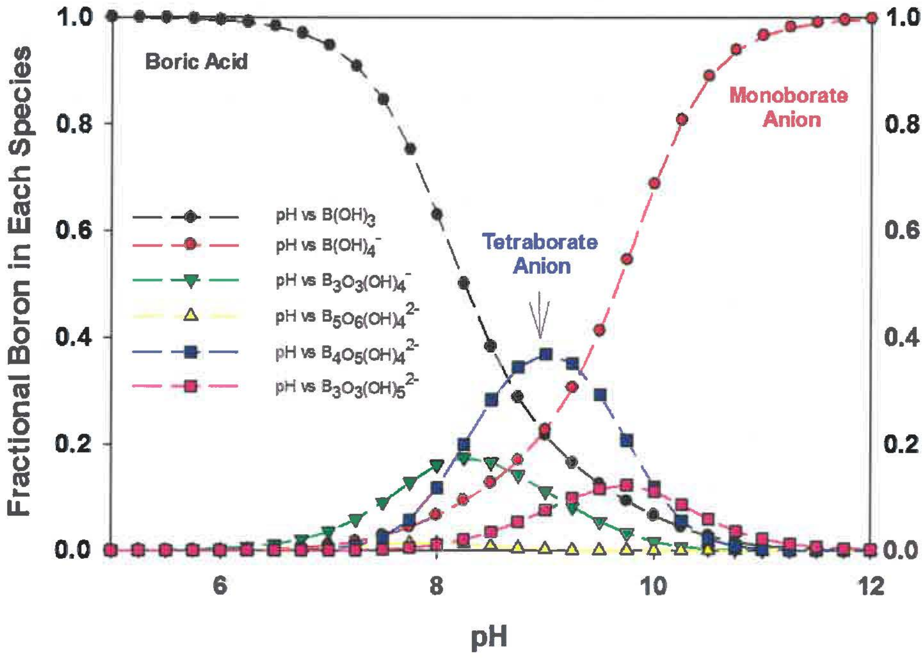


Figure 1 Speciation of borate species as a function of pH (based on Anderson et al. 1964) for 160 mM total boron and using 25°C pKw. This shows the tetraborate ($B_4O_5(OH)_4^{2-}$ species to predominate at pH ~ 9.

The CRA-2014 Appendix SOTERM, which identifies the possibility of multiple borate species, reflects the best understanding at the time of the CRA-2014 data cutoff (12/31/2012) of this chemistry. The key borate species, with respect to impact on actinide complexation, is identified as the tetraborate species

(Borkowski et al. 2010a and 2010b; Borkowski et al. 2012). This opinion is based on the following observations and evidence:

- The predominance scheme as shown in Figure 1 and the expectation that the di-anion is the strongest complexant.
- The pH correlation of the borate complexation effect with what is observed in the speciation/solubility of the An(III) and An(V) actinides – this mirrors the speciation of tetraborate in that the impacts occur between pH 7 and 11.
- Precipitated borate phases at the WIPP-relevant pH are always a tetraborate. Therefore, it does not matter if the borate is added as boric acid or a tetraborate salt, we always see only tetraborate phases.

Overall, although there remains some uncertainty about the borate speciation, the potential impacts on actinide solubility are well established and are relatively low. The following is a short summary of the current understanding of these effects under WIPP-relevant conditions:

An(III) Actinides:	The An(III) complex was measured with Nd^{3+} (Borkowski et al. 2010b), and this complexation is confirmed by more recent laser spectroscopic studies (Hinz et al. 2015). The formation constant for this interaction is Log K ~ 4 , which is relatively weak. Under WIPP-relevant conditions, this may increase the measured solubility of An(III) actinides by up to a factor of 3 when organic complexants are not present.
An(IV) Actinides:	No effect of complexation is noted. Hydrolysis predominates under all WIPP-related conditions.
An(V) Actinides:	Neptunium is the only actinide that is predicted to speciate as An(V). Neptunium does not contribute to WIPP release calculations due to its very low inventory in the WIPP. In this context the effects of borate on Np(V) speciation are negligible.
An(VI) Actinides:	The An(VI) complex also forms a weak complex with U(VI) as noted in Lucchini et al. (2013). This has not been directly measured, but has been confirmed spectroscopically with Pu(VI). Although the presence of borate has an impact on the solubility of U(VI) in the absence of carbonate, it does not effectively compete with carbonate under WIPP-relevant conditions and there is no impact predicted on the current 1 mM solubility assumption for U(VI) that is used in WIPP PA calculations.

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* Copyrighted reference not provided in Enclosure 2.

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* Copyrighted reference not provided in Enclosure 2.

EPA Comment

3-C-6 Magnesite Formation from MgO Carbonation. *Clayton (2013, Section 2.7) states that "In the event that* CO_2 *generation is occurring, but brucite is not available in BRAGFLO simulations, MgO will be converted directly to magnesite." EPA has reviewed the potential for magnesite formation in the WIPP repository directly from MgO and has repeatedly determined that hydromagnesite should be assumed to form instead of magnesite (EPA 1998, SCA 2008, EPA 2010). Correctly including the formation of hydromagnesite instead of magnesite will decrease the amount of water in the water balance calculations, which could significantly impact the amount of water in the repository. DOE must assess the effects on the water balance of incorrectly assuming magnesite formation instead of hydromagnesite in PA simulations when brucite was not available. DOE must also provide an assessment of the effects of this assumption when combined with the other assumptions summarized in Completeness Comment 2-C-3 (Edwards 2015) that also increase the amount of brine calculated for the water balance.*

Clayton, D.J. 2013. Justification of Chemistry Parameters for Use in BRAGFLO for AP-164, Rev. 1. Sandia National Laboratories, ERMS 599466.

Edwards, J.D. 2015. Second Set of CRA 2014 Completeness Questions, U.S. Environmental Protection Agency Radiation Protection Division, Letter to J.R. Franco, U.S. Department of Energy Carlsbad Field Office, February 27, 2015.

EPA (U.S. Environmental Protection Agency). 2010. Technical Support Document for Section 194.24, Evaluation of the Compliance Recertification Actinide Source Term, Backfill Efficacy and Culebra Dolomite Distribution Coefficient Values (Revision1), Docket A-98-49, Item II-B1-25, November 2010.

DOE Response

The functionality that "In the event that CO_2 generation is occurring, but brucite is not available in BRAGFLO simulations, MgO will be converted directly to magnesite" (Clayton 2013) remains in the BRAGFLO 6.03 code principally to be compatible with previous versions of the code and to reduce potential numerical instabilities. Prior to the CRA-2014, the BRAGFLO calculations assumed the direct conversion of MgO to magnesite as a modeling simplification. The modeling of MgO hydrating to brucite, reacting with CO_2 to form hydromagnesite, which then converts to magnesite, was implemented in the CRA-2014. In the CRA-2014, the direct conversion of MgO to magnesite only occurs at early times when CO_2 may be generated, but there is no water/brine available.

Figure 1 shows the fraction of the carbonation reaction in BRAGFLO that is modeled as MgO reacting directly with CO_2 to form magnesite versus CO_2 reacting with brucite to form hydromagnesite for the CRA-2014. Figure 1 has been scaled to show only the first 100 years, as all the vectors show no MgO converting directly to magnesite in the remaining 9,900 years (Zeitler and Clayton 2015). In practice, the effect of this functionality on the CRA-2014 water balance is minimal as it is only operational within 20 years of closing the repository (see Figure 1), i.e., 2% of the entire 10,000-year repository time period. After 20 years, this functionality of the code is not used at all in the 2014 BRAGFLO calculations (see Figure 1), and the only carbonation product is hydromagnesite. Calculating the potential decrease in the amount of water for each vector gives a maximum volume of 0.081 m^3 in the waste panel, which will have a minimal impact on the overall water balance.

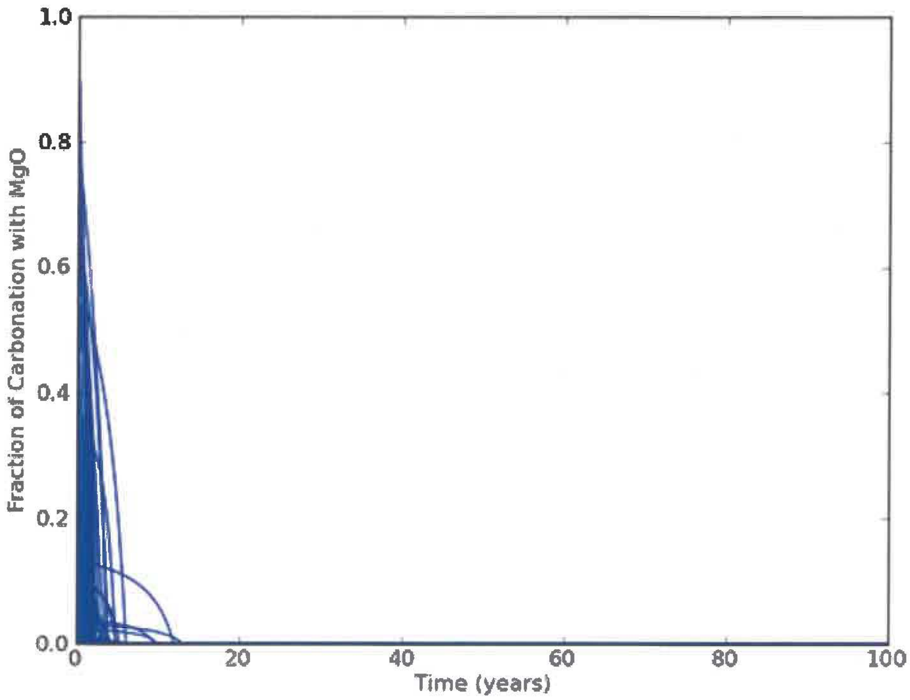

Figure 1 The fraction of carbonation with MgO as a function of time for the 100 vectors of replicate 1, scenario 1 (from Zeitler and Clayton 2015)

Because there is such a minimal effect of the use of the BRAGFLO code functionality on the CRA-2014 water balance, there is not expected to be any impact on the overall performance assessment calculations, even when combined with the other water balance assumptions discussed in Completeness Comment 2-C-3 (Edwards 2015).

References:

Clayton, D.J. 2013. Justification of Chemistry Parameters for Use in BRAGFLO for AP-164, Rev. 1. ERMS 559403. Sandia National Laboratories, Carlsbad, NM.

Edwards, J.D. 2015. Second Set of CRA 2014 Completeness Questions. U.S. Environmental Protection Agency Radiation Protection Division, Letter to J.R. Franco, U.S. Department of Energy Carlsbad Field Office, February 27, 2015.

Zeitler, T. R., and D.J. Clayton. 2015. "Rerun of CRA-2014 BRAGFLO calculations with additional output." Summary Memo to Records. July 2015. ERMS Pending. Sandia National Laboratories, Carlsbad, NM.

EPA Comment

3-C-7 Lead Inventory, Gas Generation and Water Balance. *In past WIPP performance assessments, lead corrosion has been assumed to have insignificant effects on gas generation because of the relatively small amount of lead in the packaging and waste inventory (EPA 2010). However, use of shielded containers to emplace some RH waste may significantly increase the amount of lead in the repository. Van Soest (2012) provided only the RH packaging material lead inventory and this value has decreased since PAIR-2008. Please provide an estimate of the total lead that will be in the WIPP repository (waste lead plus packaging material) and the basis for that estimate, taking into account the expected increased lead from shielded containers. Based on this total lead inventory, DOE must assess whether lead corrosion may significantly affect gas generation and repository water balance.*

Van Soest, G.D. 2012. Performance Assessment Inventory Report -2012. INV-PA-12, Revision 0, LA-UR-12-26643.

DOE Response

Lead waste is accounted for in the category of "Other Metals/Alloys." Under the category of "Other Metals/Alloys" in the 2012 Performance Assessment Inventory Report (PAIR-2012) (Van Soest 2012), the inventory in CH and RH waste is 762,000 kg and 471,000 kg, respectively. The total lead waste is unknown, but the total amounts of "Other Metals/Alloys" could be used as an overly conservative estimate. Using this approach, an overly conservative estimate for lead waste would be 1,233,000 kg. This total provides a conservative upper limit of the lead content in the waste since the amount of lead present this category is not explicitly reported.

In the PAIR-2012 (Van Soest 2012), 8,280 kg of lead packaging material are reported. After the PAIR-2012 data cutoff date (12/31/2011), nine shielded containers were emplaced in WIPP, and in the 2014 Annual Transuranic Waste Inventory Report (ATWIR-2014) (U.S. DOE Carlsbad Field Office 2014a), it is reported that the additional 27 shielded containers are anticipated to be emplaced. The total lead packaging material for the nine containers emplaced in WIPP and the 27 containers anticipated would be 15,516 kg, leading to a total lead packaging material at repository closure of 15,516 kg + 8,280 kg = 23,796 kg. Combination of lead as RH packaging materials with an overly conservative estimate of lead waste in CH and RH waste would lead to an overly conservative total lead inventory of 1,256,796 kg.

In the BRAGFLO calculation for the CRA-2014, the effect of lead corrosion on the Performance Assessment (PA) is not included. However, the stoichiometry for chemical reactions of lead corrosion is similar to that for iron corrosion, for instance, the anoxic corrosion of iron can be expressed as (U.S. DOE 2014b),

$$\mathrm{Fe(cr)} + (x)\mathrm{H_2O(l, g)} \rightleftharpoons \mathrm{Fe(OH)_2{\bullet}(x\text{-}2)H_2O} + \mathrm{H_2(g)} \qquad (1)$$

and similarly, the anoxic corrosion of lead can be cast as,

$$\mathrm{Pb(cr)} + \mathrm{H_2O(l, g)} \rightleftharpoons \mathrm{PbO(s)} + \mathrm{H_2(g)} \qquad (2)$$

Therefore, the relative magnitude of such an effect could be estimated based on their respective inventories.

The total iron inventory for this recertification, including iron-based metal/alloys and steel in CH and RH waste, is 49.1×10^6 kg. The total lead inventory based on the above overly conservative estimate is 1.26×10^6 kg. Consequently, considering the current lead inventory, the contributions of lead corrosion to gas generation and water balance would be bounded by approximately 3% relative to the scale associated with iron corrosion. Furthermore, this is an upper bound on the impact from lead because, in addition to the lead estimate being overly conservative, it assumes that the entire lead inventory degrades over the life of the repository.

References:

U.S. Department of Energy (DOE). 2014a. Annual Transuranic Waste Inventory Report – 2014 (Revision 0). DOE/TRU-14-3425. Carlsbad Field Office, Carlsbad, NM.

U.S. Department of Energy (DOE). 2014b. Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application 2014 for the Waste Isolation Pilot Plant, Appendix SOTERM-2014, Actinide Chemistry Source Term. United States Department of Energy, Waste Isolation Pilot Plant, Carlsbad Field Office, Carlsbad, New Mexico.

Van Soest, G.D. 2012. Performance Assessment Inventory Report – 2012. INV-PA-12, Revision 0, LA-UR-12-26643. Los Alamos National Laboratory, Carlsbad, NM.

EPA Comment

3-C-9 Intrinsic Colloid Parameter Values. *The concentration (CONCINT) used for intrinsic plutonium colloids in either the Pu(III) or Pu(IV) oxidation state in the actinide source term model was* 1×10^{-9} *M in the CCA PAVT, the CRA-2004 PABC and the CRA-2009 PABC. This intrinsic plutonium colloid concentration was an upper limiting value based on the detection limit in experiments conducted for the CCA (CCA Appendix SOTERM). The revised intrinsic colloid enhancement parameters used in the CRA-2014 PA do not appear to be bounding values. For example, the revised value of CONCINT for thorium(IV) is based on a single experimental data point (pcH 9.1) selected from a group of experiments because this particular experiment had the lowest concentration and was deemed closest to long-term equilibrium (Reed et al. 2013). In addition, the revised americium(III) CONCINT value is* 4×10^{-9} *M based on the average concentration in ERDA-6 experiments, even though higher concentrations were observed in GWB experiments. DOE must demonstrate that all of the CONCINT parameters used in PA represent upper bounding values based on the available experimental data.*

DOE Response

The intrinsic colloid parameters for Pu(IV) and Pu(III)/Am(III) were updated in the CRA-2014 based on the experimental results in long-term, multi-year solubility studies conducted in WIPP brine, and this rationale is summarized in Reed et al. (2013). In this update, the following parameter changes were made, along with a short summary of the rationale provided in Table 6-1 (Reed et al. 2013):

Actinide and Oxidation State	Intrinsic colloid parameter (CONCINT) CCA PAVT, CRA-2004 and CRA-2009	Intrinsic colloid parameter (CONCINT) CRA-2014 Reed et al., 2013	PA implementation in CRA-2014
Am(III)	0 (1) No available data	4×10^{-9} M (3)	4×10^{-9} M
Pu(III)	1×10^{-9} M (2)	4×10^{-9} M (4)	2×10^{-8} M (6)
Pu(IV)	1×10^{-9} M (2)	2×10^{-8} M (5)	

(1) A value of zero was assigned based on a literature assessment performed at the time of the CCA that indicated Am(III) did not form colloids in WIPP brine.

(2) This was based on the detection limits for Pu in Pu(IV) short term (~ 1 week) experiments performed (CCA-Appendix SOTERM).

(3) This is based on the most conservative value between the Pu(III) and Nd(III) studies for the ≤ 10 nm colloidal fraction that is nearest the reference pC_{H+} of 9.4.

(4) This is based on the observed ≤10 nm fraction observed in the Pu-Fe experiments where the aqueous species was shown to be Pu(III).

(5) This is based on the observed ≤10 nm fraction in the long-term Th(IV) solubility studies that is nearest the reference pC_{H+} of 9.4.

(6) Intrinsic colloidal contributions are represented by element, not oxidation state, in WIPP PA. When oxidation-state-specific values exist, the highest value was used to be conservative.

Many of the updated values for intrinsic colloid parameters in CRA-2014 are higher than those used in the CCA, CRA-2004 and CRA-2009, and are based on long-term, WIPP-specific experimental results. In this context, the overall project position is more conservative than in prior certifications and, as is shown in the following paragraphs, each value is also conservative relative to the current WIPP-relevant data set. In all cases, values near the expected pH in the WIPP were selected.

The Am(III) parameters used are conservative because 1) the factor-of-two higher Pu(III) results were used, rather than those obtained for Nd^{3+}, to maintain consistency across the oxidation states and 2) the colloid concentrations were determined in organic-free brine systems even though the presence of EDTA leads to the predominance of an An(III)-EDTA complex that would be expected to lower the overall concentration of intrinsic colloids due to its strong complexation.

Conservatism is also maintained in the selection of the intrinsic colloidal parameter for Pu(III) and Pu(IV). The single value used for both the plutonium oxidation states was derived from the Th(IV) long-term solubility studies to provide consistency across the element. For Pu(III), this value is five times higher than the value measured. Using Th(IV) data rather than Pu(IV) data is conservative for the An(IV) oxidation state since thorium has a much higher tendency to form stable colloidal species and has an overall higher solubility (as discussed in Borkowski et al. 2012).

References:

Reed, D.T., J.S. Swanson, J-F. Lucchini, and M.K. Richmann. 2013. *Intrinsic, Mineral, and Microbial Colloid Enhancement Parameters for the WIPP Actinide Source Term*. Report LCO-ACP-18, LA-UR 13-20858. Los Alamos National Laboratory, Carlsbad, NM.

U.S. Department of Energy (DOE). 1996. *Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant* (October). 21 vols. DOE/CAO-1996-2184. Carlsbad Field Office, Carlsbad, NM.

Borkowski, M., M.K. Richmann, and J-F. Lucchini. 2012. *Solubility of An(IV) in WIPP Brine: Thorium Analog Studies in WIPP Simulated Brine*. Los Alamos Report LCO-ACP-17, LA-UR 12-24417. Los Alamos National Laboratory, Carlsbad, NM.

EPA Comment

3-C-10 Phase Solubility in DATA0.FM1. *EQ3/6 database version DATA0.FMT.R1 was reviewed and accepted during the EQ3/6 code evaluation (SCA 2011, Appendix A). The database used for the WIPP CRA-2014 EQ3/6 actinide solubility calculations was DATA0.FM1 (DATA0.FMT.R2). Xiong (2011) documented that the only difference between DATA0.FMT.R1 and DATA0.FM1 is the addition of data for magnesium chloride hydroxide hydrate [*$Mg_3Cl(OH)_5{\bullet}4H_2O$*, Phase 5], citing Xiong et al. (2010) as the data source. Both Xiong et al. (2009) and Xiong et al. (2010) report a log K of 43.21 ± 0.33 at 25°C for the reaction:*

$$Mg_3Cl(OH)_5{\bullet}4H_2O + 5H^+ = 3Mg^{2+} = 9H_2O(l) + Cl^-$$

However, the data for this solid in DATA0.FM1 includes a log K at 25°C of 42.96. DOE must explain this small difference between the log K values in the documentation and the database.

SCA. (S. Cohen and Associates). 2011. EQ3/6 Computer Code Evaluation. Prepared for U.S. Environmental Protection Agency Office of Radiation and Indoor Air. Draft March 2011.

Xiong, Y.-L. 2011. Release of EQ3/6 Database DATA0.FM1. Email to J.J. Long, March 9, 2011. ERMS 555152.

Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2009. Thermodynamic Data for Phase 5 ($Mg_3Cl(OH)_5{\bullet}4H_2O$*) Determined from Solubility Experiments. Memorandum to L. Brush, Sandia National Laboratories, May 18, 2009. ERMS 551294.*

Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2010. Experimental determination of the solubility of magnesium chloride hydroxide hydrate ($Mg_3Cl(OH)_5{\bullet}4H_2O$*, phase 5) at room temperature, and its importance to nuclear waste isolation in geological repositories in salt formations. Geochimica et Cosmochimica Acta 74:4605-4611.*

DOE Response

The DOE uses the correct value in the WIPP thermodynamic database. The small difference in log K for dissolution of phase 5 as noted by EPA represents the fact that two different activity coefficient models were used for extrapolation to infinite dilution. In *Thermodynamic Data for Phase 5 (*$Mg_3Cl(OH)_5{\bullet}4H_2O$*) Determined from Solubility Experiments* (Xiong et al. 2009), the log K with a value of 43.21 ± 0.33 was obtained by using the Specific Ion Interaction Theory (SIT) model for extrapolation to infinite dilution. When *Release of EQ3/6 Database DATA0.FM1* (Xiong 2011) was formalized, the log K of 42.96 ± 0.32 was the value recomputed by using the Pitzer model for extrapolation to infinite dilution, because the WIPP thermodynamic database uses the Pitzer model for activity coefficients. In *Experimental Determination of the Solubility Constant for Magnesium Chloride Hydroxide Hydrate (*$Mg_3Cl(OH)_5{\bullet}4H_2O$*, Phase 5) at Room Temperature, and its Importance to Nuclear Waste Isolation in Geological Repositories in Salt Formations* (Xiong et al. 2010), both sets of log K, i.e., log K of 43.21 using the SIT model for extrapolation to infinite dilution, and log K of 42.96 using the Pitzer model for extrapolation to infinite dilution, were presented, and the value calculated from the Pitzer model was used in the WIPP data base. In Xiong et al. (2010) Table 7 , the log K with the SIT model was presented, and in the second paragraph on page 4610, the log K with the Pitzer model was presented.

References:

Xiong, Y.-L. 2011. Release of EQ3/6 Database DATA0.FM1. Email to J.J. Long, March 9, 2011. ERMS 555152, and the associated document, ERMS 555154.

Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2009. Thermodynamic Data for Phase 5 ($Mg_3Cl(OH)_5{\bullet}4H_2O$) Determined from Solubility Experiments. Memorandum to L. Brush, Sandia National Laboratories, May 18, 2009. ERMS 551294.

Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2010. Experimental determination of the solubility constant for magnesium chloride hydroxide hydrate ($Mg_3Cl(OH)_5{\bullet}4H_2O$, phase 5) at room temperature, and its importance to nuclear waste isolation in geological repositories in salt formations. Geochimica et Cosmochimica Acta 74:4605-4611.*

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* Copyrighted reference not provided in Enclosure 2.

<table>
<tr><th colspan="4">Status Report of DOE Responses to EPA Completeness Questions</th></tr>
<tr><th>Completeness Question</th><th>Included in This Submittal</th><th>Previously Submitted</th><th>Pending</th></tr>
<tr><th colspan="4">EPA's Completeness Questions Received December 17, 2014</th></tr>
<tr><td>40 CFR 194.15(A)(2) MONITORING
1-15-1 Water Level Fluctuations in SNL-13.
DOE/WIPP-12-3489 p. 143 states "SNL-13 was also excluded [from the Culebra groundwater analysis] due to a sudden rise and then sudden stabilization following the drilling of a new oil or gas well nearby." Please address the following:
1. Identify and provide the location, depth, and purpose of the 'new' nearby wells.
2. What activities took place at the nearby wells during the time of the changes in SNL-13, such as fluid injection? Provide pressure histories, volumes and fluid types, fluid enhancements (e.g. fracking fluids or proppants).
3. Provide a chronological history of the activities in the nearby wells compared to the "sudden" changes in adjusted freshwater heads recorded in SNL-13.
4. Were water levels in other monitoring wells influenced by activities at nearby wells?</td><td></td><td>✓</td><td></td></tr>
<tr><td>40 CFR 194.15(A)(2) MONITORING
1-15-2 Shaft Extensometers Not Taking Recordings.
DOE is not replacing the failed monitoring instruments in the shaft. However, EPA Section 42, Monitoring requirements expects, " ...<i>extent of deformation ...</i>" and "...<i>brittle deformation...</i> " to be monitored. Please provide a justification to discontinue measuring these characteristics in the WIPP shafts as these measurements are used to calibrate numerical models and predict closure rates. Additionally, identify how this requested information will be addressed in the future.</td><td></td><td>✓</td><td></td></tr>
</table>

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
40 CFR 194.15(A)(2) MONITORING **1-15-3 Derivation of Annual Culebra Water Level Map.** CRA-2014 Section 42.8 *Changes or New Information Since the CRA-2009* discusses changes to the process used to derive the Culebra groundwater flow parameters that is used to prepare the annual water level map. Please address the following: 1. For each yearly calculation (ERMS 558589, Section 2.3.2.2), if the monitored freshwater heads have changed, do the 100 calibrated T-Fields need to be recalculated? If not, why? 2. ERMS 557633 Section 2.1 states, "The PA MODFLOW model T (transmissivity), A (anisotropy) and R (recharge) input fields are appropriately averaged across 100 realizations, producing a single average MODFLOW flow model." Provide information as to how averaging is done with examples. 3. For the averaged MODFLOW model, T (transmissivity), A (anisotropy) and R (recharge) are fixed while a subset of the boundary conditions is modified (ERMS 557633, Section 2.1). Please describe how the new boundary conditions are determined and implemented. If this simply involves raising or lowering the heads along the boundaries to best match the observed water levels within the modeled area, describe how well the assigned boundaries honor the water levels in the nearest monitoring wells both inside and outside the model area. 4. If the step-by-step creation of the annual Culebra water level map is the same as that provided during 2012 and 2013 inspections, please denote as such. If generating the annual water level map differs from what has been provided during inspections, please provide these steps.		✓	
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-1 Continuing Validity of Kds.** CRA-2014 Appendix PA, Table PA-1 states that the Culebra Matrix Partition Coefficients (Kds) are, "*Carried over from CRA-2009 PABC*." Please provide the rationale for the assumption that the CRA 2014 Kds can be same as those used in the CRA-2009 despite the changes in the organic ligand content and the 2012 inventory since the last PA. Additionally, provide a discussion of the potential impacts of the organic kitty litter added to the LANL waste on the Culebra Kds.		✓	
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-2 Continuing Validity of T-Fields.** CRA-2014 Appendix PA, Table PA-1 states that the Culebra Transmissivity Fields are, "*Carried over from CRA-2009 PABC*." It appears that the last update to the geologic well data analysis was performed in 2007 (Powers 2007a and Powers 2007b). Specific questions and requests the Agency has related to the T-Fields are listed below. 1. Have changes in the Culebra well data during the past seven years changed the T-Field derivation in any way? 2. Has any additional hydraulic testing been performed that could be used for additional calibration of the T-Fields? 3. Has the saturated thickness of the Culebra remained constant since the original derivation of the T-Fields? 4. Provide justification that new well information and water level changes since the 2009 PABC do not need to be included in the T-Field derivation and that the 2009 T-Fields are still valid for use in the CRA-2014 PA. 5. Provide justification for the continued use of the CRA-2009 T-fields.		✓	

Information Only

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-3 REGION ROMPCS** The Agency agreed to the adopted parameter values used for the panel closure change request to isolate the effects and facilitate a comparison of the proposed panel closure design on the baseline PA and, at the time of the planned changed request, there was uncertainty in the emplacement technique to be used. The Agency would like DOE to address the following comments on several parameters related to the panel closures: 1. Identify and technically justify that ranges of porosity and permeability for the ROM salt PCS during the time period 0 to 100 years (material PCS_T1) are consistent with initial emplacement of the ROM salt material without wetting or compaction. 2. Provide technical justification for applying a capillary pressure model that assumes zero threshold pressure to region ROMPCS during time periods 100 to 10,000 years (T2 and T3). 3. Provide a technical justification for selecting the ranges for the residual brine and gas saturations (SAT_RBRN and SAT_RGAS) during time periods T2 and T3; the justification should include adopting a zero value as the low end. 4. Provide technical justification for using the same value for the bulk compressibility of ROM salt during the T1, T2 and T3 time periods (from 0 to 100, 100 to 200, and 200 to 10,000 years).		✓	
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-4 REGION DRZ PCS** The Agency would like DOE to address the following comments related to the parameter values adopted for the DRZ_PCS: 1. Provide technical justification for assigning the same sampled value of porosity to the material in DRZ_PCS region for both early and late time periods (T2 and T3) when the DRZ is undergoing consolidation and healing. 2. Provide technical justification for the apparent discrepancy created by independently sampling the permeability of material DRZ_PCS, representing a healed DRZ, from a distribution that can provide a sampled permeability as much as seven orders of magnitude higher than the permeability of intact halite. 3. Provide technical justifications for assigning zero values to the residual brine and gas saturations (SAT_RBRN and SAT_RGAS) in CRA-2014 for the region DRZ_PCS during the T3 time period (200 to 10,000 years). 4. Provide technical justification for applying a capillary pressure model that assumes zero threshold pressure in region DRZ_PCS during the T3 time period (200 to 10,000 years). 5. Provide technical justification for the value of the bulk compressibility of the DRZ_PCS region, and applying that same value during both early and late time periods (T2 and T3) when the material in that region is undergoing consolidation.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-5 Waste Shear Strength.** Please address the following: 1. Provide horsetail plots of the remaining fraction of uncorroded iron in the repository throughout the 10,000-year regulatory time frame from the CRA-2009 PABC from each of the three replicates and each scenario. 2. Provide horsetail plots of the remaining fraction of undegraded CPR in the repository throughout the 10,000-year regulatory time frame from the CRA-2009 PABC from each of the three replicates and each scenario. 3. Provide and justify the criteria used in advancing the surrogate waste samples during the shear strength tests when the eroded sample face was not smooth but irregular. 4. Identify and justify the consequences of using the proposed uniform distribution rather than the currently approved log-uniform distribution for TAUFAIL. 5. Provide the quality control procedures used during the shear strength tests and provide evidence that the tests were performed consistent with those procedures.		✓	

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-6 Probability of Encountering a Castile Brine Pocket.** Please address the following comments: 1. TDEM results are site specific and indicate the presence of potentially large volumes of brine beneath some waste panels. Explain why TDEM data is not used in DOE's proposed approach for estimating PBRINE. 2. DOE's approach ignored the presence of high electrical conductivity zones identified beneath four of the ten WIPP waste panels. Please explain how this omission affected the comparison of the TDEM approach with DOE's newly derived drilling data approach. 3. ERMS 558724 asserts that brine encounters of sufficient size to impact the repository would be noticed and logged by a driller. The approach does not acknowledge the potential of encountering a low yield and high volume brine pocket which would not be noticed by the driller in calculating PBRINE. Please address the basis for not considering the low yield, high volume brine pockets. 4. DOE reported the same count of 34 brine intrusions out of 678 Castile wells in 2008. It is unclear whether 2008 was the last time a brine intrusion was observed at the time of collecting data for the CRA-2014 or if 2008 was the cut-off date for recoding a brine intrusion. Please clarify. 5. The circular regions in Figure 5 of ERMS 558724 were selected to include a known brine pocket encounter. Please provide information as to whether this radius would bias the results and the sensitivity of the results to the radius size. 6. Provide information as to how the well depths, for each well that did and did not encounter a brine pocket, were incorporated into the drilling data analysis. 7. The ratios in Table 2 of ERMS 558724 include double-counting of many wells. Please provide information as to how this affected the results. 8. ERMS 558724 states that pressurized brine is associated with near-vertical fractures. However, WIPP-12 yielded large volumes of brine that is assumed to have been stored and transmitted through the extensive and primarily interconnected horizontal to sub-horizontal fractures. Please provide an explanation as to how the near-vertical fracture model adopted by DOE's modified PBRINE parameter is consistent with evidence that WIPP-12 releases are attributed to horizontal and sub-horizontal fractures.		✓	
40 CFR 194. 23 MODELS AND COMPUTER CODES **1-23-7. Volume of Repository Operations and Experimental Areas.** Please address the following: 1. Explain how DOE arrived at a volume of 148,011 m^3 for the underground. 2. In the diagram of repository ventilation during recovery (see attached, labeled *Phase 2B Underground Map* , dated March/17/2014) a large portion of the north experimental area is denoted as 'backfilled'. Please provide information of the material properties of these backfilled areas and how they are modeled during the 10,000 year regulatory period in the CRA-2014 PA.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
40 CFR 194.23 MODELS AND COMPUTER CODES **1-23-8 Fluid Flow in Repository Operations and Experimental Areas.** There have been numerous refinements of conceptual and numerical models of repository fluid flow since the 1994-95 time frame as well as changes to the panel closure system that may also change repository fluid flow. Please provide updated technical justifications for the following parameter values adopted for the experimental and operations areas: 1. Setting the permeability of the operations and experimental rooms to a constant value of value 10^{-11} m^2 throughout the modeled period. 2. Setting the porosity of the operations and experimental rooms to a constant 18% throughout the modeled period. 3. Setting the porosity and permeability of the DRZ adjacent to the operations and experimental room to the same sampled value as the DRZ surrounding a waste panel throughout the modeled period.		✓	
40 CFR 194.23 MODELS AND COMPUTER CODES **1-23-11 EQ3/6 and Supporting Files.** Please provide the following computer files related to the actinide source term modeling calculations and the determination of the cumulative distribution functions for the actinide solubilities: 1. The EQ3/6 database file DATA0.FM1 used for the CRA-2014 solubility calculations, (also known as DATA0.FMT.R2). 2. EQ3/6 input and output files used for calculating actinide solubilities for the actinide source term at different brine volumes (1x, 2x, 3x, 4x, 5x minimum brine volumes). 3. The Excel macro GetEQData.xls and all Excel spreadsheets that contain the output extracted with GetEQData.xls. 4. EQ3/6 input and output files used for calculating actinide solubilities for the +III and +IV actinide uncertainty analysis calculations. 5. Excel macros GetEQData_v101e.xls and GetEQData_v101f.xls; and 6. Excel files Thorium_Uncertainty_Results_2014_PA.xls and Americium_Uncertainty_Results_2014_PA.xls.		✓	
40 CFR 194.23 MODELS AND COMPUTER CODES **1-23-12 WIPP-Specific Organic Complexation Data.** Appendix SOTERM Section 3.8.2 provides a description and four graphs (Figure SOTERM-21) that relate to WIPP-specific experiments designed to evaluate the effects of organic chelating agents on +III and +IV actinide solubility in WIPP brines. 1. Please provide supporting documentation for these data, including a summary of the experimental approach, materials and analytical methods used to produce the data. 2. Please provide any available characterization data for the solid phases present in these experiments.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
40 CFR 194.23 MODELS AND COMPUTER CODES **1-23-13 Missing Reference.** Appendix SOTERM, Figure SOTERM-7 caption cites Altmaier (2011) but this reference is missing from the reference list. Please provide this reference.		✓	
40 CFR 194.24 WASTE CHARACTERIZATION- PERFORMANCE ASSESSMENT INVENTORY **1-24-1 Shielded Container Lead Inventory** 1. Please provide information as to how lead shielding on RH shielded containers is included in the performance assessment.		✓	
40 CFR 194.24 WASTE CHARACTER IZATION- PERFORMANCE ASSESSMENT INVENTORY **1-24-2 Inventory Report Text Unclear.** Please address the following: 1. Provide information as to how the "projected-to-stored volume ratio" is derived for both RH and CH waste. Please provide an example of this derivation. 2. Provide information of the RH waste volume that has been and will be placed in the leaded containers on the waste panels floors. 3. Provide information that specifies how potential waste inventory listed in the inventory report estimate is used in the CRA-2014 performance assessment.		✓	
40 CFR 194.24 WASTE CHARACTER IZATION- PERFORMANCE ASSESSMENT INVENTORY **1-24-3 Emplaced Inventory Chemical Constituents** 1. In the ATWIR 2012, Section 2.3, it is stated that, "Chemical constituents are not reported in the emplaced inventory". In the PAIR 2012 report, Section 4.3, it is indicated that "two additional analysis" were performed for chemical and other important constituents. It is unclear how the chemical constituents of emplaced inventory, identified in the PAIR report, are derived and calculated for the CRA-2014 PA, provide clarification.		✓	

Information Only

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
40 CFR 194.24 WASTE CHARACTER IZATION- PERFORMANCE ASSESSMENT INVENTORY **1-24-4 Missing References.** Please provide the following references: French, D. 2009. *Analysis of Container Material Masses* , INV-SAR-19. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory - Carlsbad Operations (LANL-CO) 2010. *Analyses* , LCOQP9 - Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory - Carlsbad Operations (LANL-CO) 2011a. *Data Collection, Data Management, and Control for the Comprehensive Inventory* , INV-SP-01. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory - Carlsbad Operations (LANL-CO) 2011b. *Entry, Verification, and Validation of inventory Information in the Comprehensive Inventory Database* , INV-SP-02. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory - Carlsbad Operations (LANL-CO) 2011c. *LANL-CO Software Quality Assurance Plan* , LCO-QPD-02. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory- Carlsbad Operations (LANL-CO) 2011d. *Software Quality Assurance* , LCO-QP19-1. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory - Carlsbad Operations (LANL-CO) 2011e. *Comprehensive Inventory Database* , Version 2.0, Schema Version S2.00, Data Version D.10.01. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. Los Alamos National Laboratory - Carlsbad Operations (LANL-CO) 2012. *Comprehensive Inventory Database* , Version 2.01, Schema Version S2.01, Data Version D.11.00. Los Alamos National Laboratory - Carlsbad Operations, Carlsbad, NM. *Chemical and Cement Components 2011 Inventory Estimates* . LANL-CO. INV-SAR-28, Revision 0, November 1, 2012. LANL-CO Record ID# INV-1211-01-01-01. *Estimation of Cellulose, Plastic, and Rubber Emplacement Materials in the Waste Isolation Pilot Plant (WIPP)* . LANL-CO. INV-SAR-27, Revision 0, November 5, 2012. LANL-CO Record ID# INV-1211-02-01-01.		✓	
GENERAL: CRA-2014 DOCUMENTATION **1-G-1 Reference Appendix QAPD-2014 Not Provided.** CRA-2014 Section 23, Models and Computer Codes, Section 23.5.7 states, "The DOE's quality assurance program, as applied to the CRA-2014, is contained in Appendix QAPD-2014." The appendix has not been provided. Please provide this document.		✓	
GENERAL: CRA-2014 DOCUMENTATION **1-G-2 Codes IDs Do Not Include Source Code Listing.** CRA-2014 Section 23, Models and Computer Codes, Section 23.8.7 states, "The IDs include source-code listings..." EPA examined a number of code Implementation Documents; they include a reference to the location of the source-code listing, but not the actual listing of the code. Please provide the source-code listing for the following CRA-2014 codes: BRAGFLO 6.02, MATSET 9.20, CCDFGF 6.0.		✓	

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
GENERAL: CRA-2014 DOCUMENTATION **1-G-3 New Codes EQ3/6 and JAS3D Documentation Incomplete.** DOE states in CRA-2014 Section 23, 23.7.7, "The documentation for the new codes EQ3/6 and JAS3D may be found in their respective UM, AP, VD, ID, and RD/VVP." It does not appear that this documentation has been included in CRA-2014. Please provide this documentation.		✓	
CHEMISTRY COMMENTS **1-C-1 LANL Waste Stream With Added Cellulosic Material.** Organic kitty litter was used as an absorbent for nitrate salts for Waste Stream LA-MIN02-V.001 (NMED 2014) and 349 drums of this waste were placed in Panels 6 and 7 (Wallace 2014). Please address the following: 1. Provide a complete waste profile for the kitty litter; including; cellulosic content and other ingredients; emplaced volume and mass. 2. Specify the number of drums with kitty litter placed in either Panel 6 or 7. 3. Identify the type of waste emplaced in the drums with the kitty litter. 4. Indicate whether this cellulosic kitty litter has been used in other waste streams and whether the corresponding waste profile reports adequately describe the waste material parameters. 5. Describe the effects of omitting the organic kitty litter in the waste stream(s) on the CPR inventory and consequent effects on gas generation rates calculated for the CRA-2014 PA. 6. Provide information of the quantities of soluble organics, such as organic ligands or surfactants that could affect actinide solubilities when this material is leached.		✓	
EPA's Completeness Questions Received February 27, 2015			
194.23 MODELS AND COMPUTER CODES **2-23-1 ROM Salt Panel Closures Locations.** Please provide the WIPP configuration layout (a plan view) used for the 2014 CRA that includes all locations where the ROM salt panel closures are to be placed. Provide text that provides the exact location, dimensions and properties for the set of panel closures that lie furthest north in the repository.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
194.23 MODELS AND COMPUTER CODES **2-23-2 Provide An Update of the Derivation of the Shaft Properties at the Repository Horizon.** In the BRAGFLO grid for the 2004 and 2009 CRA Performance Assessments (PAs), the modeled lower portion of the shaft included an effective permeability that incorporated both the concrete portion of the shaft (at the repository horizon level) and the furthest north panel closures located just south of the waste and exhaust shafts. The material properties of the modeled shaft (the concrete monolith segment) were combinations of the shaft properties and the Option D panel closure properties (Camphouse and Clayton 2011, ERMS 555204). Now, however, there is a new panel closure system that uses run of mine salt instead of the Option D design, and the properties of new panel closure system are different than that of the concrete portion in the lower shaft. In the CRA 2014 PA, however, it appears the material properties of the shaft at the repository horizon have not been updated to reflect the change. Please confirm this and identify how the properties would change to reflect the change in the panel closure design.		✓	
194.33 FUTURE DRILLING **2-33-1 Future Drilling Into Nitrate Waste.** Please provide the probability and describe the potential consequence(s) to PA calculations of drilling into the nitrate waste.		✓	
194.43 PASSIVE INSTITUTIONAL CONTROLS **2-43-1 Changes in Passive Institutional Controls (PICs).** Recent Nuclear Energy Agency and International Atomic Energy Agency reports describe changes and developments in international approaches to PICs. These are referenced in INIS-US-13-WM-13145 which states "The DOE/CBFO WIPP PIC's program in place today meets the regulatory criteria, but complete feasibility of implementation is questionable, and may not be in conformance with the international guidance being developed." Please explain this feasibility concern. Please also provide the complete INIS-US-WM-13145 report (the Web link only provides an Abstract) and any other recent studies or reports that may impact PICs planning in the future. Reference: INIS-US-13-WM-13145, "The Revised WIPP Passive International Controls Program – A Conceptual Plan – 13145, Dated 2013-07-01, Web link: http://www.osti.gov/scitech/biblio/22225507		✓	

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
194.44 ENGINEERED BARRIERS **2-44-1 MgO Physical Segregation.** In Franco (2012) DOE notified EPA that MgO emplacement has been modified by placing a 3,000 pound supersack of MgO on every other waste stack or on each waste stack in every other row. In the Franco 2012 letter the "effective diffusion penetration length of CO2" was considered but the information on physical segregation is limited. Please provide updated documentation to more explicitly and clearly address whether the larger lateral separation distance still allows sufficient reactions between MgO and CO2. References: Franco, J.R. 2012. Letter to A. Perrin (Subject: "Planned Change Notice for Placement of MgO Supersacks," with enclosure (Analysis of an alternative placement scheme for MgO supersacks). February 14, 2012. Carlsbad, NM: U.S. Department of Energy Carlsbad Field Office. U.S. Department of Energy (DOE). 2009. Title 40 CFR Part 191 Subparts B and C Compliance Recertification Application for the Waste Isolation Pilot Plant, Appendix MgO-2009. *Magnesium Oxide as an Engineered Barrie* r. DOE/WIPP 09-3424. Carlsbad, NM: Carlsbad Field Office. Vugrin, E.D., M.B. Nemer, and S.W. Wagner. 2006. *Uncertainties Affecting MgO Effectiveness and Calculation of the MgO Effective Excess Factor* (Rev. 0, November 17). ERMS 544781. Carlsbad, NM: Sandia National Laboratories.		✓	

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
194.46 REMOVAL OF WASTE **2-46-1 CCA Appendix WRAC Waste Removal Documentation Needs Updating.** The cited removal plan is basically the same as that given during the 1996 CCA and does not reflect updates and modifications to the repository design and waste characteristics. The Agency found discrepancies between what was used as the removal plan listed in 1996 CCA Appendix WRAC, "Waste Removal after Closure," with the current 2014 repository design, waste, and container characteristics. These are listed below. Please update the waste retrieval plan to address these discrepancies. Please assure that 40 CFR 194.46 requirements "Removal of Waste" still comply and are aligned with expected repository conditions at the time of closure, and that removal of waste remains feasible. The repository is no longer mined on one contiguous level [CCA Appendix WRAC page WRAC-7], the southern portion of the mine was moved up to the Clay Seam G level. The waste containers have changed. The CCA assumed two principal types of containers (55-gallon drums and standard waste boxes) [CCA Appendix WRAC, page WRAC-8] but with the introduction of large waste boxes, shielded RH-TRU containers, pipe over packs, and super-compacted waste, these assumptions are no longer valid. The waste characteristics have changed with the introduction of nitrate waste potentially subject to exothermic reactions. The run-of-mine salt panel closure replaced the original concrete-based Option D panel closure design, which can no longer be used "as markers for locating panels and drifts" [CCA Appendix WRAC, Section WRAC.6.4]. Given the use of shielded containers CH and RH wastes no longer must be segregated in the waste panels [CCA Appendix WRAC, Sections WRAC.4.3, WRAC.6, WRAC.6.4] and can no longer be removed using separate retrieval operations where the RH shielded containers are comingled with CH waste containers. CCA Appendix WRAC refers to performance assessment (PA) modeling to predict future characteristics of repository waste rooms. The PA assumptions, models, parameters, and inventory have changed since the CCA. Please include these changes in the waste removal reevaluation. CCA Appendix WRAC, Section WRAC.4.3 takes credit for the effectiveness of active and passive controls to deter human intrusion for up to 700 years after closure. However, this credit was denied by EPA because of difficulty predicting the future. This should be removed from the waste removal reevaluation. References: U.S. Department of Energy (DOE). 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant (October). CCA Appendix WRAC, Waste Removal After Closure". DOE/CAO-1996-2184. Carlsbad, NM: Carlsbad Area Office. U.S. Department of Energy (DOE). 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant (October). CCA Chapter 7.0, "Assurance Requirements". DOE/CAO-1996-2184. Carlsbad, NM: Carlsbad Area Office. U.S. Department of Energy (DOE). 2004. Title 40 CFR Part 191 Compliance Recertification Application for the Waste Isolation Pilot Plant (March). CRA-2004 Chapter 7.0, "Assurance Requirements". DOE/WIPP 2004-3231. Carlsbad, NM: Carlsbad Field Office. U.S. Department of Energy (DOE). 2009. Title 40 CFR Part 191 Compliance Recertification Application for the Waste Isolation Pilot Plant (March). CRA-2009 Section 46, "Removal of Waste" DOE 09-2434. Carlsbad, NM: Carlsbad Field Office.	✓		
194.55 RESULTS OF COMPLIANCE ASSESSMENTS **2-55-1 Incorrect Reference.** Appendix IGP-2014, Section IGP-2.1 makes reference to 194.55(b)(1), should this be 194.54(b)(1) "Existing boreholes…"?		✓	

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
CHEMISTRY COMMENTS **2-C-3 Data Supporting Water Balance Assumptions.** The CRA-2014 PA calculations include the effects of MgO hydration, microbial degradation of CPR and iron sulfide formation on repository water balance. For PA, it is assumed that hydrogen sulfide created by CPR degradation preferentially reacts with iron hydroxide versus metallic iron (CRA-2014 Appendix MASS, page MASS-57). These hydrogen-sulfide reactions are: $\mathrm{Fe(OH)2(s) + H2S(g) \rightarrow FeS(s) + H2O(l)}$ (1) $\mathrm{Fe(s) + H2S(g) \rightarrow FeS(s) + H2(g)}$ (2) The assumption that hydrogen sulfide preferentially reacts with iron hydroxide increases brine production and decreases gas production compared to the assumption that all or some of the hydrogen sulfide reacts with metallic iron. It is also assumed for PA that carbon dioxide preferentially reacts with brucite instead of unreacted MgO. The carbonation reactions are: $\mathrm{1.25\ Mg(OH)2(s) + CO2(g,aq) \rightarrow 0.25\ Mg5(CO3)4(OH)2 \cdot 4H2O(s)}$ (3) $\mathrm{1.25\ MgO(s) + CO2(g,aq) + 1.25\ H2O(l) \rightarrow 0.25\ Mg5(CO3)4(OH)2 \cdot 4H2O(s)}$ (4) The assumption that carbon dioxide preferentially reacts with brucite increases brine production in the repository. Please provide supporting data for these water-balance assumptions and evaluate the potential magnitude of the effects of these assumptions on the water balance.		✓	
CHEMISTRY COMMENTS **2-C-4 Hydromagnesite Conversion Rate.** Clayton (2013) formulated the conversion reaction from hydromagnesite to magnesite for inclusion in the BRAGFLO calculations as: $\mathrm{Mg5(CO3)4(OH)2 \cdot 4H2O(s) \rightarrow 4\ MgCO3(s) + Mg(OH)2(s) + 4\ H2O(l)}$ (5) Clayton (2013) calculates a range for the hydromagnesite conversion rate based on reaction times of 100 years to 10,000 years. However, the minimum reaction time for this conversion is uncertain. SCA (2008) reviewed the available experimental and natural analogue data and concluded that hydromagnesite conversion is best represented by a range of zero conversion (only hydromagnesite remains after 10,000 years) to complete conversion (only magnesite remains after 10,000 years), with a uniform distribution across this range. Please provide an explanation as to why the specific upper and lower limits used in the PA were picked. The effect of using zero rather than 100 years as the minimum conversion rate is likely to be less brine production in the water balance, based on equation (5). Please provide an explanation of the effects on PA if the lower limit of the hydromagnesite conversion rate is set to zero while the upper limit is decreased by a variety of plausible factors that are less than what Clayton had adopted. References: Clayton, D.J. 2013. Justification of Chemistry Parameters for Use in BRAGFLO for AP-164, Rev. 1. Sandia National Laboratories, ERMS 559466. SCA (S. Cohen and Associates). 2008. Review of MgO-Related Uncertainties in the Waste Isolation Pilot Plant. Final Report prepared for the U.S. Environmental Protection Agency Office of Radiation and Indoor Air, Washington, D.C., January 24, 2008.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **2-C-5 Cumulative Effects of Water Balance Assumptions on PA.** The result of several water balance assumptions is to increase brine production from waste reactions in the repository. These assumptions include that hydrogen sulfide will preferentially react with iron hydroxide instead of metallic iron (Comment 2-C-3); that carbon dioxide will preferentially react with brucite instead of MgO (Comment 2-C-3); and that the minimum rate of hydromagnesite conversion to magnesite is greater than zero (Comment 2-C-4). Please provide a description of the cumulative effects of these assumptions on the water balance calculations for the CRA-2014 PA.		✓	
CHEMISTRY COMMENTS **2-C-6 MgO Hydration Rate.** MgO has been supplied for the WIPP engineered barrier by three vendors: National Magnesia Chemicals, Premier Chemicals, and, currently, from Martin Marietta Magnesia Specialties (Martin Marietta). The majority of the MgO in the repository is from Premier Chemicals and Martin Marietta. Clayton (2013) used MgO hydration rates obtained from experiments conducted with MgO supplied by Premier Chemicals to establish the hydration rates used in PA. However, Wall (2005) performed preliminary tests with the Martin Marietta MgO and concluded that it reacted to form brucite faster than Premier MgO. Given the multiple vendors that supply MgO a summary of the following information needs to be provided; The inundated and humid MgO hydration rates for MgO from the three vendors. The potential effects of the variable MgO hydration rates on repository performance. The amounts of National Magnesia Chemicals, Premier MgO and Martin Marietta MgO that will be present in the WIPP repository at the time of closure, and assumptions regarding the future source(s) of MgO. References: Clayton, D.J. 2013. Justification of Chemistry Parameters for Use in BRAGFLO for AP-164, Rev. 1. Sandia National Laboratories, ERMS 559466. Deng, H., M. Nemer, and Y. Xiong. 2007. Experimental Study of MgO Reaction Pathways and Kinetics Rev. 1. Sandia National Laboratories TP 06-03.Deng, H., Y. Xiong, M. Nemer and S. Johnsen. 2009. Experimental Work Conducted on MgO Long-Term Hydration. Sandia National Laboratories ERMS 551421. Wall, N.A. 2005. Preliminary Results for the Evaluation of Potential New MgO. Sandia National Laboratories ERMS 538514.		✓	
CHEMISTRY COMMENTS **2-C-7 MgO Hydration Rate Data File.** Please provide a copy of the Microsoft Excel file "hydration kinetics Q & HY2 & HH djc 5-1-07.xls" used by Nowak and Clayton (2007) to calculate the MgO hydration rates. References: Nowak, E.J. and D. Clayton. 2007. Analysis of MgO Hydration Laboratory Results and Calculation of Extent of Hydration and Resulting Water Uptake versus Time under Postulated WIPP Conditions. Sandia National Laboratories ERMS 546769.		✓	
CHEMISTRY COMMENTS **2-C-8 Iron and Lead Corrosion Rate Data.** Please provide spreadsheets containing the iron and lead corrosion data listed in Appendix A, Tables A-1 and A-2 from Roselle (2013). References: Roselle, G.T. 2013. Determination of Corrosion Rates from Iron/Lead Corrosion Experiments to be Used for Gas Generation Calculations. Sandia National Laboratories ERMS 559077.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
194.32 SCOPE OF PERFORMANCE ASSESSMENT Since the original certification decision changes have been made to the repository, it is our observation that, for many of the features, events, and processes (FEPs) we have reviewed, DOE has not fully considered all of the relevant changes to the repository. Additionally, DOE has not fully considered updates relevant to activities within the WIPP vicinity. Table FEP-1 lists our comments on specific FEPS; immediately below we discuss general FEP screening issues that need further attention. **2-32-G1 Obsolete FEP Screening Arguments, Curtailed FEP Screening Arguments, and Completeness Considerations.** The screening arguments in the CRA-2014, Appendix SCR- 2014 for many FEPs have been carried forward from past baseline reviews and do not necessarily reflect changes that have occurred in the past several years. This especially applies to information on how some FEPs are accounted for in PA. Some FEPs need to be updated to reflect current repository design and new knowledge of repository behavior. These are identified in Table FEP-1. For some FEPs, the screening argument needs to provide a more complete discussion of the FEP and how it is determined to be screened-in or screened-out. The supporting arguments, along with documents incorporated by references, need to provide a basic understanding of how the FEP is accounted for in PA calculations, where the FEP is accounted for in the repository region and surrounding geosphere, and when in the regulatory time frame the FEP is accounted for. Those FEPs with inadequate or curtailed screening arguments are provided in Table FEP-1. For some FEPs that DOE has reported "no change", EPA disagrees and believes that DOE should reconsider and update the FEP discussion. Table FEP-1 includes those FEPs in this category that EPA has identified, to date, as being incomplete.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S1**. Screening argument considers only boreholes intersecting the waste region. Please supplement the argument with a discussion of boreholes that intersect the non-waste regions and the consequence to PA calculations. Provide references and specific information as to whether boreholes penetrating non-waste regions could result in the transport of radionuclides between the waste and non-waste regions, to overlying units, or to the surface. Provide information, either directly or by reference, as to how deep boreholes penetrating the non-waste and waste regions of the repository are accounted for in the PA.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S2.** The screening argument considers flow into the repository from boreholes that intercept pressurized fluid in underlying formations but only for boreholes intersecting the waste region. In the current BRAGLO model gas and brine readily flow between the waste and non-waste regions. A discussion and analysis of boreholes that could intersect the non-waste regions and their impact on the PA needs to be provided.		✓	

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S3.** Screening argument considers only boreholes intersecting the waste region and also pressurized Castile brine. In the current BRAGLO model gas and brine readily flow between the waste and non-waste regions. Please supplement the argument with a discussion and analysis of boreholes that could intersect the non-waste regions on the PA.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S4.** Please address whether enhanced production techniques are being used in the Delaware basin and in the vicinity of WIPP. Please also address the potential for these techniques to create a preferential pathway for radionuclide releases through a second well.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S5.** This FEP is screened out partially on the basis that solution mining will not occur in low ambient temperature conditions. However, solution mining is occurring in the nearby Eddy mine under similar conditions that exist in the vicinity of WIPP. Please provide text that reconciles the basis of the screening argument and the conditions at the Eddy mine where solution mining is taking place.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S6**. In the screening argument please provide evidence that the modeled excavated volume is the expected mined volume of the underground workings at the time of closure.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S7.** The screening argument citation of the CCA as the source of information on the Heterogeneity of waste forms ignores changes that have occurred in the past 15 years, including supercompacted waste and mingling RH waste in shielded containers with CH waste. Please update the information to reflect current waste forms.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S8.** Please supplement the screening argument with an explanation of the implementation in PA of the material inventory of shielded containers containing RH waste.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S9**. The screening argument for this FEP states "This excavation-induced, host-rock fracturing is accounted for in PA calculations (the CCA, Chapter 6.0, Section 6.4.5.3)." The cited CCA text indicates that the DRZ is modeled in the same way around all repository excavations. However, the DRZ is now expected to vary spatially. Provide an updated description of the DRZ in the waste and non-waste locations of the repository.		✓	

Information Only

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S10.** Screening argument was combined with that for W18 *Disturbed Rock Zone(DRZ); please see comments for FEP W18.*		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S11.** Please supplement the screening argument with a discussion of salt creep and consolidation specific to the ROM salt in the ROMPCS, and healing of the adjacent DRZ. Such a discussion can be found in Camphouse et al. (2012, Section 2.0. ERMS 557396). The screening argument for this FEP states that "Salt creep in the Salado is accounted for in PA calculations (the CCA, Chapter 6.0, Section 6.4.3.1)." The cited CCA section discusses these FEPs only in the context of the waste region. In addition, this is the only FEP that addresses DRZ healing, which is expected to vary spatially.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S12.** Screening argument was combined with that for W20 *Salt Creep* ; please see comments for FEP W20. Additionally, please supplement the screening argument with discussions of 1) the coupling between consolidation of the ROM salt in the ROMPCS and healing of the adjacent DRZ (DRZ healing cannot occur until the ROM salt is consolidated and applies a back stress sufficient to compress and heal the DRZ); and 2) lateral extrusion of the ROM salt when under compressive stress from drift creep closure.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S13**. Please supplement the screening argument with a discussion of the potential for high waste panel gas pressures to delay the consolidation of the ROM salt, thereby maintaining a higher permeability in the PCS for a longer period of time.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S14.** Please update the screening argument to reflect the LANL inventory with nitrates and added organic matter that resulted in an exothermic reaction.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S15**. Please modify the screening argument to address whether, in addition to "a reduction of TRU radionuclides from previous estimates", the quantities of fissile radionuclides have also been reduced.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S16**. Please supplement the screening argument with information on the impacts of changes in GLOBAL:PBRINE and the PCS on brine inflow.		✓	

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S17.** Please supplement the screening argument with information on the impacts of changes in GLOBAL:PBRINE and the PCS on the availability of brine in the waste panels.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S18.** Please supplement the screening argument with an expanded discussion of the importance of the availability of brine on the degradation of organic material. Changes that affect the availability of brine in a waste panel, such as the water balance implementation, the revised value of GLOBAL:PBRINE, and the properties of the ROMPCS and associated DRZ, will affect this FEP.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S19.** Please modify the screening argument to acknowledge the reduced thermal impact of seal concrete hydration because of the elimination of additional explosion walls and the Option D monolith.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S20.** The reported reason for the screening argument update is not consistent between Table SCR-1, where the update is due to new radionuclide inventory, and Section SCR-6.5.1.7.2 where the update is due to new cellulose inventory. The screening argument in Section SCR-6.5.1.7.3 refers only to the new radionuclide inventory. Please reconcile the information.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S21.** Please supplement the screening argument with a discussion of the impact of exothermic reactions in the waste panels.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S22.** Please supplement the screening argument with a discussion of the impact on the PA based on a reduced concrete inventory due to DOE now not using the Option D concrete monoliths in the panel closure system. Update the analysis to include where explosion walls are or will be installed.		✓	
194.32 SCOPE OF PERFORMANCE ASSESSMENT **2-32-S23.** Please update the screening argument to provide a description of the as-emplaced properties of the ROM salt now that *in situ* testing has been completed.		✓	

<table>
<tr><th colspan="4">Status Report of DOE Responses to EPA Completeness Questions</th></tr>
<tr><th>Completeness Question</th><th>Included in This Submittal</th><th>Previously Submitted</th><th>Pending</th></tr>
<tr><td>194.32 SCOPE OF PERFORMANCE ASSESSMENT
2-32-S24.
Please update the screening argument to include the chemical composition of the steel bulkheads that are part of the panel closure design.</td><td></td><td>✓</td><td></td></tr>
<tr><td>194.32 SCOPE OF PERFORMANCE ASSESSMENT
2-32-S25.
Please supplement the screening argument with information on consolidation specific to the ROM salt in the ROMPCS. Such a discussion can be found in Camphouse et al. (2012, Section 2.0. ERMS 557396).</td><td></td><td>✓</td><td></td></tr>
<tr><td>194.32 SCOPE OF PERFORMANCE ASSESSMENT
2-32-S26.
The screening decision for this FEP was changed from UP (screened in) to SO-P (screened out – low probability). Please supplement the screening argument with a discussion of the chemical degradation of the steel bulkheads, which are part of the ROM salt panel closure system. Please also provide technical justification for the changed screening decision in light of the presence of the bulkheads.</td><td></td><td>✓</td><td></td></tr>
<tr><td colspan="4">EPA's Completeness Questions Received June 5, 2015</td></tr>
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Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
CHEMISTRY COMMENTS **3-C-1. Assumed Plutonium Oxidation State.** The Pu oxidation state assumed for Performance Assessment (PA) is important because significantly higher brine solubilities are predicted for Pu(III) than for Pu(IV). In Appendix SOTERM Section 3.6.2, results from recent long-term experiments with aqueous Pu and iron are presented in which the predominant long term aqueous oxidation state was Pu(III). Other recent studies also have indicated that Pu(IV) is reduced to Pu(III) in the presence of reduced iron (Altmaier et al. 2009, Felmy et al. 2011, Felmy et al. 2012, Kirsch et al. 2011). Plymale et al. (2012) determined that Pu(IV) solids in contact with solutions containing chelating agents such as EDTA can undergo reductive dissolution to Pu(III) by either biotic or abiotic mechanisms. Appendix SOTERM states that "The predominance of Pu(III) at long times provides a strong data point on the reducing conditions that iron creates under WIPP-relevant conditions, but does not account for radiolytic impacts on Eh, and the effects of organic complexation which will stabilize Pu(IV) relative to Pu(III)." Assuming that radiolysis will affect the Pu oxidation state in WIPP repository brines conflicts with the peer-reviewed Chemical Conditions conceptual model assumption that radiolysis will not affect the oxidation-reduction conditions in the repository (SCA 2008). In addition, EDTA, which is present in the WIPP inventory, has been shown to cause reduction of Pu(IV) to Pu(III) rather than to stabilize Pu(IV) (e.g., Boukhalfa et al. 2007, Plymale et al. 2012). Currently, Pu(III) is the assumed oxidation state for 50% of PA realizations and Pu(IV) is the assumed oxidation state for the other 50% of PA realizations. Because of recent data showing that Pu(IV) reduction to Pu(III) may be more likely than previously assumed, DOE must provide an assessment of all currently available data relevant to the assumed Pu oxidation state for PA. If the current Pu oxidation states assumption is inconsistent with the available data, DOE must provide an analysis that supports a higher proportion of Pu(III) in the PA realizations and include this higher proportion of Pu(III) in PA. Altmaier, M., V. Neck, J. Lützenkirchen and T. Fanghänel. 2009. Solubility of plutonium in $MgCl_2$ and $CaCl_2$ solutions in contact with metallic iron. Radiochimica Acta 97:187-192. Boukhalfa, H., G.A. Icopini, S.D. Reilly, and M.P. Neu. 2007. Plutonium (IV) reduction by the metal-reducing bacteria Geobacter metallireducins GS15 and Shewanella oneidensis MR1. Applied and Environmental Microbiology 73:5897-5903. Felmy, A.R., D.A. Moore, K.M. Rosso, O. Qafoku, D. Rai, E.C. Buck and E. S. Ilton. 2011. Hetrogeneous reduction of PuO_2 with Fe(II): importance of the Fe(III) reaction product. Environmental Science and Technology 45:3952-3958. Felmy, A.R., D.A. Moore, C.I. Pearce, S.D. Conradson, O. Qafoku, E.C. Buck, K.M. Rosso and E.S. Ilton. 2012. Controls on soluble Pu concentrations in PuO_2/Magnetite Suspension. Environmental Science and Technology 46:11610-11617. Kirsch, R., D. Fellhauer, M. Altmaier, V. Neck, A. Rossberg, T. Fanghänel, L. Charlet and A.C. Scheinost. 2011. Oxidation state and local structure of plutonium reacted with magnetite, mackinawite and chukanovite. Environmental Science and Technology 45:7267-7274. Plymale A.E., V.L. Bailey, J.K. Fredrickson, S.M. Heald, E.C. Buck, L. Shi, Z. Wang, C.T. Resch, D.A. Moore and H. Bolton. 2012. Biotic and abiotic reduction and solubilization of $Pu(IV)O_2 \cdot H_2O(am)$ as affected by anthraquinone-2,6-disulfonate (AQDS) and ethylenediaminetetracetate (EDTA). Environmental Science and Technology 46:2132-2140. SCA (S. Cohen and Associates). 2008. Verification of the Waste Isolation Pilot Plant Chemistry Conceptual Models. Prepared for the U.S. Environmental Protection Agency Office of Radiation and Indoor Air, September 2008.			✓

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **3-C-2. Boron Species in WIPP Brine.** The Compliance Certification Application (CCA) and CRA-2004 refer to the presence of boric acid [$B(OH)_3$] in WIPP brine. However, the CRA-2009 (Appendix SOTERM, Table SOTERM-2) and CRA-2014 (Appendix SOTERM, Table SOTERM-4) indicate that "boron species will be present in brine as boric acid, hydroxyl polynuclear forms ($B_3O_3(OH)_4$-), and/or borate forms (e.g., $B_4O_7^{2}$-)." Borkowski et al. (2010a) indicates that tetraborate is present in WIPP brine and Borkowski et al. (2010b) determined the stability complex and Pitzer coefficients for the neodymium(III)-tetraborate aqueous species. Lucchini (2013) refers to tetraborate in WIPP brines during comparisons of measured and modeled brine compositions. Consequently, there appears to have been an evolution in the assumed boron species in WIPP brines since the CCA. Because complexation by tetraborate has been identified as important for actinide(III) speciation in WIPP brines (Borkowski et al. 2010b), DOE must identify all expected chemical constituents that contain boron species in WIPP brines. The basis for that determination must be included. Borkowski, M., J.-F. Lucchini, M.K. Richmann and D.T. Reed. 2010a. Actinide(III) Solubility in WIPP Brine: Data Summary and Recommendations. Los Alamos National Laboratory, LCO- ACP-08, Rev 0. Borkowski, M., M. Richmann, D.. Reed and Y. Xiong. 2010b. Complexation of Nd(III) with Tetraborate Ion and Its Effect on Actinide(III) Solubility in WIPP Brine. Radiochimica Acta 98:577-582. Lucchini, J.-F. 2013. WIPP Actinide-Relevant Brine Chemistry. Los Alamos National Laboratory, LCO-ACP-15, Rev. 0.	✓		

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Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
CHEMISTRY COMMENTS **3-C-3. Adequacy of EQ3/6 Database.** The actinide solubility and aqueous speciation data in the EQ3/6 database DATA0.FM1 was last updated using data available in 2002 (Giambalvo 2003, Nowak 2005). Since 2002, relevant data have been developed in investigations carried out by WIPP investigators and by outside researchers. The absence of an update to the EQ3/6 database despite more than a decade of potentially relevant new data leads to the following observations: • In CRA-2014 Appendix SOTERM Sections 3.3 and 3.7, DOE reviewed the chemistry of thorium and americium, respectively, including data that has become available since the last EQ3/6 database update. However, these data (such as Neck et al. 2002, Neck et al. 2003, Altmaier et al. 2004, Altmaier et al. 2005, Altmaier et al. 2006, Borkowski et al. 2012, Neck et al. 2009) were not used to revise the EQ3/6 database. • Xiong (2011) experimentally determined the solubilities of natural and synthetic hydromagnesite samples and calculated a different solubility for synthetic hydromagnesite than the solubility in the EQ3/6 database. An assessment was not provided in the CRA of the possible effects of this different solubility on CO2 fugacities, calculated pH values and actinide solubilities in WIPP repository brines. • Borkowski et al. (2010) determined the stability constant for the neodymium-tetraborate aqueous species and also calculated Pitzer ion-interaction parameters. These data were not incorporated into the EQ3/6 database, even though WIPP brines contain borate, boric acid or hydroxyl polynuclear species and complexation of the +III actinides by tetraborate could increase solubilities modeled for PA. • Thakur et al. (2014) determined a β^{0}_{101} for AmEDTA$^-$ (20.55) that differs from the value in DATA0.FM1 (18.97). Because AmEDTA$^-$ is the predominant Am(III) aqueous species in WIPP brines, the β^{0}_{101} for AmEDTA$^-$ could significantly affect aqueous Am speciation and solubilities, but the revised value was not included in the EQ3/6 database. DOE maintained at the time of the CRA-2009 PABC that the effects of not updating the EQ3/6 database with new data available at that time were conservative, because higher actinide solubilities would be predicted using the unrevised database. However, the cumulative effects of the new data that are now available may be non-conservative and must be quantitatively evaluated. DOE must: 1) carry out and document a thorough review of all available +III and +IV actinide aqueous speciation and solubility data and hydromagnesite solubility data; 2) use the results of this review to defensibly update the EQ3/6 database; and 3) use this revised database to recalculate the actinide solubilities and associated uncertainty distributions for PA. DOE must provide the documentation of these components as part of the CRA. Altmaier, M., V. Neck and T. Fanghänel. 2004. Solubility and colloid formation of Th(IV) in concentrated NaCl and $MgCl_2$ solution. Radiochimica Acta 92:537-543. Altmaier, M., V. Neck, M.A. Denecke, R. Yin and T. Fanghänel. 2006. Solubility of ThO_2•xH_2O(am) and the formation of ternary Th(IV) hydroxide-complexes in $NaHCO_3$-Na_2CO_3 solutions containing 0-4 M NaCl. Radiochimica Acta 94:495-500. Altmaier, M., V. Neck, R. Müller and T. Fanghänel. 2005. Solubility of ThO_2•xH_2O(am) in carbonate solution and the formation fo ternary Th(IV) hydroxide-carbonate complexes. Radiochimica Acta 93:83-92. Borkowski, M., M. Richmann, D.T. Reed and Y. Xiong. 2010. Complexation of Nd(III) with tetraborate ion and its effect on actinide(III) solubility in WIPP brine. Radiochimica Acta 98:577-582. Borkowski, M., M. Richmann and J.F. Lucchini. 2012. Solubility of An(IV) in WIPP brine: thorium analog studies in WIPP simulated brine. Los Alamos National Laboratory LCO-ACP-17 Giambalvo, E.R. 2003. Release of FMT Database FMT_021120.CHEMDAT. Memorandum to L.H. Brush, March 10, 2003, ERMS 526372. Neck, V., M. Altmaier, R. Müller, A. Bauer, T. Fanghänel and J.I. Kim. 2003. Solubility of crystalline thorium dioxide. Radiochimica Acta 91:253-262. Neck, V., M. Altmaier, T. Rabung, J. Lützenkirchen and T. Fanghänel. 2009. Thermodynamics of trivalent actinides and neodymium in NaCl, $MgCl_2$, and			✓

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **3-C-4. Exclusion of Experimental Data with Borate from Am(III) Solubility Uncertainty Analysis.** Brush and Domski (2013) used their Criterion G-9 to select data for the actinide solubility uncertainty analysis; Criterion G-9 specifies that experimental solubility data should be excluded if the solutions contained dissolved elements or species for which μ^0/RT^1 data or Pitzer parameters were not included in the EQ3/6 database (DATA0.FM1). The application of this criterion was reasonable when the experiments included species that are not present in the WIPP repository, for example, when it was used to exclude the Th(IV) experimental data of Colás et al. (2011) because of gluconate in the experimental solutions. However, Brush and Domski (2013) used the presence of borate in GWB and ERDA-6 to exclude solubility data that were obtained in mildly basic WIPP brines. The undeclared assumption for this exclusion would be an admission that the current Am(III) model is inadequate for predicting solubilities in WIPP brines at anticipated repository pcH values. A revised uncertainty analysis for Am(III) must be performed by DOE after the following items have been completed: 1) The Am(III)-tetraborate stability constant and Pitzer parameter data have been incorporated and other appropriate updates have been made to the EQ3/6 database (which satisfy Comments 3-C-3 and 3-C-4) and, 2) Solubility data obtained in mildly basic WIPP brines, such as the Khalili et al. (1994) solubility results have be included in the database. Brush L.H., and P.S. Domski. 2013. Uncertainty analysis of actinide solubilities for the WIPP CRA-2014 PA, Rev. 1. Supersedes ERMS 559278. Colás, E., M. Grivé, I. Roho and L. Duro. 2011. Solubility of $ThO_2 \cdot xH_2O$(am) in the presence of gluconate. Radiochimica Acta 99:269-273. Khalili, F.I., V. Symeopoulos, J.-F. Chen and G.R. Choppin. 1994. Solubility of Nd in brine. Radiochimica Acta 66/67:51-55.			✓

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Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
CHEMISTRY COMMENTS **3-C-5. Am(III) Solubility Uncertainty Distribution.** Brush and Domski (2013) used 172 solubility measurements to determine the Am(III) solubility uncertainty distribution: • 109 values from Borkowski et al. (2009) • 56 values from Neck et al. (2009) • 6 values from Runde and Kim (1995) • 1 value from Rao et al. (1999) Consequently, the majority of the solubility measurements used to calculated the Am(III) solubility uncertainty distribution were from Borkowski et al. (2009). Brush and Domski (2013) established Criterion G7 for the selection of data for actinide solubility uncertainty analysis; Criterion G7 states that experimental results should be included only if the solubility-controlling solid phase was characterized. As previously noted during review of the PABC-2009 (EPA 2010), inclusion of the Nd(III) solubility data from Borkowski et al. (2009) in the uncertainty analysis is inconsistent with Criterion G7 because only indirect means were used to characterize the solid phases. In fact, modeling calculations carried out during the PABC-2009 review predicted different solid phases than those indirectly determined under some conditions (EPA 2010). As previously observed in the Technical Support Document for the CRA-2009 PABC (EPA 2010), including the Borkowski et al. (2009) data in the uncertainty evaluation significantly decreased the mean concentration of the +III actinides used in PA and will lead to non-conservative predicted +III actinide concentrations. DOE must exclude the Borkowski et al. (2009) data when the Am(III) uncertainty distribution is recalculated after completion of the EQ3/6 database update (see Comment 3-C-3, above). Borkowski, M., J.-F. Lucchini, M.K. Richmann and D.T. Reed. 2009. Actinide (III) Solubility in WIPP Brine, Data Summary and Recommendations. Los Alamos National Laboratory, LCO- ACP-08, LA-14360. Brush L.H., and P.S. Domski. 2013. Uncertainty analysis of actinide solubilities for the WIPP CRA-2014 PA, Rev. 1. Supersedes ERMS 559278. EPA (U.S. Environmental Protection Agency). 2010. Technical Support Document for Section 194.24, Evaluation of the Compliance Recertification Actinide Source Term, Backfill Efficacy and Culebra Dolomite Distribution Coefficient Values (Revision1), Docket A-98-49, Item II-B1-25, November 2010. Neck , V., M. Altmaier, T. Rabung, J. Lützenkirchen and T. Fanhänel. Thermodynamics of trivalent actinides and neodymium in NaCl, $MgCl_2$, and $CaCl_2$ solutions: Solubility, hydrolysis, and ternary Ca-M9III)-OH complexes. Pure and Applied Chemistry 81:1555-1568. Rao, L., D. Rai, A.R. Felmy and C.F. Novak. 1999. Solubility of $NaNd(CO_3)3 \cdot 6H_2O(c)$ in mixed electrolyte ($Na\text{-}Cl\text{-}CO_3\text{-}HCO_3$) and synthetic brine solutions. In *Actinide Speciation in High Ionic Strength Media: Experimental and Modeling Approaches to Predicting Actinide Speciation and Migration in the Subsurface* . Proceedings of an American Chemical Society Symposium on Experimental and Modeling Studies of Actinide Speciation in Non-Ideal Systems. Held August 26-28, 1996 in Orlando, Florida. Eds. D.T. Reed, S.B. Clark and L. Rao. Kluwer Academic/Plenum Publishers, pp. 153-169. Runde, W., and J.I. Kim. 1995. Untersuchungen der Übertragbarkeit von Labordaten Natürliche Verhältnisse: Chemisches Verhalten von Drei- und Fünfwertigem Americium in Salinen NaCl- Lösungen (Study of the Extrapolability of Laboratory Data to Natural Conditions: Chemical Behavior of Trivalent and Pentavalent Americium in Saline NaCl Solutions). RCM-01094, Institute for Radiochemistry, Technical University of Munich, Munich, Federal Republic of Germany, ERMS 241862.			✓

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **3-C-6. Magnesite Formation from MgO Carbonation.** Clayton (2013, Section 2.7) states that "In the event that CO_2 generation is occurring, but brucite is not available in BRAGFLO simulations, MgO will be converted directly to magnesite." EPA has reviewed the potential for magnesite formation in the WIPP repository directly from MgO and has repeatedly determined that hydromagnesite should be assumed to form instead of magnesite (EPA 1998, SCA 2008, EPA 2010). Correctly including the formation of hydromagnesite instead of magnesite will decrease the amount of water in the water balance calculations, which could significantly impact the amount of water in the repository. DOE must assess the effects on the water balance of incorrectly assuming magnesite formation instead of hydromagnesite in PA simulations when brucite was not available. DOE must also provide an assessment of the effects of this assumption when combined with the other assumptions summarized in Completeness Comment 2-C-3 (Edwards 2015) that also increase the amount of brine calculated for the water balance. Clayton, D.J. 2013. Justification of Chemistry Parameters for Use in BRAGFLO for AP-164, Rev. 1. Sandia National Laboratories, ERMS 599466. Edwards, J.D. 2015. Second Set of CRA 2014 Completeness Questions, U.S. Environmental Protection Agency Radiation Protection Division, Letter to J.R. Franco, U.S. Department of Energy Carlsbad Field Office, February 27, 2015. EPA (U.S. Environmental Protection Agency). 2010. Technical Support Document for Section 194.24, Evaluation of the Compliance Recertification Actinide Source Term, Backfill Efficacy and Culebra Dolomite Distribution Coefficient Values (Revision1), Docket A-98-49, Item II-B1-25, November 2010.	✓		
CHEMISTRY COMMENTS **3-C-7. Lead Inventory, Gas Generation and Water Balance.** In past WIPP performance assessments, lead corrosion has been assumed to have insignificant effects on gas generation because of the relatively small amount of lead in the packaging and waste inventory (EPA 2010). However, use of shielded containers to emplace some RH waste may significantly increase the amount of lead in the repository. Van Soest (2012) provided only the RH packaging material lead inventory and this value has decreased since PAIR-2008. Please provide an estimate of the total lead that will be in the WIPP repository (waste lead plus packaging material) and the basis for that estimate, taking into account the expected increased lead from shielded containers. Based on this total lead inventory, DOE must assess whether lead corrosion may significantly affect gas generation and repository water balance. Van Soest, G.D. 2012. Performance Assessment Inventory Report -2012. INV-PA-12, Revision 0, LA-UR-12-26643.	✓		

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Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
CHEMISTRY COMMENTS **3-C-8. Incorrect Reference to Felmy et al. (1996) and Clark and Tait (1996).** Appendix SOTERM, Section 3.6.1.1 states that "Clark and Tait (Clark and Tait 1996) and Felmy et al. (Felmy et al. 1996) have experimentally observed the reduction of Pu(VI) carbonates by either Fe^0 or Fe^{2+} to Pu(IV). However, the Felmy et al. citation refers to a study of thorium(IV) hydrous oxide solubility and Clark and Tait (1996) indicate that plutonium(VI) chloride complexes were reduced to plutonium(V) by Fe^0 or Fe^{2+}. Please provide the correct references. Clark, D.L., and C.D. Tait. 1996. Memorandum to Sandia WIPP Records Center (Subject:SWCF-A: 1.1.10.1.1: NQ: Actinide Source Term: LANL Monthly Reports). Sandia National Laboratories, WIPP Central File A: WBS 1.1.10.1.1. WPO 31106. Felmy, A.R., D. Rai, S.M. Sterner, M.J. Mason and N.J. Hess. 1996. Thermodynamic models for highly charged aqueous species: solubility of Th(IV) hydrous oxide in concentrated NaHCL$_3$ and Na$_2$CO$_3$ solutions. Sandia National Laboratories, ERMS 240226.			✓
CHEMISTRY COMMENTS **3-C-9. Intrinsic Colloid Parameter Values.** The concentration (CONCINT) used for intrinsic plutonium colloids in either the Pu(III) or Pu(IV) oxidation state in the actinide source term model was 1 × 10^{-9} M in the CCA PAVT, the CRA-2004 PABC and the CRA-2009 PABC. This intrinsic plutonium colloid concentration was an upper limiting value based on the detection limit in experiments conducted for the CCA (CCA Appendix SOTERM). The revised intrinsic colloid enhancement parameters used in the CRA-2014 PA do not appear to be bounding values. For example, the revised value of CONCINT for thorium(IV) is based on a single experimental data point (pcH 9.1) selected from a group of experiments because this particular experiment had the lowest concentration and was deemed closest to long-term equilibrium (Reed et al. 2013). In addition, the revised americium(III) CONCINT value is 4 × 10^{-9} M based on the average concentration in ERDA-6 experiments, even though higher concentrations were observed in GWB experiments. DOE must demonstrate that all of the CONCINT parameters used in PA represent upper bounding values based on the available experimental data.	✓		

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **3-C-10. Phase 5 Solubility in DATA0.FM1.** EQ3/6 database version DATA0.FMT.R1 was reviewed and accepted during the EQ3/6 code evaluation (SCA 2011, Appendix A). The database used for the WIPP CRA-2014 EQ3/6 actinide solubility calculations was DATA0.FM1 (DATA0.FMT.R2). Xiong (2011) documented that the only difference between DATA0.FMT.R1 and DATA0.FM1 is the addition of data for magnesium chloride hydroxide hydrate [$Mg_3Cl(OH)_5 \cdot 4H_2O$, Phase 5], citing Xiong et al. (2010) as the data source. Both Xiong et al. (2009) and Xiong et al. (2010) report a log K of 43.21 ± 0.33 at 25°C for the reaction: $Mg_3Cl(OH)_5 \cdot 4H_2O + 5H^+ = 3Mg^{2+} = 9H_2O(l) + Cl^-$ However, the data for this solid in DATA0.FM1 includes a log K at 25°C of 42.96. DOE must explain this small difference between the log K values in the documentation and the database. SCA. (S. Cohen and Associates). 2011. EQ3/6 Computer Code Evaluation. Prepared for U.S. Environmental Protection Agency Office of Radiation and Indoor Air. Draft March 2011. Xiong, Y.-L. 2011. Release of EQ3/6 Database DATA0.FM1. Email to J.J. Long, March 9, 2011. ERMS 555152. Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2009. Thermodynamic Data for Phase 5 ($Mg_3Cl(OH)_5 \cdot 4H_2O$) Determined from Solubility Experiments. Memorandum to L. Brush, Sandia National Laboratories, May 18, 2009. ERMS 551294. Xiong, Y.-L., H.-R. Deng, M. Nemer and S. Johnsen. 2010. Experimental determination of the solubility of magnesium chloride hydroxide hydrate ($Mg_3Cl(OH)_5 \cdot 4H_2O$, phase 5) at room temperature, and its importance to nuclear waste isolation in geological repositories in salt formations. Geochimica et Cosmochimica Acta 74:4605-4611.	✓		
CHEMISTRY COMMENTS **3-C-11. Appendix SOTERM Typographical Errors/Errata.** Section SOTERM-3.6.1.3, Page SOTERM-67, line 3: Section SOTERM-3.5.1.1 and Section SOTERM-3.5.1.2 should be Section SOTERM-3.6.1.1 and Section SOTERM-3.6.1.2 Appendix SOTERM, Section SOTERM-6.0 References: The correct date for the following reference is 2010: Reed, D.T., J.-F. Lucchini, M. Borkowski, and M.K. Richmann. ~~2009~~2010. Reduction of Higher Valent Plutonium by Iron under Waste Isolation Pilot Plant (WIPP)- Relevant Conditions: Data Summary and Recommendations. LCO-ACP-09, LANL\ACRSP Report. Los Alamos, NM: Los Alamos National Laboratory.		✓	
EPA's Completeness Questions Received July 30, 2015			

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **4-C-1. Waste Incompatibilities and Gas Generation.** The WIPP Technical Assessment Team investigated the mechanisms and chemical reactions that resulted in the breach of at least one waste drum and release of waste material in the WIPP on February 14, 2014 (SRNL 2015). This report identified the presence of chemically incompatible contents in LANL Drum 68660 from waste stream LA-MIN02-V.001 as the cause of the release; the drum contents included nitrate salt residues, organic sorbent (SWheat Scoop® kitty litter), and neutralizing agent (triethanolamine or TEA), which represents a mixture of fuels and oxidizers. This mixture and the configuration of materials in the drum supported chemical reaction, thermal runaway, gas build-up and eventual venting of radioactive materials and hot matter (SRNL 2015). The WIPP performance assessment currently includes only microbial gas generation via degradation of CPR and anoxic corrosion of steel as significant gas generation mechanisms. Screening of chemical gas generation FEPs (CRA-2014 Appendix SCR Section SCR-6.5.1) did not consider gas generation caused by chemical incompatibility such as occurred in Drum 68660. Please provide a detailed assessment of whether the contents of other drums from the LA-MIN02-V.001 waste stream could have similar chemical incompatibilities that may cause gas generation sufficient to affect performance assessment. Also, if the SWheat Scoop® kitty litter was used in any other waste streams that have been emplaced in the WIPP, the DOE should discuss the potential effects on performance assessment of possible gas generation from these waste streams in its response to the Agency. SRNL (Savannah River National Laboratory). 2015. Waste Isolation Pilot Plant Technical Assessment Team Report. SRNL-RP-2014-01198, Revision 0. Wallace, T.C. 2014. Understanding the "What" and the "Why" of February 14, 2014. Los Alamos National Laboratory, LA-UR-14-2701.			✓

Information Only

Status Report of DOE Responses to EPA Completeness Questions

Completeness Question	Included in This Submittal	Previously Submitted	Pending
CHEMISTRY COMMENTS **4-C-2. Reassessment of Inundated Anoxic Steel Corrosion Rate Data.** **a. Experimental Data Used As Inputs For Parameter CORRMCO2** –The DOE needs to justify the values it has adopted for the parameter CORRMCO2 given the range of existing data. In the CRA-2014 PA the parameter CORRMCO2 has a range, distribution and median value that was modified from what was adopted in the CCA. The modification was based on experimental corrosion data under inundated conditions, at 1 atm and 0 ppm CO_2, as reported in Roselle (2013). Repository brines are predicted to be in equilibrium with CO_2 gas concentrations of 3.2 ppm CO_2 ($10^{-5.5}$ atm, Brush and Domski 2013) which is above 0 ppm CO_2. Additional corrosion experiments were performed by Roselle at CO_2 concentrations of 350 ppm, 1500 ppm and 3500 ppm, with and without organic ligands, and for partially and fully immersed coupons. This range includes the predicted CO_2 gas concentrations of 3.2 ppm. The corrosion rates determined by Roselle (2013) for experiments at 0 and 350 ppm CO_2 concentrations are summarized in the figure below. The collective results from these experiments indicate corrosion does occur above 0 ppm and up to 350 ppm CO_2 and corroborate relevant data that indicates corrosion will occur at CO_2 concentrations above 0 ppm. Please provide a justification for why the experimental corrosion data gathered from experiments above 0 ppm CO_2 concentrations were not included in the development of the parameter CORRMCO2. **b. Justify the Distribution of Parameter CORRMCO2** – In previous WIPP PAs, the lower limit of the steel corrosion rate was set equal to 0 m/sec, and, accordingly, the lower limit of the sampled range for CORRMCO2 should be 0 m/s. This lower limit is consistent with passivation of the steel surface by H_2S observed and reported in Telander and Westerman (1997). Telander and Westerman (1993, 1997) reported the results of anoxic corrosion experiments at H_2 and N_2 pressures up to 127 atm, which are applicable given the expected hydrostatic pressures anticipated in the WIPP repository. Based on an experiment with a N_2 pressure of 10 atm, Telander and Westerman (1997) recommended a corrosion rate of 2.25×10^{-14} m/s using results from the final 12 months of a 24-month experiment. EPA (1998) noted the effects of increased pressure on the steel corrosion rate in the experiments by Telander and Westerman (1993, 1997) and directed that the upper limit for CORRMCO2 used in the CCA PAVT should be increased to 3.17×10^{-14} m/s (see Table Parameter CORRMCO2). Retaining this upper limit encompasses most, but not all, of the corrosion rate data measured by Roselle (2013) and includes consideration of the results reported by Telander and Westerman (1993, 1997). The Roselle (2013) anoxic corrosion experiments with 0 ppm and 350 ppm CO_2 concentrations bracket anticipated CO_2 gas phase concentrations. It appears that the 350 ppm CO_2 corrosion data should have been included in the reassessment of the CORRMCO2 parameter because the experimental data indicate that steel corrosion rate will occur up to 350 ppm CO_2. However, the 350 ppm CO_2 corrosion data were not included in establishing the parameter valuation. Please update the range, median and distribution for the CORRMCO2 parameter that reflects this experimental data. Please provide justification as to why a uniform distribution for parameter CORRMCO2 was not adopted in the CRA-2014 PA. Brush, L.H., and P.S. Domski. 2013. *Prediction of Baseline Actinide Solubilities for the WIPP CRA-2014 PA* . Sandia National Laboratories, ERMS 559138. EPA. 1998. *Technical Support Document for Section 194.23: Parameter Justification Report.* Docket No. A-93-02 V-B-14.			✓

Status Report of DOE Responses to EPA Completeness Questions			
Completeness Question	**Included in This Submittal**	**Previously Submitted**	**Pending**
CHEMISTRY COMMENTS **4-C-3. Humid Steel Corrosion Rates.** Roselle (2013) states that steel coupons hung in a humid environment exhibited essentially no corrosion regardless of CO_2 concentration. This statement contradicts the experimental data (reported in Roselle, 2013) conducted under humid experimental conditions, where samples were tested at 0 and 350 ppm CO_2. These experiments indicate corrosion does occur under humid conditions, with a mean corrosion rate of 3.0×10^{-16} m/s and median rate or 1.1×10^{-16} m/s, both positive values. The provided histogram of the corrosion rate data, obtained with gas phase CO_2 concentrations of 0 ppm and 350 ppm—which bracket anticipated repository conditions—demonstrates that the humid corrosion rate could be greater than zero. Please justify why the DOE does not use the available and WIPP-relevant data in the derivation of corrosion rates that indicate corrosion will occur under humid conditions. Roselle, G.T. 2013. *Determination of Corrosion Rates from Iron/Lead Corrosion Experiments to be Used for Gas Generation Calculations.* Sandia National Laboratories, ERMS 559077.			✓

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CHEMISTRY COMMENTS **4-C-4. Steel Surface Area per Unit Volume in the Repository.** The anoxic steel gas generation rate due to corrosion is proportional to the steel surface area per unit volume, D_s, (Appendix PA Equation PA.67) in the repository. The parameter D_s is defined by the following equation and inputs: $D_s = A_d n_d / V_R$ (Appendix PA equation PA.75), Where, A_d - is the surface area of steel associated with a waste disposal drum (REFCON:ASDRUM, m^2/drum), V_R - is the initial volume of a single room in the repository (REFCON:VROOM, m^3), and n_d, - is the ideal number of waste drums that can be close-packed into a single room (REFCON:DRROOM). The input value for A_d used in the above equation (equation PA.75) has not changed since the CCA PAVT (Kicker and Herrick 2013), even though acceptance of significant quantities of AMWTP compressed waste since 2004 is likely to have increased the value for D_s. In addition the input n_d has not changed since the CCA, when it was based on calculations performed before waste placement began (Kicker and Herrick 2013). Steel surface area per unit repository volume is important to both gas generation through anoxic corrosion and the repository water balance. Therefore, please update the calculation to account for the increased steel surface area that is representative of current and projected repository conditions. This calculation should include a reevaluation of the input A_d based on currently available data and include the amounts of compressed waste in the repository. Please provide evidence that the calculation includes an update to the input value for n_d that is consistent with actual waste placement practices. Kicker, D.C, and C.G. Herrick. 2013. *Parameter Summary Report for the Compliance Recertification Application, Rev. 0.* Sandia National Laboratories, ERMS 560298.			✓
CHEMISTRY COMMENTS **4-C-5. Steel Sulfidation Rate.** The rate of gas production by sulfidation of iron in steel is determined by the rate of H_2S production through microbial degradation of cellulose and the stoichiometric coefficient for gas generation by sulfidation of steel (Appendix PA, equation PA.68). This formulation includes the assumption that all H_2S produced by microbial degradation of cellulose will instantaneously react to produce iron sulfide. Please provide the basis for this assumption, particularly in light of the Telander and Westerman (1997) experimental data that shows H_2S formed a passivating layer on steel and essentially halted steel corrosion.			✓

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CHEMISTRY COMMENTS **4-C-6. Effects of Green Rust Formation on Gas Generation Stoichiometry.** The stoichiometric coefficient used in PA for gas generation due to steel corrosion (STOIFX) has been maintained at its historical value of 1. This parameter value of "1" assumes no green rust will form on steel. The assumption is contradicted in Appendix SOTERM Section 2.3.4 of the CRA-2014, which includes the following statement: *Roselle (Roselle 2013) states that green rust is the most likely corrosion product in experiments with low atmospheric* CO_2 *concentrations (< 350 ppm).* Roselle (2013 Section 4.3) then contradicts the above statement stating current experiments indicate no evidence that corrosion products will occur on steel under WIPP-relevant conditions. He further claims results from recent experiments are similar to what was observed in the earlier Telander and Westerman (1993) corrosion investigations [$Fe(OH)_2$]. However, corrosion products have been reported by Roselle (2013) in WIPP related experiments and contradicts Roselle's own assumption reported in Roselle, 2013 Section 4.3. Archeological evidence indicates corrosion products will occur under harsh anaerobic conditions. Réguer et al. (2007) and Rémazeilles et al. (2009) indicate long term corrosion products have formed on iron artifacts under anaerobic conditions and saline conditions. This is further corroboration that corrosion products, such as green rust, could form on WIPP steel. Production of corrosion products could result in a higher value of STOIFX, as demonstrated in the following equation: $6Fe + CO_2 + 15H_2O = Fe_6(OH)_{12}CO_3{\cdot}2H_2O + 7\ H_2$ Given the contradictions, the DOE should discuss why a value of "1" should be used for the parameter STOIFX. In this discussion, the DOE needs to address all available data, including the solids characterization results from the iron corrosion experiments performed by Roselle (Roselle 2009, 2010, 2011a, 2011b) and analogue data that indicate corrosion occurs in anaerobic and saline high chloride media (e.g., Réguer et al. 2007, Rémazeilles et al. 2009) in the development of the parameter STOIFX. Réguer, S., P. Dillman and F. Mirambet. 2007. Buried iron archaeological artefacts: corrosion mechanisms related to the presence of Cl-containing phases. Corrosion Science 49:2726-2744. Rémazeilles, C., D. Neff, F. Kergourlay, E. Foy, E. Conforto, S. Réguer, P. Refait and P. Dillmann. 2009. Mechanisms of long-term anaerobic corrosion of iron archaeological artefacts in seawater. Corrosion Science 51:2932-2041. Roselle, G.T. 2009. *Iron and Lead Corrosion in WIPP-Relevant Conditions: Six Month Results* . Milestone report, October 7, 2009, Sandia National Laboratories, ERMS 546084. Roselle, G.T. 2010. *Iron and Lead Corrosion in WIPP-Relevant Conditions: 12 Month Results* . Milestone report, October 14, 2010, Sandia National Laboratories, ERMS 554383. Roselle, G.T. 2011a. *Iron and Lead Corrosion in WIPP-Relevant Conditions: 18 Month Results* . Milestone report, May 3, 2011, Sandia National Laboratories, ERMS 555246. Roselle, G.T. 2011b. *Iron and Lead Corrosion in WIPP-Relevant Conditions: 24 Month Results* . Milestone report, January 5, 2011, Sandia National Laboratories, ERMS 554715. Roselle, G.T. 2013. *Determination of Corrosion Rates from Iron/Lead Corrosion Experiments to be Used for Gas Generation Calculations* . Sandia National Laboratories, ERMS 559077. Telander, M.R., and R.E. Westerman. 1993. *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant*			✓

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194.14/15 CONTENT OF COMPLIANCE CERTIFICATION APPLICATION/CONTENT OF COMPLIANCE RECERTIFICATION APPLICATION(S). **4-(14)15-1 Plan View of the Repository with Updated Dimensions.** The repository layout has changed since the 2009 recertification. Please provide a plan view of the repository design. This should include the dimensions and locations of the repository and should provide the dimensions of the current and planned excavated areas and the run-of-mine salt panel closure system.			✓
194.23 MODELS AND COMPUTER CODES **4-23-1 Volume of Repository Operations and Experimental Areas.** Please clarify the planned excavated volume of the repository operations and experimental areas, accounting for past and current activities and excavations for planned experimental activities in the underground. On August 11, 2011, the DOE submitted to the EPA a Planned Change Notice to initiate mining activities for a 'contingently funded' Salt Disposal Investigations (SDI) project in the WIPP underground. The planned SDI test required increasing the repository footprint in the experimental area by mining an additional 61,000 m^3. On June 20, 2012, the DOE notified the EPA that an *alternative* to the SDI had been developed entitled the Salt Defense Disposal Investigations (SDDI). The SDDI test plans to mine 31,000 m^3 in the experimental area, approximately half of the SDI design. Verbal communication between Department and Agency staff indicated the SDI test was cancelled due to funding issues. The modeled experimental volume area in the CRA 2014 has been increased to reflect the "contingently funded" SDI volume of 61,000 m^3 and not 31,000 m^3 volume, reflective of the SDDI test. The volume of excavation that the DOE is actually planning for the testing is unclear. U.S. Department of Energy (DOE), 2011. *Notification of Intent to Begin the Salt Disposal Investigations* . Letter from Edward Ziemianski to Jonathan Edwards dated August 11, 2011. Carlsbad, New Mexico. U.S. Department of Energy (DOE), 2012. *Notification of Revisions to the Salt Disposal Investigations Testing Concepts* . Letter from Jose R. Franco to Jonathan Edwards dated June 20, 2012. Carlsbad, New Mexico.			✓