Title 40 CFR Part 191
Subparts B and C
Compliance Recertification Application 2019
for the
Waste Isolation Pilot Plant

Appendix DATA-2019
Monitoring Data and Reports

United States Department of Energy
Waste Isolation Pilot Plant

Carlsbad Field Office
Carlsbad, New Mexico

Compliance Recertification Application 2019
Appendix DATA-2019

Table of Contents

List of Tables

Acronyms and Abbreviations

CAP-88	Clean Air Act Assessment Package – 1988
CCA	Compliance Certification Application
CFR	Code of Federal Regulations
CMP	Compliance Monitoring Program
COMP	Compliance Monitoring Parameter
CRA	Compliance Recertification Application
DBDSP	Delaware Basin Drilling Surveillance Program
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
GMP	Geotechnical Monitoring Program
GWMP	Groundwater Monitoring Program
PA	Performance Assessment
PABC	Performance Assessment Baseline Calculation
SMP	Subsidence Monitoring Program
WDS	Waste Data System
WIPP	Waste Isolation Pilot Plant

This page intentionally left blank.

DATA-1.0 Introduction

Appendix DATA-2019 provides references to the data used to develop the Compliance Recertification Application (CRA) of 2019 (CRA-2019). Interpretation and analysis of those data are provided in the appropriate sections of the CRA-2019.

Title 40 CFR 194.15(a)(1), (2), (3), and (5) (U.S. EPA 1996), Content of Recertification Applications, require that the U.S. Department of Energy (DOE) provide all additional geologic, geophysical, geochemical, hydrologic, and meteorologic information obtained since the most recent compliance recertification application (CRA- 2014) (U.S. DOE 2014a). Additional monitoring results and the results of laboratory investigations completed after the CRA-2014 must also be provided, as well as information regarding the waste emplaced in the disposal system.

The DOE uses various monitoring and surveillance programs to capture and analyze relevant information. These programs are discussed in the appropriate sections of this appendix. Details on how these programs are implemented are provided in Appendix MON-2019.

DATA-2.0 Compliance Monitoring Parameters

In the initial U. S. Environmental Protection Agency (EPA) certification of compliance for the Waste Isolation Pilot Plant (WIPP) (U.S. EPA 1998), the EPA agreed that 10 compliance monitoring parameters (COMPs) would be monitored during the operational period of the project. Monitoring is performed to detect COMP values and ranges that exceed identified trigger values and indicate conditions that are potentially outside of Performance Assessment (PA) expectations (Wagner and Thomas 2016a). The locations of the data for the COMPs in this appendix are listed in Table DATA-1:

Table DATA-1. Location of COMPS in Appendix DATA-2019

COMP	Location in Appendix DATA-2019
Drilling rate	Section DATA-3.0 – Delaware Basin Drilling Surveillance Program Section DATA-11.0 – Compliance Monitoring Program
Probability of encountering a Castile brine reservoir	Section DATA-3.0 – Delaware Basin Drilling Surveillance Program Section DATA-11.0 – Compliance Monitoring Program
Waste activity	Section DATA-8.0 – Waste Information Section DATA-11.0 – Compliance Monitoring Program
Subsidence measurement	Section DATA-4.0 – Subsidence Monitoring Program Section DATA-11.0 – Compliance Monitoring Program
Change in the Culebra groundwater flow	Section DATA-6.0 – Groundwater Monitoring Program Section DATA-11.0 – Compliance Monitoring Program Section DATA-12.0 – Hydrological Investigation
Culebra groundwater composition	Section DATA-6.0 – Groundwater Monitoring Program

COMP	Location in Appendix DATA-2019
	Section DATA-11.0 – Compliance Monitoring Program Section DATA-12.0 – Hydrological Investigation
Creep closure and stresses	Section DATA-5.0 – Geotechnical Monitoring Program Section DATA-11.0 – Compliance Monitoring Program
Extent of brittle deformation	Section DATA-5.0 – Geotechnical Monitoring Program Section DATA-10.0 – Repository Investigations Program Section DATA-11.0 – Compliance Monitoring Program
Initiation of brittle deformation	Section DATA-5.0 – Geotechnical Monitoring Program Section DATA-11.0 – Compliance Monitoring Program
Displacement of deformation features	Section DATA-5.0 – Geotechnical Monitoring Program Section DATA-11.0 – Compliance Monitoring Program

DATA-3.0 Delaware Basin Drilling Surveillance Program

The Delaware Basin Drilling Surveillance Program (DBDSP) monitors drilling activities in the Delaware Basin. This section provides a brief discussion of the program and identifies the relevant data reports.

DATA-3.1 Program Overview

The EPA requires the DOE to demonstrate the expected long-term performance of the repository system using a PA. The PAs documented in the Compliance Certification Application (CCA) (U.S. DOE 1996), Performance Assessment Baseline Calculation (PABC)-2004, PABC-2009, and CRA-2014 demonstrated that the DOE complies with the EPA's containment standards for undisturbed and human intrusion scenarios. One of the human intrusion scenarios is the inadvertent and intermittent intrusion by drilling for resources.

The criteria in 40 CFR 194.33 (U.S. EPA 1996) require the use of historical drilling information up to the time of data cutoff for the CRA to derive the deep drilling rate for PA human-intrusion scenarios. The DBDSP continues to monitor drilling-related activities and provide data for determining whether the assumptions and scenarios used in PA remain valid. DBDSP activities will continue until the DOE and the EPA agree that no additional benefit can be gained by further monitoring.

DATA-3.2 Reported Data

The two COMPs monitored by the DBDSP are the deep drilling rate and the probability of encountering a Castile brine reservoir, which are discussed in the annual report for this program (U.S. DOE 2017a) and also in the COMPs assessments described in Section DATA-11.0. Additional information collected by this program include drilling-related data, mining information, and seismic information.

Relevant data generated through the Delaware Basin Monitoring Program are provided in the following reports published since the CRA-2014 data cutoff:

- Delaware Basin Monitoring Annual Report, DOE/WIPP-13-2308, September 2013 (U.S. DOE 2013a).
- Delaware Basin Monitoring Annual Report, DOE/WIPP-14-2308, September 2014 (U.S. DOE 2014b).
- Delaware Basin Monitoring Annual Report, DOE/WIPP-15-2308, September 2015 (U.S. DOE 2015a).
- Delaware Basin Monitoring Annual Report, DOE/WIPP-16-2308, September 2016 (U.S. DOE 2016a).
- Delaware Basin Monitoring Annual Report, DOE/WIPP-17-2308, September 2017 (U.S. DOE 2017a).

DATA-4.0 Subsidence Monitoring Program

Subsidence monitoring measures vertical movement of the land surface relative to a reference location. This section provides a brief discussion of the Subsidence Monitoring Program (SMP) and identifies the relevant data reports.

DATA-4.1 Program Overview

The SMP uses a leveling survey to measure the relative vertical height differences between benchmarks. A level survey consists of using one benchmark's elevation as a constant to determine the relative elevation of all other benchmarks. Comparison between level surveys allows vertical movement patterns to be established over time.

DATA-4.2 Reported Data

Each year approximately 15 miles of precision digital leveling surveys are completed utilizing 9 vertical control loops consisting of 48 subsidence monuments and 14 National Geodetic Survey vertical control points. Data generated through the SMP are provided in the following reports published since the CRA-2014 data cutoff:

- WIPP Subsidence Monument Leveling Survey 2013, DOE/WIPP 13-3512, December 2013 (U.S. DOE 2013b).
- WIPP Subsidence Monument Leveling Survey 2014, DOE/WIPP 14-3541, December 2014 (U.S. DOE 2014c).
- WIPP Subsidence Monument Leveling Survey 2015, DOE/WIPP 15-3562, December 2015 (U.S. DOE 2015b).

- WIPP Subsidence Monument Leveling Survey 2016, DOE/WIPP 16-3577, December 2016 (U.S. DOE 2016b).

- WIPP Subsidence Monument Leveling Survey 2017, DOE/WIPP 17-3595, December 2017 (U.S. DOE 2017b).

DATA-5.0 Geotechnical Monitoring Program

The Geotechnical Monitoring Program (GMP) measures in situ geotechnical data in the WIPP repository. This section provides a brief discussion of the GMP and identifies the relevant data reports.

DATA-5.1 Program Overview

The GMP obtains in situ data to support continuous assessment of the stability of underground facilities. A detailed description of the geotechnical programs and procedures is presented in WP 07-1, WIPP Geotechnical Engineering Program Plan, Rev. 8 (NWP 2017).

DATA-5.2 Reported Data

Data generated through the GMP are reported annually in a Geotechnical Analysis Report which includes data for the previous year. The report contains an assessment of the geotechnical status of the WIPP based on the data, which were collected throughout the year. References for reports published since the CRA-2014 data cutoff are provided below:

- U.S. Department of Energy, 2013, Geotechnical Analysis Report for July 2011–June 2012, DOE/WIPP 13-3501, Carlsbad, NM (U.S. DOE 2013c).

- U.S. Department of Energy, 2014, Geotechnical Analysis Report for July 2012–June 2013, DOE/WIPP 14-3516, Carlsbad, NM (U.S. DOE 2014d).

- U.S. Department of Energy, 2015, Geotechnical Analysis Report for July 2013–June 2014, DOE/WIPP 15-3556, Carlsbad, NM (U.S. DOE 2015c).

- U.S. Department of Energy, 2016, Geotechnical Analysis Report for July 2014–June 2015, DOE/WIPP 16-3559, Carlsbad, NM (U.S. DOE 2016c).

- U.S. Department of Energy, 2017, Geotechnical Analysis Report for July 2015–June 2016, DOE/WIPP 17-3560, Carlsbad, NM (U.S. DOE 2017c).

The DOE monitors four parameters relating to information collected by the GMP. These are creep closure, extent of deformation, initiation of brittle deformation, and displacement of deformation features. Creep closure and displacement of deformation features are quantitative. Extent of deformation and initiation of brittle deformation are qualitative. These four parameters are discussed and analyzed in the COMPs reports listed in Section DATA-11.2.

DATA-6.0 Groundwater Monitoring Program

The Groundwater Monitoring Program (GWMP) collects and analyzes water levels, water quality, and water density in the WIPP's well monitoring network. This section briefly describes the GWMP and identifies relevant reports.

DATA-6.1 Program Overview

While the GWMP collects and analyzes data in other hydrologic units, the collection of groundwater data from the Culebra Dolomite Member of the Rustler Formation (hereafter referred to as the Culebra) is the only data collection of importance to 40 CFR 194.42 and the COMPs. Examples of data collected include water levels and water quality from numerous wells located at and near the facility. Data obtained through this program are used to generate the Culebra groundwater composition and the Culebra groundwater flow COMPs.

DATA-6.2 Reported Data

The data collected by the GWMP are discussed and analyzed in the reports listed below and also in the COMPs reports listed in Section DATA-11.2. These analyses provide validation of the various Culebra hydrological models for CRA-2019. Appendix HYDRO-2019 and the COMPs reports provide analyses of the water levels and the fluid density in the monitoring well network used in generating the COMPs, and trigger values indicative of conditions outside of expectations. The following reports have been published since the CRA-2014 data cutoff:

- U.S. Department of Energy, 2013, Waste Isolation Pilot Plant Annual Site Environmental Report for 2012, DOE/WIPP 13-3507, Carlsbad, NM (U.S. DOE 2013d).
- U.S. Department of Energy, 2014, Waste Isolation Pilot Plant Annual Site Environmental Report for 2013, DOE/WIPP 14-3532, Carlsbad, NM (U.S. DOE 2014e).
- U.S. Department of Energy, 2015, Waste Isolation Pilot Plant Annual Site Environmental Report for 2014, DOE/WIPP 15-8866, Carlsbad, NM (U.S. DOE 2015d).
- U.S. Department of Energy, 2016, Waste Isolation Pilot Plant Annual Site Environmental Report for 2015, DOE/WIPP 16-3572, Carlsbad, NM (U.S. DOE 2016d).
- U.S. Department of Energy, 2017, Waste Isolation Pilot Plant Annual Site Environmental Report for 2016, DOE/WIPP 17-3591, Carlsbad, NM (U.S. DOE 2017d).

DATA-7.0 Meteorological Monitoring Program

The Meteorological Monitoring Program collects atmospheric data for the WIPP site. This section provides a brief description of the program and relevant reports.

DATA-7.1 Program Description

The primary WIPP meteorological station is located northeast of the Waste Handling Building. The station measures and records wind speed, wind direction, and temperature at various elevations. The station records ground-level measurements of barometric pressure, relative humidity, precipitation, and solar radiation. These data are used primarily as input for the CAP-88 model (U.S. EPA 1988) to estimate dose and risk from radionuclide emissions to air in compliance with the National Emissions Standard for Hazardous Air Pollutants. They are also used for atmospheric modeling of plume dispersion in support of consequence assessments.

DATA-7.2 Reported Data

The annual site environmental reports listed in Section 6.2 provide data relevant to the Meteorological Monitoring Program. The CCA (U.S. DOE 1996), Appendix CLI, "Long-Term Climate Variability at the WIPP," provides information on past (long-term) climatic conditions and predicted future conditions at the WIPP site. Information related to recent meteorological conditions is provided in the ASER for the reporting period (U.S. DOE 2013d, U.S. DOE 2014e, U.S. DOE 2015d, U.S. DOE 2016d, and U.S. DOE 2017d).

DATA-8.0 Waste Information

Two types of information related to waste characteristics are collected: (1) information regarding waste that has been emplaced in the WIPP underground repository, and (2) information regarding future inventory that will be emplaced in the WIPP underground repository during the entire lifetime of the project. This section provides a brief description of the programs and a list of relevant reports.

DATA-8.1 Program Overview

Information concerning waste such as waste type, container type, disposal location, etc., that has been emplaced in the repository is tracked and recorded using the Waste Data System (WDS). Information concerning future wastes to be emplaced in the WIPP is developed through updates of the Annual Transuranic Waste Inventory Reports. Section 24 of this application shows the changes in stored and projected waste reported by the sites since the CRA-2014 data cutoff.

DATA-8.2 Reported Data

The Annual Change Report 2016/2017 (U.S. DOE 2017e) provides a detailed listing of emplaced waste in the repository up to June 30, 2017. Summary information generated by the WDS on

emplaced waste and radionuclides is provided in the following reports published since the CRA-2014 data cutoff:

- U.S. Department of Energy, Annual Change Report 2012/2013 October 2013 (U.S. DOE 2013e).
- U.S. Department of Energy, Annual Change Report 2013/2014 November 2014 (U.S. DOE 2014f).
- U.S. Department of Energy, Annual Change Report 2014/2015 November 2015 (U.S. DOE 2015e).
- U.S. Department of Energy, Annual Change Report 2015/2016 November 2016 (U.S. DOE 2016e).
- U.S. Department of Energy, Annual Change Report 2016/2017 November 2017 (U.S. DOE 2017e).
- Information regarding current and future inventories stored and projected at generator sites is provided in the following reports published since the CRA-2014 data cutoff:
- U.S. Department of Energy, Annual Transuranic Waste Inventory Report–2013, DOE/TRU-13-3425, Revision 1 (U.S. DOE 2014g).
- U.S. Department of Energy, Annual Transuranic Waste Inventory Report–2014, DOE/TRU-14-3425, Revision 0 (U.S. DOE 2014h).
- U.S. Department of Energy, Annual Transuranic Waste Inventory Report–2015, DOE/TRU-15-3425, Revision 0 (U.S. DOE 2015f).
- U.S. Department of Energy, Annual Transuranic Waste Inventory Report–2016, DOE/TRU-16-3425, Revision 0 (U.S. DOE 2016f).
- U.S. Department of Energy, Annual Transuranic Waste Inventory Report–2017, DOE/TRU-17-3425, Revision 0 (U.S. DOE 2017f).

DATA-9.0 WIPP Monitoring Well Network

Information regarding WIPP monitoring wells is identified in this section.

DATA-9.1 Program Overview

Information provided in this section was reported in DOE/WIPP 95-2092, Revision 1, Waste Isolation Pilot Plant Borehole Data Report in the CCA, Appendix BH, Borehole Data Report (U.S DOE 1996). Appendix BH serves as a central document providing data on the monitoring well network. The report contains a comprehensive database of wells drilled in support of the WIPP Project and boreholes that were located within the 16-section land withdrawal area.

DATA-9.2 Reported Data

Attachment A of Appendix HYDRO-2019 is a list of all monitoring wells at the WIPP, including wells installed since the CCA and those that have been plugged and abandoned.

DATA-10.0 Repository Investigations Program

The WIPP Repository Investigations Program conducts research activities to confirm assumptions, reduce uncertainty, and resolve issues regarding the conceptual models and parameters used in PA. The program is briefly described in this section and references to relevant reports are provided.

DATA-10.1 Program Overview

The DOE has implemented and/or continued several experimental activities designed to address specific issues and needs of the WIPP repository. In addition, other investigations have been initiated to examine impacts of planned changes. The general areas covered under these investigations include:

- Geochemistry
- Microbiology
- Colloids
- Actinide Sorption, Solubility, Complexation and Redox
- Rock Mechanics

DATA-10.2 Reported Data

Data acquired by the DOE from the repository investigations are available in the following reports, publications, technical memoranda, conference posters, test plans, and analysis plans published since the CRA-2014 data cutoff.

Geochemistry

EDTA

- Experimental Determination of Solubilities of Di-Calcium $Ca_2EDTA(s)$ in NaCl and $MgCl_2$ Solutions to High Ionic Strengths & its Pitzer Model: Applications to Geological Disposal of Nuclear Waste & Other Low Temp. Environments. (Xiong 2016).

- Experimental Determination of Solubilities of Di-Calcium Ethylenediaminetetraacetic Acid Hydrate [$Ca_2C_{10}H_{12}N_2O_8 \cdot 7H_2O(s)$] in NaCl and $MgCl_2$ Solutions to High Ionic Strengths and its Pitzer Model: Applications to Geological Disposal of Nuclear Waste and Other Low Temperature Environments. (Xiong, Kirkes, and Westfall 2017a).

Citrate

- Experimental Determination of Solubilities of Tri-Calcium Di-Citrate Tetrahydrate, Earlandite, in NaCl and $MgCl_2$ Solutions to High Ionic Strengths and its Pitzer Model. (Xiong et al. 2017a).

Lead

- Experimental Determination of Solubilities of Crystalline Lead Oxalate, PbC_2O_4 (cr), in the NaCl-H_2O System. (Xiong 2013).

- Experimental Determination of Solubilities of Lead Oxalate (PbC_2O_4(cr)) in a NaCl Medium to High Ionic Strengths, and the Importance of Lead Oxalate in Low Temperature Environments. (Xiong et al. 2013).

- Experimental Determination of Solubilities of Lead Oxalate, Di-Calcium Ethylenediaminetetraacetic Acid in $MgCl_2$-H_2O System, and Earlandite in NaCl-H_2O and $MgCl_2$-H_2O Systems, and their Respective Pitzer Interaction Parameters [AP-154]. (Xiong 2015a).

- Experimental Determination of Solubilities of Lead Oxalate, Di-Calcium Ethylenediaminetetraacetic Acid in $MgCl_2$-H_2O System, & Earlandite in NaCl-H_2O & $MgCl_2$-H_2O Systems, & their Respective Pitzer Interaction Parameters, Rev. 1 [AP-154]. (Xiong 2015b).

- Experimental Determination of Lead Carbonate Solubility at High Ionic Strengths: A Pitzer Model Description. (Xiong 2015c).

- Experimental Determination of Solubilities of Lead Oxalate (PbC2O4), Ca_2EDTA.7H_2O(s) in $MgCl_2$-H2O System, & Earlandite ($Ca_3[C_3H_5O(COO)_3]_2.4H_2O$) In NaCl-$H_2O$ & $MgCl^{2-}$-H_2O Systems. (Xiong 2017a).

- A Pitzer Model for Lead Oxide Solubilities in the Presence of Borate to High Ionic Strength. (Xiong et al. 2017b).

- Experimental and Thermodynamic Modeling of $PbCIT^-$ Interactions in NaCl and MgCl2 Solutions [Work Associated With AP-154, Tasks 20 and 21]. (Xiong 2014a).

- Experimental and Thermodynamic Modeling of $PbEDTA^{2-}$ Interactions in NaCl and $MgCl_2$ Solutions [Work Associated With AP-154, Tasks 18 and 19]. (Xiong 2014b).

- Experimental and Thermodynamic Modeling Solubility of Cerussite, $PbCO_3$(Cr), in the Carbonate System to High Ionic Strengths, Revision 1, Supersedes ERMS 561917 [Work Associated With AP-154, Tasks 14 And 15]. (Xiong 2015d).

Iron

- Solubility model for ferrous iron hydroxide, hibbingite, siderite, and chukanovite in high saline solutions of sodium chloride, sodium sulfate, and sodium carbonate. *ACS Earth and Space Chemistry*. (Kim et al. 2017).

- Iron and Lead Corrosion in WIPP-Relevant Conditions Test Plan. (Sisk-Scott and Icenhower 2016).

- Test Plan for the Experimental Determination of the Solubilities of Iron and Lead in the Presence of Dissolved Hydrogen Sulfide Species. (Brush and Xiong 2014).

- Test Plan for the Measurement of the Concentration of Aqueous Complexes of Iron(II) and Organic Ligands in the Solutions of High Ionic Strength. (Jang and Kim 2016).

Borate

- Experimental Determination of Solubilities of Sodium Tetraborate (Borax) in NaCl Solutions, and A Thermodynamic Model for the Na–$B(OH)_3$–Cl–SO_4 System to High Ionic Strengths at 25 ºC. (Xiong, Kirkes, and Westfall 2013).

- Am(III)/Nd(III) Interactions with Borate: Experimental Investigations of $Nd(OH)_3$(Micro Cr) Solubility in NaCl Solutions in Equilibrium with Borax. (Xiong et al. 2017c).

- Experimental Determination of Solubilities of Magnesium Borates: Solubility Constants of Boracite [$Mg_3B_7O_{13}Cl$(Cr)] and Aksaite [$MgB_6O_7(OH)_6.2H_2O$(Cr)]. (Xiong et al. 2017d).

- Experimental Determination of Stability Constant of Ferrous Iron Borate Complex [$FeB(OH)_4^+$] at 25 Degrees Celsius from Solubility Measurements. (Xiong et al. 2017e).

- Experimental Determination of Solubilities of Sodium Polyborates in $MgCl_2$ Solutions: Solubility Constant of Di-Sodium Hexaborate Tetrahydrate, and Implications for Diagenetic Formation of Ameghinite. (Xiong, Kirkes, and Marrs 2017a).

- Experimental Determination of Solubilities of Brucite [$Mg(OH)_2$(Cr)] in Na_2SO_4 Solutions With Borate to High Ionic Strengths: Interactions of MgB(OH)4+ with Na2SO4. (Xiong, Kirkes, and Westfall 2017b).

- Experimental Investigation of Borate Interactions with Rare Earth Elements Under the WIPP Relevant Conditions at SNL Carlsbad Facility. (Xiong, Jang, and Icenhower 2015).

Microbiology

- Multistage Bioassociation of Uranium onto an Extremely Halophilic Archaeon Revealed by a Unique Combination of Spectroscopic and Microscopic Techniques. (Bader et al. 2017).

- Microbial Effects in the Context of Past German Safety Cases. (Kienzler and Swanson 2017).

- Investigation into the Post-Excavation Sources of Methane from INL TRU Waste Drums. (Swanson et al. 2015a).

- The Microbiology of Subsurface, Salt-Based Nuclear Waste Repositories: Using Microbial Ecology, Bioenergetics, and Projected Conditions to Help Predict Microbial Effects on Repository Performance. (Swanson et al. 2016).

- The Role of *Chromohalobacter* on Transport of Lanthanides and Cesium in the Dolomite Mineral System. (Zengotita et al. 2017)

- Biosorption of Actinides Towards WIPP Microorganisms. (Reed et al. 2015a).

Colloids

- Absence of Mineral Colloids in High Ionic Strength Solutions Associated with Salt Formations: Experimental Determination and Applications to Nuclear Waste Management. (Xiong et al. 2017f).

- Actinide (IV)-Humic Complexation in the WIPP Performance Assessment. (Mariner 2016).

- Experimental Investigation of Absence or Presence of Colloids of Magnesium Chloride Hydroxide Hydrate (Phase 5) in the WIPP Generic Weep Brine (GWB) Under the WIPP Relevant Conditions at SNL Carlsbad Facility. (Xiong and Kim 2014).

- Experimental Determination of the Existence of a Mobile Colloidal Fraction of Fe(II) Minerals in Two WIPP-relevant Brines. (Jang 2014).

- Experimental Investigation of Stability of Mineral Colloids under WIPP Conditions. (Sisk-Scott, Kirkes, and Mariner 2016).

Actinide Sorption, Solubility, Complexation and Redox

- Proceedings of the International Workshops ABC-Salt (II) and HiTAC 2011. (Altmaier et al. 2012).

- Uranium (VI) Solubility in Carbonate-free WIPP Brine. (Lucchini et al. 2013a).

- Actinide Solubility and Speciation in the Waste Isolation Pilot Plant (WIPP) Repository. (Reed et al. 2013a).
- Microbial Diversity Associated with Halite within the WIPP. (Swanson and Simmons 2013).
- Proceedings of the International Workshop on Actinide and Brine Chemistry in a Salt-Based Repository (ABC-Salt). (Reed and Altmaier 2014).
- Proceeding of the 15th International Conference on the Chemistry and Migration Behaviour of Actinides and Fission Products in the Geosphere Place Holder. (Reed and Rabung 2015).
- Multiscale Speciation of U and Pu at Chernobyl, Hanford, Los Alamos, McGuire AFB, Mayak, and Rocky Flats. (Batuk et al. 2015).
- Interaction of Nd(III) and Cm(III) with Borate in Dilute to Concentrated Alkaline NaCl, $MgCl_2$ and $CaCl_2$ Solutions: Solubility and TRLFS Studies. (Hinz et al. 2015).
- Proceedings of the Third International Workshop on Actinide and Brine Chemistry in a Salt-Based Repository (ABC-Salt III). (Reed and Altmaier 2015).
- Culture-dependent and Independent Analysis of Low to Intermediate Level Radioactive Waste Assessment of Two Disinterred Aged Waste Drums. (Swanson et al. 2015).
- Reassessment of the Impact of Microbial Activity on Performance of the WIPP. (Swanson et al. 2015).
- Plutonium Chemistry in the WIPP: Update and Path Forward. (Reed and Patterson 2016).
- WIPP TRU Repository: Update of the Safety Case. (Reed et al. 2017).
- The Role of Ionic Strength on Sorption of Neodymium on Dolomite. (Emerson et al. 2017).
- Sorption and Desorption of Cs(I), Sr(II), Nd(III) and Ce(IV) on Culebra Dolomite. (Dugas et al. 2017).
- Impact of EDTA on the Solubility and Redox Behavior of Dilute to Concentrated NaCl Solution. (Yalcintas et al. 2017).
- A state of the Art Report within the NEA-TDB to Assess modeling and Experimental Approaches in Aqueous High Ionic-Strength Solutions. (Altmaier et al. 2017).
- Biosorption of Neodymium onto Bacillus megaterium Spores. (Hazelton and Swanson 2017).

- Long-Term Experimental Determination of Solubilities of Micro-Crystalline Nd (III) Hydroxide in High Ionic Strength Solutions: Applications to Nuclear Waste Management. (Xiong, Kirkes, and Marrs 2017b).

- Solution Chemistry for Actinide Borate Species to High Ionic Strengths: Equilibrium Constants for AmHB4O72+ and AmB9O13(OH)4(cr) and Their Importance to Nuclear Waste Management. (Xiong 2017b).

- A State-of-the-art Report within NEA-TDB to Assess Modeling and Experimental Approaches in Aqueous High Ionic-Strength Solutions Relevant for Nuclear Waste Disposal Applications. (Altmaier et al. 2016).

- High Ionic-Strength Solutions: State of the Art Report within NEA-TDB to Assess Modeling and Experimental Approaches: OECD/NEA Thermochemical Database Project (TDB). (Altmaier et al. 2015)

- Investigation of Transuranic Waste Drums to Assess Mechanisms of Methane Generation. (Swanson et al. 2015b).

- U_3O_8 and Amorphous $UO_2(Oh)_2$ Solubility at Elevated Temperature in Sodium Chloride Brine. (Reed et al. 2015c).

- Permanent Geologic Isolation of Actinides in a Salt Repository: Update of the WIPP Safety Case. (Reed et al. 2015b).

- Insights into the Potential for Microbial Survival and Activity within a TRU Waste Drum (Swanson et al. 2017).

- Plutonium Speciation in the WIPP: An Update of the Safety Case for Plutonium Containment. (Richmann et al. 2014).

- Temperature and Ionic Strength Effects on Neptunium Speciation in Simplified Brine Systems. (Reed et al. 2013b).

- Experimental Evidence for Low Uranium (VI) Solubility in the WIPP. (Lucchini et al. 2013b).

- Long-term Plutonium Speciation in WIPP Brines. (Reed et al. 2012).

Rock Mechanics

Waste Compaction Behavior

- Laboratory Testing of Waste Isolation Pilot Plant Surrogate Waste Materials. (Broome et al. 2012).

- Compaction Behavior of Surrogate Degraded Emplaced WIPP Waste. (Broome et al. 2014).

- Laboratory Testing of Surrogate Non-degraded Waste Isolation Pilot Plant Materials. (Broome et al. 2016).

- WIPP Full Scale Hydrostatic Testing of 55-Gallon Waste Disposal Drums – Final Report. (Orlowski 2015).

Salt Reconsolidation/BAMBUS Project

- Granular Salt Summary: Reconsolidation Principles and Applications. Fuel Cycle Research & Development Program Report FCRD-UFD-2014-000590, Rev. 0. (Hansen et al. 2014).

- Milestone INT-15-02: A Synthesis of Salt Reconsolidation Analogues. (Hansen 2015a).

- Characterization of Reconsolidated Crushed Salt from the BAMBUS Site. (Hansen 2015b).

- Characterization of Reconsolidated Crushed Salt from the BAMBUS Site. (Hansen 2016a).

- Reconsolidated Salt as a Geotechnical Barrier. (Hansen 2016b).

- Experimental Investigation of Small-Scale Openings in WIPP Salt (Herrick, Reedlunn, and Jensen 2017).

- Microstructural Investigations on Natural and Laboratory Tested Salt. (Mills 2017).

Panel Closures

- Parameter Selections Associated with Modeling WIPP's ROM Salt Panel Closure System. (Herrick 2016).

WIPP Stratigraphy

- Reference Stratigraphy Applied to Rock Mechanics Studies for the Waste Isolation Pilot Plant: A Review. (Powers 2016).

- Experimental Investigation of WIPP Salt Samples and Clay Seams. (Sobolik 2017).

DATA-11.0 Compliance Monitoring Program

Annually, the Compliance Monitoring Program (CMP) extracts data from the repository investigations and five of the monitoring programs described above (DBDSP, SMP, GMP, GWMP, and WDS). The data are used to derive values for the 10 COMPs described in Section DATA-2.0 and to evaluate any changes. The CMP activities are briefly described in this section. Data generated under the CMP are also identified.

DATA-11.1 Program Overview

The objective of the CMP is to provide assurance that any deviations from the expected long-term performance of the repository are identified at the earliest possible time. The CMP is implemented in accordance with DOE/WIPP 99-3119, Compliance Monitoring Implementation Plan for 40 CFR 191.14(b), Assurance Requirement (U.S. DOE 2012). Annual evaluations of the compliance parameters follow the requirements found in Sandia National Laboratories SP 9-8, Monitoring Parameter Assessment Per 40 CFR 194.42, Revision 2 (Wagner 2017).

DATA-11.2 Reported Data

Data and results from the CMP are provided in the following reports published since the CRA-2014 data cutoff:

- Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2013. (Wagner and Kuhlman 2013).
- Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2014. (Wagner and Kuhlman 2014).
- Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2015. (Wagner and Thomas 2016b).
- Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2016. (Wagner and Thomas 2017).
- Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2017. (Wagner and Hayes 2018).

DATA-12.0 Hydrological Investigation

In response to water-level fluctuations in areas of the Culebra, the DOE initiated an investigation into the cause of the water-level fluctuations and the impact on the long-term performance of the WIPP. The results of this investigation are discussed in Appendix HYDRO-2009, Appendix HYDRO-2014, and Appendix HYDRO-2019.

A well south of the WIPP site, operated by a local ranch, is being used as a water supply well for commercial purposes and is contributing to a water level decrease in areas of the Culebra. A detailed description of the water-level decrease in areas of the Culebra is provided in Appendix HYDRO-2019, section 6.1.2. The situation is being continuously monitored and analyzed.

DATA-12.1 Reported Data

Data acquired from hydrologic monitoring are provided in the reports listed below for Culebra water-level monitoring.

DATA-12.1.1 Culebra Water-Level Monitoring

The following reports are related to Culebra water-level monitoring:

- Johnson, P.B., Letter to Records Center (Subject: 2012 Calculated Densities). (Johnson 2013).
- Johnson, P.B., Letter to Records Center (Subject: 2013 Calculated Culebra Groundwater Densities). (Johnson 2014).
- Johnson, P.B., Letter to Records Center (Subject: 2014 Calculated Densities). (Johnson 2015).
- Johnson, P.B., Letter to Records Center (Subject: 2015 Calculated Densities). (Johnson 2016).
- Johnson, P.B., Letter to Records Center (Subject: 2016 Calculated Densities). (Johnson 2017).

In addition, studies of commercial well pumping as the primary impact to Culebra water levels have been performed:

- Kuhlman K.L. & Corbet, T.F. 2017. Memo to Records Center (Subject: WIPP Milestone Report: 2016 Culebra Groundwater Level Fluctuations). (Kuhlman and Corbet 2017).
- Anthropogenic influences on groundwater in the vicinity of the Waste Isolation Pilot Plant, southeastern New Mexico, USA. (Thomas, Kuhlman, and Ward 2017).

DATA-13.0 Waste Containers and Emplacement

There have been no new waste containers or waste emplacement methods introduced since the CRA-2014 data cutoff. Because of this, the attachment to this appendix from the CRA-2014, which was titled, "WIPP Waste Containers and Emplacement," will not be included in the CRA-2019 submission.

DATA-14.0 References

(*Indicates a reference that has not been previously submitted)

Altmaier, M., C. Bube, B. Kienzler, V. Metz, and D. T. Reed (Eds.). 2012. Proceedings of the International Workshops ABC-Salt (II) and HiTAC 2011. Karlrsruhe Institute of Technology, Karlsruhe, Germany, 2012. KIT Scientific Report 7625.

Altmaier, M., L. Brush, D. Costa, A. Felmy, H. C. Moog, M. Ragoussi, D. T. Reed, W. Runde, W. Voigt. 2015. High Ionic-Strength Solutions: State of the Art Report within NEA-TDB to Assess Modeling and Experimental Approaches: OECD/NEA Thermochemical Database Project (TDB). Poster presented at Migration 2015, September 13-18, Santa Fe, NM, USA.*

Altmaier, M., D. Costa, A. Felmy, H. Moog, R. Pabalan, M. Ragoussi, D.T. Reed, W. Runde, and W. Voigt. 2016. A State-of-the-art Report within NEA-TDB to Assess Modeling and Experimental Approaches in Aqueous High Ionic-Strength Solutions Relevant for Nuclear Waste Disposal Applications. Poster presented at ISSP-17, Geneva Switzerland, July 2016.*

Altmaier, M., D. Costa, A. Felmy, H. Moog, R. Pabalan, M. Ragoussi, D.T. Reed, W. Runde, W. Voigt. 2017. A State-of-the-Art Report within the NEA-TDB to Assess modeling and Experimental Approaches in Aqueous High Ionic-Strength Solutions. Poster presented at Migration 2017, Barcelona Spain (September 10-15, 2017). *

Bader, M., K. Muller, H. Foerstendorf, B. Drobot, M. Schmidt, N. Musat, J.S. Swanson, D.T. Reed, T. Stumpf, and A. Cherkouk. 2017. Multistage Bioassociation of Uranium onto an Extremely Halophilic Archaeon Revealed by a Unique Combination of Spectroscopic and Microscopic Techniques. J Haz Mat 327: 225-232.*

Batuk, O.N., S.D. Conradson, O.N. Aleksandrova, H. Boukhalfa, B.E. Burakov, D.L. Clark, K.R. Czerwinski, A.R. Felmy, J.S. Lezama-Pacheco, S.N. Kalmykov, D.A. Moore, B.F. Myasoedov, D.T. Reed, D.D. Reilly, R.C. Roback, I.E. Vlasova, S.M. Webb, M.P. Wilkerson. 2015. Multiscale Speciation of U and Pu at Chernobyl, Hanford, Los Alamos, McGuire AFB, Mayak, and Rocky Flats. *Env. Sci. Tech*., Vol. 49, Issue 11, pp. 6474-6484, 2015.*

Broome, S.T., D. R. Bronowski, S.J. Kuthakun, C. G. Herrick, and T.W. Pfeifle. 2014. Compaction Behavior of Surrogate Degraded Emplaced WIPP Waste. Sandia National Laboratories, Albuquerque, NM. SAND2014-1897.*

Broome, S.T., D.R. Bronowski, S.J. Kuthakun, T.W. Pfeifle, and C.G. Herrick. 2012. Laboratory Testing of Waste Isolation Pilot Plant Surrogate Waste Materials. ARMA 12-391. Presented at the 46th US Rock Mechanics / Geomechanics Symposium, Chicago, IL, USA, 26–29 June 2012. SAND 2012-1405C.*

Broome, S.T., M.D. Ingraham, G.M. Flint, M.B. Hileman, P.C. Barrow, and C.G. Herrick. 2016. Laboratory Testing of Surrogate Non-degraded Waste Isolation Pilot Plant Materials. Paper ARMA 16-120. Presented at the 50th US Rock Mechanics / Geomechanics Symposium, Houston, TX, USA, 26–29 June 2016. SAND 2016-1617C.*

Brush, L.H., and Y.-L Xiong. 2014. Test Plan for the Experimental Determination of the Solubilities of Iron and Lead in the Presence of Dissolved Hydrogen Sulfide Species. Sandia National Laboratories, Carlsbad, NM. TP 14-05 0. ERMS 562861.*

Dugas, M., T. Dittrich, M. Richmann, F. Zengotita, and D.T. Reed. 2017. Sorption and Desorption of Cs(I), Sr(II), En(III), Nd(III) and Ce(IV) on Culebra Dolomite. Poster presentation at the LANL Student symposium, Los Alamos, NM (August 8, 2017). LA-UR 17-26984.*

Emerson, H., F. Zengotita, T. Dittrich, Y. Katsenovich, D.T. Reed. 2017. The Role of Ionic Strength on Sorption of Neodymium on Dolomite. Poster presented at the Fall American Chemical Society meeting, Washington DC (August 13-18, 2017). LA-UR 17-27376.*

Hansen, F.D. 2015a. Milestone INT-15-02: A Synthesis of Salt Reconsolidation Analogues. Sandia National Laboratories, Carlsbad, New Mexico. ERMS 564594.*

Hansen F. 2015b. Characterization of Reconsolidated Crushed Salt from the BAMBUS Site. Sandia National Laboratories, Carlsbad, NM. TP 16-01 0. ERMS 564990.*

Hansen, F.D. 2016a. Characterization of Reconsolidated Crushed Salt from the BAMBUS Site. Sandia National Laboratories, Albuquerque, NM. SAND2016-2794.*

Hansen, F.D. 2016b. Reconsolidated Salt as a Geotechnical Barrier. Paper 16535. Presented at the WM2016 Conference, March 6-10, Phoenix, Arizona, USA. SAND 2016-1096C.*

Hansen, F.D., T. Popp, K. Wieczorek, and D. Stührenberg. 2014. Granular Salt Summary: Reconsolidation Principles and Applications. Fuel Cycle Research & Development Program Report FCRD-UFD-2014-000590, Rev. 0, Sandia National Laboratories, Albuquerque, NM. SAND 2014-16141R.*

Hazelton, C., and J.S. Swanson. 2017. Biosorption of Neodymium onto Bacillus megaterium Spores. Poster presentation at the LANL Student symposium, Los Alamos, NM (August 8, 2017). LA-UR 17-26983.

Herrick, C.G. 2016. Parameter Selections Associated with Modeling WIPP's ROM Salt Panel Closure System. Presented at U.S.-German Workshop, Washington, D.C., 8-9 Sept 2016. SAND2016-8665C.*

Herrick, C.G., B. Reedlunn, and R.P. Jensen. 2017. Experimental Investigation of Small-Scale Openings in WIPP Salt. Sandia National Laboratories, Carlsbad, NM. TP 17-02 0. ERMS 568405.*

Hinz, K., M. Altmaier, X. Gaona, T. Rabung, D. Schild, M. Richmann, D.T. Reed, E. Alekseev, and G. Geckeis. 2015. "Interaction of Nd(III) and Cm(III) with Borate in Dilute to Concentrated Alkaline NaCl, $MgCl_2$ and $CaCl_2$ Solutions: Solubility and TRLFS Studies," *New Journal of Chemistry*, Vol. 39, Issue 2, pp. 849-859, 2015.*

Jang J.-H. 2014. Experimental Determination of the Existence of a Mobile Colloidal Fraction of Fe(II) Minerals in Two WIPP-relevant Brines. Sandia National Laboratories, Carlsbad, NM. TP 14-03 0. ERMS 561895.*

Jang, J.-H., and S. Kim. 2016. Test Plan for the Measurement of the Concentration of Aqueous Complexes of Iron(II) and Organic Ligands in the Solutions of High Ionic Strength. Sandia National Laboratories, Carlsbad, NM. TP 16-02 0. ERMS 565522.*

Johnson, P.B. 2013b. Letter to Records Center (Subject: 2012 Calculated Densities). ERMS 559277.*

Johnson, P.B. 2014b. Letter to Records Center (Subject: 2013 Calculated Culebra Groundwater Densities). ERMS 561659.*

Johnson, P.B. 2015. Letter to Records Center (Subject: 2014 Calculated Densities). ERMS 563343.*

Johnson, P.B. 2016c. Letter to Records Center (Subject: 2015 Calculated Densities). ERMS 565652.*

Johnson, P.B. 2017b. Letter to Records Center (Subject: 2016 Calculated Densities). ERMS 567889.*

Kienzler, B., J.S. Swanson. 2017. Microbial Effects in the Context of Past German Safety Cases. KIT Scientific Reports 7744.*

Kim, S., C. Marrs, M. Nemer, J., J-H. Jang. 2017. Solubility Model for Ferrous Iron Hydroxide, Hibbingite, Siderite, and Chukanovite in High Saline Solutions of Sodium Chloride, Sodium Sulfate, and Sodium Carbonate. *ACS Earth and Space Chemistry*, 1: 647-663.*

Kuhlman, K.L., and T.F. Corbet. 2017. Memo to Records Center (Subject: WIPP Milestone Report: 2016 Culebra Groundwater Level Fluctuations). May 19, 2017. Carlsbad, NM: Sandia National Laboratories. ERMS 568172.*

Lucchini, J.F., M.K. Richmann, J. Swanson, D. Cleveland, K. Simmons, M. Borkowski, and D.T. Reed. 2013a. Uranium (VI) solubility in carbonate-free WIPP brine. *Radiochimica Acta* 101, 391-398 (2013).*

Lucchini, J.F., D.T. Reed, M.K. Richmann, J.S. Swanson, D. Cleveland, K. Simmons, and M. Borkowski. 2013b. Experimental Evidence for Low Uranium (VI) Solubility in the WIPP. Poster presentation at the ABC Salt III workshop, Santa Fe, NM (April 15-17, 2013). LA-UR-13-22633.*

Mariner, P.E. 2016. Actinide (IV)-Humic Complexation in the WIPP Performance Assessment, Sandia National Laboratories. Carlsbad, NM. ERMS 567222.*

Mills, M. 2017. Microstructural Investigations on Natural and Laboratory Tested Salt. Sandia National Laboratories, Carlsbad, NM. TP 17-04 0. ERMS 568610.*

Nuclear Waste Partnership. 2017. WIPP Geotechnical Engineering Program Plan, Rev. 8. WP 07-1.*

Orlowski, M. 2015. WIPP Full Scale Hydrostatic Testing of 55-Gallon Waste Disposal Drums – Final Report. SwRI Project 18.18197.03, Issue 1, Purchase Order 1493421. Prepared for Sandia National Laboratories, 4100 National Parks Highway, Bldg. A, Carlsbad, NM.*

Powers, D.W. 2016. Reference Stratigraphy Applied to Rock Mechanics Studies for the Waste Isolation Pilot Plant: A Review. Sandia National Laboratories, Carlsbad, NM. ERMS 567705.*

Reed, D.T. and M. Altmaier (Eds.). 2014. Proceedings of the International Workshop on Actinide and Brine Chemistry in a Salt-Based Repository (ABC-Salt). Los Alamos National Laboratory report, Los Alamos, NM, USA, 2014. LA-UR-14-28463.*

Reed, D.T., and M. Altmaier (Eds.). 2015. Proceedings of the Third International Workshop on Actinide and Brine Chemistry in a Salt-Based Repository (ABC-Salt III). Los Alamos National Laboratory report, Los Alamos, NM, USA, 2015. LA-UR-15-21114.*

Reed, D. T., M. Borkowski, M.K. Richmann, J.F. Lucchini, and J.S. Swanson. 2012. Long-term Plutonium Speciation in WIPP Brines. Poster presentation at the ABC Salt III workshop, Santa Fe, NM (April 15-17, 2013). LA-UR 12-10140.*

Reed, D.T., M.K. Richmann, J M. Borkowski, J.S. Swanson, J.F. Lucchini, D. Cleveland and K. Simmons. 2013a. Actinide Solubility and Speciation in the Waste Isolation Pilot Plant (WIPP) Repository. Poster presentation at the Migration 2013 Conference, Brighton UK, September 8-13, 2013. LA-UR 13-26897.

Reed, D.T, M.K. Richmann, M. Borkowski, D. Cleveland, J.S. Swanson, and J.F. Lucchini, and. Temperature and Ionic Strength Effects on Neptunium Speciation in Simplified Brine Systems. 2013b. Poster presentation in Actinides 2013, Karlsruhe, Germany, July 21-25, 2013. LA-UR 13-25475.*

Reed, D.T., and T. Rabung, (Eds.). 2015. Proceeding of the 15th International Conference on the Chemistry and Migration Behaviour of Actinides and Fission Products in the Geosphere, Santa Fe, NM, USA. Los Alamos Report LA-UR-15-27123, 2015.*

Reed, D.T., J.S. Swanson, J.F. Lucchini, K. Nakama, T. Sontag, and M.K. Richmann. 2015a. Biosorption of Actinides Towards WIPP Microorganisms. Poster at the ABC Salt (IV) workshop, Heidelberg, Germany, April 13-14, 2015. LA-UR 13-26994.*

Reed, D. T., M.K. Richmann, J.S. Swanson, J.F. Lucchini, and T. Dittrich. 2015b. Permanent Geologic Isolation of Actinides in a Salt Repository: Update of the WIPP Safety Case. Poster presented at Migration 2015, September 13-18, Santa Fe, NM, USA. LA-UR-15-27077*

Reed, D.T., M. Richmann, J.S. Swanson, and T. Dittrich. 2017. WIPP TRU Repository: Update of the Safety Case. Poster presented at Migration 2017, Barcelona Spain (September 10-15, 2017). LA-UR 17-23396.*

Reed, D.T. and R. Patterson. 2016. Plutonium Chemistry in the WIPP: Update and Path Forward. Poster presented at Plutonium Futures 2016, Baden, Germany (September 18-23, 2016). LA-UR 16-27090.*

Reed, D.T., M. Richmann, T. Dittrich, A Hayes, T. Sontag, and M. Dugus. 2015. U_3O_8 and Amorphous $UO_2(Oh)_2$ Solubility at Elevated Temperature in Sodium Chloride Brine. Poster presented at Migration 2015, September 13-18, Santa Fe NM, USA. LA-UR-15-27124*

Richmann, M.K., D. Cleveland, J.F. Lucchini, J.S. Swanson, and D.T. Reed. 2014. Plutonium Speciation in the WIPP: An Update of the Safety Case for Plutonium Containment. Poster presented at Pu Futures 2014. Las Vegas, NV, September 7-11, 2014. LAUR 14-26982.*

Sisk-Scott, C., and J. Icenhower. 2016. Iron and Lead Corrosion in WIPP-Relevant Conditions Test Plan. Sandia National Laboratories, Carlsbad, NM. TP 06-02 3.*

Sisk-Scott, C., L. Kirkes, P. Mariner. 2016. Experimental Investigation of Stability of Mineral Colloids Under WIPP Conditions. Sandia National Laboratories, Carlsbad, NM. TP 14-04 2. ERMS 567229.*

Sobolik, S. R. 2017. Experimental Investigation of WIPP Salt Samples and Clay Seams. Sandia National Laboratories, Carlsbad, NM. TP 17-03 0. ERMS 568416*

Swanson, J.S., and K. Simmons. 2013. Microbial Diversity Associated with Halite within the WIPP. Poster presentation at the ABC Salt III workshop, Santa Fe, NM (April 15-17, 2013). LA-UR 13-22595.*

Swanson, J.S., K. Nakama, T. Sontag, M. Richmann, J.F. Lucchini, D. Reed, T. Burns. 2015. Culture-dependent and Independent Analysis of Low- to Intermediate-Level Radioactive Waste: Assessment of Two Disinterred Aged Waste Drums. Poster presented at the General Meeting of the American Society for Microbiology. LA-UR 15-23917.*

Swanson, J.S., K. Nakama, T. Sontag, M. Richmann, J.F. Lucchini, and D.T. Reed. 2015. Reassessment of the Impact of Microbial Activity on Performance of the WIPP. Poster presented at Migration 2015, Santa Fe NM (September 13-18, 2015). LA-UR 15-27009.*

Swanson, J., D.T. Reed, M. Richmann, and D. Cleveland. 2015a. Investigation into the post-excavation sources of methane from INL TRU waste drums. Los Alamos National Laboratory, Carlsbad, NM. LA-UR-15-26657.*

Swanson, J.S., D.T. Reed, M.K. Richmann, T.H. Johnsen, L.R. Frost, T.L. Clements, and T.P. Burns. 2015b. Investigation of TRU Waste Drums to Assess Mechanisms of Methane Generation. Poster presented at Migration 2015, September 13-18, Santa Fe, NM, USA.* LA-UR-15-27053.

Swanson, J.S., A. Cherkouk, T. Arnold, A. Meleshyn, and D.T. Reed. 2016. The microbiology of subsurface, salt-based nuclear waste repositories: using microbial ecology, bioenergetics, and projected conditions to help predict microbial effects on repository performance. Los Alamos National Laboratory, Carlsbad, NM. LA-UR-16-28895.*

Swanson, J.S., I. Brown, K. Nakama, and T. Sontag. 2017. Insights into the Potential for Microbial Survival and Activity within a TRU Waste Drum. Poster presented at ABC Salt V, Ruidoso NM (March 28, 2017). LA-UR 17-22432.*

Thomas, M.A., K.L. Kuhlman, and A.L. Ward. 2017. Anthropogenic influences on groundwater in the vicinity of the Waste Isolation Pilot Plant, southeastern New Mexico, USA. SAND 2016-9292c.*

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

U.S. DOE. 2012. Compliance Monitoring Implementation Plan for 40 CFR 191.14(b), Assurance Requirement, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 99-3119.*

U.S. DOE. 2013a. Delaware Basin Monitoring Annual Report, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP-13-2308.*

U.S. DOE. 2013b. WIPP Subsidence Monument Leveling Survey 2013, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 13-3512.*

U.S. DOE. 2013c. Geotechnical Analysis Report for July 2011–June 2012, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 13-3501.*

U.S. DOE. 2013d. Waste Isolation Pilot Plant Annual Site Environmental Report for 2012, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 13-3507.*

U.S. DOE. 2013e. Annual Change Report 2012/2013, October 15, 2013. Carlsbad, NM: Carlsbad Field Office. DOE/WIPP 13-3513.*

U.S. DOE. 2014a. Title 40 CFR Part 191 Subparts B and C. Compliance Recertification Application for the Waste Isolation Pilot Plant (March). U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 2014-3503.*

U.S. DOE. 2014b. Delaware Basin Monitoring Annual Report, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP-14-2308.*

U.S. DOE. 2014c. WIPP Subsidence Monument Leveling Survey 2014, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 14-3541.*

U.S. DOE. 2014d. Geotechnical Analysis Report for July 2012–June 2013, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 14-3516.*

U.S. DOE. 2014e. Waste Isolation Pilot Plant Annual Site Environmental Report for 2013, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 14-3532.*

U.S. DOE. 2014f. Annual Change Report 2013/2014, U.S. Department of Energy, Carlsbad, NM.*

U.S. DOE. 2014g. Annual Transuranic Waste Inventory Report–2013, Revision 1, U.S. Department of Energy, Carlsbad, NM. DOE/TRU-13-3425.*

U.S. DOE. 2014h. Annual Transuranic Waste Inventory Report–2014, Revision 0, U.S. Department of Energy, Carlsbad, NM. DOE/TRU-14-3425.*

U.S. DOE. 2015a. Delaware Basin Monitoring Annual Report, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP-15-2308.*

U.S. DOE. 2015b. WIPP Subsidence Monument Leveling Survey 2015 (December), U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 15-3562.*

U.S. DOE. 2015c. Geotechnical Analysis Report for July 2013–June 2014 (October), U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 15-3556.*

U.S. DOE. 2015d. Waste Isolation Pilot Plant Annual Site Environmental Report for 2014, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 15-8866.*

U.S DOE. 2015e. Annual Change Report 2014/2015, November 2015. U.S. Department of Energy, Carlsbad, NM.*

U.S. DOE. 2015f. Annual Transuranic Waste Inventory Report–2015, Revision 0, U.S. Department of Energy, Carlsbad, NM. DOE/TRU-15-3425.*

U.S. DOE. 2016a. Delaware Basin Monitoring Annual Report, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP-16-2308.*

U.S. DOE. 2016b. WIPP Subsidence Monument Leveling Survey 2016, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 16-3577.*

U.S. DOE. 2016c, Geotechnical Analysis Report for July 2014–June 2015, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 16-3559.*

U.S. DOE. 2016d. Waste Isolation Pilot Plant Annual Site Environmental Report for 2015, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 16-3572.*

U.S. DOE. 2016e. Annual Change Report 2015/2016, U.S. Department of Energy, Carlsbad, NM.*

U.S. DOE. 2016f. Annual Transuranic Waste Inventory Report–2016, Revision 0, U.S. Department of Energy, Carlsbad, NM. DOE/TRU-16-3425.*

U.S. DOE. 2017a. Delaware Basin Monitoring Annual Report, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP-17-2308.*

U.S. DOE. 2017b. WIPP Subsidence Monument Leveling Survey 2017, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 17-3595.*

U.S. DOE. 2017c, Geotechnical Analysis Report for July 2015–June 2016, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 17-3560.*

U.S. DOE. 2017d. Waste Isolation Pilot Plant Annual Site Environmental Report for 2016, U.S. Department of Energy, Carlsbad, NM. DOE/WIPP 17-3591.*

U.S. DOE. 2017e. Annual Change Report 2016/2017, U.S. Department of Energy, Carlsbad, NM.*

U.S. DOE. 2017f. Annual Transuranic Waste Inventory Report–2017, Revision 0, U.S. Department of Energy, Carlsbad, NM. DOE/TRU-17-3425.*

U.S. Environmental Protection Agency (EPA). 1988. The Clean Air Act Assessment Package – 1988 (CAP – 88) A Dose and Risk Assessment Methodology for Radionuclide Emissions to Air; Volume 1; User's Manual.

U.S. Environmental Protection Agency (EPA). 1996. 40 CFR Part 194: Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule. *Federal Register*, vol. 61 (February 9, 1996): 5223–5245.

U.S. Environmental Protection Agency (EPA). 1998. 40 CFR Part 194: Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the Disposal Regulations: Certification Decision; Final Rule. *Federal Register*, vol. 63 (May 18, 1998): 27353–406.

Wagner, S. and K. Kuhlman. 2013. Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2013, November 2013, Carlsbad, NM. WBS 4.3.1. ERMS 561163.*

Wagner, S., and K. Kuhlman. 2014. Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2014, December 2014, Carlsbad, NM. WBS 4.3.1. ERMS 563163.*

Wagner, S.W. and M. Thomas. 2016a. Trigger Value Derivation Report, Revision 3. Sandia National Laboratories: Carlsbad, NM. ERMS 566313.

Wagner, S. and M. Thomas. 2016b. Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2015, January 2016, Carlsbad, NM. WBS 4.3.1. ERMS 565310.*

Wagner, S. 2017. Sandia National Laboratories SP 9-8, Monitoring Parameter Assessment per 40 CFR 194.42, Revision 2. ERMS 568069.*

Wagner, S. and M. Thomas. 2017. Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2016, January 2017, Carlsbad, NM. WBS 4.3.1. ERMS 567610.*

Wagner, S. and A. Hayes. 2018. Sandia National Laboratories Compliance Monitoring Parameter Assessment for 2017. January 2018, Carlsbad, NM. WBS 4.3.1. ERMS 569255.*

Xiong, Y.-L. 2013. Experimental Determination of Solubilities of Crystalline Lead Oxalate, PbC_2O_4 (cr), in the NaCl-H_2O System. ERMS 560651.*

Xiong, Y.-L. 2014a. Experimental and Thermodynamic Modeling of $PbCit^-$ Interactions in NaCl and $MgCl_2$ Solutions [Work Associated With AP-154, Tasks 20 And 21]. ERMS 562836.*

Xiong, Y.-L. 2014b. Experimental and Thermodynamic Modeling of $PbEDTA^{2-}$ Interactions in NaCl And $MgCl_2$ Solutions [Work Associated With AP-154, Tasks 18 And 19]. ERMS 562877.*

Xiong, Y.-L. 2015a. Experimental Determination of Solubilities of Lead Oxalate, Di-Calcium Ethylenediaminetetraacetic Acid in $MgCl_2$-H_2O System, and Earlandite in NaCl-H_2O and $MgCl_2$-H_2O Systems, and Their Respective Pitzer Interaction Parameters [AP-154]. ERMS 564844.*

Xiong, Y.-L. 2015b. Experimental Determination of Solubilities of Lead Oxalate, Di-Calcium Ethylenediaminetetraacetic Acid in $MgCl_2$-H_2O System, and Earlandite in NaCl-H_2O and

$MgCl_2$-H_2O Systems, and their Respective Pitzer Interaction Parameters Rev. 1 [AP-154]. ERMS 564948.*

Xiong, Y.-L. 2015c. Experimental Determination of Lead Carbonate Solubility at High Ionic Strengths: A Pitzer Model Description. *Monatshefte fur Chemie - Chemical Monthly* 146, 1433-1443.*

Xiong, Y.-L. 2015d. Experimental and Thermodynamic Modeling Solubility of Cerussite, $PbCO_3$(Cr), in the Carbonate System to High Ionic Strengths, Revision 1, Supersedes ERMS 561917 [Work Associated With AP-154, Tasks 14 And 15]. ERMS 564929.*

Xiong, Y.-L. 2016. Experimental Determination of Solubilities of Di-Calcium Ca_2EDTA(s) in NaCl and $MgCl_2$ Solutions to High Ionic Strengths and its Pitzer Model: Applications to Geological Disposal of Nuclear Waste and Other Low Temp. Environments. ERMS 565609. SAND2016-1275j.*

Xiong, Y.-L. 2017a. Experimental Determination of Solubilities of Lead Oxalate (PbC_2O_4), $Ca_2EDTA \cdot 7H_2O$(s) in $MgCl_2$-H_2O System, and Earlandite ($Ca_3[C_3H_5O(COO)_3]2 \cdot 4H_2O$) in NaCl-$H_2O$ & $MgCl_2$-H_2O Systems. ERMS 567810.*

Xiong, Y.-L. 2017b. Solution Chemistry for Actinide Borate Species to High Ionic Strengths: Equilibrium Constants for $AmHB_4O_{72}$+ and AmB_9O_{13}(OH)4(cr) and Their Importance to Nuclear Waste Management. *MRS Advances* 2, 741-746.*

Xiong Y.-L., and S. Kim. 2014. Experimental Investigation of Absence or Presence of Colloids of Magnesium Chloride Hydroxide Hydrate (Phase 5) in the WIPP Generic Weep Brine (GWB) Under the WIPP Relevant Conditions at SNL Carlsbad Facility. Sandia National Laboratories, Carlsbad, NM. TP 12-01 Rev. 1.*

Xiong, Y.-L., L. Kirkes, and T. Westfall. 2013. Experimental Determination of Solubilities of Sodium Tetraborate (Borax) in NaCl Solutions, and A Thermodynamic Model for the Na–$B(OH)_3$–Cl–SO_4 System to High Ionic Strengths at 25 ºC. *American Mineralogist* 98, 2030–2036.*

Xiong, Y.-L., L. Kirkes, T. Westfall, and R. Roselle. 2013. Experimental Determination of Solubilities of Lead Oxalate (PbC_2O_4(cr)) in a NaCl Medium to High Ionic Strengths, and the Importance of Lead Oxalate in Low Temperature Environments. *Chemical Geology* 342, 128–137.*

Xiong Y.-L., J.-H. Jang, J. Icenhower. 2015. Experimental Investigation of Borate Interactions with Rare Earth Elements Under the WIPP Relevant Conditions at Sandia National Laboratories Carlsbad Facility. Sandia National Laboratories. Carlsbad, NM. TP 12-02 0. ERMS 563597.

Xiong, Y.-L, L. Kirkes, and C. Marrs. 2017a. Long-Term Experimental Determination of Solubilities of Micro-Crystalline Nd (III) Hydroxide in High Ionic Strength Solutions: Applications to Nuclear Waste Management. *Aquatic Geochemistry* 23, 359-375.*

Xiong, Y.-L., L. Kirkes, and C. Marrs. 2017b. Experimental Determination of Solubilities of Sodium Polyborates in $MgCl_2$ Solutions: Solubility Constant of Di-Sodium Hexaborate Tetrahydrate, and Implications for Diagenetic Formation of Ameghinite," *Canadian Mineralogist* 55, 1001-1008. SAND 2017-12226j.*

Xiong, Y.-L., L. Kirkes, and T. Westfall. 2017a. Experimental Determination of Solubilities of Di-Calcium Ethylenediaminetetraacetic Acid Hydrate [$Ca_2C_{10}H_{12}N_2O_8 \bullet 7H_2O(s)$] in NaCl and $MgCl_2$ Solutions to High Ionic Strengths and its Pitzer Model: Applications to Geological Disposal of Nuclear Waste and Other Low Temperature Environments. *Chemical Geology* 454, pp.15-24.*

Xiong Y.-L., L. Kirkes, and T. Westfall. 2017b. Experimental Determination of Solubilities of Brucite [$Mg(OH)_2(Cr)$] in Na_2SO_4 Solutions with Borate to High Ionic Strengths: Interactions of MgB(OH)4+ with Na_2SO_4. SAND 2017-13513j.*

Xiong, Y.-L., L. Kirkes, T. Westfall, C. Marrs, J. Knox, and H. Burton. 2017a. Experimental Determination of Solubilities of Tri-Calcium Di-Citrate Tetrahydrate, Earlandite, in NaCl and $MgCl_2$ Solutions to High Ionic Strengths and its Pitzer Model. ERMS 568747. SAND2017-10455j.*

Xiong, Y.-L., L. Kirkes, T. Westfall, J. Knox, H. Burton, and C. Marrs. 2017b. A Pitzer Model for Lead Oxide Solubilities in the Presence of Borate to High Ionic Strength. ERMS 568306. SAND2017-7184j.*

Xiong, Y.-L., L. Kirkes, C. Marrs, and J. Knox. 2017c. Am(III)/Nd(III) Interactions with Borate: Experimental Investigations of $Nd(OH)_3$(Micro Cr) Solubility in NaCl Solutions in Equilibrium with Borax. ERMS 568986. SAND2017-12040c.*

Xiong, Y.-L., L. Kirkes, J. Knox, C. Marrs, and H. Burton. 2017d. Experimental Determination of Solubilities of Magnesium Borates: Solubility Constants of Boracite [$Mg_3B_7O_{13}Cl(Cr)$] and Aksaite [$MgB_6O_7(OH)_6.2H_2O(Cr)$]. ERMS 569134. SAND2017-10729j.*

Xiong, Y.-L., L. Kirkes, J. Knox, C. Marrs, and H. Burton. 2017e. Experimental Determination of Stability Constant of Ferrous Iron Borate Complex [$FeB(OH)_{4+}$] at 25 Degrees Celsius from Solubility Measurements. ERMS 569205. SAND2017-13064j.*

Xiong, Y.-L., L. Kirkes, S. Kim, C. Marrs, J. Knox, J. Dean, H.-R. Deng, and M. Nemer. 2017f. Absence of Mineral Colloids in High Ionic Strength Solutions Associated with Salt Formations: Experimental Determination and Applications to Nuclear Waste Management. Albuquerque, NM Sandia National Laboratories (Publication date: June 2017). SAND2017-6865b. ERMS 568340.*

Yalcintas, E., D.T. Reed, X. Gaona, and M. Altmaier. 2017. Impact of EDTA on the Solubility and Redox Behavior of Uranium Dilute to Concentrated NaCl Solutions. Poster presented at Migration 2017, Barcelona Spain (September 10-15, 2017). LA-UR 17-27827.

Zengotita, F., H.P. Emerson, T.M. Dittrich, J. Swanson, D.T. Reed. 2017. The Role of *Chromohalobacter* on Transport of Lanthanides and Cesium in the Dolomite Mineral System. LA-UR-17-30894.*

This page intentionally left blank.