
**UTAH DIVISION OF RADIATION CONTROL
ENERGYSOLUTIONS CLIVE LLRW DISPOSAL FACILITY
LICENSE NO: UT2300249; RML #UT 2300249**

**CONDITION 35 COMPLIANCE REPORT; APPENDIX A:
FINAL REPORT FOR THE CLIVE DU PA MODEL**

**SAFETY EVALUATION REPORT
VOLUME 1**

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**for Utah Department of Environmental Quality
195 North 1950 West
Salt Lake City, UT 84116**

**SC&A, Inc.
1608 Spring Hill Road, Suite 400
Vienna, VA 22314**

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ABBREVIATIONS AND ACRONYMS

°F	degrees Fahrenheit
α	van Genuchten alpha
ACRS	Advisory Committee on Reactor Safeguards
ALARA	as low as reasonably achievable
Am	americium
amsl	above mean sea level
Bi	bismuth
Bq/L	becquerels per liter
Bq/m ³	becquerels per cubic meter
Br ⁻	bromide
Ca ²⁺	calcium
CAC	Class A Combined
CAS	Class A South
CaUO ₄	calcium uranate
CAW	Class A West
CCD	complementary cumulative distribution
CFR	Code of Federal Regulations
Ci/g	curies per gram
Cl ⁻	chloride
CLSM	controlled low-strength material
cm	centimeter
cm ⁻¹	per centimeter
cm/day	centimeters per day
cm ² m ⁻²	square centimeters per square meter
cm/s	centimeter per second
cm ² /s, cm/sec	square centimeters per second
cm/yr	centimeter per year
CO ₂	carbon dioxide
CO ₃ ²⁻	carbonate

CQA/QC	construction quality assurance/quality control
DEQ	Utah Department of Environmental Quality
DOE	U.S. Department of Energy
DRC	Division of Radiation Control (Utah)
DTSA	Deep Time Supplemental Analysis
DU	depleted uranium
DUF ₆	depleted uranium hexafluoride
DUO ₃	depleted uranium trioxide
DU ₃ O ₈	triuranium octoxide depleted in U-235
DU PA	depleted uranium performance assessment
E _H	oxidation/reduction potential
EPA	U.S. Environmental Protection Agency
ES	EnergySolutions, LLC
ET	evapotranspiration
F ⁻	fluoride
FEPs	features, events, and processes
ft	foot/feet
ft ³	cubic feet
g cm ⁻³	grams per cubic centimeter
g/L	grams per liter
GDP	gaseous diffusion plant
GTG	GoldSim Technology Group
GWPL	groundwater protection level
GWQ	Ground Water Quality Discharge
HELP	Hydrologic Evaluation of Landfill Performance
hr/yr	hours per year
HYPRES	Hydraulic Properties of European Soils
I	iodine
IAEA	International Atomic Energy Agency
IRIS	Integrated Risk Information System
K ⁺	potassium
Kd	absorption coefficient

kg	kilogram
km	kilometers
KOH	potassium hydroxide
kPa	kilopascal
K_{sat}	saturated hydraulic conductivity
ky	one thousand years
IAEA	International Atomic Energy Agency
L	liter
LARW	low-activity radioactive waste
LLNL	Lawrence Livermore National Laboratory
LLRW	low-level radioactive waste
LLW	low-level waste [used in some figures and quoted passages]
LN	lognormal [distribution]
m	meter
m^3/yr	cubic meters per year
MCL	maximum contaminant level
mg	milligram
Mg	megagram
Mg^{2+}	magnesium
mg/kg-day	milligrams per kilogram per day
mg/L	milligram per liter
mm	millimeter
mm/yr	millimeters per year
mol/L	moles per liter
mrem/hr	millirem per hour
mrem/yr	millirem per year
mSv	millisievert
$\mu\text{Ci}/\text{m}^3$	microcuries per cubic meter
$\mu\text{g}/\text{L}$	micrograms per liter
Na^+	sodium
NCRP	National Council on Radiation Protection and Measurements
nCi/g	nanocuries per gram

NO ₃ ⁻	nitrate
NORM	naturally occurring radioactive material
Np	neptunium
NRC	U.S. Nuclear Regulatory Commission
OHV	off-highway vehicle
ORGDP	Oak Ridge Gaseous Diffusion Plant
Pa	protactinium
PAWG	Performance Assessment Working Group
Pb	lead
pCi	picocurie
pCi/g, pCi g ⁻¹	picocuries per gram
pCi/L	picocuries per liter
pCi/m ² -s, pCi m ⁻² s ⁻¹	picocuries per square meter per second
pCi/m ³	picocuries per cubic meter
pH	hydrogen ion concentration
Po	polonium
PORTS	Portsmouth Gaseous Diffusion Plant
ppb	parts per billion
Pu	plutonium
Ra	radium
rem/yr	rem per year
RfD	reference dose
RML	Radioactive Material License
Rn	radon
RO	reverse osmosis
s ⁻¹	per second
SD	standard deviation
sec/m ³	seconds per cubic meter
SE	standard error
SER	Safety Evaluation Report
SNL	Sandia National Laboratories
SO ₄ ²⁻	sulfate

Sr	strontium
SRS	Savannah River Site
STPP	sodium tripolyphosphate
SWCA	SWCA Environmental Consultants
Tc	technetium
TDS	total dissolved solids
TEDE	total effective dose equivalent
Th	thorium
U	uranium
U ₃ O ₈	triuranium octoxide
UAC	Utah Administrative Code
UF ₆	uranium hexafluoride
U(IV)	tetravalent-state uranium
UO ₂	uranium dioxide
UO ₂ (OH) ₂	aqueous uraninite
UO ₃	uranium trioxide
U(OH) ₄	uranium hydroxide
URCB	Utah Radiation Control Board
U.S.	United States of America
UTTR	Utah Test and Training Range
U(VI)	hexavalent-state uranium
wt%	weight percent
yd ³	cubic yards
yr	year

EXECUTIVE SUMMARY

ES-1 – Purpose

The purpose of this Safety Evaluation Report (SER) is to determine the extent to which the depleted uranium performance assessment (DU PA) submitted by EnergySolutions, LLC (EnergySolutions) on June 1, 2011 (Neptune 2011), and revised on June 5, 2014 (Neptune 2014a), complies with the requirements of Utah Administrative Code (UAC) R313-25-9(5)(a) and other relevant regulations. If the DU PA is approved, amendments to EnergySolutions' license and groundwater permit will be required before depleted uranium (DU) may be disposed of at the facility. Those amendments would be addressed in separate licensing and permitting actions.

ES-2 – Background

EnergySolutions operates a low-level radioactive waste (LLRW) disposal facility west of the Cedar Mountains in Clive, Utah. The Clive Site has been used for radioactive waste management since 1985. EnergySolutions has been the Clive Site's Licensee since 2006. EnergySolutions is currently licensed to receive, store, and dispose, by land burial, the following categories of radioactive materials and waste: naturally occurring and accelerator-produced radioactive material waste, low-activity radioactive waste, Class A LLRW, special nuclear material, 11.e.(2) byproduct waste (e.g., uranium mill tailings), radioactive waste that is also determined to be hazardous (mixed waste), and naturally occurring radioactive material.

In October 2008, 5,800 drums containing DU (Class A waste) from the U.S. Department of Energy's (DOE's) Savannah River Site were sent to the EnergySolutions facility at Clive for disposal. Additionally, it was learned that DOE intended to dispose of a large quantity of DU [~700,000 megagrams (Mg); Neptune 2014d, Section 2.0] at the EnergySolutions Clive facility.

Amendments to existing Utah and federal regulations were found to be necessary to cover disposal of DU waste because DU was not considered when the U.S. Nuclear Regulatory Commission (NRC) conducted studies to determine how radioactive waste should be classified [see Title 10 of the Code of Federal Regulations (10 CFR) Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." and associated draft and final environmental impact statements, specifically, NUREG-0782 and NUREG-0945], and because, unlike other kinds of low-level radioactive waste, DU becomes more radioactive with time, not less, because of natural decay into other radionuclides. DU waste is relatively benign initially but becomes more radioactive with time due to the in-growth of daughter products, reaching peak radioactivity more than two million years into the future. Consequently, on March 2, 2010, the Utah Department of Environmental Quality (DEQ) imposed Condition 35 on the EnergySolutions Radioactive Material License to cover disposal of large amounts of DU at the Clive Site. License Condition 35 consists of five parts: (a) uranium concentration and burial depth, (b) performance assessment, (c) revised disposal embankment design, (d) remediation, and (e) surety. Many of the requirements of License Condition 35 were later codified into UAC R313-25-9(5)(a).

Federal Cell Design

EnergySolutions plans to dispose of the DU in a proposed Federal Cell at the Clive Site. EnergySolutions will construct the Federal Cell embankment to the west of the existing "11e.(2)" cell, which is dedicated to the disposal of uranium-processing byproduct waste.

The proposed Federal Cell embankment is a hipped cap, with relatively steeper sloping sides nearer the edges. The upper part of the embankment, known as the “top slope,” has a moderate slope (2.4 percent), while the side slope is markedly steeper (33 percent grading downward to 20 percent). EnergySolutions intends to dispose of DU only beneath the top slope areas of the embankment, with no DU beneath the side slopes. DU waste will be disposed of below the native grade level of the proposed Federal Cell.

An evapotranspiration (ET)¹ cover system is to be constructed above the waste in order to limit contact of water with the waste. The cover is sloped to promote runoff and designed to limit water infiltration by increasing evapotranspiration. Beginning at the top of the cover, the layers above the waste used for the ET cover design are as follows (Neptune 2014b):

- **Surface Layer:** This layer is composed of native vegetated silty clay with 15 percent gravel mixture on the top slope. The intended functions of this layer are to control runoff, minimize erosion, and maximize water loss from evapotranspiration. This layer of silty clay provides storage for water accumulating from precipitation events, enhances losses due to evaporation, and provides a rooting zone for plants that will further decrease the water available for downward movement.
- **Evaporative Zone Layer:** This layer is composed of silty clay. The purpose of this layer is to provide additional storage for precipitation and additional depth for the plant rooting zone to maximize evapotranspiration.
- **Frost Protection Layer:** This material ranges in size from 16 inches to clay-size particles. The purpose of this layer is to protect layers below from freeze/thaw cycles, wetting/drying cycles, and to inhibit plant, animal, or human intrusion.
- **Upper Radon Barrier:** This layer consists of compacted clay with a low hydraulic conductivity. This layer has the lowest conductivity of any layer in the cover system. This is a barrier layer that reduces the downward movement of water to the waste and the upward movement of gas out of the disposal cell.
- **Lower Radon Barrier:** This layer consists of compacted clay with a low hydraulic conductivity. This is a barrier layer placed directly above the waste that reduces the downward movement of water.

Directly beneath the lower radon barrier of the ET cover would be about 36 feet of non-DU material. For the purposes of the present Clive DU PA and this SER, it has been assumed that this non-DU material would be non-radioactive. However, EnergySolutions retains the option of using this space to dispose of ordinary, non-DU, LLRW. Should EnergySolutions decide to implement this option, DEQ would require EnergySolutions to perform an additional performance assessment, as required by UAC R313-25-9(5)(a).

The DU waste would be buried beneath the non-DU material. The DU would be placed in the Federal Cell in either cylinders or drums. The drums would be placed in a single layer on pallets, and the cylinders would be either in a single layer or stacked two layers high.

¹ Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

The waste would be placed on a clay liner constructed of compacted local clay and be uniformly about 60 centimeters (2 feet) thick by design. The bottom of the waste cell would have a gentle slope to it.

ES-3 – Depleted Uranium

DU is a waste byproduct of the process used to enrich natural uranium for use in nuclear reactors and nuclear weapons. Natural uranium is composed primarily of two isotopes: uranium-235 (U-235) and U-238. For the types of nuclear power plants operating in the United States, the relative concentration of U-235 in the fuel material needs to be increased (or enriched), resulting in a waste product that is *depleted* in U-235.

When U-238 decays, it produces a series of products that are other uranium radionuclides or radionuclides of other elements, including thorium, protactinium, radium, radon, polonium, lead, and bismuth. In nature, U-238 is in equilibrium with its decay products, meaning that the radioactivity of the decay products is decreasing according to the half-life of U-238.

When uranium is purified in preparation for being used as nuclear reactor fuel, all of its decay products are chemically removed from the DU. Over time, the decay products will build back up in the DU and reestablish approximate secular equilibrium with U-238. The time it takes to reestablish equilibrium with U-238 is directly proportional to the decay product's half-life. Because many of DU's decay products have very long half-lives, *EnergySolutions* has calculated that equilibrium will take millions of years to achieve (ES 2014b).

The result of this buildup of decay products is that, over long time periods, DU becomes more radioactive, rather than less.

ES-4 – Clive Depleted Uranium Performance Assessment

UAC Rule R313-25-9(5)(a) requires that any facility that proposes to dispose of significant quantities of DU must submit a performance assessment demonstrating by modeling that the performance standards specified by the NRC and the State of Utah will be met for a minimum of 10,000 years and that additional simulations be performed for the period when the peak dose occurs (which will be well beyond 10,000 years), with the results of the latter simulations analyzed qualitatively. This requirement is embedded in *EnergySolutions'* Radioactive Materials License UT2300249, Amendment 14, Condition 35B (ES 2013).

In response to this requirement, *EnergySolutions* submitted its DU PA on June 1, 2011 (version 1.0, Neptune 2011), and a revised version on June 5, 2014 (Neptune 2014a, hereafter referred to as "version 1.2" or "v1.2").

ES-5 – Regulations Governing This Review of the Depleted Uranium Performance Assessment

The performance standards that a DU waste disposal site must meet are contained in the NRC's 10 CFR Part 61. As an NRC Agreement State, Utah has established its own regulations in UAC R313, "Environmental Quality, Radiation Control," which are nearly identical to the NRC's. In this SER, DEQ evaluated the *EnergySolutions* performance assessment primarily against the following applicable Federal and Utah regulations:

Table ES-1 – Regulations Governing the DU Performance Assessment

Code of Federal Regulations (CFR)	Utah Administrative Code (UAC)	Areas Covered by the Regulation
10 CFR 61.12	R313-25-8	Specific technical information
—	R313-25-9(5)(a)	Deep time analysis
10 CFR 61.41	R313-25-20	Protection of the general population from releases of radioactivity
10 CFR 61.42	R-313-25-21	Protection of individuals from inadvertent intrusion
10 CFR 61.44	R313-25-23	Stability of the disposal site after closure

Review with respect to other UAC regulations not cited in Table ES-1 was done as needed.

The DU PA prepared by EnergySolutions also considered topics outside the purview of these NRC and UAC regulations, including uranium oral toxicity and Utah groundwater protection levels (GWPLs).

ES-6 – DEQ’s Evaluation of the Clive Depleted Uranium Performance Assessment

This SER describes in detail the analyses that DEQ and its contractor, SC&A, Inc., performed to determine whether the EnergySolutions performance assessment meets these Federal and Utah performance criteria. It is based on review of Versions 1.0 and 1.2 of the *Final Report for the Clive DU PA Model* (Neptune 2011, 2014a; hereafter “DU PA v1.0” and “DU PA v1.2,” respectively) and its supporting appendices, the Compliance Report [Revision 0 (ES 2011), Revision 1 (ES 2013), and Revision 2 (ES 2014a)], and consideration of EnergySolutions’ responses to 194 interrogatories submitted by DEQ (Rounds 1, 2, and 3 dated February 28, 2014, March 27, 2014, and July 1, 2014, respectively, and the supplementary interrogatories of August 11, 2014). The evaluation also included independent calculations and analyses conducted by the DEQ contractor on selected topics.

The SER evaluates the following areas:

Specific Technical Information

UAC Rule R313-25-8 requires the DU PA to include certain kinds of technical information. This SER evaluates the following technical information provided in the DU PA for facilities of this kind (DEQ’s findings on these matters are located in Section 4.1 of the SER):

- Principal design features (including the ET cover, waste placement and backfill, and the clay liner) [R313-25-8(2)]
- Kind, amount, classification, and specifications of the material being disposed [R313-25-8(9)]
- Quality assurance of the GoldSim computer model used to calculate the performance of the proposed Federal Cell [R313-25-8(10)]
- Uranium solubility [R313-25-8(4)]

Protection of the General Population from Releases of Radioactivity

UAC Rule R313-25-20 specifies the maximum radiation doses that members of the public may receive from concentrations of radioactive material that are released to the general environment in groundwater, surface water, air, soil, plants, or animals. DEQ evaluated the DU PA Model's calculations of the potential doses to members of the general public at various nearby locations and through a range of possible exposures, including inhalation (wind-derived dust, mechanically-generated dust, and radon), inadvertent ingestion of surface soils, ingestion of beef, exposure to contaminated groundwater, and external irradiation (soil and immersion in air). (DEQ's findings on these matters are located in Section 4.2 of the SER.)

Protection of Individuals from Inadvertent Intrusion

UAC Rule R-313-25-21 states that the design, operation, and closure of the land disposal facility shall ensure protection of any individuals inadvertently intruding into the disposal site and occupying the site or contacting the waste after active institutional controls over the disposal site are removed (around 100 years after closure). DEQ evaluated a range of inadvertent exposure scenarios described in the DU PA for industrial workers, ranch workers, hunters, and off-highway vehicle enthusiasts. Due to the quality of the groundwater in the Clive area, EnergySolutions did not calculate potential doses due to groundwater ingestion. However, DEQ has examined the potential for doses to occur to inadvertent intruders via groundwater ingestion. (DEQ's findings on these matters are located in Section 4.3 of the SER.)

Stability of the Disposal Site after Closure

UAC Rule R313-25-23 states that the disposal facility shall be sited, designed, used, operated, and closed to achieve long-term stability of the disposal site and to eliminate, to the extent practicable, the need for ongoing active maintenance of the disposal site following closure so that only surveillance, monitoring, or minor custodial care are required. DEQ evaluated the DU PA's analysis of the following long-term influences on the stability of the site, especially its cover, including infiltration, erosion of the cover, effects of plants and animals, and frost damage. (DEQ's findings on these matters are located in Section 4.4 of the SER.)

Deep Time Analysis

UAC Rule R313-25-9(5)(a) requires that a performance assessment provide additional simulations for the time period when the peak dose occurs at the disposal site. Because DU becomes more radioactive as time passes, DEQ evaluated the DU PA's "deep time" analysis of possible environmental changes and their effects on the site up to the time when the peak dose occurs. (DEQ's findings on these matters are located in Section 5.1 of the SER.)

Uranium Oral Toxicity

Although not specifically required by UAC R313-25-9(5)(a), in the DU PA EnergySolutions analyzed whether ingestion of uranium could cause non-carcinogenic biological damage, such as kidney failure. DEQ evaluated this analysis in the SER. (DEQ's findings on these matters are located in Section 5.2 of the SER.)

Compliance with Utah Groundwater Protection Levels

Ground Water Quality Discharge Permit Number UGW450005 for the Clive site specifies that it meet Utah GWPLs for uranium and various radionuclides for 500 years. The EnergySolutions

DU PA analyzed whether the GWPLs would be met at the Clive site after DU disposal. DEQ evaluated the DU PA's assessment of this requirement. (DEQ's findings on these matters are located in Section 5.3 of the SER.)

A summary of all DEQ interrogatories to *EnergySolutions* related to these topics is included in Appendix C.

ES-7 – Summary of Conclusions

All conclusions in the SER, including determinations that issues have been resolved, conditionally resolved, or not resolved, are tentative in that they are subject to notice and comment and reconsideration by the agency in light of comments made during the public comment period and the record as a whole.² A final approval of the DU PA will also be subject to the specific conditions described in Section 6 of the SER.

Conclusions

Resolved: The DEQ evaluation found that for the following topics the *EnergySolutions* DU PA satisfactory met the required regulatory criteria, and these topics have been resolved:

- UAC R313-25-7(3)(c); R313-25-8(2)–(3); R313-25-9(5)(a); R313-25-19: Uranium Solubility
- UAC R313-25-20: Protection of the General Public from Releases of Radioactivity
- UAC R313-25-21: Protection of Individuals from Inadvertent Intrusion
- U.S. Environmental Protection Agency's 40 CFR 141.66: Uranium Oral Toxicity

Conditionally Resolved: The DEQ evaluation found that for the following topics the *EnergySolutions* DU PA satisfactorily met the required regulatory *criteria*, and the following topics can be resolved, based upon the demonstration that the “Additional Conditions for Approval” listed below have been met:

- UAC R313-25-8(9): Kind, Amount, Classification, and Specifications of the Material
- UAC R317-6-4; Ground Water Quality Discharge Permit UGW450005: Compliance with Groundwater Protection Levels
- UAC R313-25-8(2), (3), (5), (6), and (10); R313-25-26(4), (5), and (10): Waste Emplacement and Backfill

Not Resolved: The DEQ evaluation found that, for the following topics, the *EnergySolutions* DU PA has not satisfied all of the Department's concerns and the topics are not resolved at this time (the principal concerns are shown in parentheses):

² “Resolved” means that a determination has been made that there is sufficient information to demonstrate that this requirement will be met. “Conditionally resolved” means that a determination has been made that there is sufficient information to demonstrate that this requirement will be met, provided that the applicable condition is also met. “Not resolved” means that a determination has been made that sufficient information has not yet been provided to DEQ to demonstrate that this requirement will be met. “Not resolvable” means that there is sufficient information to show that this condition cannot be met.

- UAC R313-25-8(2) and (3): Evapotranspiration Cover (lack of correlation between the alpha and hydraulic conductivity values, etc.)
- UAC R313-25-8(2): Infiltration (lack of correlation between the alpha and hydraulic conductivity values, etc.)
- UAC R313-25-25: Erosion of Cover (clarification of certain issues relating to Appendix 10 to the DU PA version 1.2, June 5, 2014)
- UAC R313-25-25(3) and (4): Frost Damage (need to resolve concerns with assumed recurrence intervals, estimated frost penetration depths, and hydraulic property estimates)
- UAC R313-25-24(3) and (4): Effect of Biologicals on Radionuclide Transport (need to account for natural increases in cover permeability over time)
- UAC R313-25-8(2): Clay Liner (lack of increase in K_{sat} values over time; lack of correlation between the alpha and hydraulic conductivity values)
- UAC R313-25-8(10): GoldSim Quality Assurance [the relationship between the process level model (i.e., HYDRUS) abstractions and the primary model (i.e., GoldSim) results needs to be demonstrated]
- UAC R313-25-9(5)(a): Deep Time Analysis

Not Resolvable: The DEQ evaluation found that, at this time, no topics in the *EnergySolutions* DU PA cannot be resolved because of affirmative information that standards cannot be met.

Additional Conditions for Approval

In addition, the following are conditions that *EnergySolutions* must agree to meet before final DEQ approval can be given (see Section 6.2 of the SER for more information):

- Condition 1: Agreement with DOE.
Prior to disposal of DU waste, *EnergySolutions* shall provide a written agreement letter between DOE and *EnergySolutions* indicating that DOE will accept title to the Federal Cell after closure.
- Condition 2: Disposal below grade.
DU waste must be disposed of below the original-grade level of the proposed Federal Cell.
- Condition 3: Depleted uranium will continue to be Class A waste.
EnergySolutions shall provide documentation that the NRC does not plan to reclassify DU.
- Condition 4: Remainder of waste will be modeled.
EnergySolutions shall submit for DEQ approval a revised performance assessment that addresses the total quantities of concentrated DU and other wastes as described in UAC R313-25-9(5)(a) before any radioactive wastes other than the DU waste are emplaced in the proposed Federal Cell.

- Condition 5: Waste Acceptance Criteria.
Prior to any land disposal of significant quantities of concentrated DU, the Licensee shall submit a written Waste Acceptance Criteria plan designed to ensure that all DU waste received by the Licensee conforms with all physical, chemical, and radiologic properties assumed in the DU PA modeling report.
- Condition 6: Prohibition of recycled uranium in DU waste.
The Licensee is prohibited from land disposal of any quantity of DU waste that was produced at DOE facilities from uranium-bearing materials containing recycled uranium.
- Condition 7: Hydrological and hydrogeological properties of lower confined aquifer.
The Licensee shall develop and implement a program to provide more detailed site characterization and hydrogeologic evaluation of aquifers in the area, especially the deeper confined aquifer.

ES-8 References

- Division of Radiation Control (DRC), Utah Department of Environmental Quality, 2014. “License Amendment No. 16: Radioactive Material License UT 2300249,” May 12. Available at <http://www.deq.utah.gov/businesses/E/EnSolutions/docs/2014/05May/Amend16finalandPPS.pdf>
- EnergySolutions, LLC (ES), 2011. “Utah Low-Level Radioactive Waste Disposal License – Condition 35 (RML UT2300249) Compliance Report,” June 1.
- EnergySolutions, LLC (ES), 2013. *Utah Radioactive Material License – Condition 35 (RML UT2300249) Compliance Report (Revision 1)*, November 8.
- EnergySolutions, LLC (ES), 2014a. “RML UT2300249 – Condition 35 Compliance Report – Revision 2,” July 8.
- EnergySolutions, LLC (ES), 2014b. “Responses to 28 February 2014 – Round 1 Interrogatories, Utah LLRW Disposal License RML UT 2300249 Condition 35 Compliance Report,” March 31.
- Neptune and Company, Inc., 2011. *Final Report for the Clive DU PA Model version 1.0*, June 1, 2011. (Appendix A to EnergySolutions, *Utah Low-Level Radioactive Waste Disposal License – Condition 35 (RML UT2300249) Compliance Report*, June 1, 2011).
- Neptune and Company, Inc., 2014a. *Final Report for the Clive DU PA Model, Clive DU PA Model v1.2*, June 5.
- Neptune and Company, Inc., 2014b. *Conceptual Site Model for Disposal of Depleted Uranium at the Clive Facility*, NAC-0018_R1, June 5, 2014 (Appendix 2 to Neptune 2014a).
- Neptune and Company, Inc., 2014c. *Embankment Modeling for the Clive DU PA Model v1.2*, NAC-0019_R1, June 5, 2014 (Appendix 3 to Neptune 2014a).
- Neptune and Company, Inc., 2014d. *Radioactive Waste Inventory for the Clive DU PA Model v1.2*, NAC-0023_R1, June 5, 2014 (Appendix 4 to Neptune 2014a).

1.0 INTRODUCTION

Utah Administrative Code (UAC) Rule R313-25-9,³ “Technical Analyses,” requires that any facility that proposes to dispose of significant quantities of depleted uranium (DU) must submit a performance assessment demonstrating that the performance standards specified by the U.S. Nuclear Regulatory Commission (NRC) in Title 10 of the Code of Federal Regulations (10 CFR) Part 61, “Licensing Requirements for Land Disposal of Radioactive Waste,” and corresponding State of Utah rules will be met for a minimum of 10,000 years and that additional simulations be performed for the period when the peak dose occurs (which will be well beyond 10,000 years) and the results of the additional simulations be analyzed qualitatively. The specific language of the rule is as follows:

R313-25-9. Technical Analyses

(5)(a) Notwithstanding Subsection R313-25-9(1), any facility that proposes to land dispose of significant quantities of concentrated depleted uranium (more than one metric ton in total accumulation) after June 1, 2010, shall submit for the Director's review and approval a performance assessment that demonstrates that the performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules will be met for the total quantities of concentrated depleted uranium and other wastes, including wastes already disposed of and the quantities of concentrated depleted uranium the facility now proposes to dispose. Any such performance assessment shall be revised as needed to reflect ongoing guidance and rulemaking from NRC. For purposes of this performance assessment, the compliance period shall be a minimum of 10,000 years. Additional simulations shall be performed for the period where peak dose occurs and the results shall be analyzed qualitatively.

This requirement is embedded in EnergySolutions, LLC’s (EnergySolutions’) Radioactive Material (RML) License UT2300249 (Amendment 14, Condition 35; DRC 1989), which states that:

A. In accordance with UAC R313-25-8, effective June 1, 2010 the Licensee shall not dispose of significant quantities of concentrated depleted uranium prior to the approval by the Director of the performance assessment required in R313-25-8. [Now R313-25-9].

B. Performance assessment: A performance assessment, in general conformance with the approach used by the Nuclear Regulatory Commission (NRC) in SECY-08-0147, shall be submitted for Director review and approval no later than June 1, 2011. The performance assessment shall be revised as needed to reflect ongoing guidance and rulemaking from NRC. For purposes of this performance assessment, the compliance period will be a minimum of 10,000 years. Additional

³ A new Section 6, “Director Review of Application,” was added to R313-25 in April 2014. Thus all references to R313-25 Sections 6 to 28 in prior documents are now to Sections 7 to 29.

simulations will be performed for a minimum 1,000,000-year time frame for qualitative analysis.

C. Revised disposal embankment design: If the performance assessment specified in paragraph 35.B indicates that changes to disposal operations and cover design are necessary to ensure compliance with the requirements of 10 CFR Part 61 or Utah Administrative Code R313, EnergySolutions will provide a revised design that does meet those requirements, for all wastes that have been and are reasonably anticipated to be disposed of at the facility; the revised design will be submitted within 180 days of Director approval of the performance assessment.

D. Remediation: If following the completion of DRC's review of the performance assessment described in paragraph 35.B, the disposal of DU as performed after the date of this license condition would not have met the requirements of the performance assessment, the facility will undertake remediation to ensure that the performance standards are met, or if that is not possible, shall remove the DU and transport it off-site to a licensed facility.

E. Surety: The Licensee shall fund the surety for the remediation, in License Condition 35.D. Within 30-days of the effective date of this license condition, the licensee shall submit for Director review and approval, the surety cost estimates for remediation of existing Savannah River DU waste disposal and planned, similar large quantity DU waste disposal.

The purpose of this Safety Evaluation Report (SER) is to determine the extent to which the depleted uranium performance assessment (DU PA) submitted by EnergySolutions on June 1, 2011 (Neptune 2011b), and revised on June 5, 2014 (Neptune 2014a), complies with the requirements of UAC R313-25-9(5)(a). In particular, the DU PA evaluates disposal of DU at the EnergySolutions facility at Clive, Utah.

“Performance standards” is not defined in 10 CFR Part 61 or in the corresponding Utah rules. However, DEQ notes that SECY-13-0075, Enclosure 2, “Draft Regulatory Analysis for Proposed Rule: Low-Level Radioactive Waste Disposal (10 CFR Part 61),” Section 1.2, states that “10 CFR Part 61, Subpart C, contains performance objectives, which set standards” (NRC 2013a, page 3), so it is reasonable to assume that the “performance standards” referred to in UAC R313-25-9(5)(a) are set by the NRC’s 10 CFR Part 61, Subpart C “performance objectives.”

For purposes of this SER, the Utah Department of Environmental Quality (DEQ) has defined “performance standards” as those contained in the relevant portions of Subpart C, “Performance Objectives,” of 10 CFR Part 61: Section 61.41, “Protection of the General Population from Releases of Radioactivity” (corresponding to UAC Rule R313-25-20); Section 61.42, “Protection of Individuals from Inadvertent Intrusion” (corresponding to UAC Rule R313-25-21); and Section 61.44, “Stability of the Disposal Site after Closure” (corresponding to UAC Rule R313-

25-23).⁴ The NRC performance objective specified in 10 CFR 61.43, “Protection of Individuals during Operations [corresponding to UAC Rule R313-25-22 and also required under UAC Rule R313-25-9(4)(c)], was not addressed in depth in the DU PA. However, *EnergySolutions* discussed this performance standard in some detail in Section 3.3 of Revision 1 to its “Utah Radioactive Material License – Condition 35 (RML UT2300249) Compliance Report,” dated November 8, 2013, (ES 2013b).

In addition, NRC regulations in 10 CFR 61.12, “Specific Technical Information” (corresponding to UAC Rule R313-25-8) and 10 CFR 61.13, “Technical Analyses” (corresponding to UAC Rule R313-25-9), provide supporting data necessary to demonstrate compliance with the performance standards; therefore, they are included in this SER. Sections of NRC regulation 10 CFR 61.12 judged not to be relevant to the DU PA include sub-sections 61.12(k), (l), (m), and (n). Technical information specified in these sub-sections constitutes generic requirements typically considered in disposal of any radioactive material. Hence, these issues have already been considered and approved by the Division of Radiation Control (DRC) Director (hereafter “the Director”) in previous requests for license amendment. Several other NRC regulations in 10 CFR Part 61, Subpart D underlie and support the “performance standards” for low-level radioactive waste (LLRW) disposal; some of these include: 10 CFR 61.50, “Disposal Site Suitability Requirements for Land Disposal”; 10 CFR 61.51, “Disposal Site Design for Land Disposal”; and 10 CFR 61.52, “Land Disposal Facility Operation and Disposal Site Closure” [specifically, paragraph (a)]. Again, these are generic requirements that have been addressed in previous licensing actions.

Section 4.1 of this SER evaluates the DU PA in relation to 10 CFR 61.12 (and UAC Rule R313-25-8, “Specific Technical Information”); Section 4.2 evaluates it in relation to 10 CFR 61.41 (and R313-25-20, “Protection of the General Population from Releases of Radioactivity”); Section 4.3 in relation to 10 CFR 61.42 (and R313-25-21); and Section 4.4 in relation to 10 CFR 61.44 (and UAC Rule R313-25-23, “Stability of the Disposal Site after Closure”). The technical analyses required under 10 CFR 61.13 (and UAC Rule R313-25-9), 10 CFR 61.50, 10 CFR 61.51, and relevant portions of 10 CFR 61.53 are discussed in detail in all of these sections; consequently, there is no need to address these separately in this SER.

For the reader’s convenience, Appendix A to this SER includes the text of the key cited regulations.

Section 5.1 discusses the deep time analysis required under UAC Rule R313-25-9(5)(a); specifically, that “*Additional simulations shall be performed for the period where peak dose occurs and the results shall be analyzed qualitatively.*”

The DU PA prepared by *EnergySolutions* also considered topics outside the purview of these NRC and UAC regulations, including uranium toxicity and Utah groundwater protection levels (GWPLs). This SER evaluates these topics in Sections 5.2 and 5.3, respectively.

⁴ To be consistent with R313-25-9(5)(a), which lists “performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules,” this SER lists the relevant NRC regulations first, followed by the State of Utah regulations

This SER relies on currently available information. However, the technology of in-ground waste disposal is continuously evolving. As will be subsequently discussed in this SER, several issues have been identified relating to the evapotranspiration (ET) cover to be placed on the proposed Federal Cell. These issues will need to be resolved before any license amendment related to DU waste disposal at Clive can be approved. If such approval is granted by DEQ, the approval will be based on an assessment of many uncertainties addressed in performance assessment and a determination that such uncertainties will not compromise the designed function of DU disposal embankment.

It should be noted that this SER applies only to approval/disapproval of the DU PA as required by UAC Rule R313-25-9(5)(a). That regulation does not consider “other wastes,” which must be addressed in a separate performance assessment. If the DU PA performance assessment is approved, it is expected that the next step in the regulatory process would be submission of a proposed license amendment for review by DEQ.

*References*⁵

DRC, 1989

ES, 2013b

Neptune, 2011b; 2014a

NRC, 2013a

1.1 TIMELINE OF KEY DEQ REVIEW ACTIVITIES

The timeline of the key DEQ review activities related to the DU PA, and used to develop input to this SER, is as follows:

- June 1, 2011 – EnergySolutions delivers an initial version of the DU PA. The initial package consists of the Compliance Report, Appendix A to the Compliance Report [*Final Report for the Clive DU PA Model* (hereafter “DU PA Model”), *version 1.0*], and 17 appendices to the Final Report dealing with specific technical areas such as unsaturated zone modeling, geochemical modeling, conceptual site model, and others.
- August 15, 2013 – DEQ contracts with SC&A, Inc. (SC&A) to provide technical support in reviewing the DU PA (August 15, 2013).
- October 28, 2013 – DEQ provides comments based on its preliminary completeness review of the DU PA to EnergySolutions.
- November 8, 2013 – EnergySolutions submits CD13-0302. The submittal contains both Revision 1 to the Compliance Report and partial responses to the Preliminary Completeness Review (later designated Appendix B in the EnergySolutions July 8, 2014, submittal).

⁵ All short reference lists at the ends of sections refer to the full References list in Chapter 7.

- November 13, 2013 – DEQ hosts open house meeting for public interaction on the review process.
- December 11, 2013 – DEQ provides *EnergySolutions* with feedback on Revision 1 to the Compliance Report and on its responses to the Preliminary Completeness Comments.
- February 28, 2014 – DEQ delivers Round 1 Interrogatories to *EnergySolutions*.
- March 31, 2014 – *EnergySolutions* delivers a partial response to Round 1 Interrogatories (CD14-0084). Because *EnergySolutions* determined that the initially-proposed rock armor cover for the proposed Federal Cell should be replaced by an ET cover, some interrogatories could not be addressed until a revised DU PA based on the ET cover was completed (later submitted by *EnergySolutions* on June 5, 2014).
- May 27, 2014 – DEQ provides Round 2 Interrogatories to *EnergySolutions*.
- June 5, 2014 – *EnergySolutions* delivers Version 1.2 of the Clive DU PA Model and revised supporting appendices. Version 1.2 is based on the ET cover and addresses responses to some of the prior interrogatories.
- June 17, 2014 – *EnergySolutions* delivers responses to Round 2 Interrogatories (CD14-0132).
- July 1, 2014 – DEQ provides *EnergySolutions* with Round 3 Interrogatories. The Round 3 Interrogatories focus on Version 1.2 of the Clive DU PA Model (June 5, 2014) and consider the *EnergySolutions* responses to the Round 2 Interrogatories (June 17, 2014) only to a limited extent.
- July 8, 2014 – *EnergySolutions* provides DEQ with RML UT2300249, Condition 35 Compliance Report Revision 2 and responses to DEQ Round 3 Interrogatories.
- July 14, 2014 – DEQ provides *EnergySolutions* with a White Paper on deep time analysis prepared by SC&A regarding radon emissions in the event of a return of a pluvial lake on the Clive site (and its possible effects on the DU disposal cell).
- August 5, 2014 – *EnergySolutions* submits a Deep Time Supplemental Analysis for the Clive DU PA (Clive DU PA Model vDTSA).
- August 11, 2014 – DEQ provides *EnergySolutions* with supplementary interrogatories.
- August 18, 2014 – *EnergySolutions* provides DEQ with responses to DEQ supplementary interrogatories.
- February 6, 2015 – *EnergySolutions* provides DEQ with Supplemental Responses dealing with site-specific clay studies pertinent to both the SempraSafe and DU PAs.
- March 10, 2015 – *EnergySolutions* submits revised Deep Time Supplemental Analyses for the Clive DU PA.

This SER is based on review of Versions 1.0 and 1.2 of the *Final Report for the Clive DU PA Model* (Neptune 2011b, 2014a) and its supporting appendices, the Compliance Report [Revision 0 (ES 2011b), Revision 1 (ES 2013b), and Revision 2 (ES 2014c)], and consideration of *EnergySolutions*' responses to 194 interrogatories submitted by DEQ, in documents dated

February 28, 2014, March 27, 2014, and July 1, 2014, respectively, as well as the supplementary interrogatories of August 11, 2014, which can be found in the SER Appendix B, “Supplemental Interrogatories Pertaining to the Evapotranspiration Cover”). The review also included independent calculations and analyses conducted by the DEQ contractor on selected topics. Appendix C discusses the status of resolution of all other interrogatories.

References

ES, 2011b; 2013b; 2014c

Neptune, 2011b; 2014a

1.2 FORMAT OF THE SAFETY EVALUATION REPORT

DEQ’s review findings on the Clive DU PA are included in this SER. The format of the SER is as follows:

- Section 1.0 Provides an introduction to the SER, including its purpose, important regulations, and the timeline for the development of the Clive DU PA.
- Section 2.0 Provides an historical overview of the activities that have occurred at the site of the Clive facility since it was first used by the U.S. Department of Energy (DOE) and the State of Utah between 1984 and 1988 for the disposal of Vitro Mill tailings, and thereafter for the Envirocare period, which ran from 1988 to 2006, and finally for the EnergySolutions facility.
- Section 3.0 Provides background information that DEQ felt would be useful to individuals who may not have it otherwise readily available. This includes a description of DU, the regulatory bases for disposing of DU at the Clive facility, an introduction to the Clive facility, and an introduction to how the Clive DU PA Model was developed.
- Section 4.0 Provides DEQ findings and safety evaluations of whether or not the Clive DU PA demonstrates that the performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules have been met, as is required by UAC R313-25-9(4) and R313-25-9(5)(a).

The subsections within Section 4 have been structured to correspond to the 10 CFR Part 61 and UAC R313-25 performance standards:

Section 4.1	10 CFR 61.12 – Specific technical information	UAC Rule R313-25-8
Section 4.2	10 CFR 61.41 – Protection of the general population from releases of radioactivity	UAC Rule R313-25-20
Section 4.3	10 CFR 61.42 – Protection of individuals from inadvertent intrusion	UAC Rule R-313-25-21
Section 4.4	10 CFR 61.44 – Stability of the disposal site after closure	UAC Rule R313-25-23

- Section 5.0 Provides additional DEQ findings and safety evaluations of whether or not the

Clive DU PA demonstrates that the public’s health and safety and the environment will be protected.

The criteria that have been evaluated within Section 5 are as follows:

Section 5.1 Deep Time Analysis: The deep time analysis is specifically required by UAC Rule R313-25-9(5)(a).

Section 5.2 Uranium Oral Toxicity: Because uranium is chemically as well as radiologically toxic, a uranium oral toxicity evaluation has been included pursuant to the U.S. Environmental Protection Agency’s (EPA’s) 40 CFR 141.66.

Section 5.3 Compliance with GWPLs: Compliance with the GWPLs is specified in the Clive facility’s Ground Water Quality Discharge Permit #UGW450005 (hereafter referred to as the “GWQ Permit”).

Section 6.0 Provides a summary of all of the conclusions reached in Sections 4 and 5, as well as an overall recommendation as to whether the Clive DU PA should be accepted, accepted with conditions, or denied.

Section 7.0 Provides a list of documents referred to in the SER.

Appendix A Provides the text of relevant federal and Utah regulations for the reader’s reference.

Appendix B Provides a discussion of supplemental interrogatories pertaining to the modeling of the ET cover.

Appendix C Provides a summary of DEQ interrogatories and their current status.

Appendix D Provides a summary of the applicability of transuranic limitations in the Northwest Interstate Compact on Low-Level Radioactive Waste Management.

Appendix E Describes a method for simulating the hydrology of the water balance cover.

Appendix F Responds to EnergySolutions’ February 2015 report on the impacts of freeze-thaw on the hydraulic conductivity of the clay barriers used on the ET cover.

Appendix G Provides an interpretation of the Huntsman Agreement by the State of Utah Assistant Attorney General.

Appendix H Provides a summary of historical and current understanding about the deep aquifer in the vicinity of the proposed Federal Cell.

2.0 HISTORICAL OVERVIEW

EnergySolutions is licensed by the State of Utah to receive, store, and dispose, by land burial, the following categories of radioactive materials and waste:

- Naturally occurring and accelerator produced radioactive material waste
- Low-activity radioactive waste (LARW)
- Class A LLRW
- Special nuclear material (in trace quantities only)
- 11.e.(2) byproduct waste (e.g., uranium mill tailings)
- Radioactive waste that is also determined to be hazardous (mixed waste)
- Naturally occurring radioactive material (NORM)

EnergySolutions holds the following licenses and permits:

- State of Utah Radioactive Material License UT2300249, Amendment 17 (June 4, 2014), expires January 25, 2013 (under timely renewal⁶)
- State of Utah Radioactive Material License, 11(e).2 Byproduct Material License UT2300478, Amendment 10 (August 2, 2013) (under timely renewal)
- State of Utah Part B Permit, EPA Identification Number UDT982598898, expires April 4, 2013 (under timely renewal)
- State of Utah Ground Water Quality Discharge Permit Number UGW450005, (modified effective February 18, 2014), expires June 8, 2013 (currently under timely renewal)

The first activities involving radioactive waste management at Clive, Utah, were those conducted by DOE.⁷ DOE removed uranium mill tailings from the inactive Vitro Mill site located near Salt Lake City, Utah, beginning in February 1985 and concluding in June 1989. Uranium mill tailings and radioactively contaminated materials that remained at the inactive Vitro site were excavated and relocated by rail and truck to the Clive site, located 85 miles west of Salt Lake City. The tailings and contaminated materials were transferred to a specially constructed embankment in Section 32, Township 1 South and Range 11 West, Salt Lake Baseline and Meridian, Tooele County, Utah. Concurrent with the Vitro relocation project, Envirocare of Utah, Inc. (Envirocare, Inc., which subsequently merged with other companies in 2006 to become EnergySolutions, LLC) began disposal operations at its Clive Facility in 1988 under a state radioactive materials license to dispose of NORM waste. In 1990, the Licensee submitted a license application to modify its license to allow disposal of LARW. In 1991, the Division of Radiation Control (DRC)

⁶ “Timely renewal” means that the Licensee has made a timely filing of a license renewal application and that the current license remains in effect until DRC reaches a decision on the newly submitted license renewal application.

⁷ Much of the historical material cited here was extracted directly from Utah Division of Radiation Control, *EnergySolutions LLRW Disposal Facility Class A West Amendment Request, Safety Evaluation Report*, June 2012. (DRC 2012a).

granted the amendment request by adding LARW disposal to the facility’s license. From time to time, the LARW disposal license was amended to address changes needed based on review of Licensee-furnished submittals and/or updated or new regulatory guidelines. In 1998, the DRC Director (hereafter “the Director”) renewed the Licensee’s license to dispose of LARW. In September 2009, EnergySolutions submitted a License Amendment for DU disposal (Hultquist 2010).

The ownership history of the radioactive waste disposal facilities located at South Clive, Utah, is as shown in Table 2-1.

Table 2-1 – Ownership History

Owner	Dates of Ownership
Envirocare of Utah, Inc.	February 2, 1988, through May 15, 2005
Envirocare of Utah, LLC	May 16, 2005, through March 1, 2006
EnergySolutions, LLC	Commencing March 2, 2006

The licensing and permitting history of the Clive, Utah, site is as follows:

- 1984–1989 – DOE Disposal of Vitro Tailings: Remedial activities began at the Salt Lake City Vitro mill site in February 1985 and were completed in June 1989. Contaminated materials that remained at the Vitro Mill site were excavated and relocated by rail and truck to a South Clive disposal cell, a new site acquired by the State of Utah and located 85 miles west of Salt Lake City.
- 1988 – Envirocare, Inc. Began Disposing of NORM: On February 28, 1988, Envirocare, Inc. received its first license from the State Bureau of Radiation Control to dispose of NORM.
- 1991 – License Amendment for LARW Disposal: On March 21, 1991, Envirocare, Inc. received an LARW license from the State Bureau of Radiation Control to accept 44 radionuclides with specified concentration limits less than Class A LLRW limits. This type of waste is termed LARW. The Utah GWQ Permit was issued this same day for the Envirocare LLRW facility.
- 1991 – Mixed Waste Permit: On November 30, 1991, Envirocare, Inc. received a Resource Conservation and Recovery Act hazardous waste permit from the State Bureau of Solid and Hazardous Waste to accept mixed waste.
- 1992 – Resolution and Order Agreement with Northwest Interstate Compact (hereafter “the Compact” or “Northwest Compact”): On May 28, 1992, Envirocare, Inc. entered into an arrangement, the “Resolution and Order” with the Compact, that allowed it to accept certain types of LLRW from outside of the Compact. Envirocare, Inc. did not receive Compact approval to receive LLRW from Northwest Compact states. However, Envirocare, Inc. was granted permission to accept mixed waste from all states. The Resolution and Order was the result of a discussion at a December 18, 1991, meeting of the Compact. The Resolution and Order has subsequently been modified and reviewed.

- 1993 – Uranium Mill Tailings [11e.(2)] Disposal License from the NRC: On November 30, 1993, Envirocare, Inc. received a license from the NRC to accept uranium mill tailings.
- 1993 – LARW License Amended: On August 27, 1993, Envirocare, Inc.'s LARW license was modified by the DRC to accept 14 additional radionuclides with specified concentration limits less than the Class A limits.
- 1994 – The Utah GWQ Permit was modified to authorize 11e.(2) waste receipt, management, and disposal in the southwest corner of Section 32 (April 29).
- 1995 – LARW License Amended: On June 20, 1995, Envirocare, Inc.'s LARW license was modified by the DRC to accept 17 additional radionuclides with specified concentration limits less than the Class A LLRW limits. It was subsequently amended on November 13, 1995, to accept eight additional radionuclides with specified concentration limits less than the Class A LLRW limits.
- 1996 – LARW Renewal Request Submitted: In August 1996, Envirocare, Inc. submitted a renewal request for the LARW license to the DRC.
- 1996 – Macro-encapsulation Approval: On October 3, 1996, Envirocare, Inc. received a Hazardous and Solid Waste Amendment permit for waste macroencapsulation from EPA Region 8.
- 1998 – Amended Resolution and Order Agreement with Northwest Compact: The Second Amended Resolution and Order of November 9, 1998, is currently in effect. With very few exceptions, Envirocare, Inc. could not accept waste from Northwest Compact states. Envirocare, Inc. could accept NORM, LLRW, and mixed waste from all other approved Compact states and non-approved states. The restrictions of the Amended Resolution and Order are presently followed by *EnergySolutions*.
- 1998 – LARW License Renewal Containing LLRW Amendment Request Approved: On October 22, 1998, Envirocare, Inc.'s LARW license was renewed and issued as a 5-year LLRW license by the Director, which included concentration limits by radionuclides less than and up to the Class A LLRW limits.
- 1999 – Class B & C LLRW License Application Submitted.
- 2000 – Full Class A Waste Disposal Cell Approved: On October 5, 2000, Envirocare, Inc. was issued a license amendment by the Director for a new Class A disposal cell that allowed it to begin disposing of Class A wastes within an approved Class A disposal embankment area.
- 2001 – Land Ownership Exemption Granted: On January 19, 2001, the Utah Radiation Control Board (URCB) granted Envirocare, Inc. an exemption to the state and federal land ownership rule based on several conditions being met.
- 2001 – Class B & C License Granted Pending Approval: On July 9, 2001, Envirocare, Inc. was issued a separate license from the DRC to accept Class B and C LLRW, pending legislature and gubernatorial approval. The license was subsequently appealed to the URCB.

- 2001 – Class A LLRW Cask Amendment Granted: On October 19, 2001, Envirocare, Inc. was issued an approval for a license amendment to receive and dispose of full-concentration Class A LLRW in casks.
- 2002 – Resolution and Order Agreement with Northwest Compact Reviewed: The Second Amended Resolution and Order of November 9, 1998, was most recently reviewed at the June 5, 2002, meeting of the Compact and no changes were made. Therefore, EnergySolutions is presently required to follow the 1998 Resolution and Order Agreement that was made with the Compact.
- February 2003 – Final Agency Action on Class B & C Waste: On February 10, 2003, Envirocare, Inc. was granted final agency action by the URCB on the Class B and C LLRW license, pending legislative and gubernatorial approval.
- March 2003 – NRC Uranium Mill Tailings License Amendment Request: On March 27, 2003, Envirocare, Inc. submitted a request to the NRC to amend its NRC uranium mill tailings license to accept tailings with radium-226 (Ra-226) concentrations up to 100,000 picocuries per gram (pCi/g). This was to allow it to accept the DOE Fernald Site Closure Project (Fernald) waste if it were classified as 11e(2) byproduct material.
- May 2003 – NRC Uranium Mill Tailings Disposal License Renewal Request: On May 27, 2003, Envirocare, Inc. submitted a license renewal application to the NRC for the uranium mill tailings disposal cell. Envirocare, Inc. was granted timely renewal (current license remaining in effect until a decision is reached on the license renewal application).
- July 2003 – Class A LLRW License Renewal Request: On July 2, 2003, Envirocare, Inc. submitted a license renewal application to the Division for its LLRW license. Envirocare, Inc. was granted timely renewal.
- November 2003 – Withdrawal of 2003 NRC Uranium Mill Tailings License Amendment Request: On November 19, 2003, Envirocare, Inc. withdrew its request for a license amendment from the NRC to accept waste from the DOE Fernald site.
- 2004 – Mixed Waste License Public Comment Period: On May 4, 2004, a 30-day public comment period commenced on an amendment to the LLRW license for Envirocare, Inc. to accept mixed waste up to Class A limits.
- January 2005 – Class A LLRW North Embankment Amendment Request: On January 17, 2005, Envirocare, Inc. submitted a request for a license amendment to the LLRW license to allow disposal of Class A materials in the northern area previously approved for Class A, B, and C waste disposal.
- February 2005 – Withdrawal of Class B and C Waste License Request: In February 2005, Envirocare, Inc. withdrew a request for a Class B and C waste disposal license.
- May 2005 – Name Change: On May 16, 2005, the name on the licenses and permits was changed from Envirocare of Utah, Inc. to Envirocare of Utah, LLC.

- May 2005 – Submission of the Class A Combined (CAC) Amendment Request: On May 27, 2005, Envirocare, LLC submitted a license amendment request to the LLRW license to create a CAC cell.
- June 2005 – Submittal of License Renewal Application: On June 20, 2005, Envirocare, LLC submitted an application to renew its LLRW disposal license.
- 2006 – Transfer of Licenses and Permits: On March 2, 2006, the licenses and permits were transferred from Envirocare of Utah, LLC to EnergySolutions.
- 2007 – Agreement with Governor Huntsman: On March 15, 2007, EnergySolutions entered into an agreement with Governor Huntsman to withdraw the amendment request for a CAC cell.
- 2011 – Submission of the Class A West (CAW) Embankment License Amendment Request: On May 2, 2011, EnergySolutions submitted a request to amend the LLRW license and permit to create the proposed CAW disposal embankment and to formally retract a previous request for a CAC disposal cell.
- 2012 – Submission of Radioactive Material License No. UT2300249 Renewal Application: On October 25, 2012, EnergySolutions submitted a request to renew License UT 2300249. The application specified use of an ET cover on the CAW cell.
- 2014 – DRC Issuance of LLRW License Amendment: On May 12, 2014, DRC issued a LLRW License Amendment, No. 16, approving the May 2, 2011, EnergySolutions request for redesign of the CAW Embankment. This design included a rock armor/radon barrier cover system.

References

DRC, 2012a

Hultquist, 2010

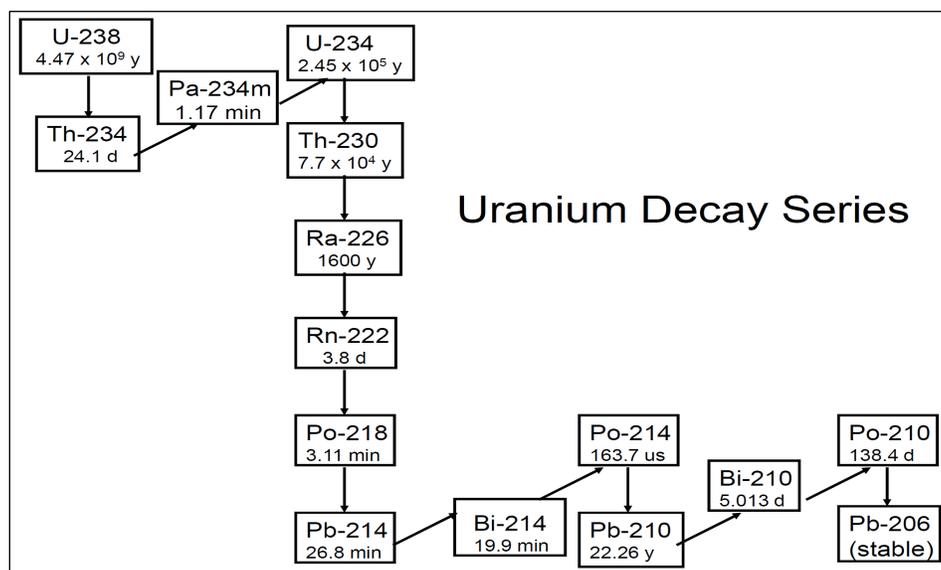
3.0 CLIVE DEPLETED URANIUM PERFORMANCE ASSESSMENT: BASIS AND DESCRIPTION

3.1 DEPLETED URANIUM

DU waste is a product of the process used to enrich natural uranium for use in nuclear reactors and in nuclear weapons. Natural uranium is composed primarily of two isotopes; uranium-235 (U-235) (0.7 percent by weight [wt%] of natural uranium), and U-238 (99.3 wt%). U-235 is the readily fissionable isotope of uranium; for the types of nuclear power plants operating in the United States, the concentration of U-235 needs to be increased (or enriched) to between 3 and 5 wt% for use as a nuclear fuel. The enrichment process concentrates the U-235 isotope in the fuel product material, resulting in a waste that is *depleted* in U-235. Uranium with a concentration of U-235 below that of natural uranium (0.7 wt%) is called “depleted uranium” (DU). For example, if an enrichment facility processes 1,000 kilograms (kg) of natural uranium to raise the U-235 concentration from 0.7 wt% to 5 wt%, the facility would produce 85 kg of enriched uranium and 915 kg of DU.

DU retains a smaller percentage of U-235 and a slightly greater percentage of U-238 (99.8 wt% instead of 99.3 wt%). Because of the shorter half-life of U-235 compared to U-238, the radioactivity associated with newly formed DU is, at that time, approximately 40 percent less than that of natural uranium.

When U-238 decays, it produces a series of decay products, as shown in Figure 3-1. In nature, U-238 is in equilibrium with its decay products, meaning that the activity of the decay products is decreasing according to the half-life of U-238.



Source: NRC (2011).

Figure 3-1 – The uranium series

However, when uranium is purified in preparation for being used as nuclear reactor fuel, all of its decay products are chemically removed. Over time, the decay products will build back up and reestablish equilibrium with the parent radionuclide, U-238. The time it takes to reestablish

equilibrium with U-238 is directly proportional to the decay product's half-life; for example, thorium-234 (Th-234) and protactinium-234 (Pa-234m), which have short half-lives, will reestablish equilibrium with U-238 in a matter of months. Because of its 2.45×10^5 -year half-life (see Figure 3-1), U-234 will not reestablish equilibrium with U-238 for several hundreds of thousands of years. The decay products after U-234 (e.g., Th-230, Ra-226, etc., see Figure 3-1) will initially establish equilibrium with U-234 and build with U-234 toward reestablishing equilibrium with U-238. For the Clive DU PA Model, EnergySolutions has calculated that, at 2.1 million years, lead-210 (Pb-210) (the last radionuclide in the series modeled) has reestablished equilibrium with U-238 to within less than one half of one percent (ES 2014d). While Ra-226 also reaches its peak activity in this same time frame, the majority of its equilibrium activity (>95 percent) is accomplished in approximately 1 million years.

References

ES, 2014d

NRC, 2011

3.2 LICENSE CONDITION 35

The framework for the technical analysis of the disposal of radioactive waste was developed in the 1980s with the NRC's issuance of Title 10 of the Code of Federal Regulations (10 CFR) Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste." Part 61 established a waste classification scheme based on the role that the radionuclide concentration and waste form play in the long-term performance of disposal facilities. The final Part 61 analyses did not consider large quantities of DU waste because, at that time, there were no commercial facilities producing large quantities of DU, and DU produced at Federal facilities was not regulated by the NRC; instead, it was controlled and managed by DOE as a possible future resource. Because Utah is an Agreement State, the Utah regulations for the issuance of licenses for the land disposal of radioactive wastes, as discussed within UAC R313-25, closely follow the NRC's Part 61 regulations.

In October 2008, 5,800 drums containing the DU from DOE's Savannah River Site (SRS) were sent to the EnergySolutions facility at Clive for disposal. Later, DEQ was informed by EnergySolutions that the SRS inventory included about 33,000 drums of DU waste needing disposition. Additionally, it was learned that DOE intended to dispose of a large quantity of DU [~700,000 megagrams (Mg) or 700,000 metric tons; Neptune 2014i, Section 2.0] at the EnergySolutions Clive facility.

Because the DU disposal issue was of more immediate concern in Utah than in the United States generally, DEQ took more timely action than did the NRC to develop a solution.

Beginning in the fall of 2009, the URCB received public comments and held discussions regarding proposed DU disposal at EnergySolutions facilities. These discussions led to a formal rulemaking effort by the URCB to amend UAC R313-25, as discussed below.

While this rulemaking was underway, DEQ, on March 2, 2010, imposed Condition 35 on the EnergySolutions RML UT2300249 to address DU and other concerns. License Condition 35 consists of five parts: (a) uranium concentration, (b) performance assessment, (c) revised

disposal embankment design, (d) remediation, and (e) surety. The first three parts of Condition 35 are directly related to this SER:

- A. *In accordance with UAC R313-25-8, effective June 1, 2010 the Licensee shall not dispose of significant quantities of concentrated depleted uranium prior to the approval by the Director of the performance assessment required in R313-25-8 [note: the relevant rule at that time was R313-25-8; it is now R313-25-9].*
- B. *Performance assessment: A performance assessment, in general conformance with the approach used by the Nuclear Regulatory Commission (NRC) in SECY-08-0147, shall be submitted for Director review and approval no later than June 1, 2011. The performance assessment shall be revised as needed to reflect ongoing guidance and rulemaking from NRC. For purposes of this performance assessment, the compliance period will be a minimum of 10,000 years. Additional simulations will be performed for a minimum 1,000,000-year time frame for qualitative analysis.*
- C. *Revised disposal embankment design: If the performance assessment specified in paragraph 35.B indicates that changes to disposal operations and cover design are necessary to ensure compliance with the requirements of 10 CFR Part 61 or Utah Administrative Code R313, EnergySolutions will provide a revised design that does meet those requirements, for all wastes that have been and are reasonably anticipated to be disposed of at the facility within 180 days of Director approval of the performance assessment.*

References

Neptune, 2014i

3.3 UAC RULES R313-28-9(4) AND R313-25-9(5)(a)

In the January 1, 2010, issue (Vol. 2010, No. 1) of the *Utah State Bulletin*, DEQ published a notice of proposed rule UAC R313-25-8, with an effective date of June 2, 2010 (DRC 2010). At that time, UAC R313-25-8 consisted of two provisions: (1) identification of five analyses needed to demonstrate that the performance objectives will be met and (2) performance assessment requirements for any facility that proposes to dispose of large quantities of DU. Since then, three more provisions have been added to R313-25-8 to better define which licensees and applicants need to conduct a site-specific performance assessment, and the rule has been re-numbered to UAC R313-25-9 (as of May 2014). The portions of R313-25-9 that are most relevant to this SER are Sections (4)(a)–(d) and (5)(a), which are reproduced here:

- (4) *The licensee or applicant shall also include in the specific technical information the following analyses needed to demonstrate that the performance objectives of Rule R313-25 will be met:*
 - (a) *Analyses demonstrating that the general population will be protected from releases of radioactivity shall consider the pathways of air, soil, ground water, surface water, plant uptake, and exhumation by burrowing animals. The analyses shall clearly identify and differentiate between the roles performed by the natural disposal site characteristics and design features in isolating and segregating the wastes. The*

- analyses shall clearly demonstrate a reasonable assurance that the exposures to humans from the release of radioactivity will not exceed the limits set forth in Section R313-25-20.*
- (b) Analyses of the protection of inadvertent intruders shall demonstrate a reasonable assurance that the waste classification and segregation requirements will be met and that adequate barriers to inadvertent intrusion will be provided.*
- (c) Analysis of the protection of individuals during operations shall include assessments of expected exposures due to routine operations and likely accidents during handling, storage, and disposal of waste. The analysis shall provide reasonable assurance that exposures will be controlled to meet the requirements of Rule R313-15.*
- (d) Analyses of the long-term stability of the disposal site shall be based upon analyses of active natural processes including erosion, mass wasting, slope failure, settlement of wastes and backfill, infiltration through covers over disposal areas and adjacent soils, surface drainage of the disposal site, and the effects of changing lake levels. The analyses shall provide reasonable assurance that there will not be a need for ongoing active maintenance of the disposal site following closure.*
- (5)(a) Notwithstanding Subsection R313-25-9(1), any facility that proposes to land dispose of significant quantities of concentrated depleted uranium (more than one metric ton in total accumulation) after June 1, 2010, shall submit for the Director's review and approval a performance assessment that demonstrates that the performance standards specified in 10 CFR Part 61 and corresponding provisions of Utah rules will be met for the total quantities of concentrated depleted uranium and other wastes, including wastes already disposed of and the quantities of concentrated depleted uranium the facility now proposes to dispose. Any such performance assessment shall be revised as needed to reflect ongoing guidance and rulemaking from NRC. For purposes of this performance assessment, the compliance period shall be a minimum of 10,000 years. Additional simulations shall be performed for the period where peak dose occurs and the results shall be analyzed qualitatively.*

It is worth noting that the performance assessment requirements for the disposal of large quantities of DU contained within R313-25-9(5)(a) are essentially the same as those required in License Condition 35B—one difference being the duration of the “qualitative analysis” period. Condition 35B specified that the qualitative analysis period be 1 million years, while UAC R313-25-9(5)(a) specifies “the period where peak dose occurs.” Currently, License Condition 35 continues to identify the qualitative analysis period as a minimum of 1 million years.

Consistent with License Condition 35B, DEQ understands that, sometime in the future, it may need to revise R313-25-9(5)(a) once the NRC issues its own requirements for the disposal of large quantities of DU.

References

DRC, 2010

3.4 PROPOSED FEDERAL CELL DESIGN

EnergySolutions operates an LLRW disposal facility west of the Cedar Mountains in Clive, Utah. Clive is located along Interstate-80, approximately 5 kilometers (km) (3 miles) south of the highway, in Tooele County. The facility is approximately 80 km (50 miles) east of Wendover, Utah, and approximately 100 km (60 miles) west of Salt Lake City, Utah. The facility sits at an elevation of approximately 1,302 meters (4,275 feet) above mean sea level (amsl) and is accessed by both road and rail transportation.

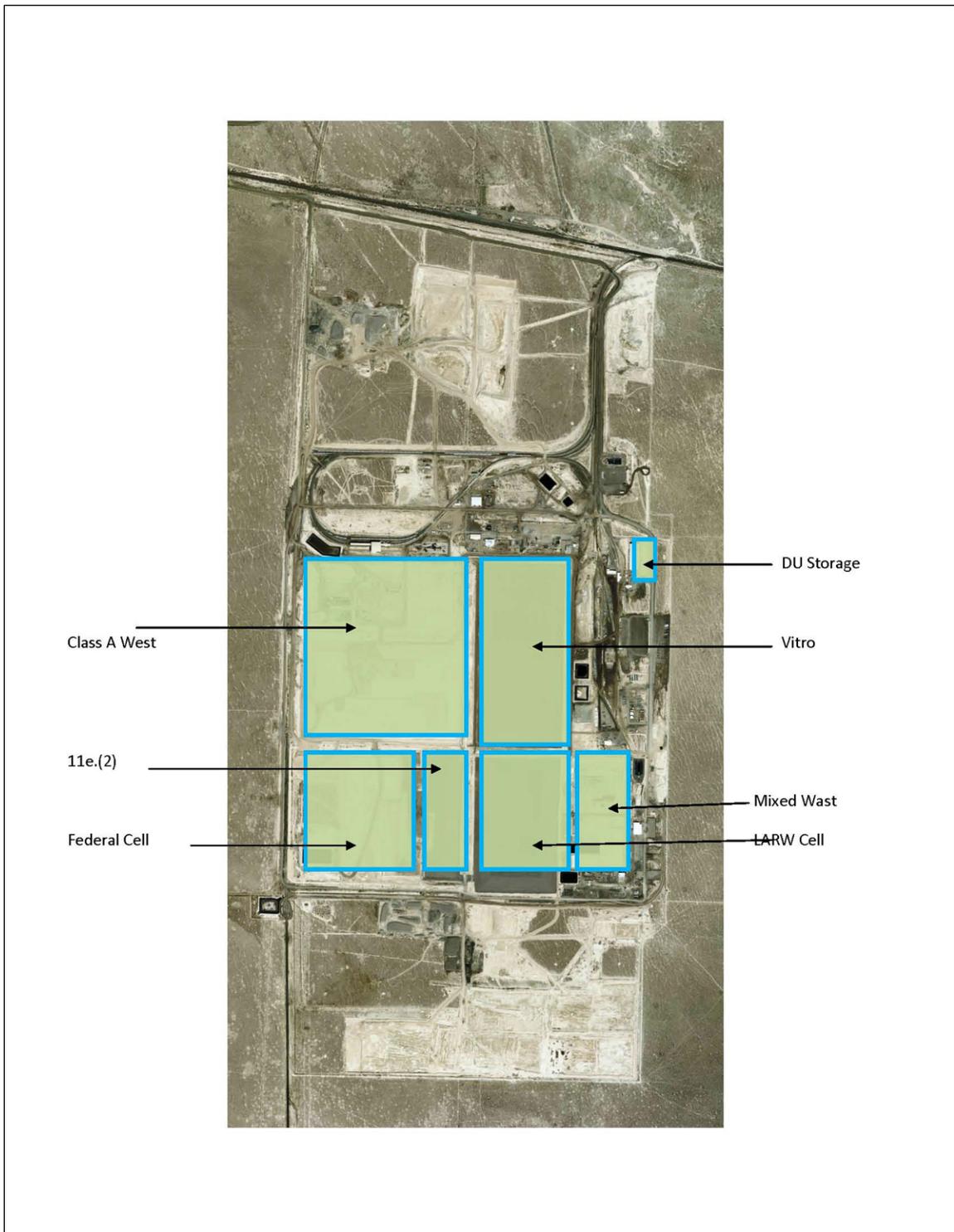
The disposal cell in the southwestern-most part of Section 32 has been defined as the “11e.(2) Cell,” which was initially authorized by the NRC in 1995, before Utah became an Agreement State.⁸ The currently approved 11e.(2) Cell occupies a footprint of about 2,254 feet (751 yards) by 1,767 feet (589 yards), which is about 3.98 million square feet (about 442,339 square yards) (ES 2002), and is licensed with a waste disposal capacity of about 5.04 million cubic yards (ES 2007).

On January 4, 2008, EnergySolutions requested a design change to the 11e.(2) Cell that would allow LLRW to be disposed of in the western portion of the 11e.(2) Cell, which was and still is unused. That configuration was known as the Class A South (CAS) Cell proposal. This LLRW disposal area was to be 1,472 feet by 1,860 feet in size (ES 2008a), with a geometry similar to that proposed today; for details, see Figure 3-3 and Table 3-2. As part of the DRC review process, a November 26, 2008, Completeness Review was issued (DRC 2008). Later, in an EnergySolutions letter of May 2, 2011, the company withdrew its request for the CAS Cell (ES 2011a).

In the initial DU PA, EnergySolutions had proposed a Federal DU embankment inside the western fraction of the Federal Cell (Figure 3-2). As before, the eastern section was to be occupied by the 11e.(2) Cell, which is dedicated to the disposal of uranium processing byproduct waste but is not considered in this analysis. Subsequently, EnergySolutions decided that the Federal Cell and the 11e.(2) Cell would be physically separate and informally provided drawings of the revised Federal Cell on November 14, 2014 (Rogers 2014b). A stylized drawing of the proposed Federal Cell and its relationship to the 11e.(2) Cell is shown in Figure 3-3; Federal Cell dimensions are given in Table 3-2.

The DU disposal zone inside the Federal Cell embankment is proposed to be located at the bottom of the cell, below native grade under the top slope area. Dimensions for the DU disposal zone are approximately 7.4 feet thick by 968 feet wide (east–west) by 1,425 feet long (north–south) [ES Drawing No. 14004 L1A (1)]. This equates to a design capacity for DU disposal of about 10.2 million cubic feet (about 378,000 cubic yards), all below native grade.

⁸ 11e.(2) waste is the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content. State regulation of the EnergySolutions 11e.(2) waste cell for engineering design and groundwater protection began with issuance of a GWQ Permit modification in April 1994.



Source: EnergySolutions.

Figure 3-2 – The Clive facility, showing the location of the proposed Federal Cell embankment and other embankments. This orthophotograph is roughly 1 mile across, and north is up.

The general aspect of the proposed Federal Cell embankment is that of a hipped cap, with relatively steeper sloping sides nearer the edges. The upper part of the embankment, known as the top slope, has a moderate slope, while the side slope is markedly steeper (33 percent transitioning to 20 percent as opposed to 2.4 percent). EnergySolutions intends to dispose of DU only beneath the top slope areas of the embankment, with no DU beneath the side slopes. All DU waste will be disposed below current grade level.

Table 3-1 lists the amount of DU potentially available from DOE’s SRS and three gaseous diffusion plants (GDPs) at Paducah, KY, Portsmouth, OH, and the former K-25 site in Oak Ridge, TN (Neptune 2014i, Table 1).

Table 3-1 – Amounts of DOE Depleted Uranium Potentially Available for Disposal

Source	Form	Mass	Containers
SRS	DUO ₃	3,577 Mg	5,408 Drums ^b
Paducah GDP	DUF ₆	436,400 Mg	36,191 Cylinders
Portsmouth GDP	DUF ₆	195,800 Mg	16,109 Cylinders
Former K-25 GDP ^a	DUF ₆	54,300 Mg	4,822 Cylinders

^a In 2004, DOE decided to relocate the DU from K-25 to Portsmouth (69 *Federal Register* 44649; July 27, 2004), and shipment was completed in FY 2007 (DOE 2014).

^b Drums in storage at Clive.

Source: Neptune (2014i), Table 1.

Table 3-2 – Dimensions of the Proposed Federal Cell Embankment

Waste bottom	4,264 ft-amsl	Length overall	1,317.8 ft	Width overall	1,775.0 ft
Original grade	4,272 ft-amsl	Length to break	175 ft	Width to break	175 ft
Break to ridge	521 ft	Length within break	968 ft	Width within break	1,425.0 ft
Ridge length	383 ft				

Source: Neptune (2014f), Section 3.1.1, and ES Drawing No. 14004-V1A(1).

A cover system is proposed to be constructed above the waste. A primary objective of the cover system is to limit contact of water with the waste. Another objective of the cover system is to limit potential flux of radon outside of the embankment. The cover as proposed is sloped to promote runoff and designed to limit water flow by increasing ET. Figure 3-4 shows the arrangement of the layers used for the ET cover design. Beginning at the top of the cover, the layers above the waste used for the ET cover design are as follows (Neptune 2014f):

- **Surface Layer:** This layer is composed of native vegetated Unit 4 material⁹ with 15 percent gravel mixture on the top slope and 50 percent gravel mixture for the side slope. This layer is 6 inches thick. The functions of this layer are to control runoff, minimize erosion, and maximize water loss from ET. This layer of silty clay provides

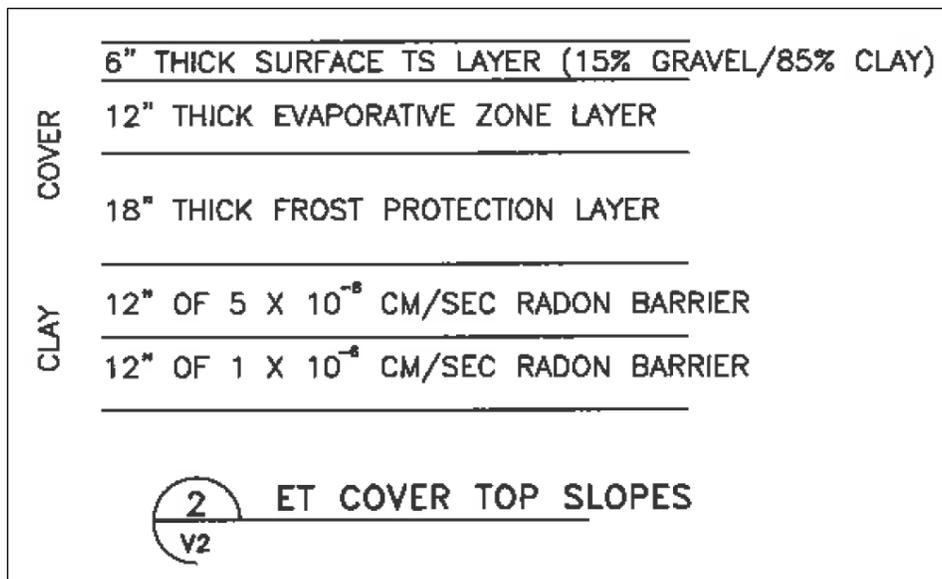
⁹ Unit 4 material is a silty clay found at the surface at and near the facility and is included in the Surface Layer, Evaporative Zone Layer, and Upper and Lower Radon Barriers, as well as the Clay Liner beneath the DU.

storage for water accumulating from precipitation events, enhances losses due to evaporation, and provides a rooting zone for plants that will further decrease the water available for downward movement.

- **Evaporative Zone Layer:** This layer is composed of Unit 4 material. The thickness of this layer is 12 inches. The purpose of this layer to provide additional storage for precipitation and additional depth for plant rooting zone to maximize ET.
- **Frost Protection Layer:** This material has particle sizes that range from 16 inches to clay-size particles. This layer is 18 inches thick. The purpose of this layer is to protect layers below from freeze/thaw cycles and wetting/drying cycles, and to inhibit plant, animal, or human intrusion.
- **Upper Radon Barrier:** This layer consists of 12 inches of compacted clay with a low hydraulic conductivity. This layer has the lowest conductivity of any layer in the cover system. However, this very low hydraulic conductivity is the result not only of compaction, but also of treatment of the clay with an application of sodium tripolyphosphate (STPP), or the equivalent, to deflocculate clays present and reduce hydraulic conductivity. Discussion of its intended use at Clive is found on page 23 of the August 7, 2014, Attachment II-9 to EnergySolutions' Construction Quality Assurance/Quality Control (CQA/QC) Manual (ES 2012b). It is unknown how long treatment by STPP will maintain a condition of low hydraulic conductivity in the Unit 4 clays. STPP is highly soluble, and it tends to be progressively hydrolyzed in natural waters (HERA 2003). When hydrolyzed, STPP can be assimilated by microorganisms. STPP treatment is more effective in some soils than in others. Yiasoumi (2004) indicates that STPP is ineffective in sandy soils or soils high in calcium carbonate. Clive Unit 4 silty clay contains about 65 percent calcium carbonate.

This barrier layer reduces the downward movement of water to the waste and the upward movement of gas out of the disposal cell. The saturated hydraulic conductivity (K_{sat}) values for the radon barriers were sampled from a distribution developed from a minimum value of 4×10^{-3} centimeters per day (cm/day) corresponding to the proposed as-built design specification for the upper radon barrier (Whetstone 2007, Table 8), and 50th and 99th percentile values of 0.7 cm/day and 52 cm/day, respectively, which are from a range of in-service ("naturalized") clay barrier K_{sat} values described by C. H. Benson et al. (2011, Section 6.4, p. 6-12). A lognormal distribution was fit to the 50th and 99th percentiles, and the minimum value of 4×10^{-3} cm/day was used as a shift.

Lower Radon Barrier: This layer consists of 12 inches of compacted clay with a low hydraulic conductivity. This lower radon barrier reduces the downward movement of water and upward migration of radon. For all HYDRUS simulations, although various K_{sat} values for the radon barriers were employed between runs, in each run the same K_{sat} value was applied to both the upper and lower radon barriers.



Source: ES (2014d), Drawing No. 14004, V7.

Figure 3-3 – Proposed Federal Cell evapotranspiration cover design

Directly beneath the lower radon barrier of the cover would be about 36 feet of non-DU material. For the purposes of the present Clive DU PA Model and this SER, EnergySolutions assumes that this non-DU material would be nonradioactive. However, EnergySolutions retains the option of using this space to dispose of ordinary, non-DU, LLRW. Beneath the non-DU material is the disposed-of DU waste. The DU would be placed in the proposed Federal Cell in either cylinders or drums. There would be a single layer of drums, and the cylinders would be in a single layer in the western area of the disposal zone, or stacked two layers high in the eastern portion of the disposal zone. Table 3-3 summarizes the estimated number of cylinders and drums of DU and their arrangement within the proposed Federal Cell.

Table 3-3 – Proposed Federal Cell: Estimated Number of Depleted Uranium Containers

Container Type	Layers	Width (ft)	Length (ft)	Area (ft ²)	Number
Cylinders	Double	205	1,425	29,213	10,500
Cylinders	Single	763	1,425	1,087,275	20,300
Drums on pallets	Single	37	615	22,755	5,408
Drums on side ^a	Single	763	1,425	1,087,275	170,800

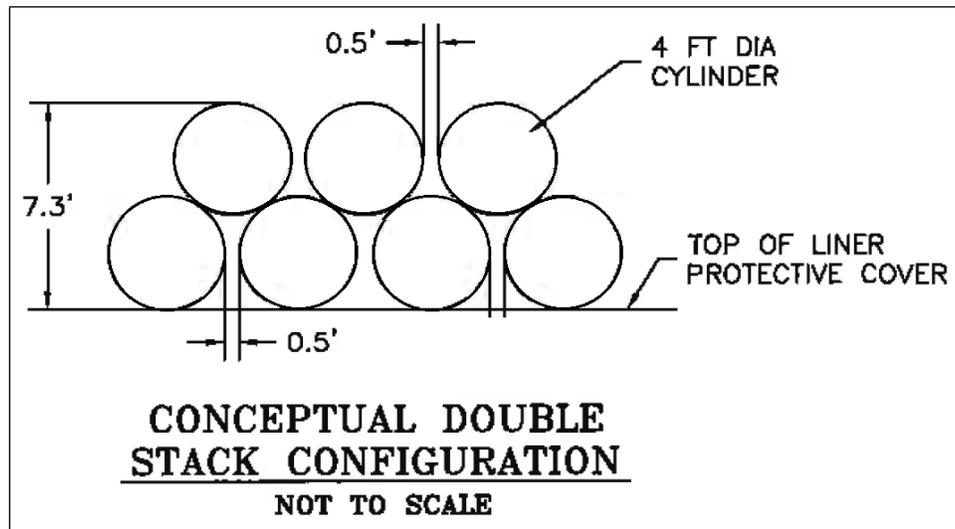
^a Possible.

Source: ES Drawing No. 14002-L1A(1).

As per ES Drawing No. 14004, L1A(1), the Table 3-3 container number estimate was based on the following assumptions: (1) all cylinders were assumed to be 12 feet long by 4 feet in diameter; (2) single-layer cylinders were assumed to be spaced 0.2 feet end-to-end and side-to-side; (3) double-layer cylinders were assumed to be spaced 0.2 feet end-to-end and

0.5 feet side-to-side for both layers; (4) drums were assumed to be placed on 4 feet-by-4-foot pallets, spaced 0.1 foot apart; and (5) additional 55-gallon drums could be laid on their sides and placed in a single layer on top of the single-layer cylinders.

Figure 3-5 shows an example of the double stacking of the DU cylinders, which is to be limited to the eastern portion of the DU disposal zone. In the western area of this zone, only one layer of DU cylinders is to be disposed.



Source: ES (2014d), Drawing No. 14004, L1.

Figure 3-4 – Double-layer placement of DU canisters

Because of the unique characteristics that disposal of the triuranium octoxide depleted in U-235 (DU_3O_8) cylinders pose for the facility, the need to ensure a stable embankment and meet the waste backfill-related requirements in UAC R313-25-8(2) and R313-25-9(4)(d), and the quality assurance requirements in R313-25-8(10), revisions to the CQA/QC manual may be required. In addition, a revised Waste Acceptance Plan will be required to ensure that all DU waste containers and shipments received by the Licensee are equivalent to and in conformance with all physical, chemical, and radiologic properties assumed in the Director-approved DU PA modeling report. This Waste Acceptance Plan must be approved by the Director before land disposal of any DU waste. Additionally, since there is no written description of the newly proposed Federal Cell, the Licensee must provide such a description and indicate how such factors as steeper side slopes, changes in disposal area and volume, and inclusion of additional waste drums (beyond those currently in storage) will affect the DU PA. Finally, the Licensee must provide additional information regarding the 1-foot-thick protective liner that is placed over the bottom clay liner including the following:

- Function of the protective liner
- Material specifications for the liner
- How evaluated in performance assessment

References

C. H. Benson et al., 2011
DOE, 2014
DRC, 2008
ES, 2002; 2007; 2008a; 2011a; 2012b; 2014d; 2014f
HERA, 2003
Neptune, 2014f; 2014i
Rogers, 2014b
Whetstone, 2007
Yiasoumi, 2004

3.4.1 Proposed Federal Cell Compliance with Existing License Condition 9.E and the March 15, 2007, Governor Huntsman–EnergySolutions Agreement

License Condition 9.E was incorporated into the EnergySolutions LLRW License with issuance of License Amendment 14 for the CAW Cell on November 26, 2012. Background information on License Condition 9.E is found in the DRC’s November 14, 2012, Public Participation Summary, pages 6–7 (DRC 2012b), as follows:

(2) License Amendment and the Huntsman Agreement

On March 15, 2007, Governor John Huntsman for the State of Utah and CEO Steve Creamer for EnergySolutions entered into an agreement (Appendix E) that committed EnergySolutions to limit its disposal to “the currently-licensed low-level radioactive waste cell volumes,” including the volume of waste that the agreement anticipated as a result of converting EnergySolutions’ 11e.(2) cell into a Class A waste cell. The Division and EnergySolutions have agreed that this total approved volume is 10,357,412 million cubic yards (Class A= 3,778,896 million yd³; Class A North= 1,722,509 million yd³; Class A South= 3,501,915 million yd³; Mixed Waste= 1,354,092 million yd³ for a total of 10,357,412 million yd³). EnergySolutions had originally anticipated that this disposal would occur in three already-licensed low-level radioactive waste cells (Class A, Class A North and Mixed Waste cells) and in the 11e.(2) cell that it expected to convert to a Class A cell. The Licensee has now chosen instead to develop this allowable capacity in two cells, the existing Mixed Waste Cell, and a new combined Class A and Class A North cell (now proposed as the Class A West cell). The Mixed Waste and Class A West cells will have a combined capacity of 10,078,189 cubic yards. This leaves a capacity of 279,223 cubic yards that EnergySolutions can still develop under the Huntsman Agreement.

Additional amendments to EnergySolutions’ License to conform to the Huntsman agreement are not necessary because this License covers all areas where Class A waste can be disposed. The only other area that is licensed to take radioactive

waste is the 11e.(2) cell. Class A waste cannot be disposed of in that cell, and only Class A waste is subject to the Huntsman Agreement. Because there is no other area that may accept Class A waste, there is no possibility that the Agreement will be violated under currently applicable licenses. Additional requirements would be redundant and unnecessary.

A modification to License Condition 9.E of the revised RML UT 2300249 will be made to address a correction in the calculations:

“The Licensee may dispose of a volume of Class A Low-Level Radioactive Waste (LLRW) and Naturally Occurring and Accelerator Produced Radioactive Materials (NARM) in the Class A West disposal cell described in License Condition 40 not exceeding ~~8,742,097~~ 8,724,097 cubic yards, and in the Mixed Waste Landfill Cell not exceeding ~~1,353,004~~ 1,354,092 cubic yards. Together the total aggregate volume of waste disposed of in the Class A West disposal Cell and the Mixed Waste Landfill Cell shall not exceed 10.08 million cubic yards. Class A waste LLRW is defined in Utah Radiation Control Rule R313-15-1009 and NARM at R313-12-3.”

As described in the Public Participation Summary statement quoted above (DRC 2012b), the Huntsman–EnergySolutions Agreement allows the company to expand its LLRW disposal capacity by 279,223 cubic yards above that already approved for the CAW Cell under License Amendment 14.

The volume limitations derived from the Huntsman Agreement and incorporated into License Condition 9.E will remain in effect unless the Licensee proposes a license amendment regarding alternative waste volumes for disposal in Section 32 and the proposed amendment is approved by the State of Utah. See Appendix G for additional details.

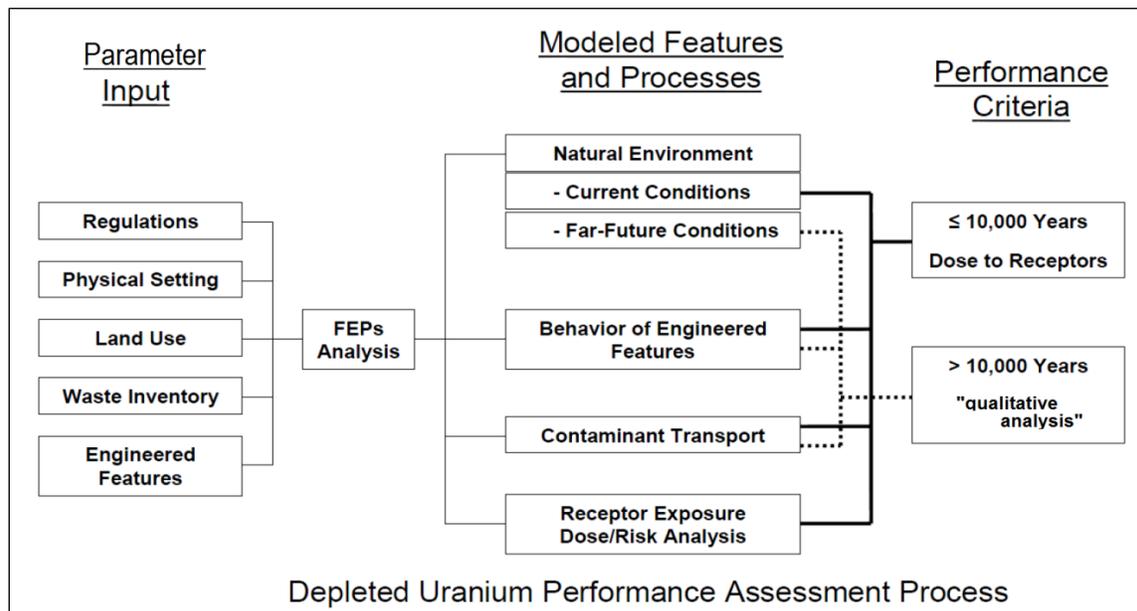
References

DRC, 2012b

3.5 CLIVE DEPLETED URANIUM PERFORMANCE ASSESSMENT DESCRIPTION AND RESULTS

The overall scope of the Clive DU PA is to evaluate the long-term siting and performance integrity of the portion of the proposed Federal Cell at EnergySolutions’ Clive facility for the proposed disposal of DU. The need for the Clive DU PA is driven by both State of Utah and proposed Federal regulations, which require an evaluation of the potential human radiation doses and consequences from the disposal of DU.

In general, the performance assessment process consists of three stages: (1) Parameter Input, (2) Modeled Features and Processes, and (3) Performance Criteria, as illustrated in Figure 3-5.



Source: Modified from Neptune (2014d), Figure 1.

Figure 3-5 – Conceptual diagram of the performance assessment process

The Parameter Input stage includes the State of Utah and Federal regulations that must be met [e.g., UAC R313-25-9(4) and (5)(a)]; the physical characteristics of the Clive site (e.g., meteorology, hydrology, geology); land use at Clive, which currently is mostly industrial; the expected amount and characteristics of DU to be disposed of in the proposed Federal Cell; and any features of the cell (e.g., the ET cover, the clay liner) designed to mitigate the potential impacts of the waste disposal.

“FEPs Analysis” is the process of identifying those features, events, and processes (FEPs) that form the basis for scenarios that are evaluated to assess site performance and that, therefore, must be accounted for in the performance assessment model. For the Clive DU PA Model, FEPs were developed in the following eleven broad areas:

- Meteorology (e.g., precipitation, atmospheric dispersion, resuspension)
- Climate change (e.g., the appearance/disappearance of large lakes)
- Hydrology (e.g., groundwater transport, in both the unsaturated and saturated zones)
- Geochemical (e.g., chemical sorption and partitioning between phases, aqueous solubility, leaching of radionuclides from the waste form)
- Engineered Features (e.g., cell design, material properties)
- Containerization (e.g., the Clive DU PA did not take any credit for the DU being containerized)
- Waste (e.g., inventory of radionuclides, physical and chemical waste forms)
- Source Release (e.g., leaching, radon emanation, plant uptake, and translocation by burrowing animals)

- Contaminant Migration (e.g., diffusion, dilution, advection-dispersion, re-suspension, atmospheric dispersion, biotically induced transport)
- Human Processes (e.g., human behaviors and activities, resource use, unintentional intrusion)
- Exposure (e.g., dosimetry, ingestion pathways, inhalation pathways)

The example FEPs given for each broad area are representative of the FEPs developed but are by no means a complete list of all the Clive DU PA Model FEPs. Neptune (2014g) should be consulted for more information on FEPs and how they were developed for the Clive DU PA Model.

In the Modeled Features and Processes stage of the Clive DU PA, the FEPs are converted into mathematical models that can then be applied using computer software. As Figure 3-5 shows, the Modeled Features and Processes stage is divided into Natural Environment, Behavior of Engineered Features, Contaminant Transport, and Receptor Exposure Dose/Risk Analysis. Figure 3-6 shows the interconnections between all of the modeled features and processes. An examination of Figure 3-6 reveals that many of the features and processes within the Clive DU PA Model can be linked back to the FEPs. Many of the FEPs are included in the Clive DU PA Model as distribution functions, e.g., a normal or lognormal distribution, with a specified mean and standard deviation.

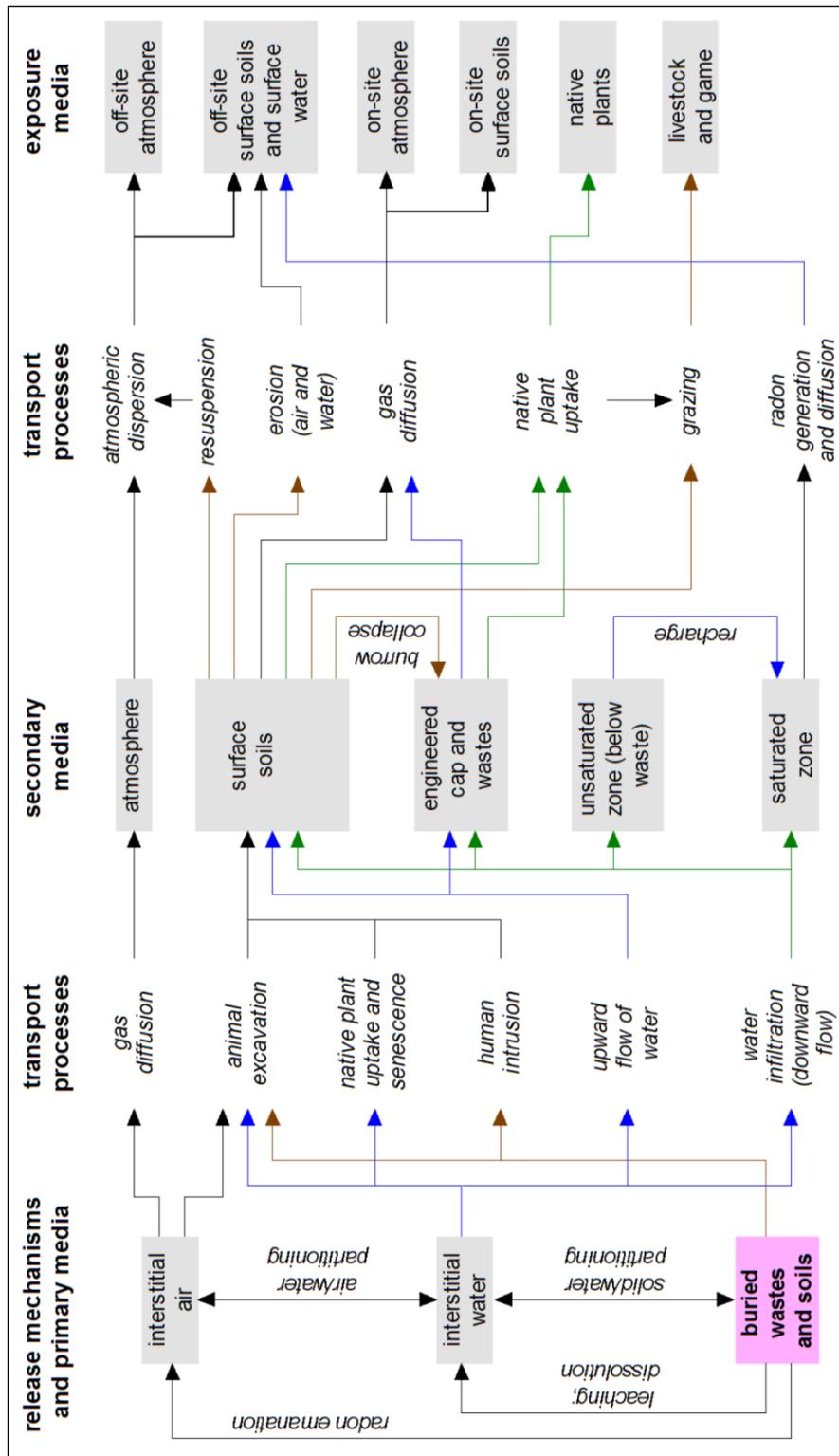
The Clive DU PA Model was developed using computer software called GoldSim (GTG 2013a, 2013b). GoldSim is a highly graphical, Windows-based program for carrying out dynamic, Monte Carlo simulations of complex systems to support management and decision-making. The GoldSim visual interface allows exploration of the model implementation. This interface facilitates traceability of codes developed with the GoldSim platform. The Monte Carlo functionality of GoldSim allows the Clive DU PA Model to be a probabilistic simulation, as opposed to a deterministic simulation.

The final stage in the performance assessment process, Performance Criteria, is to run the Clive DU PA Model and compare the results to the performance criteria contained in State and Federal regulations. GoldSim solves the Clive DU PA Model multiple times (i.e., multiple realizations), each time randomly selecting a different value for each parameter's distribution. When all of the realizations have been completed and compiled, the results (e.g., dose to the general public, dose to an inadvertent intruder, sediment concentration) can be taken as the mean, median, 95th percentile, or some other percentile from the entire distribution of results.

References

GTG, 2013a; 2013b

Neptune, 2014d; 2014g



Source: Neptune (2014d), Figure 11.

Figure 3-6 – Clive DU PA modeled features and processes. This figure describes those features and processes modeled by Neptune in the DU PA.

4.0 PERFORMANCE OBJECTIVES

4.1 10 CFR 61.12 – SPECIFIC TECHNICAL INFORMATION (UAC RULE R313-25-8)

During the course of its review of the DU PA, DEQ developed 73 interrogatories related to requests for additional specific technical information: 20 in the area of natural and demographic disposal site characteristics [under UAC Rule R313-25-8(1)]; 19 related to design features of the land disposal facility [under UAC Rule R313-25-8(2)]; 2 related to construction and operation [under UAC Rule R313-25-8(6)]; 14 related to kind, amount, classification, and specifications of the material [under UAC Rule R313-25-8(9)]; 8 related to quality assurance programs; and 10 related to multiple subsections or not assigned to any subsection of UAC Rule R313-25-8, “Specific Technical Information.”

4.1.1 Principal Design Features: Descriptions and Justification

UAC Rule R313-25-8 requires descriptions of the design features of the near-surface disposal cell, including those features related to infiltration of water; integrity of covers; structural stability of backfill, wastes, and covers; contact of wastes with standing water; disposal site drainage; disposal site closure and stabilization; elimination, to the extent practicable, of long-term disposal site maintenance; inadvertent intrusion; occupational exposures; disposal site monitoring; and the adequacy of the size of the buffer zone for monitoring. The DU PA technical review involves some aspects of UAC Rule R313-25-8, while other aspects of R313-25-8 are not specifically pertinent to the DU PA review. For example, disposal site monitoring and the adequacy of the size of the buffer zone are not directly relevant to evaluating the actual system performance; instead, they focus on the facility’s ability to measure and confirm system performance, and perform remediation if necessary. Site monitoring issues are established in any licensing action and are not part of this DU PA review. Certain modifications to current monitoring procedures may be required for the area between the proposed Federal Cell and the existing 11.e(2) Cell.

The requirements contained in UAC R313-25-8(2) and (3) addressing the design features of the facility as they relate to the performance objectives established for those design features apply in different ways and to different extents to the various principal design features incorporated into the proposed Federal Cell for the disposal of DU waste. The principal design features of the proposed Federal Cell addressed in this section of the SER are the following:

- ET cover
- Waste placement and backfill
- Clay liner

Evaluation of each of these principal design features with respect to the DU PA is addressed in separate sections below. Note that regulatory requirements that DEQ judged not to impact performance are not addressed.¹⁰

¹⁰ These include UAC Rule R313-25-8(7), (10), (11), (12), (13), and (14).

The provisions of UAC Rule R313-25-8(2) identify the following 11 required functions that the principal design features must perform:

- Minimize infiltration of water.
- Ensure integrity of covers for disposal units.
- Ensure structural stability of backfill, wastes, and covers.
- Minimize contact of wastes with standing water.
- Provide disposal site drainage.
- Ensure disposal site closure and stabilization.
- Eliminate to the extent practicable long-term disposal site maintenance.
- Protect against inadvertent intrusion.
- Limit occupational exposures.
- Allow for and provide disposal site monitoring.
- Provide a buffer zone for monitoring and allow for implementation of potential mitigative measures, if required.

EnergySolutions describes the ET cover, waste emplacement, and backfill and clay liner in Appendix 5, *Unsaturated Zone Modeling for the Clive DU PA Model v1.2*, dated June 12, 2014 (Neptune 2014k).

References

Neptune, 2014k

4.1.1.1 Evapotranspiration Cover

Disposal involves placing DU waste on a protective cover over a prepared clay liner that is approximately 8 feet below the ground surface. For the proposed Federal Cell design, the depth of the waste below the top slope is a maximum of 53 feet (16 meters), leaving as much as 45 feet of non-DU waste above natural grade. A cover system is constructed above the waste. The primary objective of the cover system is to limit contact of water with the waste. The cover is sloped to promote runoff and designed to limit water in-flow by increasing ET. The cover system also inhibits release of radon gas from the subsurface. Beginning at the top of the cover, the layers above the waste used for the ET cover design are as follows (see Section 3.4 for a full description):

- Surface Layer (6 inches)
- Evaporative Zone Layer (12 inches)
- Frost Protection Layer (18 inches)
- Upper Radon Barrier (12 inches)
- Lower Radon Barrier (12 inches)

As part of the review and response preparation for the Round 1 Interrogatories, EnergySolutions revised the proposed design of the Federal Cell from a rock armor cover to an ET cover similar to that currently under review by DRC for construction on the CAW Embankment. The DRC review (DRC 2015) should be consulted to assess interrogatories regarding apparent deficiencies of that cover system, especially when bulk waste is proposed for disposal directly beneath the cover system. DEQ’S review of EnergySolutions’ Round 1 responses resulted in a second round of interrogatories, which EnergySolutions responded to on June 17, 2014 (DRC 2014b; ES 2014h). Following delivery of the Round 2 interrogatories to EnergySolutions, DEQ proceeded to review version 1.2 of the Clive DU PA modeling report (Neptune 2014a; hereafter “the DU PA Model v1.2”), which documented the performance of the proposed Federal Cell with ET cover, and to generate Round 3 interrogatories specifically targeting the revised model. EnergySolutions provided DRC with responses to the Round 3 revised model interrogatories on July 8, 2014 (ES 2014b). The current status of each interrogatory [i.e. whether it was satisfactorily resolved (“closed”)] is found in Appendix C to this SER. Subsequent to the three rounds of interrogatories and responses, DEQ and EnergySolutions participated in several phone conferences. As result of these meetings, on August 11, 2014, DEQ requested 10 additional clarifications and proposed additional HYDRUS simulations with specific combinations of input parameters (DEQ 2014). EnergySolutions responded to the DEQ request on August 18, 2014 (ES 2014g). The 10 additional clarification comments, a summary of the EnergySolutions responses, and subsequent DEQ findings are provided in Appendix B to this SER.

In response to DEQ’s request for the additional HYDRUS simulations, the EnergySolutions response states, in part, the following:

In general, EnergySolutions strongly disagrees with the request of running highly speculative, unsupported, one-off cases suggested in the subject request. This is not consistent with the intent of the Utah regulation nor the meaning or application of a “sensitivity analysis.” In practice, an appropriate sensitivity analysis would consider only combinations of input values that are plausibly visible at the site under study. Whereas the concept of plausibility in this context is applied based on available data and professional judgment, the values that are suggested in the subject document (and repeated above) are not plausible for this site.

and

There are significant limitations in assessing the effects of parameter and conceptual uncertainty using deterministic modeling with specified (discrete) cover designs and bounding transport parameters and assumptions. Any more comprehensive sensitivity analysis for the infiltration modeling should not be based on selective, unrepresentative, and non-systematic changes in physical properties of cover materials. Moving beyond the current model in order to further refine the analysis requires more detailed site-specific data collection. However, the value of any such data collection is highly questionable, since all of the PA model endpoints are insensitive to changes in any of the hydraulic input parameters.

DEQ agrees that one-off bounding analyses are not ideal for predicting representative overall system performance. However, this approach was proposed primarily because there are still a number of unresolved concerns related to HYDRUS and GoldSim. For example, in the 20 HYDRUS simulations, it appears that the tails of the distributions describing the hydraulic properties are poorly sampled, and more extreme cases may be inadequately represented. Furthermore, for the hydraulic properties that compose the surface and evaporative zone layers of the ET cover, the van Genuchten alpha (or “ α ”) and n values were taken from the distributions (mean and standard deviation) for each parameter from the Rosetta database of hydraulic parameters for the textural class of silty clay (Schaap 2002). The parameters α , n , and K_{sat} values obtained from the Rosetta database are said by the Licensee not to be correlated. Evaluation of data from Carsel and Parrish (1988), however, demonstrates that there is a strong correlation ($R^2=0.9$) between $\log(\alpha)$ and $\log(K_{sat})$ based on regression analyses of average parameter values for 12 National Resource Conservation Service soil textural classes based on 5,097 samples for which K_{sat} data exist. Another large database exhibiting similar correlation between $\log(\alpha)$ and $\log(K_{sat})$ is that of Wösten et al. (1999). Theoretical research also shows similar relationships. Additional information regarding the correlation between the $\log(\alpha)$ and $\log(K_{sat})$ parameters is provided in Section 4.4.1 and DEQ’s Interrogatory CR R313-25-7(2)-189/3 (DRC 2014c). The lack of sensitivity of the performance assessment inputs to any of the hydraulic parameters remains a concern in that the modeled hydraulic properties of the cover system soils may be leading to unrealistically low infiltration rates.

DEQ’s proposed deterministic approach was also seen as a means to provide additional insight and defensibility in the GoldSim results. Based on the modeling results that have been provided so far, it appears that the infiltration rates could be considerably higher than those predicted by HYDRUS but still low enough to comply with the Utah regulations. However, the infiltration analysis needs to be more transparent and technically defensible in order to withstand additional scrutiny from the public and provide a measure of credibility to the entire performance assessment.

Conclusion: There are still a number of unresolved issues with respect to the selection of parameter ranges, distributions, and correlations, as well as the modeling approach and predicted sensitivities. These concerns are detailed in Appendix B. Further, because the model-predicted infiltration rates may be sensitive to the hydraulic properties assigned to each ET layer, the α and K_{sat} values assumed for modeling moisture in each soil layer within the cover system must be correlated based on experimental data. Also, additional justification is required for the soil property values used in the model by EnergySolutions. Therefore, DEQ does not consider this portion of the performance assessment resolved.

References

Carsel and Parrish, 1988

DEQ, 2014

DRC, 2014b; 2014c; 2015

ES, 2014b; 2014g; 2014h

Schaap, 2002

Wösten et al., 1999

4.1.1.2 Waste Emplacement and Backfill

The DU PA considers the emplacement of DU waste both in standard 55-gallon drums and in much-larger 10- and 14-ton steel cylinders. There are 5,408 55-gallon drums currently in a storage building at the Clive site containing depleted uranium trioxide (UO₃) from SRS that is contaminated with small amounts of activation and fission products. In addition, it is estimated that 57,122 steel cylinders will be filled with DU₃O₈ produced from the deconversion of depleted uranium hexafluoride (DUF₆) generated at three DOE GDPs (Neptune 2014i). After the deconversion process, the DU₃O₈ is being loaded back into the same cylinders in which the DUF₆ was originally stored. Most of the storage cylinders are approximately 12 feet long and 4 feet in diameter. It is estimated by EnergySolutions that about 10 percent of the cylinders will contain small amounts of fission and activation products (Henson 2006). Because these fission and activation products are predominantly found highly concentrated in localized heels, rather than generally distributed through the DU₃O₈, and because these heels, if analyzed separately, could constitute transuranic waste (Hightower et al. 2000), they are of special concern to DEQ.

EnergySolutions is committed to emplace all of the DU waste below grade and, as a corollary to that commitment, to emplace only that amount of DU waste that will fit into the available below-grade volume of the proposed Federal Cell. Further, as discussed in Section 3.4.1, the disposal volume at Clive of all wastes is constrained by the Huntsman Agreement.

The average original grade elevation is 4,272 feet amsl (ft-amsl) and the average elevation of the bottom of the waste is 4,264.17 ft-amsl, which leaves a height of under 8 feet in which the DU waste can be emplaced. (Neptune 2014f, Table 1). EnergySolutions estimated that about 44,712 cylinders and 5,408 drums could be emplaced within the available cell volume (in *Utah Radioactive Material License – Condition 35 (RML UT2300249) Compliance Report (Revision 1)*, November 8, 2013, CD13-0302, hereafter “Revision 1 of the Compliance Report” [ES 2013b]). Based on this preliminary estimate, only about 78 percent of the anticipated number of DOE DU cylinders could be emplaced below grade. However, as discussed in Section 3.4 above, EnergySolutions has now decided to physically separate the proposed Federal Cell from the 11e.(2) cell. This change has reduced the cell volume available for DU disposal. According to the Licensee, this volume will support disposal of 30,800 cylinders (see Table 3-3).

To ensure stability, EnergySolutions plans to place backfill between the cylinders and drums. According to Revision 1 of the Compliance Report, Section 3.4, p. 3-14 (ES 2013b):

Disposal of containers of depleted uranium in CLSM in the Federal Cell (mirroring the Division-approved Class A West Embankment design) is consistent with the waste disposal methods considered in that licensing action; i.e., a solid waste is disposed in a CLSM matrix that fills voids and prevents subsidence. Therefore, post-closure stability of the embankment is met.

DEQ requested additional information regarding backfill procedures under Interrogatory CR R313-25-22-166/2: Stability of Waste (DRC 2014c), including:

- Details on how headspace will be eliminated from the DU cylinders after arrival at Clive, including methods and equipment necessary for detecting

headspace, access of the container to insert controlled low-strength material (CLSM) fill, and re-sealing or closure of the waste container

- Discussion of potential interactions between CLSM and DU waste materials, including any possible effects on the ability of the CLSM to harden sufficiently to sustain needed stresses without deformation of the cover system
- Waste container spacing and geometry on a waste lift and details about any co-location of DU waste cylinders with DU waste drums
- Placement of fill material between individual containers on a waste lift

EnergySolutions, in its Round 2 Interrogatory responses (ES 2014a), stated that:

No revisions will be needed to the LLRW and 11e.(2) Construction Quality Assurance/Quality Control Manual. DUF₆ container headspace mitigation will not require revision to these procedures; field methods such as opening ports or valves will be used to gain access for CLSM. If ports or valves are not available in suitable size or location, the drums and cylinders will be penetrated. A large variety of tools are available for this task and have been used successfully at Clive for containers and waste forms ranging from steel liners to steam generators formerly used at nuclear power plants. There is no need to re-seal or close the DUF₆ canister; and this is not typically done for other waste forms placed in CLSM. These procedures have successfully been used in the disposal of approximately 40,000 tons of depleted uranium, with no adverse interactions between the Controlled Low Strength Material (CLSM) and depleted uranium. CLSM will be the fill material used in DU disposal.

As discussed in Section 3.4 of this SER, DEQ believes that it is likely that revisions to the CQA/QC Manual (ES 2012b) will be necessary. EnergySolutions must demonstrate, based on prior experience, that configurations sufficiently similar to the DUF₆ cylinders and containing similar waste products can be fully filled with CLSM. In addition, EnergySolutions must provide evidence that the interstices between arrays of cylinders with 6-inch longitudinal spacing and 2.5-inch end-on-end spacing can be adequately backfilled. Absent such a demonstration, implementation of a test pad may be required. If so, appropriate conditions can be added to any license amendment.

In the initial version of the Compliance Report, dated June 1, 2011 (ES 2011b), EnergySolutions noted that a principal design criterion for waste emplacement and backfill is that the embankment settlement be limited to 0.02 feet/foot or 1 foot over a 50-foot horizontal distance. EnergySolutions stated that compliance with this criterion was met by the conditions of License Condition 53 (RML UT2300249). In the 2008 license renewal, DRC certified that the Licensee was in compliance with all applicable regulatory requirements (ES 2008b).

Conclusion: Based on prior approvals, use of qualified procedures in the CQA/QC Manual, clarifications provided through interrogatories, and possible new license conditions, DEQ believes that the requirements of UAC Rule R313-25-8 are satisfied with regard to waste emplacement and backfill and has conditionally resolved issues relating to this portion of the performance assessment.

References

DRC, 2014c

ES, 2008b; 2011b; 2012b; 2013b; 2014a

Henson, 2006

Hightower et al., 2000

Neptune, 2014f; 2014i

4.1.1.3 Clay Liner

The waste would be placed on a protective liner covering the clay liner that is approximately 8 feet below the current, preconstruction ground surface. The clay liner is to be constructed of compacted local clay. The clay liner is uniformly about 60 centimeters (cm) (2 feet) thick by design, though the bottom of the waste cell has a gentle slope to it.

EnergySolutions developed the distribution for saturated hydraulic conductivity for the clay liner using the design value from Table 8 of Whetstone (2007) for the clay liner of 1×10^{-6} centimeter per second (cm/s) as the geometric mean of a lognormal distribution. A geometric standard deviation of 1.2 was chosen to provide an approximate order of magnitude variation above and below the geometric mean.

DEQ staff note that EnergySolutions does not account for deterioration over time of the clay liner, with resulting higher values of hydraulic conductivity that should be modeled as such. As shown in a U.S. Army Corps of Engineers assessment (Berney et al. 2008), degradation of liners over time (e.g., within 10 years) is a nearly universal occurrence. The assessment states, “*A literature review found that, in all documented in-place clay liner studies, cracking occurred in the clay liner within 10 years, leading to failure of the liner system.*” Berney et al. (2008) summarize the results of a study in this area of interest by Albrecht and Benson (2001), who state, “*the resultant cracking caused increases in hydraulic conductivity by as much as 500 times.*” EnergySolutions does not account for this magnitude of increase in liner K_{sat} in its modeling. Therefore, the conclusions developed in the DU PA Model v1.2 are unsupported and will continue to be unsupported until this shortcoming in modeling assumptions is resolved.

In a report dated February 6, 2015, EnergySolutions evaluated data and drew conclusions regarding the potential impacts of freezing and thawing on the hydraulic conductivity of clay barriers used in the final covers at the EnergySolutions LLRW disposal facility in Clive, Utah (ES 2015a).

In this report, EnergySolutions concludes that hydraulic properties of site-specific data do not mirror the impact of the freeze/thaw on hydraulic conductivity predicted in C. H. Benson et al. (2011) and, therefore, Clive’s site-specific observations should be preferentially weighted over Benson et al.’s national ranges. However, this conclusion is based on comparisons of hydraulic conductivity measurements made during construction of the clay barriers and made after the barriers had been exposed to winter weather. EnergySolutions also made comparisons between dry densities measured during construction and those measured after exposure to winter weather. Based on these comparisons, EnergySolutions concluded that the hydraulic conductivity decreased after exposure to winter weather, and the dry density increased after exposure to

winter weather. In Appendix F to this SER, Dr. Craig H. Benson raises a number of concerns with this approach, which include:

- Insufficient information on freezing and thawing
- Inconsistency with existing knowledge base
- Field-testing methodology
- Changes in dry density
- Other pedogenic processes

See Appendix F for a detailed discussion of these concerns.

Conclusion: As with the ET cover, there is still an unresolved concern that K_{sat} values will increase greatly over time, and that the α and K_{sat} values assumed for modeling flow through the liner must either be correlated or a sensitivity analysis be conducted to demonstrate that the lack of correlation assumed does not adversely affect the modeling results. In addition, there are problems with assumed liner hydraulic conductivity values. The DU PA Model v1.2 does not account for liner degradation over time. These concerns need to be resolved.

References

Albrecht and Benson, 2001

C. H. Benson et al., 2011

Berney et al., 2008

ES, 2015a

Whetstone, 2007

4.1.2 Kind, Amount, Classification, and Specifications of DU Waste Material

UAC R313-25-8(9) requires the application to include the following:

Descriptions of the kind, amount, classification and specifications of the radioactive material proposed to be received, possessed, and disposed of at the land disposal facility.

DEQ posed 14 interrogatories to EnergySolutions related to this category of specific technical information. All of the interrogatories were satisfactorily resolved except Interrogatory CR R313-25-7(9)-89/3: Contamination Levels in DUF_6 (DRC 2014c). As discussed in more detail in Section 5.3 of this SER, DEQ believes that there is significant uncertainty in technetium-99 (Tc-99) concentrations that is not fully captured in the DU PA. This can not only affect compliance with the GWPLs at 500 years but also the ability of the facility to protect the groundwater in the confined aquifer underlying the Clive site from degradation over 10,000 years. A related issue is the fact that contaminants in the DU cylinders are concentrated in the cylinder heels. Heels are the residual materials remaining in the cylinders after the gaseous uranium hexafluoride (UF_6) is removed. Contaminants include technetium, neptunium (Np), and plutonium (Pu) with bounding concentrations in the heels estimated to be as follows (Hightower et al. 2000):

- Pu-238 – 5 parts per billion (ppb)
- Pu-239 – 1,600 ppb
- Np-237 – 54,000 ppb
- Tc-99 – 5,700,000 ppb

During the deconversion process, the DUF₆ cylinders are rinsed with a neutralizing solution of potassium hydroxide (KOH) before being refilled with DU oxide. It is unlikely that the neutralization process will remove significant amounts of the contaminants in the heels.

The concentration of transuranic elements (such as Pu-238, Pu-239 and Np-237) is limited to a total of 10 nanocuries per gram (nCi/g) under the terms of the Northwest Interstate Compact on Low-Level Radioactive Waste Management. It has been established by the 10th Circuit Court that the Northwest Compact has authority over disposal at EnergySolutions. Details are included in Appendix G). Thus, the presence the contaminants from recycled uranium in the DU waste can increase groundwater contamination and may result in quantities of transuranics that exceed limits established by the Northwest Compact.

Not all cylinders contain heels contaminated with technetium, neptunium, and plutonium. It has been estimated that only about 15 percent of the cylinders are contaminated (Henson 2006). This emphasizes the importance of an appropriate Waste Acceptance Plan to ensure that cylinders containing recycled uranium are not shipped to Clive.

Conclusion: As discussed above, DEQ has resolved issues related to this portion of the DU PA based on the assumption that new license conditions regarding the CQA/QC Manual and a revised Waste Acceptance Plan will be added to any revised license. This issue resolution is further predicated upon adding one additional condition: that disposal of DU waste contaminated with the activation and fission products in recycled uranium not be permitted.

References

DRC, 2014c

Henson, 2006

Hightower et al., 2000

4.1.3 GoldSim Quality Assurance

UAC R313-25-8(10) requires the application to include the following:

Descriptions of quality assurance programs, tailored to low-level waste disposal, including audit and managerial controls, for the determination of natural disposal site characteristics and for quality control during the design, construction, operation, and closure of the land disposal facility and the receipt, handling, and emplacement of waste.

Several DEQ interrogatories have questioned various aspects of the quality assurance program for the Clive DU PA Model v1.2 (Neptune 2014a). Two important examples of these are Interrogatories R313-25-7(10)-78/1: GoldSim Model Calibration (DRC 2014a) and R313-25-7(10)-80/1: Testing of GoldSim Abstractions (DRC 2014a).

Interrogatory R313-25-7(10)-78/1: GoldSim Model Calibration (DRC 2014a) asked EnergySolutions to “Describe the role of model calibration in substantiating that GoldSim adequately simulates the physical, chemical, and biological processes at the Clive site.” EnergySolutions begins its response by indicating that, because of the nature of the problem being modeled (i.e., the behavior of the proposed Federal Cell far into the future), it would be difficult to impossible to calibrate the results to actual measured data (ES 2014d). DEQ recognizes this and is asking for something more basic: DEQ wants to be sure that the results from the DU PA Model v1.2 GoldSim calculation match (within reasonable expectations) the results that would be expected from the underlying models that form the basis of the GoldSim model. For example, DEQ is trying to better understand the fact that the infiltration rates modeled with HYDRUS do not match the GoldSim-calculated infiltration rates very closely. (See Appendix B for additional discussion.)

A related concern is how infiltration through the ET cover has been abstracted into the DU PA Model v1.2 GoldSim model. Appendix 5, Section 12.8 (Neptune 2014k) to the DU PA indicates that 20 HYDRUS runs were made for various sets of van Genuchten α and n and saturated hydraulic conductivities (K_{sat}) (see Appendix 5, Table 9). However, the varied α parameter values were only for the Surface Layer or the Evaporative Zone, whereas the varied K_{sat} parameter values were only for the radon barrier soils. No changes were made in K_{sat} for the Surface Layer or Evaporative Zone (assumed in the runs to be at constant values), and no changes were made in α for the radon barriers. Thus, a reasonably thorough sensitivity analysis, or a subset thereof, was not conducted by EnergySolutions. In Section 12.9, Table 10 (Neptune 2014k), regression coefficients are presented that relate the van Genuchten α and n and K_{sat} to the water content of the various cover layers (i.e., surface, evaporative, frost, and upper and lower radon barriers) and to the infiltration rate. On the other hand, while K_{sat} values for the Upper and Lower Radon Barrier were varied in the HYDRUS and GoldSim models, there was no correlated change made in α values. The value of α was held constant at 0.003 cm^{-1} , even though K_{sat} values were varied by orders of magnitude. There is little information provided about how EnergySolutions got from the HYDRUS input parameters to the regression coefficients, or on how well the regression analysis results match the HYDRUS results. For example, Section 12.9, Table 10 (Neptune 2014k) states that, “For the net infiltration flux regressions, K_s [saturated hydraulic conductivity] was dropped as a predictor due to poor fit of the models.” No further explanation is provided, and EnergySolutions seems to expect DEQ to accept this at face value. EnergySolutions has included additional information pertaining to the derivation of the GoldSim infiltration rates from the HYDRUS results in its responses to additional interrogatories (ES 2014d). As discussed in Appendix B, however, there are a number of questions that remain open.

In some cases, it is unclear whether unexpected GoldSim results are due to the mathematical model formulations of the code itself or to assumptions with respect to the model input parameters. For example, it is DEQ’s understanding that the intent of the model abstraction approach and linkage of process model output to the GoldSim input is that the fundamental relationships can be “abstracted” from more complex models that are time consuming to run and can be effectively maintained within the GoldSim framework in order to perform probabilistic analyses within a reasonable time frame. Therefore, as discussed in the example below and in Appendix B, the complete absence of correlation between the infiltration rates predicted by

HYDRUS and those calculated by GoldSim creates a dilemma, in that the predicted infiltration rates are the foundation for many other contaminant fate and transport and dose predictions.

In response to Supplemental Interrogatory 1, EnergySolutions indicates that the distributions for van Genuchten’s α and n were scaled in the Clive DU PA v1.2 GoldSim model to reflect the more coarse nature of the GoldSim cell structure (ES 2014d). The scaling approach that EnergySolutions describes can be used to characterize uncertainty in the mean, but the spatial variability within the hydraulic data is not represented properly. Scaling to address spatial averaging should address variance reduction using a variance function, which is defined based on the spatial correlation structure of the hydraulic properties (Vanmarcke 2010). As a result, the tails of the distributions are not represented properly, which will affect a stochastic or uncertainty analysis. It is unknown whether the spatial discretization is hardwired into GoldSim and whether any grid convergence studies were ever performed to ascertain the adequacy of the discretization.

Appendix 5, Section 12.9, to the DU PA Model report (Neptune 2014k) indicates that the HYDRUS-calculated infiltration rate into the waste zone ranged from 0.0007 to 0.29 centimeter per year (cm/yr), with an average of 0.042 cm/yr. However, when DEQ made a 1,000-realization run with the DU PA Model v1.2 file, the GoldSim-calculated infiltration rate only ranged from 0.024 to 0.047 cm/yr, with a mean of 0.034 cm/yr. These results are summarized in Table 4-1. It appears that somewhere in the GoldSim abstraction process the full range of the HYDRUS-calculated infiltration rates has been truncated, but without additional justification for the HYDRUS abstraction into GoldSim, DEQ is unable to verify the EnergySolutions approach or conclusions. This must be thoroughly explained by EnergySolutions.

Table 4-1 – Comparison of GoldSim- and HYDRUS-Calculated Infiltration Rates

	Infiltration Rate (cm/yr)	
	GoldSim v1.2, 1,000 realizations	Appendix 5, Section 12.9 ^a
Minimum	0.024	0.0007
Mean	0.034	0.042
Maximum	0.047	0.29

^a Neptune (2014k).

Moreover, until other factors, such as model inputs and correlations between these inputs, are accounted for, infiltration results from either HYDRUS or GoldSim will not necessarily provide representative infiltration values.

EnergySolutions’ response to Interrogatory R313-25-7(10)-78/1 (ES 2014d) includes the statement, “*The Clive DU PA Model is a highly-integrated system model, with many interrelated processes.*” DEQ understands that the Clive DU PA Model is very complex. This is precisely the reason that, as much as feasible, DEQ must be able to trace back all parameters used or calculated by the DU PA v1.2 GoldSim model to their original underlying models. Unless EnergySolutions provides the necessary descriptions and data in the final report, DEQ will not be able to complete this portion of the Clive DU PA Model v1.2 verification and benchmarking.

Conclusion: Specific instances where additional information and data are needed from EnergySolutions in order to allow DEQ to perform the necessary verification of Clive DU PA

Model v1.2 have been identified in Appendix B and other sections of the SER (e.g., Section 4.4.1 for infiltration). Once all of those additional requests have been satisfactorily completed, reviewed, and determined to show that the regulatory requirements have been met, DEQ will consider this concern to be resolved.

References

DRC, 2014a

ES, 2014d

Neptune, 2014a; 2014k

Vanmarcke, 2010

4.1.4 Uranium Solubility

The solubility values assumed in the DU PA are based on studies conducted by Sandia National Laboratories (SNL 2007) on the solubility of americium (Am), neptunium, protactinium, plutonium, thorium, and uranium. Some of the solubility values presented in SNL 2007 are tables with pH and partial pressure of carbon dioxide (CO₂) as variables. These studies assume that these ions are dissolving from pure solutions. However, it is more likely that the ions are present as solid solutions within the uranium solid phases [i.e., aqueous uraninite (UO₂(OH)₂)].

As part of the performance assessment review, DEQ's contractor generated the phase diagrams in Figure 4-1, Figure 4-2, and Figure 4-3 to illustrate the solubility of uranium versus redox potential in the presence and absence of carbonate using Geochemist Workbench with the Lawrence Livermore National Laboratory (LLNL) v8r6+ database. The diagrams were generated using the dissolved ion concentrations from Tables 8 and 12 in the geochemical modeling report (Appendix 6 to the DU PA, Neptune 2014m), with and without carbonate included and with the pH fixed at 7. The oxidation/reduction potential (E_H) and total uranium were varied, and the diagrams are shown in a pourbaix format with the dominant species shown in each region. Under reducing conditions, formation of tetravalent-state uranium [U(IV)] minerals limits the solubility of uranium through formation of an insoluble uraninite mineral phase. As can be seen in Figures 4-1 through 4-3 below, increased concentration of carbonate in an oxidizing groundwater environment encourages the dissolution of uranium due to formation of soluble uranyl carbonate complexes. This phenomenon has a bearing on performance assessment model assumptions for uranium fate and transport in the subsurface environment (the vadose and saturated zones).

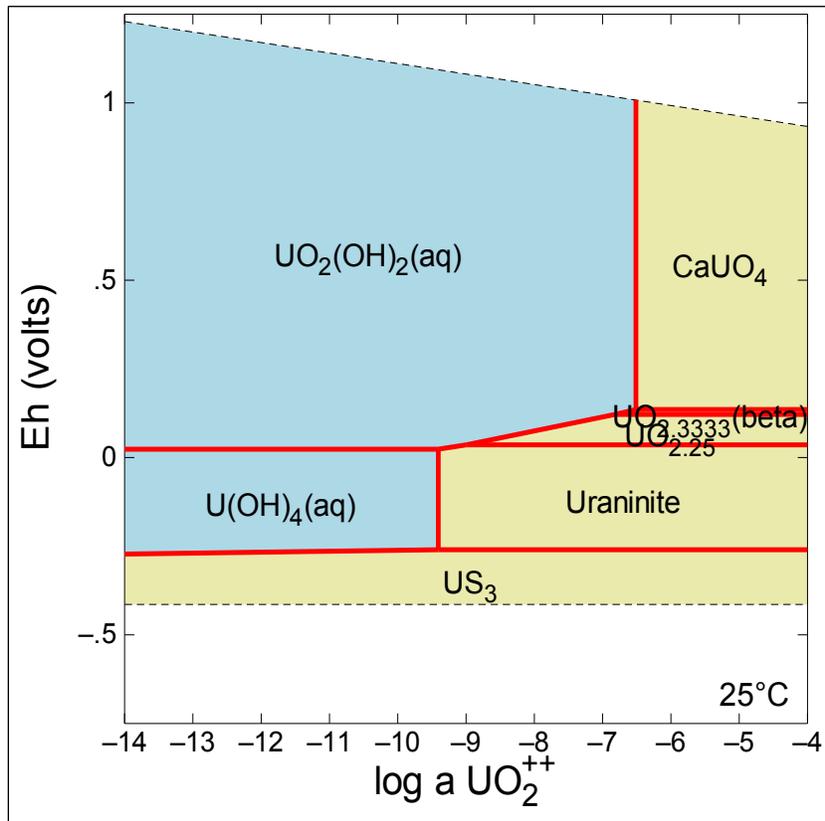


Figure 4-1 – Eh-activity diagram demonstrating uranium speciation and solubility in the absence of carbonate. Note that yellow regions indicate formation of a solid phase. Model generated using Geochemist Workbench and LLNL v8r6+ database.

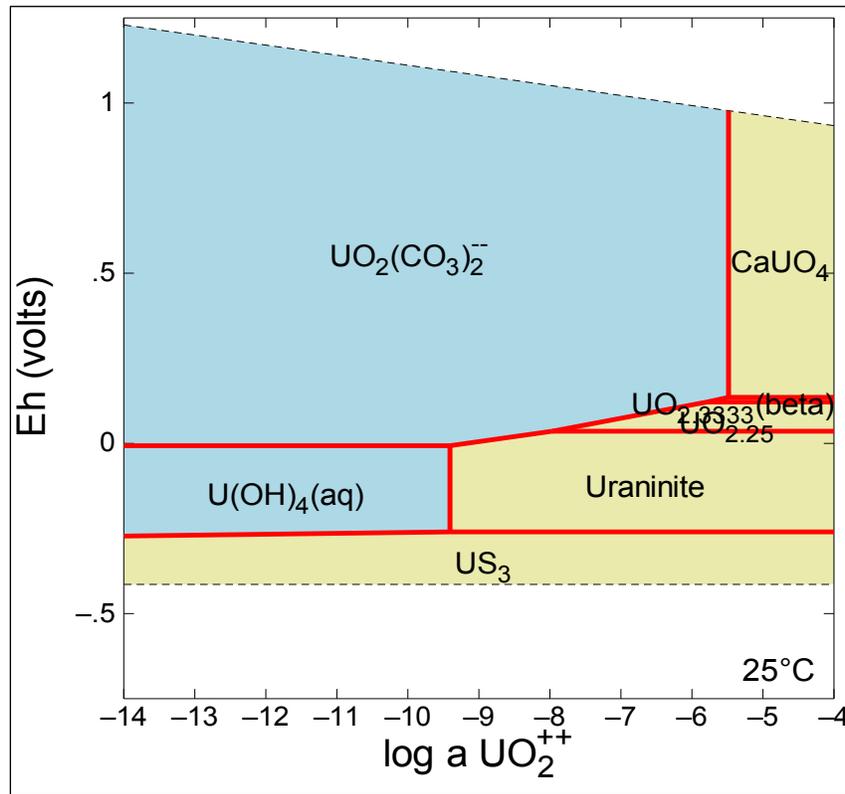


Figure 4-2 – Eh-activity diagram demonstrating uranium speciation and solubility in the presence of approximately 100 mg/L carbonate. Note yellow regions indicate formation of a solid phase. Model generated using Geochemist Workbench and LLNL v8r6+ database.

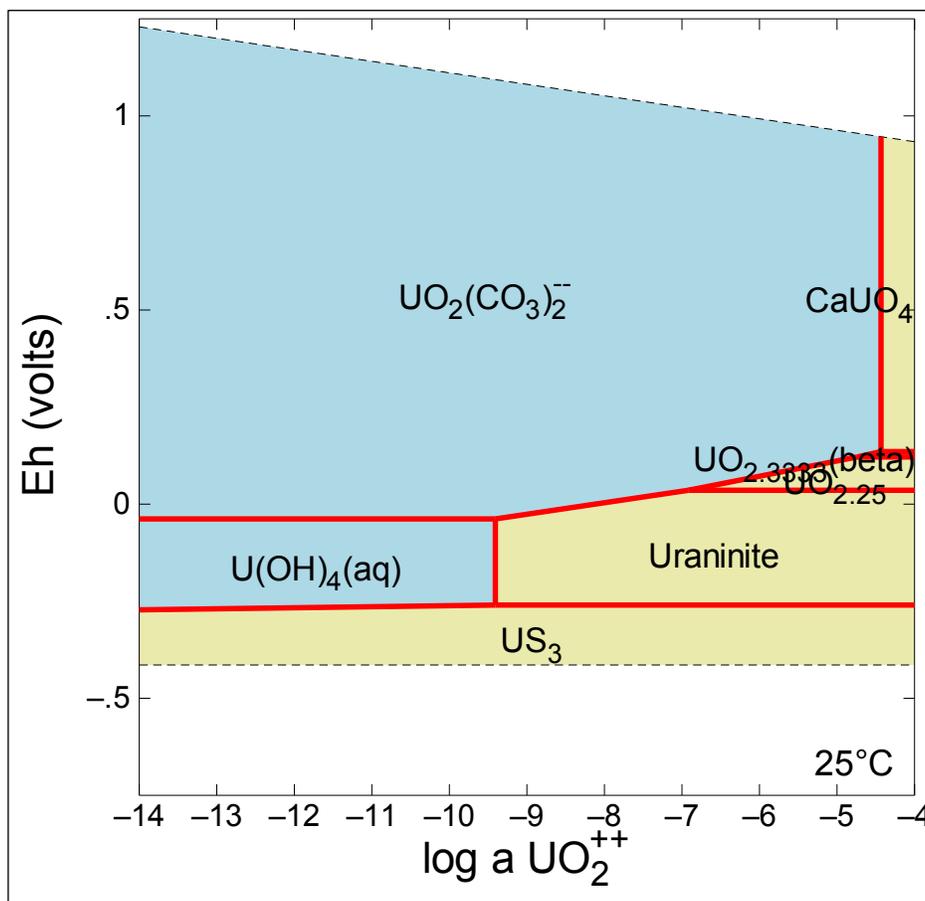


Figure 4-3 – Eh-activity diagram demonstrating uranium speciation and solubility in the presence of approximately 350 mg/L carbonate. Note yellow regions indicate formation of a solid phase. Model generated using Geochemist Workbench and LLNL v8r6+ database.

In EnergySolutions’ response to Round 1 interrogatories (ES 2014d), the last line of Table 2-64/1 presents uranium solubility data from SNL 2007. The uranium concentrations reported in EnergySolutions’ Table 2-64/1 seem to only include the solubility of hexavalent-state uranium [U(VI)] and mixed U(IV/VI) phases and do not consider the potential formation of U(IV) phases [i.e., aqueous U(IV)(OH)_x^{4-x} species and U(IV) minerals such as uraninite]. Formation of uraninite will significantly decrease overall uranium solubility in groundwater. As noted in the Round 2 Interrogatory CR R313-25-8(4)(a)-64/2 (DRC 2014b), the DU PA needed to clarify whether the geochemical model considers the potential formation of uraninite or other U(IV) phases and the expected redox conditions of the waste in the landfill, because not considering the U(IV) phases if they are indeed forming will result in an overly conservatively high estimate of aqueous uranium concentrations, due to failure to consider aqueous uranium hydroxide [U(OH)₄].

Also relevant to the overall prediction of the solubility of uranium is that the solubilities listed in Table 12 of the geochemical modeling report (Neptune 2014m) represent the output of a Visual MINTEQ model of triuranium octoxide (U₃O₈) solubility. Given the low solubilities of uranium reported in Table 12, it is clear that oxidation of U(IV) to U(VI) was not considered. This must be done by “coupling” the U(IV)/U(VI) reaction within Visual MINTEQ before running the

model. It appears that the intent of the modeling exercises examining schoepite¹¹ and U₃O₈ solubility in Tables 9 through 12 of the geochemical modeling report (Neptune 2014m) was to give the boundaries of uranium solubility. However, it is unrealistic to run a model with a relatively high E_H/pH condition (such as pH 8, E_H 200 millivolts in Table 10) and not allow for the oxidation of reduced species. Therefore, the Round 2 Interrogatory CR R313-25-8(4)(a)-64/2 expressed a concern about whether the reported low-solubility values in EnergySolutions Table 12 are reliable for use as the source term in reactive transport models. Figure 4-4 and Table 4-2 show the reported values from EnergySolutions Table 12 as well as two columns of output from additional DEQ Visual MINTEQ runs. As part of the DU PA review, DEQ used the average ion concentrations in the last row of Table 8 in conjunction with the data in Table 12 of the geochemical modeling report (Neptune 2014m) in an attempt to reproduce the reported total dissolved uranium concentrations shown in Table 12. This was done by running the model with the U(IV)/U(VI) system uncoupled, as was apparently done for the model output shown in Table 12. However, the final column in Table 4-2 shows the total uranium concentration in a Visual MINTEQ model with the U(IV)/U(VI) reaction coupled. Oxidation of U(IV) to U(VI) is therefore allowed, and the expected total dissolved uranium concentrations are significantly higher. Because the redox chemistry of the waste disposal site in this work is variable, DEQ recommended in the Round 2 interrogatory CR R313-25-8(4)(a)-64/2 (DRC 2014b) that redox-coupled solubility calculations be used when defining the source concentrations in reactive transport models. The specific E_H and pH ranges expected under the various geologic conditions considered in the reactive transport models must be used in this source term analysis.

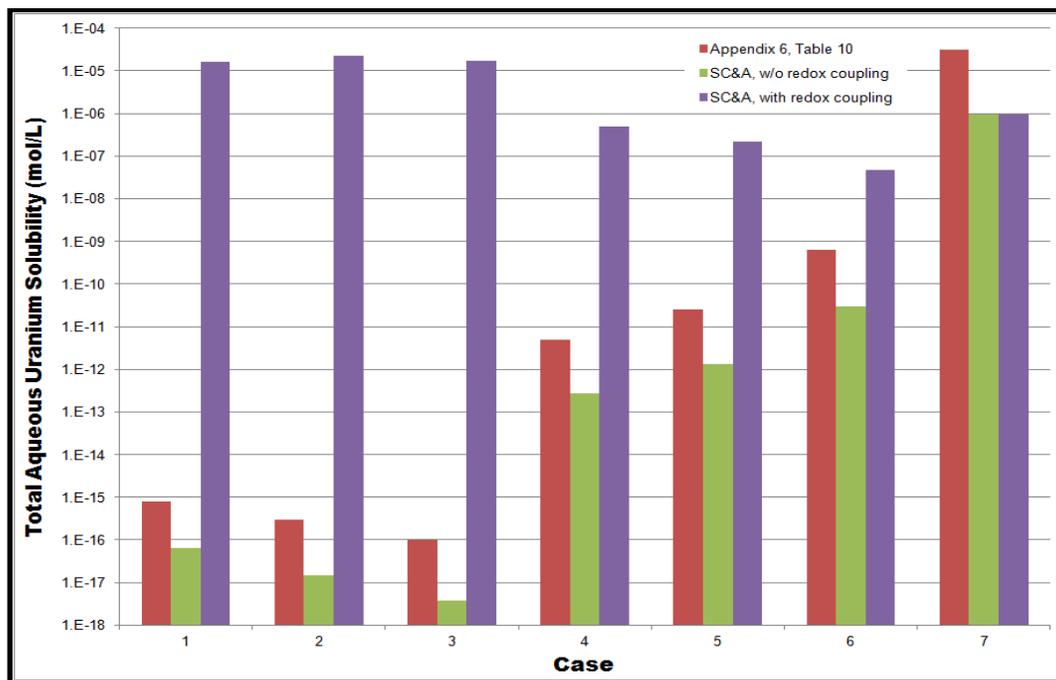


Figure 4-4 – Comparison of redox coupled and uncoupled solubility models

¹¹ Schoepite is an oxidized alteration product of uraninite, where uranium occurs as U(VI).