# UTAH DIVISION OF RADIATION CONTROL
# ENERGY*SOLUTIONS* LLRW DISPOSAL FACILITY
# CLASS A WEST AMENDMENT REQUEST

# SAFETY EVALUATION REPORT

**June 2012**

**for**
**Utah Division of Radiation Control**
**195 North 1950 West**
**Salt Lake City, UT 84116**

**URS Corporation**
**756 East Winchester Street, Suite 400**
**Salt Lake City, UT 84107**

## TABLE OF CONTENTS

**Section** **Page**

## LIST OF TABLES

**Table Title** **Page**



## TABLE OF FIGURES

**Figure Title** **Page**

## ACRONYMS AND INITIALISMS

| | |
|---|---|
| 11e.(2) | Section 11e.(2) of the Atomic Energy Act of 1954, as amended |
| 1998 LAR | License Renewal Application dated March 16, 1998 |
| 2003 LRA | License Renewal Application dated July 2, 2003 |
| 2005 LRA | License Renewal Application dated June 20, 2005 |
| ABC ALA | Application for License Amendment (Classes A, B & C waste) dated December 13, 2000. |
| Act | Utah Radiation Control Act |
| AMEC | AMEC Earth and Environmental, formerly AGRA Earth and Environmental |
| AR | amendment request |
| ASCE | American Society of Civil Engineers |
| ASTM | ASTM International, formerly American Society for Testing and Materials |
| CA | Class A |
| CAC | Class A Combined |
| CAN | Class A North |
| CAW | Class A West |
| CEDE | committed effective dose equivalent |
| CFR | Code of Federal Regulations |
| cm/sec | centimeters per second |
| CQA/QC | Construction Quality Assurance/Quality Control |
| CSLM | Controlled Low Strength Material |
| CWF | Containerized Waste Facility |
| DOE | US Department of Energy |
| DOT | US Department of Transportation |
| Division | Utah Division of Radiation Control |
| EJR | Engineering Justification Report |
| Energy*Solutions* | Formerly Envirocare of Utah, LLC and Envirocare of Utah, Inc. |
| EPA | US Environmental Protection Agency |
| EWIS | Electronic Waste Information System |
| FR | Federal Register |
| ft | feet; foot |

| | |
|---|---|
| ft/ft | feet per foot |
| g | gravity |
| H | horizontal |
| HIC | High Integrity Container |
| HMR | Hydrometeorological Report |
| hr | hour; hours |
| in | inch; inches |
| in/yr | inches per year |
| LAR | License Amendment Request |
| LARW | Low-Activity Radioactive Waste |
| LLRW | Low-level Radioactive Waste |
| LRA | License Renewal Application |
| mR/hr | milliroentgen/hour |
| mrem | millirem |
| mrem/yr | millirem/yr |
| NGA | Next Generation Attenuation |
| NORM | naturally occurring and accelerator produced material |
| NRC | US Nuclear Regulatory Commission |
| PATHRAE | Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code |
| PE | professional engineer |
| PEER | Pacific Earthquake Engineering Research Center |
| PGA | Peak Ground Acceleration |
| PMF | Probable Maximum Flood |
| PMP | Probable Maximum Precipitation |
| QAM | Quality Assurance Manual |
| QAP | Quality Assurance Program |
| R | Roentgen |
| RCRA | Resource Conservation and Recovery Act |
| SER | safety evaluation report |
| SLB&M | Salt Lake Baseline and Meridian |
| SNM | Special Nuclear Material |

| | |
|---|---|
| TEDE | total effective dose equivalent |
| TSD | Treatment, Storage and Disposal |
| UDOGM | Utah Division of Oil, Gas and Mining |
| UDSHW | Utah Division of Solid and Hazardous Waste |
| UDWQ | Utah Division of Water Quality |
| UMTRA | Uranium Mill Tailings Remedial Action |
| UNSAT-H | Unsaturated Soil Water and Heat Flow code |
| URCA | Utah Radiation Control Act |
| URCB | Utah Radiation Control Board |
| URCR | Utah Radiation Control Rules |
| URS | URS Corporation |
| USACE | US Army Corps of Engineers |
| V | vertical |
| yr | year |

# 1.0 INTRODUCTION

The purpose of this Safety Evaluation Report (SER) is to identify and summarize the information the Utah Division of Radiation Control (Division) has evaluated in its' review of the Energy*Solutions*, LLC (Licensee) license amendment request (LAR) to construct and operate a Class A West (CAW) disposal embankment. This SER summarizes the grounds upon which the Division concludes that regulatory requirements are satisfied to protect public health, safety and the environment.

The CAW embankment will be used for the disposal of radioactive materials and waste. The existing Class A North (CAN) and Class A (CA) embankments will combine, the existing footprint will be extended and the height increased. The height at the peak of the completed CAW embankment will be 75.3 ft, an increase of 22 ft from the height of the CA embankment. The total disposal volume of the CAW embankment is 8,742,097 cy, an increase of 3,222,692 cy from the combined capacity of the CAN and CA embankments.

The Division is responsible for regulating activities in the State of Utah (State of Utah or State) that involve radioactive materials, some types of radioactive waste, and radiation. As part of this responsibility, the Division enforces requirements promulgated by the State of Utah. Requirements applying to land disposal of radioactive waste are contained in Utah Radiation Control Rules (URCR), Rule R313-25, "License Requirements for Land Disposal of Radioactive Waste – General Provisions." Additional applicable rules are contained in URCR Rule R313-15 "Standards for Protection Against Radiation," which defines requirements for protecting individuals from the effects of radiation and URCR Rule R313-22, "Specific Licenses," which specifies licensing requirements, many of which are met by compliance with or superseded by the provisions of URCR Rule R313-25. Additional chapters of the URCR are also applicable.

In accordance with requirements, the Director has issued licenses to various entities within the State of Utah to possess and manage radioactive materials and wastes. One such entity, Energy*Solutions*, LLC, is licensed to receive, store, and dispose, by land burial, the following categories of radioactive materials and waste:

- Naturally-occurring and accelerator produced radioactive material (NARM) waste,
- Low-activity radioactive waste (LARW),
- Class A low-level radioactive waste (LLRW),
- Special nuclear material (SNM),
- 11.e(2) waste,
- Radioactive waste that is also determined to be hazardous (mixed waste), and
- Naturally occurring radioactive material (NORM).

Energy*Solutions* holds the following licenses and permits:

- State of Utah Radioactive Material License UT2300249, Amendment 13, expires January 25, 2013,
- State of Utah Radioactive Material License, 11(e).2 Byproduct Material License UT2300478, Amendment 6, Under timely renewal,

- State of Utah Part B Permit, EPA Identification Number UDT982598898, expires April 4, 2013, and
- State of Utah Ground Water Quality Discharge Permit Number UGW450005, expires June 8, 2013.

In order for the Division to ensure that all proposed changes to licensed facilities and operations will meet applicable regulatory requirements, a licensee must submit a LAR request, detailing and justifying the proposed action, in accordance with provisions of URCR Section R313-22-38. As required by URCR, the Licensee has submitted an LAR to construct and operate a CAW disposal embankment.

Under authority of the Utah Radiation Control Act (Act), the Radiation Control Board has established requirements and criteria for licensing commercial LLRW disposal facilities contained in URCR Rule R313-25, "License Requirements for Land Disposal of Radioactive Waste – General Provisions." Under provisions of URCR Section R313-25-4, no person may receive, possess, or dispose of waste, at a land disposal facility, unless authorized by a license issued by the Director, an Agreement State, or the U.S. Nuclear Regulatory Commission pursuant to URCR Rules R313-22 and R313-25 or equivalent requirements.

The requirements of URCR Rule R313-25 address such topics as:

- Performance Objectives,
- Site Suitability Requirements,
- Facility Design, Construction, Operating, Closure, and Post-closure Requirements,
- Waste Characteristic Requirements,
- Environmental Monitoring Requirements,
- Financial Assurance and Financial Qualifications Requirements and
- Administrative Requirements.

The Division reviews a licensee's LAR to determine the extent to which each applicable regulatory requirement is satisfied and ensure that particular licensing actions are justifiable under provisions of the regulations. The license amendment process for major modifications follows the following steps:

- Review the LAR.
- Prepare interrogatories as necessary to resolve issues not adequately addressed in the amendment request.
- Review interrogatory responses, assuring that all required information is contained in either the initial submittal or responses to interrogatories.
- Prepare draft SER and draft revised license conditions.
- Publicize the Director's decision to amend the license.
- Conduct public hearings and receive public comment.
- Prepare public participation document.
- Prepare final SER and final license revisions.

Since the LAR evaluation addresses an existing facility license, the LAR review and SER preparation paid primary attention to changes to the Licensee's currently authorized facilities and operations, as well as, previously submitted and approved scientific and engineering analyses.

The Licensee was required to update the scientific and engineering analyses to reflect current practices and state-of-the-art science and engineering procedures.

Under Section 19-1-301.5 a person who wishes to challenge a License/Permit Order may only raise an issue or argument during an adjudicatory proceeding that was raised during the public comment period and was supported with sufficient information or documentation to enable the director to fully consider the substance and significance of the issue.

# 2.0 HISTORICAL OVERVIEW

The first activities involving radioactive waste management at South Clive, Utah were those conducted by the U.S. Department of Energy (DOE). 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 South 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.) began disposal operations at its Clive Facility in 1988 under a State radioactive materials license to dispose of NORM waste. In 1990, Envirocare, Inc. submitted a license application to modify its license to allow disposal of low activity radioactive material (LARW). In 1991, the Division 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 Director renewed the Licensee's license to dispose of LARW.

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. |
| Energy*Solutions*, LLC | Commencing March 2, 2006. |

Currently, the Licensee is authorized to dispose of NORM, NARM, 11e.(2) waste, LARW, LLRW, and mixed radioactive and hazardous waste (mixed waste) at its South Clive, Utah disposal facility under radioactive material licenses issued by the Division. The licensing and permitting history of the South Clive, Utah site is summarized below:

- 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. begins 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 a 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.

- 1991 – Mixed Waste permit: On November 30, 1991, Envirocare, Inc. received a Resource Conservation and Recovery Act (RCRA) 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 (Compact): On May 28, 1992, Envirocare, Inc. entered into an arrangement, the "Resolution and Order" with the Compact, that allowed them 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 disposal license from the U.S. Nuclear Regulatory Commission (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 Division to accept 14 additional radionuclides with specified concentration limits less than the Class A limits.
- 1995 – LARW License Amended: On June 20, 1995, Envirocare, Inc.'s LARW license was modified by the Division 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 8 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 Division.
- 1996 – Macro-encapsulation approval: On October 3, 1996, Envirocare, Inc. received a Hazardous and Solid Waste Amendment permit for macroencapsulation from the U.S. Environmental Protection Agency (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 (2012) followed by Energy*Solutions*, LLC.
- 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 them 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 Division 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 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, Energy*Solutions*, LLC is presently required to follow the 1998 Resolution and Order Agreement that was made with the Compact.
- 2003 – Final agency action of 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.
- 2003 – NRC Uranium Mill Tailings license amendment request: On March 27, 2003, Envirocare, Inc. submitted a request to the NRC to amend their NRC uranium mill tailings license to accept tailings with Radium-226 concentrations up to 100,000 pCi/g. This was to allow them to accept the DOE Fernald Site Closure Project (Fernald) waste if it were classified as 11e(2) byproduct material.
- 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).
- 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.
- 2003 – Withdrawal of 2003 NRC Uranium Mill Tailings license amendment request: On November 19, 2003, Envirocare, Inc. withdrew their 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.
- 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.
- 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.
- 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.

- 2005 – Submittal of License Renewal Application: On June 20, 2005, Envirocare, LLC submitted an application to renew its LLRW disposal license.
- 2005 – Submission of the Class A Combined (CAC) amendment request: On May 27, 2005, the Envirocare, LLC submitted a license amendment request to the LLRW license to create a Class A Combined Cell.
- 2006 – Transfer of Licenses and Permits: On March 2, 2006, the licenses and permits were transferred from Envirocare of Utah, LLC to Energy*Solutions*, LLC.
- 2007 – Agreement with Governor Huntsman: On March 15, 2007, the Licensee entered into an agreement with Governor Huntsman to withdraw the amendment request for a Class A Combined Cell.
- 2011 – Submission of the CAW Embankment License Amendment Request: On May 2, 2011, the Licensee 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.

In a formal agreement with Governor Huntsman in 2007, indicating that it would withdraw its application to develop and operate its proposed "Class A Combined (CAC)" Embankment, the Licensee agreed to limit the volume of waste to be disposed of at its facility located at Clive, Utah. The major points of the 2007 agreement are summarized as follows:

1. Energy*Solutions* agreed to promptly withdraw the CAC Cell LLRW license amendment pending before the Utah Board of Radiation Control and its Executive Secretary.

2. Energy*Solutions* reaffirmed that it will not accept Class B or C low-level radioactive waste or waste having a higher radionuclide concentration than the highest radionuclide concentration allowed under licenses existing on February 25, 2005.

3. The Governor agreed to refrain from making, and would not permit his designee to make, any request to the Northwest Interstate Compact regarding low-level waste volumes for receipt at Energy*Solutions*, or to initiate or support action to limit the volume of low-level radioactive waste on Section 32, of Energy*Solutions* Clive Facility.

4. The authority and rights of the State of Utah, the Utah Board of Radiation Control, the Board's Executive Secretary, the Compact, and Energy*Solutions* are not altered by this Agreement.

On November 16, 2011, the Division approved the Licensee's 2010 financial surety report. The Licensee demonstrates annually, to the Division’s satisfaction, that it is financially capable to carry out all licensed activities. The Licensee has provided financial assurances sufficient to fund the safe closure of the facility, as well as the long-term monitoring and maintenance of the proposed facility.

# 3.0 DESCRIPTION OF CAW LICENSE AMENDMENT REQUEST

## 3.1 DESCRIPTION OF THE PROPOSED CAW EMBANKMENT

The design for the CAW Embankment is conceptually the same as the previously approved designs of the CA and CAN embankments. It is designed as primarily above-grade and will be constructed using materials native to the site or found in close proximity to the site. Engineered features of the embankment are designed based upon State of Utah requirements, NRC guidance, EPA guidance, and the Licensee's past experience at this location.

The majority of existing procedures and plans applicable to the Energy*Solutions* facility as a whole, including Radiation Safety, Quality Assurance, Health and Safety, Training, Electronic Recordkeeping, and Administration, are unaffected by the licensing and permitting of the CAW Embankment. Updated discussion and procedures are located in the Licensee's License Renewal Application LRA dated June 20, 2005, (Envirocare of Utah, LLC 2005c, LRA).

No change will result to waste placement procedures, equipment used, or forms used in documenting waste placement as a result of permitting the CAW Embankment. Certain revisions were required to be made to the Construction Quality Assurance Quality Control (CQA/QC) Manual in conjunction with permitting the CAW Embankment to accomplish the following:

- Change the name and revise the scope of the CQA/QC Manual to include the CAW Embankment;
- Provide information on updated settlement monument locations for the CAW Embankment; and
- Provide CQA/QC observation and testing procedures related to required new clay liner construction and connections of existing clay liners to newly constructed clay liner sections.

Waste placement in the CAW Embankment will be conducted in accordance with the currently approved CQA/QC Manual (which is Revision 25d approved on April 4, 2011) or any subsequent revision (e.g., proposed Revision 26b) to the CQA/QC Manual, after approval by the Division. Updated procedures are provided to the Division regularly.

The Licensee's anticipated schedule and sequence of construction activities for the CAW Embankment will begin following technical review of the embankment design and revision to licensing and permitting documents, including the Radioactive Material License, Ground Water Quality Discharge Permit, and Environmental Monitoring Plan. Once these approvals are complete, the Licensee is authorized to begin waste placement to the elevations proposed for the CAW embankment. Waste placement will proceed generally from south to north, starting on top of existing wastes placed in the Class A embankment footprint. Disposal operations in the CAW Embankment may continue for up to 17 years.

## 3.2 BASIS FOR CAW EMBANKMENT REVIEW AND CONCLUSIONS

As described in the foregoing section, the design and operation of the currently proposed CAW Embankment is substantially similar to those already approved for use in the CAN and CA disposal embankments. Although some aspects of the proposed embankment differ from those of previously proposed embankments, many remain unchanged.

Where the Division has judged the proposed change to have no effect on the rationale for previously approved amendments, the rationale for previous approved amendments is taken to apply directly to the proposed CAW Embankment LAR. While all aspects have been reviewed, only those aspects, that affect the rationale for granting approval of the CAW Embankment LAR, are addressed in this SER.

## 3.3 DESCRIPTION OF REVIEW/COMMENT/RESPONSE PROCESS

In reviewing the CAW Embankment LAR, the following major items and/or issues were identified and evaluated:

- Characteristics and design of the proposed CAW embankment, including extension and connection of the clay liners in the CA and CAN embankments, to form a continuous clay liner encompassing the proposed footprint area, waste placement and backfill, cover system, and buffer zone.
- The projected physical performance of the proposed embankment, including effects of projected differential settlement and consolidation on cover system integrity, annual infiltration rates, and effective transit times for water and potential contaminants migrating within, under, and laterally away from the waste embankment, proposed monitoring well and vadose zone monitoring device locations, the potential for a design seismic event to induce liquefaction and/or cyclic softening of soils or otherwise potentially affect embankment stability, and ability of the proposed CAW Embankment to provide adequate long-term erosion protection.
- The projected radiological performance of the proposed embankment, including determining the extent to which the Utah groundwater protection standards are satisfied and estimating potential radiological impacts to members of the public that might be exposed to releases from the facility during operations.

Where the Division judged information submitted by the Licensee to be inadequate to make an affirmative decision, formal interrogatories were issued to solicit missing information. Once required information was provided to allow resolution of issues to the Division's satisfaction, this SER was prepared. The Division and the Licensee have resolved all regulatory issues as required by Division requirements, with two exceptions. Two new license conditions will be added to the license to require the Licensee to perform an additional investigation and an embankment design modification to resolve these two issues, as discussed in detail in this SER. The Division has received or developed information that provides reasonable assurance that all applicable performance objectives and regulatory requirements involved with the regulatory issues described in this SER will be satisfied.

# 4.0 FACILITY SAFETY AND REGULATORY COMPLIANCE

URCR Rule R313-25 contains regulatory requirements that potentially apply to EnergySolution's request to amend its license to construct and dispose of Class A LLRW in the CAW embankment. The Division has previously reviewed and approved many aspects (elements) of the LAR through previous amendment requests and renewals. For these aspects, no Division review of these elements is required. Requirements of URCR Rule R313-25 are listed in Table 4-1. Requirements that do not apply to the Division's review of the CAW Embankment LAR are identified, together with reasons why they do not apply.

The applicable requirements are identified in Table 4-1. As required, review items are documented in the CAW Embankment LAR and associated submittals and are addressed in the following sections.

## 4.1 URCR SECTION R313-25-6. GENERAL INFORMATION

### 4.1.1 Identity of Licensee

**Requirement 2506-1:** The general information shall include the identity of the applicant including:

(a) the full name, address, telephone number, and description of the business or occupation of the applicant;

(b) if the applicant is a partnership, the names and addresses of the partners and the principal location where the partnership does business;

(c) if the applicant is a corporation or an unincorporated association;

- (i) the state where it is incorporated or organized and the principal location where it does business;
- (ii) the names and addresses of its directors and principal officers; and
- (iii) if the applicant is acting as an agent or representative of another person in filing the application, the applicant shall provide, with respect to the other person, information required under URCR Subsection R313-25-6(1) [URCR Subsection R313-25-6(1)].

**Table 4-1 – Applicability of URCR Section R313-25 Regulatory Requirements for CAW Embankment LAR.**

| URCR R313-25 Section | | CAW Embankment LAR Requires Review? | Reason If Review Not Required |
|---|---|---|---|
| **Number** | **Title** | | |
| URCR R313-25-1 | Purpose and Authority | No | Contains only general information, none of which is changed or affected by the CAW Embankment LAR |
| URCR R313-25-2 | Definitions | No | Presents definitions of terms with special meanings, none of which are changed or affected by the CAW Embankment LAR |
| URCR R313-25-3 | Pre-licensing Plan Approval Criteria for Siting of Commercial Radioactive Waste Disposal Facilities | No | Lists requirements for siting new LLRW disposal facilities which is not the case for the CAW Embankment |
| URCR R313-25-4 | License Required | No | Declares the State's requirement that a license is required to dispose of radioactive waste, a fact conceded by submission of the CAW Embankment LAR |
| URCR R313-25-5 | Content of Application | No | Identifies the content requirements of a license application in broad terms, with reference to URCR Sections R313-25-6 through R313-25-10 whose needs for review in connection with the CAW Embankment LAR are individually addressed below |
| URCR R313-25-6 | General Information | Yes | Addressed in Section 4.1 |
| URCR R313-25-7 | Specific Technical Information | Yes with Exceptions | Exceptions identified and justified in Section 4.2 |
| URCR R313-25-8 | Technical Analyses | Yes with Exceptions | Exceptions identified and justified in Section 4.3 |
| URCR R313-25-9 | Institutional Information | No | Deals with land ownership that is not changed or affected by the CAW Embankment LAR |
| URCR R313-25-10 | Financial Information | No | The Licensee's financial qualifications are not materially changed or affected by the CAW Embankment |
| URCR R313-25-11 | Requirements for Issuance of a License | Yes with Exceptions | Exceptions identified and justified in Section 4.4 |
| URCR R313-25-12 | Conditions of Licenses | No | Addresses the concept of license conditions that will have been determined as a result of the CAW Embankment LAR process |

**Table 4-1 – Applicability of URCR Section R313-25 Regulatory Requirements for CAW Embankment LAR.**

| URCR R313-25 Section | | CAW Embankment LAR Requires Review? | Reason If Review Not Required |
|---|---|---|---|
| **Number** | **Title** | | |
| URCR R313-25-13 | Application for Renewal or Closure | No | Addresses licensing actions for which the Applicant is not now applying in its submission of the CAW Embankment LAR |
| URCR R313-25-14 | Contents of Application for Site Closure and Stabilization | No | Addresses licensing actions for which the Licensee is not now applying. |
| URCR R313-25-15 | Post-Closure Observation and Maintenance | No | Addresses licensing actions for which the Applicant is not now applying. |
| URCR R313-25-16 | Transfer of License | No | Addresses licensing actions for which the Applicant is not now applying. |
| URCR R313-25-17 | Termination of License | No | Addresses licensing actions for which the Applicant is not now applying. |
| URCR R313-25-18 | General Requirement | No | Generally states only requirements that are covered in URCR Sections R313-25-19 and R313-25-22, without imposing additional requirements. |
| URCR R313-25-19 | Protection of the General Population from Releases of Radioactivity | Yes | Addressed in Section 4.5 |
| URCR R313-25-20 | Protection of Individuals from Inadvertent Intrusion | Yes | Addressed in Section 4.6 |
| URCR R313-25-21 | Protection of Individuals During Operations | Yes | Addressed in Section 4.7 |
| URCR R313-25-22 | Stability of the Disposal Site After Closure | Yes | Addressed in Section 4.8 |
| URCR R313-25-23 | Disposal Site Suitability Requirements for Land Disposal – Near-Surface Disposal | No | The Division has reviewed and approved the characteristics of the site at which the proposed CAW will be constructed and operated. |
| URCR R313-25-24 | Disposal Site Design for Near-Surface Land Disposal | Yes | Addressed in Section 4.9 |
| URCR R313-25-25 | Near Surface Land Disposal Facility Operation and Disposal Site Closure | Yes with Exceptions | Exceptions identified and justified in Section 4.10 |
| URCR R313-25-26 | Environmental Monitoring | Yes with | Exceptions identified and justified in Section 4.10 |

**Table 4-1 – Applicability of URCR Section R313-25 Regulatory Requirements for CAW Embankment LAR.**

| URCR R313-25 Section | | CAW Embankment LAR Requires Review? | Reason If Review Not Required |
|---|---|---|---|
| **Number** | **Title** | | |
| | | Exceptions | |
| URCR R313-25-27 | Alternative Requirements for Design and Operations | No | Addresses alternative requirements for design and operation that the CAW Embankment LAR does not involve |
| URCR R313-25-28 | Institutional Requirements | No | Deals with land ownership that is not changed or affected by the CAW Embankment LAR |
| URCR R313-25-29 | Section 29 does not exist in URCR R313-25 | No | Section 29 does not exist in URCR Rule R313-25 |
| URCR R313-25-30 | Applicant Qualifications and Assurances | No | The Licensee's financial qualifications and assurances are not materially changed or affected by the CAW Embankment LAR |
| URCR R313-25-31 | Funding for Disposal Site Closure and Stabilization | Yes with Exceptions | Exceptions identified and justified in Section 4.12 |
| URCR R313-25-32 | Financial Assurances for Institutional Controls | No | The Division has previously reviewed and accepted arrangements for assuring funding to cover costs during institutional control; the arrangements are not materially changed or affected by the CAW Embankment LAR; the Division reviews and approves adequate financial assurance annually. |
| URCR R313-25-33 | Maintenance of Records, Reports, and Transfers | No | Neither the need for nor the Licensee's procedures for maintaining records, reports, and transfers are changed or affected by the CAW Embankment LAR |
| URCR R313-25-34 | Tests on Land Disposal Facilities | No | Deals with the Director's activities and authorities that are not changed or affected by the CAW Embankment LAR |
| URCR R313-25-35 | Director Inspections of Land Disposal Facilities | No | Deals with the Director's activities and authorities that are not changed or affected by the CAW Embankment LAR |

**Basis:** At the time of this submittal, the information contained in Section 1.1 of the CAW Embankment LAR (Energy*Solutions* 2011a; 2011b) and other relevant documents (engineering reports, supplemental data submissions and interrogatory responses) that the Licensee has submitted indicates that the requirements of URCR Subsection R313-25-6(1) have been met. The 2011 CAW Embankment LAR identifies as the full name, address, and telephone number of the Licensee as follows:

**Table 4-2 – Identification of Licensee.**

| **Identification of Licensee** |
|---|
| Energy*Solutions*, LLC<br>423 W 300 S Ste 200<br>Salt Lake City UT 84101-1102<br>(801) 532-1330 |

Also included in the referenced documentation are the names and addresses of the Licensee's directors and principal officers. The LAR also specifies that the Licensee's state principal business is the operation of the radioactive waste disposal operations located at Clive, Utah. Energy*Solutions* did not act as an agent or representative of another person in submitting the LAR. Additionally, Energy*Solutions* is not a partnership. On March 2, 2006, Envirocare of Utah, LLC, a limited liability company organized under the laws of the State of Utah, changed its name to Energy*Solutions*, LLC. Directors and principal officers of Energy*Solutions*, LLC are as follows:

**Table 4-3 – Directors and Principal Officers of Energy*Solutions*, LLC.**

| | | |
|---|---|---|
| **President and Chief Executive Officer Energy*Solutions*, LLC** | Val J. Christensen<br>423 West 300 South, Suite 200<br>Salt Lake City, UT 84101 | |
| **Board Members/Managers:** | Steven R. Rogel, Chairman<br>423 W 300 South, Suite 200<br>Salt Lake City, UT 84101 | Robert Whitman, Director<br>Franklin Covey Co.<br>2200 West Parkway Blvd.<br>Salt Lake City, UT 84119 |
| | J.I. Everest II, Director<br>423 West 300 South, Suite 200<br>Salt Lake City, UT 84101 | Dr. Pascal Colombani, Director<br>Senior Advisor<br>AT Kearney Paris<br>44 rue de Lisbonne<br>75008 Paris, France |
| | David B. Winder, Director<br>490 16th Avenue<br>Salt Lake City, UT 84103 | David J. Lockwood, Director,<br>PartnerValueAct Capital<br>435 Pacific Ave., 4th Floor<br>San Francisco, CA 94133 |

| Table 4-3 – Directors and Principal Officers of Energy*Solutions*, LLC. | | |
|---|---|---|
| | J. Barnie Beasley, Jr., Director<br>729 Falling Springs Dr.<br>P.O. Box 558<br>Tiger, GA 30576 | Claire Spottiswoode, CBE,<br>Director, Chairman<br>Energy*Solutions* EU Ltd.<br>1st Floor, Stella Building<br>Windmill Hill Bus. Park<br>Whitehill Way<br>Swindon, SN5 6NX, UK |

***References:***

Energy*Solutions*, 2011a; 2011b

### 4.1.2 Qualifications of Licensee

**Requirement 2506-2:** The general information shall include the qualifications of the applicant including:

(a) the organizational structure of the applicant, both offsite and onsite, including a description of lines of authority and assignments of responsibilities, whether in the form of administrative directives, contract provisions, or otherwise;

(b) the technical qualifications, including training and experience of the applicant and members of the applicant's staff, to engage in the current activities. Minimum training and experience requirements for personnel filling key positions described in URCR Subsection R313-25-6(2)(a) shall be provided;

(c) a description of the applicant's personnel training program; and

(d) the plan to maintain an adequate complement of trained personnel to carry out waste receipt, handling, and disposal operations in a safe manner [URCR Subsection R313-25-6(2)].

**Basis:** The information contained in the CAW Embankment LAR (Energy*Solutions* 2011a; 2011b), along with supporting and relevant documents, (engineering reports, supplemental data submissions and interrogatory responses) the Licensee has submitted, indicate that the requirements of URCR Subsection R313-25-6(2) have been met. The qualifications of the Licensee for the CAW Embankment are similar to those previously approved in the 2005 CAN SER and reviewed in the 2005 LRA SER and in other previous LRA SERs (e.g., (URS Corporation 2005a; 2005b).

Based on the information summarized above, the Division concludes that the Licensee's qualifications are acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b

URS Corporation, 2005a

URS Corporation, 2005b

#### 4.1.3 Proposed Disposal Site and Activities

**Requirement 2506-3**: The general information shall include a description of:

(a) the location of the disposal site;

(b) the general character of the current activities;

(c) the types and quantities of waste to be received, possessed, and disposed of;

(d) plans for use of the land disposal facility for purposes other than disposal of wastes; and

(e) the existing facilities and equipment [URCR Subsection R313-25-6(3)].

**Basis:** The information contained in the CAW Embankment LAR (Energy*Solutions* 2011a; 2011b) and other relevant documents, (engineering reports, supplemental data submissions and interrogatory responses) the Licensee has submitted, indicate that the requirements have been met. The CAW Embankment LAR provides an adequate description of the proposed CAW Embankment. The CAW Embankment LAR and other documents describe the legal location of the operating Clive radioactive waste disposal facility as Section 32, Township 1 South, Range 11 West, Salt Lake Basin and Meridian (SLB&M), Tooele County, Utah. The Licensee also identifies other operations that are conducted by the Licensee and nearby facilities.

The proposed disposal site and activities for the CAW Embankment are conceptually the same as the previously approved CAN and CA embankments, with one exception being the larger footprint size and height of the CAW Embankment, and conceptually the same as that reviewed for the previously proposed CAC disposal embankment, with the CAW Embankment being only slightly larger in area but shorter in height than the previously proposed, but unimplemented, CAC disposal embankment. The CAW Embankment is designed as a primarily above-grade disposal embankment.

Based on the information summarized above, the Division concludes that the descriptions of the proposed CAW Embankment and proposed disposal activities are acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b

#### 4.1.4 Proposed Schedules

**Requirement 2506-4:** The general information shall include the expected schedules for construction, receipt of waste, and first emplacement of waste at the existing land disposal facility [URCR Subsection R313-25-6(3)].

**Basis:** The information contained in the CAW Embankment LAR, and other relevant documents (engineering reports, supplemental data submissions and interrogatory responses) the Licensee has submitted, indicate that the requirements of URCR Subsection R313-25-6(4) have been met. The information includes schedules for construction, receipt, and first emplacement of waste. The Licensee indicates that construction of new liner between the CA and CAN embankments could begin as early as the first construction season following approval of the license amendment (Energy*Solutions* 2011a; 2011b; Section 1.3) Disposal operations in the CAW Embankment may continue for up to 17 years from the time the amendment is approved. Final cover construction shall be completed on or before the end of 18 years after the date of initial placement of the first lift (UGWDP Condition 6).

***References:***

Energy*Solutions*, 2011a; 2011b

## 4.2 URCR SECTION R313-25-7. SPECIFIC TECHNICAL INFORMATION

The CAW Embankment LAR technical review involves some aspects of URCR Section R313-25-7, whereas other aspects of URCR Section R313-25-7 are not specifically pertinent to the review. The applicability of URCR Section R313-25-7 provisions to the review of the CAW Embankment LAR are summarized in Table 4-4. Those sections that do apply to the CAW Embankment LAR are addressed in the paragraphs following the table.

**Table 4-4 – Applicability of URCR Section R313-25-7 Provisions to CAW Embankment LAR.**

| URCR R313-25-7 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| Number | Topic | | |
| 7(1) | Site Characteristics | No | Division has previously reviewed and approved site characteristics |
| 7(2) | Design Features | Yes | Dimensions and cover system have changed |
| 7(3) | Principal Design Criteria | Yes | Clay layer distortion criteria have been reconsidered |
| 7(4) | Natural Events or Phenomena | Yes | Probable Maximum Precipitation Event was verified with additional procedure |
| 7(5) | Codes and Standards | No | Division has previously reviewed and approved codes and standards which the CAW Embankment LAR does not change or affect |
| 7(6) | Construction and Operation | No | Except for dimensions and cover design (addressed elsewhere in this SER), construction and operations are not changed or affected by the CAW Embankment LAR |
| 7(7) | Site Closure Plan | Yes | Timing and sequencing of final closure activities for the CAW Embankment have changed compared to those for the Class A and CAN embankments |
| 7(8) | Natural Resources | No | Division has previously reviewed and approved natural resources which the CAW Embankment LAR does not change or affect |

**Table 4-4 – Applicability of URCR Section R313-25-7 Provisions to CAW Embankment LAR.**

| URCR R313-25-7 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| Number | Topic | | |
| 7(9) | Radioactive Material Description | No | Division has previously reviewed and approved the description of radioactive wastes which the CAW Embankment LAR does not change or affect |
| 7(10) | Quality Assurance Programs | Yes | Provisions for constructing the final cover system stated in the Construction Quality Assurance/Quality Control Manual have been slightly revised |
| 7(11) | Radiation Safety Program | No | Division has previously reviewed and approved the Radiation Safety Program which the CAW Embankment LAR does not change or affect |
| 7(12) | Environmental Monitoring Program | Yes | The CAW Embankment LAR requires the abandonment and relocation of some vadose zone lysimeters and groundwater monitoring wells and the addition of one air monitoring station |
| 7(13) | Administrative Procedures | No | Division has previously reviewed and approved Administrative Procedures which the CAW Embankment LAR does not change or affect |
| 7(14) | Electronic Recordkeeping System | No | Division has previously reviewed and approved the Electronic Recordkeeping System which the CAW Embankment LAR does not change or affect |

### 4.2.1 Principal Design Features: Descriptions, Design Criteria, Justification, and Applicable Codes/Standards

**Requirement 2507-2**: Design features of the near-surface disposal cell includes 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 adequacy of the size of the buffer zone for monitoring and potential mitigative measures [URCR Subsection R313-25-7(2)].

**Basis**: The requirements contained in URCR Subsections R313-25-7(2) and -7(3) addressing the design features of the facility and the principal design criteria, 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 CAW embankment. For example, one principal design feature is the perimeter drainage system that performs a required function of conducting the flow of surface water run-off away from the CAW Embankment in order to minimize contact between water and disposed LLRW. However, the drainage systems would play no direct role in protecting against inadvertent intrusion. In contrast, another design feature, the rock riprap layer in the cover system, is intended to help perform the required function of protecting against inadvertent intrusion but does not have as a primary function the minimization of contact between water and disposed LLRW. That required function would be provided primarily by other components or aspects of the cover such as cover slope inclination and the radon barrier layer. Thus, the applicability of the various regulatory requirements and design criteria pertaining to the design of principal design features depends upon each individual design feature.

The principal design features of the proposed CAW Embankment, addressed in this section of the SER, are the following:

- liner,
- waste placement and backfill,
- cover,
- drainage systems and
- buffer zone.

Each of the above principal design features is addressed in separate sections below. Each principal design feature is first described, key design criteria for that design feature are discussed and their relationship to the performance objectives for that design feature are summarized. Information regarding the design-basis conditions, assumed to apply during operation and following final closure of the CAW Embankment are discussed, and the codes and standards applied to design and construction of the CAW Embankment are summarized. For completeness, and to facilitate traceability to the applicable URCR Rule R313-25 requirements, each applicable regulatory requirement is repeated as each principal design feature is discussed in this SER. Note that regulatory requirements, that the Division judged not to be affected by the changes in the proposed CAW Embankment LAR are not addressed, as enumerated in Table 4-4 of this SER.

In this SER, information pertaining to the several design features is presented in separate SER sections. For example, the clay liner is addressed in Section 4.2.1.1 and a description of the clay liner design feature is presented in Section 4.2.1.1.1. The design criteria are described in Section 4.2.1.1.2 and the design basis and justification of the design criteria are described in Section 4.2.1.1.3.

The provisions of URCR Subsection R313-25-7(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 (not applicable to disposal of Class A waste),
- Limit occupational exposures,
- Allow for and provide disposal site monitoring and
- Provide a buffer zone for monitoring and allow for implementation of potential mitigative measures, if required.

The Licensee has identified the five principal design features described in the second paragraph of this subsection. The Licensee has determined that these five principal design features perform a range of required functions as indicated in Table 4-5 below. Entries in the table indicate that at least one principal design feature performs one or more of the required functions identified during the CAW Embankment design process.

***References*:**

Energy*Solutions*, 2011a; 2011b

#### 4.2.1.1 Clay Liner

##### 4.2.1.1.1 Description of Design Feature – Clay Liner

**Requirement 2507-2:** Descriptions of the design features of the land disposal facility and of the disposal units for near-surface disposal shall include those design features related to infiltration of water; integrity of covers for disposal units; 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 adequacy of the size of the buffer zone for monitoring and potential mitigative measures [URCR Subsection R313-25-7(2)].

**Basis:** The clay liner proposed for the CAW Embankment is identical to that approved for the Class A and CAN embankments. The proposed CAW Embankment liner system consists of a prepared foundation overlain by a two-foot thick layer of compacted clay having a saturated hydraulic conductivity of 1 x 10-$^{6}$ cm/sec or less. The characteristics of the liner of the proposed CAW Embankment are presented in Table 3.3 of the CAW Embankment LAR (Energy*Solutions* 2011a) and summarized below:

- The permeability of the CAW embankment liner will be less than or equal to 1 X 10-4 cm/sec and greater than that of the cover system.
- Existing terrain is excavated to a depth of approximately seven to ten ft below native grade. Excavation depth is determined based on the top of liner elevation shown on design drawings. The minimum excavation depth is two ft deeper than the top of liner elevation shown on design drawings. Overburden removed in reaching foundation elevation is stockpiled for future use in liner construction, capping the embankment, or as fill material.
- The embankment foundation is prepared from in-situ soils to meet design, grade, and compaction specifications. Specifications and inspection activities for foundation

preparation are detailed in proposed Revision 26b to the CQA/QC Manual [Table 1, Work Element – Foundation Preparation (Energy*Solutions* 2011d)].

- Clay liner construction methods are approved with the satisfactory construction of a clay liner test pad, as detailed in the CQA/QC Manual (Table 1, Work Element – Clay Liner Test Pad). The equipment and procedures used for the test pad are reviewed and approved by a professional engineer qualified to certify such soil considerations. The test pad method is then reviewed and approved for construction by engineering staff of the DRC.

**Table 4-5 – Summary of Principal Design Features and Their Required Functions – CAW Embankment.**

| Required Function | Required Functions Performed By Principal Design Features | | | | |
|---|---|---|---|---|---|
| | Clay Liner | Waste Emplacement and Backfill | Cover | Drainage Systems | Buffer Zone |
| Minimize infiltration | | | Minimize infiltration<br>Encourage run-off<br>Prevent desiccation<br>Limit frost penetration<br>Limit biointrusion | Minimize infiltration under flood conditions | |
| Ensure cover integrity | Mitigate differential settlement to ensure no cracking occurs in radon barrier layer after embankment closure | Mitigate differential settlement | Mitigate differential settlement<br>Prevent internal erosion<br>Material stability/endure weathering, external erosion | | |
| Reduce exposures | | | Limit dose rates at the cover surface to acceptable level | | |
| Ensure structural stability | | Maintain slope stability | Ensure maximum embankment settlement amount is limited to acceptable level and ensure no slope reversal occurs<br>Maintain slope stability | | |
| Minimize contact of wastes with standing water | Minimize contact of wastes with standing water during operations<br>Minimize contact of wastes with standing water after closure | | | Facilitate flow away from embankment | |

**Table 4-5 – Summary of Principal Design Features and Their Required Functions – CAW Embankment.**

| Required Function | Required Functions Performed By Principal Design Features | | | | |
|---|---|---|---|---|---|
| | **Clay Liner** | **Waste Emplacement and Backfill** | **Cover** | **Drainage Systems** | **Buffer Zone** |
| Provide site drainage | | | | Facilitate flow away from the embankment<br>Minimize infiltration under flood conditions | |
| Ensure ditch integrity | | | | Prevent external and internal erosion | |
| Provide site monitoring &/or allow for corrective measures | | | | | Allow for and provide site monitoring<br>Allow for implementation of corrective measures, if required, in a timely fashion |

- Clay liner borrow materials are sampled and tested to verify their physical characteristics meet the requirements outlined in the CQA/QC Manual (Table 1, Work Element – Clay Liner Borrow Material). These characteristics are summarized in Table 1 of the CQA/QC Manual. Once CQA/QC testing is complete and approved, the clay liner borrow materials become clay liner materials approved for clay liner construction. Borrow materials that fail testing may be reworked or may be discarded and replaced with materials meeting the criteria.
- The clay liner materials are then placed in lifts and compacted to at least 95 percent Standard Proctor, at a moisture content between optimum and 5 percentage points above optimum. Inspection and testing performed on the placed clay liner is described in the currently approved (Revision 25d) version of the CQA/QC Manual (Table 1, Work Element – Clay Liner Placement).
- A number of CQA/QC specifications are applied to protect the placed and approved clay liner against damage. These include drying prevention, seasonal limitations on liner construction to protect against winter weather extremes, and minimization of heavy equipment travel on completed liner (Table 1, Work Element – Clay Liner Placement; Specifications: Liner Drying Prevention, Snow Removal, Cold Weather Placement of Clay Liner, Contamination of Clay Liner, and Heavy Equipment on Clay Liner).
- During operations, water will be actively removed from the open embankment by vacuuming or pumping.

In areas between the existing Class A and CAN embankments, new sections of clay liner for the CAW Embankment will be constructed according to the standards described in Section 4.2.1.1.4 of this SER. The Licensee has provided Figure E in Attachment 9 to the CAW Embankment LAR and to Energy*Solutions* (2011b, dated September 2, 2011) to show the extents of completed CA and CAN embankment liner design limits and areas where new sections of clay liner will need to be constructed and connected to the existing Class A and CAN embankment clay liners.

The proposed CAW Embankment liner system design, being identical to that previously approved for use in the CA and CAN disposal embankments, and the proposed clay liner section connection procedures, being consistent with current industry standard methods are also acceptable for use in the CAW Embankment. Based on the information summarized above, the Division concludes that the Licensee's description of the proposed CAW Embankment clay liner characteristics and description of clay liner construction process are acceptable.

***References:***

Energy*Solutions*, 2011a

Energy*Solutions*, 2011b, Drawing 10014 (Figure E) in Attachment 9 (October 4, 2011)

Energy*Solutions*, 2011d

#### 4.2.1.1.2 Principal Design Criteria – Clay Liner

**Requirement 2507-3:** Descriptions of the principal design criteria and their relationship to the performance objectives [URCR Subsection R313-25-7(3)].

**Basis**: Table 4-6 of this SER summarizes the functions required of the CAW Embankment liner. Required and complementary functions of the liner include:

- Minimize contact of wastes with standing water, both during operations and after closure.
- Ensure cover integrity by mitigating differential settlement to which secondary settlement/consolidation of the materials underlying the placed waste and backfill contribute.

Section 3 and Table 3.2 of the CAW Embankment LAR provide the design criteria pertinent to the liner (Energy*Solutions* 2011a). These design criteria are summarized in Table 4-6 below with respect to each of its defined required design functions.

**Table 4-6 – Summary of CAW Embankment Clay Liner Design Criteria.**

| Required Function/ Complimentary Aspect | Design Criteria |
|---|---|
| Minimize contact of wastes with standing water during operations. | The clay liner will be constructed with a permeability less than or equal to 1 x $10^{-4}$ cm/sec. |
| Minimize contact of wastes with standing water following closure without active maintenance being required. That is, the rate of water enters the disposal unit must be less than the rate at which water leaves. | The clay liner will be constructed with a permeability that is greater than or equal to that of the cover. |
| Ensure integrity of cover by mitigating differential settlement | Foundation and clay liner settlement will be limited (through design and construction) in concert with settlement within waste placement and backfill such that distortion in the cover does not exceed a maximum allowable distortion value specified by design, as justified through design analyses. Settlement monitoring data from a placed interim final cover soil layer overlying the embankment will be verified prior to final cover placement to demonstrate compliance with the specified maximum distortion criterion. |

The design criteria selected for the CAW embankment liner and the description of the required functions of the liner are consistent with the guidance provided in NUREG-1199 (NRC 1191). The requirement that the liner permeability equal or exceed that of the cover will help ensure against "bathtubbing" of liquids on the liner (i.e., within the CAW embankment) after embankment closure without required active maintenance, consistent with NRC requirements (NRC 1982). The technical basis for selecting a maximum allowable distortion criterion for the cover is further discussed in Section 4.2.1.2.2 and in Section 4.2.1.3.3 below under the heading "Mitigate Differential Settlement". Based on the information summarized above and on the discussion of the design basis conditions assumed for use in performance analyses as presented in the sections that follow below, the Division concludes that the Licensee's proposed design criteria for the CAW Embankment liner are acceptable.

***References:***

Energy*Solutions*, 2011a

NRC 1982

NRC 1991

#### 4.2.1.1.3 Design Basis Conditions and Design Criteria Justification – Clay Liner

**Requirement 2507-4:** Descriptions of the natural events or phenomena on which the design is based and their relationship to the principal design criteria [URCR Subsection R313-25-7(4)].

**Basis**: Section 3 and Table 3.2 of the CAW Embankment LAR (Energy*Solutions*, 2011a; 2011b) for the proposed CAW Embankment present information on normal and abnormal conditions, and accident conditions (where applicable) under which the proposed CAW Embankment LAR would be assumed to operate or that are assumed to apply following final closure of the embankment. Table 3.2 of the CAW Embankment LAR: (1) summarizes the conditions considered in the design of the CAW Embankment; (2) provides information justifying the selection of these design criteria; and (3) summarizes the relationship of the design-basis conditions to the principal design features of the CAW Embankment LAR and the design criteria for each of the identified design features.

Normal, abnormal, and accident (where applicable) design basis conditions used to evaluate the performance of the liner with respect to the specified required function(s)of the liner (see Table 3.2 of the CAW Embankment LAR) are summarized in Table 4-7.

Table 4-8 provides a summary of the design criteria for the embankment liner and provides information on procedures to be used and/or other justification for ensuring that the specified liner design criteria will be achieved.

The proposed liner design basis conditions and information provided to justify the liner design criteria are consistent with the guidelines and criteria contained in NUREG-1199 (NRC 1991), NUREG-1200 (NRC 1994), and 10 CFR Part 61 (NRC 1982). Based on the information summarized above, the Division concludes that the information provided by the Licensee regarding design basis conditions (i.e., natural events and phenomena), and their relationship to the principal design criteria and principal design features of the proposed CAW Embankment is acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b; 2011d

NRC, 1982; 1991; 1994

#### 4.2.1.2 Class A Waste Emplacement and Backfill

##### 4.2.1.2.1 Description of Design Feature – Waste Emplacement

**<u>Waste Placement and Backfill</u>**

**Requirement 2507-2:** Descriptions of the design features of the land disposal facility and of the disposal units for near-surface disposal shall include those design features related to infiltration of water; integrity of covers for disposal units; 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 adequacy of the size of the buffer zone for monitoring and potential mitigative measures [URCR R313-25-7(2)].

**Basis:** The Licensee has provided information regarding proposed waste placement descriptions, procedures, and specifications for placing and compacting wastes and backfill into the CAW Embankment. Waste placement will be done in accordance with the most current approved CQA/QC Manual or any subsequent revision to the CQA/QC Manual approved by the Division. The only changes to waste and backfill placement activities, associated with the CAW Embankment, compared to those conducted at the existing CA and CAN embankments, would be the greater quantities of wastes and backfill placed, an increase in the overall height, and an increase in size of the footprint of the CAW Embankment compared to the combined Basis: The Licensee has provided information regarding proposed waste placement descriptions, procedures, and specifications for placing and compacting wastes and backfill into the CAW Embankment. Waste placement will be done in accordance with the most current approved CQA/QC Manual or any subsequent revision to the CQA/QC Manual approved by the Division. The only changes to waste and backfill placement activities, associated with the CAW Embankment, compared to those conducted at the existing CA and CAN embankments, would be the greater quantities of wastes and backfill placed, an increase in the overall height, and an increase in size of the footprint of the CAW Embankment compared to the combined footprint of the CA and CAN embankments. Summary reports, submitted by the Licensee, describing waste and backfill emplacement configurations include "Containerized Waste Facility Engineering Justification Report," Revision 1, April 12, 2001; "Engineering Justification Report, Addendum 'Fifteen Percent Void Space Criteria,'" Revision 1, October 10, 2001; "Engineering Justification Report – Waste Placement with CLSM," Revision 0, May 16, 2001; "Geotechnical Study: Increase in Height and Footprint," AMEC Earth and Environmental (AMEC), May 27, 2005, submitted by the Licensee for the previously proposed CAC Embankment, and Attachment 5 to the CAW Embankment LAR (Energy*Solutions* 2011a;b). There would be no changes to waste or backfill placement procedures, equipment used, or forms used in documenting waste placement as a result of permitting the CAW embankment. No revisions to the currently approved "Waste Placement" Work Element of the Construction Quality Assurance Quality Control (CQA/QC) Manual (Revision 25d) are needed in conjunction with permitting the CAW Embankment other than revising the scope definition to address the CAW Embankment rather than the CA and CAN embankments.

**Table 4-7 – Summary of Design Basis Conditions Used in Analyses to Evaluate Liner Performance.**

| Required Function/ Complimentary Aspect | Design Basis Conditions |
|---|---|
| Minimize contact of wastes with standing water during operations. | • *Normal:* 25-year, 24-hour storm event is assumed to occur.<br>• *Abnormal:* 100-year, 24-hour storm event is assumed to occur.<br>• Accident: Heavy equipment damage occurs to the liner. |
| Minimize contact of wastes with standing water following closure without active maintenance being required. That is, the rate of water enters the disposal unit must be less than the rate at which water leaves. | • *Normal:* Liner and cover both retain their respective design permeabilities over time.<br>• *Abnormal:* Degraded cover conditions are assumed.<br>• *Accident:* Not required by guidance provided in NUREG-1199 (NRC 1991). |
| Ensure integrity of cover by mitigating differential settlement | • *Normal:* All settlement is assumed to be completed during the operational period of the CAW Embankment LAR.<br>• *Abnormal:* One area of the embankment is assumed to be constructed to the proposed height of the cover while an adjacent area of the embankment would be constructed to a height of less than 25 ft.<br>• *Accident:* Not required by guidance provided in NUREG-1199 (NRC 1991). |

**Table 4-8 – Comparison of Required and Achieved Conditions for CAW Disposal Embankment Liner.**

| Liner Characteristic | Design Criteria | Design Criteria Justification |
|---|---|---|
| Liner permeability | Must be ≤ 1 X $10^{-4}$ cm/sec | Proposed Revision 26b to the CQA/QC Manual (Energy*Solutions* 2011d) requires no greater than 1 X $10^{-6}$ cm/sec. Operational experience at the facility shows that a permeability of 1 X $10^{-4}$ cm/sec or less is sufficient to encourage water accumulation to occur. Any water ponds or pools on top of the working surface will immediately be removed by active means such as pumping. |
| Liner permeability | Must be greater than cover permeability | Current design requires liner permeability to be 1 X $10^{-6}$ cm/sec or less and be greater than lowest cover component (radon barrier) permeability (1 X $10^{-8}$ cm/sec) to ensure that the rate of water entering the disposal unit is less than the rate at which it leaves via infiltration into underlying materials to prevent water from accumulating on top of the liner. |
| Results in distortion in radon barrier clay layer that does not exceed specified criterion | Distortion of cover must be ≤ specified maximum allowable distortion value | Maximum distortion of Cover due to embankment settlement under abnormal conditions will be projected to be less than or equal to the Specified Maximum Allowable Distortion Criterion. |

The effects of settlement on principal design features such as the cover due to the increased height of the proposed CAW Embankment are discussed in a report by AMEC (AMEC 2011a) constituting Attachment 5 to the CAW Embankment LAR (Energy*Solutions*, 2011a) and analyzed in the "Geotechnical Study: Increase in Height and Footprint," AMEC, May 27, 2005 (AMEC 2005a). Information provided in Attachment 5 to the CAW Embankment LAR (Energy*Solutions*, 2011a;b) demonstrates that the proposed CAW Embankment will perform as well or better than the previously proposed CAC embankment with respect to the projected magnitude of distortion that might occur in the cover due to differential settlement within the completed embankment, i.e., that the CAW Embankment would be expected to achieve and comply with the specified maximum allowable distortion value criterion identified as a key criterion for ensuring long-term stability of the CAW Embankment cover. The technical basis for selecting a maximum allowable distortion criterion for the cover is further discussed in Sections 4.2.1.2.2 and 4.2.1.3.3 below under the subheading "Mitigate Differential Settlement" under "Ensure Cover Integrity".

Based on the information summarized above, the Division concludes that the Licensee's descriptions of the proposed Waste and Backfill Placement Principal Design Feature and procedures for Waste and Backfill placement in the CAW Embankment are acceptable.

***Debris and Large Component Placement:***

**Basis**: The disposal of debris and containerized waste in the large component area would continue unchanged with approval of the CAW Embankment LAR. Disposal of such waste involves construction of debris and containerized waste/Controlled Low Strength Material (CLSM) pyramids to minimize differential settlement within the embankment. Following acceptance and unloading, debris and/or large components are placed so as to minimize the volume of void spaces between containers/components. Debris and large components are placed to minimize entrapped air in each debris lift. Associated incidental debris is placed in such a manner to minimize entrapped air pockets that cannot be displaced by CLSM. Once debris or large components are placed in the debris lift, the lift is backfilled by pouring CLSM over the waste so that it flows to fill void spaces within the emplacement. CLSM is a low-strength, flowable concrete. Standard concrete mixing and delivery equipment is used to pour CLSM in each debris pour. The flowability of the CLSM is controlled to ensure adequate filling of the voids within the oversized debris pour.

The disposal of debris and containerized waste proposed for the proposed CAW Embankment is identical to that approved for the CAN embankment and the 2005 LRA (URS Corporation 2005a; 2005b). The conditions upon which the disposal is based are similar, except the overall height and surface area of the CAW Embankment are increased, thus increasing the volume of material potentially disposed of in the embankment. Analyses (Attachment 5 of Energy*Solutions* 2011a; 2011b) demonstrate that the disposal of debris and containerized waste in the CAW embankment will perform at least as well as corresponding items approved for the CA and CAN embankments (URS Corporation 2005a; 2005b) and reviewed for the previously proposed CAC embankment (AMEC 2005a; 2005b).

Specifications for CLSM placement are found in Energy*Solutions*' CQA/QC Manual (Energy*Solutions*, 2011d), Table 1, "Work Element – Waste Placement Specification: CLSM Pours."

Based on the information summarized above, the Division concludes that the Licensee's descriptions of the manner of placing debris and large components into the proposed CAW Embankment and CLSM use for backfill are acceptable.

***Bulk Waste Placement:***

**Basis**: The Licensee is proposing that the types and manner of bulk waste placement within the CAW Embankment be the same as those previously approved and used in the CA and CAN disposal embankments (URS Corporation 2005a; 2005b) and the 2005 LRA. Following acceptance and unloading, bulk waste will be emptied and spread into bulk waste lifts that are 12 inches thick or less within the CAW Embankment footprint. After spreading, bulk waste will be compacted to at least 90% of Standard Proctor. The moisture content of each bulk waste lift will be controlled to between 2% (absolute) and 3 % over optimum. After the bulk waste lift is compacted, the density and moisture content of the bulk waste will be tested in accordance with Table 1, "Work Element – Waste Placement" of proposed Revision 26b of the CQA/QC Manual. QC inspectors will document the testing and approval of each bulk waste lift (Energy*Solutions* 2011d). These primary controls used during waste placement create a stable engineered fill that will provide a suitable foundation for the final cover.

The conditions upon which the bulk waste placement are based are similar to those approved for the CA and CAN disposal embankments, except for overall volume of waste to be disposed. Analyses (Attachment 5 of Energy*Solutions*, 2011a and 2011b) demonstrate that the performance of the CAW Embankment with regard to the placed bulk wastes and cover stability will equal or better the corresponding performance approved for the CA and CAN embankments (URS Corporation 2005a; 2005b) and reviewed for the previously proposed CAC embankment (AMEC 2005a; 2005b.

Based on the information summarized above, the Division concludes that the Licensee's description of the types and manner of placement of bulk waste into the proposed CAW embankment are acceptable.

***References:***

AMEC, 2005a; 2005b

Energy*Solutions*, 2011a; 2011b; 2011d

URS Corporation, 2005a; 2005b

#### 4.2.1.2.2 Principal Design Criteria – Waste Emplacement

**Requirement 2507-3:** Descriptions of the principal design criteria and their relationship to the performance objectives [URCR R313-25-7(3)].

**Basis**: The principal design criteria pertinent to waste placement and backfill in the proposed CAW Embankment are listed in Table 3.2 of the LAR. Justification for these criteria are summarized in Table 3.2 and further detailed in Attachment 5 to the CAW Embankment LAR (Energy*Solutions* 2011a; b). Additional supporting information is provided in Sections 4.3 and 4.4 of the AMEC 2011 "Geotechnical Update Report", included as Attachment 5 to the CAW Embankment LAR (Energy*Solutions* 2011a; b), AMEC 2000, and Energy*Solutions* 2012c. A key design criterion is the limitation of allowable distortion of the upper radon barrier to less than or equal to the specified maximum allowable distortion criterion due to any settlement occurring within the CAW embankment. That is, settlement occurring within the CAW embankment due to settlement of waste and backfill must not result in a magnitude of differential settlement that would contribute to a distortion exceeding the specified maximum allowable distortion criterion. This design criterion is further discussed in Section 4.2.1.3.3 below.

With the possible exception of the Maximum Allowable Distortion Criterion, the principal design criteria proposed for the CAW Embankment with respect to waste emplacement are identical to those approved for the CA and CAN embankments (URS 2005a; b) and reviewed for the previously proposed CAC embankment (AMEC 2005a; b). Analyses performed for the proposed CAC embankment (AMEC 2005a; b), as discussed in Attachment 5 to the CAW Embankment LAR (Energy*Solutions* 2011a; 2011b), demonstrate that the CAW embankment is expected to perform at least as well, with respect to complying with a previously-proposed maximum allowable distortion criterion of 0.02 ft/ft for the cover, which is a criterion that was proposed by the Licensee for the CAN embankment and that was included in the 2005 LRA (URS Corporation 2005a, Section 4.2; URS Corporation 2005b). Other corresponding design elements reviewed for the previously proposed CAC disposal embankment are summarized in Attachment 5 to the CAW Embankment LAR (Energy*Solutions* 2011a; 2011b). As discussed in additional detail in Section 4.2.1.2.3 below under the subheading "Mitigate Differential Settlement" under "Ensure Cover Integrity", prior to placing final cover over the CAW embankment, the Licensee will: (1) Conduct and submit to the Division the results of laboratory testing of an on-site compacted clayey soil layer comprised of soils proposed for use in construction of the CAW embankment cover to assess the tensile strain and distortion-induced crack resistance properties of the compacted layer. (2) Continue to perform settlement monitoring of the interim soil cover layer placed over filled portions of the CA and CAN embankments. (3) Determine magnitudes of differential settlement currently occurring in the interim soil cover layer and calculate distortion values occurring within these embankment areas. A new license condition will be added to the facility's license to address this additional required testing and distortion analysis. The purpose of the additional testing of site-specific soils is to verify whether the 0.02 maximum allowable distortion value remains an appropriate value of maximum allowable distortion criterion for the cover for use in the design of the CAW embankment. The calculated distortion values will be compared against the highest distortion value estimated, based on the settlement monitoring data acquired to date in the CA and CAN embankments, which is approximately 0.007 ft/ft. This value is well below the previously derived maximum allowable design criterion value of 0.02 ft/ft. As discussed in Section 4.2.1.3.3 below, if required based on the laboratory testing results, a revised maximum allowable distortion criterion for the cover will be identified and invoked as a final design criterion for the cover imposed prior to final cover construction. Based on the information summarized above, the Division concludes that the Licensee's proposed principal design criteria for waste placement and backfill for the CAW Embankment are acceptable.

***References:***

AMEC Earth & Environmental, Inc., 2005a; 2005b

Energy*Solutions*, 2011a; 2011b

URS Corporation, 2005a; 2005b

#### 4.2.1.2.3 Design Basis Conditions and Design Criteria Justification – Waste Emplacement

**Requirement 2507-4:** Descriptions of the natural events or phenomena on which the design is based and their relationship to the principal design criteria [URCR R313-25-7(4)].

**Basis**: Attachment 5 to the CAW Embankment LAR and Table 3.3 of the CAW Embankment LAR describe and summarize the design basis conditions considered in the design of the CAW Embankment waste placement and backfill principal design feature. Also included in LAR are normal and abnormal conditions considered in evaluations of the performance of the CAW Embankment with respect to the identified principal design criteria. Table 3.4 of the CAW Embankment summarizes the results of evaluations conducted to assess the projected performance of the CAW Embankment with respect to waste placement and backfill (LAR Energy*Solutions*, 2011a; b).

As described in Section 4.2.1.3.3 below, updated deterministic and probabilistic seismic hazard analyses were completed. Based on the results of the updated analyses, the design PGA of 0.28g recommended by AMEC in its February 15, 2011, "Geotechnical Update Report" and used for the CAW embankment stability calculations was found to be acceptable.

The design basis conditions and design criteria justification proposed for the CAW embankment, with the possible exception for the case of the cover distortion criterion, pending results of additional soils testing, as described above, are identical to those approved for the CA and CAN embankments (URS Corporation 2005a; b) and those proposed for the previously contemplated CAC disposal embankment (AMEC 2005a; 2005b)). Information furnished in Attachment 5 to the CAW Embankment LAR demonstrates that the CAW embankment would perform at least as well as corresponding items that were previously approved for the CA and CAN embankments (URS Corporation 2005a; b) and reviewed for the previously proposed CAC disposal embankment (AMEC 2005a; 2005b).

Projected performance of the containerized waste placement and backfill is discussed in Attachment 5 to the CAW Embankment LAR (Energy*Solutions*, 2011a,b). The Licensee utilized applicable guidance issued by the NRC, including guidance described in NRC NUREG-1199 (NRC 1991) and NUREG-1200 (NRC 1994), pertaining to normal, abnormal, and accident (where applicable) conditions that should be considered during design of NRC-licensed LLRW disposal facilities.

Based on the information summarized above, the Division concludes that the Licensee’s proposed design basis conditions and justification for the design criteria for waste placement and backfill for the CAW Embankment are acceptable.

***References*:**

AMEC, 2005a; 2005b

Energy*Solutions*, 2006; 2011a; 2011b

US Nuclear Regulatory Commission, 1991

US Nuclear Regulatory Commission, 1994

#### 4.2.1.3 Cover Design

##### 4.2.1.3.1 Description of Design Feature – Embankment Cover

**Requirement 2507-2**: Descriptions of the design features of the land disposal facility and of the disposal units for near-surface disposal shall include those design features related to infiltration of water; integrity of covers for disposal units; 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 adequacy of the size of the buffer zone for monitoring and potential mitigative measures [URCR R313-25-7(2)].

**Basis**: The currently proposed cover of the proposed CAW embankment is described in Sections 3.1.1 and 3.1.2 of the CAW Embankment LAR (Energy*Solutions*, 2011a; b). Design criteria for the cover are summarized in Table 3.2 and characteristics of the cover system components are described in Table 3.3 of the CAW Embankment LAR. The proposed Cover is depicted on Drawings 10014 C01 and 10014 C02 and on Drawings 10014 C03, Rev. 2 and 10014 C04, Rev. 2, included in Energy*Solutions* (2001e). As shown in Details 1 through 4 on Drawing 10014 C04, the proposed CAW embankment cover is a multi-layer system consisting from bottom to top of a two-component compacted clay radon barrier, a lower granular filter zone ("Type B" Filter Zone), a sacrificial soil layer, an upper granular filter zone ("Type A" Filter Zone), and an erosion (rock riprap) barrier layer. Table 3.3 of the CAW Embankment LAR and Drawing 10014 C04, Rev. 2, provide material specifications for each layer of the cover (Energy*Solutions*, 2011e). The top of the cover would be sloped at 4%, with the center crest line oriented north-south. The maximum lengths of the top slope, and side slope areas, in horizontal projection, would be approximately 942 ft, and 188 ft, respectively. Sides of the cover would be sloped at 20% (5H:1V).

The radon barrier layer would be comprised of a 1-foot-thick layer of compacted clay having an as-built saturated permeability of 1 x $10^{-6}$ cm/sec and an overlying 1-foot-thick layer of compacted clay having an as-built permeability of 5 x $10^{-8}$ cm/sec or less. The radon barrier would be constructed using soil borrow materials having 85% fines less than 0.075 mm in diameter; plasticity index ranging from 10 to 25; and liquid limit values ranging from 30% to 50%. The radon barrier would be placed and constructed in lifts and compacted to meet the specified design criteria of 95% Standard Proctor at a moisture content between optimum and + 5% (Table 3.3 of CAW Embankment LAR).

A 6-inch-thick lower ("Type B") filter zone, with an overlying 12-inch-thick sacrificial soil layer, would be placed directly over the radon barrier on both the top slope and side slope areas of the cover. The sacrificial soil layer would serve as a freeze/thaw barrier layer above the lower filter zone. Specifications for gradation requirements for the Type B filter zone layer and sacrificial soil layer are as follows (Drawing 10014 C04, Rev. 2, of Energy*Solutions*, 2011e): (1) Ratio of $D_{15}$ of filter to $D_{85}$ of soil must be less than 5; (2) Ratio of $D_{50}$ of filter to $D_{50}$ of soil must be less than or equal to 25; and (3) Ratio of $D_{15}$ of filter to $D_{15}$ of soil must be greater than or equal to 4. In addition, the Type B filter zone layer must exhibit a saturated hydraulic conductivity (permeability) of 3.5 cm/sec or greater, and the sacrificial soil layer must have a minimum initial moisture content at 15 bar (atmospheres) of 3.5% (Drawing 10014 C04, Rev. 2, of Energy*Solutions*, 2011e).

The upper, 6-inch-thick ("Type A") filter zone, overlying the sacrificial soil layer and below the surficial erosion barrier layer, would comprise the final (uppermost) layers of the embankment cover. The "Type A" filter zone layer would consist of a graded mixture of rocks of less than 6 inches in diameter and finer-grained particles and soil. Specifications for thickness, gradation, and rock durability include a minimum 6 inches thick, a $D_{100}$ of 6 inches or less and a rock score of at least 50 are found in Table 3.3 of the CAW Embankment LAR. This layer would serve a similar purpose to the lower ("Type B") filter zone, serving as a protective layer for the sacrificial soil and providing a transitional gradation between the sacrificial soil layer and the overlying rip-rap erosion barrier. The Type A filter layer is also designed to promote the long-term erosional stability of the rock riprap layers on the top slope and side slopes.

The primary erosion barrier component of the cover consists of a minimum 24-inch thick layer of rock riprap consisting of large, durable rock (having a rock score of at least 50) and meeting the specifications provided in Table 3.3 of the CAW Embankment LAR. The top cover portion of the riprap layer would consist of rock riprap designated by Energy*Solutions* as "Type B Riprap" and having the following gradation (Table 3.3 of the CAW Embankment LAR): $D_{100}$ of 4 1/2 inches or less, $D_{50}$ of 1 1/4 inches or more, $D_{10}$ of 3/4 inch or more, and $D_5$ of No. 200

sieve [~0.075 mm] or more. The side cover portion of the riprap layer would consist of rock riprap designated by Energy*Solutions* as "Type A Riprap" and having the following gradation: $D_{100}$ of 16 inches or less, $D_{90}$ of 12 inches or less, $D_{50}$ of 4 ½ inches or more, $D_{10}$ of 2 inches or more, and $D_5$ of No. 200 sieve [~0.075 mm] or more. The rock sizes of the erosion barrier riprap for the top slopes of the embankment ("Type B Riprap") would be smaller than that for the side slopes ("Type A Riprap") due to the flatter inclination of the top slope compared to the side slope areas.

The descriptions of the cover and its components are consistent, in general, with the guidance provided in NUREG-1623 (NRC 2002) and NUREG-4620 (Nelson, et al., 1986). The characteristics of the cover components match those used in the analyses completed to evaluate performance of the CAW Embankment in Section 4.3.2 below. Results of the technical analyses, in Section4.3.2 below, demonstrate that the long-term stability of the CAW Embankment cover is acceptable.

Based on the information summarized above, the Division concludes that the Licensee's design of the proposed CAW embankment Cover system is acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b; 2011e

NRC, 2002

Nelson, et al., 1986

#### 4.2.1.3.2 Principal Design Criteria – Embankment Cover

**Requirement 2507-3:** Descriptions of the principal design criteria and their relationship to the performance objectives [URCR R313-25-7(3)].

**Basis**: Sections 3.1 and 3.2 of the CAW Embankment LAR provide information regarding the design criteria pertinent to the cover of the proposed CAW Embankment.. Sections 3.1 and 3.2 and Table 3.2 of the CAW Embankment LAR summarize the principal design criteria for the cover. The design criteria used by the Licensee for each required function of the cover are summarized in Table 4-9.

Energy*Solutions* furnished additional information in 2011 and 2012 in responses (Energy*Solutions* 2012a; 2012b) to Round 2 and Round 3 interrogatories that were submitted by the Division. In a subsequent letter Energy*Solutions* responded to Division requests that in light of recently published information, additional data be provided to justify the previously proposed maximum allowable distortion value of 0.02 ft/ft. The distortion value is the amount of clay distortion that is allowed, for minimizing potential occurrence of cracks in the radon barrier layer as a result of differential settlement. Additional discussion of the design distortion criterion for the cover is provided in Section 4.2.1.3.3 of this SER.

**Table 4-9 – Summary of Cover Design Criteria.**

| Required Function/Complementary Aspect | Design Criteria |
|---|---|
| Provide means of restricting inadvertent intrusion into the embankment | No specific design criteria are specified; however, the presence of a 7.0-foot thick cover with an uppermost riprap layer, the site's remoteness from population centers and other barriers such as perimeter fencing will serve to restrict inadvertent intrusion into the emplaced, covered wastes. |
| **Minimize Infiltration** | |
| Minimize infiltration | Average infiltration rate through cover < 0.036 inches/year (0.09 cm/year) topslope area; and 0.066 inches/year (0.168 cm/year) sideslope areas (Whetstone Associates 2011b) |
| Encourage run-off | Surface slope must be adequate to maintain positive drainage;<br>Maximum calculated design velocity within the drainage layer must be greater than the predicted maximum drainage velocity for extreme storm events; and<br>No accumulation of water on the surface of the embankment |
| Protect the radon barrier from desiccation | No desiccation cracking allowed in radon barrier clay layer |
| Protect the radon barrier from frost damage | Thickness of rock erosion barrier plus sacrificial soil plus filter zone layers ≥ maximum projected depth of frost penetration (3 ft) |
| Limit biointrusion-related damage to radon barrier | Cover shall discourage biointrusion and shall not cause infiltration through cover to increase above base case infiltration levels (given in second column, second row of this table) |
| **Reduce Exposures** | |
| Limit occupational exposures (by limiting exposures at the cover surface) | Dose rate at cover surface shall be less than 100 mrem total effective dose equivalent (TEDE) per year |
| **Ensure cover integrity** | |
| Mitigate differential settlement | The Division- approved final maximum allowable angular distortion criteria for the Cover will not be exceeded. |
| Prevent internal erosion | Run-off water velocity shall be < 3 ft/sec on surface of radon barrier and to minimize piping, particle size specification for Type B Filter Zone material shall conform to the following:<br>$D_{15}$ (filter)/$D_{85}$ (soil) shall not exceed 5;<br>$D_{50}$ (filter)/$D_{50}$ (soil) must be ≤ 25; and<br>Upward migration of fines will be prevented :<br>$D_{15}$(filter)/$D_{85}$(soil) must be ≥ 4 |
| Exhibit material stability and resist external erosion | Rock erosion barrier shall exhibit internal stability and endure weathering/external erosion for at least 1,000 years |
| **Ensure Structural Stability** | |
| Withstand settlement without damage | Total settlement shall be less than 15 percent of embankment height in order to not compromise drainage capability of the Cover (i.e., cause slope reversal with consequent ponding of water) |
| Maintain slope stability | Embankment shall meet minimum global factor of safety against sliding instability of 1.5 under static conditions and 1.2 under dynamic (earthquake) |

The design criteria selected for the currently proposed CAW Embankment cover and the description of the required functions of the cover are consistent with the requirements and guidance provided in 10 CFR Part 61 (NRC 1982), NUREG-1999 (NRC 1991), NUREG-CR/4620 (Nelson, et al. 1986), and NUREG-1623 (NRC 2002) and with published information pertaining to tensile strains capable of being sustainable in compacted clay layers without cracks occurring.

Based on the information summarized above, and based on the discussion of the design basis conditions, the Division concludes that the Licensee's proposed design criteria for the CAW embankment Cover are acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b; 2012a; 2012b; 2012c

Nelson, et al., 1986

NRC, 1991

NRC, 2002

Whetstone Associates Inc., 2011b

#### 4.2.1.3.3 Design Basis Conditions and Design Criteria Justification – Embankment Cover

**Requirement 2507-4:** Descriptions of the natural events or phenomena on which the design is based and their relationship to the principal design criteria [URCR R313-25-7(4)].

**Basis:** Section 3.2 of the CAW Embankment LAR provides information regarding the design basis conditions, including natural events or phenomena on which the design of the CAW embankment Cover is based. Section 3.2 and Table 3.2 of the CAW Embankment LAR summarize the relationship of the design basis conditions to each of the Principal Design Features and their required functions and the specific design criteria applicable to each cover design feature. Table 3.2 of the CAW Embankment LAR also summarizes the justification for each of the cover design criteria.

The design basis conditions used by the Licensee for design of the CAW embankment cover, corresponding to the specified required function(s) of the cover, by category of function, are summarized in Table 4-10.

**Provide Inadvertent Intruder Barrier**

Utah and NRC regulations require an intruder barrier for the disposal of only Class C LLRW. Since only Class A waste will be disposed of in the proposed Disposal Embankment, no intruder barrier, as specifically defined by Utah regulations, is required. In a more general sense, however, intruder protection is required by the performance objective stated in URCR R313-25-20. These more general requirements are satisfied by the remoteness of the facility from large population centers, the cover system provided to separate the waste from the atmosphere, the presence of an uppermost rock riprap layer on the top slope and side slopes of the CAW Embankment cover, physical access barriers erected and maintained at the closed facility, access controls maintained at the closed facility, and monuments placed denoting the locations of embankment boundaries.

**Table 4-10 – Summary of Design Basis Conditions Assumed for Design of Cover.**

| Required Function/Complementary Aspect | Design Basis Conditions |
|---|---|
| Provide means of restricting inadvertent intrusion into the embankment | All conditions described below in this table |
| Minimize infiltration | • *Normal:* Average annual precipitation<br>• *Abnormal*: All abnormal conditions related to the Complementary Aspects of "Encourage Run-off", "Desiccation", "Frost Penetration", and "Biointrusion"<br>• *Accident*: Not required under NUREG-1199 |
| Encourage run-off | • *Normal:* 100 year, 24 hour storm event assumed to occur<br>• *Abnormal:* PMP<br>• *Accident:* Downstream blockage assumed to occur in ditch |
| Prevent desiccation | • *Normal*: Historic weather patterns<br>• *Abnormal*: Drought conditions assumed to occur<br>• *Accident*: Not applicable |
| Limit frost penetration | • *Normal:* Historic weather patterns<br>• *Abnormal*: Monthly average minimum temperatures below those predicted by the 500 year return frequency<br>• *Accident*: Not required per NUREG-1199 |
| Limit biointrusion | • *Normal*: Shallow- rooted Desert plant growth<br>• *Abnormal*: Deep- rooted Desert plant growth<br>• *Accident*: Not required per NUREG-1199 |
| Limit occupational exposures (by limiting dose rates at the cover surface) | • *Normal*: Low to moderate gamma emitters<br>• *Abnormal*: High gamma emitters at top of waste<br>• *Accident*: Not applicable |
| **Ensure cover integrity** | |
| Mitigate differential settlement | • *Normal:* All primary and portion of secondary settlement in soil layers complete, no container deterioration will occur up to 100 years<br>• *Abnormal:* Container deterioration after 100 years, allowing creep of compressible waste and additional secondary settlement of soils, earthquake<br>• *Accident:* Not required per NUREG-1199 |

**Table 4-10 – Summary of Design Basis Conditions Assumed for Design of Cover.**

| Required Function/Complementary Aspect | Design Basis Conditions |
|---|---|
| Prevent internal erosion | • *Normal, Abnormal and Accident:* Filter criteria equations used are primarily used for assessing performance of filter layers within dams under fully saturated conditions. Conditions at the Energy*Solutions* Clive Facility are expected to be much less severe in terms of saturation levels The filter gradation ratios used have also been used by the Department of Energy (DOE) to assess filter layer performance under assumed abnormal saturated conditions within UMTRA Project disposal embankments |
| Material stability/Endure weathering, external erosion | • *Normal:* Historic weather patterns will occur<br>• *Abnormal:* PMP condition<br>• *Accident:* Not required per NUREG-1199 |
| **Ensure Structural Stability** | |
| Settlement | • *Normal:* Evenly distributed weight loading<br>• *Abnormal:* Creep of compressible waste and additional secondary settlement of soils after 100-year institutional control period<br>• *Accident:* Not required per NUREG-1199 |
| Maintain slope stability | • *Normal:* Static conditions to occur<br>• *Abnormal:* Earthquake conditions to occur<br>• *Accident:* Not required per NUREG-1199 |

Based on the information summarized above, the Division concludes that the Licensee's proposed means of restricting inadvertent intrusion into the CAW embankment is acceptable.

**Minimize Infiltration**

The required function of minimizing infiltration is evaluated via five complementary aspects: minimize infiltration, encourage run-off, provide protection against desiccation damage, provide protection against frost penetration damage, and provide protection against biointrusion-related damage.

The design basis conditions assumed for use in analyses and the justification for the design criteria proposed for the CAW embankment cover for minimizing infiltration through the cover are similar to those approved for the CA and CAN embankments (URS Corporation 2005a; 2005b). The conditions upon which the infiltration evaluation is based are similar to those used for evaluating performance of the CA and CAN embankments but also include updated climatological information. Analyses performed for the CAW Embankment LAR (Energy*Solutions* 2011a and 2011b; including Whetstone Associates 2011a and 2011b) demonstrate that the infiltration minimization capability of the CAW embankment will be at least as effective as that approved for the CA and CAN embankments (URS Corporation 2005a;

2005b) and that reviewed for the previously proposed CAC disposal embankment (Whetstone Associates 2006).

***Previous Cover Infiltration Sensitivity Analyses***

The Licensee previously performed a series of sensitivity analyses to assess the sensitivity of the EPA Hydrologic Evaluation of Landfill Performance (HELP) Model-predicted results for infiltration through final embankment covers at the Energy*Solutions* Clive Facility to changes in various input parameters. Parameters investigated through such sensitivity analyses have included but are not limited to: wind speed, evaporative zone depth (EZD) and precipitation. Results of such sensitivity analyses are summarized below:

- HELP Model sensitivity analyses were completed in 1997 to assess the effects of changes in a number of cover layer/design input values on infiltration rates through the LARW Cell at the Clive Facility, including, but not limited to, wind speed and filter layer hydraulic conductivity (Adrian Brown Consultants 1997). Those sensitivity analyses indicated that:
    - A decrease in the hydraulic conductivity of the lower filter layer in the LARW Cell from 3.5 to 2 cm/sec resulted in a 41% increase in infiltration through the cell, while an increase in the hydraulic conductivity of that layer in the LARW Cell from 3.5 to 6 cm/sec resulted in an 18% decrease in infiltration through the cell.
    - The HELP Model was found to be insensitive to slight variations in wind speed. The sensitivity analyses considered average wind speeds ranging between 5.75 and 8.8 mph (Adrian Brown Consultants 1997). A site-specific average wind speed of 7.2 mph was used in the CAW Embankment LAR HELP Model infiltration modeling (Energy*Solutions*, 2011a; b).
- Additional sensitivity analyses were also conducted to assess the effects of increased precipitation on infiltration rate though a cover system similar to that currently proposed for the CAW embankment for a previously proposed, but not implemented, Class A, B, and C embankment at the Clive Facility (Whetstone Associates 2000a). The modeling results from those analyses predicted that as the average precipitation rate was increased from the assumed base-case value of 7.92 inches/year to 12.78 inches/year (the average of the two highest values recorded at Clive, Utah through the time of the study), the average infiltration rate through the Class A, B, and C Cell was 0.186 cm/yr, compared to 0.169 cm/yr for the base case, for the top slope portion of the cell; and, for the side slope portion of the cell, the average infiltration rate through the cell was predicted to range from about 0.201 to 0.261 cm/yr, compared to 0.201 to 0.280 cm/yr, for the base case. These predicted increases are approximately 10% to less than 7% higher than the predicted base-case results.
- Additionally, previous sensitivity analyses were completed to assess the effects of siltation and vegetation intrusion and different depths of root penetration on infiltration rate though the previously proposed Class A, B, and C embankment cover system (Whetstone Associates 2000b). The modeling results indicated that as the depth of the root-zone was increased in the cover system, the inferred degradation of layers (e.g., loss of hydraulic conductivity in filter layers) that occurred in those filter layers due to root

penetration and siltation and other effects on layer properties (decrease in porosity, increase of wilting point of coarser-grained layers due to siltation) were found to be offset by increased evapotranspiration rates. The base case simulation (no vegetation growth in the cover and no siltation of coarse-grained layers) resulted in an average infiltration rate through the bottom of the clay liner of 0.169 cm/yr of water/year in comparison to average infiltration rates ranging between 0.020 to 0.136 cm of water/year through the top slope portion of the cover system (Whetstone Associates 2000b).

HELP Model simulations for the proposed CAW Embankment were conducted using an assumed EZD of 20 inches, which only allows water to evaporate from the uppermost 20-inch thick interval of the 24-inch thick riprap layer of the proposed final cover (Whetstone Associates Inc, 2011b). In this scenario, incident precipitation that percolates downward more than 20 inches within the cover is constrained in the model so it cannot be removed by evaporation. The Licensee provided information (Whetstone Associates Inc, 2011b) to support a finding that a 20-inch maximum EZD input value is environmentally conservative, because it allows efficient evaporation from nearly all rip rap interstices. The 20-inch EZD value used by the Licensee in infiltration modeling has not been approved by the Division. A new license condition will be added to the facility license that will require the Licensee to provide a modification to the CAW embankment’s cover design to allow this issue to be resolved (see the discussion in Section 4.3.1, “Groundwater Pathway” and Section 5.0 below).

The CAW Embankment LAR proposes that the Type B Filter Zone layer have a hydraulic conductivity of at least 3.5 cm/sec. HELP Model infiltration simulations predict that the Type B Filter Zone layer will act as an important lateral run-off component within the cover. For this reason, and because previous sensitivity analyses show that infiltration rates through the CAW Embankment may be sensitive to the hydraulic conductivity of the lower (Type B) Filter Layer, the Licensee has proposed filter permeability criteria for the design of the Sacrificial Soil Layer and the Type B Filter Zone layer in the CAW Embankment cover. See Drawing C10014 C04, Rev. 2 in Energy*Solutions*, 2011e. The design criteria are based on filter/particle gradation criteria for adjacent soil/granular particle layers as recommended by Bertram (1940), NRCS (1994), and others and are intended to help ensure that the filter (drain) layer will, after cover construction, continue to retain sufficient permeability to prevent buildup of large seepage forces and hydrostatic pressures in the filter layer.

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria and justification supporting those design criteria, and design basis conditions used in infiltration analyses for demonstrating infiltration rates through the CAW embankment, will be maintained at or below the specified (calculated) allowable levels are acceptable.

**Minimize Infiltration – Encourage Run-off**

The three design criteria selected for encouraging surface water run-off drainage from the embankment (Table 4-5) are intended to ensure that (lateral) run-off of precipitation that falls on the surface of the completed embankment will be maintained under expected and possible extreme, future environmental conditions. Encouraging run-off helps ensure that the design objective of minimizing the volume of precipitation available to infiltrate into the embankment can be achieved.

The side slopes of the CAW embankment would be graded at a 5H:1V inclination to help promote lateral run-off from the embankment side slopes while balancing long-term erosion protection requirements for the embankment in a manner consistent with published NRC recommendations and guidelines (e.g., NRC 2002). Additionally, as discussed under the heading "Minimize Infiltration" above, filter permeability criteria have been established for the Type B Filter Zone layer and Sacrificial Soil Layer in the top slope and side slope portions of the CAW embankment cover to help ensure that the Type B Filter Zone layer will maintain sufficient permeability (hydraulic conductivity) to retain its ability to function as a lateral drainage layer in the cover.

The evaluations performed by the Licensee for assessing long-term stability and maintenance of embankment slopes proposed for the CAW embankment are identical to those previously applied for evaluating the performance of the CA and CAN embankments (URS Corporation 2005a; 2005b). The conditions upon which the run-off evaluations are based are similar, except for the overall size of the embankment, and the use of updated meteorological data in the CAW embankment infiltration simulations. HELP Model infiltration analyses performed for the CAW embankment demonstrate that the run-off control of the CAW embankment will perform at least as well as corresponding items for the CA and CAN embankments (URS Corporation 2005a; 2005b) and proposed for the previously contemplated CAC embankment with respect to encouraging lateral run-off of precipitation from the embankment (e.g., see CAC Embankment Engineering Justification Report [Energy*Solutions* 2006] Section 3.3.1.2; Whetstone Associates 2006).

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria and justification supporting those design criteria and design basis conditions used in infiltration analyses for demonstrating infiltration rates through the CAW embankment will be minimized and that run-off will be encouraged are acceptable.

**<u>Provide Protection from Effects of Desiccation</u>**

The selected design criterion that there be no desiccation cracking of the radon barrier clay is based on the fact that the top foot of radon barrier clay is the primary infiltration barrier, and, therefore, the hydraulic barrier efficiency of this barrier must not be compromised by desiccation effects.

The normal condition evaluated by the Licensee, with respect to desiccation, considers performance of the radon barrier clay under historic weather patterns of precipitation and evaporation. The abnormal condition evaluation includes an analysis of the effects of a prolonged drought on moisture content of the radon barrier clay. The Licensee did not identify any credible accident scenario that would cause desiccation of the radon barrier clay in excess of the evaluated abnormal condition. Section 3.2 of NUREG-1199 does not require an evaluation of an accident condition for evaluation of desiccation effects.

The Licensee identified the critical time period for desiccation of the radon barrier clay as occurring during its construction, when the radon barrier layer of the cover will be exposed to the elements. Table 1, “Work Element – Radon Barrier Placement” of the current approved version of, and the proposed Revision 26b,1, of the CQA/QC Manual provide a discussion of protective measures that will be applied during construction to prevent or minimize desiccation of the radon barrier. After it is constructed, the lower Type B Filter Zone, sacrificial soil, upper Type A Filter Zone and erosion barrier layers, once placed, would help isolate both upper and lower parts the radon barrier layers from the atmosphere.

Moisture content modeling was performed for the radon barrier, waste, clay liner, and the Unit 3 sand and Unit 2 clay to the top of the aquifer using the UNSAT-H Model (Whetstone Associates 2011b). This modeling indicates that steady-state moisture content for the clay layers of the cover remain relatively constant at approximately 0.42% by volume. This steady-state moisture content is comparable to the initial value of saturated moisture content of 0.43% assumed for the upper foot of radon barrier.

For normal conditions, the Licensee indicates that the proposed clay borrow sources for radon barrier construction would have an average moisture content of about 18.6% by weight at the plastic limit based on evaluation of 90 data points collected from January through November 2000. The plastic limit is a laboratory-derived measurement of the moisture content at which a soil begins to crack or desiccate (ASTM D4318). This converts to a moisture content at which onset of cracking would occur of approximately 22% by volume; or slightly more than half the value of the steady-state moisture content of the radon barrier clay of 42% by volume.

For abnormal conditions, the Licensee indicates that there is no credible evaporative mechanism to dry out the radon barrier and therefore concludes that the moisture content of the radon barrier would be expected to remain relatively constant for the life of the embankment See Energy*Solutions* 2006, Section 3.3.1.3, submitted in support of the previously proposed CAC embankment. Potential effects of plant life establishment on the radon barrier layer within the cover system, following cover construction, for the previously proposed CAC embankment, similar in depth and characteristics to the proposed CAW embankment cover radon barrier layer, are discussed in Section 3.3.1.5 of the CAC Embankment Engineering Justification Report (Energy*Solutions*, 2006). Also, see the discussion below in “Limit Biointrusion-Related Damage” for a summary of the effects of plant life establishment on the moisture content of the radon barrier layer of the cover.

The Licensee identified the following two aspects of the cover design for the previously proposed and similarly designed CAC embankment cover system, that are intended to contribute to maintenance of moisture content in the radon barrier clays at the modeled steady-state condition:

- The cover is designed to promote run-off of moisture that enters the cover as percolation at the interface between the lower filter zone and the surface of the radon barrier. Run-off at this interface provides a recharge rewetting mechanism for radon barrier clay, should they fall below optimum moisture content; and
- The field capacity of the lower filter zone is over an order of magnitude less than that of the radon barrier. Accordingly, moisture in the system should preferentially migrate to the radon barrier clay. The difference in field capacities should help the lower filter zone serve as a capillary break because the lower filter zone would not be able to pull moisture

from the radon barrier clay for transport to the surface of the cover (Section 3.3.1.3 of Energy*Solutions*, 2006).

Based on the above arguments, the Licensee concluded that the design criteria of "no desiccation cracking in radon barrier clay" will be met. The abnormal conditions evaluation establishes that there is no credible mechanism to dry out the radon barrier.

The infiltration analyses provided in reports submitted by the Licensee, as part of the CAW Embankment LAR, indicate that the effects of desiccation on the integrity of the embankment cover would be no more detrimental than the corresponding (negligible) effects projected to occur for the CA and CAN embankments (URS Corporation 2005a; 2005b) (Whetstone Associates 2011a and 2011b) and for the previously proposed CAC embankment (Energy*Solutions* 2006).

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria and justification supporting those design criteria and design basis conditions, used for demonstrating that desiccation of the radon barrier clay layer in the CAW Embankment will not likely occur, are acceptable.

**Provide Protection from Effects of Frost Penetration**

Two frost penetration analyses were previously completed to assess the potential for frost penetration into final cover systems in disposal embankments at the Clive Facility for varying sacrificial soil layer components in the covers. The first report (Montgomery Watson, 1998) assessed frost penetration in the top slope portion of the cover containing a sacrificial soil layer, and with the side slope portion having no sacrificial soil layer. The second report (Montgomery Watson, 2000) examined the side slopes with a sacrificial soil layer. Different results are observed for the top and side slopes because the erosion protection rock is larger on the side slope. The report calculated frost depths of 3.4 ft for the top slopes area and 3.2 ft for the side slope area with the sacrificial soil layer as designed. These frost penetration depths are less than the radon barrier clay's design depth of 3.5 ft.

The proposed means of providing protection of the radon barrier clay layer for the proposed CAW embankment is identical to that approved for the CA and CAN embankments. Previous analyses completed for the proposed CAC embankment (Energy*Solutions* 2006, Section 3.3.1.4) demonstrated that frost protection measures would perform at least as well as corresponding items approved for the CAN embankments and the 2005 LRA (2005 CAN SER Section 4.3) in preventing frost penetration into the radon barrier layer. The proposed CAW Embankment cover consists of the same design as the design of the previously proposed CAC disposal embankment cover with the exceptions that the uppermost riprap layer in the CAW Embankment cover on the top slope and sideslopes is 24 inches thick, compared to 18 inches thick for the CAC embankment; and the lower Type B Filter Zone layer on the side slopes of the CAW Embankment cover is 18 inches thick, compared to 12 inches thick for the CAC embankment, and the radon barrier layer depth is greater for the CAW embankment than for the proposed CAC embankment.

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria and justification supporting those design criteria and design basis conditions used for demonstrating that frost penetration into, and therefore frost damage to, the radon barrier clay layer in the CAW Embankment will not occur, are acceptable.

**Limit Biointrusion-Related Damage**

The Licensee-specified design criterion that the cover design must discourage plant growth and accommodate indigenous species growth without increasing infiltration rates through the CAW Embankment cover significantly above the base case (unvegetated CAW Embankment cover) is based on the fact that the upper 12-inch-thick portion of the radon barrier clay is the primary infiltration barrier, and, therefore, the hydraulic barrier efficiency of this barrier must not be compromised by plant, animal or root penetration. The Licensee arranged for botanical specialists to conduct a literature review regarding typical plant rooting depths for shrub species identified growing at and around the Clive Facility and to conduct a reconnaissance of the site to confirm vegetation types. Also, the specialists conducted a subsurface testing program to verify, in particular, the depth of root penetration of one deeper-rooted indigenous shrub species growing at the site (Black greasewood) (SWCA 2000). Based on the results of this work, the Licensee acknowledged that it might not be possible to totally prevent establishment of deep-rooted vegetation on the cover following the 100-year period of institutional controls.

The biointrusion barrier proposed for the CAW embankment consisting of the 24-inch-thick rock rip layer, a 6-inch-thick filter zone layer, and a 12-inch-thick sacrificial soil layer on both the top slope and side slopes, and an additional 6-inch thick filter zone layer on the top slope and an additional 18-inch thick filter zone layer on the side slopes, is similar in characteristics but contains a thicker riprap layer than that for the previously proposed CAC disposal embankment (Energy*Solutions* 2006). Analyses performed for the proposed CAC disposal embankment (Section 3.3.1.5 of the CAC Disposal Embankment Engineering Justification Report [Energy*Solutions*, 2006]) and infiltration sensitivity analyses, performed for the previously proposed Class A, B and C embankment cover, (Whetstone Associates 2000b) demonstrate that the radon barrier layer and the infiltration reduction effectiveness of the cover systems would not be negatively affected by post-closure plant-related biointrusion processes, after allowing for assumed future plant root penetration. The biointrusion barrier of the proposed CAW embankment cover would be expected to perform at least as well as or better than corresponding items reviewed and approved for adequacy for the CA and CAN embankments and for the previously proposed CAC disposal embankment (Energy*Solutions*, 2006).

Published information on observed burrowing depths of animals in various soil and rock layers indicates that the thickness and proposed rock sizes of the riprap layers on the top slope and side slope areas of the CAW Embankment cover should be effective at deterring burrowing by animals into the cover throughout the required performance period of the CAW embankment (Cline 1979; Cline et al. 1980; Cline et al. 1982; Gano and States 1982; Reichman, et al. 1990; Reynolds and Wakkinen 1987; Reynolds and Laundre 1988).

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria, justification supporting those design criteria, and design basis conditions used for demonstrating that the CAW Embankment LAR's ability to withstand damage or disruption due to long-term biointrusion, are acceptable.

## Limit Occupational Exposures

The types of materials received for disposal in the CAW embankment will be no different than materials disposed of in the CA and CAN embankments. Therefore, radiation protection, access control to restricted areas, and personnel protective equipment policies will not change from current policies. Although the CAW embankment will increase the overall licensed disposal capacity at the Clive Facility, annual volumes received for disposal will continue to be bounded by the evaluations performed for license renewal.

The design criterion that the dose rate at the surface of the completed embankment must be less than 100 mrem TEDE per year is a regulatory requirement contained in URCR R313-15-301. Potential external dose rates to persons standing on top of the completed cover system from gamma radiation were evaluated using the MicroShield® computer code. The MicroShield® code was used because it is verified and publically available. A generic 55-gallon drum, consistent with the numerous dimensions of 55-gallon drums currently in use for waste storage and disposal, containing a total activity of 11 curies was assumed to be placed on its side at the top of waste, just below the CAW embankment cover. The cover consists of, from bottom to top:

- Temporary cover – 1 foot thick
- 1E-6 cm/sec radon barrier – 1 foot thick
- 5E-8 cm/sec radon barrier – 1 foot thick
- Filter layer – 0.5 ft thick on topslope; 18 inches thick on sideslopes
- Sacrificial soil layer – 1 foot thick
- Filter layer – 0.5 ft thick
- Riprap cover – 2 ft thick
- Total thickness – 7.0 ft (topslope) and 8.0 ft (sideslopes)

An effective density of 1.6 $g/cm^3$ with a consistency and mineralogy of low-density concrete was assumed. This density is conservative considering that each layer of the cover will be compacted to greater than 95% Standard Proctor density, as per the CQA/QC Manual. MicroShield® projected a contact dose rate on top of the completed cover of 3.75E-4 mR/hr. Multiplied over an entire year, this yields a dose rate of approximately 3 mrem, well below the regulatory limit of 100 mrem TEDE stated above.

Previously submitted, reviewed, and accepted information about occupational doses during operations indicates that most workers at the current facility receive annual doses less that 100 mrem/yr, when the regulatory limit for each is 5,000 mrem/yr. Thus, operational doses are demonstrated to be well within acceptable limits.

Based on the information summarized above, the Division concludes that occupational exposures that could result from the Licensee’s proposed CAW embankment are within acceptable limits.

## Ensure Cover Integrity

Ensuring cover integrity involves the following five complementary functions:

- Mitigate Differential Settlement
- Prevent Internal Erosion
- Maintain Material Stability/Withstand External Erosion

- Ensure Structural Stability – Settlement
- Ensure Structural Stability – Maintain Slope Stability

These complementary functions are addressed in the following paragraphs.

***Mitigate Differential Settlement***

Previously, the Licensee provided information indicating that, based on information available at that time, a maximum allowable distortion value of 0.02 ft/ft for the cover and liner represented a reasonably conservative design criterion (AMEC 2000, AMEC 2005a; 2005b). Published data on tensile strains, observed in laboratory tests of compacted clayey soil layers, generally supported a finding that higher tensile strains in soils, similar in plasticity to those proposed for use in the proposed CAW embankment radon barrier layer, would be required to cause failure or cracking.

The Licensee furnished additional information in 2011 and 2012, in responses to Round 2 and Round 3 interrogatories, (Energy*Solutions,* 2012a; 2012b) as part of the CAW Embankment LAR. In a subsequent response to further Division requests the Licensee provided additional data supporting the continued appropriateness of the previously proposed maximum allowable distortion value of 0.02 ft/ft (Energy*Solutions,* 2012c). The Licensee summarized results of a variety of relatively recent laboratory tests, conducted to assess the deformation behavior of compacted clay layers, including small-, full-scale, and trap-door-centrifuge tests and 3-point and 4-point bending beam tests. These recent test results are mixed with respect to the degree that they support earlier test results used by AMEC in 2000 to develop the 0.02 ft/ft distortion criterion (AMEC 2000).

The 0.02 ft/ft distortion criterion was based on the interpretation that higher maximum tensile strains (e.g., ranging from 0.5% to 3%) did not cause the compacted clay layers tested to fail. However, as described in a memorandum from URS Corporation (URS 2012), at least two professional papers published in 2010 suggest that cracking in tested compacted clay layers appeared to occur at a lower strain threshold value than had been suggested by earlier testing results. The URS memorandum acknowledged that actual compacted clay layer cracking behavior will depend on the specific clay layer materials tested.

To resolve the uncertainty associated with the selection of the most appropriate distortion criterion for design of the CAW Embankment cover, the Licensee agreed that it would, as part of the LRA to be submitted on or before December 25, 2012, do the following:

1. Conduct and submit to the Division the results of laboratory testing (including index properties and tensile strength/strain relationships) of soils representative of those expected to be used in constructing the final cover system. The purpose of this laboratory testing will be to assess properties that affect the tensile strain and distortion-induced crack resistance, to determine whether the 0.02 ft/ft maximum allowable distortion value remains an appropriate value for the distortion criterion for the cover of all disposal embankments approved to date.
2. Continue to perform settlement monitoring of the interim soil cover layer placed over filled portions of the CA and CAN embankments.

3. Continue to observe differential settlement in the interim soil cover layer, and use those data to determine the magnitude of the observed distortion within these embankment areas.
4. Demonstrate whether the calculated distortion values exceed the highest observed distortion value based on the settlement monitoring data acquired to-date in the CA and CAN embankments (i.e., 0.007 ft/ft).
5. Delay construction of final covers until observed settlement has stabilized.
6. Either substantiate the adequacy of the 0.02 ft/ft design distortion criterion or revise it, based upon the results of laboratory testing that determine index properties and tensile strength/strain relationships for clays expected to be used in constructing the final cover system.

Also, the Licensee revised the specification for the "Work Element – Temporary Cover Placement and Monitoring" in the LLRW and 11e.(2) CQA/QC Manual (proposed version 26c. dated March 20, 1012 [Energy*Solutions*, 2012c]) to delay placement of final cover until after it has confirmed that future distortion values determined through the interim cover settlement monitoring will not exceed 0.007 ft/ft (Energy*Solutions* 2012c).

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria and justification supporting those design criteria and design basis conditions used in analyses for demonstrating that differential settlement and resulting potential for settlement-induced damage to the cover (and liner) of the CAW embankment will be mitigated are acceptable.

## **Prevent Internal Erosion**

Design criteria for and projections of internal erosion for the currently proposed cover are presented in Section 3 of the CAW Embankment LAR. The Licensee presented rock riprap cover design calculations in Attachment 10 to the CAW Embankment LAR and provided an analysis of the interstitial velocities associated with the clay/rock interface. This analysis uses the slopes of the embankment and the hydraulic conductivity of the Type B Filter to calculate a maximum interstitial velocity at the interface. The maximum estimated calculated interstitial flow velocities, representing maximum possible velocities at the interface, which are not dependent on the amount of water flow, are both orders of magnitude below the selected design criteria velocity of 5.41 ft/sec. Based on this result, the Division has concluded that significant radon barrier clay erosion would not occur.

Internal erosion related to piping, the movement of soil from a soil layer to a rock/filter layer, was evaluated based on procedures developed for saturated embankment dams. Filter criteria were originally developed by evaluating the gradation limits between dissimilar materials so that finer material cannot migrate into the voids of the coarse material, thereby creating the potential for internal erosion. The Licensee indicated that, normally, the embankment cover soils, that are not part of the radon barrier, are dry or partly saturated and internal erosion due to the movement of water between the layers, is not considered to be a design issue. Under temporary saturated flow conditions, internal erosion is considered as an abnormal design event. The Licensee used U.S. Army Corps of Engineers guidance, including published filter design equations, to demonstrate that movement of particles between a soil and a filter layer would not occur (USACE).

The design criteria for preventing internal erosion involve specifications for the size distribution of soils placed adjacent to each other. These criteria are:

- D15(filter)/D85(soil) ≤ 5,
- D50(filter)/D50(soil) ≤ 25 and
- D15(Lower Layer)/D85(upper layer) ≥ 4.

In Drawing 10014-C04, the Licensee specifies that particle size distributions used in layers of the cover system must satisfy all of these criteria. Thus, the Division concludes that the design criteria necessary to protect against internal erosion will be satisfied.

Using these criteria, the interstitial water velocities were projected to be about 0.12 ft/sec for the top slope and about 0.055 ft/sec for the side slopes. The Division agrees that these velocities are small and would not contribute to piping instabilities.

**Maintain Material Stability/Withstand External Erosion**

Design criteria to ensure stability against external erosion for design basis normal and abnormal conditions, for assessing the potential for external erosion of the CAW Embankment cover, are similar to those used in the CAN embankment and the previously proposed CAC embankment. The criteria are presented in Section 3.1.2 and Tables 3.2 and 3.3 of the CAW Embankment LAR. The analysis of normal conditions would be bounded by the abnormal condition analyses. Therefore, analyses were performed for assessing material stability and ability of the CAW embankment cover to withstand external erosion under assumed abnormal conditions, for a 200- to 1,000-year cover life span. For evaluating the external erosion protection capability of the CAW Embankment cover, the Licensee assumed a 100-year, 24 hour storm event as the normal precipitation condition, and a probable maximum precipitation (PMP) 1-hr value of 6.1 inches of rain, as the abnormal precipitation condition (Table 3.2 of the CAW Embankment LAR) .

The Licensee also performed additional calculations to determine the characteristics of the PMP at the Clive Facility considering meteorological information and using procedures contained in two State of Utah Climate Center publications (Jensen 1995 and Jensen 2003). When estimating the PMP for the area of concern in designing high and moderate hazard dams in Utah, State regulations (R655-11-4) require the use of HMR 49, as well as assessment information from these two studies issued by the Utah Climate Center. Calculations based on the procedures from the Utah Climate Center, were completed as a cross check and for comparison with PMP conditions determined previously using the approach prescribed in HMR 49 (Hansen et al. 1984). Results of the updated PMP computations demonstrated that the 1-hour PMP of 6.1 inches as computed directly from HMR 49 in 1996 is the larger, more conservative PMP value.

Rock cover design calculations were conducted for the CAW Embankment LAR using the methodologies described in NUREG-1623 and NUREG/CR-4620. A revised updated erosion protection methodology developed by Abt et al. (2008) for rounded, shaped riprap was applied to the evaluation of the long-term erosional stability of the CAW embankment. The Licensee used the more conservative, larger calculated PMP value in all rock cover calculations.

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria and justification supporting those design criteria and the normal and abnormal design basis conditions used in analyses for demonstrating material stability and ability of the embankment cover to withstand external erosion are acceptable.

**Ensure Structural Stability – Settlement**

Sections 3.2.2 and 3.2.3 of the CAW Embankment LAR and Section 4 of Attachment 5 to the CAW Embankment LAR address embankment settlement within foundation materials, waste placement, backfill, and cover system. Design criteria specified for embankment settlement are that: (1) settlement not result in slope reversal and/or ponding of surface water in the final cover system (i.e., that long-term positive drainage from the cover be maintained with no active maintenance); and (2) maximum total settlement not exceed 15% of the embankment's height. The former criterion will help ensure that infiltration into the cover will be minimized and the latter criterion has been reported to be acceptable for highway embankments and major waste storage embankments (Energy*Solutions* 2012a; 2011b, Table 3.2).

Total long-term differential settlement above different waste types, including compressible debris lifts is discussed in Section 4.4.1 of Attachment 5 to the CAW Embankment LAR. In addition, settlement data acquired by Energy*Solutions* have been analyzed and a projection of total differential settlement of the CAW Embankment of less than 0.007 ft/ft is projected (Section 4.4 of Attachment 5 to the CAW Embankment LAR), indicating that slope reversal is not expected to occur on the top slope portion of the CAW Embankment. Design-basis conditions assumed for evaluating settlement of the CAW Embankment and cover (an evenly distributed weight loading as the normal condition; creep of compressible waste and additional secondary settlement of soils after a 100-year institutional control period; no accident condition assumptions required as per NUREG-1199) are the same as those assumed for the CA and CAN embankments (URS Corporation 2005a; b) and for the previously proposed CAC embankment (AMEC 2005a; 2005b). The settlement evaluation methodology used for the CAW Embankment LAR is the same as that approved for the CA and CAN embankments (URS Corporation 2005a; 2005b). The conditions upon which the settlement calculations are based are similar, with consideration of more recent and planned ongoing interim cover settlement data providing additional evidence for comparing results of the calculations to observed settlement behavior in the CA and CAN embankments, and ultimately for demonstrating the technical appropriateness and adequacy of the settlement calculations. The evaluation presented in Attachment 5 to the CAW Embankment LAR demonstrates that the CAW embankment will perform at least as well as corresponding items reviewed for the CA and CAN embankments and reviewed for the previously proposed CAC embankment (AMEC 2005a; 2005b) with respect to minimizing embankment settlement.

Based on the information summarized above, the Division concludes that the Licensee's proposed design criteria, justification supporting those design criteria and design basis conditions used for demonstrating that the CAW embankment will maintain structural stability with respect to the required function of mitigating settlement, are acceptable.

**Ensure Structural Stability – Maintain Slope Stability**

The minimum factors of safety of 1.5 under static conditions and 1.2 under dynamic (i.e., earthquake) conditions that the Licensee selected are contained in the State of Utah Statutes and Administrative Rules for Dam Safety, Rule R625-11-6.

The normal condition considers the performance of the embankment under static conditions. The evaluation for abnormal conditions compares the calculated safety factor inherent to the embankment design against the expected peak ground acceleration due to an earthquake that might affect the site, the assumed design earthquake. The Licensee did not perform analyses of reduced structural stability associated with accidents as such analyses are not required per NUREG-1199, Section 3.2 [NRC 1999]. Results of the static and seismic stability slope analyses for the CAW embankment are described in Section 4.3.2 below

The Division held discussions with the Licensee regarding the Division's request to update the seismic hazard evaluation for the site to incorporate updated published seismic attenuation prediction models and to validate that the seismic design criteria, used by AMEC for assessing the geotechnical stability of the proposed CAW Embankment, remain technically appropriate. As a result, the Division prepared independent deterministic and updated probabilistic seismic hazard analyses. The analyses were used to check previous deterministic analysis results obtained by AMEC, as reported in the February 15, 2011,"Geotechnical Update Report," and to complete an independent probabilistic analysis of seismic hazard potential at the site.

Under contract to the Licensee, AMEC presented an updated assessment of the seismic hazard for the site consistent with the requirements of URCR R313-25-8(5) and the information requested in a Round 3 Interrogatory (AMEC 2011a; 2011b; 2011 c; 2011d; AMEC 2012a). The updated seismic hazard assessment is based on an updated determination of the peak ground acceleration (PGA) associated with the Maximum Credible Earthquake (MCE) for known active or potentially active faults in the site region. The PGA is determined from a probabilistic seismic hazard analysis (PSHA) for earthquakes that may occur on unknown faults in the area, referred to as background seismicity, surrounding the project site. The PGA is calculated at the 84th percentile level and is based on the maximum rupture length and rupture area for each fault. The return period for ground motions resulting from a background earthquake is identified as 5,000 years, equal to a one percent probability of exceedance in 50 years. The approach to select a MCE PGA from the larger of the values associated with the deterministic MCE for faults or the PSHA result for background earthquakes at a 5,000 year return period is consistent with the recommendations of the Utah Seismic Safety Commission (2003) and as required by the Utah Division of Water Rights (Dam Safety Section) for assessment of dams.

AMEC used the following Next Generation Attenuation (NGA) relationships for conducting their analyses:

- Abrahamson and Silva (2008)
- Boore and Atkinson (2008)
- Campbell and Bozorgnia (2008)
- Chiou and Youngs (2008)

All of these relationships are considered to be applicable for the site conditions and types of potential sources of seismic activity in Utah and the Intermountain Region. Additional parameters for attenuation relationships include site shear wave velocity, VS30, taken as 305 m/s as described in the October 25, 2011 letter, and depth to top of bedrock (Z1.0 and Z2.5), taken as default values calculated from the site VS30 as recommended by the authors of the NGA relationships and as described in a letter from AMEC dated October 25, 2011 (AMEC 2011c; 2011d). For the Stansbury fault, the maximum magnitude is assessed as M 7.3 based on consideration of the maximum rupture length, fault width, and maximum fault displacement identified in previous investigations. The maximum of the 84th percentile PGA values for the maximum Magnitude (Mmax) events on the fault sources was calculated to be 0.24 g, as obtained for the Stansbury and the Skull Valley faults.

For the PSHA, the current version (Ver. 7.62) of commercial program EZ-FRISK® was used to calculate the PGA for the background earthquake. The program contained prepared input fault and background seismicity files for Utah for use in calculating seismic hazard. These files are based on the same fault source parameters and independent seismicity catalog used by the U.S. Geological Survey (USGS) to prepare the 2008 National Seismic Hazard Maps. The PGA, calculated as the weighted average of the mean values for the four NGA relationships at a return period of 5,000 years, was determined to be 0.24 g.

An independent seismic hazard analysis (Wong 2012) was also performed, and the results of this analysis were used to check the value of the $84^{th}$ percentile peak ground acceleration (PGA) value calculated by AMEC for the controlling deterministic source, which was an earthquake of moment magnitude (M) 7.5 on the Stansbury fault at a rupture distance of 30.4 km. from the Clive Facility site. For the updated deterministic hazard analysis, the Pacific Earthquake Engineering Research Center (PEER) Next Generation Attenuation (NGA) spreadsheet, version 19, as well as the NGA models contained in a PEER verified and validated PSHA code (HAZ38) were used. The updated deterministic analysis calculated an $84^{th}$ percentile geometric mean PGA for the Stansbury fault M 7.5 of 0.257 g (Wong 2012), compared to a PGA value calculated by AMEC of 0.23 g. This difference notwithstanding, the design basis PGA of 0.28 g is conservative.

As was recommended by the Division to AMEC, the updated PSHA was performed using background seismicity to assess the hazard from assumed background earthquakes. The background seismicity was extracted from the URS Corporation (URS) seismic source model of the Wasatch Front, which has been continually updated since the original model was developed by URS, the Utah Geological Survey, and the University of Utah (Wong, et al. 2002). Two approaches were used to treat the background seismicity in the URS model: a uniform zone and gridded seismicity weighted 0.3 and 0.7, respectively. The PGA for a return period of 10,000 years (the return period used by AMEC) was calculated to be 0.18 g. The PGA for a return period of 5,000 years (as used by Utah Division of Water Resources) was calculated to be 0.14 g. Both the 5,000- and 10,000-year return period PGAs are below the 0.28 g design value assumed by AMEC in the Geotechnical Update Report (Attachment 5 to Energy*Solutions* 2011b).

Based on the results of updated deterministic and probabilistic seismic hazard analyses, the design PGA of 0.28 g recommended by AMEC in the Geotechnical Update Report (Attachment 5 to Energy*Solutions* 2011b) and used for embankment stability calculations was found to be acceptable.

The slope stability analysis performed for the CAW cover is the same type of analysis as the analysis that was approved for the CA and CAN embankments. The analyses demonstrate that the CAW Embankment will perform at least as well as corresponding items approved for the Class A and CAN embankments with respect to long-term slope stability (Energy*Solutions* 2011b and Energy*Solutions,* 2011b).

Based on the information summarized above, the Division concludes that the Licensee's proposed CAW Embankment LAR slope stability analysis approach is acceptable. Also, the Division concludes that the Licensee's proposed design criteria, justification supporting those design criteria, and design basis conditions used for demonstrating the long-term slope stability of the CAW Embankment are acceptable.

Table 4-11 below provides a summary of the design criteria assumed for the cover and provides information on procedures to be used and/or other justification for ensuring that the specified cover design criteria will be achieved.

**Table 4-11 – Summary of Justification for Design Criteria Used for Design of Cover.**

| Required Function(s) of Cover | Design Criteria | Design Criteria Justification |
|---|---|---|
| Minimize Infiltration | Average infiltration rate through cover < 0.036 inches/year (0.09 cm/year) top slope area; and 0.066 inches/year (0.168 cm/year) side slope areas (Whetstone Associates 2011b) | Infiltration through the CAW cell was modeled using the EPA Hydrologic Evaluation of Landfill Performance (HELP) model (version 3.06). The Infiltration and Transport Modeling Report (Whetstone Associates 2011b) requires an average infiltration through the cover to be less than or equal to 0.09 cm/year in the top slope and less than or equal to 0.168 cm/year in side slope areas to limit water seepage into the waste to levels required for meeting embankment performance objectives. |
| Encourage run-off | • Maintain positive drainage<br>• Ensure maximum design velocity within the drainage layer is greater than the calculated drainage velocities<br>• Must not allow water accumulation to occur on or within the cover | Drainage calculations performed illustrate that drainage will be maintained under all conditions and meet NUREG-1199 criteria |
| Prevent desiccation | Prevent desiccation-induced | Infiltration design criteria will |

**Table 4-11 – Summary of Justification for Design Criteria Used for Design of Cover.**

| Required Function(s) of Cover | Design Criteria | Design Criteria Justification |
|---|---|---|
| | cracking in the radon barrier layer | be maintained under all conditions and meet NUREG-1199 criteria |
| Limit frost penetration | The thickness of rock/filter/sacrificial soil zones must be greater or equal to the maximum frost depth (3 ft) | Infiltration design criteria will be maintained under all conditions and meet NUREG-1199 criteria |
| Limit biointrusion | Must limit biointrusion as to not cause increased infiltration into the cover | Infiltration design criteria will be maintained under all conditions and meet NUREG-1199 criteria |
| Reduce Exposures/Surface dose rates | Limit TEDE to ≤ 100 mrem | Complies with URCR R313-15-301 requirements |
| **Ensure Cover Integrity** | | |
| Mitigate differential settlement | The specified maximum allowable distortion criteria for the cover will not be exceeded. | Settlement Monitoring Data<br><br>Proposed laboratory testing of compacted clay soil layer comprised of on-site clayey soils |
| Prevent internal erosion | Run-off water velocity shall be < 3 ft/sec on surface of radon barrier and to minimize piping, particle size specification for Type B Filter Zone material shall conform to the following:<br>$D_{15}$ (filter)/$D_{85}$ (soil) shall not exceed 5;<br>$D_{50}$ (filter)/$D_{50}$ (soil) must be ≤ 25; and<br>Upward migration of fines will be prevented :<br>$D_{15}$(filter)/$D_{85}$(soil) must be ≥4 | NUREG/CR-4620<br><br>Cedegren 1989<br><br>DOE 1989<br><br>NRCS 1994 |
| Exhibit material stability and resist external erosion | Rock erosion barrier shall exhibit internal stability and endure weathering/external erosion for at least 1,000 years | Rock Cover Design Calculations (Energy*Solutions* 2012c)<br><br>NUREG-1623 |
| **Ensure Structural Stability** | | |

**Table 4-11 – Summary of Justification for Design Criteria Used for Design of Cover.**

| Required Function(s) of Cover | Design Criteria | Design Criteria Justification |
|---|---|---|
| Limit embankment settlement to within acceptable levels and maintain long-term positive drainage from Cover | Ensure long term cover drainage and avoid cover slope reversal and ponding | Settlement calculations performed demonstrate that ponding of the cover will be minimized and slope reversal will not occur |
| | Maximum Total Settlement is less than or equal to 15% of the Embankment Height, 8.4 ft for the LARW and 9.2 ft for Class A | Settlement of 15% of the embankment height has been proven as adequate performance in highway embankments and major waste storage embankments |
| Maintain slope stability | Ensure a Static Safety Factor greater than to equal to 1.5 and a Seismic Safety Factor less than or equal to 1.2 | Safety factors calculated meet and satisfy State of Utah Statutes and Administrative Rules for Dam Safety, Rule R625-11-6 |

***References:***

Abrahamson and Silva, 2008

Abt et al., 2008

AMEC Earth & Environmental Inc., 2000; 2005a; 2005b

Bertram, 1940

Boore and Atkinson, 2008

Campbell and Bozorgnia, 2008

Cedegren, 1989

Chiou and Youngs (2008

DOE, 1989

Cline, 1979

Cline, et al., 1980

Cline, et al., 1982

Energy*Solutions*, 2006; 2011a; 2011b; 2011d; 2011e

Gano and States, 1982

Hansen et al. 1984

Jensen 1995; 2003

Montgomery Watson, 1998; 2000

Nelson, et al., 1986

NRC 2002

NRC, 1991

NRC, 2004

Reichman, et al., 1990

Reynolds and Wakkinen, 1987

Reynolds and Laundre, 1988

URS Corporation, 2005a; 2005b; 2012

Whetstone Associates 2000b; 2006; 2011a; 2011b

Wong, et al., 2002

Wong, 2012

#### 4.2.1.4 Drainage Systems

##### 4.2.1.4.1 Description of Design Feature – Drainage Systems

**Requirement 2507-2**: Descriptions of the design features of the land disposal facility and of the disposal units for near-surface disposal shall include those design features related to infiltration of water; integrity of covers for disposal units; 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 adequacy of the size of the buffer zone for monitoring and potential mitigative measures [URCR R313-25-7(2)].

**Basis**: Proposed drainage systems are described in Sections 3.1.5 and 3.2.5 and are depicted on Drawings 10014-C01, 10014-C03, Rev. 2, and 10014-C04, Rev. 2, of the CAW Embankment LAR (Energy*Solutions* 2011b; 2011e). The drainage systems are included in the design to control precipitation and surface water run-on and run-off during and after operations. Drainage system components include a minimum 4-foot-deep "V"-shaped drainage ditch, constructed with 5H:1V side slopes, to be installed adjacent to the CAW embankment. Bottoms (bases) of drainage ditch segments would be constructed of either in-place or imported clay (CL) or silt (ML) soil compacted to at least 95% of the Standard Proctor density for the soils. The compacted bases would be overlain by a minimum 6-inch-thick layer of "Type A" filter material, which in turn, would be overlain by an 18-inch-thick layer of Type A riprap material. The specifications for the Type A filter materials and Type A riprap would be identical to the material specifications in the cover system.

The description of the proposed drainage system is consistent with NRC guidelines and requirements (NRC 2002) and the drainage system design is very similar to that reviewed for the previously proposed CAC disposal embankment (Energy*Solutions* 2006), except for a slightly different overall total length of the drainage system.

Based on the information summarized above, the Division concludes that the Licensee's description of the proposed CAW embankment drainage system is acceptable.

***References:***

Energy*Solutions*, 2006; 2011b; 2011e

NRC, 2002

#### 4.2.1.4.2 Principal Design Criteria – Drainage Systems

**Requirement 2507-3:** Descriptions of the principal design criteria and their relationship to the performance objectives [URCR R313-25-7(3)].

**Basis**: Sections 3.1.5 and 3.2.5 of the CAW Embankment LAR provide information regarding the design criteria pertinent to the drainage systems for the proposed embankment. Table 3.2, "Design Criteria of the Principal Design Features," of the CAW Embankment LAR, summarizes the principal design criteria for the drainage systems and provides a summary of the design basis conditions used in analyses to assess the projected performance of the drainage systems.

The principal design criteria proposed for the CAW drainage system have incorporated a revised criterion and associated methodology (Johnson and Abt 1998) recommended in NUREG-1623 (NRC 2002). The criteria is for determining the minimum median rock size in the uppermost riprap layer to resist movement under peak flow (peak stress) conditions expected to occur in the drainage ditches (Energy*Solutions* 2011b). The design criteria used in designing the drainage systems are summarized in Table 3.2 of the CAW Embankment LAR and further described in Section 3.1.4 of Energy*Solutions*' 2005 LRA are as follows:

- Facilitate flow of precipitation away from the embankment;
- Minimize infiltration under flood conditions and,
- Ensure ditch integrity and prevent internal erosion.

The Licensee provided revised drainage ditch calculations dated November 14, 2011, in Attachment 3 to "Supplemental Response to Round 1 Interrogatories" (Energy*Solutions* 2011e) The revised calculations utilize methodologies presented in NUREG-1623 (NRC 2002) and NUREG/CR-4620 (Nelson et al. 1986) and consider a 25-year and a 100-year event and information obtained from NOAA Atlas 14.

The Licensee also completed an analysis of shear stresses around corners (bends) in the proposed drainage ditch system and completed a set of revised drainage ditch calculations, in Attachment 3 to Energy*Solutions* 2011e, to assess potential for super elevation of water in the ditches around such bends. The required size of the riprap rock was calculated based on these shear stresses.

Based on the information summarized above, the Division concludes that the Licensee's specified design criteria for the drainage systems for the proposed CAW Embankment are acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b; 2011e

Johnson and Abt., 1998

Nelson, et al., 1986

NRC, 2002

#### 4.2.1.4.3 Design Basis Conditions and Design Criteria Justification – Drainage Systems

**Requirement 2507-4:** Descriptions of the natural events or phenomena on which the design is based and their relationship to the principal design criteria [URCR R313-25-7(4)].

**Basis:** Table 3.2 of the CAW Embankment LAR summarizes information regarding the natural (meteorological, biological, and seismic) normal and abnormal conditions, and accident (as applicable) conditions under which the drainage systems of the proposed CAW Embankment were evaluated. In developing the CAW Embankment LAR, the Licensee used applicable guidance issued by the NRC, including guidance described in NRC NUREG-1199 (NRC 1991) pertaining to normal, abnormal, and accident (where applicable) conditions, that should be considered during design of NRC-licensed LLRW disposal facilities.

Table 3.4 of the CAW Embankment LAR summarizes the design criteria considered in the design of the drainage systems principal design feature and summarizes the results of evaluations conducted to assess the projected performance of the drainage systems with respect to the established design criteria. The design basis conditions and design criteria justification proposed for the CAW embankment drainage system are very similar to those approved for the CA and CAN embankments and included 25-year and 100-year storm events for representing normal and abnormal run-off conditions, downstream blockage as representing a potential accident condition, where applicable, and a 100-year flood for evaluating potential infiltration conditions.

**<u>Facilitate Flow of Precipitation Away from Embankment</u>**

The conditions upon which the drainage system design is based are similar to the conditions assumed for design of the CA and CAN embankments (URS Corporation 2005a; 2005b) and for the previously contemplated CAC embankment (Energy*Solutions* 2006), except for the overall length of the drainage system and use of information from NOAA Atlas 14 which is more recent than NOAA Atlas 2 used in previous analyses. Results of analyses and Section 4..2.2 of this document demonstrate that the drainage system of the CAW embankment will perform at least as well as corresponding items previously approved for the CA and CAN embankments (e.g., see URS Corporation 2005a, Section 5.4.2). The normal condition evaluated by the Licensee for the complementary function "facilitate flow of water away from the embankment" included an analysis of the drainage ditch design with respect to impacts of the 25-year, 24-hour storm event for the site. The 25-year, 24-hour storm event was identified as representing the probable worst-case precipitation event that might be encountered during active site operations.

The abnormal condition evaluated by the Licensee for the complementary function "facilitate flow of water away from the embankment" included an analysis of the drainage ditch design with respect to impacts of the 100-year, 24-hour storm event for the site.

The Licensee selected the design criteria of ensuring that storm water remain within the drainage ditch system with a minimum of 0.5 ft freeboard, and ensuring that the drainage ditch system have sufficient slope to allow drainage away from the embankment, under these conditions, to promote the collection of precipitation as well as promote flow away from the embankment. These choices minimize standing water adjacent to the embankment and potential infiltration into the waste" (see the discussion in Section 1.4.1.1 of Energy*Solutions* 2006).

Revised calculations, contained in Attachment 3 to the Supplemental Responses to Round 1 Interrogatories (Energy*Solutions* 2011e), using geometry and slope of the ditches and Manning's formula, address the design criteria established for the function of facilitating flow away from the embankment. Results of those calculations in Section 4.1.2 of this SER indicate that the ditch has been designed to have adequate capacity to contain normal and abnormal flow conditions storm event run-off volumes with ≥ 0.5 ft of freeboard.

**Minimize Infiltration Under Flood Conditions**

The infiltration minimization criterion proposed for the CAW embankment is identical to that approved for the CA and CAN embankments. Performance of the drainage systems related to normal conditions was not analyzed because the performance is bounded by the abnormal conditions analysis for minimizing infiltration under flood conditions. The Licensee referenced results of HEC 1 and HEC 2 Modeling analyses conducted by Bingham Environmental providing data pertaining to the depth of water expected from a PMF for the watershed encompassing the Clive site (Bingham Environmental 1996). That analysis indicated a calculated depth of the PMF across the site at approximately 1 foot above grade. The Licensee noted that the depth of the 100-year flood would be considerably less. Based on the geometry of water accumulation in the ditch, with respect to the embankment, the Licensee concluded that the abnormal flood event would not cause water to accumulate above the toe of the waste in the embankment and that the drainage system is adequately designed to minimize infiltration of water through the waste under both normal and abnormal conditions.

**Ensure Ditch Integrity**

The Licensee's evaluation of ditch integrity focused on evaluation of the drainage ditch's ability to resist disruption under anticipated normal and abnormal surface water flow conditions. The design criterion that the size of the rock used to line the ditches be able to handle projected peak flows without movement, was selected based on guidelines contained in NUREG/CR-4620 (Nelson, et al. 1986) and NUREG-1623 (NRC 2002) and Johnson and Abt (1998).

The Licensee evaluated a normal design condition that included evaluation of drainage system performance for different flow paths in the system under a 25-year storm event, and an abnormal design condition that included evaluation of drainage system performance under a 100-year storm event (Attachment 4 to Energy*Solutions*, 2011b). The rock size calculations considered both straight flow sections and flow around bends. Based on results of the calculations (Section 4.3.2 below), the Licensee concluded that no disruption of the drainage ditches would occur under the evaluated normal and abnormal conditions.

Based on its review of the information summarized above, the Division concludes that the Licensee's proposed design basis conditions and design criteria justification for the proposed CAW Embankment drainage system are acceptable.

***References:***

Bingham Environmental, 1996

Envirocare of Utah, LLC, 2004b

Envirocare of Utah, LLC, 2005a

Energy*Solutions*, 2006

Energy*Solutions*, 2011b; 2011e

Johnson and Abt., 1998

Nelson, et al., 1986

URS Corporation, 2005a

NRC, 1991

NRC, 2002

#### 4.2.1.5 Buffer Zone

##### 4.2.1.5.1 Description of Design Feature – Buffer Zone

**Requirement 2507-2**: Descriptions of the design features of the land disposal facility and of the disposal units for near-surface disposal shall include those design features related to infiltration of water; integrity of covers for disposal units; 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 adequacy of the size of the buffer zone for monitoring and potential mitigative measures [URCR R313-25-7(2)].

**Basis**: The buffer zones associated with the CAW disposal embankment are described in Section 3.1.11 of the CAW Embankment LAR (Energy*Solutions*, 2011b) and are justified by the fact that the applicable CAW embankment conditions are nearly identical to those approved by the Division for CA and CAN disposal embankments. Sections 3.1.5 and 3.3.5 of the 2005 LRA discuss the design criteria, including the justification and the conditions evaluated. The buffer zones are depicted as strips of ground lying between the edges of the disposal cell footprint (waste limits of the proposed embankment) and the respective fencelines, as shown on Drawings 10014-C01 and 10014-U01 included in Energy*Solutions* (2011a and 2011b). Drawing 10014-U01 also includes the northing and easting coordinates of the proposed CAW embankment buffer zone. As described in responses to Division interrogatories, the outer limit of the buffer zone will be located so that a minimum of 97.7 ft will exist between the design waste limit and the inner boundary of the buffer zone surrounding the CAW embankment. This buffer zone width exceeds the design requirement of 94 ft.

The distance from the toe of waste to any property boundary is no less than 300 ft, in compliance with the facilities Conditional Use Permit issued by Tooele County.

Groundwater monitoring wells are located within the buffer zones.

The dimensions of the proposed CAW buffer zones equal or exceed those approved for the CAN embankment and the 2005 LRA. The conditions upon which the buffer zone is based are similar. The CAW embankment information and analyses demonstrate that the buffer zones of the CAW embankment will perform at least as well as corresponding items approved for the CAN embankments and the 2005 LRA (2005 CAN SER Sections 1.0 and 3.0; 2005 LRA SER Sections 3.1.5 and 3.3.5; URS Corporation 2005a; 2005b).

Based on the information summarized above, the Division concludes that the proposed buffer zones for the CAW embankment are acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b

URS Corporation, 2005a; 2005b

#### 4.2.1.5.2 Principal Design Criteria – Buffer Zone

**Requirement 2507-3:** Descriptions of the principal design criteria and their relationship to the performance objectives [URCR R313-25-7(3)].

**Basis**: The design criterion, established for the buffer zone, is that it be adequately sized to allow site monitoring and corrective measures to be performed, if necessary.

The dimensions of the proposed CAW buffer zones exceed those approved for the CAN embankment and the 2005 LRA. The conditions upon which the buffer zones are based are similar. The CAW LAR analyses demonstrate that the buffer zones of the CAW embankment will perform at least as well as corresponding items approved for the CAN embankments and the 2005 LRA (2005 CAN SER Sections 1.0 and 3.0; 2005 LRA SER Sections 3.1.5 and 3.3.5 [URS Corporation 2005a; 2005b]).

Based on the information summarized above, the Division concludes that the Licensee's proposed CAW buffer zones are acceptable.

***References:***

URS Corporation, 2005a; 2005b

#### 4.2.1.5.3 Design Basis Conditions and Design Criteria Justification – Buffer Zone

**Requirement 2507-4:** Descriptions of the natural events or phenomena on which the design is based and their relationship to the principal design criteria [URCR R313-25-7(4)].

**Basis:** Justification provided by the Licensee for the selected buffer zone criteria and a buffer zone width no less than 94 ft included consideration of the following factors:

- Site monitoring is required during the 100-year period of institutional control to confirm performance of the disposal facility;
- Should unacceptable migration of radionuclides be identified, through the above monitoring program, adequate area must be available for implementation of corrective measures;

- Utah's Water Quality Rules state: "The distance to the compliance monitoring points must be as close as practicable to the point of discharge." The location of the monitoring wells, therefore, is determined by the cell geometry and other related cell configuration;
- Section 4.3.6 of SRP 4.3, "Waste Disposal Operations,) of NUREG-1200 (NRC 1994), states, "An acceptable buffer zone shall be a minimum of 30 meters wide around the entire facility." Although the proposed buffer zone is slightly less than that identified by the NRC as acceptable, the Division has assessed and has accepted the minimum distance of 97.7 ft between the toe of waste and the outer limit of the buffer zone. Additionally, the Licensee's property boundary is at a distance of at least 300 ft from the limits of waste disposal; and
- The 90-foot distance to a monitoring well found in the Statement of Basis for the Licensee's Groundwater Quality Discharge Permit (GWQDP), No. UGW450005 (LRA Section 3.3.5 [URS Corporation 2005b]).

The normal design condition evaluated by the Licensee for the buffer zone includes the condition where site-monitoring activities are performed and no unacceptable releases occur from the embankment. Under the normal condition of no releases, the Licensee noted, in Section 3.3.5 of the 2005 revision of the LRA, that the monitoring network within the buffer zone would not be necessary and the design of the buffer zone and system would be adequate.

The abnormal design condition evaluated for the buffer zone assesses adequacy of the buffer zone allowing response to a hypothetical contaminant release. The Licensee referred to groundwater infiltration and transport modeling showing that no contaminants would reach the compliance groundwater monitoring wells within 500 years, provided that Class A waste radionuclide inventories for certain radionuclides are limited to be at or below maximum allowable values as determined through by the modeling (Whetstone Associates 2011b) as described in Section 4.3.1 of this SER. The groundwater monitoring wells would be located approximately 90 ft from the edge of the waste embankments, within the boundary of the buffer zone. Based on this finding, the Licensee concluded that if contaminants were to be detected at the monitoring wells within the 100-year monitoring period, remediation measures could easily be accommodated due to the extremely slow linear velocity of the groundwater underlying the site area (2.74 ft/year, derived in Section 6.2.4 in Whetstone Associates 2011b). The Licensee has also indicated that the Licensee's property boundary is located at least 300 ft from the edge of waste; allowing adequate space as well as time for implementation of remedial measures.

The Licensee did not conduct an analysis of any accident condition for the buffer zone since such analyses are not indicated by NUREG-1199 (NRC 1991).

Based on the foregoing summary of information contained in the CAW Embankment LAR and other relevant documents the Licensee has submitted, the Division concludes that the requirements of URCR R313-25-7(4) as they pertain to the buffer zone have been met.

***References*:**

US Nuclear Regulatory Commission, 1991; 1994

Whetstone Associates Inc., 2011b

### 4.2.2 Description of Site Closure Plan

**Requirement 2507-7:** The application shall include certain technical information. The following information is needed to determine whether or not the applicant can meet the performance objectives and the applicable technical requirements of URCR R313-25: A description of the disposal site closure plan, including those design features which are intended to facilitate disposal site closure and to eliminate the need for active maintenance after closure [URCR R313-25-7(7)].

**Basis:** Fundamentally, the Licensee's proposed procedures for completing site closure, including closure of the proposed CAW embankment, are unchanged from those already approved for the CA and CAN embankments (URS Corporation 2005a; 2005b). Due to larger size of the proposed CAW embankment, the timing and phasing of final closure activities associated with the proposed CAW embankment will necessarily change relative to the previously proposed CA and CAN embankment timetables (Energy*Solutions* 2011a; 2011b). Before the final portion of the CAW embankment is closed, all on-site facilities will be decommissioned and demolished. Decommissioning and demolition may involve any of the following activities:

- Decontamination as necessary prior to release,
- Demolition,
- Disposal on site,
- Release for unrestricted use and
- Restoration to required final condition.

Once all decommissioning waste, requiring on-site disposal, has been placed in the CAW embankment, the interim cover will be placed and monitored as required for differential settlement.

The CAW embankment will be progressively closed as waste placement in portions of the embankment is completed. An interim cover system is first applied and allowed to settle, consolidate, and stabilize for at least one year. Once the interim cover is demonstrated to be stable within acceptable limits, settlement monitors will be placed and the final cover system constructed.

The design and construction of the CAW embankment will facilitate disposal site closure and are intended to eliminate the need for active maintenance after closure. Principal design features and their characteristics were chosen to support the final condition that the facility and its components must achieve as regards to stability and limits on environmental releases. This condition is required without the assistance or intervention of any individual or organization following closure.

The information contained in relevant documents the Licensee has submitted to support its proposal to develop and operate the CAW embankment indicate that the requirements of URCR R313-25-7(7) will have been met to the extent possible at the date of issuance, well in advance of actual facility closure. A description of decontamination and decommissioning procedures is provided in Appendix U of the 2005 LRA and applies to the proposed CAW embankment.

The site closure plan is nearly identical to that previously approved for use in the CA and CAN disposal embankments and is also acceptable for use in the CAW Embankment LAR. Based on the information summarized above, the Division concludes that the Licensee's proposed closure plan for final closure of the proposed CAW embankment is acceptable.

***References:***

Energy*Solutions*, 2011a; 2011b

URS Corporation, 2005a; 2005b

#### 4.2.3 Quality Assurance Programs

**Requirement 2507-10**: The application shall include certain technical information. The following information is needed to determine whether or not the applicant can meet the performance objectives and the applicable technical requirements of URCR R313-25: 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 [URCR R313-25-7(10)].

**Basis:** The Licensee's QA Program is largely unchanged from the approved 2005 LRA. The information contained in the 2005 LRA, and other relevant documents the Licensee submitted, indicate that the requirements of URCR R313-25-7(10) have been met. The Quality Assurance Manual (QAM) in Appendix T of the 2005 revision of the LRA document provides a general description of the QA program. Although the Quality Assurance Program (QAP) document does not reference specific QA and implementing procedures tailored to LLRW disposal, Section 3.0 of the 2005 revision of the LRA discusses the CQA/QC Manual. These documents are tailored to a LLRW disposal facility. In addition, the operating procedures in the 2005 LRA supplement the general requirements of the QAP.

The Licensee's description of the QAP to be used for the ongoing activities relies on the same description presented above and related appendices of the 2005 revision of the LRA. The QAP is defined by the following documents:

- Quality Assurance Manual;
- Operating Procedures Manual;
- Safety and Health Manual and the
- Construction Quality Assurance/Quality Control Manual.

Implementation of the procedures in these documents provides adequate controls to ensure the quality of activities during the design, construction, operation and closure of the LLRW disposal facility and during the receipt, handling, and emplacement of waste.

Section 9.0 of the 2005 revision of the LRA provides a general description of the QAP. This section describes how the Licensee ensures the independence and authority of the QA program and the QA personnel. It also describes the reporting relationship between contractor QA personnel, the Licensee's QA personnel and the Licensee's management.

The QAP is presented in Appendix T of the 2005 revision of the LRA. The QAP commits to implement managerial controls to ensure the accuracy, reproducibility, and documentation of quality affecting activities. The CQA/QC Manual describes the procedures used to ensure the quality of construction activities. The CQA/QC Manual provides a description of procedures that control inspection, approvals, change control, documentation, and construction project plans.

The Operating Procedures are presented in Appendix C of the 2005 revision of the LRA. These procedures describe the steps used to ensure and document quality affecting operational activities. Waste receipt, handling, and emplacement procedures are in the LLRW Operations Manual. As procedures are revised copies are given to the Division,

Appendix T of the 2005 revision of the LRA describes how audits are scheduled, implemented, reported, and documented. The controls used to ensure the independence, control, and reporting relationships of auditing personnel are described in the manual. In addition, response to non-conformances and corrective action requests are described in the manual.

The QAP, as described in the 2005 LRA, contains adequate controls to ensure the quality of activities performed at the Clive Facility.

***References:***

Energy*Solutions*, 2012

#### 4.2.4 Environmental Monitoring Program

**Requirement 2507-12:** The application shall include certain technical information. The following information is needed to determine whether or not the applicant can meet the performance objectives and the applicable technical requirements of URCR R313-25. A description of the environmental monitoring program to provide data and to evaluate potential health and environmental impacts and the plan for taking corrective measures if migration is indicated [URCR R313-25-7(12)].

**Basis:** The information contained in the CAW Embankment LAR, and supporting documents to Round 1 and Round 2 Interrogatories the Licensee has submitted, indicate that the requirements of URCR R313-25-7(12) have been met.

The Licensee demonstrates in the CAW embankment LAR that the monitoring network is situated within (beneath) the proposed CAW embankment footprint and within the buffer zone. Construction of the CAW embankment will require removal of some monitoring locations as they are located within the footprint of the proposed CAW embankment (Energy*Solutions* 2011b, Figures 10014 C01 and 10014 U02. extracts from those two figures are reproduced below in Figure 4-1, and Figure 4-2). Specifically, the existing "Environmental Monitoring Plan" will require some modifications to remove certain existing monitoring wells and certain existing or proposed lysimeters that, if not removed, would be covered with waste since they are located within the footprint of the proposed CAW Embankment. A list of environmental monitoring devices that will be abandoned and/or relocated is provided in Table 4-12. A series of new monitoring wells will be installed to replace those wells that will require removal with construction of the CAW embankment. The locations of the proposed new wells (GW-142 through GW-147, GW-148 and GW-148D, GW-149, and GW-150) are depicted on Figure 4-1, and Figure 4-2. Four existing or previously proposed lysimeters, CL-W1, CL-W2, Cl-W3, and CL-N5, will require removal as their locations lie within the proposed CAW Embankment footprint. Nine new lysimeters (CL-C1 through CL-C8 and CL-N3) are proposed for installation at various locations under the northern portion of the proposed CAW Embankment. Changes to the analytical parameters, matrices, or sampling/monitoring frequency, for the existing and new monitoring devices are not required or anticipated.

**Table 4-12 – Environmental Monitoring Stations to be Abandoned/Relocated.**

| Type | Location | Northing | Easting | Required Action |
|---|---|---|---|---|
| Air Monitoring Station | A-6 (At same location as device S-75) | See Drawing 07007 J01, January 5, 2012 (in Attachment 1 to Energy*Solutions* 2012a) | See Drawing 07007 J01, January 5, 2012 (in Attachment 1 to Energy*Solutions* 2012a)______ | Install new Air Monitoring Station A-6 |
| Groundwater Monitoring Wells | GW-81 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-82 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-83 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-84 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-85 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-86 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-109 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-110 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-111 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-112 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-137 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-138 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-139/139D | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-140 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| | GW-141 | See Drawing 10014 U02 | See Drawing 10014 U02 | Remove- inside footprint |
| Lysimeters | CL-W2 | See Drawing 10014 C01 | See Drawing 10014 C01 | Remove- inside footprint |
| | CL-W3 | See Drawing 10014 C01 | See Drawing 10014 C01 | Remove- inside footprint |
| | CL-W4 | See Drawing 10014 C01 | See Drawing 10014 C01 | Remove- inside footprint |
| | CL-N5 | See Drawing 10014 C01 | See Drawing 10014 C01 | Remove- inside footprint |

The Licensee provided documentation regarding an evaluation of the spacing of the groundwater monitoring wells, in Attachment 6 to the Energy*Solutions* 2011a LAR and in response to Round 1 and Round 2 interrogatories (Energy*Solutions* 2011b and Energy*Solutions* 2012a, respectively). The purpose of the evaluation was to demonstrate the efficiency of the proposed monitoring well network for detecting potential releases of constituents from the proposed CAW embankment. The information provided included a groundwater flow simulation using the Monitoring Efficiency Model (MEMO) Code to determine optimum well locations to detect potential releases with at least 95% efficiency. Initial modeling simulations used a series of model input parameters that were derived or estimated as described in Attachment 6 to Energy*Solutions* 2011a.

Specific information provided by the Licensee in response to Division requests related to the monitoring well spacing evaluation included a discussion of the basis for selecting the initially estimated values of 129.1 ft and 12.9 ft, respectively, for the longitudinal and transverse dispersivity values that were used in the initial MEMO Model simulations. These values were developed based on extrapolation of a correlation by Gelhar, et al 1992). Also, information by the Licensee included an alternative derivation of longitudinal and transverse dispersivity, based on a relationship developed by Xu and Eckstein 1995, resulting in revised values of 27.2 and 2.72 ft, respectively. The licensee provided a rationale for use of a hypothetical release source width of 3 ft and results of a sensitivity analyses using additional MEMO Model simulations using this assumed source width and the revised smaller (more conservative) longitudinal and transverse dispersivity values. The sensitivity analysis simulation results demonstrate that the effective efficiency of the proposed monitoring well network is equal to or greater than the targeted efficiency of 95%.

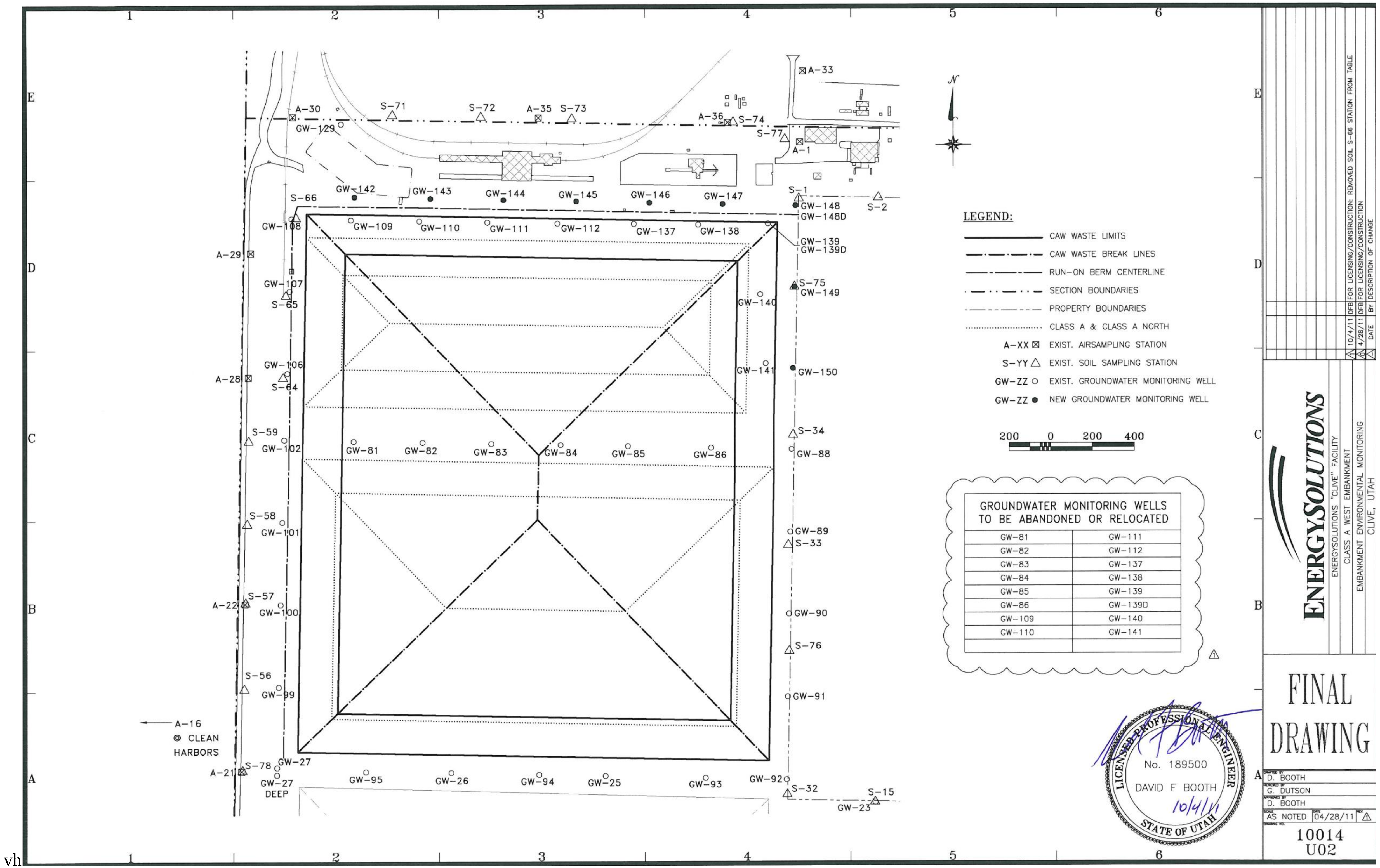


**Figure 4-1 – Locations of Monitoring Wells to be Removed and Proposed New Monitoring Well Locations.**

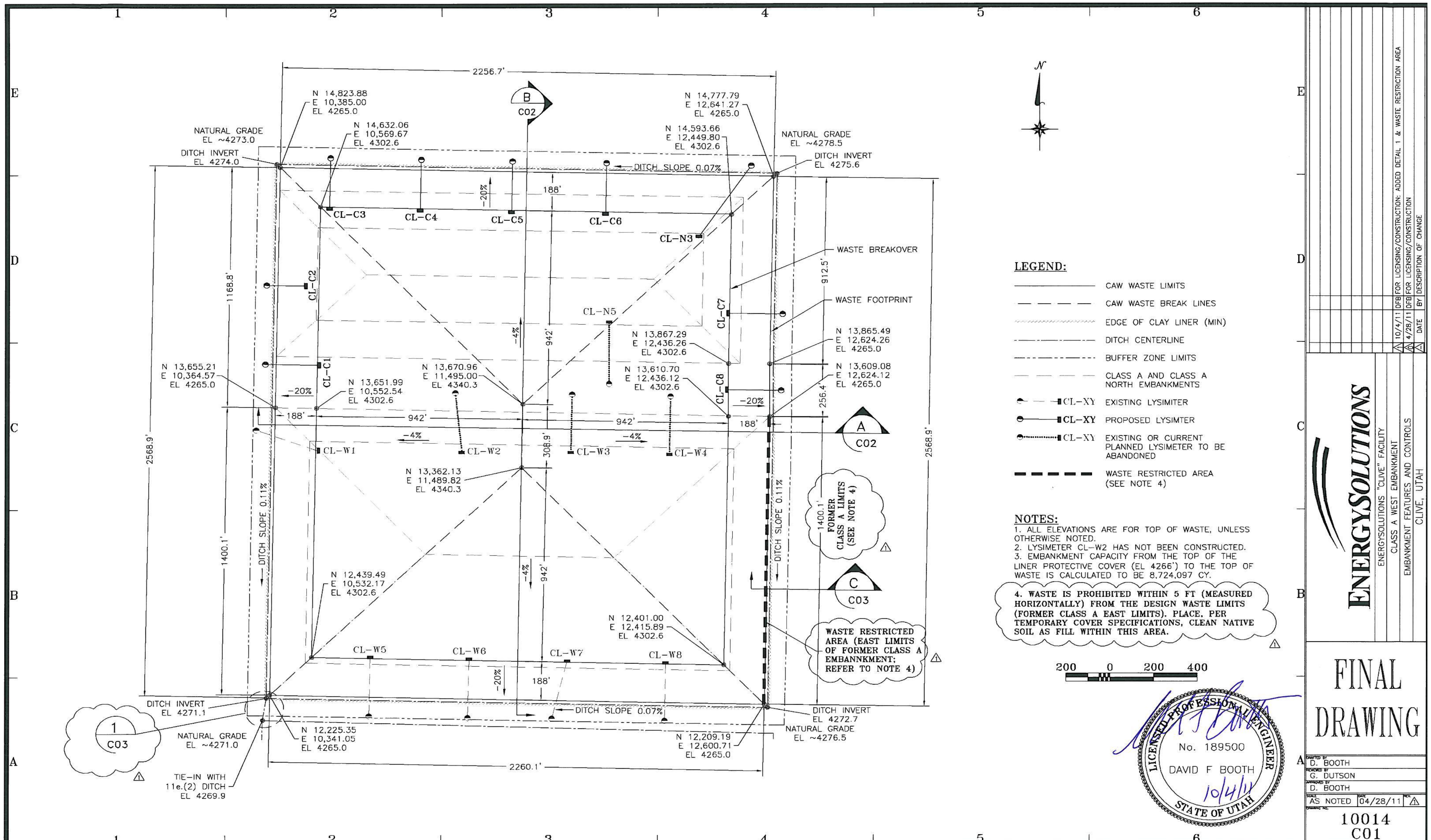


**Figure 4-2 – Locations of Lysimeters to be Removed and Proposed New Lysimeter Locations.**

**Air Monitoring**

To provide an additional level of monitoring for assessing potential airborne movement of contamination from the CAW embankment operations to the VITRO Facility to the east, the Licensee proposes to install an additional air monitoring station (A-6) on the east side of the proposed CAW embankment (see Attachment 1 to Energy*Solutions* 2012a.). The location for this station, at the same location as soil monitoring location S-75, was determined based on analysis of wind rose data indicating that the highest frequency wind speeds and directions generally occur from the south-southwest and from the northeast. Station A-6 was placed so that emissions generated near the VITRO fence could be identified. Station A-6 will be used as a data trending location not as a compliance monitoring point, and it will be monitored at the same frequency and schedule as the current air monitoring compliance network. Details regarding the proposed new Air Monitoring Station A-6 are included in a proposed revision to the Environmental Monitoring Plan, January 5, 2012, in Attachment 1 to Energy*Solutions* 2012a . The proposed location of the new device is shown on Drawing 07007 J01 dated January 5, 2012, in that document.

Based on the information summarized above, the Division concludes that the Licensee's proposed environmental monitoring plans and procedures for the CAW Embankment are acceptable.

***References:***

Energy*Solutions*, 2011a

Energy*Solutions*, 2011b

Energy*Solutions*, 2012a

## 4.3 URCR SECTION R313-25-8. TECHNICAL ANALYSIS

The CAW Embankment LAR involves limited aspects of URCR Section R313-25-8. The applicability of URCR Section R313-25-8 provisions to the review of the CAW Embankment LAR are summarized in Table 4-13. Those sections that do apply to the CAW Embankment LAR are addressed in the sections following the table.

**Table 4-13 – Applicability of URCR R313-25-8 Provisions to CAW Embankment LAR.**

| URCR R313-25-8 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| **Number** | **Topic** | | |
| 8(1)<br>8(2)<br>8(3) | Site-Specific Performance Assessment (Recently promulgated requirements inserted in URCR R313-25-8, forcing previously existing requirements to be incremented) | No | CAW Embankment LAR does not involve disposal of waste addressed by this provision |
| 8(4)(a) | Performance Objectives; Protect the General Public | Yes | The CAW Embankment potentially affects releases from the disposal facility and therefore exposures received by the general public |
| 8(4)(b) | Performance Objectives; Protect Inadvertent Intruders | Yes | The CAW Embankment involves a thicker cover system that provides slightly greater protection to inadvertent intruders |
| 8(4)(c) | Performance Objectives; Protect Individuals During Operations | No | The Division has previously reviewed and approved operations that affect individuals during operations; the CAW Embankment does not change or affect operations |
| 8(4)(d) | Performance Objectives; Long-Term Stability | Yes | The CAW Embankment LAR changes the design of the CAN and CA cover systems; additional analyses of stability must be reviewed |
| 8(5) | Concentrated Depleted Uranium | No | The CAW Embankment LAR does not involve concentrated depleted uranium |

### 4.3.1 General Population Protection

**Requirement 2508-4(a):** The specific technical information shall also include the following analyses needed to demonstrate that the performance objectives of URCR Rule R313-25 will be met: 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 URCR Section R313-25-19 [URCR R313-25-8(4)(a)].

**Basis:** The protection provided to members of the general public is largely unchanged from what the Division approved following its review of the 2005 LRA. The information contained in the LRA, and other relevant documents the Licensee submitted, indicate that the requirements of URCR Subsection R313-25-8(1) have been met. Each of the major media pathways of this requirement is addressed in the following paragraphs. The principal sources of information for the exposure assessment are Sections 6.3 and 6.4 of the 2005 revision of the LRA, Appendix A of the 2005 revision of the LRA, and Section 5.3, Appendix F, Appendix J, and Appendix K of the License Amendment [LA] document (for the previously proposed disposal of Classes A, B & C waste) dated December 13, 2000 (ABC LA document) (Envirocare 2000c). Both normal operating conditions (Section 6.3.1 of the 2005 revision of the LRA) and accident scenarios (Section 6.3.2 of the 2005 revision of the LRA) were evaluated.

**Air Pathway**

The potential releases of radionuclides through the air pathway were assessed for the facility. During operation of the facility, the transport of dust to the site boundary is affected mainly by the natural site characteristics. These characteristics include the wind speed, wind direction, and atmospheric stability conditions. The highest dose to the public is estimated to occur during operations from the atmospheric pathway at 10.2 mrem/yr. The Licensee states in LRA Section 6.3.1.1, "Control of Windborne Dispersion," that engineering and operational controls are in use to prevent the resuspension and dispersion of particulate radioactivity. Waste generators are normally required to ship bulk soil-type waste at a moisture content that allows movement without creating visible dust. Water spray is used in the cells as needed to prevent resuspension of radioactivity. The railcar rollover facility is now an enclosed area, further reducing the potential for a measurable airborne release at the boundary. Haul roads are wetted and maintained to prevent the resuspension and dispersion of particulate radioactivity. Polymers are spread on inactive, open areas to bind the surface and prevent resuspension. The Licensee also placed air samplers and reviewed the data to identify if an airborne situation is developing that might require corrective actions.

After final placement of the waste and closure of the disposal embankment, the facility design prevents any further migration of radioactivity through the air pathway because all waste will be beneath a thick earthen cover.

As discussed in Appendix A to the 2005 revision of the LRA, the Licensee demonstrated that the maximum dose to a member of the public was less than 25 mrem/yr, even if the individual is continually present at the disposal site boundary. The analysis estimates the quantities of radioactively contaminated dust suspended into the atmosphere from the unloading facilities, the hauling activities, and from waste placement in the disposal cells – under normal operating conditions. The waste concentrations used as the source term in the atmospheric transport calculations are the average concentrations accepted at the facility in the past as listed in Appendix J of the 2005 revision of the LRA.

Radon releases will be negligible because the cover design includes a clay radon barrier designed to limit the surface radon flux to less than 20 pCi/m$^2$-s, resulting in potential radon exposures well within limits. The design is based on the disposal of uranium mill tailings, which are higher in radium-226 than the Class A waste.

For accident conditions, dust or particulate matter could be released to the atmosphere and inhaled by individuals. The application evaluates a tornado and severe wind, train derailment, truck turnover or collision, and truck fire. All analyses show that the maximum dose to a member of the public is less than 25 mrem/yr, even if the individual is continually present at the disposal site boundary.

In public comments during hearings on the Division's previous Siting Evaluation Report for the proposed Class A and Class B disposal facility, concern was expressed over the potential that the proximity of the U.S. Air Force bombing test range might create conditions inconsistent with the safe operation of the proposed facility. In its response to Interrogatory 2523-11, the Licensee provided information to defend the proposed licensing action. The Licensee defends the safety of the proposed facility by asserting that ". . . the probability of a military aircraft crash or accidental bomb drop onto the site is extremely remote. . ." The Licensee also compares the probability of such an incident to that nearer Hill Air Force Base, where the consequences would be much more severe. Given the occurrence of such an incident, the Licensee argues that the potential dispersal of radioactive materials would be limited to the immediate vicinity of the proposed facility and would be cleaned up at the expense of some other entity. The Licensee demonstrates that the proposed facility is located outside restricted airspace and concludes that the probability of such an accident involving the facility is insignificant.

## Soil Pathway

The soil pathway involves the exposure of the public to contaminated soil from the facility. If an exposure occurred, doses could result from external radiation or ingestion of soil on dirty hands. The primary site characteristics that prevent the likelihood of such exposures during operations is the site's remote location, the low population density in the site vicinity and the lack of natural resources to provide for population expansion. Therefore, this pathway was not considered.

The design of the embankment also contributes to minimizing exposures to contaminated soil by members of the public. After closure of the embankment, all contaminated soil will be covered in the disposal cells. The cover system contains a surface layer of riprap to protect against erosion and human intrusion. Beneath the riprap, the cover system contains a drainage layer and a clay radon barrier. The thickness of the cover system prevents penetration of the waste by roots or burrowing animals. No contaminated soil material is expected to rise to the ground surface, or be otherwise removed from the disposal cell.

During operation, the facility will be monitored as described in Appendices Q and R of the 2005 revision of the LRA, to ensure that no releases or doses have occurred via the soil pathway.

## Groundwater Pathway

The groundwater pathway was analyzed in Whetstone Associates, Inc. (2011b, 2012). The primary site characteristics that prevent public exposures via the groundwater pathway are the very poor groundwater quality at the site, the low population density, and the relatively slow groundwater flow velocities. The groundwater is not potable because of its very high concentration of salts. This characteristic alone prevents any appreciable consumption of the water by humans or livestock. The horizontal groundwater flow velocity is approximately 0.8 meters per year, resulting in groundwater travel times of approximately 33 years from the toe of the side slope of the embankment to the compliance well. .

Additionally, several embankment design features provide protection of the public from exposure via the groundwater pathway. The cover system to be placed over the disposal waste allows very little water to flow into the disposed waste. This limits the contamination of the groundwater by minimizing the contact of water with the waste. Another design feature of the disposal embankment is the bottom clay liner below the disposed waste. The clay absorbs many of the radionuclides and slows their potential release from the cell and subsequent transport to the water table aquifer.

In its assessment of the groundwater pathway, the Licensee demonstrated that the infiltration and radionuclide transport models show that any disposed Class A waste will satisfy all of the groundwater protection criteria, provided that the concentrations of six radionuclides (Bk-247, Ca-41, Cl-36, I-129, Re-187, and Tc-99) are limited to the concentrations used in the transport model. The six modeled radionuclides in Class A concentrations were projected to exceed the groundwater protection criteria at the compliance wells located 90 ft from the nearest edge of waste, in less than 500 years, based on the side slope cover design infiltration rate of 0.168 cm/yr. All other radionuclide concentrations are limited only by what is necessary for the waste to qualify as Class A waste. The groundwater model provides a conservative estimate for the groundwater exposure scenario. The results of the model, presented in the CAW LAR, determined that the thickness of the radon barrier does not change the results.

Infiltration through the cover system was modeled with the HELP code. The model used precipitation data from over seventeen years of measurements at Clive Utah. The average annual precipitation measured at Clive, from 1993 to 2009, is 8.53 inches per year. Based on site specific evaporation, precipitation, temperature, and solar radiation data 100 years of synthetic data were generated using a synthetic weather generator. The HELP model used the measurements and generated synthetic rainfall data that varied from year to year about the appropriate long term average for Clive. The rainfall totals used in the HELP model vary from year to year in the same way that actual rainfall varies from year to year. This approach is more realistic because it allows the calculations to account for yearly variations about the mean rainfall. Both the top slope and side slopes of the cell were evaluated. The net water infiltration through the cover is calculated as 0.09 cm/yr for the top slope and 0.168 cm/yr for the side slopes.

Infiltration modeling using the HELP codes is sensitive to the choice of value for the evaporation zone depth, (EZD) parameter that represents the depth below which evaporation at the cover surface has no effect on moisture movement. The EZD influences the storage of water near the surface of the cover which affects the computation of evaporation and runoff. The choice of a value for EZD has been the object of much discussion between the Licensee and the Division. To address the uncertainty surrounding the choice of value for EZD, the Licensee designed and acquired data for many years from a Cover Test Cell (CTC) with the objective of investigating moisture movement within the cover system on surface conditions. The Division's assessment of the CTC data revealed problems that require the Licensee's attention. The Division is working with the Licensee to resolve problems encountered in assessing CTC data. Until such time as the concerns with the CTC are resolved, the EZD depth used by the Licensee in any HELP infiltration modeling will be considered an unresolved issue to the Division. To allow resolution of this issue, a new license condition will be added to the facility's license to require the Licensee to eliminate the concern by designing a modified cover system and submitting a performance assessment for that cover system that demonstrates that the modified cover system provides equal or better performance than that modeled in the infiltration and transport model for the currently propose cover design, as described in this SER.

A UNSAT-H model was used to calculate the moisture contents of the soils and waste from the ground surface down to the shallow unconfined aquifer. The moisture contents were necessary to calculate the flow velocity of infiltrating water through the soil and waste profile. The UNSAT-H model was run numerous times to approach quasi-steady-state conditions. The resulting moisture content represented the expected long-term moisture content in the CAW embankment and underlying subsurface materials. The CAW embankment cover and liner clay layers retain high volumetric moisture contents (approximately 0.42 v/v) while waste and native soil layers retain relatively low moisture contents (less than 0.05 v/v). For the modeled top slope, with 0.090 cm/yr infiltration, the average moisture content stabilized at 0.0501 v/v for the waste, and 0.0362 v/v for the native soil below the embankment. The predicted volumetric moisture contents for the CAW embankment modeled side slope is slightly higher than for the modeled top slope, due to a higher infiltration rate. For the modeled side slope, with 0.168 cm/yr infiltration, the average moisture content in the waste stabilized at 0.0541 v/v, and in the native soil below the embankment at 0.0420 v/v. The final moisture content from the UNSAT-H model is used as input in the (PATHRAE) contaminant transport model.

Radionuclide transport was modeled with the PATHRAE-RAD code. The model calculated the release and transport of radionuclides from the bottom of the waste cell, through the unsaturated zone, and horizontally through the shallow unconfined aquifer to a compliance-monitoring well located 90 ft from the edge of the disposal facility. The groundwater model included many conservative assumptions that helped to ensure that the radionuclide concentrations at the compliance monitoring well were not underestimated. For example, the distance from the bottom of the waste to the water table of the aquifer was decreased from its actual value by 2.04 ft to conservatively account for the effects of the capillary fringe at the water table and to account for variations in the water table level. No delay factors for waste container life were used to delay the onset of radionuclide releases from Class A waste under side slopes.

The transport modeling shows that, for most radionuclides at the Class A limits, groundwater protection levels are met for 500 years after disposal of the waste. Groundwater protection levels are met for all radionuclides, provided that specified concentration limits in the waste are imposed, depending on the waste placement area within the proposed CAW embankment, for either Bk-247, Ca-41, and Cl-36 (topslope area), or Bk-247, Ca-41, Cl-36, I-129, Re-187, and Tc-99 (sideslope area). Even though the groundwater is not potable, potential doses to the public from groundwater were calculated and meet all applicable limits.

Another conservative assumption is that the water table gradient is 0.001 (Whetstone Associates, Inc., 2012). The hydraulic conductivity was based on measured values from the site. The value used in the model is 7.53 x 10-4 cm/sec. which is the value at the geometric mean, which is 6.16 x 10-4 cm/sec., plus one standard deviation. This resulted in the model using a horizontal interstitial groundwater velocity of 0.819 m/year.

With few exceptions, the Class A radionuclide concentrations were set at the Class A limits specified in 10 CFR 61. Exceptions were made for radionuclides whose specific activities were less than the Class A limit, in which cases the lesser specific activity was used. The only other exceptions were the radionuclides mentioned above (Bk-247, Ca-41, Cl-36, I-129, Re-187, and Tc-99) whose concentrations were set lower than the applicable Class A limit in order to meet the groundwater protection criteria.

## Surface Water Pathway

Due mainly to the natural site characteristics, there are no radioactive releases expected through the surface water pathway. The annual precipitation is low and the evaporation is high. No permanent surface water bodies exist in the site vicinity. In addition, the site is far from populated areas. The Class A embankment design features also minimize the potential for releases by the surface water pathway. Embankment design includes drainage ditches around the waste disposal areas. After precipitation events, the ditches divert run-off from the disposal cell cover to areas away from the disposal cells to minimize contact of water with waste.

## Vegetation

The application evaluated the effects of vegetation on the cover system. Vegetation had two primary effects on the cover system: increasing the hydraulic conductivity of the cover material and root clogging of the lateral drainage layers. During operation of the embankment, releases and doses through the plant pathway are limited by the design, operation, and maintenance of the facility. Plants on the site will be removed and prevented from contacting waste materials. After final placement of the cover, releases and doses from the plant pathway are limited by the site’s natural characteristics, which include low rainfall, thin plant cover, and the presence of plants that are highly efficient at removing water from the soil and transpiring the moisture back to the atmosphere.

The plant uptake pathway is not a viable exposure pathway at the embankment because of natural site characteristics and design features of the embankment. Exposure by the plant uptake pathway could occur by: (1) the production of food crops in contaminated soil at the site, and (2) root intrusion into the waste by native plants that are subsequently consumed by humans or animals.

The natural site characteristics help prevent exposures via the plant uptake pathway because there is insufficient water at the site to produce food crops. In addition, saline soils present at the site limit the number and type of plant species that can tolerate such conditions. Additionally, there are few deep-rooted native plants in the site vicinity and relatively few plants of any kind are predicted to become established on the rock riprap-capped CAW embankment cover system at and following closure of the embankment.

Design features of the facility also help prevent exposures via the plant uptake pathway. A thick earthen cover will be placed over the disposal cells to make the waste inaccessible to plant roots after closure of the facility. The possibility of native plants extending their roots into the waste is prevented by the configuration of the earthen cover with the lower Type B filter functioning as a capillary break with minimal moisture storage to attract or even support plant roots. After closure, some limited plant species may set roots in the overlying sacrificial soil, which possesses a higher moisture storage capacity. The overall scarcity of deep-rooted plant species in the site vicinity and the configuration of the earthen cover will offer an inhospitable environment for extension of these types of roots into the waste.

## Burrowing Animals Pathway

Burrowing animals are not considered a viable exposure pathway, given the combination of site characteristics and design features. Burrowing animals at the site include jackrabbits, mice, foxes, and ants. The first deterrent to burrowing animals is the riprap erosion barrier. While this may be only partially effective in deterring animals, the primary protective barrier is the clay radon barrier. The burrowing species at the site are not known to dig to such a depth that their burrows could penetrate through the entire cover and into the waste. During operation of the facility, releases and doses from the burrowing animal pathway will be prevented by the design, operation, and maintenance of the facility. Burrowing animals will be prevented from contacting the waste materials. After final placement of the cover, the design features of the facility, primarily the thick soil cover that isolates the waste from burrowing animals, will control releases and doses. Because of this, the likelihood of any animals burrowing through the entire 0cover and exhuming waste materials is sufficiently low that it was not included in the safety assessment calculations. As such, the burrowing animals’ pathway is not expected to result in any exposures to humans.

## Doses to the Public

Appendix A of the 2005 revision of the LRA shows that doses to members of the public will be within established regulatory limits. The highest dose to the public is estimated to occur during operations from the atmospheric pathway at 10.2 mrem/yr. The groundwater pathway is not viable because of the high salinity and general poor quality of the groundwater; however, it was evaluated via the groundwater modeling and found to be less than 4 mrem/yr.

***References*:**

Envirocare of Utah, Inc. to Utah Division of Radiation Control, 2000c

Whetstone Associates, Inc., 2011b, 2012

### 4.3.2 Protection of Inadvertent Intruders

**Requirement 2508-4(b):** The specific technical information shall also include the following analyses needed to demonstrate that the performance objectives of URCR R313-25 will be met: 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 [URCR R313-25-8(4)(b)].

**Basis**: Utah regulations require special provision to protect inadvertent intruders from disposed LLRW only for Class C LLRW. Since only Class A waste will be disposed of in the proposed CAW embankment, no special intruder barrier, as defined by Utah regulations, is required. In a more general sense, however, intruder protection is required by the performance objective stated in URCR R313-25-20. The intruder protection requirement is satisfied by:

- Remoteness of the facility from large population centers,
- Lack of resources at the site,
- Provision of a cover system to separate the waste from the atmosphere,
- Use of CLSM,
- Erection and maintenance of physical access barriers at the closed facility,
- Maintenance of access controls at the closed facility and
- Placement of monuments denoting the locations of embankment boundaries.

The NRC evaluated the long-term hazards of LLRW disposal in its draft and final environmental impact statements of the regulation of LLRW disposal (NUREG/CR-4370). Radiation hazards associated with Class A waste are such that, should intrusion into disposed waste occur following the 100-year institutional control period, doses were projected to be within acceptable limits.

Since the Licensee will dispose only Class A LLRW, it implicitly complies with this regulatory requirement. Based on the information summarized above, the Division concludes that the Licensee's proposed CAW embankment provides adequate intruder protection.

***References*:**

Envirocare of Utah, Inc., 2005c

Streamline Consulting, LLC, 2005

### 4.3.3 Long-Term Stability of Disposal Site

**Requirement 2508-4(d):** The specific technical information shall also include the following analyses needed to demonstrate that the performance objectives of URCR R313-25 will be met: 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, and surface drainage of the disposal site. The analyses shall provide reasonable assurance that there will not be a need for ongoing active maintenance of the disposal site following closure [URCR R313-25-8(4)(d)].

**Basis:** The licensee has evaluated the long-term stability of the proposed CAW embankment, including analyses of the effects of natural processes that include erosion, mass wasting, slope failure, foundation settlement and settlement of wastes and backfill, infiltration through the cover and adjacent soils, and surface drainage at the disposal site. The analyses were developed to provide reasonable assurance that there will not be a need for ongoing active maintenance of the CAW Embankment cell and associated drainage features following final closure of the CAW Embankment. Collectively, the analyses completed for the proposed CAW Embankment demonstrate, to the Division's satisfaction, as further described below, that long-term stability of the CAW Embankment will be achieved with reasonable assurance.

The information provided in the Energy*Solutions'* Responses to Round 1, 2, and 3 Interrogatories (Energy*Solutions* 2011b; 2012a; 2012b), in the CAW Embankment LAR (Energy*Solutions* 2011a; 2011b) and in supporting analyses indicate that the requirements of URCR R313-25-8(4) have been or will be met, contingent upon the successful resolution of issues related to the EZD value and the resulting requirement for a modified embankment cover design, and the expected distortion of the cover radon barrier layer (see Section 5.0) . The basis for this affirmative finding, with the resolution of these stated contingencies, is presented in:

- Descriptions and justifications of the principal design features of the proposed facility provided in Sections 3.1 through 3.4 of the CAW Embankment LAR; and in subsequent Licensee submittals as described in this SER;
- Summaries of the principal design features, design criteria, and projected performance of the principal design features related to long-term stability provided in updated Tables 3.2 through 3.4 of the CAW Embankment LAR and in subsequent Licensee submittals as described in this SER; and
- Information submitted by the Licensee pertaining to the principal design features design criteria, and projected performance of the principal design features for the previously proposed CAC embankment (e.g., see AMEC 2005a and 2005b; Energy*Solutions* 2006) addressing long-term stability of that proposed embankment.

Table 3-2, Table 3.4 and the text of the CAW Embankment LAR were revised and updated from the information presented in the 2005 LRA to reflect: (1) information published after the 2005 LRA was submitted that is relevant to the design methodologies used for designing the CAW embankment; and (2) changes in the design of some principal design features that have been incorporated into the CAW Embankment design compared to the previously proposed CAC embankment design (Energy*Solutions* 2006). Such changes include:

- Change in thickness and gradation of the riprap layer lining the side slopes of the perimeter drainage ditch adjacent to the CAW embankment;
- Change in the thickness of, and particle gradation (filter) requirements for, the Type B Filter Zone layer used in the topslope and sideslope portions of the cover layer for the CAW Embankment; and
- Change in thickness of riprap used to line the sideslope portion of the CAW embankment perimeter drainage ditches.

Additionally, a possible change, depending on results of planned future testing of on-site soils proposed for use in constructing the CAW embankment cover, in the design criterion for maximum allowable distortion of the cover may be invoked and applied to the CAW embankment design prior to constructing the cover to further mitigate against possible effects of long term differential settlement within the embankment. The principal design features have been designed in accordance with applicable guidelines that are appropriate for this type of facility to perform their required functions over the period of hundreds of years, such that the need for performing ongoing active maintenance of the proposed facility following facility closure will be minimized.

#### 4.3.3.1 Erosion

The Licensee submitted an updated set of rock cover design calculations and updated determinations of the PMP that demonstrate that the proposed CAW embankment cover has been designed to provide long-term stability of the embankment and to ensure that the cover will be capable of resisting damage by erosion resulting from surface water flows expected to occur during normal and abnormal precipitation conditions at the site (Attachment 10 to Energy*Solutions* 2012a and 2012bc). As described in Section 4.2.1 above, for evaluating potential erosion in the cover, the Licensee assumed a 100-year, 24 hour storm event for the normal precipitation condition, and a PMP 1-hr value of 6.1 inches of rain, as the abnormal precipitation condition (Table 3.2 of the CAW Embankment LAR. Updated erosion calculations were performed in accordance with guidelines provided in NUREG-1623 and with analytical methodologies recommended or developed in accordance with recommendations provided therein (Attachment 10 to Energy*Solutions* 2012b). These updated calculations include a revised erosion protection-related calculation for the CAW embankment sideslopes to reflect information and procedures that were published after the CAC Embankment LAR was submitted (e.g., Abt et al. 2008). The calculations regarded erosion resistance of round-shaped riprap placed on slopes and included additional refinements to the slope erosion protection analysis methodology (Abt and Johnson 1991) discussed in NUREG-1623 (NRC 2002).

The updated rock cover calculations demonstrate that the $D_{50}$'s of the rock riprap materials, proposed for use on the embankment topslope and sideslopes, exceed the minimum $D_{50}$ rock sizes required for ensuring long-term (1,000 years) erosional stability of the embankment, when evaluated in accordance with requirements and guidelines contained in NUREG-1623 and Abt et al. 2008. Additionally, the current approved version of the CQA/QC Manual requires that rock riprap materials used in the CAW embankment Cover have a weighted average aggregate rock score of 50 or more, in accordance with NRC NUREG-1623 guidelines.

Based on the information above, the Division concludes that the Licensee's analyses of the ability of external erosion protection measures, incorporated into the CAW embankment design, are adequate and that long-term stability of the CAW embankment against erosion will be achieved with reasonable assurance.

##### 4.3.3.1.1 Internal Erosion Within Cover

The Licensee submitted updated rock cover design calculations and used appropriate filter criteria (gradation and permeability criteria) recommended in NUREG/CR-4620, NUREG-1623, Cedegren 1989, and NRCS 1994 that demonstrate that the proposed CAW embankment cover has been designed to provide long-term stability with respect to minimizing potential long-term internal erosion within the cover layers over the embankment's design life under normal and abnormal precipitation conditions at the site.

The updated calculations submitted by the Licensee demonstrate that the filter layer underlying the riprap meets the $D_{15}/D_{85}$ criteria as described in NUREG/CR-4620 for minimization of migration of the filter layer into the riprap. Furthermore, specifications on the sacrificial soil gradations ensure that migration of material between the sacrificial soil layer and the Type A Filter layer will be minimized. Additionally, the effectiveness of the Type A Filter Zone to minimize internal erosion of the underlying sacrificial soil layer was assessed by calculating the interstitial velocities associated with the rock. The calculations used methods described by Leps, 1973, Abt, et al. 1988, and Codell, et al. 1990. The calculations showed that, when comparing the calculated interstitial velocities to permissible velocities from Table 4.9 of NUREG/CR-4620, worst-case calculated interstitial velocities at the surface of the sacrificial soil layer would not be expected to cause erosion of that layer. Safety factors determined for the interstitial velocity are 1.48/0.20 = 7.40 for the top slope and 1.48/0.49 = 3.02 for the side slopes. The design filter layer, underlying the riprap, provides the necessary protection against rock migration through the layers and erosion of the underlying sacrificial soil layer. The calculations also demonstrate that the lateral drainage layer of the cover will not become plugged and therefore is expected to retain its permeability throughout the life of the embankment and protect the radon barrier from erosion.

#### 4.3.3.1.2 Long-Term Integrity of Drainage Systems

The Licensee submitted calculations that demonstrate that the selected characteristics of the proposed riprap materials, as summarized in Table 3.3 of the CAW Embankment LAR, that would be placed in and used to line the CAW Embankment perimeter ditches would be adequate to resist movement (internal erosion) of the riprap materials under flows projected to occur during normal and abnormal precipitation events at the site (Energy*Solutions* 2011a; Attachment 4 to Energy*Solutions* 2011b). For evaluating potential internal erosion in the ditches, the Licensee assumed (Table 3.2 of the CAW Embankment LAR) a 100-year, 24 hour storm event (2.4 inches) for the normal condition, and the PMP (a 1-hr value of 6.1 inches of rain, verified by calculations in Energy*Solutions* 2012b as being the most conservative PMP value for design use at the Clive site) as the abnormal condition. The updated drainage design calculations (Energy*Solutions* 2011b) were performed in accordance with guidelines provided in NUREG-1623 and with analytical methodologies recommended therein. In the updated calculations, the minimum average $D_{50}$ of the riprap lining the ditches required to prevent failure under abnormal ditch flow conditions was determined using methods (e.g., Johnson and Abt 1998; USACE 1994) recommended in NUREG-1623. In accordance with NUREG-1623 guidance, the "failure discharge" value [assumed flow rate during abnormal conditions] was increased by a factor of 1.35 to provide additional assurance that there would be no rock movement. Since the abnormal flow condition bounds the normal flow conditions, it leads to a more conservative case for evaluating the erosional stability of the drainage ditches.

Based on the information above, the Division concludes that the Licensee's analyses of the effects of erosion on long-term stability of the proposed CAW Embankment and perimeter drainage ditches are adequate and that long-term stability of the CAW Embankment will be achieved with reasonable assurance.

#### 4.3.3.2 Mass Wasting

The area of the proposed CAW Embankment, at and immediately surrounding the Clive Facility, is relatively flat with no landforms or soil conditions present that would be prone to landslides, rock toppling or rock falls, debris flows, or other forms of mass wasting. Analyses of slope stability of the CAW Embankment (see Section 4.2.1.3.3) and of other disposal embankments at the Clive Facility demonstrate that all slopes will be stable in the long term. Based on this information, the Division concludes that the long-term stability of the proposed CAW Embankment would not be impacted by mass wasting.

#### 4.3.3.3 Slope Failure

The Licensee assessed performance of the CAW embankment under normal (static) and abnormal (seismic) conditions. Slope stability analyses were performed using the computer program GSTABL7® utilizing Spencer's Method for circular modes of failure-associated movement. The calculated minimum static factor of safety, based on use of drained shear strength values for the embankment and foundation materials, was determined to be greater than 1.5 (Attachment 5 to Energy*Solutions* 2011b). For assessing stability under seismic conditions, pseudostatic stability analyses of embankment slope stability were completed. The pseudostatic analyses considered both drained and undrained foundation soil strength parameters, and assumed a Peak Ground Acceleration (PGA) magnitude of 0.28g. The calculated minimum factor of safety for seismic conditions was determined to be greater than or equal to 1.2 (Attachment 5 to Energy*Solutions* 2011b). The most critical failure surface was predicted to extend through the deep clay unit of foundation soils and remains under the "break in slope". For calculated failure surfaces located entirely within the embankment, the lowest calculated factor of safety was found to be at least 1.7. In all cases, the stability of the embankment was found to be governed primarily by the height of the 5H:1V embankment side slope. At a height of 38 ft, the static and seismic stability of the CAW embankment was found to be acceptable. This projected safety factors exceed the safety factors required by the design criteria, *i.e.*, static factor of safety $\geq 1.5$ and seismic factor of safety $\geq 1.2$. The specified design criteria factors of safety of $\geq 1.5$ and $\geq 1.2$ for evaluating static and seismic slope stability are applicable to operating dams in the state of Utah. The Division considers that these factors of safety are conservative for the Lisensee's site and for the CAW embankment because the embankments: (1) are not designed to retain water such as a dam is designed to; and (2) have gentle side slopes (5H:1V) around the entire perimeter and lower total height compared to many dams in the western United States. Based on the foregoing summary of information, the Division concludes that the Licensee's analyses of potential slope failure in the CAW Embankment are adequate, and therefore that the requirements of URCR R313-25-8(4) as they pertain to the long-term stability of the CAW embankment have been met.

#### 4.3.3.4 Settlement

**Basis:** The Licensee estimated potential settlement magnitudes for both the CAW Embankment and the underlying foundation materials. These estimates are included in the 2011 Geotechnical Update Report (Attachment 5 to Energy*Solutions* 2011b). The Energy*Solutions* 2011a study estimated magnitudes and time rates of primary settlement and secondary settlements for the CAW embankment and the foundation materials underlying the embankment, and addressed the uncertainties and variabilities associated with the CAW embankment materials (Energy*Solutions* 2011a; Attachment 4 to Energy*Solutions* 2011b).

##### 4.3.3.4.1 Waste and Backfill Settlement

The 2011 AMEC study concluded that most of the settlement would occur during operations in the waste placement phase, prior to the final cover placement (Attachment 5 to Energy*Solutions* 2011a). The Licensee has proposed a plan to monitor and measure settlement prior to cover placement which will reduce the risk of uncertainties in estimating settlements. In 2005 a settlement study was performed to support design of the previously proposed CAC embankment, which consisted of available settlement data from Vitro and Energy*Solutions* embankments. The Licensee's review of the settlement data was utilized to predict performance of increased height embankment of the CAC embankment relative the Class A and CAN embankments. The results of that settlement analysis are adequate for the CAW embankment due to the CAW embankment‘s somewhat smaller height but identical 5H:1V sideslope inclinations. The fact that the waste types proposed to be disposed in the CAW embankment and waste placement and compaction procedures are unchanged for the CAW embankment compared to the CAC embankment, indicate that settlements would be expected to be less in the CAW embankment relative to the previously proposed CAC embankment.

##### 4.3.3.4.2 Differential Settlement

Results of analyses of differential settlement for the proposed CAW Embankment (see Section 3.0 and Table 3.4 of the CAW Embankment LAR) indicate that the projected maximum distortion amounts in the Liner of the proposed CAW Embankment are 0.001 and 0.007, under normal and abnormal conditions, respectively; and projected maximum distortion amount in the Radon barrier Layer in the Cover of the proposed CAW embankment under abnormal conditions is less than 0.01, which occurs for the case of bulk waste.

#### 4.3.3.5 Foundation Settlement

Foundation settlement for the proposed CAW embankment was evaluated in the 2005 study for the CAC Embankment and reevaluated in the 2011 CAW Embankment LAR (AMEC 2005a; 2005b and Energy*Solutions* 2011a; 2011b). Subsurface site characteristics as described in Attachment 5 to the 2011 CAW Embankment LAR (Energy*Solutions* 2011b) were used to define material boundaries and soil parameters. The computer program FoSSA® (2.0) was utilized to evaluate settlements of the foundation material due to loads imposed by the proposed CAW embankment (ADAMA Engineering, Inc., Computer program, FoSSA 2.0 Foundation Stress & Settlement Analysis, Copyright 2003 -2007). Results of the analyses indicate that: (1) settlements of the foundations soils are anticipated to be generally on the order of 12 to 16 inches; (2) the foundations settlements are expected to be complete well before final cover is placed (within a 1-year period after waste placement); (3) monitoring data obtained from the interim cover layer over emplaced wastes is expected to primarily reflect embankment (i.e., waste) settlements and not foundation settlements; and (4) the maximum settlement in the foundation soil may be up to 24 inches. Based on the analysis, AMEC concluded that with primary and secondary foundation settlement incorporated into the cover design criteria, the magnitude and timing of foundation settlements, should not adversely impact drainage of the final CAW embankment cover.

A subsequent analysis identified potentially liquefiable sand-like layers in Unit 3, silty sand layers approximately 9 to 26 ft below the ground surface, and Unit 1, interbedded sand, silt and clay layers approximately 64 ft below the ground surface. The maximum depth investigated was approximately 100 ft. The characteristics of stratigraphic units 1 through 4 are summarized in Table 2.1 of Attachment 5 to Energy*Solutions* 2011a. The layers were evaluated with respect to their potential to liquefy or loose strength as a result of stresses induced by the design seismic event (AMEC 2012a). Post-liquefaction volumetric strain was analyzed in the identified liquefiable layers using a method developed by Ishihara and Yoshimine (1992). The analysis estimated settlements, due to post-liquefaction volumetric strain, ranged from 0 to approximately 0.68-inch. AMEC (2012a). Using relationships developed by Jeffries and Davies (1993) and Tokimatsu and Seed (1987), estimated settlements, due to post-liquefaction volumetric strain, ranged from 0 to less than approximately 0.65-inch.

AMEC (2012a) evaluated the potential for earthquake-induced lateral spread to occur at the site. Result of the evaluation indicated, based on criteria described in Youd et al. 2009, that due to the site's flat topography, the thin, discontinuous nature of liquefiable layers, and the generally dense subsurface soil profile with significant density variability across short distances and at variable depths, the likelihood of liquefaction-induced lateral spread is very low.

Additional analyses completed by AMEC (AMEC 2012a; 2012b) evaluated the potential for cyclic softening of "clay-like" soils underlying the site using the procedures published by Boulanger and Idriss (2004) and Boulanger and Idriss (2007). For the proposed CAW embankment, static factors of safety of 2.65 for a failure surface through Unit 2 and 4.19 for a failure surface through Unit 4 were computed for a hypothetical worst-case failure located near the embankment toe, based on consideration of static shear stresses present within the stratigraphic units under embankment loading conditions, and an embankment height ranging from 0 to 50 ft (25 ft weighted average height). For a hypothetical failure located away from the embankment toe, and for an assumed embankment height ranging from 0 to 5=60 ft (35 ft weighted average height), static factors of safety of 3.42 for a failure surface through Unit 2 and 5.28 for a failure surface through Unit 4 were computed. For evaluating these seismic factors of safety, values of cyclic stress ratio, cyclic resistance, and magnitude scaling factor and stress reduction factor were computed for a design earthquake event having a $M_w = 7.3$ and a PGA = 0.24g. Similar sets of analyses performed assuming a PGA = 0.28g yielded the same respective factors of safety for all cases. Analyses were also completed for these cases to determine factors of safety against cyclic softening within Units 2 and 4. Results indicate that all computed factors of safety against cyclic softening are greater than or equal to 1.0 in all cases analyzed. AMEC (2012b) concluded that, in the final embankment configuration prior to placement of the final clay cover, 95% consolidation or more will have been achieved in the underlying clay-like units and the computed factors of safety for this final condition indicate that the potential for cyclic softening to occur is low.

Analyses (AMEC 2012a) also included an evaluation of the potential for cyclic softening using data from six Cone Penetrometer tests (CPTs) performed at the site. The analysis results indicated average undrained shear strength values in the soils tested higher than those computed using a consolidation model (SHANSEP) developed by Ladd and Foott (1974) and used in the other analyses discussed in AMEC 2012a. Based on these findings, AMEC concluded that the undrained shear strength values computed based on the CPT data would result in higher factors of safety than those evaluated using the SHANSEP model.

Based on the information above, the Division concludes that the Licensee's analyses of settlement and analyses of liquefaction- and cyclic softening-related foundation behavior, with respect to the projected performance of the CAW embankment with regard to settlement and slope stability, are adequate.

#### 4.3.3.6 Infiltration and Transport Through Cover and Adjacent Soils

Results of HELP infiltration modeling, conducted for the proposed CAW embankment cover, indicate an average precipitation infiltration rate of 0.036 inches/year (0.09 cm/year) in the topslope area and an average infiltration rate of 0.066 inches/year (0.168 cm/year) in the sideslope areas (Whetstone Associates 2011b). Based on these infiltration results, moisture contents would stabilize at 0.05 v/v in the waste and 0.036 in the native soil below the topslope, and at 0.054 v/v and 0.042 v/v in the waste and native soil, respectively, below the sideslope (Whetstone Associates 2011b).

PATHRAE fate and transport modeling, for the portion of the CAW embankment underlying the top slope area, indicates that all radionuclides modeled would remain below the GWPLs for at least 500 years at a compliance well located 278 ft from the edge of the waste, provided that the concentrations of three radionuclides, Bk-247, Ca-41 and Cl-36, in received waste, are limited to the concentrations listed in the Table 4-14 below. All other modeled constituents would meet the groundwater standard if placed in the top slope area at Class A concentrations limits.

The PATHRAE fate and transport modeling for the portion of the CAW embankment underlying the side slopes having an 18-inch thick Type-B filter and 24-inch thick riprap layer (0.168 cm/yr infiltration case) indicates that all radionuclides modeled would remain below the GWPLs for at least 500 years at a compliance well located 90 ft from the edge of the waste, provided that Bk-247, Ca-41, Cl-36, I-129, Re-187, and Tc-99 are received in concentrations not exceeding the concentrations listed in Table 4-14 below All other modeled constituents would meet the groundwater standard if placed under the side slope areas at Class A limits.

Results of separate vertical PATHRAE model runs to evaluate transport of heavy metals from the top slope and side slope areas indicate that all thirteen metals modeled could be placed in the top slope or side slope at the maximum possible concentration based on density, and would meet GWPLs at the water table and, by extension, at a compliance well located 90 ft from the edge of the waste for the 200-year compliance period established for heavy metals.

In addition, as discussed in Section 4.2.1.4 above, based on the design and the geometry of water accumulation in the proposed perimeter drainage ditch system adjacent to the CAW embankment, the Licensee demonstrated that the abnormal flood event would not cause water to accumulate above the toe of the waste in the embankment, and that the drainage system is therefore adequately designed to minimize infiltration of water through the waste under both normal and abnormal conditions.

Based on the information above, the Division concludes that the Licensee's analyses of infiltration and transport of radionuclide and heavy metal constituents from the proposed CAW Embankment demonstrate that GWPLs would not be exceeded in downgradient Point of Compliance monitoring wells. The analysis evaluated a performance period of at least 500 years, for radionuclides, given stated required concentration limits for Bk-247, Ca-41, and Cl-36 for the topslope area and limiting source concentrations for Bk-247, Ca-41, Cl-36, I-129, Re-187, and Tc-99 for the sideslope areas (as listed in Table 4-14) and all other radionuclides at Class A concentration limits. Metals were evaluated for a performance period of at least 200 years. With the previously approved modification of License Condition 55 to include the above six radionuclides at their limiting concentrations, the analyses provide reasonable assurance that there will not be a need for ongoing maintenance of the CAW embankment following its closure.

**Table 4-14 – Limiting Radionuclide Concentrations in the CAW Topslope and Sideslopes.**

| Radionuclide | Topslope (0.09 cm/yr infiltration) Concentration that meets GWPL at Compliance well (pCi./gm) | Sideslope (0.168 cm/yr infiltration) Concentration that meets GWPL at Compliance well (pCi./gm) |
|---|---|---|
| Bk-247 | 0.0065 | 0.00388 |
| Ca-41 | 35,300 | 34.1 |
| Cl-36 | 15.9 | 9.72 |
| I-129 | - | 21.9 |
| Re-187 | - | 19,100 |
| Tc-99 | - | 1,720 |

#### 4.3.3.7 Surface Drainage

The Licensee designed a post-closure drainage system that will surround the proposed CAW embankment to direct water from precipitation or sheet flow away from the disposal unit. The design includes perimeter drainage ditches sloped at a minimum of 0.07 % and 0.11 % (Section 3.1.5 and Drawings 10014 C01 through 10014 C03 of Energy*Solutions*2011a; Drawings 10014 C01, Revision 1 and Drawing 10014 C03, Revision 1 of Energy*Solutions*2011b; and Drawing 10014 C03, Revision 2 of Energy*Solutions* 2011e). In evaluating the ability of the perimeter drainage ditches to facilitate surface water flow away from the CAW embankment, the Licensee assumed a 25-year, 24-hour storm event for the normal condition. For abnormal conditions, a 100-year, 24-hour storm event was evaluated and for accident conditions, a downstream blockage in the drainage system was evaluated (NUREG-1199, NRC 1999). Calculations from the abnormal condition demonstrated that the perimeter ditch segments surrounding the CAW embankment and the downstream 11e.(2) embankment drainage system are adequately sized to contain and facilitate the flow of surface waters away from the embankments and maintain a freeboards in the perimeter ditches greater than 0.5-ft under unrestricted flow conditions. The calculations demonstrate that surface drainage features will direct surface water drainage away from the CAW embankment and 11e.(2) embankment areas at velocities and gradients which will not result in erosion or excessive infiltration that would require future ongoing active maintenance.

The information provided demonstrates that surface water runoff in the perimeter ditches surrounding the CAW Embankment will be conveyed and merge with the surface water flows in the 11e.(2) drainage ditch near the southwest corner of the CAW Embankment. The surface water conveyed by the entire perimeter drainage ditch system, depicted in the "Clive Facility Class A West (CAW) [Revised] Drainage Ditch Calculations" (Attachment 3 to Energy*Solutions* 2011e) has been designed to discharge in a manner such that during operations, and after closure, discharge velocities and gradients would not be expected to cause excessive erosion to the drainage system components, or otherwise result in erosion that would require ongoing active maintenance in the future. The licensee also provided information and drawings indicating that a minimum 2.89-ft diameter concrete or 2.52-ft diameter plastic culvert would be used to convey flow from the CAW embankment ditch system into the 11e.(2) embankment ditch system and that a minimum 6.54-ft diameter concrete, or 5.69-ft diameter plastic, ultimate drainage outlet culvert (or, alternatively, a series of smaller diameter culverts providing an equivalent total area of flow capacity) would be used for conveying flow from the bottom of the 11e.(2) embankment ditch system to the natural ground surface at the point of discharge of the entire disposal unit area perimeter drainage ditch system (see plan sections and details – Drawing 10014 C01 and Drawing 10014 C03, Revision 2 for the CAW embankment attached to Energy*Solutions* 2011e, and Drawing 9420-04(G) for the 11e.(2) embankment area).

The calculations demonstrate that the ditch design ensures that any concentrated, severe peak storm-induced flows from runoff, from the CAW embankment, will be accommodated by the receiving 11.e.(2) ditch segment without damage to the ditch systems. Based on the information above, the Division concludes that the Licensee's analyses of long-term stability of the proposed CAW embankment drainage ditches and the downstream 11.e.(2) embankment drainage system are adequate and that long-term stability of the CAW embankment drainage system will be achieved with reasonable assurance.

***References*:**

Abt, et al., 1988

AMEC, 2012a; 2012b

Cedegren, 1989

Codell, et al., 1990

Energy*Solutions*, 2011a; 2011b; 2011c; 2011e; 2012a; 2012b

Ishihara and Yoshimine, 1992

Jeffries and Davies, 1993

Johnson and Abt., 1998

Ladd and Foott, 1974

Leps, 1973

Nelson, et al., 1986

NRC, 1991

NRC, 2002

NRCS, 1994

Tokimatsu and Seed, 1987

USACE, 1994

Youd, et al., 2009

Whetstone Associates, Inc., 2011b.

## 4.4 URCR SECTION R313-25-11; REQUIREMENTS FOR ISSUANCE OF A LICENSE

The CAW Embankment LAR involves limited aspects of URCR R313-25-11. The applicability of URCR R313-25-11 provisions to the review of the CAW Embankment LAR are summarized in Table 4-15. Those sections that do apply to the CAW Embankment LAR are addressed in the sections following the table.

**Table 4-15 – Applicability of URCR Section R313-25-11 Provisions to CAW Embankment LAR.**

| URCR R313-25-11 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| **Number** | **Topic** | | |
| 11(1) | Risk to Public Health and Safety | Yes | |
| 11(2) | Training and Experience | No | The CAW Embankment LAR does not change or effect training and experience required or provided |
| 11(3) | Protect the Public Health and Safety | Yes | The CAW Embankment LAR potentially affects releases from the disposal facility and therefore exposures received by the general public |
| 11(4) | Protect Inadvertent Intruders | Yes | The CAW Embankment involves a thicker cover system that provides slightly greater protection to inadvertent intruders |
| 11(5) | Radiation Protection Standards | No | The CAW Embankment LAR does not change or effect radiation protection standards |

**Table 4-15 – Applicability of URCR Section R313-25-11 Provisions to CAW Embankment LAR.**

| URCR R313-25-11 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| Number | Topic | | |
| 11(6) | Long-Term Stability | Yes | The CAW Embankment LAR changes the design of the cover system; additional analyses of stability must be reviewed |
| 11(7) | Satisfy Requirements of URCR R313-25 | Yes | Provides a global requirement to satisfy all requirements of URCR R313-25; Each requirement of URCR R313-25 that requires review is addressed elsewhere in this SER. |
| 11(8) | Institutional Control | Yes | |
| 11(9) | Surety Arrangements | No | The Division has previously reviewed and accepted arrangements for providing financial assurances; the arrangements are not materially changed or affected by the CAW Embankment LAR; the Division reviews and approved adequate financial assurance annually. |

### 4.4.1 Risk to Health and Safety of the Public

**Requirement 2511-1:** A license for the receipt, possession, and disposal of waste containing radioactive material will be issued by the Director upon finding that the issuance of the license will not contribute an unreasonable risk to health and safety of the public [URCR R313-25-11(1)].

**Basis:** The information contained in the CAW Embankment LAR, 2005 LRA and other relevant documents the Licensee has submitted indicate that the requirements of URCR R313-25-11(1) have been or will be met. Analyses submitted in connection with the CAW Embankment LAR and the 2005 LRA show that the groundwater protection requirements will be met for at least 500 years, as required. Doses to off-site members of the public will be below the 25-mrem/yr limit, as described in Section 4.4.2 below and in Section 5.10 of the LRA SER (URS Corporation, 2007).

**References:**

Envirocare of Utah, Inc., 2005b

URS Corporation, 2007

### 4.4.2 Protection to Public Health and Safety

**Requirement 2511-3**: A license for the receipt, possession, and disposal of waste containing radioactive material will be issued by the Director upon finding that the applicant's disposal site, disposal design, land disposal facility operations, including equipment, facilities, and procedures, disposal site closure, and post-closure institutional control, are adequate to protect the public health and safety as specified in the performance objectives of URCR R313-25-19 (URCR R313-25-11(3)).

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA and other relevant documents the Licensee has submitted indicate that the requirements of URCR R313-25-11(3) have been or will be met. The Licensee's disposal site, embankment design, operations, including equipment, facilities, and procedures, disposal site closure, and post-closure institutional control features are addressed under several other requirements in this SER. The CAW LRA shows that the groundwater protection requirements will be met for at least 500 years, as required (Whetstone 2012). Doses to off-site members of the public will be below the 25-mrem/yr limit.

Thus, based on the analyses presented in this SER, the Director would be justified in approving the requested license amendment.

***References*:**

Envirocare of Utah, Inc., 2005b

Whetstone Associates, Inc., 2012

### 4.4.3 Health and Safety Performance Objectives

**Requirement 2511-4:** A license for the receipt, possession, and disposal of waste containing radioactive material will be issued by the Director upon finding that the applicant's disposal site, disposal site design, land disposal facility operations, including equipment, facilities, and procedures, disposal site closure, and post-closure institutional control are adequate to protect the public health and safety in accordance with the performance objectives of URCR R313-25-20 (URCR R313-25-11(4)).

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA indicates that the Licensee's disposal site, disposal site design, land disposal facility operations, including equipment, facilities, and procedures, disposal site closure, and post-closure institutional control are adequate to protect the public health and safety in accordance with requirements of URCR R313-25-11(4). The basis for this finding is presented in the description and justification for requiring no intruder barrier. The basis is presented under findings contained in this SER for Requirements 2507-2 through 2507-5 and is addressed in Section 6.0 of the 2005 LRA. Given that these criteria are met, in concert with the other requirements of URCR R313-25-11, it would be appropriate for the Director to approve the requested license amendment.

***References:***

See also Sections of this document discussing requirements 2507-2 through 2507-5.

Envirocare of Utah, Inc., 2005c

### 4.4.4 Long-Term Stability

**Requirement 2511-6:** A license for the receipt, possession, and disposal of waste containing radioactive material will be issued by the Director upon finding that the applicant's disposal site, disposal site design, land disposal facility operations, disposal site closure, and post-closure institutional control plans are adequate to protect public health and safety in that they will provide reasonable assurance of the long-term stability of the disposed waste and the disposal site and will eliminate, to the extent practicable, the need for continued maintenance of the disposal site following closure (URCR R313-25-11(6)).

**Basis:** The information contained in the CAW Embankment LAR, the 2005 LRA and other relevant documents the Licensee has submitted, indicate that the disposal site, disposal site design, land disposal facility operations, disposal site closure, and post-closure institutional control plans are adequate to protect public health and safety in that they will provide reasonable assurance of the long-term stability of the disposed waste and the disposal site and will eliminate to the extent practicable the need for continued maintenance of the disposal site following closure in accordance with the requirements of URCR R313-25-11(6). The basis for this finding is presented in the description and justification of the design of the principal design features planned for the disposal facility as discussed in Section 3.0 of the 2005 LRA. These principal design features have been designed to perform their required functions over an appropriate period of time such that the facility will meet applicable performance objectives without the need for ongoing active maintenance following facility closure. Section 6.4.3 in the 2005 LRA provides additional information concerning site stability, settlement and subsidence, and the prevention of degraded conditions. The basis for this finding is presented under requirements 2507-2 through 2507-5, 2508-4, and 2522-1.

Given that the required criteria discussed above are met, in concert with the other requirements of URCR R313-25-11, it would be appropriate for the Director to approve the requested license amendment.

***References*:**

See also Sections of this document discussing requirements 2507-2 through 2507-5, 2508-4, and 2522-1.

Envirocare of Utah, Inc., 2005c

### 4.4.5 Reasonable Assurance

**Requirement 2511-7:** A license for the receipt, possession, and disposal of waste containing radioactive material will be issued by the Director upon finding that the applicant's demonstration provides reasonable assurance that the requirements of URCR R313-25 will be met ([URCR R313-25-11(7)).

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA indicate that the requirements of URCR R313-25 have been or will be met, as described and justified in this document. The basis for this finding is contained in the individual sections addressed in this SER. As demonstrated in the individual sections of this SER section, the Division concludes, with reasonable assurance that each requirement has been or will be met, subject to the license conditions identified and described in Section **Error! Reference source not found.** of this document.

***References*:**

See also Sections of this document discussing requirements related to URCR R313-25.

Envirocare of Utah, Inc., 2005c

### 4.4.6 Institutional Control Assurance

**Requirement 2511-8**: A license for the receipt, possession, and disposal of waste containing radioactive material will be issued by the Director upon finding that the applicant's proposal for institutional control provides reasonable assurance that control will be provided for the length of time found necessary to ensure the findings in URCR R313-25-11(3) through (6) and that the institutional control meets the requirements of URCR R313-25-28 [URCR R313-25-11(8)].

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA indicate that reasonable assurance exists that control will be provided as necessary to ensure the requirements in URCR R313-25-11(3) through (6) will be met. Also, information provided indicates that reasonable assurance exists that that the provisions for institutional control meet or will meet the requirements of URCR R313-25-28.

Given that these conditions are met, in concert with the other requirements of URCR R313-25-11, it would be appropriate for the Director to renew the license, subject to license conditions stated and described in Section **Error! Reference source not found.** of this document.

***References:***

See also Sections of this document discussing requirements 2511-3 through 2511-6 and 2528.

Envirocare of Utah, Inc., 2005c

## 4.5 URCR SECTION R313-25-19, PROTECTION OF THE GENERAL POPULATION FROM RELEASES OF RADIOACTIVITY

**Requirement 2519-1:** Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants or animals shall not result in an annual dose exceeding an equivalent of 25 mrem (0.25 mSv) to the whole body, 75 mrem (0.75 mSv) to the thyroid, and 25 mrem (0.25 mSv) to any other organ of any member of the public. Reasonable efforts should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable [URCR R313-25-19(1)].

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA and other relevant documents the Licensee has submitted indicate that the requirements of URCR Subsection R313-25-19(1) have been met. These documents present the results of extensive analyses addressing the potential radionuclide releases to media including groundwater, surface water, air, soil, plants and animals, and discuss potential exposure pathways resulting from these releases. The analyses consider both normal conditions and unusual or accident conditions.

Transport of releases from disposed wastes was evaluated. The annual doses resulting from the postulated releases for reasonably likely conditions were found to be within the regulatory limit of 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ (Streamline Consulting 2005). The annual doses are found to be in compliance with State rules.

The following text provides a discussion of releases to all environmental media and their corresponding doses. The information on releases and dose assessment presented in the 2005 LRA (e.g., see Streamline Consulting 2005) is qualitatively summarized below to demonstrate that the construction, operation, and closure of Clive operations will satisfy all applicable regulatory dose limits.

The Licensee has demonstrated that the intruder protection requirements have been met. Intruder protection is provided by the cover design, waste placement, remote site location, lack of natural resources, as well as the poor water quality, arid conditions, and institutional controls.

The Licensee's radiological control program has successfully maintained worker exposures as a fraction of the regulatory limit, as demonstrated by worker dosimetry records and calculation of committed effective dose equivalents (CEDE). The Licensee actively reviews work practices, performs operational radiological surveys, and has a functional ALARA review committee. The Division recognizes the Licensee's proactive approach has resulted in successfully maintaining worker doses ALARA.

**Maximum Dose**

The maximum dose for normal conditions at the Clive Facility was estimated to be 10.2 mrem to an individual at location A-21 from dust inhalation at the facility boundary due to operations in the Class A cell. This is a highly unlikely scenario as no credit was given during the analysis for actions taken to minimize releases other than dust control measures. Dust control measures will ensure that the releases are ALARA. The maximum dose for unusual or accident conditions were estimated to be 0.18 mrem to a person at the site boundary following a truck accident of uranium and other nuclides (2005 LRA Section 6.3.2). Although there are no regulatory dose criteria that apply specifically to accident conditions, the dose from the truck fire scenario is below the 25-mrem dose criterion. A complete discussion of the scenarios is present in 2005 LRA Section 6.3.2.

**Groundwater Pathway**

The groundwater protection criteria are based on an annual dose of 4 mrem to an individual drinking groundwater. The expected dose from the groundwater pathway is zero because of the poor groundwater quality. The high salinity of the groundwater, without rigorous treatment, prevents its use for drinking, livestock watering, or crop irrigation. Groundwater protection requirements place limits on the individual radionuclide concentrations in the groundwater at the compliance-monitoring well. The radionuclide concentration limits must not be exceeded for at least 500 years following closure of the facility. Computer modeling of the groundwater pathway shows that the groundwater protection criteria are satisfied for all radionuclides for at least 500 years (2005 LRA Section 6.4.1.1.1, Whetstone 2011b). The waste acceptance criteria, waste emplacement methods, and water management practices ensure that current and future releases to the groundwater pathway are kept ALARA.

**Surface Water Pathway**

Long-term surface water pathway doses are expected to be zero because of the absence of permanent surface water bodies at the site. The nearest stream channel is about 2 miles east of the facility. Surface water from precipitation is directed away from the waste disposal embankment by drainage ditches and berms. During facility operations, possibly contaminated contact stormwater is recovered and conveyed to evaporation ponds where it is monitored and controlled. No contact stormwater is released off site, thereby maintaining releases from surface water ALARA.

**Air Pathway**

Air pathway doses under normal operations and accident conditions are addressed in Section 6.3 and 6.4 of the 2005 LRA. Under both normal and accident conditions, projected doses are well within the acceptable limits of regulatory requirements. For accident conditions, dust or particulate matter could be released to the atmosphere and inhaled by individuals. The 2005 LRA evaluates doses that result from a tornado and severe wind, train derailment, truck turnover or collision, and truck fire. The highest likely dose rate occurs to an individual near a dry active waste fire for 1 hour. The individual inhales particulate matter from the fire and receives a dose estimated at 0.02 mrem. Other air pathway doses could occur from routine operations. A receptor standing at various locations on the fenceline for 8,760 hr/yr would receive a maximum estimated dust inhalation dose of 10.2 mrem. This is a highly unlikely scenario as no credit was given during the analysis for actions taken to minimize releases other than dust control measures. The regulatory requirements for protecting members of the general public will be met during operation of the Clive Facility.

**Soil Pathway**

Soil pathway doses involve exposure of the public to contaminated soil from the facility. If an exposure occurred, doses could result from external radiation or ingestion of soil on dirty hands. External radiation levels at the top of the final cover will be at or below background radiation for the site, so no doses are anticipated. During operation, the facility will be monitored as described in Appendix R of the 2005 revision of the LRA to ensure that no releases or doses occur via the soil pathway.

**Plant Pathway**

The plant pathway is not expected to cause any doses to humans. Edible crops or animal forage are not expected to grow on the waste embankment. During operations all plants will be prevented from contacting the waste. After closure, the site's low precipitation and its cell cover design will prevent crop production or growth of animal forage on the embankment (2005 LRA, Sections 6.4.1.1.4 and 6.4.2.1.4).

**Animal Pathway**

The burrowing animal pathway is not expected to cause any doses to humans. Burrowing animals at the site include jackrabbits, mice, foxes, and ants. None of these species typically burrow deep enough to penetrate through the cover system and disturb the waste materials (2005 LRA Section 6.4.2.1.4).

The Licensee has committed in Section 6.3.1 of the 2005 revision of the LRA to conduct operations in a manner that keeps exposures and doses ALARA. The Licensee's ALARA Program is defined in Appendix H of the 2005 revision of the LRA.

***References:***

Streamline Consulting, LLC, 2005

## 4.6 URCR SECTION R313-25-20. PROTECTION OF INDIVIDUALS FROM INADVERTENT INTRUSION

**Requirement 2520-1: 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 [URCR Section R313-25-20(1)].

**Basis:** Occupation of the site by inadvertent intruders after site closure is not likely due to a lack of natural resources in the area, particularly a lack of potable water. Contacting the waste after site closure is not likely due to the lack of natural resources (no reason to drill or dig) and the design of the embankment cover system. The design features and operations will minimize radiation dose to inadvertent intruders, as well. Several design features provide the required protection.

Overall features include:

- Lack of nearby residential population
- Embankment cover system
- CLSM
- Waste form (in the case of containerized waste disposal)

Operations specific features include:

- Fences
- Buffer zone
- Security plan

Post-closure specific features include:

- Granite markers

Based on the information provided, the Division concludes that potential inadvertent intruders are protected as required by regulation.

***References:***

See also Sections of this document regarding requirements 2507-2, 2507-8, 2508-2, and 2525-7.

## 4.7 URCR SECTION R313-25-21. PROTECTION OF INDIVIDUALS DURING OPERATION

**Requirement 2521-1:** Operations at the land disposal facility shall be conducted in accordance with the standards for radiation protection in URCR Rule R313-15, except for release of radioactivity in effluents from the land disposal facility, which are governed by URCR Section R313-25-19. Every reasonable effort shall be made to maintain radiation exposures as low as reasonably achievable, ALARA [URCR R313-25-21].

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA and other relevant documents the Licensee has submitted indicate that the requirements of URCR Section R313-25-21 will be met. NUREG-1199 describes the items that together encompass conduct of operations. The topics and references to the components are shown in this SER:

## 4.8 URCR SECTION R313-25-22. STABILITY OF THE DISPOSAL SITE AFTER CLOSURE

**Requirement 2522-1:** 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 [URCR Subsection R313-25-21(1)].

**Basis:** Applicable Utah rules require that a LLRW disposal facility 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.

Based on the results of analyses as described in Section 4.3.3 of this SER, the Division concludes that reasonable assurance exists that this performance objective will be satisfied. Refer to Section 4.3.3 for additional details.

## 4.9 URCR SECTION R313-25-24. DISPOSAL SITE DESIGN FOR NEAR-SURFACE LAND DISPOSAL

### 4.9.1 Long-Term Isolation without Active Maintenance

**Requirement 2524-1:** Site design features shall be directed toward long-term isolation and avoidance of the need for continuing active maintenance after site closure [URCR R313-25-24(1)].

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA and other relevant documents (engineering reports, supplemental data submissions and interrogatory responses) the Licensee submitted indicate that the requirements of URCR R313-25-24(1) have been met.

- The disposal site is located in an area with a precipitation rate smaller than an average of about 9 inches per year (Energy*Solutions* 2011c; Meteorological Solutions, Inc. 2010).
- The disposal site is located in an area where the concentration of dissolved solids in groundwater is greater than 20,000 mg/L, making it undesirable for use without prior processing, thereby minimizing exposure that might otherwise result from groundwater ingestion.
- Waste is placed and covered with no less than 7 ft of earthen cover materials.
- Both vertical and horizontal groundwater velocities are slow.
- The final cover will not be constructed until the embankment settlement is demonstrated to be within acceptable limits through construction of an interim cover prior to construction of the final cover.
- Waste is disposed of no less than 13 ft above the historic high water table at the site.
- The cover system is designed to limit the potential for water erosion, wind erosion, plant intrusion, and animal intrusion (Section 4.3.3).
- The cover system is designed and constructed to limit radiation exposure rate at its top surface to less than 100 mrem/yr, as required by regulation (Section 4.3.1).
- The boundaries of the closed CAW Embankment LAR will be marked with permanent monuments or markers that will warn against intrusion.

The Licensee provided information that provides confidence that the need for continuing active maintenance after site closure is avoided. This conclusion is established by the following facts:

- The cover system is designed to limit the potential for water erosion, wind erosion, plant intrusion, and animal intrusion (Section 4.3.3).
- Settlement and differential settlement within the disposal embankment will be demonstrated to be sufficiently small that damage to the cover system layers primarily responsible for limiting infiltration and encouraging run-off will not occur (Section 4.3.3).
- The clay (radon barrier) layers in the cover system are located deep enough in the cover system (no less than 4 ft) that they would not be damaged by either desiccation or freezing (see, for example, Energy*Solutions* 2006).
- The layer of riprap and the type A filter layer in the cover system would act to discourage root penetration and animal intrusion (Energy*Solutions* 2006).
- Internal erosion between layers of the cover system is prevented by design and construction (Section 4.3.3).
- Cover system slopes are stable under static and dynamic conditions (Section 4.3.3).
- The permeability of the cover system is designed and constructed to be lower than that of the liner system to minimize the potential that infiltrating water will accumulate in the closed disposal embankment after final embankment closure (Section 4.2.1.1.3).
- No features are incorporated into the design of the disposal embankment that rely upon external energy sources or require human support or intervention

Bases for this affirmative finding are presented under requirements 2508-01 through 2508-4 provided in Sections 5.5.1 through 5.5.4 of this SER. Reference to Requirements 2507-2 through 2507-5 of this SER also demonstrate that the Principal Design Features have been designed to perform as intended for many years following the Institutional Control period without reliance on active ongoing maintenance.

The Licensee's clay mining activities in areas adjacent to Section 32 where LLRW is disposed of previously raised concerns regarding their potential long-term effects on stability of and releases from waste disposed of within the CAW embankment and other embankments at the site. These concerns will be addressed in the Division's consideration of the Licensee's 2012 LRA, due to be submitted on or before December 25, 2012.

***References:***

See also Sections of this document referencing requirements 2507-2 through 2507-5 and 2508-1 through 2508-4.

Energy*Solutions*, 2006; 2011c

Meteorological Solutions Inc., 2010

### 4.9.2 Design Compatible with Closure and Stabilization

**Requirement 2524-2:** The disposal site design and operation shall be compatible with the disposal site closure and stabilization plan and lead to disposal site closure that provides reasonable assurance that the performance objectives will be met [URCR R313-25-24(2)].

**Basis:** As described in the "Basis" section above under Requirement 2507-7, waste would be covered soon after each embankment section is filled. Waste containers placed in the embankment would be placed concurrently with backfill placement and compaction efforts. The waste placement and backfill plan, including the specific waste/backfill and geometry of waste areas, as well as the amounts of compaction required for each type of backfill, were developed based on results of well-defined and controlled testing performed under the observation of the Division.

The process of stabilizing a completed disposal embankment is summarized as follows:

1. An interim cover system is constructed over a portion of the embankment only after disposal operations in that portion have been completed.
2. Settlement and differential settlement magnitudes will be monitored (e.g., see Energy*Solutions* 2012c) to ascertain whether the design Cover distortion criteria developed and used for evaluating long-term stability of the embankment with respect to settlement has been achieved.
3. The final cover system will be constructed only after settlement has been shown, after placement of the interim cover system, to be within prescribed acceptable limits (to be verified through analysis of future settlement monitoring, site-specific compacted soils geotechnical testing, and/or additional modeling if required).
4. Placement of the interim and final cover systems are major activities in the stabilization of the disposal units.

5. Because no disposal operations will occur in any area where interim or final cover systems have been constructed, continued active operations within the CAW embankment would not affect stabilized areas of the disposal embankment.

For the reasons stated above, the disposal site design and operation are compatible with the disposal site closure and stabilization plan and are expected to lead to disposal site closure that provides reasonable assurance that the performance objectives will be met. Based on the information summarized above, the Division concludes that the Licensee's proposed design and operation is compatible with the disposal site closure and stabilization plan and would lead to disposal site closure that provides reasonable assurance that this performance objective will be met for the CAW embankment.

***References:***

Energy*Solutions*, 2012c.

#### 4.9.3 Complement and Improve the Disposal Site's Natural Characteristics

**Requirement 2524-3:** The disposal site shall be designed to complement and improve, where appropriate, the ability of the disposal site's natural characteristics to assure that the performance objectives will be met [URCR R313-25-24(3)].

**Basis:** Site characteristics that influence the extent to which radioactive material may be released to the general environment and potentially cause radiation exposure to members of the general public include:

- Precipitation rate
- Depth to groundwater
- Dissolved solids content of groundwater
- Probable maximum magnitude of flood events

Proposed CAW embankment design, operating, and closure features provided that complement and improve the ability of the site to limit the release of radioactive material from the site and potentially cause radiation exposure to members of the general public include the following:

- Multi-layer engineered cover system;
- Waste emplacement procedures and configurations that produce a stable disposal embankment;
- Clay liner under disposed waste with permeability greater than that of the cover system;
- Inventories of radionuclides disposed in the embankment will meet limitation requirements determined through the CAW embankment infiltration and contaminant transport modeling analyses (Whetstone Associates 2011b); and
- Final cover will not be constructed until settlement shown to be within acceptable limits.

The site characteristics that influence the extent to which individuals may be exposed to radiation during facility operations include:

- Sparse population density in vicinity of the disposal embankment; and

- Unstable or neutral stability conditions prevail in winds at the site for more than 70% of the time.

Design, operating, and closure features provided that complement and improve the ability of the site to limit the extent to which individuals may be exposed to radiation during facility operations include:

- Waste with highest radioactive concentrations and hazards are contained in shipping containers that are disposed of without opening them; and
- Waste handling and placement operations are conducted so as to limit the release of radioactive materials during operations.

The site characteristics that influence the extent to which long-term stability of the disposal site is achieved and to which the need for ongoing active maintenance of the disposal site following closure is eliminated include:

- Average annual precipitation rate is less than 9 inches per year; and
- Concentration of dissolved solids in groundwater is greater than 20,000 mg/L.

Design, operating, and closure features provided that complement and improve the ability of the site to limit the extent to which long-term stability of the disposal site is achieved and to which the need for ongoing active maintenance of the disposal site following closure is eliminated include:

- The final cover will not be constructed until the embankment settlement has been demonstrated to be within acceptable limits
- The cover system is designed to limit the potential for water erosion, wind erosion, plant intrusion, and animal intrusion
- Internal erosion between layers of the cover system will be minimized or prevented by adhering to specified design (e.g., filter) criteria during construction
- The proposed cover system slopes have been demonstrated to be stable under static and dynamic conditions; and
- The permeability of the cover system is designed and would be constructed to be lower than that of the liner system.

Additional license conditions will require:

- A modification to the currently proposed embankment cover system and demonstration of equivalent or better performance for that modified cover compared to the currently proposed cover, to allow resolution of a remaining concern regarding the EZD value used in infiltration modeling for the current cover design; and
- Submittal and approval by the Division of a study plan to determine geotechnical properties, including maximum tensile strain of both average axial and localized lengthening/bending effects and associated angular distortion for the point of crack initiation, of samples of Licensee's clay materials proposed for use in constructing the CAW embankment compacted-clay radon barrier cover layers, and submittal of findings from such testing demonstrating that expected radon barrier layer distortions are within acceptable limits as prescribed by the specified distortion design criteria.

Based on the information summarized above, the Division concludes, subject to the stated conditions being placed into effect and the associated issues successfully resolved, that the proposed CAW embankment is designed to complement and improve, where appropriate, the ability of the disposal site's natural characteristics to assure that the performance objectives will be met.

***References:***

Whetstone Associates Inc., 2011b

#### 4.9.4 Minimize Water Infiltration

**Requirement 2524-4:** Covers shall be designed to minimize, to the extent practicable, water infiltration, to direct percolating or surface water away from the disposed waste, and to resist degradation by surface geologic processes and biotic activity [URCR R313-25-24(4)].

**Basis:** The information contained in the CAW Embankment LAR and the 2005 LRA and other relevant documents (engineering reports, supplemental data submissions and interrogatory responses) the Licensee submitted indicate that the requirements of URCR R313-25-24(4) have been met. The infiltration and transport modeling simulations provided in the CAW Embankment LAR (Whetstone Associates 2011b) support the finding that the groundwater protection criteria for Class A wastes will be met provided that inventories of radionuclides do not exceed limitations determined through the modeling. In order to meet this objective the infiltration must be minimized to limit release and transport of radionuclides from the waste through the unsaturated zone and the shallow water table.

The cover design currently proposed for the CAW embankment is the same as that proposed for the previously contemplated CAC embankment and that previously approved for the CAN embankment and the 2005 LRA, except that the riprap cover layer has been increased to 24 inches in thickness and the proposed Type B filter zone layer thickness on the CAW embankment will be 18 inches on the sideslopes and 6 inches on the topslope and the filter design criteria for the Type B filter zone layers has been updated to reflect additional (permeability) filter criteria. Modeling provided by the Licensee demonstrates that the infiltration through the cover system is expected to be 0.090 cm/yr for the topslope area and 0.168 cm/yr or less for the sideslope areas. The Type B filter zone layer has been designed to drain most water away laterally from the disposed waste. The clay layer in the cover is designed to limit water infiltration. The riprap at the upper surface of the cover is designed to resist degradation by surface geologic processes and biotic activity.

Based on the information summarized above, the Division concludes that the projected performance of the currently proposed CAW embankment cover design (with an EZD value of 20 inches assumed for infiltration modeling) would be adequate to minimize water infiltration and resist degradation. As discussed previously, a new license condition (Section 5.0) will require the Licensee to provide a cover design modification and a submit a performance assessment demonstrating that this modified cover design will provide equal or better performance than that currently predicted.

***References:***

Whetstone Associates, Inc., 2011b

### 4.9.5 Direct Surface Water Drainage Away from Disposal Units

**Requirement 2524-5:** Surface features shall direct surface water drainage away from disposal units at velocities and gradients which will not result in erosion that will require ongoing active maintenance in the future [URCR R313-25-24(5)].

**Basis:** Drainage systems for installation in conjunction with construction and operation of the CAW Embankment are designed to prevent run-on of surface water onto the facility from adjacent areas under flooding conditions and facilitate run-off of storm water resulting from precipitation at velocities that would not cause excessive erosion to the drainage system components. Drainage system components include run-on protection berms and run-off berms, which would be constructed and used during operations, and a permanent drainage ditch system, to be constructed and retained for long-term use. More information about how these drainage system features satisfy regulatory requirements has been presented in Section 4.3.3 and other sections of this SER.

During operations, the embankment would be protected against off-site floodwaters by run-on berms. The off-site environment would also be protected from potentially contaminated water running off the open embankment by run-off berms constructed near the disposal area.

Run-on berms would surround the perimeter of the disposal embankment at all times during operations. These berms would be constructed to a minimum height of 3 ft above the design grade at that location (as determined by original engineering drawings showing site topographic contours) and have a minimum width of 10 ft at the top. The berms would be compacted to 90% of the Standard Proctor density (ASTM D-698). In addition, inspection/travel roads constructed 1 foot above natural grade with a 12-foot width will also be provided.

Run-off berms would be constructed immediately following approval of clay liner construction for a zone of the embankment to be opened for waste placement. Run-off berms would be constructed directly on the clay liner to a height of 3 ft above the finished grade. Run-off berms have a minimum width of 3 ft at the top and are compacted to 90% Standard Proctor density for the soils used to construct them. Once the run-off berms are constructed, waste materials would be placed on the clay liner. However, a minimum separation of 10 ft would be maintained between the toe of the run-off berm and the toe of waste. This 10-foot separation is designed to allow for collection of run-off water from the active embankment and minimize potential contact of waste with standing water.

In order to facilitate the flow of precipitation away from the embankment, the Licensee (Sections 3.1.4, 3.2.4 and 3.3.4 of the 2005 LRA) designed the drainage ditch system so that during operations, storm water would remain within the drainage ditch system (including the ditch east of the CAW embankment and the ditches surrounding the 11e.(2) embankment) with a freeboard of greater than 0.5 foot under the normal precipitation event and no overflow occur (i.e., that the depth of water would be less than the depth of the ditches) under the abnormal precipitation event. Calculations performed by the Licensee indicate that the proposed drainage ditch systems surrounding the CAW embankment (Section 4.3.3 of this SER), as well as downstream drainage ditch systems on the eastern side of the CAW embankment and surrounding the 11e.(2) embankment, have a sufficient slope to allow drainage of surface water run-off away from the disposal embankment. The 25-year storm event was identified as representing the probable worst-case precipitation event that might be encountered during active site operations. Based on these results, and under the assumed conditions, the drainage ditch system should promote the collection of precipitation as well as promote flow away from the embankment, thus minimizing standing water adjacent to the embankment; thereby minimizing potential infiltration into the waste.

Results of an accident condition involving downstream blockage of the drainage ditch system on Section 3.3.4.1 of the 2005 LRA indicate that, although downstream blockage in the drainage ditch would lead to a localized flood situation in that section of the ditch, once the water level reached the outside berm height, water would disperse away from the embankment as overland flow.

Results of HEC-1 and HEC-2 Modeling analyses conducted by Bingham Environmental, Inc. (1996) and the 1998 LRA Appendix KK) provide data pertaining to the depth of water expected from the Probable Maximum Flood (PMF) for the watershed encompassing the Clive site, indicate that, based on the geometry of water accumulation in the ditch, with respect to the CAW, the abnormal flood event would not cause water to accumulate above the toe of the waste in the embankment, and that the drainage system is therefore adequately designed to minimize infiltration of water through the waste under both normal and abnormal conditions.

The Licensee specified as a design criteria for the CAW embankment perimeter drainage ditch system that the size of the rock used in the ditches be adequate to handle stresses related to flow without disruption in order to prevent internal erosion of the soils beneath the rock erosion barrier of the ditches. Calculations performed by the Licensee (Section 4.3.3 of this SER) indicate that the selected characteristics of the proposed riprap materials (summarized in Table 3.3 of the CAW Embankment LAR) that would be placed in and used to line the CAW Embankment perimeter ditches would be adequate to resist movement (internal erosion) of the riprap materials under flows projected to occur during normal and abnormal precipitation events at the site. Therefore, significant erosion of the ditch clay substrate surface is not expected to occur.

Based on the information summarized above, the Licensee has discussed how the facility's surface features have been designed to direct surface water away from the disposal units at velocities and gradients which would not be expected to result in erosion that would require ongoing active maintenance in the future.

The Licensee's clay mining activities in areas adjacent to Section 32 where LLRW is disposed of previously raised concerns regarding their potential long-term effects on stability of and releases from waste disposed of within the CAW and other embankments at the site. These concerns will be addressed in the Division's consideration of the Licensee's 2012 LRA, due to be submitted on or before December 25, 2012.

**Reference Notes:**

See also Section 4.3.3 of this document.

Bingham Environmental, 1996

### 4.9.6 Minimize the Contact of Water with Waste

**Requirement 2524-6:** The disposal site shall be designed to minimize to the extent practicable the contact of water with waste during storage, the contact of standing water with waste during disposal, and the contact of percolating or standing water with wastes after disposal [URCR R313-25-24(6)].

**Basis:** As earlier approved for the CA and CAN disposal embankments, the Licensee proposes a number of measures to minimize the potential for water contacting waste during and following operations. The Licensee designed the clay liner to be more permeable than the final cover in order to minimize the possibility of infiltrating water accumulating on the liner after closure, thereby limiting the possibility of standing water coming into contact with waste following final closure of the disposal cell (Section 3.3.1.1.2 and Table 3-4 of the 2005 LRA). This design minimizes the potential for any "bathtub effect" of water to occur within the embankment following closure.

The liner is comprised of a 2-ft-thick layer of compacted clay having an in-place, as-built design saturated hydraulic conductivity (permeability) of $1 \times 10^{-6}$ cm/sec. The liner materials will be compacted to at least 95% Standard Proctor density for the soils used in constructing the liner, at a moisture content between optimum and plus 5% of the optimum moisture content. The liner will be constructed of soil having 85% fines less than 0.075 mm in diameter; plasticity index range 10 to 25; and liquid limit values ranging between 30 and 50. The completed liner will be flat and level. The liner has been specified to have sufficiently low permeability to encourage precipitation to accumulate on liner surface during the embankment's operational phase, where it is removed as it accumulates as part of ongoing facility operations. During disposal operations, a vacuum truck removes water that accumulates on the working surface.

The cover system has been designed to limit the amount of infiltration of water through the cover system and emplaced waste after waste disposal. A series of simulations using the HELP Model (Version 3.06) (Schroder *et al*, 1994 and Whetstone Associates, Inc., 2011a; 2011b) showed that the amount of water infiltrating through the cover and waste is sufficiently low to meet required groundwater protection criteria provided that inventories of radionuclides do not exceed limitations determined through the modeling analyses. The model used precipitation data taken from 17 years of measurements at Clive, Utah and longer-term measurements from Dugway, Utah. Both the top slope and side slopes of the embankment were evaluated. The net water infiltration through the cover was calculated as 0.090 cm/yr for the topslope and 0.168 cm/yr or less for the sideslopes. This is sufficiently low to meet the groundwater protection criteria for Class A waste.

Several infiltration sensitivity analyses have been conducted to evaluate the effects of possible future establishment and growth of vegetation on cover systems at the Clive Facility that are very similar to the proposed CAW embankment Cover. Plant roots had two primary effects on the cover system: increasing the hydraulic conductivity of the cover material and clogging of the lateral drainage layers. Both of these effects were evaluated with the HELP model to determine if they adversely affected the net water infiltration rate through the cover system. Nine sensitivity cases with plant roots were conducted. The analyses showed that the presence of roots in the cover system did not adversely affect the net amount of water infiltrating to the waste. In fact, in all nine cases the transpiration of water by the roots more than compensated for the increased soil hydraulic conductivity that the roots cause. When plant roots were present in the cover system, the net water infiltration rate through the waste was lower because the plant roots transpired water from the soil back to the atmosphere. These sensitivity analyses provided increased confidence that the cover system would perform as designed over long periods of time and would be resistant to the effects of natural ecological processes at the site.

Based on the information summarized above, the Division concludes that the Licensee's proposed CAW embankment design with respect to minimizing the contact of water with waste is acceptable.

***References:***

Whetstone Associates Inc., 2011a; 2011b

## 4.10 URCR SECTION R313-25-25. NEAR SURFACE LAND DISPOSAL FACILITY OPERATION AND DISPOSAL SITE CLOSURE

The CAW Embankment LAR involves limited aspects of URCR Section R313-25-25. The applicability of URCR Section R313-25-25 provisions to the review of the CAW Embankment LAR are summarized in Table 4-16. Those sections that do apply to the CAW Embankment LAR are addressed in the sections following the table.

**Table 4-16 – Applicability of URCR Section R313-25-25 Provisions to CAW Embankment LAR.**

| URCR R313-25-25 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| Number | Topic | | |
| 25(1) | Segregated Class A from Class B and Class C LLRW | No | CAW Embankment LAR does not involve disposal of Class B or Class C LLRW |
| 25(2) | 5m Cover on Class C LLRW | No | CAW Embankment LAR does not involve disposal of Class C LLRW |
| 25(3) | Only Class A, Class B, and Class C LLRW | No | CAW Embankment LAR involves only disposal of Class A LLRW |
| 25(4) | Package Integrity | No | Division has reviewed and accepted operating procedures that are not changed or affected by CAW Embankment LAR |
| 255) | Void Spaces | No | Division has reviewed and accepted operating procedures that are not changed or affected by CAW Embankment LAR |
| 25(6) | Radiation Dose at Cover System Surface | Yes | The CAW Embankment LAR involves changes to the cover system that could affect |

**Table 4-16 – Applicability of URCR Section R313-25-25 Provisions to CAW Embankment LAR.**

| URCR R313-25-25 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| Number | Topic | | |
| | | | the projected dose rate following closure |
| 25(7) | Disposal Unit Boundaries and Locations | Yes | The CAW Embankment LAR involves slight adjustments to the footprint of the disposal embankment |
| 25(8) | Buffer Zones | Yes | The CAW Embankment LAR involves slight adjustments to the footprint of the disposal embankment |
| 25(9) | Closure as Disposal Units Are Filled | No | Division has reviewed and accepted operating procedures that are not changed or affected by CAW Embankment LAR |
| 25(10) | Active Disposal Operations Not Affect Stabilized Disposal Units | No | Division has reviewed and accepted operating procedures that are not changed or affected by CAW Embankment LAR |
| 25(11) | Only Radioactive Materials | No | CAW Embankment LAR involves only disposal of Class A LLRW |
| 25(12) | Waste for Near-Surface Disposal | No | CAW Embankment LAR involves only disposal of Class A LLRW |

### 4.10.1 Limits the Radiation Dose at the Surface of the Cover

**Requirement 2525-06:** Waste shall be placed and covered in a manner that limits the radiation dose rate at the surface of the cover to levels that at a minimum will permit the licensee to comply with all provisions of URCR Section R313-15-105 at the time the license is transferred pursuant to URCR Section R313-25-16 [URCR R313-25-25(6)].

**Basis:** The cover proposed for the CAW Embankment (Energy*Solutions*, LLC. 2012a; 2012b; 2012c) is thicker than that previously reviewed and approved by the Division for the CAN and CA embankments (URS Corporation 2005a; 2005b). Values of all factors that affect the projected dose rate at the surface of the final cover system for the proposed CAW embankment are either the same as or greater than (in the sense that projected dose for the revised cover design will be smaller) those of the Class A and CAN embankments. Since these factors were acceptable for the Class A and CAN embankments, they are also acceptable for the proposed CAW embankment.

***References:***

URS Corporation, 2005a

URS Corporation, 2005b

Energy*Solutions*, 2012a; 2012b; 2012c

### 4.10.2 Boundaries and Locations of Disposal Units

**Requirement 2525-07:** The boundaries and locations of disposal units shall be accurately located and mapped by means of a land survey. Near-surface disposal units shall be marked in such a way that the boundaries of the units can be easily defined. Three permanent survey marker control points, referenced to USGS or National Geodetic Survey (NGS) control stations, shall be established on the site to facilitate surveys. The USGS or NGS control stations shall provide horizontal and vertical controls as checked against USGS or NGS record files [URCR Subsection R313-25-25(7)].

**Basis:** The information contained in the CAW Embankment LAR and 2005 LRA the Licensee has submitted indicate that the requirements of URCR R313-25-25(7) will be met. As is presented in Sections 3 and 5 of the CAW Embankment LRA, closed embankments will be marked in the same way as a closed uranium mill tailings cell. Permanent granite markers, similar to those placed at the Vitro embankment, will be placed at the closed embankment. Markers will consist of unpolished granite of specified minimum dimensions, inscribed with lettering of specified characteristics. The markers will be set in a bed of reinforced concrete and slightly raised from the ground/cover surface.

Markers will be placed at the entrance to the site and near the center of the crest of the completed embankment. They will identify the site; the general location of the disposed materials; dates of construction and closure; volume, mass, or tonnage of disposed material; kilograms of source material; grams of special nuclear material; and total activity of radioactive material disposed of in the embankment.

The proposed marking for the CAW embankment is identical to that approved for the CAN embankment and the 2005 LRA (URS Corporation 2005a; 2005b). Based on the information summarized above, the Division concludes that the Licensee's proposed marking for the proposed CAW embankment is acceptable.

**References:**

URS Corporation 2005a; 2005b

### 4.10.3 Buffer Zone

**Requirement 2525-08:** A buffer zone of land shall be maintained between any buried waste and the disposal site boundary and beneath the disposed waste. The buffer zone shall be of adequate dimensions to carry out environmental monitoring activities specified in URCR Subsection R313-25-26(4) and take mitigative measures if needed [URCR R313-25-25(8)].

**Basis:** The information contained in the CAW Embankment LAR, 2005 LRA, and other relevant documents the Licensee has submitted indicate that the requirements of URCR R313-25-25(8) will be met. As indicated in Section 3 of the 2005 LRA, the horizontal buffer zone will be no less than 97.7 ft between the toe of the disposed waste and perimeter fence. During construction and waste emplacement operations, a 300-ft buffer zone exists between the closest edge of any embankment and the site boundary.

A vertical buffer zone is provided between the bottom of the embankment and the underlying unconfined aquifer water table. This buffer zone consists of the 2-foot-thick clay liner and at least 10 ft of undisturbed soils. Although the water surface elevation may rise slightly over time, it is not anticipated that this elevation will exceed the 10 ft of buffer zone in addition to the 2-foot clay liner. In the event that remedial actions are required, they will be performed as a corrective action for a specific nonconforming event. As such, an event-specific plan will be developed at that time under the direction and approval of the Utah Division of Radiation Control and the Utah Division of Water Quality.

Based on its review of the information provided, the Division has concluded that the plans to maintain a buffer zone satisfy applicable regulatory requirements. The dimensions and characteristics of the buffer zone are such that monitoring and mitigative measures can be undertaken as needed.

## 4.11 URCR SECTION R313-25-26; ENVIRONMENTAL MONITORING

The CAW Embankment LAR involves limited aspects of URCR R313-25-26. The applicability of URCR R313-25-26 provisions to the review of the CAW Embankment LAR are summarized in Table 4-17. Those sections that do apply to the CAW Embankment LAR are addressed in the sections following the table

**Table 4-17 – Applicability of URCR Section R313-25-26 Provisions to CAW Embankment LAR.**

| URCR R313-25-26 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| Number | Topic | | |
| 26(1) | Pre-Operational Monitoring Program | No | The Division has previously reviewed and accepted the Pre-Operational Monitoring Program |
| 26(2) | Operational Monitoring Program | Yes | The CAW Embankment LAR requires minor alterations in monitoring locations |
| 26(3) | Post-Closure Monitoring Program | No | The Division has previously reviewed and accepted plans for the post-closure monitoring program that is not changed or affected by the CAW Embankment LAR |
| 26(4) | Corrective Measures | No | The Division has previously reviewed and accepted plans for taking corrective measures if required; these are not changed or affected by the CAW Embankment LAR |

### 4.11.1 Operational Environmental Monitoring Program

**Requirement 2526-2:** During the land disposal facility site construction and operation, the licensee shall maintain an environmental monitoring program. Measurements and observations shall be made and recorded to provide data to evaluate the potential health and environmental impacts during both the construction and the operation of the facility and to enable the evaluation of long-term effects and need for mitigative measures. The monitoring system shall be capable of providing early warning of releases of waste from the disposal site before they leave the site boundary (URCR R313-25-26(2)).

**Basis:** The information contained in the CAW Embankment LAR and other relevant documents (engineering reports, supplemental data submissions and interrogatory responses) the Licensee has submitted indicate that the requirements of URCR R313-25-26(2) will be met. Since the Licensee has ongoing waste disposal operations at the site, the operational environmental monitoring program for those activities will be sufficient to constitute the future operational environmental monitoring program for the subject facility. As described in Section 4.2.4 of this SER, for the CAW embankment, certain revisions to the current air, vadose zone, and groundwater monitoring components of the environmental monitoring plan are proposed based on the proposed footprint and configuration of the embankment. Additional details regarding the proposed environmental monitoring program for the CAW embankment, including a summary of proposed abandoned and relocated monitoring locations, is provided in Section 4.2.4 of this SER. Quarterly environmental monitoring reports have been developed by the Licensee following this Plan and submitted to the Division since 1999 to document and evaluate potential long-term trends in environmental monitoring parameters and assess potential environmental effects and the need for mitigative measures. The Division finds that the current Plan is capable of providing early warning of releases of waste from the disposal site before they leave the site boundary.

Based on the information summarized above, the Division concludes that the Licensee's proposed CAW Embankment operational monitoring plan is acceptable.

## 4.12 URCR SECTION R313-25-31: FUNDING FOR DISPOSAL SITE CLOSURE AND STABILIZATION

The CAW Embankment LAR involves limited aspects of URCR R313-25-31. The applicability of URCR R313-25-31 provisions to the review of the CAW Embankment LAR are summarized in Table 4-18 below. Those sections that do apply to the CAW Embankment LAR are addressed in the sections following the table.

**Table 4-18 – Applicability of URCR Section R313-25-31 Provisions to CAW Embankment LAR.**

| URCR R313-25-31 Section | | CAW Embankment LAR Requires Review? | Justification |
|---|---|---|---|
| **Number** | **Topic** | | |
| a31(1) | Provide Assurances before Operations Begin | Yes | The CAW Embankment LAR involves changes that could affect costs of closing and stabilizing the disposal embankment |
| 31(2) through 31(8) | Details of Acceptable Surety Arrangements | No | The Division has previously reviewed and accepted arrangements for assuring funding; the Division reviews and approved adequate financial assurance annually. |

**Requirement 2531-1:** The applicant shall provide assurances prior to the commencement of operations that sufficient funds will be available to carry out disposal site closure and stabilization, including:

(a) decontamination or dismantlement of land disposal facility structures, and

(b) closure and stabilization of the disposal site so that following transfer of the disposal site to the site owner, the need for ongoing active maintenance is eliminated to the extent practicable and only minor custodial care, surveillance, and monitoring are required. These assurances shall be based on Director approved cost estimates reflecting the Director approved plan for disposal site closure and stabilization. The Applicant's cost estimates shall take into account total costs that would be incurred if an independent contractor were hired to perform the closure and stabilization work [URCR R313-25-31(1)].

**Basis:** The information contained in the CAW LAR, and other relevant documents (engineering reports, supplemental data submissions and interrogatory responses) the Licensee has submitted, indicate that the requirements of URCR R313-25-31, 25-32(1), and 25-32(2) have been or will be met. The Licensee will supplement the financial assurances, prior to initiating any waste placement in portions of the Class A West embankment that exceed horizontally or vertically beyond the current approved CA and CAN embankment designs.

The Licensee has provided a binding arrangement between the Licensee, the Division, and the Licensee's fiduciary agents, Wells Fargo Bank, that ensures that sufficient funds will be available to cover the costs of closing and stabilizing the proposed disposal facility, and monitoring and maintaining it during the institutional control period. The binding arrangement is an Irrevocable Letter of Credit with a Standby Trust Agreement.

The binding arrangement has been and continues to be periodically reviewed by the Division Director to ensure that changes in inflation, technology, and disposal facility operations are reflected in the arrangements. The Licensee is required by regulation to support similar reviews on an annual basis. Any changes to the binding arrangement will be submitted to the Division Director for review and approval before becoming effective.

Based on the information summarized above, the Division concludes that the financial assurance arrangements the Licensee has proposed and will provide for the proposed CAW are acceptable.

# 5.0 SUMMARY OF LICENSE CONDITIONS AND REVISIONS REQUIRED

The Licensee's request to amend the radioactive materials license (RML) to allow construction and operation of the proposed CAW embankment will require that certain revisions be made to the current facility license to properly reflect the proposed new activities and the proposed embankment configuration. In addition, two new license conditions (LCs) will need to be added to the RML to address two currently unresolved technical issues that require resolution prior to cover construction. These required revisions and new LCs are discussed below, and are categorized in terms of whether they constitute a major or minor change to the RML.

## 5.1 MAJOR CHANGES

***New License Conditions***

Allowable Distortion in Final Cover Radon Barrier Layer Components

The Licensee has committed to provide additional information to confirm the existing or support selection of a new maximum allowable distortion value for use in evaluating long-term performance (potential for cracking) of the radon barrier components of the cover in response to differential settlement. A new LC will be added to the RML to address this requirement. The new LC will require that, on or before August 1, 2012, the Licensee submit a detailed study plan for Director review and approval to determine the geotechnical properties, including the maximum tensile strain of both average axial and localized lengthening/bending (angular) effects and associated angular distortion for the point of crack initiation, of samples of the Licensee's clay materials to be used in the construction of the embankment compacted-clay radon barrier cover layers. The LC will also require that within nine months of the Director's approval the Licensee will report the results of the detailed study plan to the Director.

The new LC will also require that final cover placement not occur until the Licensee demonstrates that actual distortion values, based on settlement measurements made on the interim cover soil layer, placed over filled waste areas within the proposed CAW embankment footprint, do not exceed the maximum allowable distortion value determined from results of the study described above, or the current value approved by the Director (e,g, EnergySolutions 2012c).

The proposed LC 41 is as follows:

> *On or before August 1, 2012, the Licensee shall submit, for Director's review and approval, a detailed plan for a study of the clayey soils to be used in the radon barrier of the CAW embankment cover. The objective of this study is to determine the amount of strain that the soils can withstand without cracking when subjected to both axial lengthening and bending as would be experienced when the clay settles differentially as part of the cover system. Within nine months of Director's approval of the study plan, the Licensee shall execute the study and submit a report with results of the study. Based on*

> *results of the study and the Director's review, the Director may require the Licensee to modify the embankment and cover design.*

Revised Cover Design and Associated Modeling Activities

The Licensee has committed to provide a revised cover design to the DRC by December 25, 2012. The cover design will include detailed design information including descriptions, design calculations, drawings and specifications. Also, the Licensee has committed to using a different infiltration model to support the revised design of the cover as well as a transport model to assess migration in the saturated zone. The Evaporative Zone Depth (EZD), previously used in infiltration modeling of the CAW embankment, is no longer relevant. The licensee has committed to use a different infiltration model that does not require an EZD input parameter value. In addition to a revised cover design and new infiltration and transport models to support the revised cover, the Licensee will provide an assessment addressing performance of the revised cover design and potential releases from the proposed disposal unit.

The proposed LC 42 is as follows:

> *On or before December 25, 2012, the Licensee shall submit a revised cover design (including at least descriptions, design calculations, drawings, and specifications) and an assessment addressing performance of the revised Class A West cover design and transport of releases from the proposed Class A West disposal unit.*

***Revisions to Existing License Conditions***

Limitation on Disposed LLRW Volume

License Condition 9.E is revised to reflect the limitation on the volume of LLRW allowed to be disposed of under the agreement between the Licensee and Governor Jon M. Huntsman, Jr. dated March 15, 2007.

The proposed revised language for License Condition 9.E is as follows:

> *E. 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 both the Class A West ~~and Class A North~~ disposal cell described in License Condition 40, and in the Mixed Waste Landfill Cell not exceeding a total of 10.1 million cubic yards. Class A waste is defined in Utah Radiation Control Rule R313-15-1008 and NARM at R313-12-3.*

Revised and Additional Limiting Radionuclide Concentrations

Performance assessment modeling results for the proposed CAW embankment indicate that concentrations of selected radionuclides in Class A wastes placed under top slope and under side slope areas within the proposed CAW embankment must not exceed certain revised concentration limitations in order for the CAW embankment to achieve required performance objectives.

The radionuclides identified in Sections 4.3.1 and 4.3.2 of this SER will be incorporated into the amended License at *LC 29, Reporting*.  The proposed revised LC 29 follows:

E. *For the ~~Class A and Class A North~~ Class A West disposal cell~~s~~, the Licensee shall ensure that the maximum acceptable activities used as source terms in the groundwater performance modeling are not exceeded after facility closure. Therefore, the Licensee shall notify the Director ~~Executive Secretary~~, at the earliest knowledge, that the following nuclides are scheduled for disposal: ~~aluminum-26,~~ berkelium-247, calcium-41, ~~californium-250,~~ chlorine-36, iodine-129, rhenium-187, ~~terbium-157, and terbium-158~~, and technetium-99.*

The revised radionuclide concentration limitations (maximum acceptable activities) described in Sections 4.3.1 and 4.3.2 of this SER will be incorporated into the amended License at *LC 55, Specific Operating Procedures.*  The proposed revised LC 55 follows:

~~*A. For the Class A and Class A North disposal cells, the Licensee shall ensure that the actual cumulative activity of chlorine-36 does not exceed 0.2828 picocuries per gram in accordance with the following formula:*~~

~~*Total Activity of chlorine-36 Received (picocuries) < 0.2828 picocuries per gram*~~
~~*Total Mass of Active Cell (grams) + Completed Cell (grams)*~~

A. *For the Class A West disposal cell, the Licensee shall ensure that the average concentrations of selected radionuclides do not exceed the limits stated in Table 55A.*

**Table 55A. Limiting Radionuclide Concentrations in Waste Disposed of in Class A West Disposal Cell.**

| Radionuclide | Maximum Average Radionuclide Concentration[1] in Waste Disposed of Under Top Slope (pCi/g) | Maximum Average Radionuclide Concentration[1] in Waste Disposed of Under Side Slope (pCi/g) |
|---|---|---|
| berkelium-247 | 6.50E-03 | 3.88E-03 |
| calcium-41 | 3.53E+04 | 3.41E+01 |
| chlorine-36 | 1.59E+01 | 9.72E+00 |
| iodine-129 | --- | 2.19E+01 |
| rhenium-187 | --- | 1.91E+04 |
| technetium-99 | --- | 1.72E+03 |

*1. Maximum average radionuclide concentration for a radionuclide is determined as the quotient of the Total Activity (in picocuries) of that radionuclide disposed of under the respective slope and the Total Mass disposed of under the respective slope for the Active Cell (in grams) + Completed Cell (in grams).*

~~*B. For the Class A and Class A North disposal cells, the Licensee shall ensure that the actual cumulative activity of berkelium-247 does not exceed 0.0001 picocuries per gram in accordance with the following formula:*~~

~~*Total Activity of berkelium-247 Received (picocuries) < 0.0001 picocuries per gram*~~
~~*Total Mass of Active Cell (grams) + Completed Cell (grams)*~~

~~*C.*~~*B.* *For the Mixed Waste disposal cell, the Licensee shall ensure that the actual cumulative activity of chlorine-36 does not exceed 8.75 picocuries per gram in accordance with the following formula:*

*Total Activity of chlorine-36 Received (picocuries) < 8.75 picocuries per gram*
*Total Mass of Active Cell (grams) + Completed Cell (grams)*

~~*D.*~~*C.* *For the Mixed Waste disposal cell, the Licensee shall ensure that the actual cumulative activity of berkelium-247 does not exceed 0.00314 picocuries per gram in accordance with the following formula:*

*Total Activity of berkelium-247 Received (picocuries) <0.00314 picocuries per gram*
*Total Mass of Active Cell (grams) + Completed Cell (grams)*

## 5.2 MINOR CHANGES

***Required General Revisions***

The RML will be revised throughout as needed to reflect and reference the CAW Embankment, to remove references to the existing Class A and CAN Embankments where appropriate, and to reference the approved CAW Embankment Drawings ("Series 10014"). These required changes include:

- Update the RML at *LCs 6*, *9*, *11*, *14*, *16*, *29*, *36*, *38*, *39*, *40*, *43*, *50*, and *53* to reflect the change in the designation and the location of the CAW Embankment and the change in the Class A waste disposal area footprint and height;
- Update the RML at *LCs 38, 43, 48, 89*, and/or other LC's as applicable and appropriate to reference the approved CAW Embankment Drawings ("Series 10014"); and
- Update the last section of LC 89 (Closeout Conditions) to add the following statement at the end of the section:

*The following documents refer to documents the Licensee submitted in support of proposed Amendment #10:*

1) *AMEC Earth & Environmental, Inc. 2011. Report: Geotechnical Update Report – EnergySolutions Clive Facility Class A West Embankment, February 15, 2011*
2) *AMEC Earth & Environmental, Inc. 2011. Cover Letter – Response to Interrogatory CAW R313-25-8(4)-16/1: Seismic Hazard Evaluation, EnergySolutions Clive Facility, Class A West Embankment, Clive, Tooele County, Utah. eport: Geotechnical Update Report – EnergySolutions Clive Facility Class A West Embankment, Clive, Tooele County, Utah. October 25, 2011.*
3) *AMEC Earth & Environmental, Inc. 2011. Response to Interrogatory CAW R313-25-8(4)-16/1: Seismic Hazard Evaluation, EnergySolutions Clive Facility, Class A West Embankment, Clive, Tooele County, Utah. October 25, 2011*
4) *AMEC Earth & Environmental, Inc. 2011. Response to Interrogatory CAW R313-25-8(4)-16/2: Seismic Hazard Evaluation, EnergySolutions Clive Facility, Class A West Embankment, Clive, Tooele County, Utah. December 23. 2011.*
5) *AMEC Earth & Environmental, Inc. 2012. Report: Response to Interrogatory CAW R313-25-8(4)-16/3: Seismic Hazard Evaluation/Seismic Stability Analysis Update, EnergySolutions Clive Facility, Class A West Embankment, Clive, Tooele County, Utah. April 6, 2012.*
6) *AMEC Earth & Environmental, Inc. 2012. Addendum: Additional Cyclic Softening Analysis, EnergySolutions Clive Facility, Class A West Embankment, Clive, Tooele County, Utah. May 3, 2012.*
7) *EnergySolutions, LLC. 2011. License Amendment Request: Class A West Embankment, with Attachments 1 Through 7 and cover letter to Mr. Rusty Lundberg at Utah Division of Radiation Control dated May 2, 2011.*
8) *EnergySolutions, LLC. 2011. Responses to Round 1 Interrogatories: License Amendment Request (UT2300249) for the Class A West Embankment and cover letter to Mr. Rusty Lundberg at Utah Division of Radiation Control, October 28, 2011.*
9) *EnergySolutions, LLC. 2011. Supplemental Responses to Round 1 Interrogatories: License Amendment Request (UT2300249) for the Class A West Embankment, November 28, 2011 and cover letter to Mr. Rusty Lundberg at Utah Division of Radiation Control, November 29, 2011.*
10) *EnergySolutions 2012. Radioactive Material License #UT2300249 and Ground Water Quality Discharge Permit No. UGW450005, Amendment and Modification Request - Class A West Embankment: Response to Round 3 Interrogatory URCR R313-25-7(3)-04, with attachments. Letter from Tim Orton, EnergySolutions, to Mr. Rusty Lundberg, Utah Division of Radiation Control, dated March 20, 2012.*
11) *Whetstone Associates, Inc. 2011. EnergySolutions Class A West Disposal Cell Infiltration and Transport Modeling Report, April 19, 2011.*
12) *Whetstone Associates, Inc. 2011. EnergySolutions Class A West Disposal Cell Infiltration and Transport Modeling Report, November 28, 2011.*
13) *Whetstone Associates, Inc. 2012. EnergySolutions Class A West Disposal Cell Infiltration and Transport Modeling Report, February 23, 2012.*

***Changes to Environmental Monitoring System Network***

Changes to the air, vadose zone, and groundwater monitoring networks that will be required as a result of the construction and operation of the proposed CAW embankment are discussed in Section 4.2.4, "Environmental Monitoring Program," of this SER. These changes will require certain revisions to the RML and the Groundwater Quality Discharge Permit. Required revisions to the RML to reflect some of these changes are summarized below.

Revision to Air Monitoring Network

A new air monitoring station will be added to the environmental monitoring network to provide an additional level of monitoring for assessing potential airborne movement of contamination from the CAW embankment operations to the Vitro Facility to the east. This additional monitoring station (A-6) will be installed on the east side of the proposed CAW embankment (Attachment 1 to EnergySolutions 2012e). The Licensee has revised the Environmental Monitoring Program (EnergySolutions 2012e) to reflect the addition of one new air monitoring station at the location shown on Drawing 07007 J01, January 5, 2012 (Attachment 1 to EnergySolutions 2012f).

The license will be revised at LC 26 to reference the updated Environmental Monitoring Program.

Revisions to Vadose Zone and Groundwater Monitoring Networks

One or more revisions to the existing Groundwater Quality Discharge Permit will be required to reflect the changes to the vadose zone and groundwater monitoring systems that will result from constructing and implementing the proposed CAW embankment.

# 6.0 REFERENCES

Abrahamson, N.A., and Silva, W.J., 2008, *Summary of the Abrahamson & Silva NGA Ground Motion Relations: Earthquake Spectra*, vol. 24, no. 1, p. 67-97.

Abt, S.R., Wittler, R.J., Ruff, J.F., LaGrone, D.L., Khattak, M.S., Nelson, J.D., Hinkle, N.E., and Lee, D.W. *Development of Riprap Design Criteria by Riprap Testing in Flumes: Phase IL Followup Investigations. NUREG/CR-4651*, ORNL lTM-10100N2, Vol. 2, 1988.

Abt, S.R., and Johnson, T.L. 1991. "Riprap Design for Overtopping Flow." *Journal of Hydraulic Engineering*, Vol. 117, No. 8.

Abt, S.R., Thornton, C.I., Gallegos, H.A., and Ullmann, C.M. 2008. "Round-Shaped Riprap Stabilization in Overtopping Flow." *Journal of Hydraulic Engineering*, Vol. 134, No. 8, pp. 1035-1041.

Adrian Brown Consultants. 1997. Volume I. *LARW Infiltration Modeling Input Parameters and Results*, prepared for Envirocare of Utah, Inc. May 15, 1997.

AMEC Earth & Environmental, Inc. 2000. Letter: "Allowable Distortion of Liner and Cover Materials, New LARW and Proposed LLRW Embankments," letter to Ken Alkema of Envirocare of Utah, Inc., October 4, 2000.

AMEC Earth & Environmental, Inc. 2005a. Geotechnical Study:" Increase in Height and Footprint," May 27, 2005.

AMEC Earth & Environmental, Inc. 2005b. Report: "Combined Embankment Study, Envirocare," December 13, 2005.

AMEC Earth & Environmental, Inc. 2011a. Report: "Geotechnical Update Report – Energy*Solutions* Clive Facility Class A West Embankment," February 15, 2011.

AMEC, Earth & Environmental, Inc., 2011c. "Response to Interrogatory CAW URCR R313-25-8(4)-16/1: Seismic Hazard Analysis," Job Number 10-817-05290, October 25, 2011.

AMEC Earth & Environmental, Inc. 2011d. Cover Letter: "Response to Interrogatory CAW R313-25-8(4)-16/1: Seismic Hazard Evaluation, Energy*Solutions* Clive Facility, Class A West Embankment, Clive, Tooele County, Utah: Geotechnical Update Report – Energy*Solutions* Clive Facility Class A West Embankment, Clive, Tooele County, Utah," October 25, 2011.

AMEC Earth & Environmental, Inc. 2011e. "Response to Interrogatory CAW R313-25-8(4)-16/2: Seismic Hazard Evaluation, Energy*Solutions* Clive Facility, Class A West Embankment, Clive, Tooele County, Utah," December 23, 2011.

AMEC Earth & Environmental, Inc. 2012a. "Response to Interrogatory CAW URCR R313-25-8(4)-16/3: Seismic Hazard Evaluation/Seismic Stability Analysis Update, Energy*Solutions* Clive Facility, Class A West Embankment, Clive, Toole County, Utah,' April 6, 2012.

AMEC Earth & Environmental, Inc. 2012b. "Addendum, Additional Cyclic-Softening Analysis, Energy*Solutions* Clive Facility, Class A West Embankment, Clive, Tooele County, Utah," May 3, 2012.

Bertram, G.E. 1940. "An Experimental Investigation of Protective Filters." Graduate School of Engineering, Harvard University, Cambridge, Massachusetts. *Soil Mechanics Series No. 7*. pp. 1-21.

Bingham Environmental. 1995. "Isopach of Minimum Historical Depth to Groundwater," Job 2019-034, Figure 23, October 1995.

Bingham Environmental. 1996. David Cline – Project Manager, *HEC-1 and HEC-2 Analysis, LARW Application for License Renewal, Envirocare Disposal Facility, Clive, Utah*. November 26, 1996 (Appendix KK of the Envirocare LARW License Renewal Application).

Boore, D.M., and Atkinson, G.M. 2008. Ground-Motion Prediction Equations for the Average Horizontal Component of PGA, PGV, and 5%-Damped PSA at Spectral Periods Between 0.01 s and 10.0 s, Earthquake Spectra, Vol. 24, No.1. p. 99-138.

Boulanger, R.W., and Idriss, I.M. 2004. "Evaluating the Potential for Liquefaction and Cyclic Failure of Silts and Clays," Center for Geotechnical Modeling, University of California, Davis, Report No. UCD/CGM-04/01.

Boulanger, R.W., and Idriss, I.M. 2007. "Evaluation of Cyclic Softening in Silts and Clays." *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 133, No. 6, June 1, 2007 pp. 641- 652.

Campbell, K.W., and Bozorgnia, Y. 2008. "Ground Motion Model for the Geometric Mean Horizontal Component of PGA, PGV, PGD and 5% Damped Linear Elastic Response Spectra for Periods Ranging from 0.01s to 10.0 s." *Earthquake Spectra*, Vol. 24, No. 1. p. 139-171.

Cedegren., H.R., 1989. *Seepage, Drainage, and Flow Nets*. 3rd Edition. John Wiley & Sons, Inc., New York, NY.

Chiou, B.S.J., and Youngs, R.R.. 2008." An NGA Model for the Average Horizontal Component of Peak Ground Motion and Response Spectra." *Earthquake Spectra*, Vol. 24, No.1. p. 173-215.

Cline, J.F. 1979. "Biobarriers Used in Shallow-Burial Ground Stabilization." Technical Report. Pacific Northwest Laboratory, PNL-2918. March 1, 1979.

Cline, J. F., K. A. Gano, and L. E. Rogers. 1980. "Loose Rock as Biobarriers in Shallow Land Burial." *Health Physics,* Vol. 39, pp. 494–504.

Cline, J. F., F.G. Burton, D. A. Cataldo, W. E. Skiens, and K. A. Gano. 1982. *Long-Term Biobarriers to Plant and Animal Intrusion of Uranium Tailings*, DOE/UMT-0209, Pacific Northwest Laboratory, Richland, Washington.

Codell, R.B., Abt, S.R., Johnson, T., and Ruff, J. 1990. "Estimation of Flow Through and Over Armored Slopes." *Journal of Hydraulic Engineering*, Vol. 116, No. 10, October 1990, pp. 1252-1269.

DOE (U.S. Department of Energy). 1989. Technical Approach Document, Revision II. UMTRA-DOE/AL 050425.0002.

Dinter, D.A., and Pechmann, J.C. 2005. "Paleoseismology of the East Great Salt Lake Fault." NEHRP Final Technical Report (Phase 2), Project Number 00HQGR0099, Wash., DC.

Envirocare of Utah, LLC. 2005a. "Class A Combined (CAC) Disposal Embankment Engineering Justification Report," Revision 01, December 12, 2005.

Envirocare of Utah, LLC. 2005b. *Application for Renewal: Radioactive License Materials License Number UT-2300249*, Revision 2. June 20, 2005.

Envirocare of Utah, Inc., 2005c. "License Renewal Application; Radioactive Material License Number 2300249, Revision 2, June 20, 2005

Energy*Solutions*, LLC.2006. *Class A Combined (CAC) Disposal Embankment Engineering Justification Report*, Revision 2, CD06-0172, April 28, 2006. Submitted as Attachment 1 *Revised Engineering Justification Review* to Round 3 Interrogatory Responses.

Energy*Solutions*, LLC. 2011a. *License Amendment Request: Class A West Embankment, with Attachments 1 Through 7* and cover letter to Mr. Rusty Lundberg at Utah Division of Radiation Control, May 2, 2011.

Energy*Solutions*, LLC. 2011b. Responses to Round 1 Interrogatories: License Amendment Request (UT2300249) for the Class A West Embankment and cover letter to Mr. Rusty Lundberg at Utah Division of Radiation Control, October 28, 2011.

Energy*Solutions*, LLC. 2011c. "18-Year Summary Report on Meteorology and Climatology, Clive Facility: January 1, 1993 through December 31, 2010" – CD11-0035.

Energy*Solutions*, LLC. 2011d. *LLRW and 11e.(2) Construction Quality Assurance/Quality Control (CQA/QC) Manual* ([Proposed] Revision 26b), November 15, 2011.

Energy*Solutions*, LLC. 2011e. *Supplemental Responses to Round 1 Interrogatories: License Amendment Request (UT2300249) for the Class A West Embankment*, November 28, 2011 and cover letter to Mr. Rusty Lundberg at Utah Division of Radiation Control, November 29, 2011.

Energy*Solutions*, LLC. 2012a. Radioactive Material License #UT2300249 and Ground Water Quality Discharge Permit No UGW450005, Amendment and Modification Request – Class A West Embankment: Response to Round 2 Interrogatory. Letter from Sean McCandless, Energy*Solutions*, to Mr. Rusty Lundberg, Utah Division of Radiation Control, with enclosures dated January 12, 2012.

Energy*Solutions*, LLC. 2012b. Radioactive Material License #UT2300249 and Ground Water Quality Discharge Permit No UGW450005, Amendment and Modification Request – Class A West Embankment: Response to Round 3 Interrogatory. Letter from Sean

McCandless, Energy*Solutions*, to Mr. Rusty Lundberg, Utah Division of Radiation Control, with enclosures dated February 23, 2012.

Energy*Solutions*, LLC. 2012c. Radioactive Material License #UT2300249 and Ground Water Quality Discharge Permit No. UGW450005, Amendment and Modification Request – Class A West Embankment: Response to Round 3 Interrogatory URCR R313-25-7(3)-04, with attachments. Letter from Tim Orton, Energy*Solutions*, to Mr. Rusty Lundberg, Utah Division of Radiation Control, dated March 20, 2012.

Energy*Solutions*, LLC 2012d. LLRW and 11e.(2) Construction Quality Assurance/Quality Control (CQA/QC) Manual" ([Proposed] Revision 26c), March 20, 2012.

Energy*Solutions*, LLC. 2012e. Environmental Monitoring Program. January 30, 2010.

Energy*Solutions*, LLC. 2012f. "Drawing 07007 J01, Environmental Monitors. Rev. 7, January 5, 2012. Attachment to Revised Environmental Monitoring Program, dated January 5, 2012.

Francis, M., Yeh, H., Dinter, D., Thio, H.K., and Olig, S. 2011. *Tsunami and Seiche Risk Framework for the Great Salt Lake.* ASCE Proceedings of the 2011 *Solutions* to Coastal Disasters Conference, doi:10.1061/41185(417) 34,http://link.aip.org/link/?ASC/417/34.

Gano, K. A. and J. B. States. 1982. *Habitat Requirements and Burrowing Depths of Rodents in Relation to Shallow Waste Burial Sites*, PNL-4140, Pacific Northwest Laboratory, Hanford, Washington.

Gelhar, L.W., Welty, C. and Rehfeldt, K.R. 1992."A Critical Review of Data on Field-Scale Dispersion in Aquifers." *Water Resources Research*, Vol.28, No. 7, pp.1955-1974.

Hansen, E.M, Schwarz, F.K., and Reidel, J.T. 1984. HMR 49. *Hydrometeorological Report No. 49, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration and U.S. Department of Army Corps of Engineers, 1984 reprint.

Ishihara, K., and Yoshimine, M., 1992, "Evaluation of Settlements in Sand Deposits Following Liquefaction during Earthquakes. Soils and Foundations." *JSSMFE*, Vol. 32 No. 1, March, p. 173-188.

Jefferies, M.G., and Davies, M.P. 1993. "Use of CPTu to Estimate Equivalent SPT N60." *Geotechnical Testing Journal, ASTM*, Vol. 16, No. 4, December 1993, p. 458-468.

Jensen, D.T. 1995. "Final Report Probable Maximum Precipitation Estimates for Short-Duration, Small-Area Storms in Utah, Utah Climate Center," 1995.

Jensen, D.T. 2003. *Final Report 2002 Update for Probable Maximum Precipitation, Utah 72-Hour Estimates, Areas to 5,000 mi$^2$, Utah Climate Center, 2003.*

Johnson, T.L. and Abt, S.R. 1998. "Design of Channel Riprap Using Overtopping Flow Methods." *Proceedings of the First Federal Interagency Hydrologic Modeling Conference*, Las Vegas, NV, April 19-23, 1998.

Ladd, C.C., and Foott, R., 1974, New Design Procedures for Stability of Soft Clays, Journal of the Geotechnical Engineering Division, ASCE, Vol. 100, No. GT7, pp. 763-786.

Leps, T.M., 1973. "Flow through Rockfill." *Embankment Dam Engineering*, John Wiley and Sons.

Meteorological Solutions, Inc. (MSI), 2010. "January 2009 Through December 2009 and January 1993 Through December 2009 Summary Report of Meteorological Data Collected at Energy*Solutions*' Clive, Utah Facility", prepared for: Energy*Solutions*, LLC, by Meteorological Solutions Inc., Project No. 021008134. February 2010.

Montgomery Watson 1998. LAWR Embankment License Application Appendix BB, Frost Penetration. 1998.

Montgomery-Watson (John Pellicer and Patrick Corser) to Envirocare of Utah, Inc. (Tim Orton). 2000. Letter Report LLRW Cover Frost Penetration. March 1, 2000.

Nelson, J.D., S.R. Abt, R.L. Volpe, D. van Zyl, N.E. Hinkle, and W.P. Staub. 1986. NUREG/CR-4620, *Methodologies for Evaluating Long-Term Stabilization Designs of Uranium Mill Tailings Impoundments*, ORNL/TM-1006, prepared for U.S. Nuclear Regulatory Commission, June 1986.

NRCS (Natural Resources Conservation Service) 1994. U.S. Department of Agriculture, Part 633, *National Engineering Handbook*, Chapter 26: Gradation Design of Sand and Gravel Filters. October 1994.

Reichman, O.J., and Smith, S. C. 1990. "Burrows and Burrowing Behavior by Mammals," pp. 197-244 in H.H. Genoways, ed., *Current Mammalogy*. Plenum Press, New York and London. 1990.

Reynolds, T. D. and W. L. Wakkinen, 1987. "Burrow Characteristics of Four Species of Rodents in Undisturbed Soils in Southeastern Idaho." *American Midland Naturalist*, Vol. 118, pp. 245–260.

Reynolds, T. D. and J. W. Laundre, 1988. "Vertical Distribution of Soil Removed by Four Species of Burrowing Rodents in Disturbed and Undisturbed Soils." *Health Physics*, Vol. 54, No. 4, pp. 445–450.

Sharma, H., and Lewis, S. 1994. *Waste Containment Systems, Waste Stabilization, and Landfills – Design and Evaluation*. John Wiley & Sons, N.Y.

SWCA, Inc. 2000. A*ssessment of Vegetative Impacts on LLRW*. November 2, 2000.

Streamline Consulting, LLC, 2005, "Potential Health Impacts from Open Disposal Cells at Envirocare of Utah's Waste Disposal Facility, Clive, Utah", April 6, 2005

Tokimatsu, T., and Seed, H.B. 1987. "Evaluation of Settlements in Sands due to Earthquake Shaking." *Journal of Geotechnical Engineering, ASCE*, Vol.113, No. 8.

URS Corporation 2005a. *Envirocare Class A North Amendment Request: Safety Evaluation Report*. _____________, 2005.

URS Corporation 2005b. *Envirocare License Renewal Application: Safety Evaluation Report*. _____________, 2005.

URS Corporation 2006. PRELIMINARY DRAFT. *Safety Evaluation Report*. Utah Division Of Radiation Control, Energy*Solutions* LLRW Disposal Facility Class A Combined Amendment Request. August 25, 2006.

URS Corporation 2007. *Safety Evaluation Report*. Utah Division of Radiation Control, Energy*Solutions* LLRW Disposal Facility Radioactive Material License Renewal. June 14, 2007.

URS Corporation 2012. Technical Memorandum from Travis Gerber and Robert Baird of URS to John Hultquist, Utah Division of Radiation Control: CAW Cover System Design, Clay Strain and Distortion, March 13, 2012.

US Army Corps of Engineers (USACE) 1994. *Hydraulic Design of Flood Control Channels*. EM 1110-2-1601, Office of the Chief of Engineers, Washington, DC. June 30, 1994.

US Nuclear Regulatory Commission (NRC) 1982. 10 CFR Part 61. *Licensing Requirements for Land Disposal of Radioactive Waste. U*.S. NRC, Washington, DC.

US Nuclear Regulatory Commission (NRC) 1991. NUREG-1199. Rev. 2, *Standard Format and Content of a License Application for a Low-Level Radioactive Waste Disposal Facility Safety Analysis Report.* Office of Nuclear Material Safety and Safeguards, Rev. 2, U.S. NRC, Washington, DC. January 1991.

US Nuclear Regulatory Commission (NRC) 1994. NUREG-1200, Rev. 3. *Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Waste Disposal Facility*. Rev. 3, April 1994.

US Nuclear Regulatory Commission (NRC), Office of Nuclear Material Safety and Safeguards. 2002. NUREG-1623, *Design of Erosion Protection for Long-term Stabilization*, Final Report. September 2002.

US Nuclear Regulatory Commission (NRC). 1994. NUREG-1200, *Standard Review Plan for the Review of a License Application for a Low-Level Radioactive Disposal Facility*, Revision 3. April 1994.

Whetstone Associates, Inc. 2000a. *Report. Envirocare of Utah Class A, B, and C Cell Infiltration and Transport Modeling*, August 1, 2000.

Whetstone Associates, Inc. 2000b. Technical Memorandum. *Sensitivity Analysis of Vegetated Class A, B & C Cell Cover*, October 20, 2000.

Whetstone Associates, Inc., 2005. *Envirocare of Utah Class A Combined (CAC) Cell Infiltration and Transport Modeling Report*, November 18, 2005. Document Number 4101W.051118.

Whetstone Associates, Inc. 2006. *EnergySolutions Class A Combined (CAC) Disposal Cell Infiltration and Transport Modeling Report*, April 2006.

Whetstone Associates, Inc. 2011a. *EnergySolutions Class A West Disposal Cell Infiltration and Transport Modeling Report,* April 19, 2011.

Whetstone Associates, Inc. 2011b. *EnergySolutions Class A West Disposal Cell Infiltration and Transport Modeling Report*, November 28, 2011.

Whetstone Associates, Inc. 2012. *EnergySolutions Class A West Disposal Cell Infiltration and Transport Modeling Report*, February 23, 2012.

Wong, I., Silva, W., Olig, S., Thomas, P., Wright, D., Ashland, F., Gregor, N., Pechmann, J., Dober, M., Christenson, G., and Gerth, R. 2002. *Earthquake Scenario and Probabilistic Ground Shaking Maps for the Salt Lake City, Utah, Metropolitan Area*: Utah Geological Survey Miscellaneous Publication MP-02-05.

Wong. I. 2012. Technical Memorandum: Ivan Wong, URS Corporation, Clive Seismic Hazard Analysis; Wong Calculations, March 12, 2012.

Youd, T.L., DeDen, D.W., Bray, J.D., Sancio, R., Cetin, K.O., and Gerber, T.M. 2009. “Zero Displacement Lateral Spreads, 1999 Kocaeli, Turkey Earthquake.” *Journal of Geotechnical and Geoenvironmental Engineering, ASCE*, Vol. 135, No. 1, pp. 46-61.

Zu, M. and Eckstein, Y. 1995. “Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Field Scale.” *Ground Water*, Vol. 33, No. 6, pp. 905-9 08.