Draft Safety Evaluation Report

For the proposed reclamation plan for the Sequoyah Fuels Corporation Site in Gore, Oklahoma; Materials License No. SUB-1010

Docket No. 40-8027
Sequoyah Fuels Corporation

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

September 2005

ABSTRACT

This draft Safety Evaluation Report (SER) summarizes the U.S. Nuclear Regulatory Commission staff's review of Sequoyah Fuels Corporation's (SFC's) proposed reclamation plan for its uranium conversion facility site near Gore, Oklahoma. The proposed reclamation would allow SFC to (1) remediate the site by encapsulating contaminated material in a disposal cell to be constructed onsite in preparation for long-term custodial care by a government agency, (2) prepare the site for closure, and (3) relinquish responsibility of the site after having its NRC license terminated. The NRC staff concludes that, subject to resolution of open issues identified in the draft SER, the proposed reclamation plan meets the requirements identified in NRC regulations, which appear primarily in 10 CFR Part 40.

SEQUOYAH FUELS CORPORATION SITE
DRAFT Safety EVALUATION REPORT

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1.0 INTRODUCTION

1.1 Background

Materials License SUB-1010 for the Gore facility is held by the Sequoyah Fuels Corporation (SFC). The facility operated as a uranium conversion facility but has not operated since 1993. SFC submitted decommissioning plans for the site in 1998 and 1999[(1)]. The decommissioning plan proposed utilizing an onsite, above-grade disposal cell for the permanent disposal of waste. The plan proposed restricted release of the site in accordance with 10 CFR 20.1403 (the license termination rule). However, restricted release requires the commitment of a responsible party to act as a custodian of the site. SFC was not able to obtain a commitment from an acceptable responsible party, although it held discussions with the U.S. Department of Energy (DOE) in that regard[(2)]. In January 2001, SFC requested a determination by NRC whether waste from the solvent extraction portion of the uranium hexafluoride conversion process could be classified as byproduct material defined in Section 11e.(2) of the Atomic Energy Act of 1954, as amended. 11e.(2) byproduct material sites must be remediated in accordance with Appendix A of 10 CFR Part 40. Additionally, sites remediated in accordance with Appendix A, that contain 11e.(2) byproduct material above specified concentrations must be transferred to a government custodian for perpetual custodial care. The custodian can be the State where the 11e.(2) site is located, but if the State declines, DOE must accept the site and become the custodian.

In July 2002, the Commission determined that most of the waste material at the site can be classified as 11e.(2) byproduct material. On September 30, 2002, SFC requested an amendment to its license to allow it to possess 11e.(2) byproduct material. On December 11, 2002, the U.S. Nuclear Regulatory Commission (NRC) amended the license to allow possession of 11e.(2) byproduct material and include several conditions necessitated by the change to an 11e.(2) site. One of those conditions (LC 48) required SFC to submit a site reclamation plan to NRC by March 15, 2003. SFC submitted its reclamation plan by letter dated January 28, 2003. The reclamation plan has been updated by submittals dated August 8, 2003, August 29, 2003, February 17, 2004, and April 12, 2005.

This draft Safety Evaluation Report (SER) documents the NRC staff's review of SFC's reclamation plan and staff conclusions with respect to the appropriate regulations. The regulations governing reclamation of uranium mill tailings appear primarily in 10 CFR Part 40. Technical criteria appear in Appendix A to Part 40, which also allows licensees to propose alternatives to the specific requirements in the Appendix. NRC can approve an alternative if it finds that it will achieve a level of stabilization and containment of the site, and a level of protection of public health, safety, and the environment, equivalent to, to extent practicable, the level which would be achieved by the requirements in the Appendix.

1.2 Site Description

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(1) SFC submitted a decommissioning plan which was rejected by NRC on February 11, 1999 for failure to meet the minimum criteria for technical review. The second decommissioning plan was accepted for review by NRC on May 20, 1999.

(2) DOE has the authority to accept sites with radioactive material for long-term custodial care but is not required to do so.

1.2.1 Location and Description

The SFC site is located in Sequoyah County in mid-eastern Oklahoma about 150 miles east of Oklahoma City, Oklahoma, 40 miles west of Fort Smith, Arkansas, 25 miles southeast of Muskogee, Oklahoma, and 2.5 miles southeast of Gore, Oklahoma in Section 21 of Township 12 North, Range 21 East.

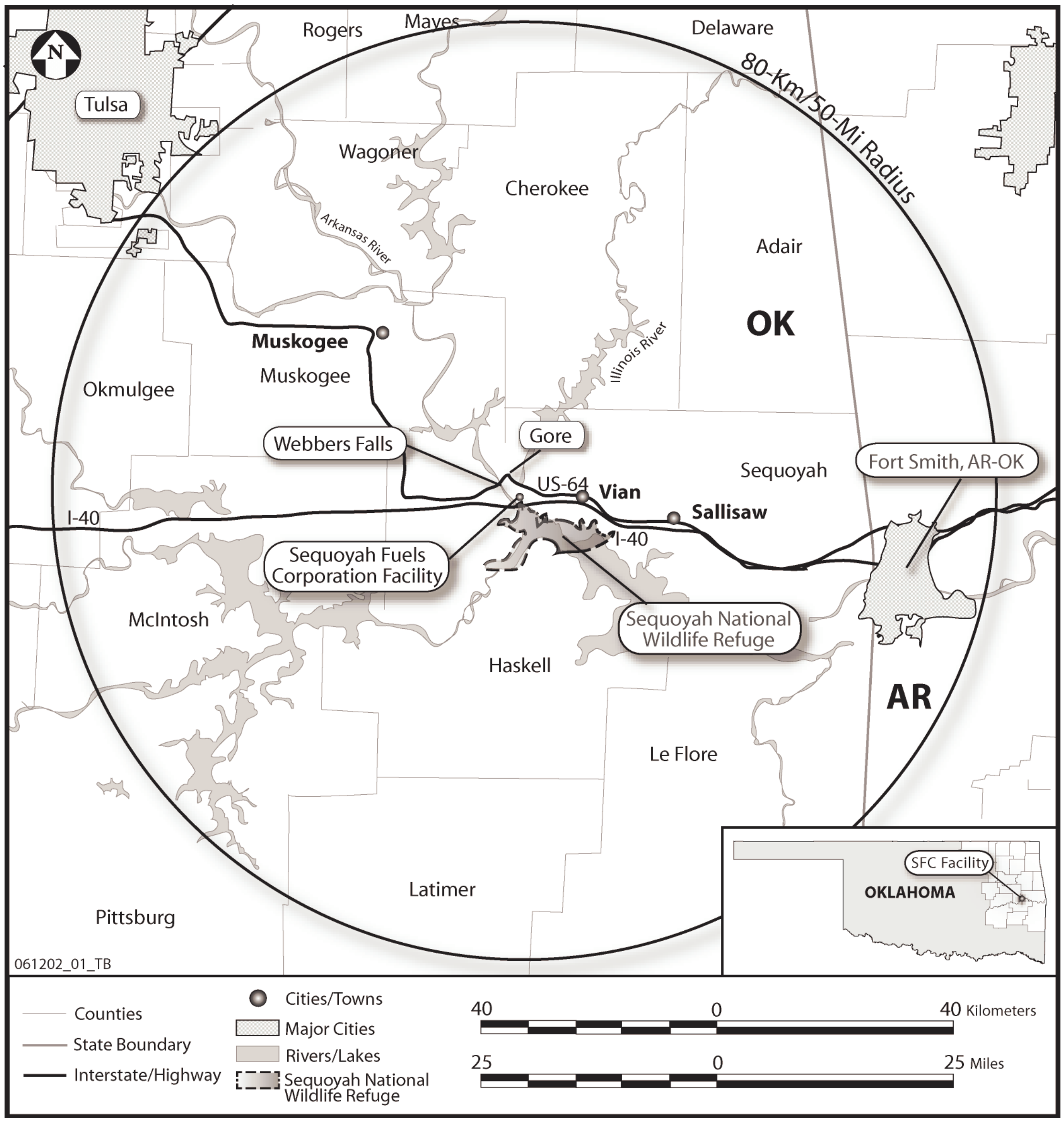


Figure 1-1 SFC Facility Location and Environs

The site is a 600-acre parcel of land containing a 200 acre Industrial Area where the uranium conversion process occurred. The site is bounded on the north by private property, on the east by State Highway 10, on the south by Interstate 40 (I-40) and on the west by U.S. Government-

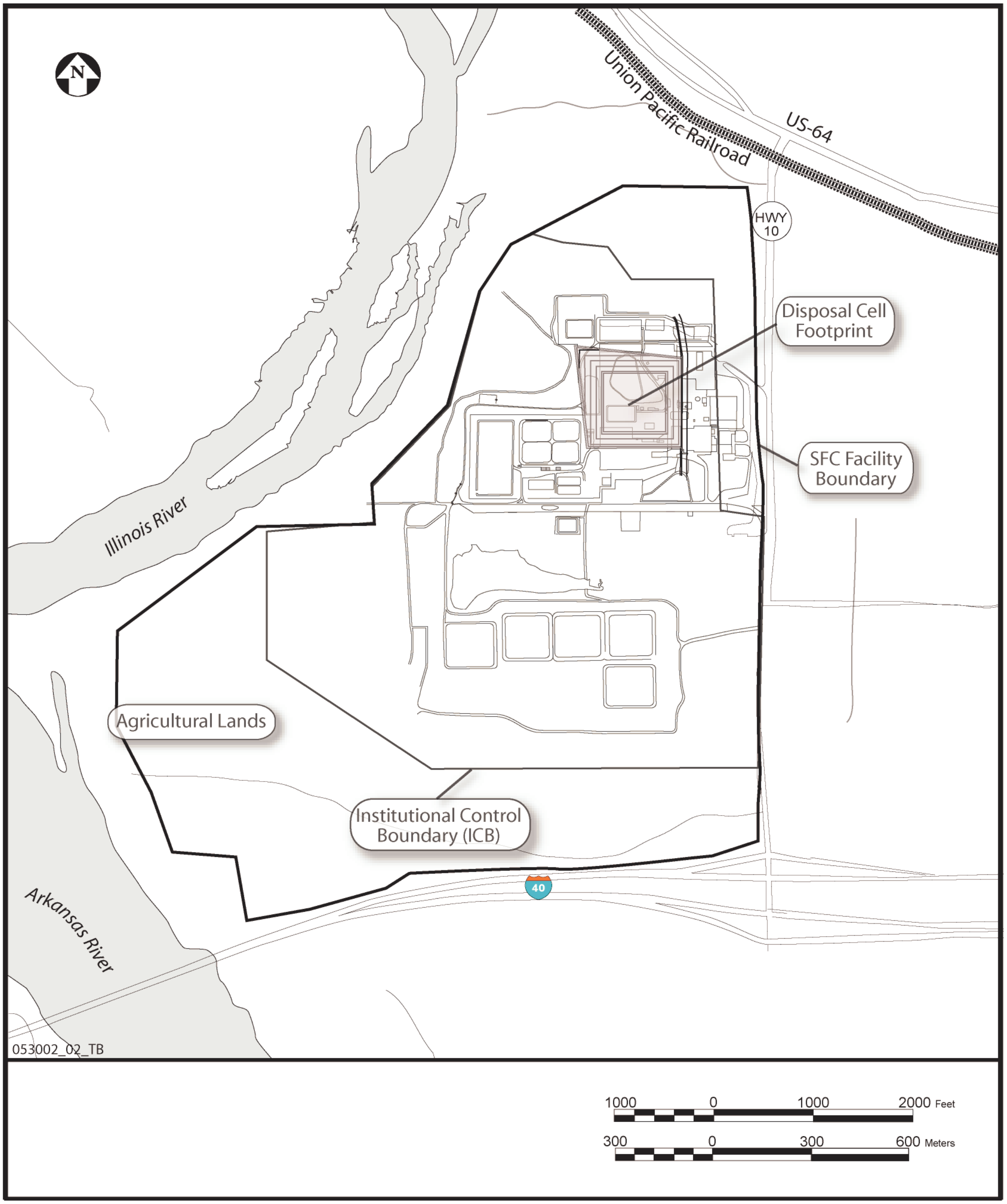


Figure 1-2 The Disposal Cell Footprint and the Proposed ICB at the SFC Facility

owned land managed by the U.S. Army Corps of Engineers (USACE) adjacent to the Illinois and Arkansas River tributaries of the Robert S. Kerr Reservoir.

The site is located above the east bank of the Illinois River at its confluence with the Arkansas River. The site is on the western end of a broad upland area approximately 100 feet above the normal elevation of the Illinois River (as impounded by the Robert S. Kerr Reservoir).

The site is on gently rolling to level land with several steep slopes to the northwest and wooded lands to the north and south. Elevations on or near the site range from 460 feet above mean sea level (MSL) for the normal pool elevation of the Robert S. Kerr Reservoir to nearly 600 feet MSL. Slopes over most of the upland areas of the site are less than seven percent. Steeper slopes in creek ravines and on hillsides average roughly 28 percent. Near the Robert S. Kerr Reservoir, slopes are very steep. This area is owned by the Federal government and is administrated by the USACE.

1.2.2 Description of Facility

Most of the uranium-processing operations were conducted on an 85-acre portion of the site that is referred to by SFC as the Process Area. SFC uses an additional 115 acres to manage storm water and store by-product materials. The reclamation activities will focus on the Process Area and the additional management areas that are collectively referred to by SFC as the Industrial Area. Most of the land outside of the Industrial Area is used either for grazing cattle or forage production.

Prior operations at the Facility can be summarized as follows. The ore concentrates (yellowcake) received at the Facility were subjected to concentration and purification processes. The purpose of these processes was to control the grade of materials entering the conversion process in order to avoid the contamination of the conversion processing system and the production of off-specification material. Following the concentration and purification processes, the materials were transferred to the conversion facility which produced high purity UF_6 using the purified yellowcake as feed material. Also located at the Facility was a separate reduction facility which produced UF_4 using depleted UF_6 as feed material.

In addition to the facilities for concentration and purification, conversion, and reduction, the SFC site also includes: (1) an area where the yellowcake received from conventional uranium mills was stored; (2) a yellowcake sampling facility; (3) an area that was used for bulk storage of chemicals such as ammonia (NH_3), tributylphosphatehexane solvent, and hydrofluoric (HF), nitric (HNO_3), and sulfuric (H_2SO_4) acids; (4) a facility for electrolytic production of fluorine from HF; (5) treatment systems and storage ponds for both radiological and non-radiological liquid effluent streams; and (6) a facility for the recovery and beneficial use of ammonium nitrate solution (which originated from the solvent extraction system) as fertilizer on SFC-owned land. Additional facilities include the following: a yellowcake drum storage area, an electrical substation, UF_6 cylinder storage area, tank farm for liquid chemicals and fuel oil, cooling tower for waste heat dissipation, sanitary sewage facilities, retention ponds for calcium fluoride sludge, retention ponds for processing raffinate into fertilizer and raffinate sludge, a raffinate sludge concentration and loading facility, retention ponds for fertilizer, and a reservoir for an emergency water supply. A general Facility layout is presented in figure 1-3.

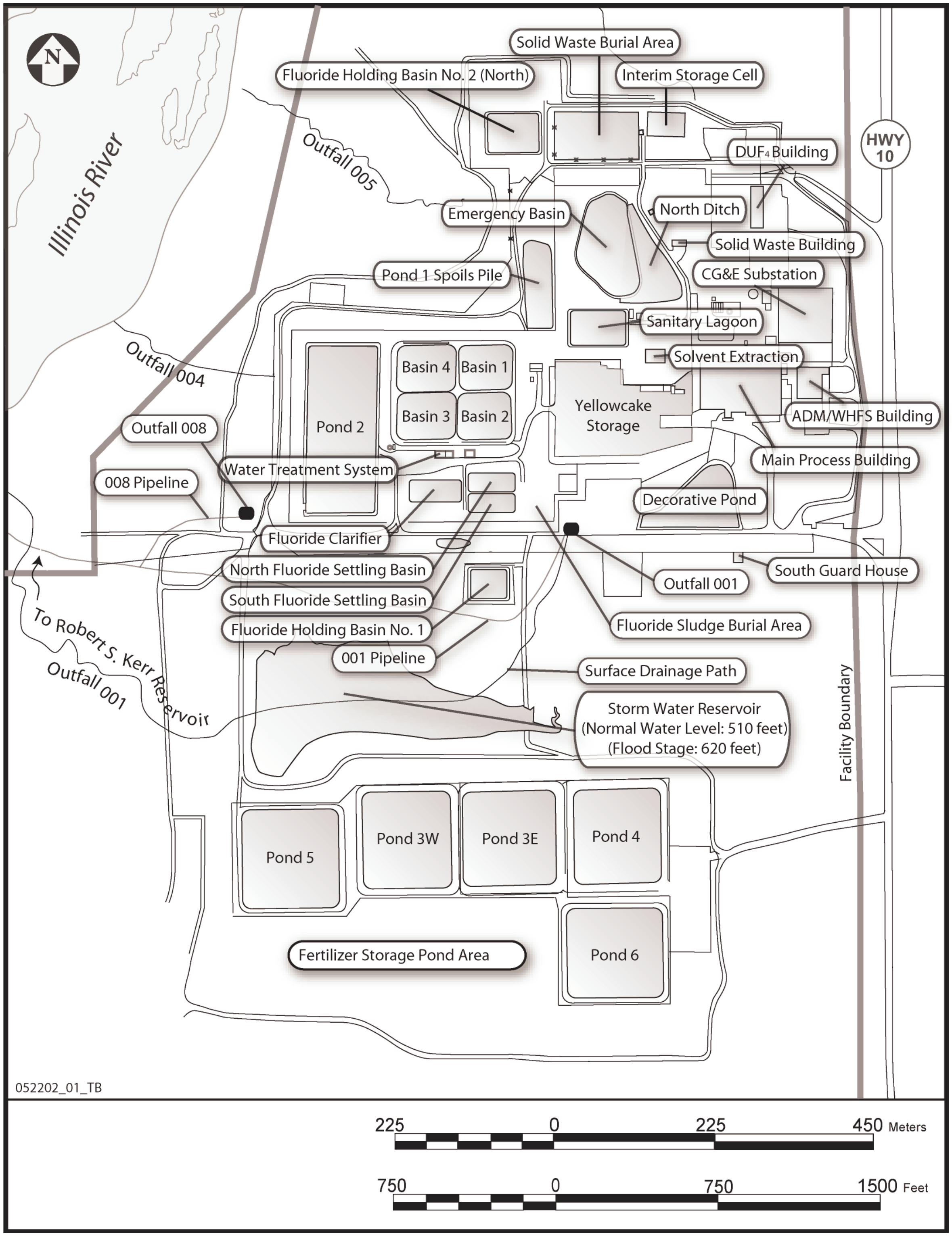


Figure 1-3 The SFC Facility Layout

1.2.3 Description and Characteristics of Waste

The wastes that will be cleaned up and permanently disposed of in the cell are comprised of three categories of materials: 1) rubble and other material from structures, systems and equipment; 2) contaminated materials that have been collected and stored onsite; and 3) contaminated soils.

1.2.3.1 Structures, Systems and Equipment

After a detailed volume estimate of the facility equipment and structural materials, the licensee estimated the volume to be disposed of as 824,660 cubic feet. The licensee's estimate was based on a review of drawings and other data for the facility structures, equipment, utilities, and concrete and considers the effect of dismantlement and size reduction and assumes that 50 percent of the concrete will be left in place. The licensee states that majority of the salvageable or recyclable equipment and materials have already been removed and dispositioned and thus only limited decontamination of the remaining materials for unconditional release is planned. All remaining equipment and structures will be dismantled and size reduced, as necessary. The dismantled equipment and structural components will be placed into the cell. Concrete and asphalt will be broken into manageable pieces and placed in the cell.

1.2.3.2 Sludges and Sediments

Several different materials fall into this category.

Raffinate sludge was produced, as a waste, during the operation of the SFC facility. Approximately 1,000,000 cubic feet of sludge, containing 15 to 20 percent solids, was stored in three hypalon-lined impoundments on the site (identified as the Clarifier Basin). The raffinate sludge contains a significant fraction of the radionuclides presently on the SFC site (34 percent of the uranium or 60,800 kg, 76 percent of the thorium 230 or 156 Ci, and 38 percent of the radium 226 or 1.1 Ci). Additionally, the sludge contains various metals. A detailed description of the characteristics of the sludge is provided in Tables 1, 2, and 3 of Enclosure 1 to SFC's January 7, 2004, request to dewater the sludge. That request was approved by NRC on January 26, 2005, and the dewatering is currently proceeding. The de-watering method will remove free water from the sludge resulting in a 50 percent reduction in the weight to approximately 15,000 tons of de-watered sludge. The de-watered sludge is being placed in polyproylene bags and stored on the South Yellowcake Pad prior to placement in the disposal cell.

Calcium fluoride (CaF_2) sludge resulted from the lime neutralization process. The licensee stated that it will be dewatered to improve its structural strength prior to placement into the disposal cell, but has not described the dewatering method to be used nor the criteria to be used to determine if adequate structural strength has been achieved - **this is an open issue; see Section 3.6.1 for a more detailed discussion of this open issue**. In addition to CaF_2, the licensee estimated the sludge contained uranium in a concentration of 0.032 percent by weight, radium-226 in a concentration of approximately 1.0 pCi/g, and thorium-230 in a concentration of approximately 188 pCi/g.

Sediments from the Emergency Basin, North Ditch and Sanitary Lagoon will be dewatered or stabilized to improve their structural strength prior to placement into the disposal cell. However, the reclamation plan does not provide any information on the dewatering or stabilization methods to be used or the criteria to determine when adequate structural strength has been achieved - **this is an open issue; see Section 3.6.1 for a more detailed discussion of this open issue**.

1.2.3.3 Contaminated Soils

Soils outside the footprint of the disposal cell which contain uranium, radium, or thorium in excess of the proposed site-specific cleanup criteria will be excavated and placed in the disposal cell. The cleanup criteria for soils are 100 pCi/g for uranium, 5 pCi/g for radium, and 14 pCi/g for thorium at the surface. See Section 6.3.3 for further details. Soils under the footprint of the disposal cell that exceed 560 pCi/g uranium (the concentration that would result in an equivalent dose from Ra-226 at 5 pCi/g) will also be excavated, and placed in the cell. Additional soil will be excavated (most likely to the soil/bedrock interface) in those areas where the uranium concentration in the perched groundwater is elevated in excess of 150 pCi/l (the SFC license action level, 225 µg/l) to facilitate the removal and treatment of the impacted perched groundwater. It is likely that some of the soils in the areas of perched groundwater impact contain uranium in the forms of uranyl nitrate and related compounds, which are much more soluble than the oxide forms.

Soils collected from prior cleanup activities that are presently located in the Interim Storage Cell and in the Pond 1 Spoils Pile will also be removed and placed in the disposal cell. The licensee states that these materials have a volume of about 578,000 cf. The licensee estimates that an additional 952,000 cf of potentially contaminated clay and soil lies beneath the facility ponds, basins and clarifiers. The licensee estimates the fraction of this soil exceeding the applicable cleanup criteria to be less than 10 percent of the total volume, or 95,200 cf.

1.3 Site History and Proposed Action

From 1970 through 1992, the SFC facility converted yellowcake (U_3O_8), which was received from uranium mills, to uranium hexafluoride (UF_6). The production of UF_6 is an important step in the nuclear fuel cycle leading to the production of fuel elements for nuclear reactors. From 1987 to cessation of operations in 1993 the SFC facility also converted depleted uranium hexafluoride (DUF_6) tailings from the DOE gaseous diffusion process to a more stable form - DUF_4.

There have been some significant accidents resulting in offsite releases during the period the facility was operating. On January 4, 1986, a plume of UF_6 gas was released into the atmosphere as a result of a ruptured cylinder. The NRC estimated that 6,700 kg (14,750 lbs) of UF_6 were released during the accident (NRC, 1986). The release of UF_6 and its reaction products, uranium dioxide difluoride (UO_2F_2) and hydrogen fluoride (HF), formed a dense white cloud that engulfed the main process building and formed a plume expanding to the south-southeast. The releases lasted for about 40 minutes. One employee died and some workers were hospitalized as the result of exposure to hydrogen fluoride, a chemical that results from the interaction of UF_6 to vapors in the air.

On November 17, 1992, a chemical accident occurred that resulted in the airborne release of approximately 2,970 lbs of gaseous nitrogen oxide gases (NO and NO2, also referred to as NOX) over an 18-minute period. There were no other chemical or radioactive constituents released during this event. As a result of this accident, 27 workers at a tree farm approximately 1 mile downwind of the facility were injured and received medical evaluations. Several workers were treated for inhalation of NOX and released. Within less than an hour, the NOX was diluted and dispersed into the air by the wind to non-detectable concentrations.

On February 16, 1993, SFC notified NRC that it intended to cease operations at the facility. On July 7, 1993, SFC notified NRC that all operations with licensed material ceased on July 6, 1993, and that all activities onsite were limited to those necessary for decommissioning. As the calculated doses of radioactive contamination exceeded NRC's criteria for allowing license termination (10 CFR Part 20, Subpart E), the SFC site required decommissioning.

In February 1993, SFC submitted a Preliminary Plan for Completion of Decommissioning that indicated that decommissioning of the facility would include construction of an on-site disposal cell using the performance criteria contained in Appendix A to 10 CFR 40 to isolate the waste.

In July 1997, NRC adopted new regulations that established radiological criteria for license termination which included restricted release. Under these criteria, in March 1999 SFC submitted a decommissioning plan proposing an onsite disposal cell meeting the performance criteria in Appendix A of 10 CFR 40 with restricted release of the site once decommissioning activities were completed. During its review of the plan, NRC expressed concern that SFC had not identified a third party that would accept responsibility to enforce the proposed institutional controls. As this was a significant requirement for approval of a restricted release decommissioning plan and SFC was having difficulty finding an appropriate entity to perform this function, the viability of the SFC plan was in question.

On January 5, 2001, SFC requested that NRC determine if some of the waste material at the site could be classified as byproduct material, as defined in Section 11e.(2) of the Atomic Energy Act. SFC argued that the waste produced during the concentration and purification of yellowcake (which comprise most of the waste on the site) meets the definition of 11e.(2) byproduct material. The regulations governing reclamation of an 11e.(2) site with an onsite disposal cell also require a long-term custodian responsible for surveillance and maintenance of the site. That role can only be performed by the State in which the site is located (Oklahoma in this instance) or DOE. However, by law, DOE must accept the role of custodian if the State declines. After review of the matter, the Commission concluded (and reaffirmed upon an appeal) that the front-end waste at the SFC facility could be classified as 11e.(2) byproduct material, and that such waste may be disposed of in accordance with Appendix A to 10 CFR 40. SFC subsequently submitted a license amendment request to possess 11e.(2) byproduct materials which was approved on December 11, 2002.

On January 28, 2003, SFC submitted a reclamation plan for the site. The proposed action is approval of the SFC reclamation plan of January 28, 2003 as amended by revisions dated August 8, 2003, August 29, 2003, February 17, 2004, and April 12, 2005. As identified by SFC, the proposed reclamation (note that clean up of existing ground water contamination is not considered as part of reclamation but is instead considered separately in the ground water corrective action plan) consists of the following elements:

• Construction of an above-grade, engineered disposal cell on the SFC site for permanent disposition of the SFC decommissioning and reclamation wastes.

• Removal of sludges and sediments from the ponds and lagoons, excavation of buried low-level wastes, removal of stored soils and debris, and placement of these materials into the disposal cell.

• Dismantlement of process equipment, followed by recovery of gross quantities of contained uranium.

• Size reduction/compaction of process equipment, piping and structural materials (including scrap metal, empty drums, and packaged wastes that will accumulate prior to decommissioning) to satisfy disposal requirements for maximum void volume.

• Dismantlement/demolition of structures except for the new SFC administrative office building and the storm water impoundment.

• Demolition of concrete floors, foundations and storage pads and asphalt or concrete paved roadways outside the footprint of the cell.

• Removal of clay liners and/or contaminated soils from under impoundments.

• Excavation of underground utilities, contaminated sand backfill from utility trenches and building foundation areas and more highly contaminated soils under the cell footprint.

• Excavation of contaminated soils lying outside the footprint of the disposal cell that exceed site-specific radiological cleanup criteria.

• Handling and treatment of produced ground water and storm water during cell construction.

• Placement of all SFC decommissioning wastes into the onsite disposal cell, followed by capping and closure of the cell.

• Re-grading the site, backfilling of excavations to the finished grade, and re-vegetation.

SFC proposes to build a disposal cell in the Process Area (see Figure 1-2). The cell will be a four-sided, domed structure, with a soil cover. The contaminated material will be placed in the cell in four layers, with the higher activity material nearer the bottom and less radioactive material near the top. Depending on the volume of material excavated during soil cleanup, the cell may hold from 5 million to 12 million cubic feet of waste. The waste will be underlain by a clay layer with a synthetic liner above providing additional seepage control. The contaminated material will be covered by a clay layer with a synthetic liner above the clay. Eight feet of earthen material will be placed above the synthetic cover material. The cover will be vegetated. The top will slope to the southeast at one percent. The side slopes will incorporate a rock mulch layer for erosion protection and have a 20 percent slope. The maximum height of the completed cell will be 30 to 50 feet above the surrounding ground elevation, depending on the volume of waste emplaced.

As the footprint of the proposed disposal cell overlaps areas where contaminated material must be removed for disposal in the cell, SFC proposes to build the cell in three stages. The first stage will be built on an uncontaminated area and contaminated material from areas to be covered by the later stages will be removed to completed sections of the cell prior to cell construction in those areas.

1.4 Review Process and SER Organization

The NRC staff review of the reclamation plan was performed in accordance with the Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (NUREG-1620, Final Rev. 1, 2003) and is a comprehensive assessment of SFC's reclamation plan as documented by this SER. Appendix A to 10 CFR Part 40 contains the technical requirements for disposition of 11e.(2)

byproduct material. The SER, following NUREG-1620, is organized by the technical disciplines involved in the assessment of the reclamation plan to assure compliance with Appendix A. Each SER section describes the compliance with the applicable criteria in Appendix A as it pertains to the specific discipline addressed in that section. NUREG-1620 provides a cross-walk of the technical criteria in Appendix A with the technical evaluations performed in accordance with NUREG-1620.

Sections 2, 3, and 4 provide the technical basis for the NRC staff's conclusions with respect to long-term stability, by addressing geologic, seismic, geotechnical, and surface erosional aspects of long-term stability. Section 5 addresses the reclamation plan's compliance with ground-water standards and Section 6 addresses radiation protection including radon emanation control. Section 7 addresses SFC's proposal to include in the cell, the onsite radioactive waste that can not be classified as 11e.(2) byproduct material.

1.5 Open Issues

The NRC staff review of the reclamation plan identified a number of issues that have not been adequately resolved through previous rounds of questions and requests for information. These open issues are given in Table 1-1. Until these open issues are adequately resolved, the staff cannot support the issuance of a license amendment approving the reclamation plan.

Table 1-1: Open Issues

Open Issue	Section
1. The licensee needs to provide an analysis regarding the potential for Stream 005 to encroach upon the foot or apron of the proposed cell.	2.4.2
2. The licensee needs to provide information characterizing the shear strength of the colluvium if such information is needed to resolve the open issue regarding the stability of the natural slopes identified in Section 3.3.	3.2.1.1
3. The licensee needs to provide an evaluation of the stability of the natural slopes under seismic and long-term static conditions.	3.3.1
4. The licensee needs to provide technical specifications for the synthetic liner at the base of the cover system consistent with information used in the licensee stability analysis.	3.3.2
5. The licensee needs to provide particle size specifications for the synthetic liner bedding and cover materials consistent with information used in the licensee's stability analysis.	3.3.2
6. The licensee needs to provide its proposed approach to addressing the compaction specification for the disposal-cell subgrade.	3.4.1
7. The licensee needs to provide its proposed approach to addressing placement and compaction specifications for layer-C material and soils placed around such structural materials.	3.4.2
8. The licensee needs to provide its proposed approach to addressing placement specifications for any crushed structural materials, such as piping or tanks.	3.4.2

9. The licensee needs to provide an evaluation of potential disposal-cell settlement.	3.4.3
10. The licensee needs to provide an evaluation of potential cracking damage to the cover system owing to differential settlement of the cell.	3.4.3
11. The licensee needs to provide its proposed approach to controlling potential settlement of the disposal cell through settlement monitoring.	3.4.3
12. The licensee needs to provide an analysis of potential instability of the disposal cell from liquefaction of the cell foundation.	3.5.1
13. The licensee needs to provide material and placement specifications for the liner bedding and cover layers to ensure the completed liner bedding and cover will protect the liner from cutting or tearing and provide for free drainage of seepage water along the liner top surface.	3.6.1
14. The licensee needs to provide specifications for the dewatering of calcium fluoride sludge and sediments from the emergency basin, north ditch, and sanitary lagoon; and the placement of such materials in the disposal cell.	3.6.1
15. The licensee needs to revise the technical specifications to include restrictions to protect the liner and cover during construction.	3.7.1
16. The issue of representing flow in fissures and desiccation cracks in the infiltration model is yet to be resolved.	3.8.2
17. The licensee needs to provide analysis of rock size for the riprap apron.	4.5.1.2
18. The licensee needs to provide a design of the rock apron to protect against gullies caused by overland flow.	4.5.1.2.1
19. The licensee needs to provide a design of the rock apron on the east side of the cell to accommodate high flows.	4.5.1.2.2
20. The licensee needs to provide a design for rock armor protection of stream 005.	4.5.1.3
21. The licensee needs to provide specifications for riprap rock gradation.	4.5.2
22. The licensee needs to provide information necessary to show that rock of acceptable durability will be used for flood protection.	4.5.3
23. The licensee needs to provide information regarding the licensee’s erosion protection testing, inspection, and quality control program.	4.5.4
24. The licensee needs to provide information regarding the licensee’s rock durability testing program.	4.5.4.1
25. The licensee needs to provide information regarding the licensee’s riprap placement procedures.	4.5.4.3
26. The licensee needs to provide information regarding the licensee’s rock layer thickness testing.	4.5.4.4

27. The licensee needs to provide information regarding the adequacy of the soil cover to resist wind erosion.	4.5.5
28. The licensee needs to resolve conflicts in the reclamation plan regarding hydraulic connection between the terrace and shallow ground-water systems.	5.2.2.2
29. The licensee needs to provide information to show that the liner cover material will comply with standard filter design criteria to prevent piping and promote drainage.	5.3.2
30. Detection monitoring along the west side of the disposal must be addressed.	5.4.1
31. The licensee must specify and justify the saturated zones that will be monitored by the detection monitoring system.	5.4.2
32. The licensee must provide information to show that the proposed detection monitoring system will be capable of detecting leaks in the disposal cell, as required by Criterion 7A of Appendix A.	5.4.4
33. The licensee must describe the manner in which it will identify potential hydraulic conduits below the disposal cell and how it will address the risk of further contamination to the shallow ground-water system.	5.4.4
34. The licensee must provide a sampling plan to provide data to justify the source term values used for the upper 15 feet of contaminated material in the radon flux calculations.	6.2.2.1
35. The licensee must either provide the borrow material radiological data, or commit to testing the placed upper two feet of cover, and compare the results to established site background radionuclide levels.	6.2.3
36. The licensee must provide the gamma-radium correlation graph and indicate the gamma guideline value and its use. The licensee must also provide the Ra-226 to Th-230 correlation if it plans to use it.	6.3.4
37. The licensee must describe the gamma survey procedure for soil verification indicating the speed and spacing of the readings or scan path, and discuss how management oversight of field personnel will be adequate to provide reliable survey data.	6.3.5
38. The Data Management Plan and QAPP procedure must be summarized in some detail in the reclamation plan and be available for NRC staff review during decommissioning.	6.3.6
39. The licensee must demonstrate that a single sample result is representative of the entire grid (i.e., radionuclide concentration is fairly homogeneous for the area).	6.3.7
40. The licensee must identify the location where the records of information important to decommissioning are kept, as required by §40.36(f).	6.3.8
41. The licensee must address the non-radiological hazardous constituents of the byproduct material to comply with Criterion 6(7).	6.3.9

42. The licensee needs to provide documentation from EPA and the State of Oklahoma that they do not have regulatory authority over the non-11e.(2) byproduct material.	7.3

1.6 Confirmatory Items

The NRC staff review of the reclamation plan identified several instances in which the licensee had agreed to revision of the reclamation plan but has not formally provided that revision. These items, which the staff considers to be confirmatory items, are given in Table 1-2. Confirmatory items must be resolved before the staff can support the issuance of a license amendment approving the proposed reclamation plan.

Table 1-2: Confirmatory Items

Confirmatory Item	Section
1. The licensee needs to revise figures to show that the terrace ground-water system consists of both the terrace deposits and Unit 1 Shale.	5.2.2
2. The licensee needs to include arsenic background water quality data in the reclamation plan.	5.2.4
3. The licensee needs to remove references to transplanting seedlings in the reclamation plan.	5.3.1
4. The licensee needs to include the grain size distribution for the liner cover material in the reclamation plan.	5.3.2
5. Monitoring well construction details must be added to the Technical Specifications or incorporated into the reclamation plan by reference.	5.4.2
6. The licensee must revise the reclamation plan to incorporate its commitment regarding radioactivity levels in the upper part of the cover.	6.2.3
7. The licensee must revise Appendix G as it indicated in Sequoyah Fuels Corporation, 2005a.	6.3.3
8. The licensee must include soil sampling procedures and analytical methods in the reclamation plan.	6.3.5
9. The licensee must revise the final status survey plan as it indicated in Sequoyah Fuels Corporation, 2005a.	6.3.7

2.0 GEOLOGY AND SEISMOLOGY

2.1 Introduction

The SFC site is located in a relatively tectonically stable part of the North American tectonic plate, the craton. It's in a tectonic province called the Ozark Uplift, adjacent to the Arkoma Basin. Rocks and sedimentary deposits in the province and at the site have been uplifted, tilted, faulted, fractured and subjected to earthquakes. The average rates of these geologic processes are likely to continue over the design lifetime of the proposed facility (i.e., 200 to 1,000 years). The rates of the processes or potential effects of regional uplifting and tilting on, and the magnitude of on-site changes to, faults and fractures over the next 1,000 years are expected to be sufficiently small, or relatively inconsequential, as to not be considered quantitatively in the design. However, the province has been subjected to low-moderate earthquake activity since records of earthquakes have been available. SFC has considered potential ground motions in the facility design commensurate with the assumption compatible with the prevailing regional tectonic model of the province that the recent and current level of seismicity will persist.

The site includes part of the eastern flood plain and adjacent undulating upland of the Arkansas and Illinois Rivers at their confluence, southeast of Gore, Oklahoma. Streams drain the upland slopes toward the rivers. The streams and slopes facilitate conditions of erosion that the SFC has considered in its reclamation plans. The potential effects of one stream on the proposed reclamation cell of one stream bears further analysis.

The geology of the site is essentially bedrock of gently-southwesterly-dipping layers of alternating sandstone and siltstone (exposures of the Atoka Formation) underlain by carbonates (at the site - in boreholes beneath the Atoka Formation), partially covered by sediments (Terrace Deposits; alluvium) and soil, all of which lie on top of Precambrian basement rocks (described from the literature by SFC). The layer-cake stratigraphy of the SFC site is best depicted on cross sections in figure 11 of the reclamation plan. A detailed geologic map showing the distribution of 8 bedrock units is in figure 15 of SFC's Draft Site Characterization Report (SFC, 1996).

In addition to the reclamation plan, supporting documents (e.g., consultant reports, letter correspondence between NRC staff and SFC, draft documents, and original SFC geologic maps) describe the regional and site-specific geologic and seismologic information related to the reclamation cell and its design, including regional and site-specific stratigraphic features, structural geologic and tectonic features, geomorphic features, and seismology and ground motion estimates.

2.2 Stratigraphic Features

2.2.1 Stratigraphic Description

The reclamation plan describes observations of the surface sediments, soils and rock outcrops and subsurface strata from boreholes and core samples, including information about their gently southwesterly-tilted orientation, distribution of sediments and rocks, thicknesses, mineralogical composition, age of deposition, depositional environments, and interrelationships of the interlayered sandstones, siltstones and shales of the Atoka Formation (Pennsylvanian Period), and the overlying sedimentary deposits (Quaternary Period). The overlying sedimentary deposits form a discontinuous veneer of paleo-terrace and recent alluvial deposits associated with the ancestral and modern Illinois and Arkansas River systems, colluvial deposits associated with steeper slopes around the site, and soils. These are described in the reclamation plan, Section 3.3.2.

The licensee has provided an acceptable description of the stratigraphic features of the site and regional stratigraphy using published information for the region and original information collected for the specific purpose of supporting surface and ground water analyses at the site. Data gathering, investigations, and analyses have used acceptable standards and practices regarding the characterization of lithostratigraphic information from field observations, lab analyses and borehole and core tests and measurements. Lithostratigraphic data and interpretations of such data are presented to allow effective incorporation into surface and ground-water hydrostratigraphic model units and analyses of the model results.

The licensee identified 10 hydrologic layers that are correlated with lithologic units for which the following parameters are briefly described: thickness, lateral continuity, degree of fracturing of sandstones including fracture spacing, fracture width, fracture-fill compositions, mineralogy of the sandstones, shales and sediments, texture, grain size, and other attributes of the sediment and rock strata. These properties and the results of hydrologic tests and measurements are used to describe and explain the surface and ground-water hydrology. The staff independently developed a 3-dimensional hydrogeologic model from the SFC data and generally corroborated the hydrologic model units described by SFC (Stirewalt and Shepherd, 2004).

The staff observed the interbedded nature of the sandstone and shaley-silty rock units on a field trip. Two controls on flow were also observed in the field. One is that the shaley-silty units were more conductive than the sandstones. The other is that the flow was focused along the bedding and planes of fissility in the shaley-silty units. The staff found SFC's stratigraphic descriptions derived from hundreds of monitoring wells, boreholes and field observations sufficient for its review.

2.2.2 Evaluation Findings

The staff has completed its review of the characterization of the regional and site stratigraphy at the SFC Gore, Oklahoma, site. This review included field observations of the Atoka Formation in the site vicinity and an evaluation using the review procedures in Section 1.1.2 and the acceptance criteria outlined in Section 1.1.3 of NUREG-1620, Rev.1 (NRC, 2003).

This review determined that characterization of site and regional stratigraphy is adequate to support technical bases used in the reclamation plan.

On the basis of the information and analysis presented in the reclamation plan on the stratigraphic features at the SFC site, the NRC staff concludes that the description of the geologic formations of the site is sufficient to meet the requirements of 10 CFR Part 40, Appendix A, Criterion 5G(2), with regard to the extent to which they are likely to affect future transport of contaminants and solutions.

2.3 Structural and Tectonic Features

2.3.1 Description of Structural and Tectonic Features

The SFC site is located in the interior of the North American craton on the southwestern flank of a tectonic province known as the Ozark Uplift (Arbenz, 1956). The Uplift continues to be incised and denuded by streams that expose sedimentary rocks in the site vicinity that are mainly sandstones and shaley-siltstones. The layered rocks are tilted gently southwestward, generally up to four degrees or so. In addition to tilting, the layers have been subjected to faulting (primarily normal faults), broad folding, and fracturing. The strike of the faults and fold axes is generally northeastward. None of the faults that have been identified at the ground surface in the tectonic province is associated with a recorded earthquake. However, the Uplift is subjected to earthquakes of low to moderate magnitudes likely caused by buried faults which create a "background" seismic hazard that has been described and considered by SFC in its reclamation plan design (see Section 2.5 for further discussion).

The staff reviewed the information submitted by the licensee, and in addition, visited and interviewed geoscientists in the offices of the State Geologist, the State Seismologist, and obtained and reviewed additional reports. The staff also visited and interviewed the licensee's geologist and made independent observations of rock outcrops and evidence of faults on and in the vicinity of the site.

The SFC site is in the transition zone between the Ozark Uplift and the Arkoma Basin (Luza and Larson, 1981). The regional structural bedrock framework of the site is one of gently, southwestwardly-dipping Late Paleozoic sedimentary rocks (striking in the general direction of N 65 degrees west, dipping about 4 degrees southwest). The Paleozoic rocks are disrupted by northeast-trending normal faults (extensional features) and open folds (compressional features) (Arbenz, 1956; Van Ardsdale, 1998). Instrumentally recorded seismicity in Oklahoma through March 2005, for events larger than magnitude 3, indicate low to moderate seismicity within 100 km (160 mi) of the site, with epicenters not attributable to any specific faults mapped on the surface (LaForge, 2005).

The Carlile School Fault (CSF), the fault closest to the site, is shown to intersect the Marble City Fault (MCF) on one map, but not on another map. Both maps were submitted by SFC (SFC, 1996, figure 9; and figure 3.2 in the reclamation plan, Appendix E). Also, a cross section showed that parts of the South Fault of Warner Uplift and the CSF are a few kilometers deep and do not penetrate the granitic basement rocks (SFC, 1996, figure 11). The fault lengths, fault-zone widths, depths, and connectivity of the faults on the SFC maps and cross sections are not well constrained, and vary from map to map. This is due to a dearth of data that may only be derived from better exposures, borehole penetrations and geophysical surveys. However, these and other discrepancies have been satisfactorily explained by SFC (Harlin, 1998). Faults associated with the South Fork of Warner Uplift and the CSF are shown on the geologic map of Webber Falls area (reclamation plan, figure 5 of Appendix D) and the site vicinity map of Carlile School Fault (ibid., figure 6).

Other map sources of fault information submitted by SFC, or that the staff consulted, include the tectonic map of Oklahoma (Arbenz, 1956), Hydrologic Atlas Map HA-1 (Marcher, 1969), geologic map of Webber Falls area (Chenoweth, 1983), and the trace map of the CSF (Van Arsdale, 1998). Of the faults on these maps, the Chenoweth map and others submitted by SFC based on SFC's own or its consultants' investigations are most relevant to the capable fault investigations. The SFC-sponsored maps have some bases to support them, whereas, the smaller scale State maps do not appear to have bases traceable to observations of the geology made in the vicinity of the SFC site. Therefore, the staff review relied more heavily on the observations and interpretations of local geology and local features of faults reported in the SFC reports and maps than on State reports and maps.

The SFC site and vicinity must be investigated for earthquake sources that might impose a seismic hazard to the planned facility. Faults are the principal source of earthquakes. Faults that are potential sources of earthquakes may be identified from evidence of movement, association with recorded earthquakes, or by structural association with known active faults. If a fault has one or more of the following characteristics, it is called a “capable fault,” is a potential hazard to the planned facility, and must be investigated in detail: (a) movement at or near the ground surface al least once in the past 35,000 years, or more than once in the last 500,000 years; (b) earthquake recordings that clearly show a relationship to a particular fault; (c) a structural relationship to a capable fault such that movement on one could be reasonably expected to be accompanied by movement on the other (10 CFR Part 100, Appendix A, definition (g)). In the absence of capable faults that dominate the seismic hazard, the seismic hazard is determined from investigations of the historic earthquakes of greatest intensity in the tectonic province, and assuming these earthquakes occur at the site. The staff considers that the faults within eight kms (5 mi) of the site are not capable faults. SFC assumes that virtually all known faults up to 200 kms (62 mi) from the site are capable faults. This assumption and consequences are discussed in Section 2.5.

The faults on and around the SFC site that were investigated specifically by SFC as candidates for capable faults include: (1) faults associated with the South Fault of Warner Uplift (observed at the dam a few kilometers upriver from Webbers Falls, OK); (2) the Carlile School Fault and an east-west splay of the “Carlile Fault” (an alternate name of the Carlile School Fault) near the southern boundary of the SFC property; and (3) the Marble City Fault and its splay. These are all shown in SFC’s Site Characterization Report (Appendix E of the reclamation plan).

2.3.2 Evaluation of Faults

Faults associated with the South Fault of Warner Uplift (SFWU): This fault was observed in the cliff face below the Webbers Falls lock and dam on the Arkansas River a few kilometers northwest of Gore, Oklahoma. There is no evidence that suggests this fault is a capable fault.

Evaluation of the Carlile fault, or Carlile School Fault (CSF) as a seismic source: The trace of the CSF was observed by NRC staff to be marked by a rubbly, vegetated ridge up to about 3.6 m (12 ft) in relief and up to about 1.6 km (1 mi) long. Chenoweth (1983) and Van Arsdale (1998) both show the CSF to be about 1.6 km (1 mi) long, whereas, it is shown to be about 6.4 km (4 mi) long in the draft Site Characterization Report (SFC, 1996, figure 9). The fault has a northeast strike, displacement about 30 m (100 ft) down to the southeast and a moderate dip to the southeast. Van Arsdale (1998) indicates that the fault zone is characterized by rock strata with dips of up to 17 degrees southeast which interrupt the regional southwestern dips of about 5 degrees. The fault does not appear to have any of the criteria of a capable fault. The absence of disruption of Quaternary (the last 2 million years or so), or Holocene (the last 10,000 years or so) sediments and soils that veneer the fault zone (Van Arsdale, ibid; and SFC, 1996, figure 10), and the lack of steep scarps, mitigates against displacements in the Late Quaternary Period. On the criterion of macroseismicity, there is no definitive alignment of instrumentally-recorded seismic events on the CSF (e.g., Lawson and Luza, 1995). On the criterion of structural relationship with a capable fault, the CSF is not connected to a known capable fault (it may be connected to the MCF, which is not considered to be a capable fault). Therefore, the CSF is considered not to be a capable fault, and it need not be investigated in further detail for the purpose of ascertaining the seismic design basis.

The licensee’s explanation for the east-west splay of the CSF that appears in Harlin (1998; attachment 1, dashed line) is adequate. Therefore, the east-west splay, the only fault that has been suggested to occur within the site boundary, appears to have little basis in fact, and need not be considered in establishing the seismic design basis.

Evaluation of the Marble City Fault (MCF) as a seismic source: The trace of the MCF near the SFC site has not been located consistently by SFC (e.g., Chenoweth, 1983; and figure 3.2 in Appendix E of the reclamation plan). No direct observation of this fault has been reported by SFC. Negative evidence of activity on the fault derived from reviews of previous fault investigations and historical seismicity in the region suggests that the MCF is not a capable fault because it does not meet any of the criteria of a capable fault. That is, (i) there is no single displacement recognized as less than 35,000 years old, nor two or more displacements in the last 500,000 years (Shannon and Wilson, 1975); (ii) there is no macro-seismicity associated with it (Lawson and Luza, 1995; and updates and NRC staff interviews with State Seismologist, K. Luza); and (iii) absence of a structural relationship to a known capable fault (Shannon and Wilson, 1975). Therefore, no additional information about the MCF is needed for the purpose of ascertaining the seismic design basis for the SFC site.

Evaluation of faults as ground water flow paths: No surface faults have been identified on site or along the hydrolgic gradients toward the north, west, and south. The CSF is shown in a geologic cross section to be at depth greater than 486 m (1600 ft) and intersecting or close to intersecting monitoring wells 2332 and 2307 (SFC, 1996, figure 11). There is no clear evidence of faulting reported from subsurface investigations, or observations from boreholes or drill core reported by the SFC.

Evaluation of future uplifting, tilting and fracturing of the rocks at the site: In the absence of evidence of significant changes since the Quaternary Period in (a) uplift rate of the terrain at the site and vicinity, (b) tilting of sedimentary deposits, and (c) fracture characteristics, these processes need not be considered in the facility design. The staff presumes that these processes are on-going and their cumulative effects in the next 1,000 years will not significantly change conceptual models of the site conditions to such an extent that the licensee’s analyses of stratigraphic features, geomorphic, faulting, and seismic hazards would be significantly adversely changed.

2.3.3 Evaluation Findings

The staff has completed its review of the characterization of structural and tectonic features at the SFC site. This review included an evaluation using the review procedures in Section 1.2.2 and the acceptance criteria outlined in Section 1.2.3 of NUREG-1620, Rev.1 (NRC, 2003).

The licensee has acceptably described the regional and site-specific structural and tectonic features by presenting discussions and interpretations of pertinent data and reports that may have impact on the site or reclamation system, commensurate with their importance to design. Information presented includes descriptions of faults or potential faults on and adjacent to the site, and general descriptions of fractures in sandstones in the Atoka Formation that underlies the site. The closest known capable fault, the Meers fault, is about 300 km (186 mi) to the southwest (LaForge, 2005). There are no known active faults within 100 km (62 mi) of the SFC site (LaForge, 2005). The licensee used generally acceptable methods of investigation and analysis to support its conclusions.

The reclamation plans and supporting documents adequately describe the surface and subsurface structural and tectonic features of the site in the regional context of the Ozark Uplift, including faults, folds, and tectonic provinces, and an interpretation of their origin, distribution, age, and potential impacts on site stability commensurate with their importance to design.

On the basis of the information and analysis presented in the reclamation plan on the structural and tectonic features at the SFC site, the NRC staff concludes that the information is sufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 4(e), have been met. These require that impoundments not be located near a capable fault that could cause a maximum credible earthquake larger than that which the impoundment could reasonably be expected to withstand. Reasonable assurance also has been provided that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1)(i), which requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years, have been met with regard to the potential seismic hazards associated with a capable fault.

2.4 Geomorphic Features

2.4.1 Geomorphic Setting

The SFC site is on an upland surface adjacent to and east of the confluence of the Illinois and Arkansas Rivers on the southwestern flank of the Ozark Plateaus geomorphic province (Thornbury, 1965). This part of the Ozark Uplift contains dissected, generally gently-dipping rock strata capped by the interbedded sandstones, siltstones, and shales of the Atoka Formation, disrupted by northeast-striking, predominantly normal faults and broad folds (see figure 5 of Appendix D to the reclamation plan). The site has a veneer of bedded alluvial sediments - the Terrace Deposit and colluvium, and soil (figure 9 in reclamation plan, Appendix D). The Arkansas River is dammed below the SFC site such that the elevation of the Robert S. Kerr Reservoir at the site is about 146 m (480 ft) above mean sea level (see drawing 5 of Attachment A to the reclamation plan). The site is drained to the north, west, and south by short streams or gullies shown on SFC's maps (e.g., figure 2-5, and drawing 5 in Attachment A of the reclamation plan). There is no similar high-ground or gullying of the terrain across the rivers from the site (U.S. Geological Survey, 1963 and 1974).

The level of the Arkansas River at the site will change when the dams upriver (on the Arkansas and the Illinois) and the dam impounding the Kerr Reservoir are removed, rebuilt, or destroyed. The effects of changes to the base level of these master streams include potential perturbation of the tributary streams and gullies with regard to their ability to incise or extend headward. One of the gullies, designated 005 on reclamation plan figure 2-5, encroaches upon the proposed disposal cell, and is of some concern for its headward erosion potential (see Section 2.4.2 for further discussion of this issue).

The reclamation plan (Section 2.6, and Appendix E, Section 6.0) and letters (e.g., Harlin, 2003) briefly describe the regional and site-specific geomorphic features and the landforms that provide evidence for geomorphic processes that may impact the long-term stability of the site. They include information to support the NRC staff's evaluation of potentially destructive processes such as mass wasting, and stream encroachment.

2.4.2 Stream 005

SFC recognized a potential for Stream 005 (also referred to as gully 005, and as Outfall 005 in Ellis, 1997) to encroach upon the foot or apron of the proposed cell. SFC concluded that gully encroachment will not pose a significant hazard to the cell mainly for these reasons: (1) the current slow rate of erosion because the stream that intermittently occupies the gully is on resistant bedrock; (2) the gully captures too small a drainage area to effect significant headward erosion; and (3) the apron would be sufficient to thwart potential effects of headward erosion during the compliance period. SFC indicated it would consider a mitigation method (Ellis, 2003; Harlin, 2003). The mitigation method suggested by SFC, if needed, would be to emplace an apron of rock mulch and topsoil from the foot of the cell over the head of gully 005. The purpose would be to achieve erosional stability under peak flow conditions from the Probable Maximum Precipitation event. **In the absence of an analysis to support any of the reasons, the staff considers the potential for Stream 005 to encroach upon the foot or apron of the proposed cell to be an open issue.**

If any one of the reasons are substantiated, the issue will be closed. Regarding the first reason, the staff was not provided an analysis on which to evaluate the rates of stream incision or headward erosion in bedrock. SFC discussed the development of the streams during the glacial periods qualitatively (for example, in Section 2.6 of the reclamation plan). An estimate of the average rate of incision and/or extension over the last 10,000 years or so, with technical basis, would be an appropriate baseline for estimating the rates over the next 200 - 1000 years. Also, such stream erosion processes might be significantly affected by long-term lowering (or raising) of the mean annual level of the Kerr Reservoir (for example, the future elimination or ineffectiveness of the upstream or downstream dams might significantly change the gully erosion rate by inducing change in gradient of the gullies). Regarding the second reason, the analysis supporting the correlation of the drainage area to headward erosion capability would need to be explained and evaluated. Thickness and distribution of soil and weathered bedrock - erodability - are factors in such an analysis. Regarding the third reason, an explanation of what the design basis is for an apron over the head of 005 would need to be explained and evaluated, if that mitigation method was considered to be necessary. Additional methods of addressing the issue may be acceptable.

2.4.3 Evaluation Findings

The NRC has completed its review of the information concerning the characterization of geomorphic features at the SFC site. This review included an evaluation using the review procedures in Section 1.3.2 and the acceptance criteria outlined in Section 1.3.3 of NUREG-1620, Rev.1 (NRC, 2003).

The licensee adequately described the geomorphic features by presenting a brief description of regional and site geomorphology using information collected for the specific purpose of supporting determinations of the stability of site commensurate with their importance to design. Data gathering and analyses have used acceptable standards and practices. Data and interpretations are presented to allow an evaluation of potential geomorphic hazards.

The review determined that the information presented is sufficient to support the technical bases used in the reclamation plan and design of the tailings cell regarding the geomorphic stability of the site by mass wasting (e.g., landslides). The staff considers that mass wasting processes acting on the rocks, sediments and soils on slopes outside the cell boundary are volumetrically small and at sufficient distances from the cell as to not pose a significant hazard to the integrity of the proposed cell.

On the basis of the information and explanations presented in the reclamation plan on the geomorphic features at the SFC facility, the NRC staff concludes that the information is insufficient to support a decision with reasonable assurance that the requirements of 10 CFR Part 40, Appendix A, Criterion 6(1), have been met, specifically with regard to the potential effects of headward erosion of gully 005 on the integrity of the edge of the cell, or of any attendant significant radiological releases. Criterion 6(1) requires that the design of the disposal facility provide reasonable assurance of control of radiological hazards to be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

2.5 Seismicity and Ground Motion Estimates

The SFC site is located in the Central Stable Tectonic Province of the United States. The earthquake history of this region includes several small and moderate earthquakes. Small earthquakes appear to be randomly distributed in the region while larger earthquakes throughout the states of Oklahoma, Kansas, and Nebraska show a north-south alignment which was identified by Docekal (1970) as the Midcontinent Seismic Trend.

2.5.1 Technical Information

2.5.1.1 Seismicity

Instrumentally recorded earthquakes in the region are few in number. The hypocenter locations of these earthquakes are generally lacking in precision due to the non-existence of a good crustal model for the region. Therefore, there is a lack of accurate correlation between the earthquakes and faults in the area.

The licensee reviewed the seismic activity in the area from local publications, earthquake data search (Lawson and Luza, 1983, and Luza and Lawson, 1993), earthquake catalog data (National Earthquake Information Center (NEIC) of the U.S. Geological Survey (USGS)), and local geomorphic information. The licensee's review of the records for events within 400 miles (650 km) of the site identified 6 large earthquakes ranging in magnitude from 5.1 to 7.2 (Richter magnitude). Another 61 earthquakes between magnitude 4.0 and 5.0 were identified; all but three events were greater than 140 miles (224 km) from the site. Another set of earthquakes ranging in magnitude between 2.1 and 3.9 where identified within 60 miles (97 km) of the site.

The licensee indicated that seismic activity is concentrated in southwest Missouri (New Madrid area) and central and south central Oklahoma. The site is located in a seismically quiet region of the United States; it lies on the southwest flank of the Ozark uplift, a major stable tectonic feature in northeast Oklahoma. Although distant earthquakes may produce shocks strong enough to be felt in this area, the region is considered to be one of minor seismic risk. The most recent movement known to have occurred within the region occurred along the Meers Fault system (Ramelli and others, 1987) an estimated 2,000 years ago. This system is located in south central Oklahoma. Field studies by Geomatrix (1990) indicate that the fault ranges from 26 (16 miles) to 37 km (23 miles) in length and is capable of producing a moment magnitude (M_w) earthquake of 6.75 to 7.25. Recent seismicity has not been associated with this fault. Recent tectonic movements have also occurred along the El Reno-Nemaha Ridge, which extends from central Oklahoma through Kansas and into Nebraska. Micro seismicity appears to be associated with this feature in Kansas (Hildebrand and others, 1988).

Other structural features in the site area are: 1) the Carlile School Fault, a normal fault about 5,000 ft in length; 2) the Marble City Fault, another structural feature identified by the Oklahoma Geological Survey; and 3) the South Fault of the Warner Uplift. As discussed in Section 2.3, all these faults are considered to be noncapable faults.

2.5.1.2 Tectonic Province

Historic earthquakes within 400 miles of the site have been reported as far back as 1811, although the early records can be considered complete only for large events with magnitude intensity greater than or equal to VII.

The licensee identified five major tectonic provinces within 200 miles of the site. These are: 1) Ozark Uplift, 2) Cherokee-Basin-Central Oklahoma Platform Province, 3) Arkoma Basin Province, 4) Nemaha Uplift province, and 5) Anadarko Basin Province. The licensee identified recurrence rates and maximum magnitudes for these provinces.

The licensee indicated that the faults within the Ozark uplift are non-capable faults (Geotechnical Investigations, Black Fox Station, 1975); movement along these faults had ceased by the end of Permian time (225 million years ago). Prior to late Middle Pennsylvanian time, folding and faulting may have occurred in the Cherokee Basin-Central Oklahoma Platform Province. However, there is no indication of Quaternary deformation in recent photographic reconnaissance. Therefore, none of the faults in this province are considered to be capable faults.

2.5.1.3 Maximum Historical Earthquake and Seismic Design Ground Motion

Based on the USACE (1982) seismic hazard map, the licensee indicated that the site is classified as a Zone 1 area, with a recommended seismic coefficient of 0.025 g. Additionally, based on the Uniform Building Code, the site is classified as a Zone 1 area with seismic coefficient of 0.075 g. The USGS National Seismic Hazard Mapping Project (2003) website estimates a seismic acceleration of 0.09 g for the site region with 2 percent probability of exceedance in 50 years (which equates to a 2475 years return period). Algermissen and others (1982) estimated the maximum expected ground acceleration at the site to be less than 0.05 g, for a recurrence interval of 250 years.

The reclamation plan discussed two approaches to quantify the potential seismicity in the site area. The first approach identified the maximum credible earthquake associated with capable faults in the site area. The second evaluated the seismicity of tectonic provinces in the site area.

Based on a very conservative assumption that all the faults within 200 miles of the site are capable, the licensee estimated the maximum peak ground acceleration associated with these faults to be 0.168 g (excluding the non-capable Marble City fault which is 0.6 mile (1.0 km) from the site (Appendix B to Appendix E, Reclamation Plan). The ground motion estimates were based on an old empirical relationship relating fault length to earthquake magnitude by Slemmons (1982) as well as an outdated attenuation relationship by Campbell (1981).

Based on tabulated seismic data from the NEIC from prior to 1811 through 2003, and using Campbell's 1981 empirical attenuation equation, the licensee calculated the ground accelerations at the site for six critical earthquakes (June 20, 1926, m = 4.2, Sequoyah County, OK; Dec. 16, 1811, m=7.2, New Madrid, MO; Dec. 16, 1811, m = 7.0, New Madrid, MO; March 31, 1975, m = 2.9, Muskogee County, OK; October 22, 1882, m = 5.5, South-Central, OK; and October 8, 1915, m = 3.4, Rogers County, OK). The ground accelerations from these earthquakes calculated by the licensee ranged from 0.006 g to 0.023 g.

At the request of the staff, the licensee re-analyzed peak ground acceleration at the site using more recent attenuation equations. Using attenuation equations from Atkinson and Boore (1995) and Campbell (2003) the licensee estimated the accelerations from the maximum credible earthquakes associated with all faults considered to be active within 20 miles (32 km) of the site to range from 0.1 g to 0.5 g. However, the licensee stated that these high acceleration values are not consistent with the measured seismic activity in the area and the assumption of considering all the faults in the area capable was unrealistically conservative. The licensee proposed instead that the estimation of ground accelerations for the site be based primarily on random earthquake analyses.

Based on Atkinson and Boore's 1995 attenuation relation and using a random earthquake within the Ozark Uplift, the licensee estimated the peak horizontal ground acceleration at the site to be 0.27 g and proposed this value as the design basis for the disposal site.

In a memorandum dated December 21, 2004, the licensee submitted, as Attachment 2, a probabilistic seismic hazard analysis for the McGee Creek dam, Oklahoma (LaForge, 1997). The licensee identified the Sequoyah site, which is about 90 miles northeast of the McGee Creek dam, as being located in the same seismic zone as the dam. The licensee's memorandum included an updated mean hazard curve for the McGee Creek dam which showed a mean ground acceleration of 0.15 g for a 10,000 year return period.

2.5.2 Technical Evaluation

This section of the SER provides the staff's evaluation of the seismological investigations the licensee conducted to determine the design ground acceleration for the disposal cell at the site. The staff's evaluation of the SFC reclamation plan was conducted in accordance with Section 1.4 of the Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (NUREG-1620, 2003). The licensee presented information and investigations that support its conclusions about the seismic characterization of the site and the seismic design value. The licensee used a simplistic approach, not commonly used today, to estimate the ground acceleration, but, as discussed in this section, the staff found the value proposed to be acceptable.

The staff focused its review of the licensee's description of the historical seismicity and the different seismic sources in the region on whether the seismic activities in the region can be correlated with tectonic features in the area. The staff finding is that none of the earthquakes can be directly correlated with the faults identified around the site area.

From the USGS National Seismic Hazard Mapping Project (2003), the peak ground acceleration at the Sequoyah site is estimated to be 0.2 g at the 1×10^{-4} (1 in 10,000) probability of exceedance per year. Also, using the seismic hazard software developed by Risk Engineering (2004), the staff estimated a peak ground acceleration of 0.25 g at a 1×10^{-4} probability of exceedance from background seismic sources within 200 miles of the site. The staff performed a sensitivity study using different minimum magnitudes for the source zones identified in LaForge (1997) and found little difference in the peak ground acceleration at the site.

Additional local amplification of ground motion at the SFC site is expected to be minimal. As detailed in memoranda to NRC (September 7, 2004 and June 1, 2005), the disposal cell will be constructed on sandstones and siltstone units of the Atoka Formation which has a velocity of about 2000 ft/sec. Terrace deposits and highly weathered portions of the Atoka Formation in the site area are approximately 10 to 20 ft thick. Most of these surficial soils will be excavated during subsoil cleanup operations. Therefore, the staff concludes that because of the competent nature of the bedrock and minimal thickness of the softer surficial materials, amplification will be minimal.

Based on these analyses, the staff considers the licensee's seismic result provided in the memorandum dated April 27,2005 to be appropriate (MFG Project: 180734) and the seismic design of 0.27 g proposed for the SFC facility is acceptable.

3.0 GEOTECHNICAL STABILITY

3.1 Introduction

This section presents the results of the NRC staff review of the geotechnical engineering aspects of the proposed reclamation plan at the SFC site near Gore, Oklahoma. The final disposal cell will be constructed in the northeast portion of the current facility boundary and will consist of a four-sided dome structure to contain the disposed materials beneath a soil cover.

Geotechnical review of the reclamation plan focused on evaluating the site characterization and design information relevant to the long-term performance and integrity of the disposal-cell embankment. The aspects reviewed include: (i) information related to the disposal and borrow sites; (ii) materials associated with the closure action, including the foundation and excavation materials, and contaminated materials proposed for disposal; (iii) stability of the embankment side slopes and natural slopes around the disposal site; (iv) potential deformation and cracking of the embankment owing to differential settlement; and (v) properties of the disposal cell that may affect water flow into or out from the cell and radon barrier characteristics. The review is based on information provided by the licensee, especially in the revised reclamation plan (Sequoyah Fuels Corporation, 2004a) and the related appendixes and attachments. Review methods and acceptance criteria in Section 2.0 of NUREG-1620, Rev.1 (NRC, 2003) were used in conducting the review.

3.2 Site and Disposal-Cell Characteristics

The materials proposed for disposal include process waste materials, structural debris, pond residual materials, soils and subsoils from the planned site cleanup and reclamation, and raffinate sludges. The materials will be emplaced in four layers from A (bottom) through D (top) as described in SFC (2004a, pp. 3-15 through 3-16). Depending on the volume of material excavated during site soil cleanup and the density of the material after placement in the cell (mostly in layer D), the cell may hold from 140,000 to 340,000 m^3 [5 to 12 million ft^3]. Preliminary designs call for a final disposal cell volume of approximately 250,000 m^3 [9 million ft^3], based on a cleanup level to a natural uranium activity concentration of 27 pCi/g (Sequoyah Fuels Corporation, 2004a, Appendix C).

When construction is completed, the maximum height of the proposed cell will be approximately 9–15 m [30–50 ft] above the general ground elevation, with a maximum elevation of approximately 180 m [590 ft] above mean sea level. The top surface will be contoured to a 1-percent slope to ensure drainage to the southeast (Sequoyah Fuels Corporation, 2004a, Appendix C, Figure 4.3, Attachment A, Drawing Number 5). The preliminary disposal cell design consists of a perimeter embankment of compacted soils and materials from onsite cleanup operations. The inside slopes of the embankment will be lined with a multilayered synthetic and clay liner system that includes provisions for leachate collection and leak detection. The side slopes of the disposal cell will be set at a maximum slope of five horizontal to one vertical units (5h:1v) (Sequoyah Fuels Corporation, 2004a, Attachment E).

3.2.1 Geotechnical Investigations

3.2.1.1 Disposal-Cell Area

Geotechnical characteristics of the disposal-cell area are based on information included in the licensee's hydrogeological and geochemical site characterization report, which is summarized in recent reports (Sequoyah Fuels Corporation, 2003a; 2004a, Appendix D). The SFC site is underlain by Quaternary sediments and bedrock of the Pennsylvanian Akota Formation. The disposal-cell area consists of approximately 1.5–4.6 m [5–15 ft] of terrace deposits (mostly silt and clay) on bedrock. Colluvial deposits overlie bedrock on a slope that dips to the northwest from the disposal-cell area, and alluvial deposits occur near the feet of the slopes adjacent to the Arkansas River (Sequoyah Fuels Corporation, 2004a, Appendix D, Figure 9). The bedrock consists of alternating layers of shale and sandstone with bedding planes dipping generally southwest to southeast.

Groundwater levels at the site have been evaluated by the licensee based on measurements at more than 300 wells (Sequoyah Fuels Corporation, 2004a, Appendix D, Section 3.4.2). Depth to perched water in the terrace deposits varies from 1.5–3.7 m [5–12 ft] in the vicinity of the proposed disposal cell. The water levels are closer to the surface in the southeastern portion of the proposed site, near the main process building, and the water table elevation generally decreases to the west, similar to the ground topography. These levels are below the proposed grade for the disposal cell (Sequoyah Fuels Corporation, 2004a, Attachment A, Drawing Numbers 9 and 12). Monitored water levels in the terrace deposits show seasonal fluctuations on the order of 0.3–0.6 m [1–2 ft] or less (Sequoyah Fuels Corporation, 2004a, Appendix D, Section 3.4.2, Figure 17; 2003b, Table 4). The licensee argues that the perched ground water system is due, at least in part, to artificial ground water recharge by leakage from fire–water lines and unlined basins. The regional and site hydrology and ground water protection are evaluated in Chapter 5.

The geotechnical information needed to assess the long-term stability of the disposal cell relates to (i) stability of the embankment slopes, (ii) differential settlement of the embankment, and (iii) stability of natural slopes that dip away from the disposal-cell area. The geotechnical information provided by the licensee is sufficient to assess the first two items. For the third item, the licensee needs to either provide the shear strength of the colluvium, which is needed to determine the stability of natural slopes or use a method that does not require the shear strength of the colluvium. **Information defining the shear strength of the colluvium, therefore, is an open issue**.

3.2.1.2 Borrow Areas

The geotechnical information for the borrow areas relates to the suitability of the proposed materials for the clay liner and cell cover system. Materials for the planned clay liner and most of the soil cover for the disposal cell will come from a borrow area at the southern end of the SFC facility and from the Agland area in the southern and western parts of the facility (Sequoyah Fuels Corporation, 2004a, Attachment A, Drawing Numbers 1 and 2). Additional material for the cover may come from existing berms and embankments. Material balance calculations by the licensee (Sequoyah Fuels Corporation, 2004a, Appendix C, Attachment A.1, and Attachment E, Appendix A) indicate there are sufficient volumes of material for the construction of the clay liner and cover system.

Seventeen test boreholes were drilled in the borrow area using a rotary rig (Sequoyah Fuels Corporation, 2004b, Enclosure 4). In each borehole, bag samples of cuttings were obtained for each layer, and Shelby tube samples (undisturbed soil samples obtained using a thin-wall cylinder sampling device referred to as a “Shelby tube”) were collected in the materials considered for clay liners. The Shelby tube samples were subjected to more detailed geotechnical testing to determine suitability of these materials. In a later investigation, 7 test pit samples and 11 boring samples were collected for geotechnical testing (Sequoyah Fuels

Corporation, 2004b, Enclosure 4). In addition, during radiological characterization of the site, 32 soil samples were collected in Site Characterization Unit 54, which includes the borrow and Agland areas (Sequoyah Fuels Corporation, 2004a, Appendix C, Attachment A.1, Attachment A, Drawing Number 2).

3.2.2 Testing Program

The technical specifications for the disposal cell call for a 0.6-m [2-ft]-thick (minimum) compacted clay liner (Sequoyah Fuels Corporation, 2004a, Attachment A, Sections 4.2.2 and 4.3.4). The clay liner material will be taken from the borrow area at the south end of the facility and will consist of material with a particle size smaller than 2.5 cm [1 in], free from roots, branches, rubbish, and process area debris. Fifty percent of the material used in the clay liner is to pass a No. 200 sieve, and the material is to exhibit a minimum plasticity index of 10. These specifications meet design criteria in existing U.S. Environmental Protection Agency (EPA) guidance for solid waste disposal facilities (EPA, 1993, Subpart D).

The licensee geotechnical testing of the borrow material included gradation, moisture density (Proctor), specific gravity, clay dispersivity, permeability, and unconsolidated, undrained triaxial testing (Sequoyah Fuels Corporation, 2004b, Enclosure 4). The licensee also performed testing to determine the liquid and plastic (Atterberg) limits, and plasticity index for the materials using procedures from ASTM International [e.g., ASTM–D4318 (ASTM International, 2003)]. The test results indicate the Quaternary deposits at the site consist of silt and silty clay classified as CL or ML in the Unified Soil Classification System. Geotechnical laboratory tests of the borrow material indicate that the soils are low-plasticity, nondispersive clays with hydraulic conductivity values (K) below 1×10^{-7} cm/sec [2.8×10^{-4} ft/d] when compacted. With two exceptions, samples exceeded 50 percent passing a No. 200 sieve, with a measured plasticity index that ranged from 10 to 30 (Sequoyah Fuels Corporation, 2004b, Table 1, Figures 1–3). The tests and testing methods are reasonable and the staff agrees that the borrow area soils are suitable material for clay liner and cover materials. As outlined in the technical specifications section of the reclamation plan (Sequoyah Fuels Corporation, 2004a, Attachment A, Section 4), the licensee will ensure material acceptability by using appropriate standards published by the ASTM International to conduct additional testing during construction. Disposal-cell hydraulic conductivity is evaluated in Section 3.8.

3.2.3 Evaluation Findings

The staff has completed its review of the geotechnical characteristics of the design for the proposed disposal cell at the SFC facility near Gore, Oklahoma. This review included an evaluation using the procedures in Section 2.1.2 and the acceptance criteria outlined in Section 2.1.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee has acceptably described the geotechnical characteristics of the site based on sampling techniques that are acceptable, and technical specifications will ensure a representative range of *in-situ* soil conditions will be examined. Investigations and analyses have used acceptable standards and practices. Laboratory sample preparation and testing techniques are appropriately described and relevant physical properties were determined. Records of historic groundwater-level fluctuations are presented to allow effective incorporation into geotechnical stability analyses.

The licensee did not provide information characterizing the shear strength of the colluvium. This remains an open issue. Staff cannot conclude its review of the geotechnical characterization of the site and disposal materials and associated conceptual and numerical models because of this unresolved open issue.

Open Issue: The licensee needs to provide information characterizing the shear strength of the colluvium if such information is needed to resolve the open issue regarding the stability of the natural slopes identified in Section 3.3 of this safety evaluation report.

3.3 Slope Stability

Potential slope instabilities that may affect the integrity of the disposal cell are (i) a landslide down a natural slope that dips away from the disposal site and (ii) a sliding failure on an interior surface through the disposal cell.

3.3.1 Stability of Natural Slopes

The proposed disposal cell is located near the crest of a natural slope that dips approximately northwest toward the Illinois River (Sequoyah Fuels Corporation, 2004a, Drawing Number 5). The slope appears to be stable under current conditions, however, the proposed disposal cell can potentially increase the likelihood of a landslide down the slope. The height of the slope and its steepness near the crest will both increase after construction of the disposal cell. Potential mechanisms for such a landslide include slip on bedding planes, on interior shear planes through the colluvium, or at the bedrock–colluvium contact. An analysis of the stability of the natural slopes under seismic and long-term static conditions is needed to assess the long-term integrity of the disposal cell. The licensee did not provide such analysis. **The stability of natural slopes, which may affect the proposed disposal cell, therefore, is an open issue.**

3.3.2 Stability of the Disposal-Cell Embankment

The licensee performed an analysis of the stability of the disposal cell considering the potential for sliding failure along a circular surface through the cell or along the top surface of the synthetic liner at the base of the 3-m [10-ft]-thick cover system (Sequoyah Fuels Corporation, 2004a, Appendix C). The synthetic liner at the base of the cover is included in the design to prevent downward seepage of infiltration water. Such water would be diverted laterally along the top surface of the liner. The analysis indicates sliding failure along a circular surface through the cell is less likely than sliding failure along the liner surface at the base of the cover system. The licensee, therefore, focused its stability analysis on evaluating the potential for sliding on the liner surface. The top surface of the synthetic liner is considered critical for potential sliding because the liner, if it functions properly, would intercept water infiltration and redirect it down the slope away from the underlying disposed material. The contact surface between the synthetic liner and the overlying soil may lose some of its shear resistance because of the lubricating effect of moisture.

The licensee initially proposed to use smooth, high-density polyethylene as the synthetic liner at the base of the cover (Sequoyah Fuels Corporation, 2004a, p. 3-20). An analysis provided by the licensee indicated an adequate safety factor against sliding at the soil-to-liner interface under static and seismic loading conditions (Sequoyah Fuels Corporation, 2004a, p. 3-14). Staff confirmatory analysis, however, indicated the licensee likely overestimated the shear resistance of the soil-to-liner interface in its stability analysis especially considering the potential lubrication of the interface by moisture. The licensee subsequently modified its design to use textured, high-density polyethylene as the synthetic liner material on the side slopes of the disposal cell at the base of the cover system (Sequoyah Fuels Corporation, 2004c). The textured, high-density polyethylene liner would be placed between two layers of gravelly sand in the modified design. Direct shear tests provided by the licensee indicate a residual friction angle of approximately 30E between the textured, high-density polyethylene and gravelly sand (Sequoyah Fuels Corporation, 2004c, Attachment 1). The licensee indicates this value of frictional resistance would provide adequate stability for the cover-system slope. A confirmatory calculation performed by staff indicates the factor of safety against failure of the cover-system slope considering sliding on the synthetic liner would be greater than 1.1 [the minimum acceptable safety factor under dynamic loading based on staff guidance (NRC, 2003, p. 2-9)] for seismic ground motions with a peak ground acceleration smaller than 0.44g. Seismic characterization information provided by the licensee and reviewed in Section 2.4 indicates a design-basis seismic ground motion of approximately 0.27g for the site. Also, a staff confirmatory calculation shows the safety factor under long-term static conditions would be greater than 1.5 [the minimum acceptable safety factor under static loading based on staff guidance (NRC, 2003, p. 2-9)] if the friction angle for the soil-to-liner interface is greater than approximately 17E, which is smaller than the 30E determined by the licensee.

The licensee needs to modify its technical specifications (Sequoyah Fuels Corporation, 2005) as follows to be consistent with the information used in its analysis of sliding at the soil-to-liner interface: (i) revise Section 4.2.4 (Sequoyah Fuels Corporation, 2005, page 13) to specify the liner at the base of the cover is textured high-density polyethylene and (ii) modify the particle size specifications for the synthetic liner bedding material and synthetic liner cover (Sections 4.2.3 and 4.2.5 of the technical specifications) to not include any fine soil particles (i.e., fraction passing through #200 sieve). The licensee stability analysis assumes gravelly sand below and above the synthetic liner. **Technical specifications for the synthetic liner at the base of the cover and the particle size distributions of the synthetic liner bedding and cover materials, therefore, are open issues**.

3.3.3 Evaluation Findings

The staff has completed its review of the slope stability evaluation provided by the licensee considering the design for the proposed disposal cell at the SFC facility. This review included an evaluation using the procedures in Section 2.2.2 and the acceptance criteria outlined in Section 2.2.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee has acceptably described the slope stability evaluation by (i) providing cross sections used for the analysis in sufficient detail and number to represent the slope and foundation conditions that may affect the stability of the disposal cell, (ii) proposing a disposal-cell design with side slopes at 5h:1v, (iii) providing standard measurements of the material properties needed for the slope stability analysis, (iv) selecting locations for slope stability analyses while considering the locations of maximum slope angle and slope height, and (v) describing in detail vegetative cover and its primary function.

The static loads analysis is acceptable and includes (i) indication of appropriate uncertainties and variabilities in important soil parameters, (ii) consideration of appropriate failure modes, and (iii) discussion of the effect of the assumptions inherent in the method of analysis used.

The analysis for stability under seismic loading conditions is acceptable and includes (i) use of calculations with appropriate assumptions and methods, (ii) treatment of important interaction effects in a conservative fashion, (iii) consideration of the potential effects of dynamic stresses on shear strength, (iv) determination that the slope is unlikely to sustain any significant deformation during a maximum credible earthquake, (v) selection of appropriate design-level seismic events or strong ground motion accelerations, (vi) evaluations of local site conditions, and (vii) design of a self-sustaining vegetative or rock cover consistent with commonly accepted engineering practice.

The licensee did not provide an analysis of the stability of natural slopes that may affect the proposed disposal cell. This is an open issue. Additionally, the technical specifications must be modified to be consistent with the information used in the licensee's analysis of sliding at the soil-to-liner interface. Staff, therefore, cannot conclude its review of the slope stability evaluation of the disposal plan because of these unresolved open issues.

Open Issues: The licensee needs to provide the following to resolve the open issues identified in this section:

(1) An evaluation of the stability of the natural slopes under seismic and long-term static conditions

(2) Technical specifications for the synthetic liner at the base of the cover system consistent with information used in the licensee's stability analysis

(3) Particle size specifications for the synthetic liner bedding and cover materials consistent with information used in the licensee's stability analysis

3.4 Settlement

Potential settlement of the disposal cell is a concern because soil strain owing to differential settlement may cause the cover system to crack and deteriorate. Differential settlement of the cell may occur because of variations in thickness and compressibility of the disposed and cover materials through the cell embankment. The composition of layer C of the proposed disposal cell, which consists of used structural materials such as steel beams and columns, concrete, and asphalt, is of particular concern because overlying soil may flow into large pore spaces in layer C. Such deformation of the overlying soil may result in excessive differential settlement. Variability of the proposed disposal cell subgrade also is of concern because parts of the cell will overlie existing concrete pads and other parts will overlie softer materials such as weathered sedimentary rock. The licensee addressed these concerns by proposing a combination of fill-placement control, material selection, construction sequencing, and settlement monitoring. Specifically, placement procedures for layer C materials will be controlled to minimize compressibility of layer C, excavated areas will be filled with compacted granular materials to minimize variability of subgrade compressibility, and cell construction sequence will be timed to allow settlement monitoring. The licensee, in addition, provided calculations to make a case that potential differential settlement of the cell would be smaller than the maximum tolerable differential settlement.

3.4.1 Subgrade Variability

The subgrade material for the proposed disposal cell will vary. Parts of the cell will overlie relatively clean natural soil or areas excavated to remove contaminated soil, and the remaining part, approximately the easternmost one-third of the foundation area, will overlie a concrete pad (Sequoyah Fuels Corporation, 2004a, Drawing Number 2). Information provided by the licensee to respond to a staff request (Sequoyah Fuels Corporation, 2004d, pp. 12–14) indicates the excavated areas will be filled with granular material identified as subgrade fill. The granular material will be placed in lifts not exceeding 30.5 cm [12 in] in loose thickness and will be compacted to at least 90 percent of the maximum dry density at a water content of 1-percent greater or 4-percent smaller than the optimum moisture content (Sequoyah Fuels Corporation, 2004d, p. 14). The licensee did not explain why it expects the desired subgrade stiffness would be achieved with a compaction to 90 percent of the maximum dry density. Compaction to 95 percent of the maximum dry density obtained in the modified Proctor test, and a compaction moisture content of not more than 2-percent greater or smaller than the optimum moisture content, are typically specified to reduce potential settlement of a compacted subgrade (e.g., U.S. Department of the Navy, 1982, p. 7.2-46). Furthermore, the licensee's revised technical specifications (Sequoyah Fuels Corporation, 2005) do not include changes promised by the licensee to address staff's concerns regarding placement specifications for the subgrade material. **Compaction specification for the subgrade, therefore, is an open issue.**

3.4.2 Construction Control for Layer C

Information provided by the licensee indicates disposal cell layer C will include structural materials such as steel, concrete, and asphalt. The large and irregular sizes and shapes of such materials are of concern because of the potential occurrence of relatively large pore spaces between the individual pieces after placement in the cell. Excessive differential settlement of the cell could result from overlying soil flowing into pore spaces between the layer C materials.

Information provided by the licensee to respond to a staff request (Sequoyah Fuels Corporation, 2004c, Attachment 2) included a specification of maximum sizes for pieces of structural materials to be disposed of in the cell, maximum lift thickness, filling the pore spaces with soil, and compaction control for such soil. The proposed specifications include the following, among other details (Sequoyah Fuels Corporation, 2004c, Attachment 2):

(1) Material that is not compressible (steel columns, beams, concrete, and other solid material) will be reduced in size for handling and placed in the disposal cell without crushing. This material shall be placed in the disposal cell in a manner that minimizes void spaces below, between, and above the pieces. Material with a large length-to-width ratio will be placed in the disposal cell with the long dimension oriented horizontally wherever possible. Dismantled flat steel, sheet metal, and other large pieces shall not exceed 3.1 m [10 ft] in width by 6.1 m [20 ft] in length. **However, the specification for the placement of "material that is not compressible" (as used in this item) is an open issue because the licensee needs to explain the meanings of "large length-to-width ratio" and "wherever possible" (as used in this item)**.

(2) Materials that are compressible (such as thin-walled piping and thin-walled tanks) will be crushed prior to final placement in the disposal cell. Such materials will be laid out in a staging area to facilitate crushing or compacting. The licensee, however, did not specify how such crushed materials will be placed in the disposal cell to reduce differential settlement that might occur if such materials are not adequately mixed with other cell materials such as soils. **Placement specifications for any crushed structural materials (such as piping or tanks), therefore, is an open issue.**

(3) Soil and soil-like materials will be placed around and within the demolition materials to reduce pore spaces and, therefore, future settlement. Soil-like materials will be placed and compacted around the outside of partially buried tanks and vessels and in horizontal lifts over flat-lying demolition materials.

(4) Soil placed as demolition material cover, interim cover, or layer D sublayers will not exceed 0.61 m [2 ft] in loose-lift thickness and will be compacted with a minimum of four passes of a tamping-foot compactor prior to placement of additional lifts. However, the licensee did not explain why it expects the desired settlement reduction would be achieved with this compaction specification. Compaction to 90 percent of the maximum dry density obtained in the modified Proctor test is typically specified to reduce potential settlement of backfill surrounding a structure (U.S. Department of the Navy, 1982, p. 7.2-46). **Compaction specification for soil placed around disposed structural material, therefore, is an open issue.**

The licensee-revised technical specifications (Sequoyah Fuels Corporation, 2005), however, do not include the changes promised by the licensee to address staff concerns regarding placement specifications for layer-C materials. **Technical specifications for controlling placement of layer-C materials, therefore, is an open issue**.

3.4.3 Settlement Estimates and Monitoring

A representative compressibility of the disposal cell material would be difficult to determine through laboratory or *in-situ* testing because of the variability of the size and constituents of the individual pieces of disposed material. The licensee based its settlement estimates on literature information regarding historical measurements of landfill settlement, which indicate total settlements of 5–25 percent of the landfill height (Sequoyah Fuels Corporation, 2004c, Attachment 2). The licensee argued that a large fraction of the measured landfill settlements can be attributed to decomposition of biodegradable materials and settlement of the proposed disposal cell should be smaller than the measured landfill settlements because biodegradable materials will not be included in the cell. The licensee, therefore, estimated settlement of the disposal cell would lie in the range of 5–10 percent of the total cell height. Staff agrees that settlement of the disposal cell will likely be smaller than measured landfill settlements because biodegradable materials will not be disposed in the cell. The settlement of 5–10 percent of the cell height estimated by the licensee, however, is not supported by any data. Potential settlement of the cell could be larger than the licensee estimated, even considering the settlement could be smaller than suggested by the landfill data cited by the licensee. **Potential settlement of the disposal cell, therefore, is an open issue.**

The licensee estimated potential differential settlements by considering the difference in total settlement for two hypothetical soil columns separated by a horizontal distance of at least 10.7 m [35 ft]. One hypothetical soil column was assigned a minimum compressibility (equal to 0.05 settlement units per height unit), and the other was assigned a value of compressibility based on the licensee's best estimate (Sequoyah Fuels Corporation, 2004c, Attachment 2, p. 3). Using this approach, the licensee estimated a maximum horizontal tensile strain of 5.7×10^{-4} owing to the potential differential settlement. The licensee also estimated an allowable tensile strain of 6.5×10^{-4} for the cover soil based on a relationship between plasticity index and allowable tensile strain, having estimated a plasticity index of 5 for the soil. The licensee, therefore, concluded that the cover soil would likely not experience cracking from differential settlement because the estimated tensile strain owing to potential differential settlement is smaller than the estimated tolerable tensile strain for the cover soil. The approach used by the licensee—determine the tensile strain owing to the potential differential settlement would be smaller than the tolerable tensile strain—is acceptable. The licensee used several input data for its calculation, which were not based on well-supported information. For example, the licensee calculated lateral strain from settlement by assuming the maximum differential settlement would occur over a horizontal distance of at least 10.7 m [35 ft]. This assumption could result in underestimating the potential lateral strain across the edge of the concrete slab in the foundation or a stiff inclusion such as steel beam in layer C. Such uncertainty in the input data implies an uncertainty in the calculated strain and in the licensee's conclusion regarding potential damage to the cover system. **Potential cracking damage to the cover system owing to differential settlement of the cell, therefore, is an open issue.**

The licensee proposed to monitor settlement using a grid of monuments on the cover surface that would be surveyed approximately four times per year until the rate of settlement decreases to an acceptable value (Sequoyah Fuels Corporation, 2004a, p. 6-1). The licensee also proposed to construct the cell in phases at a rate to accommodate monitoring settlement of the completed phases prior to constructing the cover system (Sequoyah Fuels Corporation, 2004b, p. 2). The proposed monitoring could be used to further reduce the potential for excessive settlement, but the licensee needs to explain how the measured settlements would be used to control the construction sequence. Monitoring the settlement of a completed phase to ensure a predetermined fraction of such settlement occurs prior to construction of the next phase could potentially result in an adequate reduction of the postconstruction settlement. To use this approach, the licensee needs to provide specific information defining (i) the settlement monitoring (e.g., frequency and spatial location of settlement measurements) and (ii) an approach to determine when the measured settlement is sufficient to allow constructing a subsequent phase. **Controlling the potential settlement of the disposal cell, therefore, is an open issue.**

3.4.4 Evaluation Findings

The staff has completed its review of the settlement analysis for the proposed disposal cell at the SFC facility. This review included an evaluation using the procedures in Section 2.3.2 and the acceptance criteria outlined in Section 2.3.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee did not provide: (i) adequate specifications for the placement and compaction of subgrade and disposal-cell materials to reduce potential settlement, (ii) adequate basis for the estimated total and differential settlements of the disposal cell, or (iii) information needed for the staff review of its proposal to control postconstruction settlement by monitoring settlement during construction. Staff cannot conclude its review of the settlement analysis of the reclamation plan because of these unresolved open issues.

<u>Open Issues</u>: The licensee should provide its proposed approaches for addressing the following open issues:

(1) Compaction specification for the disposal-cell subgrade

(2) Placement and compaction specifications for layer-C material (e.g., structural materials such as steel columns, beams, concrete, and other such solid material) and soils placed around such structural materials

(3) Placement specifications for any crushed structural materials, such as piping or tanks.

(4) Evaluation of potential disposal-cell settlement

(5) Evaluation of potential cracking damage to the cover system owing to differential settlement of the cell

(6) Controlling potential settlement of the disposal cell through settlement monitoring

3.5 Liquefaction Potential

3.5.1 Liquefaction Potential Analysis

The licensee did not provide any analysis of potential instability of the disposal cell from liquefaction of the cell materials or its foundation. Liquefaction was initially not a concern because information provided by the licensee indicated a design basis ground motion of approximately 0.05g (Sequoyah Fuels Corporation, 2004a, Appendix C). Such a low ground motion indicates seismic-loading conditions are likely below the trigger threshold for liquefaction, considering Youd, et al. (2001). The licensee, however, revised its ground motion estimates for the site and indicated a potential seismic ground motion of 0.27g (Sequoyah Fuels Corporation, 2004b, p. 6). An analysis of the liquefaction potential of the soils needs to be provided for such ground motion conditions. The criteria of Youd, et al. (2001) indicate such ground motions could cause liquefaction if the soil properties and ground water conditions are conducive to liquefaction.

Information provided by the licensee indicates the foundation of the proposed disposal cell would consist of at least 1.5–4.6 m [5–15 ft] of terrace deposits overlying bedrock. The terrace deposits consist of silt, sandy silt, and silty clay (Sequoyah Fuels Corporation, 2004a, Appendix D, p. 3-6) and are hydrologically saturated in some areas and unsaturated in other areas (Sequoyah Fuels Corporation, 2004a, Appendix D, p. 3-12). Potential liquefaction of the terrace deposits cannot be ruled out based on the soil description and ground water condition provided by the licensee. **Potential damage to the disposal cell owing to liquefaction of the terrace deposits during an earthquake, therefore, is an open issue.**

3.5.2 Evaluation Findings

The staff has completed its review of the analysis of potential instability from liquefaction for the proposed disposal cell at the SFC facility. This review included an evaluation using the procedures in Section 2.4.2 and the acceptance criteria outlined in Section 2.4.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee did not provide information to characterize the potential for liquefaction of the disposal-cell foundation during an earthquake. The information is needed to assess the stability of the disposal cell during a potential earthquake. Staff cannot conclude its review of the geotechnical stability of the disposal cell because of this unresolved open issue.

Open Issue: The licensee needs to provide an analysis of potential instability of the disposal cell from liquefaction of the cell foundation.

3.6 Disposal-Cell Liner and Cover Engineering Design

3.6.1 Disposal-Cell Materials and Testing

Detailed drawings and cross sections for the design of the proposed disposal cell are provided in Sequoyah Fuels Corporation (2004a, Attachment A, Drawing Numbers 1–12). With the exception of bedding layers of sand below and above the synthetic liner material, the materials to be used in constructing the disposal cell liner system and the cell cover system will come from onsite sources (Sequoyah Fuels Corporation, 2004a, Attachment E). Silty clays from the borrow area at the southern end of the facility are described as CL or ML in the Unified Soil Classification System. Geotechnical laboratory tests of the borrow material indicate the soils are low-plasticity, nondispersive clays with compacted hydraulic conductivity values below 1×10^{-7} cm/sec [2.8×10^{-4} ft/day]. Test samples exceed 50 percent passing a No. 200 sieve, with a measured plasticity index that ranges from 10 to 30 (Sequoyah Fuels Corporation, 2004b, Enclosure 1, Table 1, Figures 1–3). The borrow area soils are suitable material for clay liner and cover materials. Material from existing berms and embankments is described in well borings, but geotechnical testing is not reported. Testing will be used during installation of the cover system to ensure that geotechnical specifications are met. As outlined in the technical specifications section of the reclamation plan (Sequoyah Fuels Corporation, 2004a, Attachment A, Section 4), the licensee will ensure material acceptability for the liner and cover systems by using appropriate standards published by ASTM International to conduct additional testing during construction.

Synthetic, high-density polyethylene liners will be placed over the clay layer at the base of the disposal cell, on the inside slope of the stormwater retention berms, surrounding filtered raffinate sludge, and at the base of the disposal cell cover. The liners will be transported, stored, installed, inspected, and tested in accordance with the manufacturer's specifications. The specific installation (e.g., panel deployment, seaming, and anchoring) and testing methods are described in the technical specifications in the reclamation plan (Sequoyah Fuels Corporation, 2004a, Attachment A, Section 5). Shear and peel tests will be conducted in accordance with appropriate standards published by ASTM International (Sequoyah Fuels Corporation, 2004a, Attachment A, Section 5.4.3). A 30-cm [12-in] layer of topsoil will be placed on top of the cell cover system, and growth of long-term native vegetation will be promoted to reduce infiltration. Estimates of long-term effectiveness of surface vegetation are evaluated in Section 3.8.

Information provided by the licensee indicates the synthetic liner at the base of the cover system will be placed between layers of sand or gravel approximately 15-cm [6-in] thick below the liner bedding and 45-cm [18-in] thick above the liner cover. The functions of the liner bedding and cover are to protect the liner from large or angular particles that may cut or tear the liner. In addition, the liner cover provides for free drainage of seepage water along the top surface of the liner. To perform these functions satisfactorily, the bedding and cover layers must have a minimum thickness and minimum shear strength. In addition, the cover layer must have a minimum permeability. These characteristics of the liner bedding and cover are controlled by their layer thickness, particle-size gradation, and the placement procedure (e.g., compaction method, degree of compaction, and lift thickness). The material and placement specifications provided by the licensee {i.e., no particle larger than 2.5 cm [1 in] and single-lift placement} are not adequate to ensure appropriate properties for the liner bedding and cover. For example, the specifications do not provide any control to ensure pore spaces in the liner cover are not clogged by overlying fine particles. **Material and placement specifications for the liner bedding and cover layers, therefore, are open issues**.

Information provided by the licensee indicates the disposal cell materials will include calcium fluoride sludge and sediments from the emergency basin, north ditch, and sanitary lagoon; which will be dewatered or stabilized to improve their structural strength prior to placement in the disposal cell (Sequoyah Fuels Corporation, 2004a, p. 3-4). The licensee, however, did not describe how the materials will be dewatered or how much improvement of the structural strength is desirable so the stability of the disposal cell would not be impaired by the disposal of such materials in the cell. **Processing of the calcium fluoride sludge and sediments from**

the emergency basin, north ditch, and sanitary lagoon; and the placement of such materials in the disposal cell, therefore, is an open issue.

The selection and testing of materials for erosion protection (rip-rap, rock mulch) and design issues related to erosion protection are evaluated in Chapter 4. The installation and testing of the liner and cover systems related to the hydraulic conductivity of the disposal cell are evaluated in Section 3.8. The potential effects of settlement on the cover system are evaluated in Section 3.4.

3.6.2 Evaluation Findings

The staff has completed its review of the cover design for the proposed disposal cell at the SFC facility. This review included an evaluation using the procedures in Section 2.5.2 and the acceptance criteria outlined in Section 2.5.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee did not provide adequate material and placement specifications for the liner bedding and cover layers (for the synthetic liner at the base of the cover system) to ensure the completed liner bedding and cover will protect the liner from cutting or tearing and provide for free drainage of seepage water along the liner top surface. The licensee also did not provide specifications for dewatering the calcium fluoride sludge and sediments from the emergency basin, north ditch, and sanitary lagoon to ensure the desired structural strength will be achieved. Staff cannot conclude its review of the disposal cell liner and cover engineering design because of these open issues.

Open Issues: The licensee needs to provide the following to resolve the open issues identified in this section:

(1) Material and placement specifications for the liner bedding and cover layers to ensure the completed liner bedding and cover will protect the liner from cutting or tearing and provide for free drainage of seepage water along the liner top surface.

(2) Specifications for the dewatering of calcium fluoride sludge and sediments from the emergency basin, north ditch, and sanitary lagoon; and the placement of such materials in the disposal cell.

3.7 Construction Considerations

The disposal cell construction plan proposed by the licensee is described in Sequoyah Fuels Corporation (2004a, Attachment E) and technical specifications for cell construction are included in (2004a, Attachment A).

3.7.1 System Installation and Material Placement

The licensee indicates that a multilayered liner system would be installed within the footprint of the disposal cell to provide protection against leachate migration (Sequoyah Fuels Corporation, 2004a, Attachment A, Sections 4.3 and 4.4). The proposed liner system would consist of a 0.6-m [2-ft] compacted clay liner at the bottom, a 15-cm [6-in] bedding layer of sand, a synthetic geomembrane, and a 46-cm [18-in] bedding layer of sand at the top (Sequoyah Fuels Corporation, 2004a, Attachments A and E). A leachate detection system, consisting of a series of 10-cm [4-in] slotted, high-density polyethylene pipes would be installed in the bedding layer immediately above the clay liner. For water management, high shear-strength materials would be used to construct a berm around the footprint of the disposal cell, and a leachate collection system consisting of a series of 15-cm [6-in]-diameter slotted pipes would be installed in the sand layer above the synthetic geomembrane.

The planned construction sequence would consist of completing the entire liner system for each phase, including clay and sand bedding layers and the synthetic membrane as one unit. This sequence includes covering completed, tested, and approved areas of the clay liner with the 15-cm [6-in] (minimum) bedding layer of sand. The potential for freeze-thaw cycles and desiccation on the clay liner and cell cover system during construction is not evaluated by the licensee. The licensee indicated that, for protection from freeze-thaw cycles, erosion, or desiccation cracking, the clay liner would be covered with the bedding material within 24 hours of completion, testing, and approval. Covering the liner system within 24 hours would mitigate the effects of freeze/thaw cycles and dessication on the clay layer (National Oceanographic and Atmospheric Administration, 2004). The monthly normal mean winter temperatures at the facility are not below freezing, although monthly normal minimum temperatures from December through February can drop slightly below 0 EC [32 EF]. Maximum frost penetration in natural soils near the facility is 250-500 mm [10-20 in], and would be less for compacted materials (Koerner and Daniel, 1997). The synthetic geomembrane would be installed over the 15-cm [6-in] bedding layer, and tested and approved areas of the geomembrane would be covered with the second 46-cm [18-in]-thick (minimum) bedding layer for protection. The thickness of the bedding layer and the prompt covering of the clay liner are acceptable restrictions to protect the liner. The licensee has committed to these restrictions in a response to a request for additional information (Sequoyah Fuels Corporation, 2004b, Enclosure 1), but the revised technical specifications (Sequoyah Fuels Corporation, 2005) do not include the promised restrictions. The technical specifications will need to be updated to include these restrictions to protect the liner during construction. **Establishing the proposed liner installation requirements as commitments in the technical specifications, therefore, is an open issue.** As outlined in the technical specifications section of the reclamation plan (Sequoyah Fuels Corporation, 2004a, Attachment A, Section 4), the licensee will ensure material acceptability during installation by using appropriate standards published by ASTM International to conduct additional testing during construction.

The licensee proposes to construct the disposal cell in three phases (Sequoyah Fuels Corporation, 2004a, Attachment E, Section 5.0). The material placement sequence (layers A–D) and material volumes are presented by the licensee in Sequoyah Fuels Corporation (2004a, Attachment E, Appendix A). The main concern with settlement during material placement and possible cover cracking is addressed in Section 3.4.

3.7.2 Evaluation Findings

The staff has completed its review of construction considerations for the proposed disposal cell at the SF facility. This review included an evaluation using the procedures in Section 2.6.2 and the acceptance criteria outlined in Section 2.6.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee has acceptably described the construction considerations by (i) providing complete engineering drawings showing all design features; (ii) describing sources and quantities of borrow material, including acceptable field and laboratory testing; and (iii) identifying methods, procedures, and requirements for excavations, haulage, stockpiling, and placement of materials and by demonstrating that all are consistent with accepted engineering practices for earthen works. Disposal cell compaction plans are supported by field and laboratory tests that assure stability and performance. The licensee has an acceptable program to determine the extent of cleanup using appropriate testing and surveying programs. All tailings and contaminated materials have been demonstrated to fit within the planned configuration of the stabilized pile.

The licensee has not committed to technical specifications for protecting the clay liners from cracking during installation due to dessication or freeze-thaw cycles. Staff cannot conclude its review of the revised technical specifications because of this open issue.

Open Issue: The licensee needs to revise the technical specifications to include restrictions to protect the liner and cover during construction.

3.8 Disposal-Cell Hydraulic Conductivity

3.8.1 Disposal-Cell Liner System

The disposal-cell liner system will consist of a multilayered synthetic and clay liner system that includes provisions for leachate collection and leak detection (Sequoyah Fuels Corporation, 2004a, Attachment A, Drawing Number 10). The proposed liner system would consist of a 0.6-m [2-ft] compacted clay liner at the bottom, a 15-cm [6-in] bedding layer of sand, a synthetic geomembrane, and a 46-cm [18-in] bedding layer of sand at the top (Sequoyah Fuels Corporation, 2004a, Attachments A and E). The sand layer will be screened to minus 2.5-cm [1-in] size and free from angular debris (roots, sharp rocks) that could damage the synthetic liner material (Sequoyah Fuels Corporation, 2004a, Attachment A, Section 4.2.5). While this specification is adequate to provide physical protection of the membrane, it is not adequate to ensure appropriate properties for the bedding and cover layers (see Section 3.6.1).

Materials for the planned clay liner and most of the soil cover for the disposal cell will be obtained onsite from the SFC facility (Sequoyah Fuels Corporation, 2004a). The technical specifications for the disposal cell call for a 0.6-m [2-ft]-thick (minimum) compacted clay liner (Sequoyah Fuels Corporation, 2004a, Attachment A, Sections 4.2.2 and 4.3.4). As stated in Section 3.6, specifications for the clay liner meet design criteria in existing EPA guidance for solid waste disposal facilities (e.g., EPA, 1993, Subpart D). Geotechnical tests of the borrow material indicate the soils are low-plasticity, nondispersive clays with hydraulic conductivity values below 1×10^{-7} cm/sec [2.8×10^{-4} ft/d] when compacted. Synthetic high-density polyethylene liners will be placed over the clay layer at the base of the disposal cell and at the base of the disposal cell cover. Protection of the clay liner during construction is evaluated in Section 3.7.

3.8.2 Disposal-Cell Cover System

For the cell cover, a 2.6-m [8.5-ft]-thick subsoil zone consisting of onsite soils provides a root zone and moisture retention zone for infiltrating meteoric water. The soil cover will consist of gravelly clay to silty clay obtained from onsite sources, including the facility boundary. The bottom 46 cm [18 in] will be a protective soil zone (Sequoyah Fuels Corporation, 2004a, Attachment A, Drawing Number 10) that consists of material with a maximum particle size of 2.5 cm [1 in] and placed in one lift. A synthetic liner (60-mil, high-density polyethylene) will be placed below the protective soil zone. The disposal cell cover design is a homogeneous (store-and-deplete) cover with a vegetated surface. The cover is designed to promote long-term vegetative growth that optimizes evapotranspiration and, subsequently, minimizes infiltration.

Infiltration analyses for the cell cover system (Sequoyah Fuels Corporation, 2004a, Attachment E, Appendix E) indicate that, during the initial period of disposal cell operation, drainage through the bottom of the cover is approximately 17 percent of precipitation. Synthetic liner material planned for incorporation above the layers of disposal material will perform as a barrier. For the long term, infiltration model results (Sequoyah Fuels Corporation, 2004a, Attachment E, Appendix E) indicate performance of the vegetation and cover systems will minimize migration of percolation (2 percent of precipitation) from beneath the root zone. The hydraulic conductivity value used to represent the cell cover top soil and subsoil zone can be considered conservative. The issue of representing flow in fissures and desiccation cracks in the infiltration model, however, is yet to be resolved. **The licensee approach of using conservative hydraulic conductivity values to incorporate the complex flow processes in a heterogeneous (potential for preferential flow) subsoil zone is not adequate and, therefore, is an open issue.**

As stated in Section 3.7.4, disposal cell compaction plans are supported by field and laboratory tests that ensure the performance of the liner system. As outlined in the technical specifications section of the reclamation plan (Sequoyah Fuels Corporation, 2004a, Attachment A, Sections 6 and 7), the licensee will ensure performance and quality control of the clay and synthetic liners by using appropriate standards published by ASTM International to conduct additional testing during construction. The synthetic liners will be transported, stored, installed, inspected, and tested in accordance with manufacturer specifications. Details of the planned construction sequence are discussed in Section 3.7. The planned construction sequence was found reasonable and includes provisions to prevent the clay liner from eroding or cracking, pending the licensee updating the detailed technical specifications (see Open Issue, Section 3.7.2). The construction sequence of the cell cover described in the reclamation plan (Sequoyah Fuels Corporation, 2004a, Section 3.5.2) also was found reasonable and practical.

3.8.3 Evaluation Findings

The staff has completed its review of the hydraulic conductivity of the cover design for the proposed disposal cell at the SFC facility. This review included an evaluation using the procedures in Section 2.7.2 and the acceptance criteria outlined in Section 2.7.3 of NUREG–1620, Rev. 1 (NRC, 2003).

The licensee has acceptably evaluated the disposal-cell cover materials hydraulic conductivity (K) by providing a sufficient technical basis for the design K-value for the disposal cell. A field testing program adequate to verify the constructability of the clay liner for the disposal cell with a design hydraulic conductivity of 2.8×10^{-4} ft/day [1×10^{-7} cm/sec] is presented. The licensee proposes an acceptable quality control program for the field testing to determine the hydraulic conductivity. The licensee, however, has not provided an adequate technical basis for its treatment of potential preferential flow pathways through the proposed cover system. Staff cannot conclude its review of the hydraulic conductivity because of this unresolved open issue.

<u>Open Issue</u>: The issue of representing flow in fissures and desiccation cracks in the infiltration model is yet to be resolved. The licensee should provide technical basis for using conservative hydraulic conductivity values to account for the effects of possible fissures and dessication cracks and the complex flow processes in a heterogeneous (potential for preferential flow) subsoil zone. The licensee should also provide sufficient material and placement specifications for the liner bedding and cover layers (see Open Issue, Section 3.6.2).

4.0 SURFACE WATER HYDROLOGY AND EROSION PROTECTION

4.1 Introduction

This section of the SER describes the staff's review of surface water hydrology and erosion protection issues related to long-term stability. In this section, the staff provides the technical bases for the acceptability of the licensee's reclamation design. Review areas that are covered include: estimates of flood magnitudes; water surface elevations and velocities; sizing of riprap to be used for erosion protection; long-term durability of the erosion protection; and testing and inspection procedures to be implemented during construction. The review is based on information provided by the licensee, especially in the revised reclamation plan (Sequoyah Fuels Corporation, 2004) and the related appendixes and attachments. Review methods and acceptance criteria in Section 3.0 of NUREG-1620, Rev.1 (NRC, 2003) were used in conducting the review.

4.2 Hydrologic Description and Site Conceptual Design

The site is located near the east bank of the Illinois River at its confluence with the Arkansas River. The site is situated approximately 100 feet above the Illinois River. Flows in the Illinois River are regulated by releases from the Tenkiller Ferry Reservoir, located on the Illinois River approximately seven miles upstream of the site.

To comply with Criterion 6 of 10 CFR 40, Appendix A, which requires stability of the tailings for 1000 years to the extent reasonably achievable and in any case for 200 years, the licensee proposes to construct a disposal cell to reclaim the contaminated material in place and to protect the material from flooding and erosion. The design basis events for design of erosion protection include the Probable Maximum Precipitation (PMP) and the Probable Maximum Flood (PMF) events, both of which are considered to have very low probabilities of occurring during the 1000-year stabilization period.

As shown in Figure 3-1 of the reclamation plan, the top surface of the cell will be configured to drain toward the east at a slope of about one percent, and the embankment side slopes will be constructed on a 1 vertical (V) on 5 horizontal (H) slope. To protect against erosion, the top slope will be covered with a 10-foot thick soil cover, and the side slopes of the tailings cell will include, within a 10-foot thick cover, a layer of rock riprap overlain by a 9-inch-thick soil layer to promote the growth of vegetation. At the toes of the side slopes, a rock riprap apron will be constructed to provide protection against the potential migration of gullies toward the disposal cell.

4.3 Flooding Determinations

Because of the elevation of the site, floods on the Arkansas and Illinois Rivers do not pose a threat to the cell. Also, because the cell will be located on local high ground, with no upstream drainage area, flooding from local streams does not pose a threat to the cell. The primary flood and erosion threat to the cell is from precipitation on the cell and the resulting flow on the cell and drainage of water coming off the cell.

The computation of peak flood discharges for various site design features was performed by the licensee in several steps. These steps included: (1) selection of a design rainfall event; (2) determination of infiltration losses; (3) determination of times of concentration; (4) determination of appropriate rainfall distributions, corresponding to the computed times of concentration; and (5) calculation of flood discharge. Input parameters were derived from each of these steps and were then used to calculate the peak flood discharges to be used in the final determination of rock sizes for erosion protection (Section 4.5).

4.3.1 Selection of Design Rainfall Event

One of the phenomena most likely to affect long-term stability is surface water erosion. To mitigate the potential effects of surface water erosion, it is very important to select an appropriately conservative rainfall event on which to base the flood protection designs. Further, the staff considers that the selection of a design flood event should not be based on the extrapolation of limited historical flood data, due to the unknown level of accuracy associated with such an extrapolation. The licensee utilized a probable maximum precipitation (PMP) event, computed by deterministic methods (rather than statistical methods) and based on site-specific hydrometeorological characteristics. The PMP has been defined as the most severe reasonably possible rainfall event that could occur as a result of a combination of the most severe meteorological conditions occurring over a watershed. No recurrence interval is normally assigned to the PMP; however, the staff has concluded that the probability of such an event being equaled or exceeded during the 1000-year stability period is very low. Accordingly, the PMP is considered by the NRC staff to provide an acceptable design basis.

Prior to determining the runoff from the drainage basin, the flooding analysis requires the determination of PMP amounts for the specific site location. Techniques for determining the PMP have been developed for the United States by Federal agencies in the form of hydrometeorological reports for specific regions. These techniques are widely used and provide straightforward procedures with minimal variability. The staff, therefore, concludes that use of these reports to derive PMP estimates is acceptable.

PMP values were estimated by the licensee using Hydrometeorological Report No. 51 (HMR-51) (COE, 1978) and HMR-52 (COE, 1982). These reports also provide information on distributing the rainfall that falls over a particular drainage area. A 1-hour PMP of 19 inches and a 5-minute PMP of 6.3 inches were used by the licensee as a basis for estimating a probable maximum flood (PMF) for the smaller areas at the site such as the top and side slopes of the cell. (The PMF is a hypothetical flood that is considered to be the most severe reasonably possible, based on comprehensive hydrometeorological application of the PMP and other hydrologic factors favorable for peak runoff. The PMF is considered by the NRC staff to provide an acceptable design basis for erosion protection.) The procedures for estimating PMP values were reviewed, and it was concluded that the PMP amounts are acceptable for the small drainage areas at the site.

4.3.2 Infiltration Losses

The determination of the peak runoff rate is also dependent on the amount of precipitation that infiltrates into the ground during its occurrence. If the ground is saturated from previous rains, very little of the rainfall will infiltrate and most of it will become surface runoff. The loss rate is highly variable, depending on the vegetation and soil characteristics of the watershed. Typically, all runoff models incorporate a variable runoff coefficient or variable runoff rates. Commonly-used models such as the U.S. Bureau of Reclamation (USBR) Rational Formula (USBR, 1977) incorporate a runoff coefficient (C); a C value of 1 represents 100% runoff and no infiltration. Other models such as the USACE Flood Hydrograph Package HEC-1 (COE, 1988) separately compute infiltration losses within a certain period of time to arrive at a runoff amount during that time period.

In computing the peak flow rate for the small drainage areas at the site, the licensee used the Rational Formula (USBR, 1977). In this formula, the runoff coefficient was assumed to be 0.8; that is, the licensee assumed that very little infiltration would occur. Based on the conservatism associated with the use of a 5-minute PMP of 6.3 inches and a resulting rainfall intensity of 75 inches per hour (See Section 4.3.4, below), the staff concludes that this is an acceptable assumption.

4.3.3 Times of Concentration

The time of concentration (t_c) is the amount of time required for runoff to reach the outlet of a drainage basin from the most remote point in that basin. The peak runoff for a given drainage basin is inversely proportional to the time of concentration. If the time of concentration is assumed to be smaller, the peak discharge will be larger. Times of concentration and/or lag times are typically computed using empirical relationships such as those developed by Federal agencies. Velocity-based approaches are also used when accurate estimates are needed. Such approaches rely on estimates of actual flow velocities to determine the time of concentration of a drainage basin.

Times of concentration for the riprap design were estimated by the licensee using the Kirpich Method (USBR, 1977). This method is generally accepted in engineering practice and is considered by the staff to be appropriate for estimating times of concentration at this site. Times of concentration on the disposal cell ranged from 0.5 minutes for the east side slope to 5.4 minutes for the top slope. Based on a review of the calculations provided, the staff concludes that the t_c values used by the licensee were acceptably derived.

4.3.4 Rainfall Distributions

After the PMP is determined, it is necessary to determine the rainfall intensities corresponding to shorter rainfall durations and times of concentration. A typical PMP value is derived for periods of about one hour. If the time of concentration is less than one hour, it is necessary to extrapolate the data presented in the various hydrometeorological reports to shorter time periods. To accomplish this, the licensee utilized a procedure recommended in HMR-52. This procedure involves the determination of rainfall amounts as a percentage of the one-hour PMP, and computes rainfall amounts and intensities for very short periods of time.

To determine peak flood flows for the cell, the 5-minute PMP rainfall intensity was determined to be 33 percent of the 1-Hr PMP, or 6.3 inches. Based on a review of this aspect of the flooding determination, the staff concludes that the computed peak rainfall intensities are acceptable.

4.3.5 Computation of PMF

Various methods are used to determine peak PMF flows, depending on the location of the feature, the drainage area, and other factors.

4.3.5.1 Top and Side Slopes

To estimate PMF peak discharges for the cell top and side slopes, the licensee used the Rational Method (Chow, 1959). This method is a simple procedure for estimating flood discharges that is recommended in NUREG-1623 (Johnson, 2002). In using the Rational Method, the licensee assumed a runoff coefficient equal to 0.8. The licensee also assumed a flow concentration factor of about 3 and a factor of safety of about 1.35 that would be used to increase the flows for design purposes .

For a maximum top slope length of 500 feet (with a slope of 0.01) and a side slope length of 100 feet (with a slope of 0.2), the licensee estimated the peak flow rates to be about 1.2 cubic feet per second per foot of width (cfs/ft) for the top slope and 1.4 cfs/ft for the side slope. Based on a review of the calculations, including the time of concentration, rainfall intensity, and runoff, the staff concludes that the estimates are acceptable.

4.3.5.2 Apron

The licensee designed a rock apron to provide a transition section from the side slopes of the disposal cell to natural ground. Its purpose is to reduce flow velocities to non-erosive levels. PMF flow rates for overland flow for the downstream apron were estimated by the licensee and are similar to the flow rates for the side slopes. As discussed above, the flow rates are considered to be acceptable.

4.3.6 Evaluation Findings

The staff has completed its review of the flooding potential at the SFC site. On the basis of the information presented in the reclamation plan and the detailed review it conducted, the staff concludes that the flood analysis and investigations adequately characterize the flood potential at the site.

4.4 Water Surface Profiles and Velocities

Following the determination of the peak flood discharge, it is necessary to determine the resulting water levels, velocities, and shear stresses associated with that discharge. These parameters then provide the basis for the determination of the required erosion protection features, including riprap size and layer thickness, needed to ensure stability during the occurrence of the design event.

4.4.1 Top and Side Slopes

The top slope of the cell is designed with a vegetated 10-foot-thick soil cover. With respect to velocities and shear stresses, the cover was designed using procedures recommended by the NRC staff in NUREG-1623. See Section 4.5.1.1, below.

In determining riprap requirements for the side slopes, the licensee used the Abt Method (Johnson, 2002), the Safety Factors Method (Stevens et al., 1976) and the Stephenson Method (Stephenson, 1979). The validity of these design approaches has been verified by the NRC staff through the use of flume tests at Colorado State University. It was determined that the selection of an appropriate design procedure depends on the magnitude of the slope (Abt, et al., 1987). The staff, therefore, concludes that the procedures and design approaches used by the licensee are acceptable and reflect state-of-the-art methods for designing riprap erosion protection. Input parameters and design methods for riprap sizing are discussed further in Section 4.5.

4.4.2 Apron

The design of the apron for the cell must be adequate to withstand forces from several different phenomena and is based on the following general concepts: (1) provide riprap of adequate size to be stable against overland (downslope) flows produced by the design storm (PMP), with allowances for turbulence along the downstream portion of the toe; (2) provide uniform and/or gentle grades along the apron and the adjacent ground surface such that runoff is distributed uniformly onto natural ground at a relatively low velocity, minimizing the potential for flow concentration and erosion; (3) provide an adequate apron length and quantity of rock to allow the rock apron to collapse into a stable configuration if gullying occurs and erodes toward the site; and (4) provide an apron with adequate rock size to resist flows that will occur laterally along the apron. Detailed discussion of the riprap design of various components of the apron can be found in Section 4.5.1.2, below.

4.5 Erosion Protection

The ability of a riprap layer to resist the velocities and shear forces associated with surface flows over the layer is related to the size and weight of the stones which make up the layer. Typically, riprap layers consist of a mass of well-graded rocks which vary in size. Because of the variation in rock sizes, design criteria are generally expressed in terms of the median stone size, D_{50}, where the numerical subscript denotes the percentage of the graded material that contains stones of less weight. For example, a rock layer with a minimum D_{50} of 4 inches could contain rocks ranging in size from 0.75 inches to 6 inches; however, at least 50 percent of the weight of the layer will be provided by rocks that are 4 inches or larger.

Depending on the rock source, variations occur in the sizes of rock available for production and placement on the reclaimed pile, and it is therefore necessary to ensure that these variations in rock sizes are not extreme. Design criteria for developing acceptable gradations are provided by various sources (e.g., Simons and Li, 1982), and examples of acceptable gradations may be found in NUREG-1623.

4.5.1 Sizing of Erosion Protection

Riprap layers of various sizes and thicknesses are usually proposed for use at many reclaimed sites, and the design of each layer is dependent on its location and purpose. To reduce the number of gradations that need to be produced, a licensee can place larger rock than is required in some areas. For example, rock with a minimum D_{50} of about 2 to 3 inches could be used on the west side slope, and rock with a minimum D_{50} of 4.7 inches is needed for the east side slope. For ease of construction and to minimize the number of gradations, the licensee has purposely over-designed several areas by proposing to use the 4.7-inch rock on all of the side slopes. Discussion of the design for different locations is provided in the sections that follow.

4.5.1.1 Top and Side Slopes

The top portion of the reclaimed pile will be protected by a 10-foot-thick soil layer. The licensee proposes that the soil cover will be vegetated and that the vegetation will provide the necessary erosion protection for a 1000-year period. Using the PMP/PMF flows and assumptions discussed above, the licensee concluded that the top slope would be stable.

The top slope was evaluated for erosional stability by the licensee using procedures discussed in NUREG-1623. Using a peak discharge of about 1.2 cfs/ft, the maximum velocities were computed to range from 1.4 to 2.3 feet per second. Permissible velocities recommended in NUREG-1623 range from about 2 - 2.5 feet per second for a vegetated soil cover. The top slope was also evaluated using procedures discussed by Temple (1987). The licensee determined that the maximum shear stresses resulting from the peak discharge would be less than the allowable shear stresses. The staff has reviewed the licensee's analyses and finds them acceptable. Based on the conservatism associated with the design discharge and the ability of the cover to provide adequate protection against the computed velocities and shear stresses, the staff concludes that the top slope design is acceptable.

The stability of the top cover is further justified by its relatively flat slope of 1 percent over a maximum top slope length of about 500 feet. Even if gullying were to occur, gullying would not result in erosion of contaminated material, because the maximum depth of gullying could be only about 5 feet, and the soil cover is 10 feet thick. This conclusion is based on the presence of the riprap on the side slopes of the cell (at an elevation about 5 feet below the top of the cell), which will provide a stabilizing base level at the edges of the cell This conclusion assumes that the rock layer on the side slopes of the cell has been properly designed and constructed.

For the side slopes of the cell, the licensee proposes to use a 9-inch layer of rock with an average D_{50} of 4.7 inches. The Abt Method (Johnson, 2002) was used to determine the required rock size. Based on staff review of the licensee's analyses and the acceptability of using design methods recommended by the NRC staff, as discussed in Section 4.4 of this report, the staff concludes that the proposed rock size for the side slope is adequate. However, this rock size should be considered to be the minimum D_{50}, not the average D_{50}. See Section 4.5.2, for additional discussion of the rock gradation proposed by the licensee.

4.5.1.2 Apron

As previously discussed, the design of the apron must be capable of withstanding various phenomena. The riprap design is dependent on the specific location of the apron, and erosion protection needs to be provided against overland flows down the side slope onto the apron. The licensee proposes to use rock with a D_{50} of 4.7 inches in the apron area. No computations were provided to justify this design, but the staff concludes that if 4.7-inch rock is needed on the side slopes, rock of about twice that size is needed for the toe. The design criteria suggested in NUREG-1623 indicate that, in general, the rock size in a toe/apron should be about twice the size of the rock on the side slope to account for turbulence and other erosional forces. The staff recognizes that the toe/apron may be over-designed on some portions of the west, south, and north sides of the cell, but concludes that the rock size in the apron may need to be increased on the east side of the cell and possibly on some other portions on the west, south, and north sides. **The size of riprap for the apron, therefore, is an open issue.**

4.5.1.2.1 Overland Flows

In many cases, there is a potential for gullies to form downgradient of the toe of the slope of a disposal cell. Runoff from the top and sides of the cell may concentrate and cause a gully to form some distance away from the toe of the cell. This gully may not be stable and may erode in an upstream direction toward the cell. To prevent this occurrence, it is usually necessary to provide a rock apron that will prevent further headward erosion into the contaminated material.

The licensee has designed the side slopes to simply transition to natural ground and the riprap on the pile side slope will be extended. Based on review of the information provided, the staff concludes that the proposed apron may not provide rock of adequate size or volume to protect the side slope from gully migration. The licensee did not estimate the depth of scour, and this depth may be greater than the thickness of rock proposed

Based on review of the information provided by the licensee, the staff concludes that this aspect of the design is not acceptable. To provide adequate erosion protection and to prevent erosion of the embankment side slope, the licensee will need to design a rock apron to collapse into the scour hole of the head-cutting gully. The rock volume and size should be sufficient to prevent further erosion of the gully into the pile side slope. The riprap to be provided for the rock apron may be designed using the guidance suggested in NUREG-1623. Specific methods for estimating scour depth from overland flows are provided in NUREG-1623 (Johnson, 2002) and include methods used by DOT (1975) or Pemberton and Lara (1984). Because the apron length is about 20 feet, the staff recognizes that the actual volume of rock may be adequate, but scour analyses should be provided to justify assumptions used by the licensee. **Therefore, the design of the rock apron to protect against gullies caused by overland flow is an open issue.**

4.5.1.2.2 Flows Adjacent to Apron

On the east side of the cell, the rock apron will transition into an area which will receive surface runoff from both the top of the cell and upland areas further to the east. These flows will collect and flow to the north and south along the toe of the east side slope (in what appears on the drawings to be a small channel). Staff review indicates that the slopes to the north and south will be relatively steep and that these flood flows have not been considered in the design of the rock apron. The licensee may need to provide rock of larger size in the apron to resist these flow velocities. The licensee should provide analyses to justify that the apron design accounts for this occurrence. In particular, the PMF in the channel should be estimated, and maximum velocities and shear stresses should be evaluated to assure that the rock size is adequate to resist these forces. In addition, the scour depth associated with these flows should be determined, to verify that the rock size and volume is adequate to protect the disposal cell. Scour depths may be estimated using criteria developed by COE (1995). **Therefore, the design of the apron on the east side of the cell to accommodate high flows along the apron is an open issue.**

The staff notes that several previously-approved designs at Title I and Title II sites incorporated a rock-lined channel at the toes of side slopes. These channels served both as rock aprons and drainage channels and were designed to prevent erosion and scouring at or near the toe of the side slopes of the cells.

4.5.1.3 Stream 005

As discussed in Section 2.4.2, a gully exists at the head of stream 005, located to the west of the proposed cell. Based on the information provided, as discussed in Section 2.4.2, the staff was unable to conclude that further gullying would not occur. The staff is concerned that further gullying could affect the proposed cell. Furthermore, in its settlement agreement with Oklahoma and the Cherokee Nation, SFC committed to “install rock armor in the 005 Drainage adequate to assure that erosion will not undermine the cell.” However, the reclamation plan does not include a design for rock armoring stream 005. **Therefore, the design for rock armor protection of stream 005 is an open issue.**

To resolve this issue, the licensee can propose riprap for the gully and provide additional information for NRC staff review regarding the proposal. This information should include: detailed drawings showing the design configuration of the erosion protection; justification of the design bases, input parameters, and assumptions that were used; and calculations used in the design.

4.5.2 Riprap Gradations

The average D_{50} value to be used as the basis for the design of well graded mixture of rock to resist the shear forces of the PMF peak discharge was estimated by the licensee to be 4.7 inches. Riprap gradations and layer thicknesses were developed by the licensee using criteria that were not specified. Staff review of the information provided indicates that the proposed gradation is not adequate to assure adequate protection, for several reasons.

First, the proposed D_{50} of 4.7 inches should represent the minimum D_{50} of the gradation. The proposed gradation indicates a minimum D_{50} of 3.0 inches. If the rock gradation meets only the minimum sizes in the specifications, the rock will be too small and may contain an excessive amount of fines.

Second, the proposed gradation would allow up to 40 percent of the material of pass the No. 4 sieve (4.75 mm). Staff experience indicates that if 40 percent of the material is that small, the layer would contain an excessive amount of fine material, would be difficult to place, and would likely not meet in-place gradation specifications. This gradation would be acceptable only if the larger sizes in the gradation are actually produced, and the minimum D_{50} is at least 4.7 inches.

It should be pointed out that to reduce the number of different riprap sizes and gradations, the licensee elected to use larger rock than required in many areas. Thus, additional conservatisms are added to the design in those areas where larger rock than required will be used. In those places, the proposed average rock size may be acceptable. However, the staff considers that the rock layer would still contain an excessive amount of fine material and concludes that any gradation specified should contain minimal amounts of fines. Examples of gradations that contain minimal amounts of fine material my be found in NUREG-1623. **Therefore, rock gradation for the riprap is an open issue.**

4.5.3 Rock Durability

NRC regulations require that control of residual radioactive materials be effective for up to 1000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. The previous sections of this SER examined the ability of the proposed erosion protection design to withstand flooding events reasonably expected to occur in 1000 years. In this section, rock durability is evaluated to determine if there is reasonable assurance that the rock itself will survive and remain effective for 1000 years.

Rock durability is defined as the ability of a material to withstand the forces of weathering. Factors that affect rock durability are: 1) chemical reactions with water, 2) saturation time, 3) temperature of the water, 4) scour by sediments, 5) windblown scour, 6) wetting and drying, and 7) freezing and thawing.

To assure that the rock used for erosion protection remains effective for up to 1000 years as required by Criterion 6 of 10 CFR Part 40, Appendix A, potential rock sources must be tested and evaluated to identify acceptable sources of riprap. A procedure for determining the acceptability of a rock source is presented in NUREG-1623. This procedure includes the following steps:

Step 1. Test results from representative samples are scored on a scale of 0 to 10. Results of 8 to 10 are considered "good"; results of 5 to 8 are considered "fair"; and results of 0 to 5 are considered "poor."

Step 2. The score is multiplied by a weighting factor. The effect of the weighting factor is to focus the scoring on those tests that are the most applicable for the particular rock type being tested.

Step 3. The weighted scores are totaled, divided by the maximum possible score, and multiplied by 100 to determine the rating.

Step 4. The rock quality scores are then compared to the criteria which determines its acceptability, as defined in the NRC scoring procedures.

After these tests are conducted, a rock quality score is determined. Different minimum scores, depending on the location and use of the rock, are recommended in NUREG-1623.

In general, rock durability testing is performed using standard test procedures, such as those developed by the American Society for Testing and Materials (ASTM). The ASTM publishes and updates an Annual Book of ASTM Standards, and rock durability testing is usually performed using these standardized test methods.

The licensee has not identified any acceptable potential rock source in the proximity of the site, but has committed to using the durability procedures found in NUREG-1623. Before the staff can approve this approach, some rock durability information should be provided for staff review. At a minimum, the licensee should perform petrographic analyses using ASTM C 295 on representative samples of the rock. An example of an acceptable testing program would include testing for Bulk Specific Gravity and Absorption (ASTM C 127), Sodium Sulfate Soundness (ASTM C 88), Los Angeles Abrasion (ASTM C 131 or C 535) and Tensile Strength. The results of these tests should then evaluated using procedures recommended in NUREG-1623.

Based on a review of the rock durability information, the staff is not able to conclude at this time that acceptable rock will be used for erosion protection. The licensee should identify a rock source and provide the results of rock durability data for staff review and analysis. **Therefore, information necessary for the staff to conclude that rock of acceptable durability will be used for flood protection is an open issue.**

4.5.4 Testing and Inspection of Erosion Protection

The licensee did not provide adequate information regarding testing, inspection, and quality control procedures to be used for the erosion protection materials. The information should have included detailed programs for durability testing, gradation testing, rock placement, and verification of rock layer thicknesses. NUREG-1623 provides guidance regarding acceptable testing programs, and the licensee should provide programs that are equivalent to those found in NUREG-1623. **Therefore, information regarding the licensee’s testing, inspection, and quality control program is an open issue.**

4.5.4.1 Durability Testing

The licensee did not provide adequate information regarding the testing program that will be used to document the durability of the rock source selected. Information regarding acceptable programs may be found in NUREG-1623, and the licensee should provide a program equivalent to those suggested in that reference. The licensee should propose a rock durability testing program and justify it based on the characteristics of the rock source selected.

Durability test results should be used by the licensee to determine a rock durability rating. Guidance on this can be found in NUREG-1623. The licensee should propose that a minimum of one initial test series will be performed prior to placing rock. Additional tests should be performed when approximately one-third and two-thirds of the total volume of the riprap have been delivered. The licensee should also commit to performing additional tests when the rock characteristics (i.e., color or texture) in the rock borrow source vary significantly from the rock that was previously tested.

Based on a review of the proposed procedures, the staff concludes that a detailed durability testing program has not been provided for staff review to ensure that rock of acceptable quality is provided. The testing program should be equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction. **This is an open issue.**

4.5.4.2 Gradation Testing

The licensee proposes that rock gradation testing will be performed, as follows:

1. Rock gradations will be tested using ASTM D 422, Standard Test Method for Particle-Size Analysis of Soils, as appropriate.

2. Gradation testing will be performed at a frequency of one test for every 2000 cubic yards of material placed.

Based on a review of the proposed procedures, the staff concludes that the gradation testing program will ensure that rock layers with acceptable gradations are provided. The testing program is equivalent to several which were approved by the staff and have been implemented at other reclaimed sites during construction.

4.5.4.3 Riprap Placement

The licensee did not provide sufficient information regarding the placement of the rock, and merely stated that the rock would be placed in lifts to assure uniformity. As a minimum, the licensee should propose construction specifications for the rock placement program where: (1) riprap will be placed to the depths and grades shown on the drawings; (2) riprap will be placed in a manner to ensure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the void spaces between the larger rock fragments, so that a densely packed, uniform layer of riprap of the specified thickness will result; (3) hand placing will be used, as necessary, to ensure proper results; and (4) material that does not meet these specifications will be either reworked or removed and replaced as necessary.

Further, because the rock layer will be covered with soil, it is important to assure that the soil will be placed in the rock voids in a manner that will assure that the voids are uniformly filled with soil and that differential settlements are minimized. The rock placement should be inspected before the soil is placed into and over the rock. The licensee should provide construction specifications and a specific program that will be used to assure (1) proper placement of the rock layer, (2) proper placement of the soil layer, and (3) proper compaction of the soil into the rock voids.

Based on a review of the licensee's proposal, the staff concludes that the proposed information and procedures are not sufficient to ensure acceptable placement of the riprap or the soil that will be packed into the rock voids. **This is an open issue.**

4.5.4.4 Rock Layer Thickness Testing

Essentially no information was provided regarding the testing program that will be conducted to assure that adequate thicknesses of riprap are provided. Prior to placement of the soil cover over the rock, the thickness of the rock layers should be verified by establishing a grid over the tailings impoundment and using specific procedures for measuring and recording depths. Visual examinations should also be conducted to verify the uniformity of depths.

Based on a review of the information provided, the staff concludes that the proposed testing for program for rock layer thickness is not adequate. **This is an open issue**.

4.5.5 Wind erosion

The licensee did not provide information to document the adequacy of the soil cover to resist wind erosion. The site is located in an area that has experienced droughts in the past, and wind erosion may be significant if the vegetation is not able to provide the required wind protection. The licensee should provide justification that the site will be adequately protected for up to 1000 years from wind erosion, especially considering that droughts have occurred in the past, droughts are likely to occur again, and the vegetation cover may be considerably affected by wind erosion. **This is an open issue.**

4.5.6 Evaluation findings

Based on review of the information submitted by the licensee and on independent calculations, the NRC staff concludes that the licensee has not provided sufficient information for the staff to conclude that the erosion protection design is adequate to provide reasonable assurance of protection for 1000 years, as required in Criterion 6 of 10 CFR Part 40, Appendix A.

Open Issues: The licensee needs to provide the following to resolve the open issues identified in this section:

(1) Analysis of rock size for the riprap apron.

(2) Design of the rock apron to protect against gullies caused by overland flow.

(3) Design of the rock apron on the east side of the cell to accommodate high flows.

(4) Design for rock armor protection of stream 005.

(5) Specifications for riprap rock gradation.

(6) Information necessary to show that rock of acceptable durability will be used for flood protection.

(7) Information regarding the licensee's erosion protection testing, inspection, and quality control program.

(8) Information regarding the licensee's rock durability testing program.

(9) Information regarding the licensee's riprap placement procedures.

(10) Information regarding the licensee's rock layer thickness testing.

(11) Information regarding the adequacy of the soil cover to resist wind erosion.

4.6 Upstream Dam Failures

As discussed in Section 4.1, above, there are several impoundments upstream of the site. However, due to the elevation of the site relative to the reservoir levels, their failure would not affect the site.

5.0 PROTECTING WATER RESOURCES

5.1 Introduction

This section presents the results of the NRC staff's review of the detection monitoring program and final disposal cell construction, as it relates to ground-water protection. NRC staff performed this review using Section 4.0 of NUREG-1620, Rev. 1, which is a standard review plan (SRP) for Title II reclamation plans. However, much of Section 4.0 - Protecting Water Resources, is not applicable to new disposal cells because NUREG-1620, Rev. 1, assumes that a disposal cell for 11.e(2) byproduct material already exists. Therefore, detection monitoring is not addressed in the standard review plan, while corrective action and compliance monitoring are addressed in the SRP. Where elements of NUREG-1620, Rev. 1 are applicable, NRC staff utilized them to prepare this section of the SER.

5.2 Site Characterization

5.2.1 Site History

Appendix D (Site Characterization Report) of the reclamation plan contains detailed site history information, as recommended in the SRP. Section 2.0 of Appendix D contains site and licensing history. Section 4.0, Appendix D, and Section 2.0, Appendix B (Hydrogeological and Geochemical Site Characterization Report) of the reclamation plan, contain descriptions of chemicals used in site activities and the resulting wastes. The aforementioned sections also describe environmental impacts associated with various onsite processes and structures. Surrounding land use is described in Section 2.2 of the reclamation plan main text and provides a brief description of the expected impacts of the proposed plan on adjacent land uses.

Section 3.4.1, Appendix D, describes surrounding water uses. Surrounding water uses are potable water supplies from the Robert S. Kerr Reservoir system and livestock/residential ground-water users within 2 miles of the site to the north, east, and south. No ground-water users exist between the site and the Arkansas and Illinois rivers. Meteorological data is presented in Section 3.2 of Appendix D, which includes information regarding temperature, precipitation, hail storms, tornados, evaporation, and wind patterns.

5.2.2 Geology, Hydrogeology, and Surface Water

Geology is described in Section 3.3 of Appendix D and provides a comprehensive description of soils and geologic units underlying the site. Geologic descriptions were obtained from 300 monitoring well borings and over 500 exploratory borings drilled over a 25-year period. A discrepancy exists between the written geologic descriptions and associated maps contained in Appendix D. Page 3-14 in Appendix D states that Sandstone 1 underlies the Terrace Groundwater System; however, cross-sections contained in Figure 11, Appendix D, and in Figure 14, reclamation plan show that Shale 1 underlies the Terrace system. However, according to SFC, the current terminology defines the “Terrace Groundwater System” as the upper terrace soils and the Shale 1 unit. Sandstone 1, therefore, underlies the Terrace Groundwater System, as stated in the text. Figure 11, Appendix D should be revised to clarify exactly what the terrace ground-water system is. **This is a confirmatory item.** See Section 2.0 of the SER for a more detailed discussion of the site geology.

SFC has provided stratigraphic cross-sections depicting the underlying geologic units, water levels in the uppermost aquifer, and existing monitoring wells. Figure 14 in the reclamation plan depicts the relationships among the disposal cell, geologic units, monitoring wells, and water levels. Hydraulic conductivities for the terrace ground water system, shallow ground water system, and deep ground water system were determined by multiple slug tests in each system (Section 3.4.3, Appendix D).

5.2.2.1 Regional Hydrogeology

Regionally, ground water occurs in the thicker alluvial and terrace deposits of the Arkansas, Illinois, and Canadian rivers and in the Keokuk and Reed Springs formations. The only significant fresh water aquifer near the site is the alluvium aquifer deposited along the Arkansas and Illinois rivers. The lower part of the alluvium consists of a maximum of 15 feet of coarse sand and gravel capable of producing up to 900 gallons per minute (gpm). Water quality is hard to very hard; therefore, it is considered sufficient for irrigation and watering stock.

The Keokuk and Reed Springs aquifers are the only major bedrock aquifers near the site. These aquifers are located approximately 10 miles northeast of the site and produce 3 to 50 gpm of good quality water. Closer to the site, the Atoka Formation may be a limited source of water. Lower permeabilities reduce potential yields from this formation. Regionally, ground water flows westerly toward the Arkansas and Illinois rivers, which are potential discharge points for shallow ground water. Therefore, the site is downgradient of the Keokuk and Reed Springs aquifers. Ground water may also discharge to springs, evapotranspire, or recharge other strata.

Two offsite ground-water investigations were performed. In September 1990, the Oklahoma State Department of Health (OSDH) sampled seven domestic ground-water supply wells in the site vicinity at the request of the landowners. Analytical results indicated that none of the wells exceeded drinking water standards for gross alpha, gross beta, or radium-226. In 1991, SFC and OSDH initiated a survey to identify any water wells within a 2-mile radius of the site. Wells identified during this survey are shown in Figure 16 of Appendix D.

A total of 37 wells were identified during this survey, ten of which were on properties owned by SFC or Sequoyah Fuels International Corporation (SFIC). No ground-water users were identified in the area between the site and the Arkansas and Illinois rivers. Of the total 37 wells, samples were collected from 23. Results indicated that site operations have not impacted offsite ground-water users.

5.2.2.2 Site Hydrogeology

SFC classifies site hydrogeologic units into the following four regimes: alluvial, terrace, shallow, and deep ground-water systems. The terrace ground-water system is the upper most regime and contains the terrace deposits and the Unit 1 shale. Depth to ground water varies from 8 to 11 feet; however, a few unsaturated zones exist in this system near the SX building, Pond 2 area, and southwest and west of the Fluoride Holding Basin No. 2. Ground water appears to flow radially northwest through southwest from the Main Processing Building (MPB) area (see Figure 17 of Appendix D). Recharge to this system occurs as infiltrating precipitation; however, artificial recharge from leaks in the fire suppression system and unlined ponds has occurred in the past.

Mean hydraulic conductivity (geometric mean) for the terrace ground-water system is approximately 2×10^{-5} cm/s. Such a conductivity represents relatively slow moving water, which would be expected for the fractured shale of the Unit 1 Shale and sediments of the terrace deposits. This conductivity also indicates that ground water contamination would migrate slowly.

The alluvial ground-water system underlies the extreme western portion of the site. This system comprises the only significant fresh water aquifer at the facility. Regionally, yields from the alluvial ground-water system vary from 10 to 900 gpm; however, the water is hard to very hard making it useful only for irrigation or stock watering. Ground water within this system flows from east to west or southwest discharging into the Arkansas or Illinois River. No part of the proposed disposal cell overlies the alluvial system and the alluvial and terrace systems are not hydraulically connected because the alluvial system overlies Atoka Units 3, 4, and 5, while the terrace system overlies Unit 1.

Beneath the terrace ground-water system is a low permeability, highly cemented sandstone (Unit 1 Sandstone) that provides some degree of hydraulic separation between the terrace system and the underlying shallow bedrock ground-water system. The degree of hydraulic separation it provides is at issue. According to Section 7.3, Appendix B, of the reclamation plan, zones of vertical, unfilled fractures and wells and boreholes completed in multiple layers can provide pathways for contaminant transport from the terrace ground-water system to the shallow ground-water system. The presence of contamination in the shallow ground-water system appears to support the idea that some degree of hydraulic communication exists. This is in contrast, however, to Section 3.4.1, Appendix D, of the reclamation plan that states the terrace ground water system is not in hydraulic connection with the shallow ground water system. **This apparent discrepancy regarding hydraulic separation between the terrace and shallow ground water systems is an open issue.**

The shallow system is comprised of interbedded shale and sandstone identified as Unit 2 Shale, Unit 2 Sandstone, Unit 3 Shale, Unit 3 Sandstone, and the Unit 4 Shale. Depths to the top of this system (Unit 2 Shale) are 10 to 40 feet depending upon the location at the site. Similar to the terrace ground water system, ground water in the shallow system flows radially from northwest through southwest from the MPB (See Figure 18 in Appendix D). The mean horizontal hydraulic conductivity is 7×10^{-5} cm/s and the mean vertical hydraulic conductivities measured in the Unit 4 Sandstone that confines the shallow system on the bottom ranges from $<9 \times 10^{-9}$ to 1.8×10^{-8} cm/s, which is extremely low. As a result, SFC states that no hydraulic connection appears to exist between the shallow and deep bedrock ground water systems.

The deep bedrock ground water system is a shale bed identified as Unit 5 Shale that is separated from the shallow system by the Unit 4 Sandstone. As previously stated, there is no known hydraulic connection between the shallow and deep systems. Depending on the location at the facility, depth to the deep system ranges from 5 to 60 feet. Ground water in the deep system flows from east to west (see Figure 19 in Appendix D). The mean horizontal hydraulic conductivity in the deep system is 3×10^{-6} cm/s.

5.2.2.3 Surface Water Hydrology

Surface water hydrology is discussed in Section 3.5 of Appendix D and Section 2.3.2 of the main text of the reclamation plan, in which SFC discusses the types of surface water bodies on and near the site. Such water bodies include the Robert S. Kerr Reservoir composed of the Illinois and Arkansas rivers (west and south, respectively), 8 small artificial farm ponds, six ephemeral onsite streams, Creek A (southern part of site), Salt Branch (to the north), and northeast flowing tributary of Salt Branch (to the east). Discharges in the Illinois River are controlled by the Tenkiller Ferry Reservoir dam; average discharge is approximately 1,600 cubic feet per second (cfs). See Section 4 of the SER for a more detailed discussion of surface water hydrology.

5.2.3 Water Quality and Geochemical Conditions

Various contamination studies have been performed, the most comprehensive of which were the Facility Environmental Investigation (FEI) (SFC, 1991) and additional site characterization activities presented in an addendum to the FEI (SFC, 1992). Results of these investigations are summarized in the reclamation plan in Appendix D and adequately describe the types and concentrations of contaminants in the soils associated with each site characterization unit at the site. Ground-water contamination has also been delineated and is presented on a series of isoconcentration maps in Appendix D of the reclamation plan that depict ground water contamination in different saturated zones. Also, Appendix B describes geochemical tests performed in 2001 to obtain information regarding chemical transport properties of the saturated zones for use in geochemical transport models.

5.2.3.1 Water Quality

SFC currently conducts ground-water monitoring through a comprehensive monitoring well network to comply with the requirements of its Source Materials License issued by the NRC. Although ground-water monitoring has been conducted at the site for over 20 years, most of the wells in the current network were installed during the FEI in July 1991. Section 4.5.6, Appendix D of the reclamation plan presents contamination assessments for uranium, nitrates, and fluoride, which are listed as constituents of concern (COCs) in Appendix D. However, Section 5.7, Appendix B, of the reclamation plan also lists arsenic as a COC.

SFC has not provided a comprehensive list of COCs in the reclamation plan. However, all the COCs discussed in Appendices B and D are found on the list of analytical parameters for the detection monitoring program found in Attachment E to the reclamation plan. The lack of a COC list does not impact NRC staff's ability to approve the reclamation plan; however, reviews of the ground-water monitoring plan and the corrective action plan will focus on this issue. Such reviews may result in COCs not currently mentioned in the reclamation plan (i.e., arsenic, fluoride, nitrate, uranium).

Total uranium continues to be detected above the SFC environmental action level (EAL) of 152 pCi/l (225 µg/l) in the terrace and shallow bedrock ground-water systems. Uranium has not been detected above the EAL in the deep ground-water system. Total uranium found in the terrace system ranges from <0.7 pCi/l to 75,824 pCi/l. The high value occurs north of the solvent extraction (SX) building in well MW025. According to SFC, the concentration in this well appears to have increased due to ground-water recovery efforts occurring nearby. Uranium impacts also occur near the MPB, west of the Emergency Basin, in the Clarifier Basins area, and in the Solid Waste Burial Areas. Figure 40 in Appendix D of the reclamation plan presents uranium concentrations in the terrace system.

Uranium in the shallow system varies in concentration from <0.7 to 5,179 pCi/l, with the high concentration occurring at the northwest corner of the MPB. Concentrations exceeding the EAL also occur north of the Fluoride Holding Basin No. 2, north of the Solid Waste Burial Area No. 2, and north of the SX Building. Figure 41 in Appendix D of the reclamation plan presents uranium concentrations in the shallow system.

Nitrates continue to be detected above the EPA maximum contaminant level (MCL) of 10 mg/l in the terrace and shallow systems. Nitrate has not been detected above the MCL in the deep system. Nitrate concentrations detected in the terrace system varied from <0.6 mg/l to 1,190 mg/l. The high concentration was detected north of Clarifier 1A. Other areas exceeding the nitrate MCL include the MPB, SX Building, Pond 1 Spoils Pile, and Pond 2. Figure 42 in Appendix D of the reclamation plan presents nitrate concentrations in the terrace system.

Nitrate concentrations in the shallow system varied from 0.8 to 5,650 mg/l, with the highest concentration occurring at the southwest corner of Pond 2. Other areas exceeding the nitrate MCL include the MPB, SX Building, Emergency Basin, Sanitary Lagoon, Yellowcake Storage Area, Pond 1 Spoil Pile, Pond 2, and the Fertilizer Pond Area. It appears from SFC's data that nitrate contamination encompasses a larger area in the shallow system when compared to the terrace system (excluding the Fertilizer Pond Area which is not in the terrace system). Figure 43 in Appendix D of the reclamation plan presents nitrate concentrations in the shallow system.

Fluoride has been extensively monitored at the site. Although concentrations have decreased since 1991, fluoride continues to be detected above the 4.0-mg/l MCL in the terrace and shallow systems. Fluoride has not been detected in the deep system. Figure 44 in Appendix D of the reclamation plan presents nitrate concentrations in the terrace system.

Fluoride concentrations in the terrace system varied from <0.3 mg/l to 8.5 mg/l. The high concentration occurred north of the MPB, and exceedances of the MCL also occur northeast of the SX Building. Fluoride concentrations in the shallow system varied from <0.2 to 4.7 mg/l, with the high fluoride concentration occurring west of the Pond 2. It should be noted that Section 4.5.6 of Appendix D states that this high concentration occurs west of the Emergency Basin; however a review of Figure 4 of this Appendix indicates that it is actually west of Pond 2. Figure 45 in Appendix D of the reclamation plan presents fluoride concentrations in the shallow system.

5.2.3.2 Geochemical Conditions

Appendix B of the reclamation plan describes the geochemical testing and analyses performed to support contaminant transport modeling. SFC performed mineralogical analyses using x-ray diffraction and partition coefficient analyses using batch desorption and batch adsorption tests. According to SFC, some of the partition coefficient results were unsatisfactory; therefore, geochemical modeling was performed to confirm and adjust laboratory generated partition coefficients. Results of the laboratory analyses and geochemical modeling indicate that adsorption is the primary mode of retardation.

5.2.4 Background Water Quality

A presentation of background water quality is found in Section 4.1, Appendix D, of the reclamation plan and also in the Groundwater Monitoring Plan (SFC, 2003). To collect background ground water samples, SFC installed three wells in the terrace ground water system, three wells in the shallow bedrock ground water system, and two wells in the deep ground water system. A discrepancy exists between Appendix D and the Groundwater Monitoring Plan regarding the actual analytical parameters. The Groundwater Monitoring Plan states that uranium, arsenic, nitrate, and fluoride were analyzed; however, Appendix D states that uranium, radium-226, thorium-230, nitrate, and fluoride were analyzed. Regardless of the discrepancy, it appears that background samples were analyzed for all constituents of concern, and subsequent statistical analyses appear appropriate.

Background water quality data provided in Appendix D and the Groundwater Monitoring Plan (arsenic only) are summarized in Table 5-1.

Table 5-1: Background Water Quality Data Summary

Aquifer	U-nat (pCi/l	Nitrate (mg/l)	Fluoride (mg/l)	Arsenic (mg/l)
Terrace	<3.4 to 17.4	0.2 to 2.4	<0.2 to 1.9	<0.005 to 0.01
Shallow	0.4 to <3.4	<1 to 4.1	0.4 to 4.9	<0.005 to <0.011
Deep	<3.4 to 6.8	<1 to 3.5	0.9 to 2.7	<0.003 to 0.021

Background ground-water analysis appears adequate for assessing background concentrations of the constituents of concern. However, the arsenic background data does not appear in the reclamation plan. Instead this data appears in the Groundwater Monitoring Plan. **The lack of arsenic background data in the reclamation plan is a confirmatory item.**

5.2.5 Evaluation Findings

The NRC staff has completed its review of the site characterization at the SFC, Gore, Oklahoma, uranium conversion facility. This review included an evaluation using the review procedures in Section 4.1.2 and the acceptance criteria outlined in Section 4.1.3 of the standard review plan.

Based on the information provided by SFC, the NRC staff can draw the following conclusions regarding the site characterization aspects of the reclamation plan. Site history and geology discussions are sufficient to meet the requirements of 10 CFR 40, Appendix A, Criterion 5G, with the following exception. Although the text of Appendix D states that the terrace deposits and Unit 1 Shale comprise the terrace ground-water system, it is not clear that from Figure 11, Appendix A, and Figure 14, main reclamation plan text, that this is the case. SFC should resolve this apparent discrepancy.

SFC's discussion of site hydrogeology appears comprehensive and provides an adequate representation of the hydrogeologic regime at the site. However, as discussed in Section 5.2.2.2, there appears to be a contradiction regarding the aquitard properties of the Unit 1 Sandstone.

Regarding water quality, SFC does not present a single comprehensive list of COCs. Instead COCs are listed in multiple places, causing confusion. As previously stated, this does not impact the NRC staff's ability to approve the reclamation plan. Because arsenic is listed as a COC, however, background water quality data should be added to the reclamation plan. **This is a confirmatory item.**

The staff cannot conclude its review of the site characterization aspects of the reclamation plan because of these unresolved open and confirmatory issues.

<u>Open Issue:</u> The licensee needs to provide the following to resolve the open issue identified in this section:

(1) Resolve conflicts in the reclamation plan regarding hydraulic connection between the terrace and shallow ground-water systems.

<u>Confirmatory Items:</u>

(1) Revise figures to show that the terrace ground-water system consists of both the terrace deposits and Unit 1 Shale.

(2) Include arsenic background water quality data in the reclamation plan.

5.3 <u>Disposal Cell Design</u>

NRC staff reviewed the design of the disposal cell as it relates to ground-water quality and detection monitoring. The purpose of this review is to determine if some of the disposal cell design features would impact ground-water quality or the effectiveness of the detection monitoring program. NRC staff based this review on Section 4.4 Ground-Water Corrective Action and Compliance Monitoring Plan in NUREG-1620, Rev. 1. Although this NUREG section does not specifically address detection monitoring, certain review components related to cell construction are nonetheless appropriate.

5.3.1 Disposal Cell Cover

SFC designed the disposal cell cover to be a 10-ft thick store/deplete system whereby meteoric water would be sequestered and subsequently evapotranspired resulting in no available water for infiltration into the cell. The cell cover is a multi-layered system consisting of the following layers from top to bottom:

- Vegetation
- Topsoil - 0.75 feet thick
- Rock Mulch - 0.75 feet thick
- Subsoil - 5 feet thick
- Liner Cover Material - 1.5 feet thick (See Section 5.3.2)
- Synthetic Liner
- Compacted Clay Liner - 2-feet thick

To fulfill the store/deplete function, meteoric water would run off or infiltrate the topsoil and rock mulch prior to the establishment of cover vegetation. SFC states that infiltrating water would either be sequestered in the subsoil layer and/or infiltrate the subsoils to the underlying liner cover layer where it would drain to the sides of the cell. SFC further states that after vegetation establishment, transpiration would remove water from the topsoil, rock mulch, and subsoil to the point where infiltration through the subsoil would be minimized substantially. The compacted clay liner and overlying synthetic liner would prevent infiltrating water from entering the disposal cell, thus, preventing the production of hazardous seepage.

Topsoil would be planted with native grassland and maintained annually to prevent tree growth on the cover. Section 8.0, Attachment A to the reclamation plan, specifies native grass species for revegetation and that no trees will be allowed to grow on the cover. However, the main text of the reclamation plan requires revisions to remove any reference to transplanted seedlings and should also either present the full revegetation plan or cite Attachment A. Attachment E of the reclamation plan also requires revisions to remove any reference to transplanted seedlings and should reference Attachment A for the revegetation plan instead of Appendix A. **This is a confirmatory item.**

NRC staff does not expect the cover to function as a store/deplete system over the long-term because recent research indicates that such covers do not perform, as expected, in humid areas. Areas receiving over 40 inches of rain annually generate too much infiltrating water to be removed by store/deplete covers. However, this long-term store/deplete functionality is not necessarily a concern because of the use of a compacted clay liner below the synthetic liner. Research indicates that such liner systems are effective at minimizing seepage. Regardless of whether the store/deplete aspects of the cover function properly, the cell contents would remain adequately protected by the composite cover.

5.3.2 Liner Cover Material

Liner material is a component of the disposal cell cover described in Section 5.3.1. The purpose of this layer is to allow water infiltrating from the top of the cell to drain to the sides. This would prevent water from accumulating above the synthetic liner and potentially infiltrating into the cell. NRC staff is concerned with the adequacy of this layer with respect to its long-term ability to transmit water. If this layer becomes clogged, infiltrating water will linger in the cover. Excessive pore water pressure between the synthetic liner and the subsoil could promote seepage into the cell if liner perforations occur, or the cover slopes could destabilize because of lower shear strengths in the liner cover material and overlying subsoil. To assess this possibility, NRC staff performed the following standard filter computations.

SFC provided grain size distribution data for the liner bedding cover material, which is as follows:

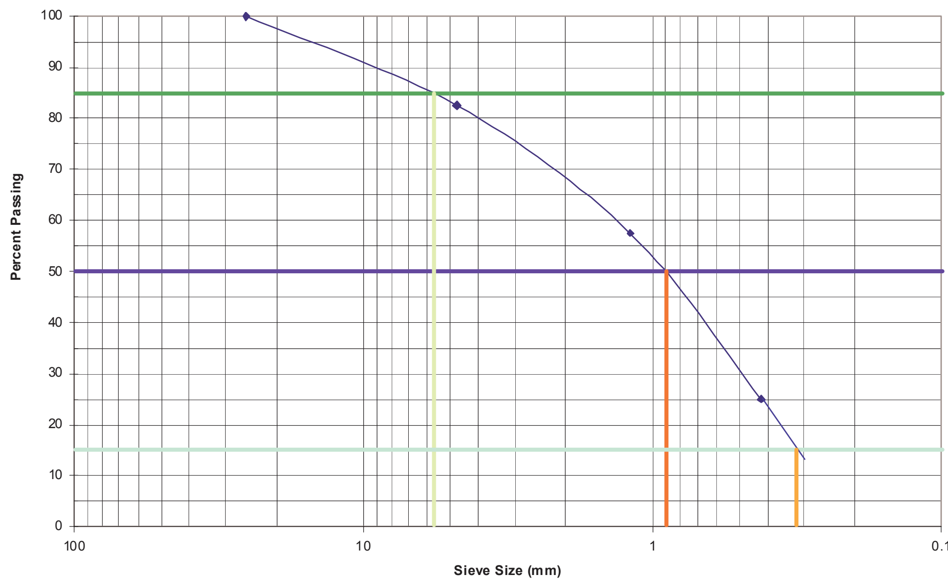
100 percent passing 1-inch sieve (25.4 mm)
65 to 100 percent passing No. 4 sieve (4.76 mm)
30 to 85 percent passing No. 16 sieve (1.19 mm)
0 to 50 percent passing No. 40 sieve (0.42 mm)

(This information was provided in a response to a request for information but is not currently in the reclamation plan. **This is a confirmatory item**.)

To determine the adequacy of the liner cover material filtering capacity, NRC computed a grain size distribution curve using the averages for the No. 4, 16, and 40 sieves (Figure 5-1). Linear extrapolation was used to continue the curve to the lower percent passing values. Quantiles of interest for the liner cover material are D_{50} and D_{15}, which equal 0.9 mm and 0.32 mm, respectively. Because no grain size data were provided for the fine-grained soil, conservative values for the D_{85} (0.074 mm) and D_{50} (0.01 mm), were assumed. Quantiles for the liner cover and the overlying fine-grained soil were compared using the USACE filter equations:

1. $D_{15LINER}/D_{85SOIL}$ #5 Piping Equation
2. $D_{50LINER}/D_{50SOIL}$ #25 Permeability Equation

Figure 5-1 - Liner Cover Material Grain Size Curve



Solutions to equations 1 and 2 are 32 and 21, respectively. This indicates that the liner cover is not designed to prevent piping; however, it will provide sufficient drainage according to equation 2. The fact that the liner cover material does not meet the piping criteria may indicate that this layer is susceptible to clogging by fines from the overlying soil as they migrate through the liner cover material. **The NRC staff, therefore, considers this issue open. A similar issue was raised in the Section 2.3.2 of this SER regarding the geotechnical stability of the disposal cell.**

5.3.3 Disposal Cell Liner

Criterion 5 of Appendix A requires a liner to be constructed under a disposal cell. The purpose of the liner is to prevent seepage of hazardous constituents from the cell. SFC's liner design consists of the following from top to bottom:

- Liner Cover Material - 1.5 feet thick
- Synthetic Liner
- Liner Bedding Material - 0.5 feet thick
- Clay Liner - 3.0 feet thick

The liner cover material is the same material as that described in Section 5.3.2. Within the liner system, the liner cover material serves to protect the underlying synthetic liner from the puncture during waste placement and acts as a drainage layer for the leachate collection system. Leachate collection pipes will be installed in this layer to convey fluids to external sumps for sampling, removal, and disposal. Liner cover material directly underlies Layer A of the waste material that consists of the following components: (1) raffinate sludge, (2) Pond 2 residual materials, (3) Emergency Basin sediment, (4) North Ditch sediment, and (5) Sanitary Lagoon sediment. SFC did not provide grain size data for these materials; therefore, it is not clear whether the liner cover material will become clogged. An analysis similar to that performed in Section 5.3.2 should be provided to assess clogging potential of this layer. However, this is not an open issue because plugging of the liner cover material will not significantly impact the ability of the liner to prevent seepage.

The synthetic liner consists of 60-mil thick high density polyethylene (HDPE) with both sides being smooth (Attachment A of the reclamation plan). It will serve as a hydraulic barrier between the waste and the clay liner preventing dissolved hazardous constituents from accumulating above the clay liner. Synthetic liners are effective hydraulic barriers; however, insufficient data exists that demonstrates whether the liners would retain structural integrity for the entire 1000-year design lifetime. Nonetheless, the synthetic liner could be an effective hydraulic barrier for at least decades if not the 200-year minimum performance period required by 10 CFR 40, Appendix A.

Liner bedding material is composed of the same material as the liner cover material described in Section 5.3.2 and will function as a drainage layer for the leak detection system under the synthetic liner. This system is required per 10 CFR 40, Appendix A, Criterion 5E(1). As discussed in Section 5.3.2, filter analysis indicates that this material would provide sufficient permeability to drain infiltrating water toward the leak detection system to be installed within this layer. Clogging is not a likely issue because this layer is effectively isolated from the overlying waste. The leak detection system is a series of perforated pipes that direct infiltrating water of a central trunk and subsequently to an external sump. Sump water will be tested, removed, and disposed. The liner bedding material and associated leak detection system are acceptable.

The clay liner will consist of a 3 foot thick layer of clayey soils from approved on-site borrow areas (Attachment A of the reclamation plan). Clay liner material will contain particles with a maximum diameter of 1 inch and will be free from roots, branches, rubbish, and process area debris. Compacted clay material will exhibit a maximum saturated hydraulic conductivity of 1×10^{-7} cm/s (0.1 ft/yr) and radionuclide activity concentrations lower than the selected subsurface soil cleanup level. A review of the liner thickness, composition, and hydraulic properties indicates that it is acceptable for precluding seepage from entering the subsurface from the disposal cell.

A review of the liner system indicates that it is acceptable for the purpose of containing seepage from the disposal cell. Although, it is not clear whether plugging will impact the performance of the leachate collection system, such a condition would not directly impact the ability of the liner to contain seepage. Furthermore, although the synthetic liner may not remain effective for the entire 1000-year design lifetime, it would provide effective hydraulic separation for the time that its integrity remains intact.

5.3.4 Disposal Cell Location

SFC intends to construct the disposal cell in the northeast portion of the SFC facility at the current location of the emergency basin, solid waste building, solvent extraction building, the western half of the Main Processing Building, and other ancillary and support structures. Soils and ground water in the area of the proposed cell are currently contaminated with uranium, radium-226, thorium-230, arsenic, nitrates, and fluoride. The licensee’s intent was to place the cell in a currently contaminated area to minimize the amount of property required for transfer to long-term care.

Cell construction will occur in three phases. During cell construction, SFC intends to excavate contaminated materials and place such materials in a phase of the cell that has already been prepared. For example, phase I of the cell will be constructed over a concrete pad; therefore, no significant foundation preparation work or excavation is required for that phase. Contaminated soils from the phase II area will be placed in the phase I cell prior to construction of phase II. Contaminated materials from the phase III area will be placed in the phase II cell, and contaminated materials from outside the cell will be placed in various locations of the cell. This sequencing will allow SFC to avoid stockpiling and double handling contaminated materials. During the construction of each phase, SFC will dewater contaminated ground water from the excavation, and construct a cell foundation on the excavation bottom of phases II and III.

5.3.5 Evaluation Findings

On the basis of the information presented in the application, the NRC staff concludes the following regarding the disposal cell design. The disposal cell liner system is of adequate size and composition to provide a high degree of seepage containment. Similarly, the cover system is sufficient to prevent seepage encroachment into waste portion of the cell. However, NRC staff cannot conclude that the cover system design will provide long-term stability based on the filter computations presented in Section 5.3.2, above.

The staff cannot conclude its review of the design of the disposal cell with respect to protection of ground water because of the following unresolved open and confirmatory issues.

Open Issues: The licensee needs to provide the following to resolve the open issue identified in this section:

(1) Information to show that the liner cover material will comply with standard filter design criteria to prevent piping and promote drainage.

Confirmatory Items:

(1) The licensee should review the reclamation plan to remove references to transplanting seedlings. Based on our review, references to transplanting seedlings are found in Section 8.2 of Attachment A, Section 7.2 of Attachment E, and Section 6.2 of the reclamation plan text.

Section 6.2 of the reclamation plan should reference Section 8.0 of Attachment A that addresses cover revegetation.

Section 7.2 of Attachment E should reference Section 8.0 of Attachment A that addresses cover revegetation instead of Appendix A.

(2) The licensee should include the grain size distribution for the liner cover material in the reclamation plan.

5.4 Detection Monitoring

5.4.1 Detection Monitoring Network

SFC has proposed a detection monitoring network that consists of 5 monitoring wells, one upgradient and four downgradient. The area of the proposed cell appears to coincide with a ground water divide with the strongest gradients trending northwest and southwest. A gentler ground-water gradient trends due west. SFC's proposed well placement scheme does not provide adequate coverage along the western side of the cell. Approximately 900 feet separate the two western-most downgradient wells, which leaves most of the western side unmonitored. If a leak were to occur along or near the western edge of the disposal cell, contaminated seepage could enter the ground water without detection. **Therefore, detection monitoring on the western side of the cell is an open issue.**

5.4.2 Monitoring Well Construction

In response to a staff question, SFC provided monitoring well construction specifications for the point of compliance wells. SFC stated that this information is contained in the Ground Water Monitoring Plan. However, well construction specifications should either be placed in the Technical Specifications (Attachment A to the reclamation plan), or SFC should incorporate the well construction specifications in the reclamation plan by reference. **This is a confirmatory item.**

According to SFC, wells are to be constructed using 10-slot, PVC screens with PVC casing. SFC does not specify the schedule of the PVC screen and casing; however, schedule 40 is the most common pipe and screen used for monitoring wells. Screen lengths could range from less than 10 feet to 20 feet depending on the thickness of the saturated zone. SFC states that it will monitor discrete zones using smaller screen lengths. This technique is acceptable and standard practice. However, because the saturated zones are in shale, sufficient screen length should be provided to allow sufficient flow into the wells for sampling.

SFC does not specifically state which zones will be monitored by the detection monitoring system. Furthermore, as stated in Section 5.2.2.2 above, zones of vertical, unfilled fractures and wells and boreholes could be present and provide pathways for contaminant transport from the terrace ground water system to the shallow ground-water system. **Therefore, details regarding the particular zone to be monitored in the detection monitoring system and the manner in which this system addresses the aforementioned potential hydraulic pathways is an open issue.**

5.4.3 Parameters and Sampling Frequency

Attachment E of the reclamation plan main text describes the detection monitoring plan. SFC will sample and analyze all detection monitoring wells quarterly for the following constituents: antimony, arsenic, barium, beryllium, cadmium, chromium, fluoride, molybdenum, nickel, nitrate, radium-226, selenium, thallium, thorium-230, uranium (natural). The parameters list and frequency are acceptable for the purpose of detection monitoring at this site.

5.4.4 Leak Detection

Appendix A, Criterion 7A, requires a detection monitoring system that can detect leakage from an impoundment or, in this case, a disposal cell. Detection monitoring systems consist of ground-water monitoring wells that are sampled for a specific set of parameters based on the waste characteristics. Appendix A also addresses leak detection within liner systems, such as that proposed by SFC. As discussed above, SFC's liner design consists of both a synthetic liner and a clay liner. SFC intends to install a leak detection system in the synthetic liner bedding material that will drain to sumps for sampling and fluid removal. Appendix A, Criterion 5E(1), requires that such a leak detection system be installed under synthetic liners and that this system be in addition to the detection monitoring system required in Appendix A, Criterion 7A.

NRC staff is concerned that because the cell will be built in an area of residual ground-water contamination, SFC's ability to detect contamination that may leak from the disposal cell may be impaired. This is because the concentration of some constituents in ground-water monitoring wells due to existing contamination may be high enough to mask contamination potentially leaking from the cell. SFC, however, states that removing contaminated soil and ground water from the excavation site would reduce ground water contamination levels to below the point where residual concentrations would mask potential contamination emanating from the cell.

To support its view, SFC states that soils in excess of 540 pCi/g uranium will be excavated from the foundation areas of Phases II and III, in the manner described above (Section 3.2.2 of reclamation plan), and contaminated ground water in excess of 150 pCi/l uranium will be removed. However, a review of Figures 38 - 40 of Appendix D to the reclamation plan indicates that a substantial area of ground-water contamination will exist immediately outside the excavation area. After excavation is completed, a period of hydrostatic adjustment will likely draw contaminated water into the excavation area. Considering that ground-water contamination of 150 pCi/l of uranium will likely remain, NRC staff concludes that it is likely that existing contamination could mask potential contamination originating from the cell.

SFC states that it has a high degree of confidence that the cell will not leak in the first 3 years. SFC is specifying a multi-layered disposal cell liner system discussed above. Such a liner system could provide a high degree of seepage containment. However, poor construction or quality control could result in cover and liner cracks that allow seepage to pass into the subsurface within the first year. This 3-year period also appears arbitrary and the reclamation plan does not address any environmental consequences after the 3-year period passes. Furthermore, irrespective of any particular time period, the licensee must be able to detect cell leakage at any time.

SFC's approach regarding cell seepage is that either it will not occur or, if it occurs, the quantities will be too small to be detected by the point-of-compliance wells. Therefore, SFC states that public health and the environment would not be impacted. This position could be the basis for requesting an alternative to the regulations (as discussed in the introduction to 10 CFR 40, Appendix A), although SFC does not make that request. It appears that, as designed, SFC's detection monitoring program may not fulfill the requirement in Criterion 7A.

SFC can propose an alternative to the specific requirements, as allowed per Appendix A. Alternatives to specific requirements are permitted, as long as the applicant or licensee demonstrates that the alternative is as protective to public health and the environment, as the specific requirement. Although SFC appears to initiate a discussion of an alternative to the specific requirements of 10 CFR 40, Appendix A, it does not explicitly present or request one. **Therefore, the issue of being able to detect, through ground-water monitoring, leaks from the disposal cell, is an open issue.**

As discussed in Section 5.2.2.2 of this SER, well or rock borings may provide hydraulic communication between the terrace and shallow ground-water systems. Constructing a disposal cell in an area with known hydraulic conduits, poses a risk of further polluting an aquifer system below which the disposal cell is constructed. Therefore, SFC needs to provide information regarding the presence of ground-water conduits through Sandstone 1 below the proposed disposal cell and the manner in which SFC will address the risk these conduits pose. **This is an open issue.**

5.4.5 Evaluation Findings

On the basis of the information presented in the application and the detailed review conducted of the detection monitoring program for the SFC uranium conversion facility, the NRC staff can not conclude that the proposed detection monitoring network is sufficient to detect potential ground-water contamination from all locations under the cell. However, the proposed monitoring frequency and parameters list is sufficient. SFC also did not specify which saturated zones would be monitored by the detection monitoring system. SFC has also not demonstrated that it will be able to discern ground-water contamination emanating from the cell versus existing ground-water contamination, nor has SFC proposed a satisfactory alternative to the specific requirements of 10 CFR 40, Appendix A, Criterion 7A. SFC also has not addressed the risks posed by natural or artificial conduits through Sandstone 1.

<u>Open Issues:</u> The licensee needs to provide the following to resolve the open issues identified in this section:

(1) Detection monitoring along the west side of the disposal must be addressed.

(2) The licensee must specify and justify the saturated zones that will be monitored by the detection monitoring system.

(3) The licensee must provide information to show that the proposed detection monitoring system will be capable of detecting leaks in the disposal cell, as required by Criterion 7A of Appendix A.

(4) The manner in which the licensee will identify potential hydraulic conduits below the disposal cell and how the licensee will address the risk of further contamination to the shallow ground-water system.

<u>Confirmatory Item:</u>

(1) Monitoring well construction details must be added to the Technical Specifications or incorporated into the reclamation plan by reference.

6.0 RADIATION PROTECTION

6.1 Introduction

The reclamation plan addresses the radon and gamma attenuation design of the byproduct material disposal cell cover, and the remediation of soils and buildings contaminated with byproduct material and source material (as defined in 10 CFR Part 40). Also, the health and safety aspects of site decommissioning are addressed. The NRC staff reviewed the radiation protection portions of the reclamation plan following the guidance in the Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (NRC 2003, NUREG-1620, Rev. 1, Section 5).

6.2 Cover Radon and Gamma Attenuation and Radioactivity Content

Part 40, Appendix A, Criterion 6(1), requires a demonstration (via calculation) that the long-term radon flux rate of the proposed disposal cell cover meets the radon attenuation limit, and that the direct gamma exposure on the cover is background. Criterion 6(5) requires that the near surface portion of the cover contain background levels of radionuclides.

SFC proposes to use material with a lower content of radionuclides in the upper layer of contaminated material in the disposal cell. Then a cover would be placed with the following layers: 2 feet clay, synthetic liner, 1.5 feet liner cover (sand), 5 feet subsoil, and 1.5 feet topsoil. The cell top slope will be vegetated while the upper 6 inches on the side slopes will contain rock mulch. The radon attenuation model cannot incorporate any radon attenuation by the synthetic liner because the liner's ability to remain intact for 200 years has not been demonstrated.

6.2.1 Radon Attenuation

Part 40, Appendix A, Criterion 6(1), requires that a disposal cell design limit releases of radon (Rn-222) from uranium byproduct materials to not exceed an average (over at least a year) release rate of 20 $pCi/m^2/s$ from the surface of the cell for 1000 years, to the extent reasonably achievable, but at least 200 years. Because Rn-222, the daughter of radium (Ra-226), is a gas with a short half-life (3.8 days), the amount of radon from disposed byproduct material reaching the atmosphere is reduced by restricting the gas movement long enough so that the radon decays to its solid daughter that remains within the disposal cell. The expected long-term physical and radiological characteristics of the cell materials that influence the amount of radon available to the soil pore spaces and its movement through the soil, are incorporated into the RADON computer code (NRC Regulatory Guide 3.64) to calculate the estimated long-term radon flux from the cover.

In addition, Criterion 6(2) requires measurement of radon flux on the radon barrier portion of the cover before erosion protection materials (vegetation and rock mulch) are placed. This average measured flux value will be from the newly built cover and may not directly relate to an estimated long-term flux value that reflects assumed conditions after years of settlement and drying of the materials. The radon flux measurement and supporting data must be provided to NRC in a separate document, within the time frame allowed by regulation (Criteria 6(2) and 6(4)), and the results summarized in the Construction Completion Report.

6.2.1.1 Radon Flux Model Parameters

The staff evaluated the physical and radiological data for the contaminated materials and the cover soils used for input into the RADON computer code by the licensee. In some cases, conservative estimates or assumptions, instead of measured values, were used for input, and in other cases, limited measurement results were used. The staff evaluated the justification and assumptions made, to confirm that each input value was representative of the material, consistent with construction specifications, and reasonably conservative or based on anticipated long-term conditions. The sampling and testing methods for the materials were also reviewed to determine their appropriateness and to ensure that the resulting data would be adequate.

The licensee indicated (Sequoyah Fuels Corporation, 2005c) that the placement of various types of contaminated material required flux modeling for four different areas of the disposal cell. The thickness of each layer of contaminated material was based on the estimated volume of the various areas to be excavated. For example, Layer A (the deepest layer in the cell) in Area I is composed of sediment from the emergency basin, north ditch, and sanitary lagoon, while in Area IIA , it is composed of raffinate sludge and Pond 2 residue.

Because site soil thorium (Th-230) levels are generally much higher than the radium (Ra-226), accounting for the in-growth of Ra–226 from its parent Th-230, provides a higher value at the 1000-yr design period, than the current Ra-226 value. SFC has minimal characterization data for some material, and compensated in the flux models by using the 95 percent upper confidence interval of the 1000-year Ra-226 value for the source term. Typically, the important Ra-226 value in the model is the average for the upper 10 to15 ft of each cell area, if the radionuclide concentration is fairly homogeneous. Otherwise, layers with significantly higher levels of Ra-226, or Th-230 in this case, need to be modeled. For Area I, SCF used a Ra-226 level of 74.3 pCi/g for the upper 14 feet of contaminated material but 77 percent of the material had only estimated Ra-226 levels based on questionable analytical results.

The density values for the contaminated materials and cover layers were based on engineering estimates for the various soil types, except the clay value was based on compaction specifications. Porosity values were calculated assuming the materials have a specific gravity of 2.65. The uncertainty in these values should have only a minor effect on the model results.

The long-term moisture content of the cover is an important factor. SFC included only one measurement of the optimum water content (18.5 percent) for placement of the clay layer and did not indicate if placement specifications would be plus or minus 1 or 2 percent of optimum moisture. The long-term moisture value is expected to be lower than the placement moisture because of drying and cracking of the cover. The 15 percent moisture value used in the model for this layer would be reasonable only if the average placement moisture for the clay layer is 18 percent or higher. To check the importance of this value, the NRC staff modeled Area I using moisture content values of 12 percent for the clay and subsoil cover layers and 8 percent for the cover liner to conservatively reflect long-term conditions. The resulting flux rate was 5.9 $pCi/m^2/s$ compared to the SFC value of 2.0 $pCi/m^2/s$, so, considering that the standard is 20 $pCi/m^2/s$, the licensee's model is robust with respect to the moisture content. The other three cell areas had lower calculated flux values reported and were not modeled by staff.

The radon emanation coefficient RADON code default value of 0.35 was used for all materials/layers. This value is conservative for many types of soil. The radon diffusion coefficient was calculated in the RADON code for all materials, and is an acceptable method.

SFC used a few very conservative assumptions, but some assumptions cannot be assessed. The parameter value with the highest degree of uncertainty appears to be the 1000-year Ra-226 value for the upper 15 feet of contaminated material, which had only a few valid sample results. The staff needs to review adequate and representative sample data to assess the degree of uncertainty and determine the adequacy of the Ra-226 values used. Therefore, SFC must provide a sampling plan to provide data to justify the source term values used for the upper 15 feet of contaminated material in the radon flux calculations. If the data indicate that 1000-year Ra-226 values will be significantly higher than those used in the current flux model, SFC will be required to demonstrate to the NRC staff that the long-term radon flux will meet the criterion (using a value less than the expected average placement moisture for the clay layer) before the cover is completed. **This is an open issue.**

6.2.2 Gamma Attenuation

As demonstrated by the licensee, the proposed cover will reduce the gamma radiation from the byproduct material to background levels because of the cover thickness and the low level of Ra-226 in the upper contaminated layers.

6.2.3 Cover Radioactivity Content

In a response to an NRC request for additional information, the licensee (Sequoyah Fuels Corporation, 2005a) indicated that at least the upper 2 feet (61 cm) of the disposal cell cover will contain levels of radioactivity essentially the same as non-impacted surrounding soils. However, SFC's commitment to revise the reclamation plan has not been implemented. **This is a confirmatory item.** Furthermore, SFC did not provide supporting data. SFC must either provide the borrow material radiological data, or commit to testing the placed upper two feet of cover, and compare the results to established site background radionuclide levels. The placed cover radiological data must be provided in the Final Status Survey Report or the Construction Completion Report. **This is an open issue.**

6.2.4 Evaluation Findings

The demonstration that the radiological criteria for the cover will be met is adequate except for the following open issues and confirmatory item:

Open Issues:

(1) The licensee must provide a sampling plan to provide data to justify the source term values used for the upper 15 feet of contaminated material in the radon flux calculations.

(2) The licensee must either provide the borrow material radiological data, or commit to testing the placed upper two feet of cover, and compare the results to established site background radionuclide levels.

Confirmatory Item:

(1) The licensee must revise the reclamation plan to incorporate its commitment regarding radioactivity levels in the upper part of the cover.

6.3 Decommissioning Plan

The sections of the reclamation plan concerning decommissioning of land and buildings must address the regulations in 10 CFR Part 40. Appendix A, Criterion 6(6), requires soil cleanup to meet specific radiological criteria, and Criterion 6(7) requires prevention of threats to human health and the environment from non-radiological hazards associated with the wastes. Other sections of Part 40 require submission of a decommissioning plan addressing proposed activities and describing how a reasonable effort will be made to eliminate residual radioactive contamination (§40.42). The licensee also must specify the location of records of information important to decommissioning (§40.36(f)).

6.3.1 Site Characterization

SFC has not adequately characterized all the potentially contaminated areas, some of which are covered by structures or ponds. As described in the reclamation plan, areas will be better characterized during decommissioning, and the currently inaccessible areas will be adequately surveyed and sampled (Class 1 and 2 surveys). This data must be included in the Final Status Survey Report.

6.3.2 Soil Background Radioactivity

The licensee indicated that the background soil gamma level is 10,000 counts per minute. The licensee provided soil radionuclide background values (Attachment 4, Sequoyah Fuels Corporation, 2005a). The average of 14 background sample results were: Ra-226, 1.0 pCi/g; Th-230, 0.7 pCi/g; and uranium (U-nat), 2.1 pCi/g. These are typical values for much of the country, and are based on representative sampling. The staff concludes that the characterization of background radioactivity is acceptable.

6.3.3 Proposed Radiological Criteria

For land cleanup, the residual Ra-226 in soil must meet the concentration limits in Part 40, Appendix A, Criterion 6(6), of 5 pCi/g above background in the top 6 inches (15 cm) of soil and 15 pCi/g above background in subsurface layers, in areas that are not evaluated by the radon flux criterion (i.e., areas other than the disposal cell). For licensees subject to Part 40, Appendix A (i.e., 11e.(2) byproduct material licensees), that did not have a decommissioning plan approved by June 11, 1999, or that subsequently submit a revised plan, the radium benchmark dose applies for cleanup of residual radionuclides other than radium (primarily U-nat and Th-230). This requirement therefore applies to SFC. The requirement is that the total dose from Ra-226 and the other radionuclides present not exceed the dose that would result if the soil were contaminated with Ra-226 at the maximum allowable concentration.

The SFC dose modeling used the resident farmer scenario to represent the critical group. This was supported by data on farm type and size for the county. The modeling results (Sequoyah Fuels Corporation, 2005b) indicated a radium benchmark dose of 34 mrem/yr. This dose corresponds to soil concentrations of 140 pCi/g Th-230 and 460 pCi/g U-nat. Considering the NRC guidance in NUREG-1620, Rev. 1, SFC chose surface cleanup levels of 14 pCi/g Th-230 and 100 pCi/g U-nat. While the U-nat value is high for residual surface soil, the calculation by SFC indicated the value was as low as reasonably achievable (ALARA). A subsurface soil Th-230 criterion of 43 pCi/g will be used only for the clay liners of ponds 2 and 4, and the Clarifier A Basin, totaling approximately 14 acres (3 percent of the impacted area). These areas will be covered with at least 5 feet of clean soil. The criteria for the three radionuclides will be reduced by application of the sum of ratios, such that if any grid contains more than one radionuclide above background, the ratios of soil concentration to the criterion must add to one or less.

The remediated land surface will likely contain much lower radionuclide levels than the cleanup criteria, and the land will not be released for public use. The site will be deeded to DOE for perpetual custodial care. Therefore, there would be very limited human exposure to the residual radionuclides in soil. The NRC staff concludes that the proposed radiological criteria for soil cleanup meet the requirements of Criterion 6 of 10 CFR Part 40, Appendix A and are acceptable. However, in responses to staff requests for additional information, the licensee (Sequoyah Fuels Corporation, 2005a) committed to revising Appendix G of the reclamation plan in several places, but those changes have not been made. **This is a confirmatory item.**

According to SFC, the only building to remain on site after decommissioning is the Administration Building which is routinely scanned for radioactivity and is not contaminated. Therefore, no criteria for structure surface cleanup were proposed.

6.3.4 Gamma Guideline

The licensee must show compliance with the soil cleanup criteria for all areas, averaged over 100 square meter sections, outside of the disposal cell. The licensee can analyze soil samples from each 100 square meter area to show compliance with the soil cleanup criteria. However, because of the expense of collecting and analyzing soil samples from all 100 square meter sections, SFC (as most other licensees have done) has proposed to measure gamma radiation and correlate that to radionuclide concentration.

The gamma-radium correlation is used to determine a gamma guideline value to use in a gamma survey (scan) that represents the Ra-226 cleanup limit. The licensee indicated in Attachment B of the reclamation plan the general approach for the gamma-radium correlation, but the data and the gamma guideline value were not provided. Although the licensee stated that the correlation will provide a 95 percent level of confidence that the grid (survey unit) meets the criterion, the correlation graph and gamma guideline level and the degree of its use (maximum percent of grids, areas) must be approved by staff. The NRC staff approves the percentage and method of using gamma measurements in place of Ra-226 analysis based on the reliability of the gamma-radium correlation. Also, the licensee must provide a similar graph of the final data in the Final Status Survey Report to substantiate that gamma readings can be substituted for Ra-226 analysis. If, as it suggested, SFC plans to use a Ra-226 to Th-230 correlation to reduce the number of Th-230 soil analyses, this correlation must also be reviewed by the staff before soil decommissioning is completed to avoid additional work being required after the Final Status Survey Report is submitted. **This is an open issue.**

6.3.5 Instruments and Procedures

Attachment B of the reclamation plan indicates that the instruments and techniques to be used for verification of compliance with soil cleanup criteria will be the same or very similar to those used to assess background values and develop the radium-gamma correlation. Measuring and testing equipment was addressed in Section 4 of Attachment C to the reclamation plan. Instrument sensitivity appears adequate to reliably identify the proposed guideline levels.

The licensee has the responsibility to ensure that the procedures provide acceptable data and documentation to allow NRC to approve the final status survey report as meeting applicable standards. The soil sampling procedures and analytical methods used in 1994 for site characterization were provided as the soil sampling quality assurance plan (Sequoyah Fuels Corporation, 2005a). However, this information has not been incorporated into the reclamation plan. **This is a confirmatory item.** Soil sample handling (e.g., chain of custody) will follow appropriate procedures, and the proposed method of soil preparation for Ra-226 analysis is acceptable. However, the soil gamma survey procedure was not provided and not summarized in sufficient detail for the staff to evaluate. Many procedures and their implementation will be inspected during decommissioning, but the reclamation plan must provide enough information for the staff to determine that soil cleanup can be adequately demonstrated. The reclamation plan does not describe the gamma survey procedure for soil verification indicating the speed and spacing of the readings or scan path, nor does it indicate how management oversight of field personnel will be adequate to provide reliable survey data. **This is an open issue.**

6.3.6 Quality Assurance and Quality Control

Page 19 of Attachment 1 of Sequoyah Fuels Corporation (2005a) refers to a Data Management Plan but provides no information on its contents nor any reference to its being reviewed by NRC. Also, Attachment B, Section 4, of the reclamation plan indicates that a quality assurance project procedure (QAPP) will be developed. SFC states that this procedure will address survey planning and implementation, results evaluation, data assessment, verification, validation, and data quality assurance but adequate details were not provided. The Data Management Plan and QAPP procedure must be summarized and discussed in some detail in the reclamation plan and be available for NRC staff review during decommissioning. **This is an open issue.**

Attachment C of the reclamation plan adequately discusses staff qualifications and training, the Audit and Surveillance Program, corrective actions, and quality assurance records.

6.3.7 Final Status Survey Plan

In response to an NRC request, the licensee (Sequoyah Fuels Corporation, 2005a) provided additional information regarding the Final Status Survey Plan, which is described in Attachment B of the reclamation plan. However, this information has not been incorporated into the reclamation plan. **This is a confirmatory item.** SFC proposes to use an alternative strategy for verification of soil cleanup. Part of the site is contaminated by byproduct material, but other areas contain source material contamination (U-nat) from the conversion process. SFC stated that the cleanup of U-nat will be in accordance with the guidance in NUREG-1575, and the procedures were summarized. This approach is different than cleanup of a few grids at a uranium mill site where each grid is sampled and analyzed, but is acceptable, considering the large area of source material contamination. Implementation of this guidance will be inspected during decommissioning.

The survey plan includes an adequate analytical program. However, the proposed number and pattern of grids to be soil sampled and analyzed for Ra-226 were not indicated. SFC stated that gamma measurements may be substituted for some soil samples but no details were provided (see the discussion under Gamma Guideline above).

SFC proposes to take only one soil sample per survey unit (100 m^2) to analyze for Ra-226 and Th-230 instead of a composite sample, and apparently, only one gamma reading per grid is planned. This method would provide a good gamma-radium correlation, but may not provide representative verification data. Usually, licensees composite 5 to 9 samples for each grid, and gamma readings are integrated during a one minute scan or 10 to 15 stationary readings are averaged. SFC must demonstrate in the reclamation plan or in the Final Status Survey Report, that a single sample result is representative of the entire grid (i.e., radionuclide concentration is fairly homogeneous for the area). This could be done by taking five or more individual samples in randomly selected Ra-226 or Th-230 contaminated grids and providing the analytical results and standard deviation of the average for each grid. If Ra-226 is the radionuclide of concern, a consistent gamma value during a grid scan would suffice. **This is an open issue.**

SFC committed to track soil samples that fail the Ra-226 criteria, and to perform additional cleanup after a verification soil sample exceeds the Ra-226 standard and revise the gamma guideline downward if the rate of failures is excessive. Also, some gamma surveying is planned in presumably uncontaminated areas (Class 3 areas).

6.3.8 Records and Health and Safety

The licensee has not identified a location to keep the records of information important to the decommissioning as required by §40.36(f). **This is an open issue.**

The licensee has in the past provided acceptable radiation safety controls and monitoring for worker, public, and environmental protection. Existing procedures and programs identified in Attachment D of the reclamation plan address the requirements of §40.42(g)(4) for the health and safety of workers, the public, and the environment.

6.3.9 Non-Radiological Hazardous Constituents

The reclamation plan has not addressed the non-radiological hazardous constituents of the byproduct material to comply with Criterion 6(7). For surface contaminated areas, meeting the surface soil Ra-226 and Th-230 standards could be adequate to control these constituents such as heavy metals, but testing may be needed in some areas. **This is an open issue.**

6.3.10 Evaluation Findings

The staff has determined that the reclamation plan did not demonstrate that enough data of the proper quality can be provided after decommissioning to support compliance with Criterion 6(6) of Appendix A and §40.42(k)(2), as indicated by the following open issues and confirmatory items:

<u>Open Issues</u>:

(1) The licensee must provide the gamma-radium correlation graph and indicate the gamma guideline value and its use. The licensee must also provide the Ra-226 to Th-230 correlation if it plans to use it.

(2) The licensee must describe the gamma survey procedure for soil verification indicating the speed and spacing of the readings or scan path, and discuss how management oversight of field personnel will be adequate to provide reliable survey data.

(3) The Data Management Plan and QAPP procedure must be summarized in some detail in the reclamation plan and be available for NRC staff review during decommissioning.

(4) The licensee must demonstrate that a single sample result is representative of the entire grid (i.e., radionuclide concentration is fairly homogeneous for the area).

(5) The licensee must identify the location where the records of information important to decommissioning are kept, as required by §40.36(f).

(6) The licensee must address the non-radiological hazardous constituents of the byproduct material to comply with Criterion 6(7).

Confirmatory Items:

(1) The licensee must revise Appendix G as it indicated in Sequoyah Fuels Corporation, 2005a.

(2) The licensee must include soil sampling procedures and analytical methods in the reclamation plan.

(3) The licensee must revise the final status survey plan as it indicated in Sequoyah Fuels Corporation, 2005a.

6.4 Radiation Safety Controls and Monitoring

SFC already has site procedures in place to meet the radiation control and monitoring requirements of Part 20 (§20.1101 and §20.2102). The requirement in 10 CFR 40.42(g)(4)(iii) is to describe methods to ensure protection of workers and the environment against radiation hazards during decommissioning.

In its most recent inspection (inspection report IR 040-08027/04-001, February 5, 2004), the NRC staff found that SFC has been properly implementing the Radiation Safety Program. Also, SFC is required by License Condition (LC) 9.4, to follow the guidance set forth in Regulatory Guides 8.22, "Bioassay at Uranium Recovery Facilities," 8.30, "Health physics Surveys in Uranium Recovery Facilities," and 8.31, "Information Relevant to Ensuring that Occupational Radiation Exposure at Uranium Recovery Facilities will be As Low As Reasonably Achievable" or NRC-approved equivalent. Additionally, health physics procedures are reviewed during inspections.

SFC's Radiation Safety Program During Decommissioning and Reclamation (Attachment D of the reclamation plan) meets the requirements of LC 9.4. In accordance with Regulatory Guide 8.31, SFC will review and approve the Radiation Safety Program, and any revisions that are made during decommissioning and reclamation. Any such adjustment to the requirements shall be made in a manner consistent with existing document control procedures. The program will be implemented directly and/or by additional written procedures or instructions. The SFC Manager of Health and Safety is responsible for its implementation.

The NRC staff recently reviewed the radiation safety aspects of SFC's proposed Radiation Safety Plan in association with the request to dewater raffinate sludge that had been stored in three lined impoundments on the site, and to store the bagged dewatered sludge on the Yellowcake Storage Pad. The staff considered worker safety and protection during normal operations and in the event of an accident and the potential for offsite radiological effects. The average concentration of natural Uranium and Thorium-230 in the dewatered raffinate sludge (based on SFC measurements during the test phase of the dewatering project) is 19,400 μg/g and 16,200 pCi/g respectively. Based on its review, the staff concluded that the radiological consequences of potential accidents during the raffinate sludge dewatering project are acceptable and that atmospheric and fluid releases of radioactive material as a result of the raffinate sludge dewatering project will be within regulatory limits, and the project will be protective of public health and safety. This aspect of decommissioning, working with higher levels of radioactivity, was approved with several conditions added to the license concerning the storage bags and inspection of the temporary cover. The other aspects of decommissioning and reclamation covered in the reclamation plan would pose less potential risk to worker and public safety.

6.4.1 Evaluation Findings

Based on its review, the staff concludes that the “Radiation Safety Program During Decommissioning and Reclamation” (Attachment D of the reclamation plan) provides an acceptable program of radiation safety controls and monitoring to protect worker and public health and safety.

7.0 NON-11e.(2) BYPRODUCT MATERIAL DISPOSAL

7.1 Background

In July 2002, the Commission determined that most of the waste material at the SFC site can be classified as 11e.(2) byproduct material. That decision was reaffirmed by the Commission on November 13, 2003 in response to a challenge from the State of Oklahoma. Wastes classified as 11e.(2) byproduct material must be remediated in accordance with Appendix A of 10 CFR Part 40. Additionally, sites remediated in accordance with Appendix A, that contain 11e.(2) byproduct material above specified concentrations must be transferred to a government custodian for perpetual custodial care. The custodian can be the State where the 11e.(2) site is located, but if the State declines, DOE must accept the site and become the custodian.

Although most of the radioactive waste at the SFC site is 11e.(2) byproduct material, approximately 23 percent is not. That waste resulted from processes at the SFC facility that occurred after the yellowcake was concentrated and purified. The wastes derived from those latter stages of the conversion process can be classified as low-level waste. Those wastes can be disposed of onsite in accordance with 10 CFR Part 20 or sent off site to be disposed of in a facility licensed under 10 CFR Part 61 to accept and dispose low-level waste.

Alternately, radioactive waste similar to 11e.(2) byproduct material, can be disposed of in an 11e.(2) cell under certain conditions. Those conditions are identified in NRC Regulatory Information Summary (RIS) 2000-23 (November 30, 2000), Attachment 1, "Interim Guidance on Disposal of Non-Atomic Energy Act of 1954, Section 11e.(2) Byproduct Material in Tailings Impoundments." SFC has proposed to dispose of the onsite non-11e.(2) wastes in the 11e.(2) disposal cell to be constructed onsite.

7.2 Description of the Non-11e.(2) Wastes

The non-11e.(2) wastes on the SFC site are the radioactive wastes that resulted from stages in the conversion process after the yellowcake had been concentrated and purified. The non-11e.(2) wastes consist primarily of soils and pond sediments; buildings, equipment, concrete, and scrap metal; solid waste burials; drummed contaminated trash; and Calcium Fluoride sludge. Figure A-1 of the reclamation plan identifies the current location on the site of various non-11e.(2) wastes.

The licensee stated that approximately 10 percent of the in-place soil identified for disposal in the cell is contaminated with non-11e.(2) byproduct material. The soil is contaminated with uranium, with almost all of the contamination below 110 pCi/g of uranium.

The licensee stated that approximately 50 percent of the buildings, equipment, and concrete identified for disposal in the cell is contaminated with non-11e.(2) byproduct material. The licensee estimated the uranium concentration of the debris to be 0.025 percent with minor amounts of radium and thorium.

The licensee stated that approximately 50 percent of the scrap metal identified for disposal in the cell is contaminated with non-11e.(2) byproduct material. The licensee estimated the uranium concentration of the scrap metal to be 0.002 percent with negligible amounts of radium and thorium.

The licensee stated that approximately 50 percent of the solid waste burials, which will be disposed of in the cell, are contaminated with non-11e.(2) byproduct material. The buried material consists of contaminated equipment, scrap metal, lab sample bottles, defective 55-gallon yellowcake drums, insulation, combustible trash, pipe containing calcium sulfate deposits, UF_4 ash, yellowcake, incinerator ash, and miscellaneous material from spill cleanups. The licensee stated that due to the physical nature of the burial area contents, it was not possible to obtain representative samples without full exhumation.

The licensee stated that approximately 50 percent of the drummed contaminated trash, which will be disposed of in the cell, is contaminated with non-11e.(2) byproduct material. The licensee estimated the uranium concentration of the drummed contaminated trash to be 0.029 percent with negligible amounts of radium and thorium.

The licensee stated that approximately 75 percent of the sediment and soil from the Emergency Basin and the North Ditch identified for disposal in the cell is contaminated with non-11e.(2) byproduct material. Uranium concentrations in the Emergency Basin ranged from 1600 to 6000 pCi/g, nitrate ranged from 3.8 to 210 μg/g, and fluoride from 1800 to 9900 μg/g. In the North Ditch, uranium concentrations ranged from 0.1 to 22,000 pCi/g, nitrate ranged from 2.5 to 930 μg/g, and fluoride from 810 to 15,000 μg/g. Soils were considerably less contaminated, with most of the contamination below 110 pCi/g of uranium.

The licensee stated that approximately 50 percent of the contaminated material in Interim Soils Storage Cell, which will be disposed of in the cell, is contaminated with non-11e.(2) byproduct material. The Interim Soils Storage Cell contains uranium-contaminated soils from several sources including: sod contaminated by a 1986 cylinder rupture (average uranium content of 150 μg/g), limestone gravel associated with a former hydrofluoric acid neutralization area (average uranium content of 14 μg/g), soils excavated from around the solvent extraction building (average uranium content of 1220 μg/g), and small amounts of soil from various other areas.

The licensee stated that all of the calcium fluoride sludges and the associated basin liners are contaminated with non-11e.(2) byproduct material. The calcium fluoride sludges were derived from the neutralization of hydrogen fluoride off-gas scrubber water with calcium oxide (lime) and are currently in several holding basins. The licensee estimated the uranium concentration of the sludge to be 0.032 percent by weight, with the radium-226 concentration approximately 1.0 pCi/g, and the thorium-230 concentration approximately 188 pCi/g.

7.3 Compliance with NRC Guidance

The NRC guidance in RIS 2000-23 identifies eight criteria that must be met in order for NRC to approve the disposal of non-11e.(2) byproduct material in an 11e.(2) cell. SFC has addressed each of the eight criteria, discussing how it has been met or why it is not applicable. NRC staff has reviewed SFC's assessments. The staff's analysis and conclusions for each of the criteria are presented below.

> Criterion 1 *In reviewing licensee requests for the disposal of wastes that have radiological characteristics comparable to those of Atomic Energy Act of 1954, Section 11e.(2) byproduct material [hereafter designated as "11e.(2) byproduct material"] in tailings impoundments, the Nuclear Regulatory Commission staff will follow the guidance set forth below. Since mill tailings impoundments are already regulated under 10 CFR Part 40, licensing of the receipt and disposal of such material [hereafter*

designated as "non-11e.(2) byproduct material"] should also be done under 10 CFR Part 40.

This criterion is primarily directed at the NRC staff, stating that the staff should license disposal (receipt is not an issue, as SFC has not requested permission to receive non-11e.(2) from offsite) of non-11e.(2) byproduct material under 10 CFR Part 40. SFC has addressed the issue of the comparability of the radiological characteristics of the non-11e.(2) byproduct material. SFC has stated that the radiological contaminants in the non-11e.(2) byproduct material, U_{nat}, Th_{230}, and Ra_{226} are also typically found in uranium mill tailings and in the SFC 11e.(2) byproduct material. Furthermore, both the average and maximum concentrations of these radionuclides are lower in the SFC non-11e.(2) byproduct material than in the SFC 11e.(2) byproduct material. The staff has reviewed the material presented by SFC and concludes that Criterion 1 has been met.

<u>Criterion 2</u> *Special nuclear material and Section 11e.(1) byproduct material waste should not be considered as candidates for disposal in a tailings impoundment, without compelling reasons to the contrary. If staff believes that such material should be disposed of in a tailings impoundment in a specific instance, a request for Commission approval should be prepared.*

SFC has not requested approval for disposal of special nuclear material or 11e.(1) byproduct material waste and stated that the non-11e.(2) byproduct material to be disposed of in the 11e.(2) cell does not contain such waste. The staff concludes that Criterion 2 is not applicable.

<u>Criterion 3</u> *The 11e.(2) licensee must provide documentation showing necessary approvals of other affected regulators (e.g., the U.S. Environmental Protection Agency or State) for material containing listed hazardous wastes or any other material regulated by another Federal agency or State because of environmental or safety considerations.*

SFC stated that no approvals by regulators other than NRC are necessary because the non-11e.(2) byproduct material does not contain listed hazardous wastes or any other material regulated by another Federal agency or State. The staff has asked SFC to provide documentation from EPA and the State of Oklahoma that they do not have regulatory authority over the non-11e.(2) byproduct material. That documentation has not yet been provided. **This is an Open Issue.** Until such documentation is provided, the staff cannot conclude that Criterion 3 has been met.

<u>Criterion 4</u> *The 11e.(2) licensee must demonstrate that there will be no significant environmental impact from disposing of this material.*

SFC stated that the only environmental impact of disposing of the non-11e.(2) byproduct material in the 11e.(2) cell would be an increase in volume of material in the cell. SFC stated that most of the non-11e.(2) byproduct material is similar to the 11e.(2) byproduct material that will be disposed of in the cell and would thus not significantly increase the environmental impact. The only material that is chemically different from the 11e.(2) byproduct material is the calcium fluoride sludge. SFC stated that testing showed the uranium to be less leachable from this material than from most of the 11e.(2) byproduct material and that there will be no adverse chemical reaction with other material in the cell. The staff has reviewed the material presented by SFC and concludes that Criterion 4 has been met.

> <u>Criterion 5</u> *The 11e.(2) licensee must demonstrate that the proposed disposal will not compromise the reclamation of the tailings impoundment by demonstrating compliance with the reclamation and closure criteria of Appendix A of 10 CFR Part 40.*

This Safety Evaluation Report addresses whether the SFC proposed reclamation plan meets the applicable criteria in Appendix A of 10 CFR Part 40. Based on its review of the non-11e.(2) byproduct material and its comparison to the 11e.(2) byproduct material to be disposed of in the cell, the staff concludes that the non-11e.(2) byproduct material does not pose any additional burden to meeting the Appendix A criteria. That is, the inclusion of the non-11e.(2) byproduct material in the cell will not make it more difficult to meet the Appendix A criteria. The staff therefore concludes that Criterion 5 has been met.

> <u>Criterion 6</u> *The 11e.(2) licensee must provide documentation showing approval by the Regional Low-Level Waste Compact in whose jurisdiction the waste originates as well as approval by the Compact in whose jurisdiction the disposal site is located, for material which otherwise would fall under Compact jurisdiction.*

SFC states that this criterion is not applicable because the relevant Regional Low-Level Waste Compact, the Central Interstate Low-Level Radioactive Waste Compact, does not require approval for a generator of radioactive waste to dispose of that waste on its own site and cites Article VI of the Compact's regulations. The staff has reviewed the material presented by SFC and concludes that Criterion 6 is not applicable.

> <u>Criterion 7</u> *The U.S. Department of Energy (DOE) and the State in which the tailings impoundment is located, should be informed of the U.S. Nuclear Regulatory Commission findings and proposed action, with a request to concur within 120 days. A concurrence and commitment from either DOE or the State to take title to the tailings impoundment after closure must be received before granting the license amendment to the 11e.(2) licensee.*

This criterion is primarily directed at NRC staff, stating that it must obtain a concurrence and commitment from Oklahoma or DOE to take title to the tailings cell and site, including the non-11e.(2) material. However, in order for the government custodian to be able to make a reasoned decision regarding this, it must be aware of any approvals and constraints imposed by other affected regulators. That is, the information identified in Criterion 3 must be available. However, that information has not yet been provided and is an open issue. **Therefore, NRC staff will not write to DOE and Oklahoma, requesting a commitment to become the government custodian, until after the open issue regarding Criterion 3 is closed.**

> <u>Criterion 8</u> *The mechanism to authorize the disposal of non-11e.(2) byproduct material in a tailings impoundment is an amendment to the mill license under 10 CFR Part 40, authorizing the receipt of the material and its disposal. Additionally, an exemption to the requirements of 10 CFR part 61, under the authority of 10 CFR 61.6, must be granted, if the material would otherwise be regulated under Part 61. (If the tailings impoundment is located in an Agreement State with low-level waste licensing authority, the State must take appropriate action to exempt the non-11e.(2) byproduct material from regulation as low-level waste). The license amendment and the 10 CFR 61.6 exemption should be supported with a staff analysis addressing the issues discussed in this guidance.*

SFC's request for approval of its proposed reclamation plan includes a request to dispose of the non-11e.(2) byproduct material. If the staff approves SFC's reclamation plan it will amend

SFC's license (Materials License SUB-1010) authorizing SFC to implement its reclamation plan. Included in that authorization will be the authorization to dispose of the non-11e.(2) byproduct material.

An exemption from Part 61 is not required because Part 61 is not applicable to SFC's disposal of its own radioactive waste. Part 61 is applicable to radioactive waste received from other persons. It is not applicable to disposal of waste by an individual licensee. (See 10 CFR, 61.1(a)). SFC states that Oklahoma has regulatory authority over land disposal of source, byproduct, and special nuclear material as an NRC Agreement State, but that its authority is limited to regulation of land disposal of radioactive waste received from others. As SFC has not requested authority to receive non-11e.(2) byproduct material from others, the staff concludes that this aspect of Criterion 8 is not applicable.

7.4 Conclusions

The staff has reviewed the information presented by the licensee, using the guidance in RIS 2000-23. Based on its review, the staff concludes that six of the eight criteria in the guidance have either been met or are not applicable. The staff cannot conclude that Criterion 3, which requires documentation of approvals by other affected regulators for material regulated by them, has been met. The licensee stated that the non-11e.(2) material dose not contain listed hazardous wastes or any other material regulated by another Federal agency or State, but has not provided documentation to that effect from appropriate regulators. Additionally, the staff has not received a concurrence and commitment, as required by Criterion 7, from either DOE or the State of Oklahoma to take title to the tailings impoundment after closure. After the open issue regarding Criterion 3 is closed, staff will request the concurrence and commitment.

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