Final 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 Federal and State Materials and Environmental Management Programs

April 20, 2009

Enclosure 1

ABSTRACT

This final safety evaluation report summarizes the U.S. Nuclear Regulatory Commission (NRC) staff's review of the Sequoyah Fuels Corporation (SFC) proposed reclamation plan for its uranium conversion facility site near Gore, OK. The proposed reclamation would allow SFC to (1) remediate the site by encapsulating contaminated material in a disposal cell to be constructed on site in preparation for long-term custodial care by a Government agency, (2) prepare the site for closure, and (3) relinquish responsibility for the site after the termination of its NRC license. The NRC staff concludes that the proposed reclamation plan meets the requirements identified in NRC regulations, which appear primarily in Title 10, Part 40, "Domestic Licensing of Source Material," of the *Code of Federal Regulations* (10 CFR Part 40).

1. INTRODUCTION

1.1 Background

The Sequoyah Fuels Corporation (SFC) holds Materials License SUB-1010 for its facility in Gore, OK. 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 using an onsite, above-grade disposal cell for the permanent disposal of waste. The plan proposed restricted release of the site in accordance with Title 10, Section 20.1403, "Criteria for License Termination under Restricted Conditions" of the *Code of Federal Regulations* (10 CFR 20.1403, known as 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 discussed this possibility with the U.S. Department of Energy (DOE).[2] In January 2001, SFC requested a determination by the U.S. Nuclear Regulatory Commission (NRC) as to whether waste from the solvent extraction portion of the uranium hexafluoride (UF_6) conversion process could be classified as byproduct material, defined in Section 11e.(2) of the Atomic Energy Act of 1954, as amended. Section 11e.(2) byproduct material sites must be remediated in accordance with Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to 10 CFR Part 40, "Domestic Licensing of Source Material." 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 because of the presence of the 11e.(2) material.

On July 25, 2002, in Staff Requirements Memorandum (SRM)-02-0095), "Applicability of Section 11e.(2) of the Atomic Energy Act to Material at the Sequoyah Fuels Corporation Uranium Conversion Facility," the Commission determined that most of the waste material at the

1 SFC submitted a decommissioning plan which the NRC rejected on February 11, 1999, because it failed to meet the minimum criteria for technical review. The NRC accepted the second decommissioning plan for review on May 20, 1999; however, the review was put on hold pending resolution of the request for Section 11e.(2) classification of the material.

2 In accordance with Section 151(b) of the Nuclear Waste Policy Act of 1982, DOE has the authority to accept sites with radioactive material in the form of low-level waste for long-term custodial care but is not required to do so.

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 NRC amended the license to allow possession of 11e.(2) byproduct material and included several conditions necessitated by the change to an 11e.(2) site. One of those conditions (License Condition 48) obviated the need for a decommissioning plan by requiring SFC to submit a site reclamation plan (RP) to the NRC by March 15, 2003. SFC submitted its RP by letter dated January 28, 2003. The RP has been updated by submittals dated August 8, 2003, August 29, 2003, February 17, 2004, April 12, 2005, January 31, 2006, and January 4, 2008. All revisions have been incorporated into the January 4, 2008 submittal. Therefore, this safety evaluation report (SER) will refer to the January 4, 2008, submittal as it presents the proposed RP in its final form. The January 4, 2008, RP was later supplemented by letter dated June 25, 2008, in which SFC provided revisions to Chapter 7.0 (Cost) and Chapter 8.0 (Schedule).

After the NRC amended the license on December 11, 2002, to authorize SFC to possess 11e.(2) byproduct material, the State of Oklahoma, the Cherokee Nation, and others filed requests for a hearing on the license amendment. On May 1, 2003, the Atomic Safety Licensing Board (ASLB) Presiding Officer wrote to the Commission regarding the issue of whether the material at the SFC site qualifies as 11e.(2) byproduct material. On November 13, 2003, the Commission ruled that the front-end waste at the SFC site can be considered 11e.(2) byproduct material (CLI-03-15). On November 21, 2003, the ASLB Presiding Officer denied the hearing requests. On December 1, 2003, Oklahoma appealed that decision to the Commission. On January 8, 2004, the Commission affirmed the Presiding Officer's decision to terminate the proceeding. On January 8, 2004, Oklahoma appealed the Commission's decision to the Tenth Circuit Court of Appeals. Under the auspices of a mediator from the Appeals Court, the parties attempted to resolve Oklahoma's concerns without trying the case in court. The parties signed a settlement agreement on November 30, 2004. On December 9, 2004, the court approved the parties' joint request to dismiss the proceeding.

The State of Oklahoma and the Cherokee Nation requested a hearing on the January 28, 2003, RP. After being held in abeyance pending the Commission's decision on the 11e.(2) issue, the ASLB process resumed, with the staff filing its response on November 25, 2003. On December 23, 2003, the ASLB granted the hearing request. On December 6, 2004, in accordance with the November 30, 2004, settlement agreement, the petitioners requested termination of the hearing, which the ASLB granted on December 14, 2004.

The State of Oklahoma and the Cherokee Nation requested a hearing on two ground water plans, which SFC submitted in June 2003. However, the ASLB Presiding Officer denied both requests on the grounds of their being inexcusably untimely and referred the petitions to the staff as 2.206 petitions. The petitions are being held in abeyance until the staff completes its licensing reviews. In accordance with the settlement agreement with SFC, petitioners will request withdrawal of the 2.206 petitions after SFC revises the ground water plans.
This SER documents the NRC staff's review of the RP and the staff's conclusions. This SER does not address cost estimates or financial assurance because License Condition 9.3 of SFC's license, SUB-1010, already requires SFC to comply with the provisions of the Settlement Agreement between NRC and SFC dated August 18, 1995.

The regulations governing reclamation of uranium mill tailings appear primarily in Appendix A to 10 CFR Part 40, under which licensees may propose alternatives to the specific requirements in the appendix. The NRC can approve an alternative if it finds that the alternative 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 the level that would be achieved by the requirements in the appendix, to the extent practicable.

1.2 Site Description

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, OK, 40 miles west of Fort Smith, AR, 25 miles southeast of Muskogee, OK, and 2.5 miles southeast of Gore, OK, in Section 21 of Township 12 North, Range 21 East (Figure1-1).

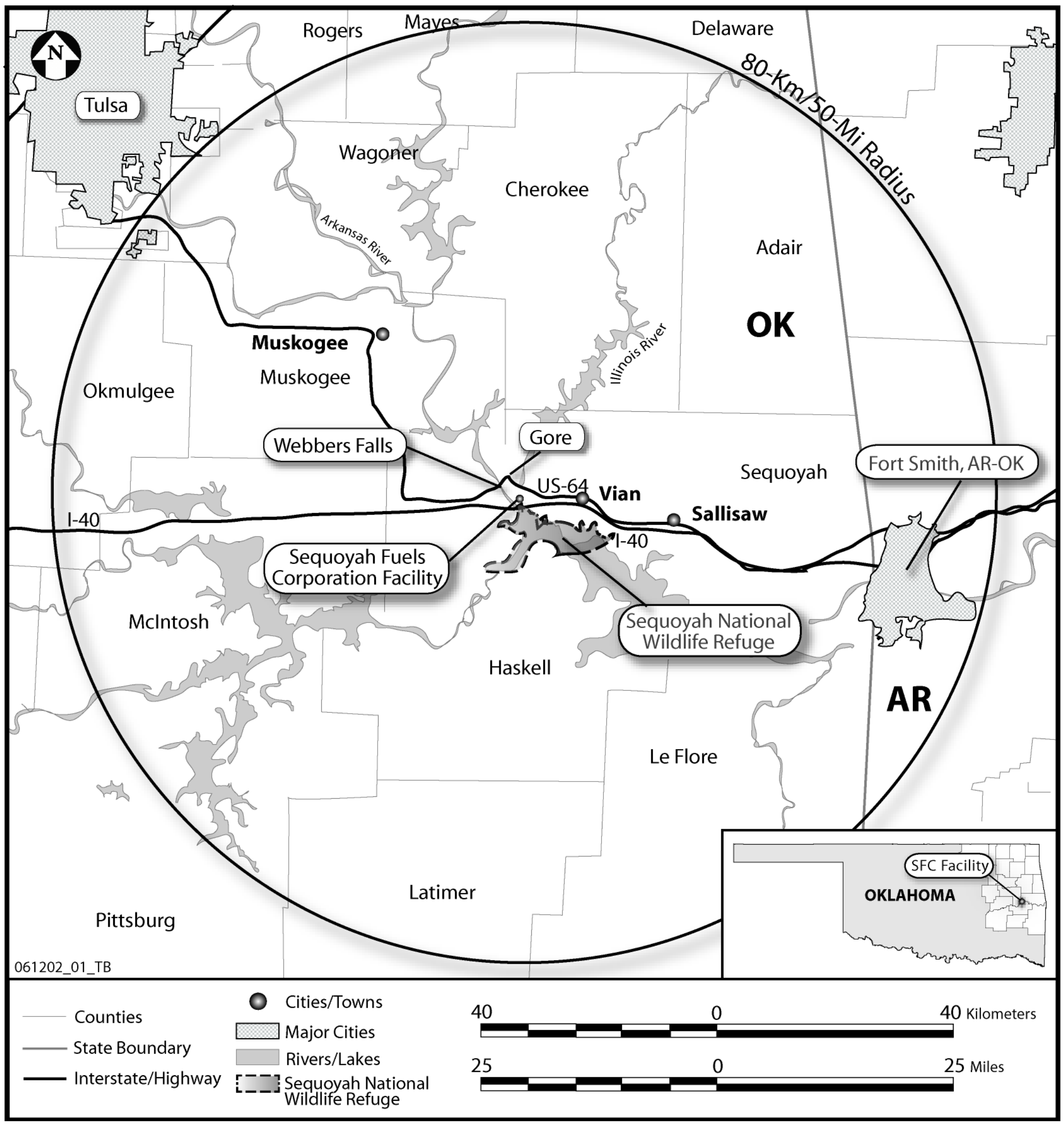

Figure 1-1 SFC facility location and environs

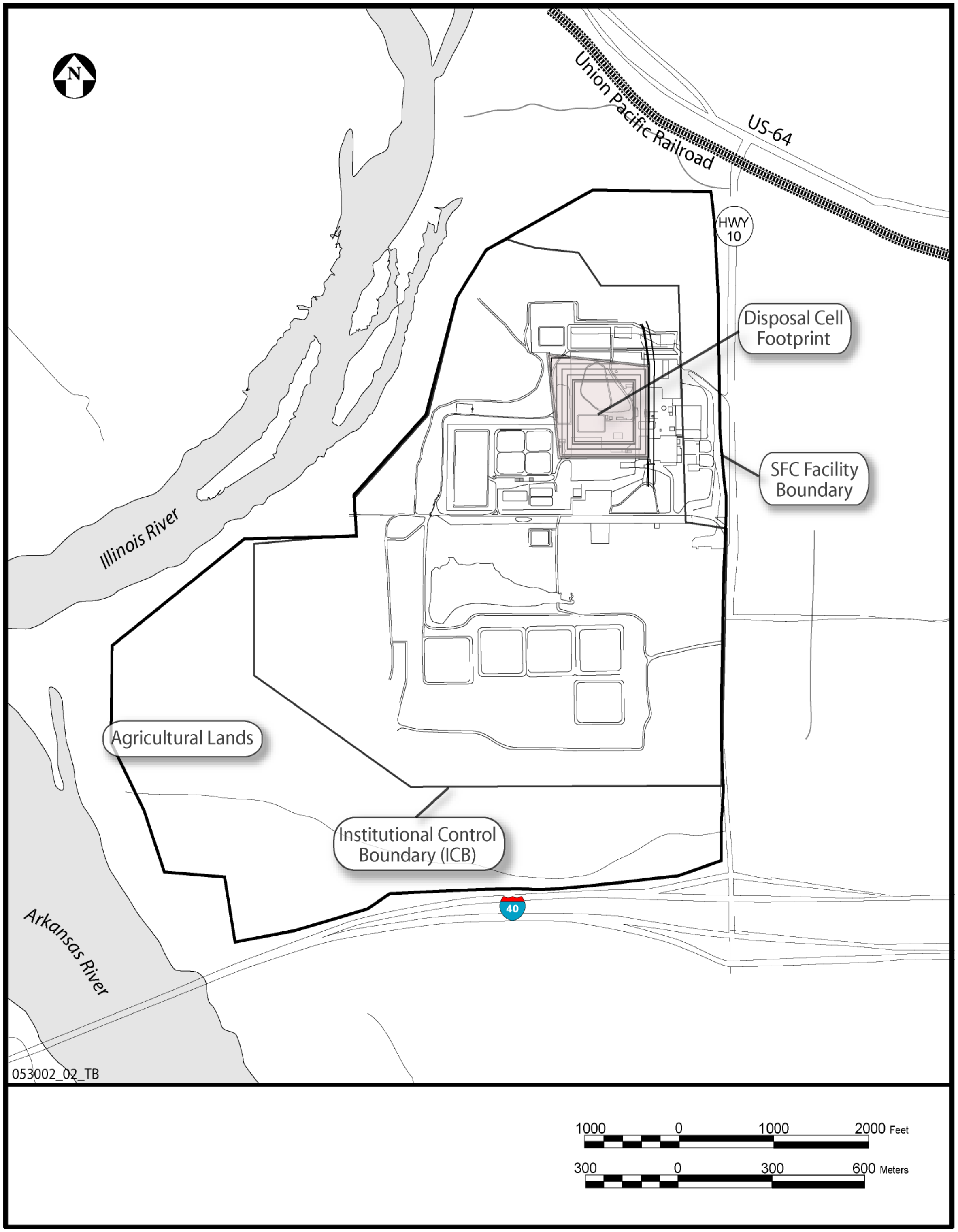

Figure 1-2 The disposal cell footprint and the proposed ICB at the SFC facility

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-owned land managed by the U.S. Army Corps of Engineers 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 (ft) 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 ft above mean sea level for the normal pool elevation of the Robert S. Kerr Reservoir to nearly 600 ft above mean sea level. Slopes over most of the upland areas of the site are less than 7 percent. Steeper slopes in creek ravines and on hillsides average roughly 28 percent. Near the Robert S. Kerr Reservoir, slopes are very steep. The Federal Government owns this area, and the U.S. Army Corps of Engineers administers it.

1.2.2 Description of Facility

Most of the uranium processing operations were conducted on an 85-acre portion of the site (Figure 1-3) that SFC refers to as the Process Area. SFC uses an additional 115 acres to manage storm water and store byproduct materials. The reclamation activities will focus on the Process Area and the additional management areas that SFC refers to collectively 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 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 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 nonradiological 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. Figure 1-3 presents a general facility layout.

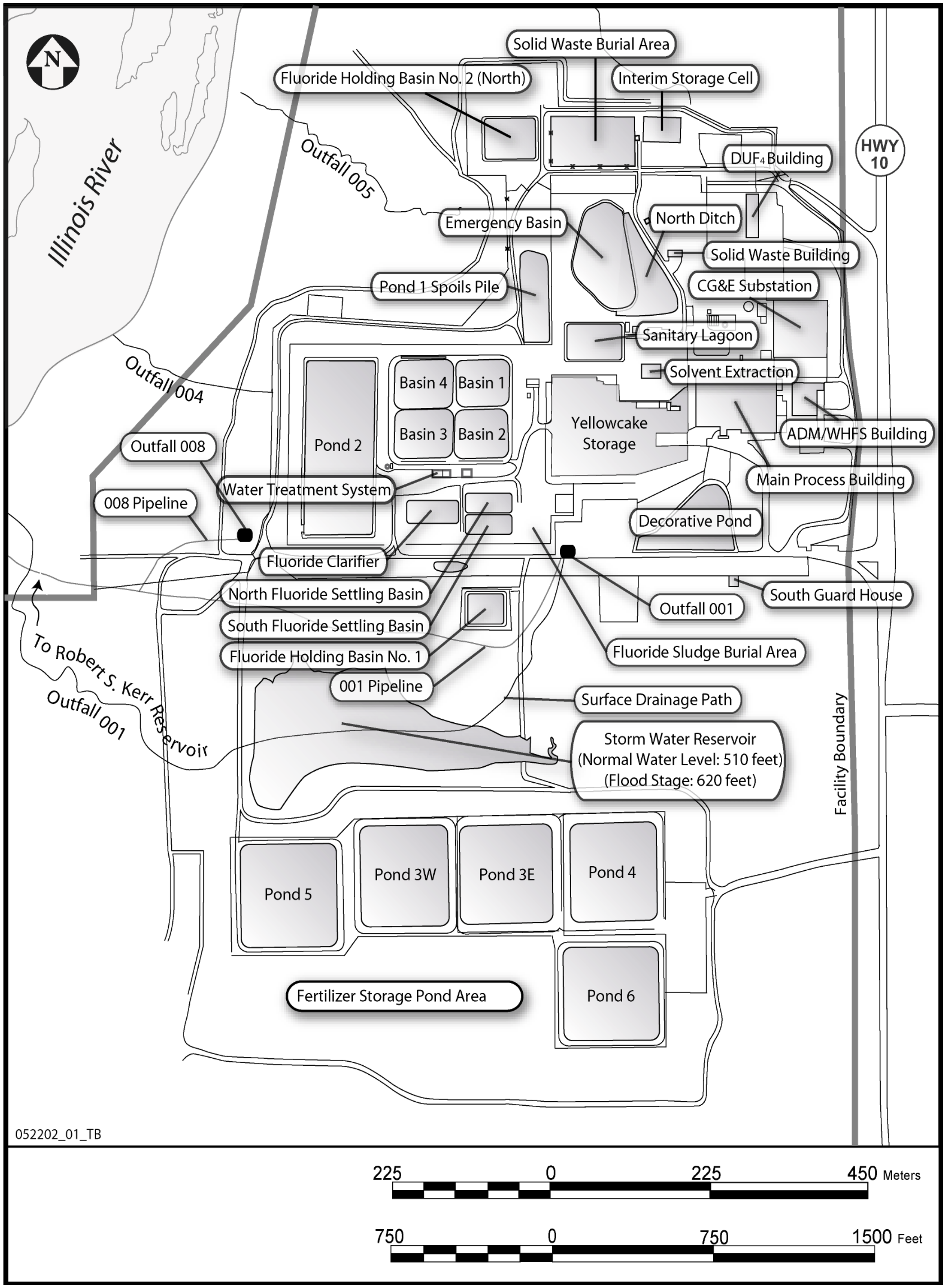

Figure 1-3 The SFC facility layout

1.2.3 Description and Characteristics of Waste

The wastes that will be cleaned up and permanently disposed of in the cell comprise three categories of materials: (1) rubble and other material from structures, systems, and equipment, (2) contaminated materials that have been collected and stored on site, 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 (cf). The licensee based this estimate on a review of drawings and other data for the facility structures, equipment, utilities, and concrete. The estimate 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 the majority of the salvageable or recyclable equipment and materials has 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 million cf 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 kilograms (kg), 76 percent of the thorium-230 or 156 curies (Ci), and 38 percent of the radium-226 or 1.1 Ci). Additionally, the sludge contains various metals. Tables 1, 2, and 3 of Enclosure 1 to SFC's January 7, 2004, request to dewater the sludge describe the characteristics of the sludge in detail. The NRC approved that request on January 26, 2005, and the dewatering is currently proceeding. The dewatering method will remove free water from the sludge and result in a 50-percent reduction in the weight to approximately 15,000 tons of dewatered sludge. The dewatered sludge is being placed in polypropylene bags and stored on the South Yellowcake Pad.

Calcium fluoride (CaF_2) sludge resulted from the lime neutralization process. The licensee stated that the sludge will be dewatered to improve its structural strength before placement into the disposal cell. In addition to CaF_2, the licensee estimated that the sludge contained uranium in a concentration of 0.032 percent by weight, radium-226 in a concentration of approximately 1.0 picocuries per gram (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 before placement into the disposal cell.

1.2.3.3 Contaminated Soils

Soils outside the footprint of the disposal cell that 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 of this SER for further details.) Soils under the footprint of the disposal cell that exceed 570 pCi/g uranium (the concentration that would result in an equivalent dose from radium-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 ground water is elevated in excess of the SFC license action level of 150 pCi/l to facilitate the removal and treatment of the affected perched ground water. It is likely that some of the soils in the areas of perched ground water 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 lay beneath the facility ponds, basins, and clarifiers. The licensee estimates the portion 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 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 the 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.

Some significant accidents resulted 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 the result of a ruptured cylinder. The NRC estimated that 6,700 kg (14,750 pounds (lb)) of UF_6 were released during the accident. The release of UF_6 and its reaction products, uranium dioxide difluoride (UO_2F_2) and 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 HF, a chemical that results from the interaction of UF_6 with vapors in the air.

On November 17, 1992, a chemical accident occurred that resulted in the airborne release of approximately 2,970 lb of gaseous nitrogen oxide gases (NO and NO_2, also referred to as NOX) over an 18-minute period. No other chemical or radioactive constituents were 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 nondetectable concentrations.

On February 16, 1993, SFC notified the NRC that it intended to cease operations at the facility. On July 7, 1993, SFC notified the NRC that all operations with licensed material ceased on July 6, 1993, and that all activities on site were limited to those necessary for decommissioning. As the calculated doses of radioactive contamination exceeded the NRC's criteria for allowing license termination, 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 onsite disposal cell using the performance criteria in Appendix A to 10 CFR Part 40 to isolate the waste.

In July 1997, the NRC established its license termination rule. In March 1999, SFC submitted a decommissioning plan proposing an onsite disposal cell meeting the performance criteria in Appendix A to 10 CFR Part 40 with restricted release of the site once decommissioning activities were completed.

On January 5, 2001, SFC requested that the 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 constitutes 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 be performed only by the State in which the site is located (Oklahoma in this instance) or by DOE. However, by law, DOE must accept the role of custodian if the State declines. After review of the matter, the Commission concluded in SRM-02-0095 and reaffirmed upon an appeal (CLI 03-15) 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 Part 40. SFC subsequently submitted a license amendment request to possess 11e.(2) byproduct materials, which the NRC approved on December 11, 2002.

As stated above, this SER evaluates the January 4, 2008, RP, as supplemented by letter dated June 25, 2008. As identified by SFC, the proposed reclamation (note that cleanup of existing ground water contamination is not considered as part of reclamation but is instead addressed 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 before 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

- regrading of the site, backfilling of excavations to the finished grade, and revegetation

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 cf of waste. The waste will be underlain by a clay layer with a synthetic liner above providing additional seepage control. A clay layer will cover the contaminated material with a synthetic liner above the clay. Above the synthetic cover material 8 ft of earthen material will be placed. The cover will be vegetated. The top will slope to the southeast at 1 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 ft 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 before cell construction in those areas.

1.4 Review Process and Safety Evaluation Report Organization

The NRC staff reviewed the RP in accordance with NUREG-1620, "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," Final Revision 1, issued June 2003. The review is a comprehensive assessment of SFC's RP as documented by this SER. Appendix A to 10 CFR Part 40 contains the technical requirements for disposition of Section 11e.(2) byproduct material. The SER, following NUREG-1620, is organized by the technical disciplines involved in the assessment of the RP to ensure compliance with Appendix A. Each SER section describes compliance with the applicable criteria in Appendix A as the criteria pertain 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 of this SER describe the technical basis of 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 compliance of the RP 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 cannot be classified as 11e.(2) byproduct material.

1.5 License Conditions

The NRC staff review of the RP identified a number of issues for which a license condition may be desirable to ensure that staff requirements are met. Table 1-1 identifies these items, with appropriate references to related sections of this SER.

Table 1-1 License Conditions

License Condition	Section
The licensee shall submit a written request for NRC approval prior to the installation of the Radon Barrier. The licensee will use data obtained from the upper 15 ft of contaminated material placed in the cell to demonstrate that the long-term radon flux will meet the requirement of 10 CFR Part 40, Appendix A, Criterion 6(1).	6.2.1.1
The licensee shall submit a written request for NRC approval of gamma guideline values prior to use in verification of soil cleanup. The licensee will provide the gamma-radium correlation graph and indicate the gamma guideline value and its use. The licensee will also provide the Ra-226 to Th-230 correlation for NRC approval, if it plans to use the correlation.	6.3.4
The licensee shall develop a quality assurance project procedure (QAPP) prior to the initiation of remediation activities that incorporates the Data Management Plan, oversight and QA, soil sampling quality assurance, and the final status survey. Implementation of the QAPP will be reviewed during inspections.	6.3.6

In addition, as a result of the "NUREG-1888, Final Environmental Impact Statement for the Reclamation of the SFC Site," the following license condition will be added to avoid adverse environmental effects:

> Clearing of the proposed clay borrow area shall be conducted in accordance with the U.S. Nuclear Regulatory Commission's mitigation plan for the Sequoyah Fuels Corporation (SFC) site dated May 2, 2008 (ML081210037).
>
> This action shall be subject to the following two (2) conditions:
>
> 1) In order to avoid any adverse impacts on the endangered American burying beetle identified at the Sequoyah Fuels site, SFC will follow Conservation Approach 1 and Avoidance Measure 1 as described in United States Fish and Wildlife Service (USFWS) guidance "Conservation Approaches for the American Burying Beetle." The "*Bait Away Protocol*" for the American burying beetle must be employed prior to ground disturbance and during the beetle's active season

(May 20 to September 20) to avoid adversely affecting the beetle. Bait away stations shall be placed in timbered areas in areas T1, T2, T3 and T4 shown in Figure 1 of NRC's mitigation plan. The bait away must be coordinated with the Oklahoma Field Office of the USFWS under an appropriate section 10 permit from the USFWS. To complete the required Section 7 consultation, SFC must submit the completed "Bait Away Form" to the Oklahoma Field Office of the USFWS within 30 days following cessation of bait away efforts. To meet the no "take" (i.e., no mortality) provision of the Migratory Bird Treaty Act, clearing of the clay borrow area woodland and other potential nesting areas must be performed outside of the nesting season of migratory birds in Oklahoma—from August 1 to the end of February as per USFWS recommendations.

2) To help mitigate the habitat loss associated with modification of the existing borrow area habitat, SFC shall recontour, regrade and revegetate portions of the site outside of the engineered disposal cell footprint (18 acres) within the 324 acre proposed institutional control boundary (ICB). A total of 124 acres inside the ICB will be regraded, covered with 6 inches of topsoil, and revegetated with a native seed mix (see Table 1 below). Of the 124 acres, 83 acres will involve substantial excavating and recontouring in order to recreate, to the extent practicable, the original topography of the site prior to its development (following the United States Geologic Survey 7.5 minute quadrangle maps).

Table 1 Proposed Seed Mix for Revegetation

Species		**Pounds of Pure Live Seed per Acre**
Common Name	**Latin Name**	
Big bluestem	*Andropogon gerardii*	6
Little bluestem	*Schizachyrium scoparium*	3
Switchgrass	*Panicum virgatum*	2
Indiangrass	*Sorghastrum nutans*	2
Hairy wildrye	*Elymus villosus*	2
High plains goldenrod	*Solidago altiplanities*	1.5
Prairie sunflower	*Helianthus petiolaris*	1.5
Compassplant	*Silphium laciniatum*	0.5
Blazing star	*Liatris Gaertn. Ex Schreb.*	0.5
Littleleaf sumac	*Rhus microphylla*	2

References

Sequoyah Fuels Corporation, “Reclamation Plan Sequoyah Facility,” Gore, OK, January 4, 2008. Agencywide Documents Access and Management System (ADAMS) Accession No. ML080220345.

U.S. Nuclear Regulatory Commission, NUREG-1888, “Environmental Impact Statement for the Reclamation of the Sequoyah Fuels Corporation Site in Gore, Oklahoma—Final Report,” May 2008.

2. 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 is 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 geologic processes are expected to be sufficiently small, or relatively inconsequential, so as not to 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 that the recent and current level of seismicity will persist. This assumption is compatible with the prevailing regional tectonic model of the province.

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, OK. Streams drain the upland slopes toward the rivers. The streams and slopes facilitate conditions of erosion which SFC has considered in its RP. The potential effects of one stream on the proposed reclamation cell bear further analysis.

The geology of the site is essentially bedrock of gently, southwesterly dipping layers of alternating sandstone and siltstone underlain by carbonates, partially covered by sediments (terrace deposits and alluvium) and soil, all of which lie on top of Precambrian basement rocks. The layer-cake stratigraphy of the SFC site is best depicted on cross-sections in Figure 11 of the RP. A detailed geologic map showing the distribution of eight bedrock units appears as Figure 15 of SFC's "Draft Site Characterization Report" (SFC, 1996).

In addition to the RP, supporting documents (e.g., consultant reports, letter correspondence between the U.S. Nuclear Regulatory Commission (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 RP 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. Section 3.3.2 of the RP describes them.

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 specifically to support 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 and fracture width; fracture-fill compositions; mineralogy of the sandstones, shales, and sediments; and 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 three-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. In the field, the staff also observed two controls on flow. 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 site in Gore, OK. 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, "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," Final Revision 1 (NRC, 2003). This review determined that characterization of site and regional stratigraphy is adequate to support technical bases used in the RP.

On the basis of the information and analysis presented in the RP 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 Title 10, Part 40, "Domestic Licensing of Source Material," of the *Code of Federal Regulations* (10 CFR Part 40), Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," Criterion 5G(2), with regard to the extent to which the formations are likely to affect future transport of contaminants and solutions.

<u>2.3 Structural and Tectonic Features</u>

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 4 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 subject to earthquakes of low to moderate magnitudes likely caused by buried faults which create a "background" seismic hazard, which SFC has described and considered in its RP design.

The staff reviewed the information submitted by the licensee, visited and interviewed geoscientists in the offices of the State Geologist and 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.

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 its 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 faults on and around the SFC site that SFC investigated specifically 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 CSF 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. SFC's "Site Characterization Report" (SFC, 2008, Appendix E) shows all of these faults.

2.3.2 Evaluation of Faults

<u>Faults associated with the South Fault of Warner Uplift</u>: 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, OK. There is no evidence that suggests this fault is a capable fault.

<u>Evaluation of the Carlile School Fault,(CSF), as a seismic source</u>: The NRC staff observed the trace of the CSF. The fault does not appear to have any of the criteria of a capable fault, nor its it 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 as a seismic source: SFC has not consistently located the trace of the MCF near the SFC site (e.g., Chenoweth, 1983; SFC, 2008, Appendix E, Figure 3.2). SFC has reported no direct observation of this fault. 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, (1) 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), (2) there is no macroseismicity associated with it (Lawson and Luza, 1995; updates and NRC staff interviews with State Seismologist, K. Luza), and (3) a structural relationship to a known capable fault is absent (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 hydrologic gradients toward the north, west, and south. A geologic cross-section shows the CSF to be at a depth greater than 486 m (1600 ft) and intersecting or close to intersecting monitoring wells 2332 and 2307 (SFC, 1996, Figure 11). Subsurface investigations and observations from boreholes or drill core reported by SFC have found no clear evidence of faulting.

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 (1) uplift rate of the terrain at the site and vicinity, (2) tilting of sedimentary deposits, and (3) fracture characteristics, these processes need not be considered in the facility design. The staff presumes that these processes are ongoing, 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 and geomorphic, faulting, and seismic hazards would change significantly in an adverse way.

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, Revision 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 an 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 which 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 RP 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 RP 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. The licensee has also demonstrated 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. The site has a veneer of bedded alluvial sediments (the Terrace Deposit and colluvium, and soil). 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 RP). The site is drained to the north, west, and south by short streams or gullies shown on SFC's maps. 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.

The RP and letters (e.g., Harlin, 2003) briefly describe the regional and site-specific geomorphic features and the landforms that provide evidence of 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 on 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 rate of erosion is slow 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 proposed emplacing an apron of rock mulch and topsoil from the foot of the cell over the head of Stream 005. The staff reviewed the design drawings and concluded that the lateral extent of the apron, in a north-south direction, across the regraded (recontoured) reach and head of Stream 005, is sufficient to prevent the encroachment of a headward-advancing gully in the thalweg that could potentially intercept the rock apron

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, Revision 1 (NRC, 2003).

The licensee adequately described the geomorphic features in its brief presentation of regional and site geomorphology using information collected for the specific purpose of supporting determinations of the stability of the 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 RP 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 so as not to pose a significant hazard to the integrity of the proposed cell.

On the basis of the review of the mitigation methods for curtailing potential headward erosion of Stream 005, which include regrading the upper reach of the stream and emplacing a rock mulch apron across the stream to bedrock at the SFC facility, 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 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 that control of radiological hazards will be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years.

<u>**References**</u>

Arbenz, J.K., 1956, Tectonic Map of Oklahoma Showing Surface Structural Features: Oklahoma Geological Survey, 1:750,000.

Chenoweth, P.A., 1983, Geologic Map of Webber Falls Area (Figure 5 in SFC, 2008, Appendix D.

Ellis, J.H., 1997, letter to J.W.N. Hickey, dated July 22, 1997, "License SUB-1010; Docket No. 40-8027, Response to NRC Questions Related to Seismic Conditions Near The Sequoyah Facility" (in SFC, 2008, Appendix E).

Ellis, J.H., 2003, letter to S. Frant, dated August 8, 2003, "License No. SUB-1010, Docket No. 040-08027, Reclamation Plan Acceptance Review, Request for Additional Information:" Enclosure 1, SFC Responses to RAI, August 8, 2003, G2, Requirement to account for geomorphic stability [criteria 4(d) and 6(1)(I) of 10 CFR 40, Appendix A." ADAMS Accession No. ML032400449.

Ellis, J.H., 2008, letter to M. Fliegel dated January 4, 2008, "Sequoyah Fuels Corporation Docket—40-8027, Final Reclamation Plan." ADAMS Accession No. ML080220345.

Harlin, C., 1998, Letter to J.C. Shepard, April 8, 1998, Subject: License SUB-1010; Docket No. 40-8027, Seismic Conditions Near the Sequoyah Facility (in SFC, 2008, Appendix E).

Harlin, C.L., 2003, letter to M. Fliegel, dated December 9, 2003, "Sequoyah Fuels Corporation, Docket—40-8027, Additional Information on Site Seismicity and Geomorphology Follow-up to Telephone Conference of September 29, 2003," Enclosure item (1) geomorphology and hydrologic stability. ADAMS Accession No. ML033490088.

LaForge, R.C., 2005, "Probabilistic Hazard Curves for Peak Horizontal Acceleration, Sequoyah Fuels Nuclear Site, Oklahoma" (in Memorandum from R. Stern and C. Straham to A.K. Ibrahim, dated April 27, 2005, subject: Sequoyah Fuels Corporation Site, Seismicity Issues). ADAMS Accession No. ML051960018.

Lawson, J.E., Jr., and K.V. Luza, 1995, Earthquake Map of Oklahoma: Oklahoma Geological Survey, Map GM-35.

Luza, K.V., and J.E. Lawson, Jr., 1981, "Seismicity and Tectonic Relationships of the Nemaha Uplift in Oklahoma," Part IV, NUREG/CR-2439, U.S. Nuclear Regulatory Commission.

Marcher, 1969, Hydrologic Atlas Map HA-1: Oklahoma Geological Survey.

Sequoyah Fuels Corporation (SFC), 2008, "Reclamation Plan Sequoyah Facility," Gore, OK, January 4, 2008. Agencywide Documents Access and Management System (ADAMS) Accession No. ML080220345.

Sequoyah Fuels Corporation (SFC), 1996, "Draft Site Characterization Report," Gore, OK, February 2, 1996.

Shannon and Wilson, Inc., 1975, Geotechnical Investigations, Black Fox Station, Rogers County, Oklahoma. To Black and Veatch for the Public Service Company of Oklahoma, April 1975.

Thornbury, 1965, “Regional Geomorphology of the United States.”

U.S. Geological Survey, 1963, Topographic map, Stigler NE, Oklahoma, 7.5 degree quadrangle, 1:24,000.

U.S. Geological Survey, 1974, Topographic map, Gore, Oklahoma, 7.5 degree quadrangle, 1:24, 000.

U.S. Nuclear Regulatory Commission (NRC), 2003, “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,” Final Rev. 1, NUREG-1620, June 2003. ADAMS Accession No. ML003725860.

Van Arsdale, R., 1998, “Paleoseismic Analysis of the Carlile Fault in Sequoyah County, Oklahoma” (in Harlin, 1998).

10 CFR Part 40, “Domestic Licensing of Source Material.”

10 CFR Part 100, “Seismic and Geologic Siting Criteria for Nuclear Power Plants.”

3. GEOTECHNICAL STABILITY

3.1 Introduction

This section presents the results of the review by the NRC staff of the geotechnical engineering aspects of the proposed RP for the SFC site near Gore, OK. 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 RP 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 (1) information related to the disposal and borrow sites, (2) materials associated with the closure action, including the foundation and excavation materials, and contaminated materials proposed for disposal, (3) stability of the embankment side slopes and natural slopes around the disposal site, (4) potential deformation and cracking of the embankment owing to differential settlement, and (5) 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 RP and the related appendices and attachments. In conducting the review, the staff used review methods and acceptance criteria in NUREG-1620, "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," Final Revision 1 (NRC, 2003).

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. A site drawing provided by the licensee's RP shows the current location of the various materials at the SFC site (SFC, 2008, Drawing 2, Revision D). Four types of materials, designated Type A, B, C, or D, will be disposed of in the proposed cell. Type A material will be placed as the lowest layer in the cell and will be overlain with Types B, C, and D materials in that general order. Type A materials will consist of raffinate sludge; sediments from the Emergency Basin, North Ditch, and Sanitary Lagoon; and residual materials from Pond 2. Type B materials will consist of soil liner and subsoil materials beneath the clarifier, Calcium Fluoride Basin, Pond 3E, the Emergency Basin, North Ditch, and Sanitary Lagoon, as well as the Pond 1 spoils pile material. Type C materials will consist of structural debris such as concrete and asphalt, calcium fluoride basin materials and sediments, and onsite buried materials. Type D materials will consist of onsite contaminated soils and sedimentary rock that require disposal. Depending on the volume of material excavated during site soil cleanup and the density of the material after placement in the cell (mostly material Type D), the cell may hold from 5 to 12 million cubic feet (ft^3). Preliminary designs call for a final disposal cell volume of approximately 9 million ft^3, based on a cleanup level to a natural uranium activity concentration of 27 picocuries per gram (pCi/g).

When construction is completed, the maximum height of the proposed cell will be approximately 30–50 ft above the general ground elevation, with a maximum elevation of approximately 590 ft above mean sea level. The top surface will be graded to a 1-percent slope to ensure drainage to the southeast. 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 provides 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 unit (5h:1v).

3.2.1 Geotechnical Investigations

The following sections of this SER discuss the geotechnical investigations of the disposal cell area conducted by the licensee.

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 Appendix D of the RP. Quaternary sediments and bedrock of the Pennsylvanian Akota Formation underlie the SFC site. The disposal-cell area consists of approximately 5–15 ft of terrace deposits (mostly silt and clay) on bedrock. Colluvial deposits overlay 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. The bedrock consists of alternating layers of shale and sandstone with bedding planes dipping generally southwest to southeast.

The licensee has evaluated ground water levels at the site based on measurements at more than 300 wells. Depth to perched water in the terrace deposits varies from 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. Monitored water levels in the terrace deposits show seasonal fluctuations on the order of 1–2 ft or less. The licensee stated that the perched ground water system is, at least in part, the result of artificial ground water recharge by leakage from fire–water lines and unlined basins. Chapter 5 of this SER presents an evaluation of the regional and site hydrology and ground water protection.

The licensee provided sufficient geotechnical information to allow assessment of the long-term stability of the disposal cell, specifically (1) stability of the embankment slopes, (2) differential settlement of the embankment, and (3) stability of natural slopes that dip away from the disposal-cell area.

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. Additional material for the cover may come from existing berms and embankments. Material balance calculations by the licensee indicate that 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. 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 the suitability of these materials.

In a later investigation, 7 test pit samples and 11 boring samples were collected for geotechnical testing. 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.

3.2.2 Testing Program

The technical specifications for the disposal cell call for a 2-ft-thick (minimum) compacted clay liner. 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 1 inch (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. 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} centimeters per second (cm/s) (2.8×10^{-4} feet per day (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. 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 RP, the licensee will ensure material acceptability by using appropriate standards published by ASTM International to conduct additional testing during construction. Section 3.8 of this SER contains an evaluation of disposal-cell hydraulic conductivity.

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. 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 (NRC, 2003).

The licensee has adequately described the geotechnical characteristics of the site based on acceptable sampling techniques, and technical specifications will ensure that 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 fluctuations in ground water level are presented to allow effective incorporation into geotechnical stability analyses.

On the basis of the information presented in the application and the detailed review conducted of the geotechnical characteristics of the site and disposal materials, the NRC staff concludes that the geotechnical characterization of the site and disposal materials provides an acceptable input, which along with other information such as results of design analysis, will enable the staff to make a finding about the demonstration of compliance with the following criteria in Title 10, Part 40, "Domestic Licensing of Source Material," of the *Code of Federal Regulations* (10 CFR Part 40), Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content": Criterion 1, which relates to the site features that contribute to the permanent waste isolation characteristics of the site; Criterion 4, which relates to the design of embankment and cover slopes; Criterion 5(G)(2), which relates to the permeability characteristics of the site; and Criterion 6(1), which requires 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.

3.3 Slope Stability

Potential slope instabilities that may affect the integrity of the disposal cell are (1) a landslide down a natural slope that dips away from the disposal site and (2) 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. 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. The licensee provided an analysis of the stability of the natural slope under seismic and long-term static conditions in Attachment E, Appendix F of the RP. The stability of the natural slope with the proposed embankment was analyzed considering a lower-bound shear strength for the colluvium. The shear strength of the colluvium was set using a friction angle of 25 degrees having estimated a range of friction angle of 25–38 degrees using the plasticity index for the soil. The analysis indicated minimum safety factors of 2.48 and 1.33 under long-term and seismic loading conditions, respectively. Such safety factors are acceptable based on staff guidance.

3.3.2 Stability of the Disposal-Cell Embankment

The licensee analyzed 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 cover system which is 10-ft thick (Appendix C). The design includes the synthetic liner at the base of the cover to prevent downward seepage of infiltration water. Such water would be diverted laterally along the top surface of the liner. The analysis indicates that 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 subsequently proposes 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. As is shown in Drawings 10 and 11 of the RP, the textured, high-density polyethylene liner will be placed on top of a 2-ft thick clay liner at the base of the cover system and will be overlain by a 1.5-ft thick layer of gravelly sand in the modified design.

To assess the potential for a sliding failure along the top surface of the synthetic liner, the licensee provided direct shear test data that indicate a residual friction angle of approximately 30 degrees between the textured, high-density polyethylene and gravelly sand. The licensee indicates that this value of frictional resistance would provide adequate stability for the cover-system slope. A confirmatory hand calculation performed by staff indicates that the factor of safety against failure of the cover-system slope considering sliding on the top surface of the synthetic liner would be greater than 1.1 (the minimum acceptable safety factor under dynamic loading based on staff guidance) for seismic ground motions with a peak ground acceleration smaller than 0.44 g (acceleration of gravity). This limiting value of peak ground acceleration that can cause sliding failure is greater than the design-basis peak ground acceleration of 0.27 g for the site, considering seismic characterization information provided by the licensee and reviewed in Section 2.3 of this SER. The staff calculation used a friction angle of 30 degrees at the contact between the synthetic liner and gravelly sand. Also, a staff confirmatory hand calculation shows that 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)) if the friction angle for the soil-to-liner interface is greater than approximately 17 degrees, which is smaller than the 30 degrees determined by the licensee.

To assess the potential for sliding failure along the contact between the synthetic liner and the underlying clay liner, the licensee provided an analysis of the sliding resistance at the interface considering long-term static loading and seismic loading from a potential earthquake. The licensee's stability analyses indicate that the factor of safety against sliding failure would be at least 2.6 under static loading conditions and at least 1.3 under seismic loading from an earthquake with a peak horizontal acceleration of 0.27 g. These values satisfy the stability criteria of a minimum safety factor of 1.5 under static loading and 1.1 under seismic loading based on staff guidance. The licensee's analysis includes an assumption that the textured synthetic liner would penetrate into the underlying clayey soil such that the potential for sliding at the interface between the liner and the soil would be governed by the internal frictional resistance of the soil. The staff agrees with the licensee's assumption, because the liner will be textured and will be subjected to vertical loading from the weight of overlying materials. The staff performed a confirmatory calculation to evaluate the effects of an earthquake with a peak horizontal acceleration of 0.27 g on the stability of the disposal cell design. The staff calculation indicates that the factor of safety against failure of the cover-system slope, considering sliding of the synthetic liner, would be greater than 1.1 if the friction angle for the compacted clayey soil is greater than approximately 24 degrees. A staff confirmatory calculation to evaluate stability of the cell under long-term static conditions also shows that the safety factor would be greater than 1.5 if the friction angle for the clayey soil is greater than approximately 17 degrees.

The licensee indicated that the compacted clayey soil will have a plasticity index of approximately 17 and, therefore, a friction angle of approximately 32 degrees. The staff determined from information in the literature that the friction angle for a compacted clayey soil with a plasticity index of approximately 17 could lie in the range of 26–37 degrees based on Lambe and Whitman (1969, p. 307) or 28–32 degrees based on U.S. Department of the Navy (1982, p. 7.2-39). These values of potential friction angle for the clayey soil rely on an assumption that the plasticity index will not exceed approximately 17 and the soil will be compacted to at least 95 percent maximum Proctor density. The friction angle for a clayey soil that meets these specifications likely will exceed the minimum of 24 degrees needed to ensure the stability of a disposal cell of the proposed design in a potential earthquake.

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 (NRC, 2003).

The licensee has acceptably described the slope stability evaluation by (1) 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, (2) proposing a disposal-cell design with side slopes at 5h:1v, (3) providing standard measurements of the material properties needed for the slope stability analysis, (4) selecting locations for slope stability analyses while considering the locations of maximum slope angle and slope height, and (5) describing in detail vegetative cover and its primary function.

The static loads analysis is acceptable and includes (1) indication of appropriate uncertainties and variability in important soil parameters, (2) consideration of appropriate failure modes, and (3) 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 (1) use of calculations with appropriate assumptions and methods, (2) treatment of important interaction effects in a conservative fashion, (3) consideration of the potential effects of dynamic stresses on shear strength, (4) determination that the slope is unlikely to sustain any significant deformation during a maximum credible earthquake, (5) selection of appropriate design-level seismic events or strong ground motion accelerations, (6) evaluations of local site conditions, and (7) design of a self-sustaining vegetative or rock cover consistent with commonly accepted engineering practice.

On the basis of the information presented in the application and the detailed review conducted of the slope stability at the proposed facility, the NRC staff concludes that the slope stability evaluation provides an acceptable input demonstrating compliance with the following criteria in 10 CFR Part 40, Appendix A: Criterion 4(c), which provides requirements for the long-term stability of the embankment and cover slopes for tailings, and Criterion 6(1), which requires 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.

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 nature of material Type C proposed for disposal in the 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 between disposed structural materials. The resulting 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 and material selection. Specifically, placement procedures for material Type C will be controlled to minimize pore spaces and compressibility and excavated areas will be filled with compacted granular materials to minimize subgrade variability. The licensee, in addition, provided calculations to make the 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 (Drawing 2 of the RP). The licensee specifies in its technical specifications (Attachment A of the RP) that the excavated areas will be filled with material identified as subgrade fill and defined as granular materials from offsite commercial sources or soils and weathered sedimentary rock from approved onsite excavation areas. Any fine-grained subgrade fill will be placed in lifts not exceeding 8 in. in loose thickness and will be compacted to at least 90 percent of the maximum dry density at a water content not more than 3-percent greater or smaller than the optimum moisture content (Attachment A of the RP). The coarse-grained subgrade fill will be placed in lifts not exceeding 8 in. in loose thickness and compacted to a minimum relative density of 75 percent. 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). The licensee, however, proposes to use a reduced loose lift thickness of 8 in., which would increase the uniformity of compaction and reduce the potential for differential settlement, even under the design earthquake acceleration of .27g. The placement procedure specified by the licensee, therefore, is likely to result in an adequate subgrade for the proposed disposal cell embankment.

3.4.2 Placement Control for Material Type C

Information provided by the licensee indicates that material type 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 disposed structural materials.

However, information provided by the licensee includes a specification of placement control and maximum sizes for pieces of structural materials to be disposed of in the cell, filling the pore spaces with soil, and compaction control for such soil. Among other details, the specifications include the following:

- Structural materials will be broken or cut to manageable size and hauled to the disposal cell for placement. The material placement strategy for incompressible structural materials is to minimize void spaces around these materials in the cell by spreading or laying out the materials in lifts. Materials of large size will be cut for loading and transport to the designated area of the disposal cell, with a maximum dimension of 20 ft (unless loading or handling conditions dictate a smaller dimension). Large or odd-shaped materials will be laid flat in the disposal cell (i.e., placed with the longest dimension oriented horizontally). Each lift of material will be covered with soil and compacted to minimize void spaces within the incompressible materials in the cell.

Large incompressible materials exceeding 2 ft in vertical dimension (such as thick-walled tanks or vessels) will be placed in the cell with interior void spaces filled with sand or grout. Soil or sand will be placed outside of the large materials and compacted with standard compaction equipment (where possible) or hand-operated equipment.

- The material placement strategy for compressible structural debris or soil-like materials is to make them incompressible by cutting, crushing, solidifying, or compacting the materials. Compressible structural material (such as thin-walled piping and tanks) will be flattened or crushed at the disposal cell with hydraulic excavator attachments, or with a dozer or other steel-tracked equipment. Compressible sludge material (such as calcium fluoride sludge) will be amended with fly ash, placed in lifts in the disposal cell, and compacted.

- 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. Placement of soil and soil-like materials will be controlled as defined in the technical specifications in Attachment A of the RP.

- Soil placed as demolition material cover, interim cover, or material type D will not exceed 2 ft in loose-lift thickness and will be compacted with a minimum of six passes with vibratory compaction equipment to 95 percent of the maximum dry density. The licensee will conduct field tests during construction to confirm the number of passes needed to achieve the specified density. 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). The compaction control specified by the licensee, therefore, is adequate for soil placed as demolition material cover.

The staff concludes that the placement specification for material type C provided by the licensee is likely to be adequate to eliminate excessive void space in the disposed material. Soil overlying disposed type C material, therefore, likely will remain intact and not flow into type C material zones or undergo excessive deformation or differential settlement.

3.4.3 Settlement Estimates

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 initial estimates of potential settlement on information in the literature from historical measurements at uranium tailings impoundments, uranium mill demolition and disposal sites, and municipal landfills. Information from uranium tailings impoundments suggests settlement values on the order of 10–20 percent of the tailings thickness. The licensee, however, explained that settlement at tailings impoundments is influenced by compression of slurry-deposited tailings and is likely to be larger than potential settlement of the proposed disposal cell. Information from uranium mill demolition and disposal sites indicates that settlement is limited to areas of void spaces between pieces of disposed structural debris. The licensee has committed to reducing such void spaces using placement control as reviewed under Section 3.4.2 of this SER. Information from municipal landfills suggests a settlement of 5–25 percent of the landfill height. The licensee stated that a large fraction of landfill settlement can be attributed to decomposition of biodegradable materials such as wooden pallets but settlement of the proposed disposal cell should be smaller than landfill settlement because the cell will not include the large percentage of biodegradable materials typically associated with landfills. Furthermore, interstices of the pallets will be filled with soil so as to minimize the settlement caused by biodegredation. To estimate potential settlement of the disposal cell, the licensee indicated that settlement would arise mainly from compression of mixtures of sludge and fly ash (see information reviewed in Section 3.6.1 of this SER) placed near the base of the disposal cell. The thickness of the sludge and fly ash mixture will be approximately 2 ft based on licensee information. The licensee also indicated that the compaction equipment proposed for use at the site will preload each compaction lift by a vertical stress of approximately 5,000 pounds per square foot. Potential settlement from compression of a given compacted lift can be considered negligible if the superimposed vertical stress (e.g., from overlying disposed materials) does not exceed the preload vertical stress (e.g., Lambe and Whitman, 1969, p. 520). The licensee estimated that potential settlement of the disposal cell from compression of the sludge and fly ash mixture would not exceed 0.017–0.17 in. by varying the compressibility of the sludge and fly ash mixture (using a compression index of 0.01–0.1).

The licensee provided an assessment of the potential for cracking of the clay liner at the base of the cover system owing to any differential settlement of the disposal cell. The licensee estimated a minimum cracking strain of 8×10^{-4} based on a plasticity index of 10 for the clay liner material. The plasticity index of 10 is the minimum specified for the clay liner by the licensee. Also, the cracking strain would increase as the plasticity index increases based on the model cited by the licensee. The licensee stated that the amount of differential settlement needed to cause a lateral strain equal to the minimum cracking strain is approximately one order of magnitude greater than the potential settlement estimated by the licensee. The staff agrees with the licensee that a differential settlement large enough to cause cracking of the clay liner is unlikely, if the licensee follows the placement specifications for the disposal cell and cover materials, such as those reviewed in Section 3.4.2 of this SER.

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 (NRC, 2003).

The settlement analysis used acceptable procedures. The standard approach for determining the values of soil properties for settlement analysis is not applicable to the proposed disposal cell. The licensee, instead, used historical settlement measurements for similar structures to estimate settlement and specified placement procedures and compaction equipment to ensure a negligible settlement for the completed disposal cell. Results of the settlement analyses are properly documented.

On the basis of information presented in the application and the detailed review conducted of the potential for settlement of the proposed disposal cell, the NRC staff concludes that the settlement analysis provides information needed to demonstrate compliance with 10 CFR Part 40, Appendix A Criterion 6(1), which requires 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.

3.5 Liquefaction Potential

3.5.1 Liquefaction Potential Analysis

Analysis of liquefaction potential provided by the licensee in Attachment E of the RP indicates a safety factor greater than 2.1 against liquefaction. The analysis considered vertical profiles through the disposal cell, including approximately 8 ft of saturated alluvium or compacted granular material at the base. The analysis was based on a standard technique described by Youd, et al. (2001). The calculated safety factor indicates that the estimated potential seismic ground motion for the site would not cause liquefaction of the disposal-cell foundation. Also, the licensee indicated that liquefaction of the disposal-cell material is unlikely because the base of the disposal cell is designed to be a minimum of 2 ft above the ground water table.

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 (NRC, 2003).

The licensee has acceptably evaluated the liquefaction potential based on results from properly conducted analysis using appropriate input data. On the basis of the information presented in the application and the detailed review conducted of the liquefaction potential at the facility, the NRC staff concludes that the results of evaluation of liquefaction potential and associated conceptual and numerical models present input to a demonstration of compliance with the following criteria in 10 CFR Part 40, Appendix A. Criterion 4(c), which provides long-term stability requirements for the slopes of such embankment and cover, and Criterion 6(1), which requires 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.

<u>3.6 Disposal-Cell Liner and Cover Engineering Design</u>

3.6.1 Disposal-Cell Materials and Testing

SFC's RP (Attachment A, Drawings 1–12) provides detailed drawings and cross-sections for the design of the proposed disposal cell. The construction materials for the disposal cell liner system and the cell cover system will come from onsite sources, except sand and gravel used as bedding or cover layers for synthetic liners that may be obtained from offsite sources (Attachment E to the RP). 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 that the soils are low-plasticity, nondispersive clays with compacted hydraulic conductivity values below 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. 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 RP, 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 storm water 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 technical specifications section of the RP describes the specific installation (e.g., panel deployment, seaming, and anchoring) and testing methods. Shear and peel tests will be conducted in accordance with appropriate standards published by ASTM International. A 18-in. layer of topsoil will be placed on top of the cell cover system, and growth of long-term native vegetation consisting of grasses and forbs will be promoted to reduce infiltration. Section 3.8 of this SER presents an evaluation of estimates of long-term effectiveness of surface vegetation.

Information provided by the licensee in Drawing 11 indicates that the synthetic liner at the base of the cover system will be covered with a layer of gravelly sand 1.5 ft thick and of particle size distribution specified in the RP 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 liner cover must have a minimum thickness, shear strength, and permeability. These characteristics of the liner cover are controlled by layer thickness, particle-size gradation, and the placement procedure (e.g., compaction method, degree of compaction, and lift thickness). Particle size specifications and placement procedures provided by the licensee for the liner cover will be adequate.

Information provided by the licensee indicates that 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 before placement in the disposal cell. Based on the licensee's information, calcium fluoride sludge and other loose or soft materials such as pond sediments will be solidified by mixing with fly ash at a minimum sludge to fly ash ratio of 1 to 1 by volume. The mixture will be compacted with a minimum of six passes with self-propelled, towed, or hand-held vibratory compaction equipment. The licensee will confirm the number of passes using actual compaction equipment on site with a field test section of soil to establish a correlation between the field compaction method and 95 percent of maximum dry density for the soil.

Section 4 of this SER presents an evaluation of the selection and testing of materials for erosion protection (riprap, rock mulch) and design issues related to erosion protection. Section 3.8 addresses the installation and testing of the liner and cover systems related to the hydraulic conductivity of the disposal cell. Section 3.4 of this SER describes the evaluation of the potential effects of settlement on the cover system.

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 (NRC, 2003).

The licensee has acceptably defined the disposal cell cover design by presenting detailed descriptions of the disposal cell material types, soil mixtures, or both, including the basis for selection. The licensee has identified an adequate quantity of the specified borrow material at the borrow source. The licensee has provided an acceptable schematic diagram displaying various disposal cell layers and thicknesses and a description of the applicable field and laboratory investigations and testing, including identification of material properties. The properties of the cover materials have been measured properly using standards such as those developed by ASTM International, the NRC, or the U.S. Army Corps of Engineers, which are identified in NUREG-1620 (NRC 2003). The licensee has presented details (including sketches) of (1) disposal cell termination boundaries, (2) penetrations, including sealing and disposal cell integrity, and (3) geomembranes and their physical, mechanical, and chemical properties.

Methods of installation for the membranes have been discussed, and the expected service life has been justified.

On the basis of the information presented in the application and the detailed review conducted of the disposal cell cover design at the SFC facility, the NRC staff concludes that the disposal cell engineering parameters and associated conceptual and numerical models are acceptable and provide input to demonstration of compliance with the 10 CFR Part 40, Appendix A criteria. Criterion 4(c) which provides requirements for the embankment and cover slopes for tailings, and Criterion 6(1) which requires 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.

3.7 Construction Considerations

SFC's RP describes the proposed disposal cell construction plan in Attachment E and includes the technical specifications for cell construction in 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 protect against leachate migration. The proposed liner system would consist of a 2-ft compacted clay liner at the bottom, a 6-in. bedding layer of sand, a synthetic geomembrane, and a 18-in. bedding layer of sand at the top. A leachate detection system, consisting of a series of 4-in., slotted, high-density polyethylene pipes would be installed in the bedding layer immediately above the clay liner. For water management, materials with high shear strength would be used to construct a berm around the footprint of the disposal cell, and a leachate collection system consisting of a series of 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 6-in. (minimum) bedding layer of sand. The licensee did not evaluate the potential for freeze-thaw cycles and desiccation on the clay liner and cell cover system during construction. 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 desiccation 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 32 degrees Fahrenheit. Maximum frost penetration in natural soils near the facility is 10–20 in. and would be less for compacted materials (Koerner and Daniel, 1997). The synthetic geomembrane would be installed over the 6-in. bedding layer, and tested and approved areas of the geomembrane would be covered with the second 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 included these restrictions in the technical specifications of the RP. As outlined in the technical specifications section of the RP, 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. The licensee presents the material placement sequence (layers A–D) and material volumes in its RP. Section 3.4 of this SER addresses the main concern with settlement during material placement and possible cover cracking.

3.7.2 Evaluation Findings

The staff has completed its review of construction considerations for the proposed disposal cell at the SFC 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 (NRC, 2003).

The licensee has acceptably described the construction considerations by (1) providing complete engineering drawings showing all design features, (2) describing sources and quantities of borrow material, including acceptable field and laboratory testing, and (3) identifying methods, procedures, and requirements for excavations, haulage, stockpiling, and placement of materials. The licensee has demonstrated that all are consistent with accepted engineering practices for earthen works. Disposal cell compaction plans are supported by field and laboratory tests that ensure 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 also committed to technical specifications for protecting the clay liners from cracking during installation because of desiccation or freeze-thaw cycles.

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. The proposed liner system would consist of a 0.6-m (2-ft) compacted clay liner at the bottom, a 6-in. liner bedding layer of gravelly sand, a synthetic geomembrane, and a 18-in. liner cover material (gravelly sand) at the top. The licensee’s technical specifications include particle size specifications for the synthetic liner bedding and cover materials. Also, the materials will be free from angular debris (roots, sharp rocks) that could damage the synthetic liner material.

Materials for the planned clay liner and most of the soil cover for the disposal cell will be obtained on site from the SFC facility. The technical specifications for the disposal cell call for a 3-ft-thick (minimum) compacted clay liner. As stated in Section 3.6 of this SER, 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 that the soils are low-plasticity; nondispersive clays with hydraulic conductivity values below 1×10^{-7} cm/s (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. Section 3.7 of this SER presents an evaluation of the protection of the clay liner during construction.

3.8.2 Disposal-Cell Cover System

The disposal-cell cover design is a layered system with a moisture retention (store-and-deplete) zone and a vegetated surface. The total cover thickness is 10 ft. The upper 15 ft acts as an erosion protection and vegetation zone. On the top surface of the cell, the upper 1.5 ft of the cover thickness consists of a topsoil layer. On the side slopes, the upper 1.5 ft consists of a 0.75 ft-thick topsoil layer above a 0.75-ft-thick rock mulch layer.

Below the top soil layer, a 5.0-ft-thick subsoil zone consisting of onsite soils provides a root zone and moisture retention zone for infiltrating meteoric water. Beneath this zone is a 1.5 ft-thick drainage layer (liner cover material) consisting of granular material that will be free from roots, branches, rubbish, process area debris, and other angular or pointed materials that could damage the synthetic liner (60-mil, high-density polyethylene) below it. The bottom 2.0 ft of the cover will be a compacted clay layer that consists of material with a maximum particle size of 1 in. and will be placed in lifts with maximum compacted thickness of 6 in. to form a continuous layer with a total minimum compacted layer thickness of 2 ft. Clay liner material will consist of soils from approved onsite borrow areas. Compacted clay liner material will have a maximum saturated hydraulic conductivity of 1×10^{-7} cm/s (2.8×10^{-4} ft/d) when compacted as per the technical specifications.

Infiltration analyses for the cell cover system using the TerreSIM code indicate downward percolation of meteoric water below the root zone depth (essentially above the clay layer). The average infiltration rate over the simulated 200-year period was approximately 5.1 in./yr, or 11.3 percent of average annual precipitation of 45 in.. The average rate is higher during the first 50 years (6.5 in./yr) while vegetation species are becoming established and is lower (4.6 in./yr) after 50 years. This indicates that on average, approximately 10 percent of annual precipitation percolates downward through the cover past the root zone depth. For a saturated hydraulic conductivity of 10^{-7} cm/s (1.2 in./yr) in the clay layer, the downward migration of water through a unit area of the compacted clay layer is estimated to be 0.3 in./yr.

The HELP model (Schroeder et al., 1997) was used to track moisture movement in the cover system and to provide a rough comparison of estimated infiltration with the TerreSIM model. The daily precipitation record in the HELP model database was for Tulsa, OK (approximately 70 miles) northwest of the site), with an average annual total of approximately 39 in.. The model was run for a simulation period of 100 years. The model used a grass cover (fair quality) with a root depth of 7 ft. A provision for lateral drainage was included in the model at the top of the clay layer. The HELP model results indicate an average rate of infiltration of 2.7 in./yr (6.9 percent of average annual precipitation). This average value, approximately 10 percent of average annual precipitation is lower than that calculated with the TerreSIM model. The downward percolation rate over this period through the base of the cover (below the compacted clay layer) averaged approximately 1.5 in./yr, or 3.9 percent of average annual precipitation. The input values used in the HELP model are reasonable and conservative estimates with respect to percolation to represent the layers in the cover system. The synthetic liner was not included in either the TerreSim or the HELP models for long-term scenarios.

To prevent the long-term “bathtub” effect caused by a more permeable cover than the underlying liner, the leachate collection system incorporated into the cell design is where fluids that accumulate on top of the liner at the base of the cell will be collected in a sand and drainage pipe network and conveyed by gravity to ponds outside the perimeter of the cell. This collection system is designed primarily for fluid removal during and immediately after cell construction, but the system also provides a secondary method of preventing the long-term “bathtub” effect. Section 5.3 of this SER presents a detailed description of the leachate collection system.

Field and laboratory tests that ensure the performance of the liner system support disposal-cell compaction plans. As outlined in the licensee’s technical specifications, 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. Section 3.7 of this SER discusses details of the planned construction sequence. The construction will include provisions to prevent the clay liner from eroding or cracking. The construction sequence of the cell cover described in the technical specifications and construction plan 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 (NRC, 2003).

The licensee has acceptably evaluated the hydraulic conductivity (K) of the disposal-cell cover materials 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 is presented. The licensee proposes an acceptable quality control program for the field testing to determine the hydraulic conductivity. On the basis of the information presented in the application and the detailed review conducted of the disposal cell hydraulic conductivity at the SFC facility, the staff concludes that the disposal cell hydraulic conductivity and associated conceptual and numerical models provide an acceptable input to the demonstration of compliance with the following criteria in 10 CFR Part 40, Appendix A. Criterion 4(c), which provides requirements for the embankment and cover slopes for tailings, and Criterion 6(1), which requires 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.

3.9 References

ASTM International, 2003, "Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils," ASTM–D4318, West Conshohocken, PA: ASTM International.

Koerner, R.M. and D.E. Daniel, 1997, "Final Covers for Solid Waste Landfills and Abandoned Dumps," Reston, VA: American Society of Civil Engineers Press.

Lambe, T.W. and R.V. Whitman, 1969, *Soil Mechanics*, New York: John Wiley and Sons, Inc.

National Oceanographic and Atmospheric Administration, 2004, "Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days, 1971–2000: 34–Oklahoma," *Climatography of the United States*, No. 81, Asheville, NC: National Oceanographic and Atmospheric Administration.

Sequoyah Fuels Corporation, "Corrective Action Plan Report," Gore, OK, June 16, 2003. ADAMS Accession No. ML031710049.

Sequoyah Fuels Corporation, "2002 Annual Groundwater Report," Gore, OK, January 31, 2003. ADAMS Accession No. ML030360076.

Schroeder, P.R, C.M. Lloyd, and P.A. Zappi, 1997, "Hydrologic Evaluation of Landfill Performance," HELP Model Version 3.07, developed by USAE Waterways Experiment Station for U.S. EPA Risk Reduction Engineering Laboratory, November 1, 1997.

U.S. Environmental Protection Agency, 1993, "Solid Waste Disposal Facility Criteria: Technical Manual," EPA530–R–93–017, Washington, DC. http://www.epa.gov/epaoswer/non-hw/muncpl/landfill/techman/.

U.S. Department of the Navy, 1982, "Foundations and Earth Structures," NAVFAC DM–7.2, Alexandria, VA: U.S. Department of the Navy, Naval Facilities Engineering Command.

U.S. Nuclear Regulatory Commission, 2003, NUREG–1620, "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," Rev. 1, Washington, DC, June 2003.

Youd, T.L., I.M. Idriss, R.D. Andrus, I. Arango, G. Castro, J.T. Christian, R. Dobry, W.D.L. Finn, L.F. Harder, Jr., M.E. Haynes, K. Ishihara, J.P. Koester, S.S.C. Liao, W.F. Marcuson, III, G.R. Martin, J.K. Mitchell, Y. Moriwaki, M.S. Power, P.K. Robertson, R.B. Seed, and K.H. Stokoe, II, 2001, "Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils," *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 127, No. 10, pp. 817–833.

4. 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 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 RP and the related appendices and attachments. In conducting the review, the NRC staff used review methods and acceptance criteria in Section 3.0 of NUREG-1620, Revision 1, "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).

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 and is situated approximately 100 feet (ft) above the Illinois River. Releases from the Tenkiller Ferry Reservoir, located on the Illinois River approximately 7 miles upstream of the site, regulate flows in the Illinois River.

To comply with Criterion 6 of Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content," to Title 10, Part 40, "Domestic Licensing of Source Material," of the *Code of Federal Regulations* (10 CFR Part 40), which requires stability of the tailings for 1,000 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 1,000-year stabilization period.

As shown in Figure 3-1 of the RP, the top surface of the cell will be configured to drain toward the east at a slope of about 1 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-ft-thick soil cover, and the side slopes of the tailings cell will include, within a 10-ft-thick cover, a layer of rock riprap overlain by a soil layer 9 inches (in.) thick 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 licensee performed computation of peak flood discharges for various site design features 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 (see Section 4.5 of this SER).

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, because of the unknown level of accuracy associated with such an extrapolation. The licensee utilized a 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, in accordance with NUREG-1623, the staff has concluded that the probability of such an event being equaled or exceeded during the 1,000-year stability period is very low. Accordingly, the NRC staff considers the PMP to provide an acceptable design basis.

Before determining the runoff from the drainage basin, the flooding analysis requires the determination of PMP amounts for the specific site location. Federal agencies have developed techniques for determining the PMP for the United States 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.

The licensee estimated PMP values by using Hydrometeorological Report No. 51 (HMR-51) (USACE, 1978) and HMR-52 (USACE, 1982). These reports also provide information on distributing the rainfall that falls over a particular drainage area. The licensee used a 1-hour PMP of 19 in. and a 5-minute PMP of 6.3 in. as a basis for estimating a 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 NRC staff considers the PMF to provide an acceptable design basis for erosion protection.) The staff reviewed the procedures for estimating PMP values and 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 the precipitation. 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 Rational Formula (USBR,

1977) incorporate a runoff coefficient (C); a C value of 1 represents 100-percent runoff and no infiltration. Other models, such as the U.S. Army Corps of Engineers Flood Hydrograph Package HEC-1 (USACE, 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 in. (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.

The licensee used the Kirpich Method (USBR, 1977) to estimate times of concentration for the riprap design. This method is generally accepted in engineering practice, and the staff considers it 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 1 hour. If the time of concentration is less than 1 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 (USACE, 1982). This procedure involves the determination of rainfall amounts as a percentage of the 1-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-hour PMP, or 6.3 in. 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 which is recommended in NUREG-1623, "Design of Erosion Protection Covers for Long-Term Stabilization" (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 ft (with a slope of 0.01) and a side slope length of 100 ft (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 nonerosive levels. The licensee estimated PMF flow rates for overland flow for the downstream apron and found them to be 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 RP 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-ft-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 of this SER.)

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 NRC staff has verified the validity of these design approaches 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. Section 4.5 of this SER provides additional discussion of input parameters and design methods for riprap sizing.

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. Section 4.5.1.2 of this SER presents a detailed discussion of the riprap design of various components of the apron.

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 that 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 in. could contain rocks ranging in size from 0.75 in. to 6 in.; 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. Various sources provide design criteria for developing acceptable gradations (e.g., Simons and Li, 1982), and NUREG-1623 presents examples of acceptable gradations.

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 ease of construction and to minimize the number of gradations, the licensee has purposely overdesigned several areas of the side slopes by proposing to use 3.7-in. rock on the south and east side slopes and 3.0-in. rock on the north and west slopes. The following sections discuss the design for different locations.

Unless otherwise noted, the staff evaluation presented below assumes that angular rock from the Soutar Quarry will be used for the erosion protection. If another source is selected and rounded rock is used, the rock size will be about 40 percent larger than the angular rock.

4.5.1.1 Top and Side Slopes

The top portion of the reclaimed pile will be protected by a 10-ft-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 1,000-year period. Using the PMP/PMF flows and assumptions discussed above, the licensee concluded that the top slope would be stable.

Using procedures discussed in NUREG-1623, the licensee evaluated the top slope for erosional stability. Using a peak discharge of about 1.2 cfs/ft, the maximum velocities were computed to range from 1.4 to 2.3 ft per second. Permissible velocities recommended in NUREG-1623 range from about 2 to 2.5 ft per second for a vegetated soil cover. The top slope was also evaluated using procedures discussed by Temple et al. (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 adequately protect 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 ft. 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 ft, and the soil cover is 10 ft thick. This conclusion is based on the presence of the riprap on the side slopes of the cell (at an elevation about 5 ft 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 9-in. layers of rock with minimum D_{50} values of 3.7 and 3.0 in. The licensee used the Abt Method (Johnson, 2002) 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 SER, the staff concludes that the proposed rock sizes for the side slopes are adequate.

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 a 24-in. layer of rock with a minimum D_{50} of 7.5 in. in the apron area. The rock size was calculated by the licensee using design criteria suggested in NUREG-1623. Based on review of the calculations provided, the staff concludes that the rock size for the apron is acceptable.

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 mitigate 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. To prevent erosion of the embankment side slope, the licensee designed a rock apron to collapse into the scour hole of a head-cutting gully, with the rock volume and size sufficient to prevent further erosion of the gully into the pile side slope. The riprap to be provided for the rock apron was designed using the guidance suggested in NUREG-1623, with an apron length of about 20 ft and a thickness of 24 in. Based on its review of the information provided, the staff concludes that the size and volume of rock are acceptable.

4.5.1.2.2 Flows Adjacent to Apron

On the east side of the cell, the rock apron will transition into a diversion channel which will receive surface runoff from both the top of the cell and upland areas further to the east. These flows will collect in the channel and flow to the north and south along the toe of the east side slope. The licensee designed the riprap for the diversion channel by using the criteria suggested in NUREG-1623 and a peak PMF flow of 6.4 cfs/ft. Based on review of the calculations provided, the staff concludes that the proposed rock size of 7.5 in. is acceptable.

4.5.1.3 Stream 005

As discussed in Section 2.4.2 of this SER, a gully exists at the head of Stream 005, located to the west of the proposed cell. 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."

The licensee has proposed a design to mitigate the erosion in this gully, where the apron on the west side of the cell is enlarged and extended. The staff reviewed the calculations provided by the licensee and concludes that the rock size and apron slope are acceptable. Based on review of the design drawings, the staff also concludes that the lateral extent of the apron (in a north-south direction) is sufficient to prevent the encroachment of any headward-advancing gully in this area that could potentially intercept the rock apron.

4.5.2 Riprap Gradations

Riprap gradations and layer thicknesses were developed using criteria suggested in NUREG-1623. The proposed D_{50} values represent the minimum D_{50} of the gradation, and the proposed gradations will not contain an excessive amount of fine material. Staff review of the information provided indicates that the proposed gradations are acceptable.

4.5.3 Rock Durability

NRC regulations require that control of residual radioactive materials be effective for up to 1,000 years, to the extent reasonably achievable and, in any case, for at least 200 years. The previous sections of this SER examine the ability of the proposed erosion protection design to withstand flooding events reasonably expected to occur in 1,000 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 1,000 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 ensure that the rock used for erosion protection remains effective for up to 1,000 years as required by Criterion 6 of Appendix A to 10 CFR Part 40, potential rock sources must be tested and evaluated to identify acceptable sources of riprap. NUREG-1623 presents a procedure for determining the acceptability of a rock source. 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 that determines its acceptability, as defined in the NRC scoring procedures.

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

In general, rock durability testing is performed using standard test procedures, such as those developed by the American Society for Testing and Materials (ASTM). 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 identified the Soutar Quarry as the potential rock source for the riprap erosion protection. For the angular limestone rock, the licensee performed durability tests and indicated that the rock scored approximately 77–78 using the NUREG-1623 scoring procedure. The licensee also indicated that the rock would be oversized by a factor of about 10 percent, exceeding the minimum recommendations of NUREG-1623. The licensee also provided the results of petrographic analyses tests for the rock. This information was evaluated to determine if the rock contains any specific deleterious features, clays, or other minerals that could weather rapidly. Based on review of the information provided, the staff concludes that the proposed rock is acceptable.

4.5.4 Testing and Inspection of Erosion Protection

The licensee provided information regarding testing, inspection, and quality control procedures to be used for the erosion protection materials. The information included programs for rock production, durability testing, gradation testing, rock placement, and verification of rock layer thicknesses.

4.5.4.1 Rock Production

The rock will be produced from a thick unit on the north wall of the Soutar Quarry and will be a limestone from the Hale/Bloyd Formation of Pennsylvanian age. Both the licensee and the staff observed that the limestone from this unit contains easily identifiable and avoidable features that could be adverse to rock durability. In addition, unacceptable rock units overlying and underlying the selected limestone unit are easily identifiable and will be avoided during rock production.

The licensee provided rock production procedures to ensure that only rock of acceptable quality will be used. Unacceptable rock will be removed and segregated from the limestone unit before drilling and blasting. After drilling and blasting, trained personnel at the quarry will monitor and segregate rock that is not high-quality limestone. Undesirable features have been identified and include vugs (voids) and stylolites. Based on evaluation of the licensee's procedures, the staff concludes that the rock production process is acceptable.

4.5.4.2 Durability Testing During Production and Placement

The licensee will use durability test results to confirm the acceptability of the rock durability during production based on rock durability data and the scoring method discussed in Section 4.5.3, which is based on guidance in NUREG-1623. The licensee has proposed that four durability tests will be conducted on representative samples. As suggested in NUREG-1623, the licensee proposes that one initial test series will be performed before placing rock, and additional tests will be performed when approximately one-third and two-thirds of the total volume of the riprap have been delivered. The licensee also committed to performing additional tests when the rock characteristics 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 an adequate durability testing program has been provided to ensure that rock is of acceptable quality. The testing program currently proposed is equivalent to several that have been approved by the staff and implemented at other reclaimed sites during construction.

4.5.4.3 Gradation Testing

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

- Rock gradations will be tested using ASTM D 422, C117, or C136, as appropriate.

- Gradation testing will be performed at a frequency of one test for every 2,000 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 that have been approved by the staff and implemented at other reclaimed sites during construction.

4.5.4.4 Riprap Placement

The licensee indicated that the rock would be placed using a program that generally meets the criteria outlined in NUREG-1623. Based on review of the program, the staff concludes that the program is acceptable.

4.5.4.5 Rock Layer Thickness Testing

The licensee has committed to a program where, before placement of the soil cover over the rock on the side slopes, the thickness of the rock layers will be verified by establishing a grid over the tailings impoundment and using specific procedures for measuring and recording depths. Visual examinations will also be conducted to verify the uniformity of depths. Based on a review of the information provided, the staff concludes that the proposed testing program for rock layer thickness is adequate.

4.5.5 Wind Erosion

Using procedures suggested in NUREG-1623, the licensee provided calculations to show that the soil losses associated with wind erosion will be minimal. Based on review of these calculations, the staff concludes that the site will be adequately protected for up to 1,000 years from wind erosion.

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 erosion protection design is adequate to provide reasonable assurance of protection for 1,000 years, as required in Criterion 6 of Appendix A to 10 CFR Part 40.

4.6 Upstream Dam Failures

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

References

Abt, S.R., M.S. Khattak, J.D. Nelson, J.F. Ruff, A. Shaikh, R.J. Wittler, D.W. Lee, and N.E. Hinkle, 1987, "Development of Riprap Design Criteria by Riprap Testing in Flumes, Phase I," NUREG/CR-4651.

Chow, V.T., 1959, *Open Channel Hydraulics*, McGraw-Hill Book Co., New York.

Johnson, Terry L., 2002, "Design of Erosion Protection Covers for Long-Term Stabilization," NUREG-1623, U.S. Nuclear Regulatory Commission.

Pemberton, E.L. and J.M. Lara, 1984, "Computing Degradation and Local Scour," U.S. Bureau of Reclamation.

Sequoyah Fuels Corporation (SFC), 2008, "Reclamation Plan Sequoyah Facility," Gore, OK, January 4, 2008. ADAMS Accession No. ML080220345.

Simons, D.B. and R.K. Li, 1982, "Surface Mining Diversions Design Manual," Office of Surface Mining, U.S. Department of the Interior, OSM/TR-52/2, September 1982.

Stephenson, D., 1979, *Rockfill in Hydraulic Engineering*, Elsevier Scientific Publishing Co., New York.

Stevens, M.A., D.B. Simons, and G.L. Lewis, 1976, "Safety Factors for Riprap Protection," American Society of Civil Engineers, *Journal of the Hydraulics Division*, v. 102, No. HY5.

Temple, D.M., K.M. Robinson, R.A. Ahring, and A.G. Davis, 1987, "Stability Design of Grass-Lined Open Channels," U.S. Department of Agriculture Handbook 667.

U.S. Army Corps of Engineers (USACE), 1995, "Toe Scour and Bank Protection Using Launchable Stone," Waterways Experimental Station, Technical Report HL-95-11, September 1995.

U.S. Army Corps of Engineers, 1988, "HEC-1 Flood Hydrograph Package," Hydrologic Engineering Center, Davis, CA.

U.S. Army Corps of Engineers, 1982, "Application of Probable Maximum Precipitation Estimates, United States East of the 105^{th} Meridian," Hydrometeorological Report (HMR) No. 52.

U.S. Army Corps of Engineers, 1978, "Probable Maximum Precipitation Estimates, United States East of the 105^{th} Meridian," Hydrometeorological Report (HMR) No. 51.

U.S. Bureau of Reclamation, 1977, *Design of Small Dams*, U.S. Department of the Interior.

U.S. Department of Transportation, 1975, "Hydraulic Design of Energy Dissipators for Culverts and Channels," Hydraulic Engineering Circular No. 14, December 1975.

U.S. Nuclear Regulatory Commission, 2003, NUREG–1620, "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," Rev. 1, Washington, DC, June 2003.

U.S. Nuclear Regulatory Commission, 2002, NUREG–1623, "Design of Erosion Protection for Long-tTerm Stabilization" Final Report,, Washington, DC, September 2002.

5. 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. The NRC staff performed this review using Section 4.0 of NUREG-1620, Revision 1, "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). However, much of Section 4.0, "Protecting Water Resources," is not applicable to new disposal cells because NUREG-1620 assumes that a disposal cell for Section 11.e(2) byproduct material already exists. Therefore, while the Standard Review Plan (SRP) addresses corrective action and compliance monitoring, it does not deal with detection monitoring. Where elements of NUREG-1620 do apply, the NRC staff used them to prepare this section of the SER.

5.2 Site Characterization

5.2.1 Site History

Appendix D ("Site Characterization Report," January 2008) of the RP contains detailed site history information, as recommended in the SRP. Section 2.0 of Appendix D contains site and licensing history. Section 4.0 of Appendix D, and Section 2.0 of Appendix B ("Hydrogeological and Geochemical Site Characterization Report" (MFG, 2002) contain descriptions of chemicals used in site activities and the resulting wastes. These sections also describe environmental impacts associated with various onsite processes and structures. Section 2.2 of the RP main text describes surrounding land use and briefly describes the expected impacts of the proposed plan on adjacent land uses.

Section 3.4.1 of Appendix D of the RP describes surrounding water uses. The Robert S. Kerr Reservoir system is used for recreation, navigation, and irrigation. Ground water uses include livestock and residential ground water users within 2 miles (mi) of the site to the north, east, and south. No ground water users exist between the site and the Arkansas and Illinois Rivers. Section 3.2 of Appendix D of the RP presents meteorological data, which include information on temperature, precipitation, hail storms, tornadoes, evaporation, and wind patterns.

5.2.2 Geology, Hydrogeology, and Surface Water

Section 3.3 of Appendix D of the RP describes geology 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. 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 RP 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 of 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 (ft) 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 (upgradient) 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. 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 of the RP.

This survey identified a total of 37 wells, 10 of which were on properties owned by SFC. 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: terrace, alluvial, shallow, and deep bedrock ground water systems. The terrace ground water system is the uppermost regime and contains the terrace deposits and the Unit 1 Shale. Depth to ground water varies from 8 to 11 ft; however, a few unsaturated zones exist in this system near the Solvent Extraction (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 of the RP). 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} centimeters per second (cm/s). Such 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 is the only significant fresh water aquifer at the facility. Yields from the alluvial ground water system vary from 10 to 900 gpm; however, the water is hard to very hard, which makes 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 in Appendix B of the RP, 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 in Appendix D of the RP, which states that the terrace ground water system is not in hydraulic connection with the shallow ground water system. SFC provided the locations of the known borings and agreed to plug any boring discovered during cell base excavation. However, even if no borings are found, the quantity of potential seepage migrating vertically is quite small and is not expected to impact the water quality of deeper aquifers as the vertical impact is limited by an almost impervious sandstone layer. Furthermore, these borings will be located below the future disposal cell, which by the nature of its construction, will direct groundwater away from the area in which these borings are located. Also, the clay liner will essentially seal the borings. The combination of these factors will minimize the quantity of water that is capable of reaching these borings.

The shallow system comprises interbedded shale and sandstone identified as Unit 2 Shale, Unit 2 Sandstone, Unit 3 Shale, Unit 3 Sandstone, and Unit 4 Shale. Depths to the top of this system (Unit 2 Shale) are 10 to 40 ft depending on 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 (Figure 18 in Appendix D of the RP). 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 less than 9×10^{-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, which 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 ft. Ground water in the deep system flows from east to west (Figure 19 in Appendix D of the RP). The mean horizontal hydraulic conductivity in the deep system is 3×10^{-6} cm/s.

5.2.2.3 Surface Water Hydrology

In Section 3.5 of Appendix D of the RP, SFC discusses surface water hydrology and, in Section 2.3.2 of the main text of the RP, describes 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), eight small artificial farm ponds, six ephemeral onsite streams, Creek A (southern part of site), Salt Branch (to the north), and the northeast-flowing tributary of Salt Branch (to the east). The Tenkiller Ferry Reservoir dam controls discharges to the Illinois River; average discharge is approximately 1,600 cubic feet per second (cfs). Section 4 of this SER contains 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). Appendix D of the RP summarizes the results of these investigations and adequately describes 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 RP which depict ground water contamination in different saturated zones. Also, Appendix B of the RP 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 of Appendix D of the RP presents contamination assessments for uranium, nitrates, and fluoride, which are listed as constituents of concern (COCs) in Appendix D. However, Section 5.7 of Appendix B of the RP also lists arsenic as a COC.

SFC has not provided a comprehensive list of COCs in the RP. However, all the COCs discussed in Appendices B and D appear on the list of analytical parameters for the detection monitoring program found in Attachment E of the RP. The lack of a COC list does not affect the NRC staff's ability to approve the RP.

Total uranium continues to be detected above the SFC environmental action level (EAL) of 150 picocuries per liter (pCi/L) in the terrace and shallow bedrock ground water systems. Uranium above the EAL has not been detected 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 SX Building in well MW025. According to SFC, the concentration in this well appears to have increased as the result of 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 RP presents uranium concentrations in the terrace system.

Uranium in the shallow system varies in concentration from 0.7 pCi/L 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 RP presents uranium concentrations in the shallow system.

Nitrates continue to be detected above the U.S. Environmental Protection Agency maximum contaminant level (MCL) of 10 milligrams per liter (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 vary from less than 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 RP presents nitrate concentrations in the terrace system.

Nitrate concentrations in the shallow system vary from 0.8 mg/L 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. SFC's data indicate 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 RP 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 MCL of 4.0 mg/L in the terrace and shallow systems. Fluoride has not been detected in the deep system. Figure 44 in Appendix D of the RP presents nitrate concentrations in the terrace system.

Fluoride concentrations in the terrace system vary from less than 0.3 mg/L to 8.5 mg/L. The high concentration occurred north of the MPB, and the MCL has also been exceeded northeast of the SX Building. Fluoride concentrations in the shallow system vary from less than 0.2 mg/L to 4.7 mg/L, with the high fluoride concentration occurring west of Pond 2. It should be noted that Section 4.5.6 of Appendix D of the RP states that this high concentration occurs west of the Emergency Basin; however, a review of Figure 4 in this appendix indicates that it is actually west of Pond 2. Figure 45 in Appendix D of the RP presents fluoride concentrations in the shallow system.

5.2.3.2 Geochemical Conditions

Appendix B of the RP 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

Section 4.1 of Appendix D of the RP and the Ground Water Monitoring Plan (SFC, 2005) include a presentation of background water quality. 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 Ground Water Monitoring Plan regarding the actual analytical parameters. The Ground Water 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 this discrepancy, it appears that background samples were analyzed for all constituents of concern, and subsequent statistical analyses appear appropriate. Table 5-1 summarizes background water quality data provided in Appendix D and the Ground Water Monitoring Plan (arsenic only).

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. Arsenic data are incorporated by reference in Section 7.4 of the RP, Attachment E.

5.2.5 Evaluation Findings

The NRC staff has completed its review of the site characterization at the SFC, Gore, OK, 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 NUREG-1620 (NRC, 2003).

Based on the information provided by SFC, the NRC staff concludes the site history and geology discussions of the RP are sufficient to meet the requirements of Title 10, Part 40, “Domestic Licensing of Source Material,” of the *Code of Federal Regulations* (10 CFR Part 40), Appendix A, “Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content,” Criterion 5G. SFC’s discussion of site hydrogeology appears comprehensive and adequately represents the hydrogeologic regime at the site. Regarding water quality, SFC does not present a single comprehensive list of COCs. Instead, COCs are listed in multiple places, which causes confusion. As previously stated, this does not affect the NRC staff’s ability to approve the RP.

5.3 Disposal Cell Design

The 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. The NRC staff based this review on Section 4.4 of NUREG-1620.. 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 water available for infiltration into the cell. The cell cover is a multilayered system consisting of the following layers from top to bottom:

- vegetation
- topsoil—0.75 ft thick
- rock mulch—0.75 ft thick
- subsoil—5 ft thick
- liner cover material—1.5 ft thick (see Section 5.3.2)
- synthetic liner
- compacted clay liner—2 ft thick

To fulfill the store/deplete function, meteoric water would run off or infiltrate the topsoil and rock mulch before 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, of Attachment A of the RP, specifies native grass species for revegetation and states that no trees will be allowed to grow on the cover.

The cover may not 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. For example, areas receiving more than 40 inches of rain annually generate too much infiltrating water to be removed by store/deplete covers. However, higher evaporation rates in Oklahoma may facilitate the store/deplete functionality. Regardless of whether the store/deplete aspects of the cover function properly, the cell contents would remain adequately protected because of the use of a compacted clay liner below the synthetic liner. Research indicates that such liner systems are effective at minimizing seepage because the synthetic liner maintains a sufficient moisture content in the compacted clay to prevent cracking.

5.3.2 Liner Cover Material

Liner material is a component of the disposal cell cover described in Section 5.3.1 of this SER. 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. 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.

SFC provided the following grain size distribution data for the liner bedding cover material in the technical specifications of the RP:

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

SFC evaluated the filtering capabilities of these liner materials using procedures found in the *National Engineering Handbook* (USDA, 1994). These procedures assess whether filter components are appropriately sized to be more permeable than the soil and prevent clogging. The NRC staff reviewed the licensee's filter computations and determined that the filter is appropriately designed.

5.3.3 Disposal Cell Liner

Criterion 5 of Appendix A of 10 CFR Part 40 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 ft thick
- synthetic liner
- liner bedding material—0.5 ft thick
- clay liner—3.0 ft thick

The liner cover material is the same material as that described in Section 5.3.2 of this SER. Within the liner system, the liner cover material serves to protect the underlying synthetic liner from 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 which 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 appear to provide grain size data for these materials; therefore, it is not clear whether the liner cover material will become clogged. If the liner cover material were to clog, the leachate collection piping would not function properly. However, ground water below the cell would still be protected by the synthetic liner, leak detection system, and clay liner underlying the leachate collection system.

As described in Attachments A and E of the RP, the synthetic liner consists of textured 60-mil-thick, high-density polyethylene. This liner will serve as a hydraulic barrier between the waste and the clay liner and prevent dissolved hazardous constituents from accumulating above the clay liner. Synthetic liners are effective hydraulic barriers; however, insufficient data exist to demonstrate that the liners would retain structural integrity for the entire 1,000-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 Part 40, Appendix A.

Liner bedding material is composed of the same material as the liner cover material described in Section 5.3.2 of this SER and will function as a drainage layer for the leak detection system under the synthetic liner. This system is required by 10 CFR Part 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-ft-thick layer of clayey soils from approved onsite borrow areas as described in Attachment A of the RP. 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 plugging of the liner cover material could impact the performance of the leachate collection system, such a condition would not directly affect the ability of the liner to contain seepage. Furthermore, although the synthetic liner may not remain effective for the entire 1,000-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, SX Building, the western half of the MPB, 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 is 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 before 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 remove 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 the waste portion of the cell.

5.4 Detection Monitoring

5.4.1 Detection Monitoring Network

SFC has proposed a detection monitoring network that consists of six monitoring wells, one upgradient and five 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 provides adequate coverage along the perimeter of the cell.

5.4.2 Monitoring Well Construction

SFC provided monitoring well construction specifications for the point of compliance wells by reference to the Ground Water Monitoring Plan, which contains that information. 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 ft to 20 ft 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.

The detection monitoring system will monitor the terrace ground water system. The detection monitoring plan does not include deeper aquifers because the amount of seepage that could enter deeper systems after cell construction is expected to be negligible. Furthermore, contamination in the terrace ground water system would be detected before any contamination would be detected in the deeper units. The staff concurs with this assessment and therefore considers the detection monitoring network acceptable.

5.4.3 Parameters and Sampling Frequency

Attachment E of the RP 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, and uranium (natural). The parameters list and frequency are acceptable for the purpose of detection monitoring at this site.

5.4.4 Leak Detection

In Appendix A to 10 CFR Part 40, 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. In 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 Criterion 7A of Appendix A.

As stated in Section 5.2.2.2 of this SER, SFC identified borings that could be conduits to aquifers below the terrace ground water system. However, SFC has committed to plugging any conduits identified during the foundation excavation phase of cell construction. If none are identified, the risk of channeling contamination to lower aquifers is minimal; the cell would first need to leak, then contamination would need to enter a conduit. Considering that the combined surface area of the conduits is orders of magnitude smaller than that of the cell foundation, the likelihood of such an occurrence is small. Therefore, SFC's commitment to locating and plugging any conduits sufficiently addresses this 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 concludes that the proposed detection monitoring network is sufficient to detect potential ground water contamination from all locations under the cell.

References

MFG, Inc., 2002, “Hydrogeological and Geochemical Site Characterization Report,” October 2002.

Sequoyah Fuels Corporation (SFC), 2008, “Reclamation Plan, Sequoyah Facility, Sequoyah Fuels Corporation, Gore Oklahoma,” January 4, 2008.

Sequoyah Fuels Corporation, 2003, “Site Characterization Report, Sequoyah Fuels Corporation, Gore Oklahoma,” January 2003.

Sequoyah Fuels Corporation, 2005, “Groundwater Monitoring Plan, Sequoyah Facility,” February 2005.

Sequoyah Fuels Corporation, 1992, “Addendum, Facility Environmental Investigation Findings Report,” May 21, 1992.

Sequoyah Fuels Corporation, 1991, “Facility Environmental Investigation Findings Report,” July 31, 1991.

U.S. Department of Agriculture, National Engineering Handbook, 1994

U.S. Nuclear Regulatory Commission (NRC), 2003, “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, Rev. 1, June 2003.

6. RADIATION PROTECTION

6.1 Introduction

The RP 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 Title 10, Part 40, “Domestic Licensing of Source Material,” of the *Code of Federal Regulations* (10 CFR Part 40). The RP also addresses the health and safety aspects of site decommissioning. NRC staff reviewed the radiation protection portions of the RP following the guidance in NUREG-1620, Revision 1, “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, Section 5).

6.2 Cover Radon and Gamma Attenuation and Radioactivity Content

Criterion 6(1) of Appendix A, “Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content,” to 10 CFR Part 40 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 (ft) of clay, synthetic liner, 1.5 ft of liner cover (sand), 5 ft of subsoil, and 1.5 ft of 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

Criterion 6(1) of Appendix A to 10 CFR Part 40 requires that a disposal cell design limit releases of radon-222 from uranium byproduct materials to a level not to exceed an average (over at least a year) release rate of 20 picocuries per square meter per second ($pCi/m^2/s$) from the surface of the cell for 1,000 years, to the extent reasonably achievable, but at least for 200 years. Because radon-222, the daughter of radium-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 for the radon to decay to its solid daughter which 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, “Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers”(NRC, 1989)) 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 emplaced. 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 the NRC in a separate document, within the timeframe 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 NRC staff also reviewed the sampling and testing methods for the materials to determine their appropriateness and to ensure that the resulting data would be adequate.

The licensee indicated 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, layer A is composed of raffinate sludge and Pond 2 residue.

Because site soil thorium-230 levels are generally much higher than the levels of radium-226, accounting for the in-growth of radium-226 from its parent, thorium-230, provides a higher value at the 1,000-year design period, than the current radium-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 1,000-year radium-226 value for the source term. Typically, the important radium-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 radium-226, or thorium-230 in this case, need to be modeled. For Area I, SCF used a radium-226 level of 74.3 picocuries per gram (pCi/g) for the upper 14 ft of contaminated material, but 77 percent of the material had only estimated radium-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 for the clay value which was based on compaction specifications. Porosity values were calculated assuming that 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 calculated flux values reported for the other three cell areas were lower, and the staff did not model them.

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, which 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 1,000-year radium-226 value for the upper 15 ft of contaminated material, which had only a few valid sample results. The staff needed to review adequate and representative sample data to assess the degree of uncertainty and determine the adequacy of the radium-226 values used. By letter dated September 19, 2005, the staff asked SFC to submit a sampling plan to provide data to justify the source term values used for the upper 15 ft of contaminated material in the radon flux calculations. If the data indicate that 1,000-year radium-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.

SFC provided a sampling plan for obtaining data to justify the radium-226 source term values for the upper 15 ft of contaminated material in the radon flux calculations (SFC, 2006). For layers A and C, the sampling plan identified a sufficient number of archived samples that will be analyzed for radium-226. For layer B, characterization samples will be obtained during remediation activities and analyzed for radium-226. The staff finds the sampling plan adequate for justifying the source term values used for the upper 15 ft of contaminated material.

SFC will use the samples obtained during remediation and final status surveys to demonstrate to the NRC staff that the long-term radon flux will meet the criterion. Demonstrating that the long-term radon flux will meet the criterion will be a license condition that will require NRC approval before the installation of the radon barrier.

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 radium-226 in the upper contaminated layers.

6.2.3 Cover Radioactivity Content

In Section 5.13 of the RP, SFC stated that the borrow area soils in the cover were radiologically similar to native soils in the site area. SFC provided borrow material data demonstrating that the soil layers have radioactive levels consistent with natural background levels of native soil when compared with the background soil sample locations shown in Figure 21 of Appendix D, Volume II, of the RP.

The sources of the borrow material for the construction of the disposal cell cover and liner system will be the following site locations: the soil area south of the fertilizer ponds, the tornado berm, the cut area east of the DUF_4 building, uncontaminated portions of the settling pond (Pond 2) berms, and the fertilizer pond berms. In addition, the Agland area has been selected as the borrow area where topsoil will be obtained for finishing the cell cover.

The staff concludes that the SFC borrow cover plan is adequate.

6.2.4 Evaluation Findings

The demonstration that the radiological criteria for the cover will be met is adequate, with the incorporation of the following license condition:

> The licensee shall submit a written request for NRC approval prior to the installation of the Radon Barrier. The licensee will use data obtained from the upper 15 feet of contaminated material placed in the cell to demonstrate that the long-term radon flux will meet the requirement of 10 CFR Part 40, Appendix A Criterion 6(1).

6.3 Decommissioning Plan

The RP sections concerning decommissioning of land and buildings must address the regulations in 10 CFR Part 40. Criterion 6(6) in Appendix A requires soil cleanup to meet specific radiological criteria, and Criterion 6(7) requires prevention of threats to human health and the environment from nonradiological hazards associated with the wastes. Other sections of 10 CFR Part 40 require submission of a decommissioning plan addressing proposed activities and describing how reasonable effort will be made to eliminate residual radioactive contamination (10 CFR 40.42, “Expiration and Termination of Licenses and Decommissioning of Sites and Separate Buildings or Outdoor Areas”). The licensee also must specify the location of records of information important to decommissioning (10 CFR 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 RP, areas will be better characterized during decommissioning, and the currently inaccessible areas will be adequately surveyed and sampled (Class 1 and 2 surveys). The final status survey report must include these data.

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. The averages of 14 background sample results were radium-226, 1.0 pCi/g; thorium-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 radium-226 in soil must meet the concentration limits in 10 CFR Part 40, Appendix A, Criterion 6(6) of 5 pCi/g above background in the top 6 inches (15 centimeters) 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 10 CFR Part 40, Appendix A (i.e., Section 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 thorium-230). This requirement therefore applies to SFC. The requirement is that the total dose from radium-226 and the other radionuclides present should not exceed the dose that would result if the soil were contaminated with radium-226 at the maximum allowable concentration.

The SFC dose modeling, which appears in Appendix G to the RP, used the resident farmer scenario to represent the critical group. This selection was supported by data on farm type and size for the county. The modeling results indicate a radium benchmark dose of 34 millirem per year (mrem/yr). This dose corresponds to soil concentrations of 140 pCi/g thorium-230 and 460 pCi/g U-nat. Considering the NRC guidance in NUREG-1620, SFC chose surface cleanup levels of 14 pCi/g for thorium-230 and 100 pCi/g for U-nat. As the cleanup values chosen by the licensee are below the levels required by Criteria 6 of 10 CFR 40, Appendix A, the NRC staff concludes that cleanup to these levels will be protective of public health and safety. A subsurface soil thorium-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 ft 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 1 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 the U.S. Department of Energy for perpetual custodial care. Therefore, human exposure to the residual radionuclides in soil would be very limited. The NRC staff concludes that the proposed radiological criteria for soil cleanup meet the requirements of Criterion 6 of Appendix A to 10 CFR Part 40 and are acceptable.

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, SFC proposed no criteria for structure surface cleanup.

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 has proposed to measure gamma radiation and correlate that to radionuclide concentration (as most other licensees have done).

The gamma-radium correlation is used to determine a gamma guideline value to use in a gamma survey (scan) that represents the radium-226 cleanup limit. In Attachment B of the RP, the licensee indicated the general approach for the gamma-radium correlation for collecting the data and developing the gamma guideline value. In Attachment B, Section 2.5.4, the licensee has committed to developing the gamma guideline value for radium-thorium areas in accordance with NUREG-1620 when the footprints of the Pond 1 Spoils Pile, Clarifier A Basin, and Pond 2 become accessible during the remediation. If SFC determines that it will use a gamma guideline as stated in Attachment B, Section 3.5.4, then the correlation must provide a 95-percent level of confidence that the grid (survey unit) meets the criterion. The NRC staff must approve the correlation graph and gamma guideline level and the degree of its use (maximum percent of grids, areas). SFC must also include the percentage and method of using gamma measurements in place of radium-226 analysis based on the reliability of the gamma-radium correlation for NRC approval. 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 radium-226 analysis. If, as it suggested in Attachment B, Section 3.5.4, SFC plans to develop a gamma measurement threshold for uranium and radium-226 to thorium-230 correlation to reduce the number of thorium-230 soil analyses, the staff must also review this correlation before its implementation and before soil decommissioning is completed to avoid additional work being required after submittal of the final status survey report.

The commitment in Attachment B to develop the gamma guidelines, if SFC decides to use it for uranium and radium-thorium in accordance with NUREG-1620, is a license condition that will require NRC approval before implementation.

6.3.5 Instruments and Procedures

Attachment B of the RP 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. Attachment C, Section 4, of the RP addresses measuring and testing equipment. 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 the NRC to approve the final status survey report as meeting applicable standards. In Attachment B of the RP, SFC makes the following statements and commitments:

- In Section 1.0, SFC has committed to designing and performing final status surveys in accordance with NUREG-1575, “Multi-Agency Radiation Survey and Site investigation Manual” (MARSSIM) (NRC, 2000), or 10 CFR Part 40, Appendix A, Criterion 6.

- In Section 2.0, Survey Design, SFC states that the survey designs will be developed in accordance with the data quality objectives using the guidance provided in Appendix D of MARSSIM.

- In Section 2.5, Survey Techniques, SFC provides a general description of the performance of both structural and soil gamma surveys.

- In Section 2.5.3, SFC summarizes appropriate procedures for general soil sampling, collection, and handling (e.g., chain of custody).

- In Section 3.5, SFC proposes an acceptable number of sample data points and the method for compositing and preparing thorium-radium soil samples for radium-226 analysis.

The data quality objective process for survey design and application to survey and sampling procedures, and their implementation, will be inspected before and during decommissioning. During final status survey implementation, the inspection will focus on the survey and sampling performance (detection and reliability of survey data) and methodologies (human performance) that establish the speed and spacing of readings of measurements and scanning. The inspections will also focus on the quality assurance project plan (QAPP), specifically on the management oversight of field personnel and the field performance of measurements for providing reliable survey data.

The soil sampling procedures and analytical methods used in 1994 for site characterization were provided as the soil sampling quality assurance plan. This information will be incorporated into the QAPP as described in Section 6.3.6 of this SER.

6.3.6 Quality Assurance and Quality Control

SFC's RP refers to a data management plan but provides no information on its contents or any reference to its being reviewed by the NRC. Also, Attachment B, Section 4, of the RP indicates that SFC will develop a QAPP. SFC states that this procedure will address survey planning and implementation, results evaluation, data assessment, verification, validation, and data quality assurance but does not provide adequate details. In addition, SFC stated that the QAPP will describe oversight and quality assurance (QA) for the final status surveys. However, the RP does not describe the Data Management Plan and QAPP in adequate detail. Therefore, a license condition will be added requiring the licensee to develop a QAPP prior to the initiation of remediation activities that incorporates the Data Management Plan, oversight and QA, soil sampling quality assurance, and the final status survey. The NRC will review the implementation of the QAPP during inspections.

Attachment C of the RP adequately discusses staff qualifications and training, the Audit and Surveillance Program, corrective actions, and QA records.

6.3.7 Final Status Survey Plan

In response to an NRC request, the licensee provided additional information (SFC, 2005b) regarding the final status survey plan, which is described in Attachment B of the RP. 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 follow the guidance in NUREG-1575 and summarized the procedures. 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. The implementation of this guidance will be inspected during decommissioning.

The survey plan includes an adequate analytical program. However, SFC did not indicate the proposed number and pattern of grids to be soil sampled and analyzed for radium-226. SFC stated that gamma measurements may be substituted for some soil samples but provided no details (see the discussion in Section 6.3.4).

In Attachment B to the RP, SFC proposes, for Class Thorium-Radium Survey units, that at least 30 composite soil samples will be collected. At each soil sample location, soil plugs will be collected from five evenly spaced locations and composited for analysis for radium-226 and thorium-230. This sampling method is consistent with NUREG-1620, Section 5.2.2 (5), and should provide adequate data to develop the gamma-radium correlation and representative verification data. For uranium survey units, SFC has committed to MARSSIM (NUREG-1575), Section 5.5.2.2, for determining the number of soil samples and locations, which is acceptable. Procedures implementing the MARSSIM guidance will be inspected during decommissioning.

SFC committed to tracking soil samples that fail the radium-226 criteria, and to perform additional cleanup if a verification soil sample exceeds the radium-226 standard. SFC also committed to 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

In Section 1.4 of the RP, SFC has identified the Administration Building at the SFC facility for the retention of records of information important to decommissioning, as required by 10 CFR 40.36(f). 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 to the RP address the requirements of 10 CFR 40.42(g)(4) for the health and safety of workers, the public, and the environment.

6.3.9 Nonradiological Hazardous Constituents

To demonstrate compliance with 10 CFR Part 40, Appendix A, Criterion 6(7), SFC addressed nonradiological hazardous constituents of the byproduct material in the Draft Corrective Actions Report (CMS), dated October 27, 1997. In the CMS report, Section 2.5 and Tables 1 and 2 summarize source and soil sampling results. Treatability studies, including conducting the toxicity characteristic leaching procedure (TCLP) extraction of sludges, were performed, as well as metal analyses. Subsequent to the TCLP extraction, the results indicated that the raffinate and calcium fluoride are not characteristically hazardous. In the CMS, SFC committed to evaluating buried solid waste and calcium fluoride sludge, which are potential source media, when exhumed. In CMS Sections 2.5, 2.6, and 2.7, as referenced in the Resources Conservation and Recovery Act (RCRA) Facility Investigation Report, SFC identified antimony, beryllium, lead, nickel, selenium, and thallium as constituents of concern in source, soil, and ground water. The staff finds this acceptable.

6.3.10 Evaluation Findings

The staff has determined that the RP, in combination with the following license conditions, meets the requirements of Criterion 6(6) of Appendix A to 10 CFR Part 40 and 10 CFR 40.42(k)(2):

(1) The licensee shall submit a written request for NRC approval of gamma guideline values prior to use in verification of soil cleanup. The licensee will provide the gamma-radium correlation graph and indicate the gamma guideline value and its use. The licensee will also provide the Ra-226 to Th-230 correlation for NRC approval, if it plans to use it.

(2) The licensee shall submit a written request for NRC approval of the Data Management Plan, oversight and QA, soil sampling quality assurance, final status survey, and their incorporation into the quality assurance project procedure (QAPP) prior to the initiation of remediation activities. Implementation of the QAPP will be reviewed during inspections.

6.4 Radiation Safety Controls and Monitoring

SFC already has site procedures in place to meet the radiation control and monitoring requirements of 10 CFR Part 20, “Standards for Protection Against Radiation” (10 CFR 20.1101, “Radiation Protection Programs,” and 20.2102, “Records of Radiation Protection Programs”).

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) 040-08027/08-001, dated March 20, 2008) (NRC, 2008), 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 in Regulatory Guides 8.22, “Bioassay at Uranium Recovery Facilities” (NRC, 1988); 8.30, “Health Physics Surveys in Uranium Recovery Facilities” (NRC, 2002a); and 8.31, “Information Relevant to Ensuring that Occupational Radiation Exposure at Uranium Recovery Facilities Will Be as Low as Reasonably Achievable (ALARA)” (NRC, 2002b); or an NRC-approved equivalent. Additionally, health physics procedures are reviewed during inspections.

SFC’s “Radiation Safety Program During Decommissioning and Reclamation” (Attachment D to the RP) 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 micrograms per gram (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 RP 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 RP) provides an acceptable program of radiation safety controls and monitoring to protect worker and public health and safety.

References

Sequoyah Fuels Corporation (SFC), 2006, "Sequoyah Fuels Corporation, Docket 40-8027. Response to Draft Safety Evaluation Report—Reclamation Plan (TAC L52511)," Gore, OK, January 31, 2006. Agencywide Documents Access and Management System (ADAMS) Accession No. ML060370532.

______, 2005a, "Sequoyah Fuels Corporation, Docket 40-8027. Response to Request for Additional Information—Reclamation Plan, Radiation Protection and Erosion Protection (TAC L52528)," Gore, OK January 24, 2005. ADAMS Accession No. ML050420033.

______, 2005b, "Sequoyah Fuels Corporation, Docket 40-8027. Response to Request for Additional Information—Reclamation Plan, Radiation Protection and Erosion Protection (TAC L52528)," Gore, OK, March 30, 2005. ADAMS Accession No. ML050970438.

______, 2005c, "Reclamation Plan Review, Request for Additional Information, Radiation Protection and Erosion Protection, RP1 A-RP1 D," Gore, OK, April 2005. ADAMS Accession No. ML051250468.

U.S. Nuclear Regulatory Commission (NRC), 1988, Regulatory Guide 8.22, "Bioassay at Uranium Recovery Facilities," August 1988.

______, 1989, Regulatory Guide 3.64, "Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers," June 1989.

______, 2000, NUREG-1575, Rev. 1, "Multi-Agency Radiation Survey and Site Investigation Manual," August 2000.

______, 2002a, Regulatory Guide 8.30, Rev. 1, "Health Physics Surveys in Uranium Recovery Facilities," May 2002.

______, 2002b, Regulatory Guide 8.31, Rev. 1, "Information Relevant to Ensuring That Occupational Radiation Exposure at Uranium Recovery Facilities Will Be as Low as Reasonably Achievable (ALARA)," May 2002.

______, 2003, NUREG-1620, Rev. 1, "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," June 2003.

______, 2008, NRC Inspection Report 040-08027/08-001, March 20, 2008. ADAMS Accession No. ML080800408.

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

7.1 Background

On July 25, 2002, in Staff Requirements Memorandum (SRM)-02-0095, "Applicability of Section 11e.(2) of the Atomic Energy Act to Material at the Sequoyah Fuels Corporation Uranium Conversion Facility," the Commission determined that most of the waste material at the SFC site can be classified as Section 11e.(2) byproduct material. The Commission reaffirmed that decision on November 13, 2003 (CLI 03-15) in response to a challenge from the State of Oklahoma. Wastes classified as 11e.(2) byproduct material must be remediated in accordance with Title 10, Part 40, "Domestic Licensing of Source Material," of the *Code of Federal Regulations* (10 CFR Part 40), Appendix A, "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content." 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, the U.S. Department of Energy 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 on site in accordance with 10 CFR Part 20, "Standards for Protection Against Radiation," or sent off site to be disposed of in a facility licensed under 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," to accept and dispose of low-level waste.

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

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 RP identifies the current location on the site of various non-11e.(2) wastes.

The licensee stated the following:

> 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.

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.

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.

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.

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.

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.

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.

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 for the 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 met the criterion or why the criterion is not applicable. The 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, as it states that the staff should license disposal (receipt is not an issue, as SFC has not requested permission to receive non-11e.(2) byproduct material from off site) 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, thorium-230, and radium-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.

> *Criterion 2* *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 has 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.

> *Criterion 3* *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 the 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 Oklahoma Department of Environmental Quality (DEQ) wrote to the NRC on this matter in May 2006, at SFC's request (DEQ, 2006). DEQ stated that it had authority to regulate hazardous waste under the Resources Conservation and Recovery Act (RCRA). Based on its review of information and tests provided by SFC, DEQ concluded that the non-11e.(2) byproduct material was not hazardous waste and that DEQ was not, therefore, asserting jurisdiction over that waste under its RCRA authority. The staff therefore concludes that Criterion 3 has been met.

> _Criterion 4_ *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 the 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.

> _Criterion 5_ *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 SFC's proposed RP 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.

> _Criterion 6_ *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.

> _Criterion 7_ *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 to the 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) byproduct material. In August 2006, the NRC wrote to DOE, requesting that commitment. In January 2007, DOE replied to the NRC, stating that it was prepared to accept the cell with the non-11e.(2) byproduct material (DOE, 2007). The staff therefore concludes that Criterion 7 has been met.

> Criterion 8 *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 RP includes a request to dispose of the non-11e.(2) byproduct material. If the staff approves SFC's RP, it will amend SFC's license (Materials License SUB-1010) to authorize SFC to implement its RP. Included in that authorization will be the authorization to dispose of the non-11e.(2) byproduct material.

An exemption from 10 CFR 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 does not apply 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

Using the guidance in RIS 2000-23, the staff has reviewed the information presented by the licensee. Based on its review, the staff concludes that all eight criteria in the guidance have either been met or are not applicable.

References

Oklahoma Department of Environmental Quality (DEQ), 2006, Letter from S. Thompson to M. Fliegel, "Disposal of Non-11e.(2) Byproduct Materials (Non-hazardous Calcium Fluoride Sludge) On-site at Sequoyah Fuels Corporation (SFC) Site, Gore, Oklahoma." May 24, 2006. Agencywide Documents Access and Management System (ADAMS) Accession No. ML061530367.

U.S. Department of Energy (DOE, 2007, Letter from M. Owen to R. Pierson, January 11, 2007. ADAMS Accession No. ML070260084.

U.S. Nuclear Regulatory Commission, 2000, Regulatory Issue Summary 2000-23, "Recent Changes to Uranium Recovery Policy," November 30, 2000. ADAMS Accession No. ML003773008.

U.S. Nuclear Regulatory Commission, 2006, Letter from R. Pierson to M. Owen, "Non-11e.(2) Byproduct Material at the Sequoyah Fuels Corporation Site," August 14, 2006. ADAMS Accession No. ML062060103.

LIST OF PRINCIPAL REVIEWERS

Chapter 1	Myron Fliegel, NRC/FSME/DWMEP/DURLD
Chapter 2	Phil Justus, NRC/NMSS/DHLWRS
	Abou-Bakr Ibrahim, NRC/NMSS/DWM
Chapter 3	Goodluck Ofoegbu, CNWRA
Chapter 4	Robert Johnson, NRC/FSME/DWMEP/DURLD
Chapter 5	Stephen Cohen, NRC/FSME/DWMEP/DURLD
Chapter 6	Bruce Watson, NRC/FSME/DWMEP/DURLD
	John Lusher, NRC/NMSS/FCSS
`	Elaine Brummett NRC/NMSS/FCSS
Chapter 7	Myron Fliegel, NRC/FSME/DWMEP/DURLD
Project Management	Myron Fliegel, NRC/FSME/DWMEP/DURLD
	Ken Kalman, NRC/FSME/DWMEP/DURLD