



July 31, 1991

Charles J. Haughney, Chief
Fuel Cycle Safety Branch
Division of Industrial and
Medical Nuclear Safety, NMSS
U.S. NUCLEAR REGULATORY COMMISSION
11555 Rockville Pike
Rockville, Maryland 20852

RE: License No. SUB-1010; Docket No. 40-8027
Facility Environmental Investigation

Dear Mr. Haughney:

Please find enclosed twelve (12) copies of "Sequoyah Fuels Corporation Facility Environmental Investigation Findings Report," Volumes I through V, dated July 31, 1991. Although the attached investigation is complete in accordance with the original scope of the Facility Environmental Investigation Plan (October, 1990), some related investigations are in progress or planned. It is likely that a revision to this report will be issued at a later date to address these related investigations.

Should you have any questions concerning this report, you may contact me at 918/489-3207.

Sincerely,

Lee R. Lacey
Vice President
Regulatory Affairs

LRL:nv

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- Gary Konwinski, NRC-URFO (1)
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change: LA

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SEQUOYAH FUELS CORPORATION
FACILITY ENVIRONMENTAL INVESTIGATION
FINDINGS REPORT
VOLUME I

Prepared by

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July 31, 1991

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LIST OF ACRONYMS

AEC	Atomic Energy Commission
AHF	Anhydrous Hydrofluoric Acid
ALARA	As Low As Reasonably Achievable
AMSL	Above Mean Sea Level
ASCS	Agricultural Stabilization and Conservation Service
BH	Borehole
CD	Combination Stream Drain
CFR	Code of Federal Regulations
CME	Colorado Mining Equipment
CWE	Cooling Water Emergency
CWS	Cooling Water Supply
CWSR	Cooling Water Supply Return
DUF ₄	Depleted Uranium Tetrafluoride
EAL	Environmental Action Level
EM	Electromagnetic
EPA	Environmental Protection Agency
F ₂	Fluorine Gas
FEI	Facility Environmental Investigation
FES	Final Environmental Statement
GC/MS	Gas Chromatograph/Mass Spectrophotometer
HA	Hand Auger
HF	Hydrogen Fluoride
HNO ₃	Nitric Acid
H ₂ SO ₄	Sulfuric Acid
IAP	Ion-Activity Products

LIST OF ACRONYMS

CONTINUED

MCL	Maximum Contaminant Level
MPB	Main Process Building
MPC	Maximum Permissible Concentration
MW	Monitor Well
NH ₃	Ammonia
NO _x	Nitrous Oxides
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
OML	Order Modifying License
OSDH	Oklahoma State Department of Health
OVM	Organic Vapor Monitor
OWRB	Oklahoma Water Resources Board
RAB	Restricted Area Boundary
RSA	Roberts/Schornick & Associates, Inc.
RW	Recovery Well
SAIC	Science Applications International Corporation
SFC	Sequoyah Fuels Corporation
SI	Saturation Index
SX	Solvent Extraction
TM	Trench Monitor
UF ₄	Uranium Tetrafluoride

LIST OF ACRONYMS

CONTINUED

UF ₆	Uranium Hexafluoride
UNH	Uranyl Nitrate Hexahydrate
UO ₂	Uranium Dioxide
UO ₃	Uranium Trioxide

EXECUTIVE SUMMARY

On August 22, 1990, the Sequoyah Fuels Corporation (SFC) notified the Nuclear Regulatory Commission (NRC) that licensed material (i.e. uranium) had been encountered in soils during excavation work on two (2) underground storage tanks adjacent to and just north of the Solvent Extraction (SX) Building within the restricted area boundary. An inspection of this discovery and related activities was initiated by the NRC on August 23, 1990. Concurrent with its notification of NRC, SFC was planning activities to begin an initial characterization of the SX Building and environs.

Subsequently, on August 27, 1990, SFC began a borehole investigation of potential releases of licensed material in the SX Building area using a drilling rig which was located and brought on site for that purpose. On September 4, 1990, SFC retained and directed Roberts/Schornick and Associates, Inc. (RSA) of Norman, Oklahoma, an environmental consulting firm, to assist SFC with ongoing environmental investigations and responses in the SX Building area and to initiate an investigation of the nearby Main Process Building and environs. SFC's response action objectives were to adequately characterize the quantity and location of licensed material in the subsurface soils in the SX Building area and identify all potential pathways that could contribute to migration of licensed material away from the SX Building. In addition, SFC implemented mitigation activities to prevent further releases and migration of licensed material to the environment.

SFC prepared several milestone reports documenting the specific response activities and findings beginning with an initial status summary report on September 9, 1990 and later with the Final Findings Report on February 1, 1990. Investigation and mitigation activities continued in the SX Building area within the context of a comprehensive Sequoyah Facility Environmental Investigation (FEI).

On September 4, 1990, SFC directed RSA to also begin an environmental investigation of the Main Process Building (MPB). RSA immediately initiated a review of MPB subsurface utilities and assisted SFC with designing trench monitors and hydraulic barriers installed by SFC in the SX Building and MPB areas as part of the mitigation response. Further, on September 19, 1990, the NRC issued SFC an Order Modifying License (OML) to complete actions at the Sequoyah Facility to investigate and prevent further releases of licensed material from the Main Process Building (MPB) and to develop a comprehensive Facility Environmental Investigation (FEI) Plan. SFC responded quickly and comprehensively to the OML requirements.

By September 24, 1990 an intensive soil assessment and groundwater monitoring well installation program was underway. The information obtained from the initial SFC responses in September and October 1990 allowed complete assessment of licensed material releases in the MPB area. Further, a groundwater monitoring system capable of

monitoring not only the uppermost groundwater system with confidence but also the next deeper system was installed around the MPB. The initial groundwater investigation completed during this period included the installation of sixty-eight (68) groundwater monitoring wells and completion of thirty-seven (37) soil characterization borings. This investigation detected only isolated and limited releases of licensed material associated with the MPB. SFC completed all responses in accordance with the OML by October 15, 1990 and completed a detailed findings report. Two (2) comprehensive findings reports were subsequently completed by SFC, the Main Process Building Final Findings Report (December 15, 1990) and the SX Building Final Findings Report (February 1, 1991).

The comprehensive FEI Plan was also developed by October 15, 1990 and was aggressively implemented by SFC over the subsequent nine (9) month period with the same intensive level of effort put forth for the MPB investigation. The OML actions included the development of a FEI Plan. The FEI Plan expanded the environmental investigation from the work already completed relative to the MPB and SX Building areas to the total Sequoyah Facility area. Upon its completion, SFC immediately implemented the FEI Plan, an action not specifically required by the OML. Further, SFC progressed far beyond the OML scope by implementing a number of corrective actions.

This FEI Findings Report presents the activities and findings from implementation of the comprehensive FEI. Much of the investigation activities and findings relative to the SX Building and MPB are included or referenced in this FEI report as integral components of the total facility investigation. This level of effort demonstrates SFC's continued commitment to environmental protection and public safety. The following paragraphs summarize the overall SFC activities and findings presented in detail in the FEI Findings Report.

SFC identified twenty-eight (28) past or present operational unit areas on the Sequoyah Facility property (approximately 85 acres in area) where detailed FEI investigations would be completed. Two (2) of these units are the SX Building and MPB areas. An initial task of the FEI completed was a detailed file search and SFC employee interview process to document historical information for each unit's operation and environmental release history. These units represent the potential sources for release of licensed material to the environment at the Sequoyah Facility. The history of each unit, summarized in the FEI Report (Section 2.0), provided an important reference information base to help direct the technical investigation work and assist in interpretation of the findings.

The unit information base was supplemented by a comprehensive assessment of the Sequoyah Facility operation processes (Section 3.0). The process evaluation culminated in the development of a detailed process flow diagram for the entire Sequoyah Facility. This characterization effort resulted in a clear understanding of the seven (7) principal waste streams generated by the overall Sequoyah Facility process, as well as the constituents present in the waste streams. Further, the process evaluation defined with clarity the various forms, concentrations, and sources of licensed material at the Sequoyah Facility.

A surface water investigation of the Sequoyah Facility was completed as an FEI task to evaluate the potential for migration of licensed material in stormwater runoff not routed to the Combination Stream Drain (Section 4.0). Surface water exits the Sequoyah Facility at well-defined outfalls which are monitored by SFC. As part of the FEI, a comprehensive network of twenty (20) monitoring stations was defined to characterize the surface water runoff. These monitoring stations included all pertinent SFC monitored outfalls plus additional sites selected at key transitional surface water drainage locations. Two (2) separate sampling efforts were performed during rainfall events on January 15, 1991 (Event No. 1) and March 1, 1991 (Event No. 2). All fluoride concentrations measured for all monitoring sites were less than the maximum concentration level (MCL) for drinking water (4.0 mg/L). The measured nitrate concentration was less than the permit

limit (20 mg/L) at the regulated discharge outfall (008) in Event No. 1 and was only slightly above the permit limit in Event No. 2. At all other Sequoyah Facility exit points (3) for surface water, the nitrate concentrations measured were below the SFC license limit (20 mg/L). Three (3) units are identified as the most likely sources of nitrate contribution to the surface water. Event No. 1 uranium concentrations for all four (4) Sequoyah Facility exit point monitoring sites were well below the Sequoyah Facility action level (225 $\mu\text{g/L}$). The Event No. 2 uranium concentrations were slightly above the Sequoyah Facility action level for two (2) of the four (4) exit point monitoring sites. Two (2) units are identified as potential sources for the measurable uranium concentrations.

A Facility-Wide Underground Utility Investigation characterized the quantity and location of licensed materials in the subsurface fill soils in SFC underground utility trenches (Section 5.0). Utility trenches backfilled with more porous material provide a potential preferential migration pathway away from the Sequoyah Facility. From this FEI effort, a complete set of utility drawings which locate past and present utilities at the Sequoyah Facility was generated. This effort also included review of the SX Building and MPB construction drawings relative to site geology and documented that no construction foundations or piers penetrate the underlying upper shale unit. Twenty-seven (27) utility trench excavations were performed to investigate migration potential. Eighteen (18)

hydraulic barriers and twenty-three (23) trench monitors were installed. The FEI findings document that varying levels of licensed materials are present in the utility trench soil and porewater. SFC has implemented an aggressive corrective action program which, to date, has resulted in removal of 3,081 kilograms of uranium in excavated soils, recovery of 95,719 gallons of soil porewater containing 6.6 kilograms of uranium from utility trench monitors, recovery of 108,295 gallons of water from the SX Building Tank Vault drain containing 322 kilograms of uranium, recovery of 145.1 gallons of water from the MPB digestion subfloor monitor containing 5.9 kilograms of uranium, and recovery of 675 gallons of water from the MPB denitration subfloor monitor containing 5.5 kilograms of uranium.

Also, as a separate FEI task, the Combination Stream Drain (CD) was thoroughly investigated both internally and externally (Section 6.0). The internal investigation identified all contributing waste streams to the CD and clarified the operation dynamics of the CD. Two (2) flow and sampling events were completed in the internal investigation of the CD. The uranium limit applicable to the CD permitted outfall was never exceeded or even approached during the internal investigation. The internal characterization investigation determined that the greatest uranium loadings to the CD are from the cooling tower equalization basin. The potential sources of greatest uranium concentrations in CD inflows are the sanitary sump and cooling water hot side basin. No measurable

infiltration or exfiltration occurred to or from the CD. For external investigation of the CD, several trench monitors and two (2) recovery wells were installed. The results of the external monitoring indicated licensed material has migrated into the backfill surrounding the CD. The uranium concentration in the porewater decreased from an average of 45.5 mg/L upstream in the SX Building area to 0.019 mg/L downstream near the Outfall 001 location, a value well below both the maximum permissible concentration (MPC) for discharge (45 mg/L) and the SFC action level (225 µg/L). The source of the licensed material external to the CD is most likely historical releases in the SX Building area. As noted, SFC has installed two (2) recovery wells in the external CD trench backfill soils to initiate corrective action.

An extensive groundwater and soil investigation of the Sequoyah Facility was performed. The comprehensive environmental investigation conducted at the Sequoyah Facility fully defined the geological conditions which control the occurrence and movement of groundwater and any associated licensed materials beneath the entire Sequoyah Facility. As of July 17, 1991, SFC had installed seventy-nine (79) shallow shale/terrace groundwater monitoring wells, seventy-eight (78) deep sandstone wells, one (1) groundwater recovery well, two (2) CD trench recovery wells, and three (3) CD monitoring wells. In addition, approximately ninety-nine (99) lithological characterization borings and approximately two hundred ten (210) soil chemical characterization borings were drilled for

the purpose of defining the extent and quantity of licensed material and associated constituents in soils at the Sequoyah Facility. Isopleth or concentration maps are presented in Section 7.0 for the entire Sequoyah Facility to show the extent of licensed material and associated constituents in the subsurface groundwater and soils.

The results of the groundwater and lithological characterization programs indicate that the Sequoyah Facility is underlain by a thin veneer of Quaternary-age terrace deposits. These terrace deposits are underlain by the Pennsylvanian-age Atoka formation which consists of an alternating interbedded sequence of shale and sandstone.

Also, there are two (2) hydraulically separate groundwater flow systems present in the upper fifty (50) feet at the Sequoyah Facility. The uppermost groundwater system, referred to as the shallow shale/terrace groundwater in the FEI report, is found in the weathered and fractured shale that is in hydraulic communication with groundwater contained in overlying terrace deposits. Beneath the uppermost shale/terrace groundwater system, but hydraulically separated by a dense, highly cemented, non-porous sandstone, is an interbedded shale and sandstone sequence referred to as the deep sandstone/shale groundwater system. The groundwater flow rates vary from five (5) to sixteen (16) feet per year in the

shallow shale/terrace groundwater and from eight (8) to one hundred twelve (112) feet per year in the deep sandstone/shale groundwater.

No major bedrock or alluvial aquifers underlie the Sequoyah Facility. An area-wide water well survey conducted by SFC documents no impacts to groundwater from Sequoyah Facility operations have occurred on area water wells. Most of the water wells identified in the off-site well survey are not in current use. There are no groundwater users noted downgradient of the Sequoyah Facility process area and therefore no potential exists to impact downgradient groundwater users from the releases identified at the Sequoyah Facility.

Further, from the groundwater investigation, the uranium isopleth maps indicate that limited areas of groundwater at the Sequoyah Facility are impacted and the impacts are generally in the MPB and SX Building areas which are well within the site boundaries. The uranium is fully defined in the shallow shale/terrace and deep sandstone/shale groundwater at the Sequoyah Facility and no uranium has migrated through the groundwater beyond the Sequoyah Facility property boundary. The extent of nitrate, fluoride, and arsenic in the two (2) groundwater systems was also comprehensively evaluated. The limits of these constituents (nitrate, fluoride, arsenic) in the groundwater are fully defined in the Sequoyah Facility area. SFC is committed to expanding the FEI scope and additional wells

will be drilled west and south of Pond 2 to further characterize the groundwater impacts in this area.

A special sampling and analysis investigation was performed to characterize the presence or absence of a broad range of metal and organic constituents in the groundwater. Metal analyses of the Sequoyah Facility groundwater indicate that the only metal concentrations that are significantly higher than EPA primary drinking water standards are arsenic and barium. Organic analyses of groundwater indicated that 1,1,1-trichloroethane, tributylphosphate, methylene chloride, and trichlorofluoromethane are present in limited areas of groundwater at the Sequoyah Facility but in the low parts per billion levels.

A geochemical modelling study completed indicates that uranium in groundwater exists mainly as uranyl carbonate and uranyl phosphate complexes. These anionic complexes are soluble in the Sequoyah Facility groundwater. However, there are several areas where groundwater is predicted to be oversaturated with respect to U_3O_8 , U_4O_9 , $B-UO_2(OH)_2$, schoepite, rutherfordine, uraninite, and $USiO_4$. These wells are mostly in the MPB, SX Building, and Combination Stream Drain trench areas. Uranium is removed from solution through a precipitation process in these areas. Significant removal of uranium from solution through adsorption with ferric oxyhydroxide and adsorption with the geologic formation clays and shales is also predicted to occur naturally at the Sequoyah

Facility. Uranium migration is greatly retarded by the very low groundwater movement rates resulting from the geology of the area which was well within the SFC site boundaries.

The soil isopleth maps completely define the location of uranium in soils within the 85-acre Sequoyah Facility boundary. Most of the uranium found in the Sequoyah Facility soils is in the upper five (5) feet and is found mainly in the MPB and SX Building areas.

Further, upon completion of the FEI Investigation Plan, SFC now has a comprehensive groundwater monitoring system capable of detecting releases from all areas at the Sequoyah Facility. To date, one hundred fifty-seven (157) new groundwater monitoring wells have been installed adjacent to the past and present operational units at the Sequoyah Facility. This system also provides a complete perimeter groundwater monitoring system for the Sequoyah Facility.

In summary, SFC has responded quickly and comprehensively to the OML requirements by planning and implementing the FEI. The information obtained from the SFC responses allows complete assessment of all associated questions concerning releases of licensed material at the Sequoyah Facility. Further, a groundwater monitoring system is in place to monitor not only the uppermost groundwater system with confidence but also the next deeper system. This investigation has detected only isolated and limited releases of licensed material associated with the entire Sequoyah Facility.

SFC has progressed far beyond the OML scope by implementing a number of corrective actions which to date have resulted in recovery of an estimated 3,421 kilograms of licensed material. This level of effort demonstrates SFC's continued commitment to environmental protection and public safety.

SFC recognizes that this commitment must continue. There are a number of on-going follow-up responses pursuant to the FEI which are underway. First, a comprehensive corrective action plan is being developed for the Sequoyah Facility. This comprehensive plan will mold the existing corrective action responses into an overall program for the Sequoyah Facility. Further, SFC intends to continue follow-up environmental investigation as necessary. Currently, SFC is planning and implementing these follow-up investigations:

1. A soil investigation of two (2) defined operational areas in the vicinity of Unit 10 will be completed so that a corrective action plan can be developed. These areas were identified in the FEI as having sufficient surface soil impact to warrant a corrective action response consideration.
2. An expanded groundwater investigation of the groundwater impacts will be completed. SFC intends to expand the scope of work defined by the FEI to include definition of impacts from

non-radiological constituents identified to be present in the groundwater in significant concentrations during the FEI.

3. A surface water drainage sediment investigation will be implemented. SFC, in cooperation with the NRC, recently began assessing the presence of low levels of licensed material in the surface water drainage areas and intends to continue this effort.

These and potentially other activities will be completed expeditiously by SFC to supplement the existing FEI findings. The results and interpretations will be reported to the NRC and other pertinent regulatory agencies as the investigations progress.

SEQUOYAH FUELS CORPORATION
FACILITY ENVIRONMENTAL INVESTIGATION
FINDINGS REPORT
JULY 31, 1991

1.0 INTRODUCTION

1.1 Background

Sequoyah Fuels Corporation (SFC), a subsidiary of General Atomics, operates a uranium conversion facility (Sequoyah Facility) southeast of Gore in east-central Oklahoma. The Sequoyah Facility was purchased by General Atomics from Kerr-McGee Corporation in November, 1988. SFC refines uranium ore concentrate and converts it to uranium hexafluoride (UF_6) for use by enrichment facilities. SFC also reduces depleted UF_6 to depleted uranium tetrafluoride (DUF_4), primarily for the defense industry.

SFC has operated the Facility under U.S. Nuclear Regulatory Commission (NRC) License SUB-1010 since February 20, 1970. SFC's license expired on September 30, 1990, and SFC has made a timely application for license renewal. On August 2, 1990, in the course of excavating two (2) underground storage tanks adjacent to and north of the Solvent Extraction (SX) Building, an NRC licensed material, uranium, was encountered in the soils and water in the excavation. On Wednesday, August 22, 1990, SFC notified the NRC of the findings, and began efforts to locate a drilling rig to begin preliminary characterization

of the SX Building and environs. An NRC inspector arrived on site on Thursday, August 23, 1990. A drilling rig was located and was brought on site on Monday, August 27, 1990 and, that same day, the NRC Augmented Inspection Team arrived on site to further investigate the discovery and conditions in the vicinity of the SX Building. On September 4, 1990, SFC retained the services of Roberts/Schornick and Associates, Inc., an environmental consulting firm, to assist in the SX investigations.

In late August, within a few days of notifying NRC of the discovery of elevated levels of licensed material in the SX excavation, a discussion between the President of SFC and a member of NRC Region IV management raised the issue of whether other areas of the Sequoyah Facility may have the potential for problems similar to those found in the SX Building environs. SFC acknowledged that the potential for similar problems existed for certain areas in the Facility's Main Process Building (MPB). At that point, the President of SFC committed to an investigation of the MPB upon completion of the on-going SX investigations.

On September 4, 1990, when SFC retained RSA to assist in the SX investigation, RSA was also directed to begin an investigation and identification of potential releases of licensed material from the Main Process Building (MPB).

Initial work on the MPB investigation began on September 6, 1990. On September 14, 1990, SFC reported to the NRC that liquid containing licensed material was present in a subfloor monitor floor of the MPB. The NRC issued an Order Modifying License (OML) on September 19, 1990, requiring SFC to obtain information and develop characterization investigations regarding the uranium-bearing liquid which was present under the MPB. On September 20, 1990, SFC received the OML and, with assistance from the RSA staff on-site on this date, began implementing the actions requested in the OML. SFC and RSA conducted a conference call with the NRC on September 20, 1990 to clarify the NRC requests contained in the OML for incorporation of the OML objectives into the ongoing SFC investigations.

The OML contained six (6) specific actions, five (5) of which required investigation and prevention of further releases of licensed material from the MPB. The completion of those five (5) actions and the subsequent findings were reported in two separate final findings reports (Roberts/Schornick and Associates, Inc., 1990 and 1991). The sixth action required SFC to develop a Facility Environmental Investigation (FEI) Work Plan to identify and characterize other locations on SFC property where past or present operations could have resulted in releases of licensed material to the environment. A written FEI Work Plan, finalized by SFC and RSA on October 15,

1990, proposed comprehensive environmental investigation activities and reporting of findings which would span a time period of approximately nine (9) months, through July 1991. SFC immediately implemented the FEI Work Plan. The FEI activities have now been completed, and this report was prepared to present the findings resulting from those activities.

The FEI objectives and tasks are summarized in Section 1.2 of this report. Other significant activities occurring within the nine-month time period of the FEI Plan included two (2) presentations to the NRC, in which SFC and RSA presented interim findings on January 30, 1991, and again on May 23, 1991. The presentations were conducted in Washington, D.C., with attendees including representatives from NRC staff, NRC consultants (SAIC), SFC staff, General Atomics, RSA, and a group intervening in SFC's NRC license renewal process. SFC and RSA also presented FEI interim findings to the Oklahoma Water Resources Board and the Oklahoma State Department of Health on October 31, 1990, November 8, 1990, and May 30, 1991.

1.2 FEI Plan Summary

The FEI Plan was developed to identify and investigate, in accordance with the NRC's OML, locations on the Sequoyah Facility property where past or present operations could have

resulted in the release of licensed material to the environment.

The FEI Plan was implemented over an approximate nine (9) month period and included six (6) major Work Plan Tasks. These major Work Plan Tasks, as outlined in Sequoiah Fuels Corporation, Facility Environmental Investigation Plan, (October 15, 1990), are:

- Task 1. Facility-Wide Surface Water Investigation;
- Task 2. Facility Process Flow and Process Stream Characterization Investigation;
- Task 3. Past and Present Operations, Historical Information Review;
- Task 4. Facility-Wide Underground Utility Investigation;
- Task 5. Past and Present Operation, Material Characterization; and
- Task 6. Groundwater (Saturated Zone) and Unsaturated Zone Soil Investigation.

1.3 Report Organization and Section Overview

As an NRC licensee, SFC is regulated by Title 10 of the Code of Federal Regulations (CFR). The provisions of 10 CFR 20 in Sections 20.1 through 20.601 define permissible doses, levels, and concentrations of radioactive materials. The 10 CFR 20 concentration limits for radioactive materials in effluents to

unrestricted areas are applicable to the SFC environmental monitoring programs.

The findings in this report are grouped according to Work Plan Tasks, with a particular Task being addressed by a specific section of the report. The findings from these Work Plan Tasks are presented in Sections 2.0 through 7.0 of this report.

Section 2.0 discusses results from Task 3 - Past and Present Operations, Historical Information Investigation. Task 3 work activities identified 26 operational units at the Sequoyah Facility for which a historical review and file search would be conducted. As the FEI progressed, two (2) additional units were defined, bringing the total to 28 units. The review and file search determined the scope of operations which had been performed at each unit. Other pertinent historical information collected included dates of operation, aerial photographs, characterization of material managed at each unit, release and/or mitigation data, and data from any associated environmental monitoring programs.

Section 3.0 addresses results from Task 2 - Facility Process Flow and Process Stream Characterization Investigation. The process flow and process stream characterization investigation was designed to provide a more complete understanding of the

overall Sequoyah Facility unit operations and processes, and to also serve as a reference for assessing and identifying potential release sources. Additionally, other constituents which have release potential were identified at the Sequoyah Facility.

Results from Task 1 - Facility-Wide Surface Water Investigation appear in Section 4.0. The purpose of Task 1 was to develop a detailed understanding of surface water flow paths on SFC property in order to identify potential licensed material pathways. Analytical results from surface water samples are presented, along with conclusions as to the source of various constituent loadings.

Section 5.0 summarizes the findings from Task 4 - Facility-Wide Underground Utility Investigation. The objective of the utility investigation was to characterize the quantity and location of licensed material in the subsurface fill soils in all SFC property utility trenches with potential for transporting licensed material away from the Sequoyah Facility. The utility investigation also identified and verified all potential pathways that could contribute to the migration of licensed material to and away from past and present operational units.

One exception to the organization of the report by FEI Work Plan Task is Section 6.0, which presents the Combination Stream Drain Investigation activities. The investigation of the Combination Stream Drain was not one of the original major Work Plan Tasks but emerged as a major component of Task 4 - Facility-Wide Underground Utility Investigation. Because the scope of the Combination Stream Drain Investigation was so extensive, a separate section is devoted to the discussion of the Combination Stream Drain.

Section 7.0 contains results from Tasks 5 and 6 - Unit and Groundwater Investigations. Extensive soil borings, monitor well installations, and unsaturated zone soil samplings provided a wealth of data, which is presented in this section of the report. Also presented in Section 7.0 is a description of a domestic water well survey.

Following the presentation of results from each Work Plan Task, principal conclusions and findings relative to the entire FEI Plan are summarized in Section 8.0. Finally, Section 9.0 summarizes corrective actions implemented during the FEI Plan. It is emphasized that implementation of corrective actions is not within the scope of the FEI Work Plan tasks but is reported herein to provide a comprehensive presentation of SFC's environmental response activities. These corrective actions discussed include: 1) impacted

soils, 2) a Combination Stream Drain trench migration pathway mitigation project, and 3) the utility trench porewater and groundwater recovery program. SFC will submit a comprehensive environmental Corrective Action Plan to the NRC subsequent to the submittal of this report.

A list of references immediately follows the text body. The list of references contains those documents cited throughout the report, as well as those reference documents which served as research aids during FEI activities but were not cited in the report.

2.0 PAST AND PRESENT OPERATIONS, HISTORICAL INFORMATION
INVESTIGATION (TASK 3)

2.1 Introduction

2.1.1 Sequoyah Facility Description and History

The Sequoyah Facility has been in operation with authority to use source material for the conversion of natural uranium ore concentrations into UF_6 since February, 1970, and for the reduction of UF_6 into UF_4 since February, 1987. The UF_6 Conversion Plant produces high-purity UF_6 using uranium ore concentrates as feed material, while the UF_6 Reduction Plant produces UF_4 using either UF_6 or depleted UF_6 as feed material.

In addition to facilities for conversion and reduction of UF_6 , the SFC site (Site) also includes: (1) a storage area for uranium ore concentrates received from uranium mills; (2) a uranium sampling facility; (3) bulk storage of chemicals such as ammonia (NH_3), tributylphosphate-hexane solvent, and three acids: hydrofluoric (HF), nitric (HNO_3), and sulfuric (H_2SO_4); (4) a facility for electrolytic production of fluorine from HF; (5) treatment systems and storage ponds for both radiological and non-radiological liquid waste streams; and (6) a land-treatment program for beneficial use of ammonium nitrate solution (which results from the UF_6 conversion process's solvent extraction system) as fertilizer on SFC-owned land.

2.1.2 Sequoyah Facility Layout

The Sequoyah Facility shown in Figure 1 occupies approximately 85 acres of the 1550 acre Site. The 85-acre Sequoyah Facility is approximately the area shown on the aerial photograph presented in Figure 2. The total area under roof is comprised of manufacturing, warehousing, and office space in five principal buildings. The Main Process Building (MPB) contains the administrative offices, a process laboratory, the sampling plant, the major UF_6 conversion processing operations, fluorine generation operations, a utility area and a maintenance area. About 200 feet west of the MPB is the Miscellaneous Digestion Building, where yellowcake slurry can be received and processed. Facilities in this building enable slurry to be dissolved in nitric acid and the solution to be sampled before piping it into the processing circuit. The Solvent Extraction (SX) Building is located in a separate building about 150 feet west of the MPB. A one-story warehouse about 200 feet north of the MPB provides storage for spare mechanical equipment. A solid waste sorting building north of the MPB provides sorting and waste handling capabilities. About 400 feet north of the MPB is the UF_6 Reduction Plant.

Additional facilities include the following: an electrical substation, UF_6 cylinder storage area, tank farm for liquid chemicals and fuel oil, uranium ore concentrate (yellowcake)

drum storage area, cooling tower for waste heat dissipation, sanitary sewage facilities, retention ponds for calcium fluoride wastes, retention ponds for treating raffinate waste from the solvent extraction process which contains radioactive material, a raffinate sludge concentration and loading facility, retention ponds for fertilizer, and a reservoir for emergency supply of water. These areas are depicted in the recent October 31, 1990 aerial photograph of the Sequoyah Facility and Site, presented in Figure 2.

Several areas of the Sequoyah Facility are delineated as areas to which access is limited for the purpose of limiting radiation exposure to personnel. These areas have been defined as either "restricted" or "controlled access" areas and are delineated in Figure 3.

A Restricted Area is an area of the Sequoyah Facility to which access is controlled for the purpose of protection of unauthorized individuals from inadvertent exposure to radiation and radioactive materials. All Restricted Areas are fenced, and only authorized personnel wearing appropriate protective clothing and monitoring equipment are allowed to enter Restricted Areas. Generally, areas at the Sequoyah Facility where licensed material is stored or managed are designated as Restricted Areas. The facility process laboratory is posted as a radioactive restricted area, and

only areas of the MPB such as administrative offices, warehouse storage areas, control room, lunch room, and restrooms are considered unrestricted.

Controlled Access Areas are uranium process areas located within Restricted Areas. Due to the processing activities in these zones, Controlled Access Areas present a greater potential for contact with licensed material. Controlled Access Areas include the northwest and southwest portions of the MPB, the entire SX Building, and the Miscellaneous Digest Building.

2.1.3 Site Location

The SFC Site is located in Sequoyah County in mideastern Oklahoma at 95°5' west longitude and 35°30' north latitude, about 150 miles east of Oklahoma City, 40 miles west of Fort Smith, Arkansas, 25 miles southeast of Muskogee, and 2.5 miles southeast of Gore (Figures 4 and 5). The Site is located in portions of Sections 15, 16, 21, 22, 23, 26, 27, and 28 of Township 12 North, Range 21 East, and consists of a total of 1550 acres bounded on the north by U.S. Route 64 and on the west by U.S. Government-owned land along the Illinois and Arkansas Rivers. The eastern boundary of the Site is the eastern boundary line of Survey Section 22 (T12N, R21E). Most of the Site is north of Interstate 40, with approximately 370 acres lying south of the interstate. The principal industrial

facilities (including the MPB and SX Building) are located in a fenced area of about 85 acres in Section 21, as shown in Figure 1 and referred to herein as the Sequoyah Facility.

The SFC Site is located in rural Sequoyah County, which had a 1990 population of 33,838. The four (4) adjacent counties of Muskogee, Haskell, McIntosh, and Cherokee had a combined 1990 population of about 129,846. The major population center is the city of Muskogee (37,708), about 25 miles to the northwest. Nearby towns include Gore (population 690), Webbers Falls (722), Warner (1479), Vian (1414), Checotah (3290) and Sallisaw (7122), all of which are located along Interstate 40 or old U.S. Route 64. The total population within 5 miles of the Site is about 3103.

The SFC Site is situated on gently rolling to level land of which about two-thirds is forested and one-third is open field. Elevations on or near the Site range from 460 feet AMSL for the normal pool elevation of the Robert S. Kerr Reservoir to 700 feet on top of a hill in the southeastern corner of the Site. Slopes over most of the upland areas of the Site are less than 7%. Steeper slopes in creek ravines and on hillsides average roughly 28%. The SX Building and MPB areas are located on land 555 to 565 feet in elevation. Approximately 85 acres of the 1550-acre site are occupied by the Sequoyah Facility industrial complex, and most of the

remaining land is used for grazing cattle and forage production in conjunction with SFC fertilizer application program.

2.1.4 Adjacent Area Land Use

Prior to the advent of railroads in the area, the land was primarily cattle range. With availability of railroads, corn and cotton became the main agricultural products. In the last 30 years, however, the trend has been away from cultivation of these crops and back to cattle grazing and production of other food crops. Areas remaining in cultivation are primarily in the bottom lands along the Arkansas River. In 1970, about 30% of the acreage of Sequoyah County was used for range and about 40% was forested. The range is usually grazed year round, but the forage is supplemented with protein cubes, prepared pasture, and hay consisting of tame grasses and small grain. High-quality trees have been largely eliminated from the forested areas by heavy cutting, fires, and uncontrolled grazing. Most woodland in the county is used for grazing.

Within a 10-mile radius of the Sequoyah Facility, the following land uses have been estimated:

Land Use	Percent ^a
Agricultural (mostly pasture)	30
Recreation	35
Residential	20
Commercial & Industrial	15
Unused Rough Terrain	25

^aDue to multiple use of some areas, the total exceeds 100%.

The large acreage for recreation is represented primarily by the federally-owned land and water areas along the Arkansas and Illinois Rivers and the Robert S. Kerr Reservoir, and includes the 21,000 acre Sequoyah National Wildlife Refuge, where large numbers of migrating waterfowl are found in the spring, fall, and winter.

2.1.5 Surface Water

The Sequoyah Facility is located on the east bank of the headwaters of the Robert S. Kerr Reservoir (Illinois River) approximately 2.5 miles south-southeast of Gore, Oklahoma. The Illinois River flows in a southwesterly direction to join the Arkansas River (Robert S. Kerr Reservoir) approximately 2 miles downstream from Webbers Falls, Oklahoma. Although the Illinois River in the vicinity of the Site is part of the

reservoir, it is not considered navigable. The river flow has been regulated since 1952 by Tenkiller Ferry Reservoir, which is approximately 7 miles upstream of the Site. The average flow of the river near the Site is 1600 cubic feet per second.

In the vicinity of the SFC Site, the Illinois River drains an area of 1620 square miles. Most of the Site drains to the headwaters of the Robert S. Kerr Reservoir. The principal Site drainage consists of the permitted Sequoyah Facility effluent, identified as the Combination Stream Drain (Figure 6), and Salt Branch, which flows along the northern boundary of the Site. The only known spring in the vicinity of the Sequoyah Facility is about 1000 feet west of Pond 2 and has an average flow of less than 0.5 liters/minute. Location of surface waters in the area are shown on Figure 5.

2.1.6 Climate

Sequoyah County has a warm, temperate, continental climate. Storms bring ample precipitation as moisture-laden air from the Gulf of Mexico meets cooler, drier air from the western and northern regions. The most variable weather occurs in the spring, when local storms can be severe and bring large amounts of precipitation. The Sequoyah County weather station nearest to the Site is in the town of Sallisaw. The mean annual temperature is 61.5°F. The monthly average ranges from 40°F in January to 82°F in July. The average daily range in

temperature is 24°F. The lowest temperature on record was -19°F in January, 1930, and the highest was 115°F in August, 1936. The mean annual precipitation ranges from 42.9 inches in the town of Sallisaw, to approximately 44.1 inches in the northeastern part of Sequoyah County. The seasonal distribution of rainfall is fairly even, with 31% in spring, 26% in summer, 23% in fall, and 20% in winter. The average amount of snowfall from November through April is about 5.2 inches. Lake evaporation averages about 47.5 inches annually. Of this amount, 72% occurs from May through October. Based on the precipitation and lake evaporation values, there is a net annual evaporation rate of about 4 inches in the SFC area.

2.2 Scope and Objectives

The objectives of the Historical Information Investigation were: (1) to identify past and present operation units which had the potential to contribute licensed material to the environment, and (2) to conduct a detailed historical review and file search for each operational unit. A major requirement of the historical review was to identify and describe all documented historical releases from the units to the environment and any associated environmental characterization data. Also, the historical review information obtained for each unit was analyzed to determine if a deficiency of information existed concerning the characterization of licensed material or other material

present or released from each unit. If a deficiency existed, a plan was developed for field investigation to better characterize the material at the unit.

2.2.1 Unit Selection

Selection of the units was based on historical information gathered from SFC personnel interviews and SFC internal correspondence, as well as knowledge of the current uranium conversion process. After reviewing the information gathered, SFC initially selected 26 operational units for the historical information investigation. As the FEI progressed, two (2) additional units were identified for investigation. Some of the units are distinct entities, such as an impoundment or basin, while others are general operational areas, such as the surface water system, with no distinct boundaries. All 28 operational units are listed in Table 1 and shown in Figure 6.

The first 26 operational units are listed in the general order of priority for investigation. The priorities were determined by the potential for environmental release, based on discussions with SFC personnel. Priority was given to those areas where an environmental release of licensed material was possible, and the release could potentially migrate outside the restricted area boundary. Some exceptions to the priority designation rationale must be noted. For example, a priority designation is not applicable to the Unit 4 - Surface Water,

Entire Facility, which was implemented for the entire SFC property simultaneously. Also, Units 27 and 28 are so numbered due to the fact that they were added later in the course of the FEI Plan activities, rather than due to their priority ratings.

2.2.2 Unit Investigation

A detailed historical review and file search for each operational unit was performed to:

1. Determine the scope of the operations at the unit,
2. Identify dates each unit was in actual operation,
3. Characterize material managed at the operational unit and document if licensed material was present during any dates of operation,
4. Compile existing data on waste characterization,
5. Compile data on release information and any associated mitigations or remediations performed at the operational unit,
6. Compile and identify any data on environmental monitoring programs associated with the operational unit, and
7. Identify aerial and vertical boundaries of each operational unit.

The historical review proceeded generally in the order of priority discussed in Section 2.2.1, with each unit's review being completed before that unit's material investigation and

field investigation was begun. A discussion of investigation activities and sources of historical information appears in the following section of this report.

2.3 Investigation Activities

Historical information for each unit was gathered from a variety of sources. On-site review of all available SFC records provided a wealth of historical information, and interviews with SFC personnel clarified several issues which were not addressed adequately through the file search. All pertinent documents discovered during the file search or notes resulting from interviews were photocopied, documented as to their source, and filed by operational unit in a single historical investigation repository. File reviews, interviews, and other historical investigation activities are discussed in greater detail in the following sections of this report.

2.3.1 Aerial Photographs

The Agricultural Stabilization and Conservation Service (ASCS), a branch of the U.S. Department of Agriculture, maintains an extensive set of aerial photographs covering approximately 95 percent of the U.S. Six (6) aerial photographs of the land surrounding the SFC Site were obtained from the ASCS. These photographs, flown in the years 1990, 1958, 1972, 1980, 1981, and 1984, appear in Figures 2 and 7

through 11, respectively. A comparison of the photographs provides information as to the approximate time frames in which certain operational units at SFC were constructed, operated and/or closed. These photographs functioned as the key foundational documents on which all subsequent historical information investigation activities were based.

2.3.2 File Search

The review of all available SFC files was an essential element of the historical information investigation and was the source of the majority of information collected. SFC has numerous collections of files maintained by several different departments, and these files were examined closely for all pertinent documents which could provide information on the history of use and characterization of materials present at each investigation unit. The locations of files reviewed and types of records maintained in each file were:

File Location

Types of Records

Environmental Department	Environmental records
Health and Safety Department	Decommissioning files
Regulatory Affairs/ Licensing Files	Various memoranda and correspondence
Engineering Department	Drawings, blueprints, sketches
On-site Laboratory	Analytical data
Carlile School	SFC Operating Procedures
	Archival records dating from Kerr-McGee Corp. ownership

The records maintained by the Environmental Department contained many memoranda, regulatory correspondence, and chain of custody forms pertinent to the historical information investigation. Several of these records were indexed according to operational units, while other records were grouped by event or by regulatory reporting agency.

SFC's Health and Safety Department provided several decommissioning files for review. Decommissioning files are repositories of information maintained for the life of a process unit and serve as a reference tool when use of that unit is discontinued, and the unit completes the decommissioning process.

SFC memoranda and NRC/SFC correspondence filed in the SFC Regulatory Affairs files were found to be useful records of items of regulatory concern, such as releases of licensed material to the environment. Sequoyah Facility drawings maintained in the Engineering Department provided valuable information as to investigation unit dimensions, dates of unit construction, and Sequoyah Facility utilities.

SFC's process and environmental laboratories maintain an extensive database of all sample analyses conducted. These analyses are organized by sample source and month of analysis

and provided an excellent history of material characterization for several operational units.

SFC's operating procedure documents provided information on process and waste sampling parameters and frequencies. The archival records stored at Carlile School included numerous SFC documents pertaining to investigation units operation prior to General Atomics ownership. Other helpful documents found in the archives were analyses of soils contaminated by the 1986 incident and records of soil volumes removed. In general, review of the archival records yielded a better understanding of the evolution of operations at SFC, especially with respect to documentation of the rationales for implementation of new processes, as well as for process changes considered but not implemented.

2.3.3 Interviews

Frequent interviews were conducted with SFC engineering, environmental, health and safety, and laboratory personnel to provide information necessary to address questions which arose during the file review. In addition to supplying missing dates of operation and pertinent details, SFC personnel were often able to direct the search activities to previously unidentified record files for more thorough investigation of an operational unit's history.

2.4 Investigation Results

Results of the Historical Information Investigation are summarized in this section and include a definition and scope of operations for each of the 28 units. The summary for each unit also includes any available information found relative to the following topics:

- each unit's location and defined boundaries;
- dates of operation, if known;
- any available characterization of material managed at the unit;
- any existing data found on unit environmental sample characterization; and
- any data on release information and associated migrations or remediations.

Exceptions to this format include Units 1, 2, 4, and 27. The results of characterization and investigation activities relative to Units 1 and 2 are documented in detail in the respective final findings reports (Roberts/Schornick & Associates, Inc., 1990, 1991). The scope of FEI activities associated with Units 4 and 27 is extensive and these activities are discussed in detail in Sections 4.0 and 5.0, respectively, of this report.

The summary of information presented for each unit includes only historical information obtained in the course of the historical investigation. Investigation and characterization activities conducted as a part of the FEI are described in subsequent sections of this report. The locations of all 28 units are shown in Figure 6.

2.4.1 Unit 1 - Main Process Building (MPB) Area

The MPB, one of five principal buildings on the 85-acre Sequoyah Facility, contains the administrative offices, laboratory, the sampling plant, the major UF₆ conversion processing operation, fluorine generation facilities, and utility and maintenance areas. MPB construction began in 1968, reached completion in 1969, and operations began in 1970. The results of the MPB investigation have been previously reported in the December 15, 1990 final findings report and are expanded on in a subsequent section of this report (Roberts/Schornick & Associates, Inc., 1990).

The historical review for Unit 1 included a search of archival records for any references to material releases or remediations/mitigations relative to the Unit 1 area. One incident of note is the 1986 release in which an overfilled UF₆ cylinder ruptured, resulting in the release of UF₆. This release occurred in the UF₆ cool-down area, just north of the MPB. Though the release occurred outside the confines of the MPB, the northerly wind carried the UF₆ into the MPB. This incident was thoroughly investigated and documented by both SFC and the NRC.

SFC personnel interviews and correspondence provided information pertaining to a 1978 incident. A tank in the boildown area overflowed, resulting in elevated uranium concentrations in the Combination Stream Drain.

Routine Contamination Survey records from the early 1980's contained several references to the ash receiver enclosures, ash grinders, and fluorination tower downcomer trays as areas frequently requiring cleanup of uranium. First Aid Reports included incidents of employees sustaining minor hydrogen fluoride burns from condensate dripping from overhead piping in the MPB. Hazardous Work Permits from 1973 recorded typical MPB maintenance work such as replacement of leaking pump seals and repair of leaking process lines and valves.

Contamination Incident Reports dating from 1972 through 1987 recorded several occurrences causing elevated airborne concentrations of uranium within the MPB. Such occurrences included material handling problems, cooling system failures, packing and seal failures, process equipment overfilling, and operating system pressure build-up. Most historical documents indicated that actions were taken to clean up all spills within the MPB, and these releases typically did not escape the confines of the MPB. Two events within the 1972-1987 timeframe which did result in uranium leaving the MPB were noted. The first event was a leak in the #1 digester heating

and cooling coil which resulted in elevated uranium concentrations in the Combination Stream Drain, and the second was a uranyl nitrate hexahydrate leak into the cooling water system from the #1 adjustment tank.

Engineering Progress Reports indicated that various areas of the MPB floor had been repaired through the years. Areas repaired or lined with stainless steel in approximately 1985 included the Digestion Area and the Boildown Area.

2.4.2 Unit 2 - Solvent Extraction (SX) Areas

The SX Building area includes the area surrounding the SX Building which is approximately 150 feet west of the MPB. SX Building construction began in 1968, reached completion in 1969, and operations began in 1970. The results of the SX area investigation have been previously reported in the final findings report, dated February 1, 1991 (Roberts/Schornick & Associates, Inc., 1991).

The historical review for Unit 2 included a search of archival records for any references to material releases or remediations/mitigations relative to the Unit 2 area. A First Aid Report from 1982 referred to a leaking gasket on the 40% nitric acid pipe, located outside the west SX Building wall. The gasket was replaced. Hazardous Work Permits from 1973 recorded typical SX Building maintenance work such as

replacement of leaking pump seals. Contamination Incident Reports dating from 1972 contained some references to occasional elevated airborne concentrations of uranium in the SX Building as a result of uranium escaping from the pulse column. No reports indicated that uranium escaped the confines of the SX Building. Engineering Progress Reports indicated that repairs were made to the SX Building floor in 1985.

SFC installed a group of four (4) trench monitoring pipes (called "SX sand wells") within the firewater line trenches in the SX Building area. While no records have been found of the exact date of installation, the first data from the wells was collected in January 1976. The "SX sand well" data is analyzed and discussed further in Section 7.0 of this report.

2.4.3 Unit 3 - Initial Lime Neutralization Area

Unit 3, the Initial Lime Neutralization Area, is located southwest of the Decorative Pond, approximately 150 feet south of the Sequoyah Facility entrance road. The unit currently consists of approximately 175 tons of crushed limestone covering an 80 feet by 20 feet area. The unit depth from surface to sandstone ranges from one (1) to four (4) feet. The limestone pile functioned as the initial neutralization facility for SFC's hydrogen fluoride scrubber wash water. Scrubber wash water was discharged to the lime pile from 1969,

the Sequoyah Facility's start-up year, until construction of the Fluoride Settling Basins (Unit 14) was completed in 1971.

Upon completion of the Fluoride Settling Basins, the scrubber wash water was re-routed for treatment through these Settling Basins, and use of Unit 3 was discontinued.

An extensive investigation of the unit was performed during the FEI. Soil samples taken from the middle of Unit 3 in October 1990 indicated uranium concentrations ranging from <5.0 to 636 $\mu\text{g/g}$. A sludge/slurry sample contained 90.0 mg/L uranium, while water samples taken downgradient of the unit from a small rainwater runoff depression area contained uranium concentrations of 7.6 to 93.3 $\mu\text{g/L}$. Sediment samples taken from the area also confirmed uranium, with concentrations ranging from 9.3 to 64.0 $\mu\text{g/g}$.

The potential for release of licensed material at Unit 3 was identified by SFC personnel in the early stages of the FEI. In 1990, SFC excavated and exposed the old abandoned line, which historically routed HF scrubber liquid to the limestone pile, at two (2) upgradient locations. Also, at that time, SFC installed a cut-off trench with a trench monitor at both locations. A detailed investigation of the area was also conducted by RSA and SFC in October 1990 to determine the extent of licensed material at Unit 3 and to assess groundwater quality.

SFC has developed a corrective action plan for the unit, based on results from the investigation. The corrective action plan is described in Section 9.2.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 3 area.

2.4.4 Unit 4 - Surface Water, Entire Facility

Unit 4 addresses surface water from the 85-acre facility, as well as surface water runoff exit points and outfalls. The surface water for the Sequoyah Facility is identified as one of the 28 operational units requiring historical file review. The scope of the Unit 4 FEI Plan work was extensive; therefore, an entire section of this report, Section 4.0, is devoted to a description of the surface water management system and the associated Facility-Wide Surface Water Investigation.

A 1988 study, commissioned by the Army Corps of Engineers, evaluated the level of uranium and other radionuclides present on government lands as a result of surface water runoff through various SFC outfalls. This study indicated uranium present in the soils along these drainage streams were at levels below permitted release levels (University of Oklahoma, 1988).

2.4.5 Unit 5 - Construction Equipment Burial Area

According to historical documentation, Unit 5, the Burial Area, operated from September 10, 1970 to January 21, 1981, and was used for disposal of radioactive waste materials such as drums, sludges, and other solids. Prior to disposal, the records reviewed indicated non-combustible radioactive trash was converted to an insoluble oxide form and placed in steel drums. According to SFC's Final Environmental Statement (FES) prepared in 1975, the burial method of disposal received OSDH approval on September 17, 1974, and complied with federal regulations (10 CFR 20.304) requiring a minimum burial depth of four (4) feet and a spacing of at least six (6) feet between burials. Wastes which were previously disposed of by burial in Unit 5 are now either decontaminated or compacted and shipped off-site for disposal. Unit 5 consists of approximately 0.6 acres south of the service road and 0.3 acres north of the service road near the northern perimeter of the restricted area boundary, between Units 6 and 20.

Material Burial Authorization forms from 1970 through 1981 indicate the presence of licensed material in Unit 5. During this time period, 51,115 cubic feet of waste was buried, according to the forms. The total uranium content of the waste was estimated by SFC to be 1,012.33 kilograms.

On February 28, 1984, according to an internal memorandum, SFC employees determined that an estimated 15,000 gallons of surface water had drained from the burial ground to surface water Outfall #004 northwest of the plant. The memo stated that the burial ground sump drain valve apparently had been in the open position and plugged with mud and debris for several months. SFC employees concluded that the blockage probably dislodged under liquid head pressure as the level in the sump increased.

Water samples from the ditch located downstream from the burial ground sump were analyzed, and an estimated release of 8 to 10 pounds of uranium was calculated by SFC. The sump drain valve and the four-inch drain line were closed to prevent a release recurrence.

Analysis of Unit 5 sump samples taken from February to October 1990 indicate that the uranium concentrations ranged from <0.01 to 0.04 g/L.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 5 area.

2.4.6 Unit 6 - Emergency Basin

Unit 6, the Emergency Basin, is located within the restricted area boundary just west of the North Ditch (Unit 9). The unlined basin has an estimated capacity of approximately 133,300 cubic feet. Unit 6 was constructed in 1969 to provide temporary storage of surface runoff water from controlled areas within the plant. SFC originally had planned to sample all water collected in the basin and, if not impacted, discharge the water to the Combination Stream Drain by way of the sanitary lagoon. If the water was impacted, the water was to be combined with other waste streams and disposed of by injection into a proposed deep well. When authorization for use of deep well disposal was denied, the basin was used for raffinate storage during the four (4) month period after plant start-up while the lined ponds were being built. Since that time period, the basin has been used for the containment of accidental spills, washdown, environmental laboratory waste water, and contents of sumps and pits, including the Yellowcake Pad Sump Area (Unit 16), Burial Ground Sump (Unit 5), Incinerator Pit (Unit 10), and North Ditch (Unit 9).

Data discovered during the file search indicated that licensed material has consistently been present in Unit 6 in varying concentrations. Laboratory data from 1990 basin pump discharge samples indicated uranium concentrations of 0.01 to

0.09 g/L. Analysis of an October 18, 1990, sediment sample indicated 2430 $\mu\text{g/g}$ uranium.

Records of soil analyses conducted by SFC during installation of Monitoring Well 2301B indicated uranium in the soil to a depth of 3.5 feet. In 1986, emergency rinse water from the UF_6 release incident was collected in Unit 6 and analyzed. The analysis indicated uranium concentrations of 34,000 $\mu\text{g/L}$.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 6 area.

2.4.7 Unit 7 - Sanitary Lagoon

Unit 7, the Sanitary Lagoon, was built in 1971 and is used for microbiological oxidation of waste water from toilets, lavatories, showers, and laundry facilities. According to the FES, the wastes were routed to the lagoon which had an average retention time of 43.8 days. The lagoon water was then treated and discharged via the Combination Stream Drain (Unit 27). However, with the construction of a sanitary treatment facility in 1988, the Sanitary Lagoon is now used primarily as backup storage prior to sanitary treatment. Further discussion of SFC's waste treatment appears in Section 3.0. The lagoon is located within the restricted area boundary west of the MPB (Unit 1) and SX Building (Unit 2). The lagoon is

approximately 233 feet wide (East-West), 148 feet long (North-South), and eight (8) feet deep, with a capacity of approximately 129,000 cubic feet.

Two (2) pre-existing Monitoring Wells, 2302A and 2302B, are located downgradient of Unit 7. Groundwater samples collected from these wells indicated uranium concentrations ≤ 3.4 $\mu\text{g/L}$ in February 1990 and ≤ 2.7 $\mu\text{g/L}$ in May 1990.

Sediment and liquid samples from the Sanitary Lagoon were collected in October 1990. Sediment samples indicate uranium concentrations of 12,495 $\mu\text{g/g}$ and 0.011 g/L in liquid samples collected from Unit 7.

No releases or remediations were discovered in the historical research of this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 7 area. Corrective action currently in planning which relates to Unit 7 includes relocation of the laundry system, described in Section 9.3.

2.4.8 Unit 8 - Pond 1 Spoils Pile

Unit 8, the Pond 1 Spoils Pile, consists of soils and clays removed from the old raffinate Pond 1 during construction of Clarifier A (Unit 17) in May 1980. Unit 8 is located west of the Emergency Basin (Unit 6) and Sanitary Lagoon (Unit 7), just outside the restricted area boundary. The pile's dimensions are approximately 400 feet long, 50 feet wide, and 20 feet deep, consisting of approximately 16,200 cubic yards of Pond 1 sludge and cover soil.

Soil sample analytical data obtained from the Unit 8 file search indicate the presence of uranium in the Pond 1 Spoils Pile, as well as thorium, radium, and nitrates. Sampling conducted in 1987 detected a range of 1 $\mu\text{g/g}$ to 28 $\mu\text{g/g}$ uranium in the soils. SFC had initially planned to dispose of the material by spreading it on SFC-owned farm land to dispense the nitrates. The thorium levels, however, ranged from 0.11 to 155 pCi/g. SFC placed the material into storage at its present location at Unit 8.

Pre-existing groundwater monitoring wells adjacent to Unit 8 included 2302A, 2302B, 2315, and 2316. An SFC memorandum dated October 24, 1990 noted that data from monitor well 2316 indicated some nitrate migration from Unit 8 and possibly from past raffinate spills (Unit 25). In an SFC memorandum dated June 19, 1989, summarizing a meeting between SFC and the

Oklahoma Water Resources Board, both parties agreed that Unit 8 was contributing to exceedances in permitted nitrate discharge levels at Outfall 005. Recent groundwater investigation activities and upgrading of the monitor well system in the Unit 8 area are discussed in Section 7.0.

2.4.9 Unit 9 - North Ditch

Unit 9, the North Ditch, was formed in 1972 when an additional wing was added to the north end of the Emergency Basin retaining dike. The North Ditch is located within the restricted area boundary, immediately east of the Emergency Basin (Unit 6) between the Contaminated Equipment Area (Unit 10) and the Solvent Extraction Area (Unit 2). Unit 9 is of triangular area with an estimated capacity of 12,500 cubic feet.

The North Ditch is primarily utilized to contain stormwater runoff, which is then routed to the sanitary sump located near the sanitary treatment facility. Analysis of sediment samples taken from the ditch in October 1990 indicated uranium levels of 400 $\mu\text{g/g}$ to 2,230 $\mu\text{g/g}$. Analysis of water samples taken from the ditch in October 1990 indicated uranium concentrations of 0.015 g/L.

In 1979, SFC concluded that a drain tile from the new tank farm was the source of uranium in the North Ditch. The tile suspected of containing uranium was removed. Samples taken in June 1979 from the North Ditch, prior to tile removal and clay backfill, indicated uranium levels of 99 mg/L, while samples taken November 1, 1979, after tile removal and 2.4 inches of rainfall, indicated uranium levels reduced to 28 mg/L.

According to an SFC memorandum, in June 1980 SFC employees discovered that a solution of material containing uranium was leaking from a hole in the north tank farm retention curbing and was flowing into the north drainage ditch. Uranium was present in the north tank farm curbed area due to occasional overflowing of the 40 percent nitric tank. A dam was constructed across the ditch to temporarily stop the flow. SFC concluded from samples taken from the ditch that uranium concentrations were within limits for release to the unrestricted area, and the nitrate concentrations were slightly elevated.

The ditch was flushed with raw water, then pumped into the Emergency Basin (Unit 6). Further investigation resulted in SFC's conclusion that almost all of the uranium released from the north tank farm was retained within the dammed area of the ditch. To prevent a recurrence of the release, the hole in the tank farm curb was to be repaired. Additional corrective

actions taken were the construction of a new dam for the drainage ditch downstream of the existing dam and installation of a drainage system for the north tank farm.

In February 1982, SFC reported to the NRC that a pipeline rupture had resulted in the release of 3,000 gallons of raffinate into the North Ditch (Unit 9). The breach in the containment ditch, which allowed the spill to enter the North Ditch, was repaired.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 9 area.

2.4.10 Unit 10 - Incinerator Area (Ash Receivers, Contaminated Equipment)

Unit 10, the Incinerator Area, is located to the east of the North Ditch (Unit 9) and the Burial Area (Unit 5) within the restricted area boundary. The northern half of the area is approximately 100 feet wide by 280 feet long, and the southern half is 100 feet wide by 250 feet long. According to the FES, the open-pit incinerator was used to burn non-radioactive combustibles such as boxes, crates, paper and rags, and has a capacity of 50 pounds per hour. Formerly, process ash (non-incinerator) was drummed in this area and recycled to a miscellaneous digester, to be dissolved in aluminum nitrate

solution and fed back through the solvent extraction system. SFC personnel stated that drumming in this area was discontinued in approximately 1972 when the ash grinding unit was added to the MPB (Unit 1). The beginning date of operation of the unit was not determined through historical review activities.

Soil sampling from 1985 indicates uranium levels of 75 to 3500 $\mu\text{g/g}$ in Unit 10 area. Soil nitrate levels ranged from <40 to 260 $\mu\text{g/g}$. Sampling of the incinerator sump in August and October 1990 indicated uranium levels of <0.01 g/L.

No releases or remediations were discovered in the research of this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 11 area.

2.4.11 Unit 11 - Drainage Area

Unit 11 includes the drainage areas around the Emergency Basin (Unit 6), the Sanitary Lagoon (Unit 7), the North Ditch (Unit 9), the Incinerator Area (Unit 10) and old raffinate lines. The Drainage Area flows from the northern side of Unit 6, the southern side of Unit 6 between Units 6 and 7, and the western side of Unit 7. The area provides drainage for rainwater

runoff to the headwater of the Robert S. Kerr Reservoir via permitted and monitored outfalls. The unit has operated since plant start-up in 1970.

Analysis of water samples from January and February 1985 detected uranium levels ranging from 117 to 10,970 $\mu\text{g/L}$. Soil analyses from the drainage area in September 1990 indicated uranium concentrations of <400 to 7020 $\mu\text{g/g}$.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 11 area. Unit 11 was a component of the Facility-Wide Surface Water Investigation as described in Section 4.0.

2.4.12 Unit 12 - Fluoride Sludge Basin #2

Unit 12, the Fluoride Sludge Basin #2, stores sludge collected from the lime neutralization. Construction of the clay-lined basin was completed in 1985. The basin's estimated capacity is 201,000 cubic feet, and it measures 220 feet wide, 150 feet long, and 9 feet deep. The unit is located west of the Contaminated Equipment Storage and Burial Areas (Units 20 and 5) in the far northwestern corner of the restricted area boundary. The fluoride waste stream flows west from the lime treatment area near the SX Building (Unit 2) to a point where the line divides. From the dividing point, the flow can

either be routed north to Unit 12, or south to the Settling Basins (Unit 14) or Basin 1 (Unit 13).

Fluoride sludge is presently accumulated in either Unit 12 or 13. Until federal regulations changed in 1980, fluoride sludge was buried on site (Unit 15). Subsequently, the two (2) basins were built to store the sludge. SFC is presently evaluating options available for disposal of fluoride sludge.

The SFC Impoundments Report, October 1990, estimated the uranium concentration in the sludge to be approximately 790 pCi/g (12 mg/g) (Jackson, 1990). Fluoride concentrations in routine sludge samples taken in 1990 varied from 2.9 to 19.5 mg/L.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 12 area.

2.4.13 Unit 13 - Fluoride Sludge Storage Pond (Basin 1)
Unit 13, the Fluoride Sludge Storage Pond or Basin 1, was constructed in June 1981 to hold sludge collected from the Lime Neutralization Area (Unit 3). Prior to that time, the sludge had been buried in pits (Unit 15). Due to changes in regulations prohibiting the burial of sludge, Basin 1 was built. Unlike Basin 2 (Unit 12), Basin 1 is unlined. The

fluoride waste stream is routed from the lime treatment area to either Basin 1, Basin 2, or the Settling Basins (Unit 14). Basin 1 measures 190 feet wide by 130 feet long by 16 feet deep, with an estimated capacity of 186,800 cubic feet.

The Impoundments Report estimated the uranium concentration in the sludge to be approximately 790 pCi/g (12 mg/g) (Jackson, 1990). Fluoride concentrations in routine liquid samples taken in 1990 varied from 2.9 to 19.5 mg/L.

An internal SFC memorandum reported that in February 1990, Basin 1 liquid overflowed, resulting in a total overflow of 4,189 gallons. When the overflow was discovered, SFC immediately terminated pumping of sludge to the basin and began "sand bagging" the overflow area to prevent spreading of the release. The overflow terminated approximately forty (40) minutes after it began. The overflow streams were then sampled to determine uranium and fluoride content. The analytical results of these samples were not found in the historical review.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 13 area.

2.4.14 Unit 14 - Fluoride Settling Basins

Unit 14, the Fluoride Settling Basins, is located within the restricted area boundary and is bordered by the Fluoride Sludge Burial Areas (Unit 15) to the east and south, the Clarifier Pond Area (Unit 17) to the north, and Pond 2 (Unit 18) to the west. The unit consists of three (3) separate basins, each measuring fourteen (14) feet deep. The westernmost basin, known as the clarifier, measures 220 feet long by 85 feet wide, and the two eastern basins, called the settling basins, measure 190 feet long by 75 feet wide. The estimated capacities are 102,100 cubic feet (clarifier) and 46,800 cubic feet (each settling basin). The basins were built in 1971 and receive sludge from the Unit 12, 13, or 15 basins. The liquid flows through those units to the two (2) Unit 14 settling basins. Liquid from these basins is routed to Unit 14 clarifier, which then is routed to the Combination Stream Drain (Unit 27). None of the Unit 14 basins are lined.

The Impoundments Report estimated the uranium concentration of the sludge to be approximately 740 pCi/g (11 mg/g) (Jackson, 1990). Routine liquid samples taken in 1990 have detected fluoride concentrations ranging from 3.2 to 15.4 mg/L.

No releases were discovered relative to this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 14 area.

2.14.15 Unit 15 - Fluoride Sludge Burial Areas

Unit 15, the Fluoride Sludge Burial Areas, is located directly east and south of the Fluoride Settling Basins (Unit 14) and was used prior to 1981 for the burial of fluoride sludge. Unit 15 consists of three (3) distinct sections. The northern section measures 100 feet by 200 feet and was filled in two phases, known as the West Pit and the East Pit. Burial occurred in the West Pit on September 20, 1978, and in the East Pit on December 21, 1979. The second section of Unit 15, located directly south of the East and West Pits, measures 275 feet by 50 feet. It is divided into Pit 3 (the eastern section) and Pit 4 (the western section). Burial occurred in Pit 3 on December 31, 1980, and in Pit 4 on January 21, 1981. The third section of the unit, located at the southwest corner of Unit 15, is currently used for the retention of sludge. It has a capacity of 69,000 cubic feet. None of the Unit 15 areas are lined.

An analysis compiled by SFC in January 1985 of waste burials included fluoride sludge samples taken from each burial authorization. The analytical results indicated that a total

of 96,830 cubic feet of fluoride sludge had been buried, with a total activity of 1.5 Curies.

No releases were discovered relative to this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 15 area.

2.4.16 Unit 16 - Yellowcake Sump Area

Unit 16, the Yellowcake Sump Area, was built in 1980 and is located inside the restricted area boundary, directly south of the Yellowcake Storage Pad (Unit 21). The unit is constructed of concrete and measures 75 feet by 75 feet by eight (8) feet deep. It receives surface water runoff from the Yellowcake Pad (Unit 21).

Analyses of the yellowcake sump contents indicated that uranium was present in the yellowcake sump between August and November 1990 in concentrations ranging from <0.01 to 0.025 g/L. No information was located during the historical review concerning releases or remediations in this unit. On October 4, 1990, during clean out activities, elevated uranium levels were found in sludge, according to an SFC contact report. The sump area has been incorporated into the restricted area.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 16 area.

2.4.17 Unit 17 - Clarifier Pond Area

Unit 17, the Clarifier Pond Area, was built in 1980 and consists of four (4) clay and hypalon-lined ponds, each measuring 250 feet wide, 200 feet long and thirteen (13) feet deep. The ponds are located directly north of the Fluoride Settling Basins (Unit 14) within the restricted area boundary and receive raffinate from the solvent extraction process. The raffinate is treated to remove metals and radionuclides and then transferred by above ground pipeline south to the Ammonium Nitrate Lined Ponds (Unit 24).

The 1985 Impoundments Report estimated uranium concentrations in Unit 17 sludge to be <270 pCi/g (<400 µg/g) (Jackson, 1990).

All four basins have underdrain monitoring systems. Because of SFC concern for potential leaks, as of October 1990, automated underdrain pumping systems were installed.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 17 area.

2.4.18 Unit 18 - Pond 2

Unit 18, Pond 2, was constructed in June 1971 and first used in October 1971, according to a 1973 SFC memo titled "History of Pond 2". Pond 2 was not in service while modifications to the dikes were made in August 1973, but its use continued thereafter until prohibited by changes in regulations in 1980. Subsequently, a remediation plan was developed for Pond 2 and is being implemented. The pond measures 300 feet wide by 700 feet long by 18 feet deep, with an estimated total capacity of 2,963,000 cubic feet. The pond lies directly west of the Clarifier Pond Area (Unit 17) and the Fluoride Settling Basins (Unit 14), spanning the length of both units. Unit 18, which contained raffinate and sludge by-products, was taken out of service in the early 1980s.

The SFC Impoundments Report established uranium concentrations in Unit 18 of <270 pCi/g (<400 µg/g) (Jackson, 1990). SFC documents indicate that seepage from Pond 2 was first detected in 1974. Therefore, extensive characterization of Unit 18 material has occurred from 1974 to the present.

Seepage from Pond 2 was originally believed to be from a narrow strip (less than thirty feet wide) in the middle of Pond 2. In an effort to minimize the seepage, SFC spread 25 tons of quicklime in the south end and one (1) ton of

bentonite in the southeast quadrant of the pond in 1974. This treatment was not successful.

By 1977, there were a total of 19 monitor wells in the shallow zone around Pond 2. Weekly sampling of these wells was conducted. For the year of 1977, the samples showed elevated nitrate concentrations of up to 1550 mg/L. In a 1978 report to the NRC, SFC estimated the rate of leakage to be 0.3 ml/min.

Between 1977 and 1984, eight new shallow wells were added. In 1982 bentonite was injected into the Pond 2 dike on the ravine side (west) in an attempt to arrest further seepage. When this action failed, the culvert in the ravine dike was plugged. In 1984 an electromagnetic (EM) survey was performed in an attempt to locate groundwater plumes and determine the flow of the seepage. The EM survey was successful in delineating areas where pond leakage was occurring; however, the EM survey was hampered by interference from power lines, fences and other extraneous objects. Subsequently, two (2) collection trenches and accompanying flow barrier slurry walls were installed.

Submersible electric sumps were installed in the collection trenches to pump the collected water back to Pond 2. A 1984 SFC report concluded that a maximum leakage rate of 1.76

gallons per day (gpd) was occurring, compared to 0.06 gpd reported in 1977.

Groundwater analyses conducted in 1988 showed that nitrate concentrations had increased from 900 to near 4400 mg/L. The leakage rate from Unit 18 was calculated at 0.32 gpd.

In a meeting with the OWRB in June 1989, SFC indicated that Pond 2 was the major contributor to exceedances at Outfalls 008 and 004. An SFC Remediation Plan, developed with the NRC prior to the June 1989 meeting with OWRB, called for the removal of Pond 2 sludge. Contaminated soils were to be removed and the pond covered with a synthetic liner to eliminate rainwater intrusion and subsequent migration. SFC is continuing to implement this plan and expects work to be completed in 1991.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 18 area.

2.4.19 Unit 19 - Ditch West of Pond 2

Unit 19 consists of a ditch located west of Pond 2 and lies outside the restricted area boundary. The exact dimensions of the area were not determined during the historical review.

The ditch was used for stormwater drainage until, according to SFC documents, the culvert was plugged in 1982.

In the spring of 1977, testing of soil samples collected from the Unit 19 area indicated nitrate concentrations ranging from 20 to 10,000 $\mu\text{g/g}$. Lab data from 1982 showed nitrate levels in soil ranging from <20 to 460 $\mu\text{g/g}$ and uranium levels ranging from 0.37 to 196 $\mu\text{g/g}$. Nitrate seepage from Pond 2 (Unit 18) has been acknowledged by SFC as a consistent problem since 1974.

According to an environmental report prepared by SFC in June 1984, a small, stained area was observed in the ditch area in October 1976. In August 1977 absorption cups (lysimeters) were installed in the stained area above the sandstone, and sandstone samplers were placed just below the sandstone. A collection/pump-back system was also installed to collect and return seepage to Pond 2 (Unit 18). A study conducted from June 1979 to 1980 showed elevated nitrate levels in groundwater from Pond 2 seepage. In the summer of 1982, an attempt was made to control the Pond 2 surface water release point (thought to be a culvert in the ravine dike) by covering the ravine with soil and sprigging the area. Bentonite was injected to stop seepage, but the bentonite failed to adequately seal the release point. The culvert was then plugged, with no further release. An underdrain system was

installed into the ravine in March of 1990 with a pump system and the ravine was backfilled.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 19 area.

2.4.20 Unit 20 - Contaminated Equipment Storage

Unit 20, the Contaminated Equipment Storage area, is also known as the "Boneyard" and bounds the north side of the Contaminated Equipment Burial Area (Unit 5) within the restricted area boundary. The area measures 355 feet on the north, 203 feet on the west, 230 feet on the south and 103 feet on the east. The unit has operated from plant start-up in 1969 to the present time for the storage of contaminated equipment. Included in the area is a trench which was dug for contaminated equipment burial but used only briefly. Collected water was pumped out of the unused portion of the trench, and the trench was filled with clean soil; however, the historical review did not determine the date of these activities.

Soil analyses from 1985 detected uranium concentrations ranging from 57 to 1525 $\mu\text{g/g}$ in the 0 to 3 inch interval and 30 to 3425 $\mu\text{g/g}$ in the 3 to 6 inch interval. Analysis of the

"boneyard" sump contents completed in 1990 indicated uranium concentrations of 0.01 to 0.02 g/L.

Monthly analysis is performed on the "boneyard" sump contents. No releases were discovered for this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 20 area.

2.4.21 Unit 21 - Yellowcake Storage Pad

Unit 21, the Yellowcake Storage Pad, is primarily used for storage of uranium yellowcake contained in 55-gallon drums. According to SFC personnel, Unit 21 is also presently used for some contaminated equipment and soil storage. The unit now measures 550 feet by 370 feet and has existed since plant start-up in 1970. The pad was concreted in 1979 and lies within the restricted area boundary north of the Decorative Pond (Unit 26) and west of the MPB (Unit 1).

No releases were discovered for this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 21 area.

2.4.22 Unit 22 - Ditch From UF₆ Cylinder Cool Down Area

The UF₆ Cylinder Cool Down Area, located inside the restricted area boundary, is used to prepare the UF₆ for shipping. After cylinders are filled with liquid UF₆, they are moved to the cool down area until the UF₆ solidifies. Unit 22, which is located immediately east of the cool down area outside the restricted boundary, was identified as a general investigation area due to its proximity to and associated potential impact from licensed material present in the cool down area.

Unit 22 includes the ditch from the UF₆ cool down area and the adjacent electrical substation. The ditch is located to the east of the MPB (Unit 1) outside the restricted area boundary and carries surface water runoff, as discussed in Section 4.0 of this report. The substation lies directly north of the ditch. No records indicating the date of construction of the substation were found during the investigation. No releases were discovered for this unit.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 23 area. Unit 22 was a part of the Facility-Wide Surface Water Investigation described in Section 4.0.

approximately 400 feet by 400 feet by 25 feet deep. The ponds are clay and hypalon-lined. The volumes (as reported in the SFC Impoundments Report) and dates of construction are as follows:

Pond 3E: 2,166,000 cubic feet, September 1978
Pond 3W: 2,213,000 cubic feet, September 1978
Pond 4: 2,235,000 cubic feet, February 1980
Pond 5: 2,178,000 cubic feet, December 1984
Pond 6: 2,142,000 cubic feet, April 1985

The material stored in the four (4) ammonium nitrate ponds consists of fertilizer from the Unit 17 clarifiers. Data collected in 1990 from Unit 24 contents indicated ammonium nitrate concentrations of <1 lb/gal and radium-226 concentrations of <2 pCi/L.

No releases were discovered for this unit. The fertilizer is analyzed frequently, and all five (5) ponds have underdrains and monitor wells.

2.4.25 Unit 25 - Areas of Operational Spills

Unit 25, the Operational Spills Areas, is the raffinate treatment area located between the Clarifier Pond Area (Unit 17) and the Yellowcake Storage Pad (Unit 21). The raffinate treatment area was built in the fall of 1970. The definite

2.4.23 Unit 23 - Contaminated Soil from 1986 Release

Unit 23, Contaminated Soil from the 1986 Release, consists of approximately 457 cubic yards of soil which was contaminated from a UF_6 release in 1986. As a remediation action, the sod was stripped from the Sequoyah Facility front lawn, and the soil was excavated, placed in its present position, and totally encapsulated with a hypalon cover and liner on January 9, 1986. The unit is a restricted area north of Pond 2 (Unit 18) and is surrounded by a chain link security fence.

Analysis of the contaminated soil stored at Unit 23 has verified the presence of uranium. Soil samples taken in 1986 indicated average uranium concentrations of 249 $\mu\text{g/g}$ and average fluoride concentrations of 210 $\mu\text{g/g}$.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 23 area.

2.4.24 Unit 24 - Ammonium Nitrate Lined Ponds

Unit 24, the Ammonium Nitrate Lined Ponds, consists of four ammonium nitrate fertilizer ponds with one raffinate sludge pond. These ponds are located south of the Fluoride Sludge Burial Areas (Unit 15) outside the main restricted area boundary. However, the raffinate sludge pond is a restricted area and is appropriately fenced. All ponds measure

boundaries of the unit were not determined during the historical review and were defined by SFC based on the known history of spills in this vicinity.

In 1982, SFC reported to the NRC that an estimated 3000 gallons of raffinate were released when a transfer pipeline from the solvent extraction area to Unit 17 ruptured. The material was released to a drainage ditch located northwest of the Sequoyah Facility. Uranium concentrations of the released material were reported to be 0.11 g/L. Water sample results showed 40 mg/L uranium in the north drainage ditch at the restricted area fence, 60 mg/L at the property line fence, and <7 µg/L at the north ditch outfall. Downstream uranium concentrations ranged from <7 µg/L to 58 µg/L. The ruptured line was immediately repaired, along with the breach in the containment ditch which allowed the spill to enter the drainage ditch.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 25 area.

2.4.26 Unit 26 - Decorative Pond

Unit 26, the Decorative Pond, is located south of the MPB (Unit 1) outside the restricted area boundary and was built

around the time of plant start-up. The pond is decorative only and has a capacity of 75,000 cubic feet.

SFC personnel believe that no licensed material is typically present in Unit 26 on a consistent basis. However, after the 1986 incident, analysis of Unit 26 contents indicated uranium levels of 5910 $\mu\text{g/L}$ and fluoride levels of 10.2 mg/L. After the 1986 incident, 2000 gallons of water was transferred from Unit 26 to Unit 17 with the approval of the on-site NRC representative.

Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 26 area.

2.4.27 Unit 27 - Combination Stream Drain

The Combination Stream Drain was not initially identified as one of the operational units requiring historical file review, but was added sometime later during the course of the FEI. However, the scope of the FEI work on this unit is so extensive that an entire section of this report, Section 6.0, has been devoted to the description of the Combination Stream Drain characterization and investigation activities.

Several corrective actions relative to the Combination Stream Drain are described in Section 9.5.

2.4.28 Unit 28 - Present Lime Neutralization Area

Unit 28, the Present Lime Neutralization Area, which was not identified in the initial stages of the FEI, was determined during the FEI to have a potential to release licensed material. Unit 28 is a curbed area approximately 23 feet wide and 30 feet long, located in the far northeast corner of the Unit 21. The unit was constructed in 1970 and originally consisted of four (4) tanks used to neutralize both raffinate and hydrogen fluoride (HF) through the use of lime. The raffinate treatment equipment was removed circa 1973, and presently only the HF neutralization process continues in the area.

The original tanks in Unit 28 included a 2200-gallon lime storage tank, a 1000-gallon lime slurry tank, a 450-gallon raffinate neutralization tank, and a 3000-gallon HF neutralization tank. The only tanks currently remaining in the area are the lime storage and HF neutralization tanks. SFC drawings indicate the streams entering the neutralization process from the Anhydrous HF (AHF) Vaporizer Sump, HF Scrubber, and the Laboratory Sump Pump. The output stream from Unit 28 can be valved to flow either to Unit 12 or Unit 14.

SFC has initiated an engineering request to improve stability of the curbing and foundation around Unit 28.

No record of releases or remediations were discovered in the research of Unit 28. Section 7.0 of this report describes results from the FEI soil investigation, groundwater investigation activities and upgrading of the monitoring well system in the Unit 28 area.

3.0 FACILITY PROCESS FLOW AND PROCESS STREAM CHARACTERIZATION INVESTIGATION (TASK 2)

3.1 Introduction

3.1.1 Products and Production Rates

The primary process at the Sequoyah Facility is the conversion of uranium ore concentrate to UF_6 to be used as feed material for enrichment facilities.

A byproduct of the uranium conversion process at the Sequoyah Facility is liquid ammonium nitrate fertilizer. SFC produces approximately 7 million gallons of fertilizer per year.

Depleted uranium tetrafluoride (DUF_4) is produced from depleted uranium hexafluoride by a separate processing facility located to the north of the MPB.

3.1.2 Brief Summary of UF_6 Process

The UF_6 production process is summarized in Drawing 1. Most of the uranium received at the Sequoyah Facility for processing is in the form of dry uranium ore concentrate, commonly referred to as "yellowcake". Yellowcake is received and stored in 55 gallon drums. Uranium is also received and stored in slurry form in 55 gallon drums or tankers. After sampling the raw materials to determine the uranium concentration, the raw materials are sent to "digestion" to begin processing.

The yellowcake and/or slurry is digested (dissolved) by nitric acid into solution to facilitate further refinement. The uranium is chemically converted to uranyl nitrate hexahydrate (UNH) during this process. The UNH solution is then sent to "solvent extraction" for purification.

During the solvent extraction process, UNH is extracted from the aqueous acid phase with an organic solvent. The impurities remain in the aqueous acid phase, or "raffinate", and the UNH is removed in the organic phase. The raffinate is further treated and refined to a high purity liquid fertilizer solution.

The purified UNH is returned to the aqueous phase by introduction of water, and the solvent is recovered and recycled for reuse in the extraction process.

Concentration of the uranium begins in the recompression evaporator with final concentration of uranium in the boildown tanks. After excess water is removed, the molten UNH is ready for "denitration".

The UNH is thermally decomposed to form uranium trioxide (UO_3) in the denitration process. Nitrogen and water are driven off in the form of nitrous oxides (NO_x) and water vapor. The nitric acid is recovered for reuse in the digestion phase.

The NO_x vapor is scrubbed prior to discharge to the atmosphere.

The UO_3 is chemically reduced to uranium dioxide (UO_2) in "reduction". The resulting UO_2 is a very porous solid which provides a large surface area for subsequent reactions with hydrogen fluoride (HF) in "hydrofluorination".

In hydrofluorination, HF vapor is reacted with the UO_2 to form solid uranium tetrafluoride (UF_4).

The final reaction in the production of UF_6 is "fluorination". The solid UF_4 is reacted with fluorine gas (F_2) to produce gaseous UF_6 .

During recovery, the process stream, containing gaseous UF_6 , is passed through refrigerated "cold traps" to remove the UF_6 by "freezing" it out of the process stream. The process waste gas stream passes through the cold trap while the purified UF_6 remains as a solid. When the cold trap contents have reached capacity, the cold trap is isolated and heated. A purified stream of UF_6 is thus produced and prepared for shipping.

The UF_6 is drained from the cold traps into cylinders. The UF_6 solidifies as it is cooled, and the product is shipped as a solid.

3.2 Scope and Objectives

The objective of the Sequoyah Facility process flow and process stream characterization investigation was to understand and characterize the unit operations and resulting process streams and waste streams, such that the information obtained could be used in developing Sequoyah Facility environmental investigation strategies and the subsequent evaluation of findings. To accomplish the objective, a thorough assessment of the entire Sequoyah Facility unit operation processes and process flow stream characteristics was necessary, as well as an understanding of the Sequoyah Facility water use in order to evaluate potential licensed material release paths and/or mechanisms.

A complete process flow diagram was developed and verified for the Sequoyah Facility to satisfy the requirement given in the FEI Plan submitted October 15, 1990. Each unit operation was identified and the process and waste streams characterized to identify the forms of uranium present. Characterization of the yellowcake was obtained. Other constituents with the potential for environmental release were also identified in the process flow diagram. The liquid and solid process waste streams and flow paths, and their relation to process operations, impoundments, and surface discharges, are identified on the process flow diagram. Underground utilities are discussed extensively in Section 5.0, Facility-Wide

Underground Utility Investigation. Surface water drainage in relation to Sequoyah Facility operations and waste streams is discussed in Section 4.0, Facility-Wide Surface Water Investigation.

3.3 Investigation Activities

3.3.1 Document Review

The initial action required to accomplish the objectives of this task was to conduct a thorough review of existing information concerning the SFC process of uranium conversion. Numerous written documents, including memoranda and internal correspondence from the SFC files, were reviewed in detail. Many of these documents were generated while SFC was owned and operated by the Kerr-McGee Corporation (1970-1988), while recent documents were generated by SFC under General Atomics ownership. An SFC prepared document entitled Uranium Hexafluoride Process was the primary reference document for this investigation. The document was prepared by SFC on August 23, 1989. Other documents which were significant sources of information were the SFC Operating Procedures.

Numerous SFC and Kerr-McGee drawings were reviewed which contained significant amounts of information about the process. Many of the drawings were utility drawings, and many were detailed process and instrumentation diagrams. Other documents contributing information to the investigation

include various data bases, draft water balances, and sample analyses compiled by SFC.

3.3.2 SFC Employee Interviews

Employee interviews were the primary source of information used to complete information gaps and resolve inconsistencies in the information obtained during the document review. Most of these interviews consisted of numerous, brief conversations with SFC technical staff. Two formal meetings with SFC personnel were conducted in which the process flow diagram was reviewed in detail by SFC employees. The first meeting occurred on April 3, 1991, and the second meeting occurred on May 8, 1991.

3.3.3 Field Verification

Field investigations were performed to verify the process flow diagram as it relates to the Combination Stream Drain. Field investigation consisted of visual observations identifying waste stream flow paths contributing to the Combination Stream Drain. The draft process flow diagram was submitted to SFC for in-house review and verification on May 24, 1991. The diagram is considered proprietary by SFC and is not presented in this report, but is discussed in detail in the following section. A simplified UF₆ process flow diagram is presented in Drawing 2.

3.4 Investigation Results

3.4.1 Detailed UF₆ Process Description

The process flow diagram shows process and waste streams associated with the conversion of uranium ore concentrate to UF₆. Emphasis has been placed on accurately identifying all waste stream sources and flow paths. The process is very complex and, for simplicity, some of the internal detail within each unit operation has been omitted from the diagram. However, all major process flow paths and all waste paths have been identified on the diagram in relation to the unit operations. The uranium compounds present at various points in the process are identified on the diagram as well as in Table 2. Other chemical constituents used in the process are also identified on the diagram and in Table 3. A typical chemical analysis of yellowcake is presented in Table 4.

With the exceptions of some cooling water lines and the hydrogen fluoride scrubber wastewater line, process lines are generally located above ground on pipe racks and therefore do not directly intersect underground utility trenches. For further information on underground utilities, see Section 5.0, Facility-Wide Underground Utility Investigation.

3.4.2 Fertilizer Production

A byproduct from the process of converting uranium concentrate to UF_6 is a high purity liquid ammonium nitrate fertilizer. The fertilizer originates as raw raffinate from the solvent extraction process. Solvent extraction is a separation process in which uranyl nitrate is purified by removing it from the aqueous solution with a solvent. The remaining aqueous solution is referred to as raffinate. The solvent used in this unit operation is a mixture of tributylphosphate and n-hexane. The purified uranyl nitrate is returned to the water phase, or reextracted, in the pulse column. The purified uranyl nitrate hexahydrate solution is then further processed to produce UF_6 .

The raw raffinate consists of a 6 to 10 percent mixture of dilute nitric acid and water. The acidic condition causes the metal impurities, which were removed during solvent extraction, to remain in solution. Molybdenum and radium are two of the metal impurities which are monitored. In addition, less than 0.01 g of uranium passes through in the raw raffinate.

The raw raffinate is pumped to a series of four "raffinate clarifiers" where chemical treatment and precipitation of metal impurities, as sludge, occurs. Anhydrous ammonia is slowly added to the first raffinate clarifier, neutralizing

the raw raffinate. Metallic impurities precipitate and settle as the pH is further raised. The resulting ammonium nitrate is treated with barium chloride as it is transferred to the other raffinate clarifiers. Barium chloride addition produces a precipitate that removes any remaining radium from the raffinate. The resulting byproduct is a fertilizer grade ammonium nitrate solution. The clarified ammonium nitrate fertilizer is then pumped to one of four (4) fertilizer holding ponds until it can be utilized on SFC-owned property.

Sludge produced by raffinate treatment contains a recoverable amount of uranium. The sludge is allowed to accumulate in the raffinate clarifiers.

Presently, the sludge from the clarifiers is pumped to a gravity settling tank. Concentrated sludge is removed from the bottom of the tank, mixed with polymers and fed to a centrifuge. The resulting concentrated sludge typically contains 25 to 50 percent solids. The concentrated sludge is pumped into tank trucks that transport it to an off-site uranium mill to recover the uranium. The extracted liquor is recycled to the raffinate clarifiers for additional processing.

3.4.3 Waste Streams

3.4.3.1 Introduction

For the purpose of this section, waste streams are defined as any solids (sludges) or liquids (wastewaters) produced in the process which are not recoverable as a product, byproduct or raw material. Seven (7) sources of waste streams have been identified at the Sequoyah Facility. It is also emphasized that surface water runoff or discharge to a permitted outfall is not defined as wastewater herein, but is recognized as a potential migration pathway for licensed material (see Section 4.0, Facility-Wide Surface Water Investigation, for assessment of surface water). The waste streams include:

1. Hydrogen fluoride scrubber wastewater treated in the fluoride treatment system and the resulting sludge,
2. Sludge produced in the fluorine production cells,
3. Overflow or excess cooling water,
4. Steam condensate,
5. Sedimentation basin blowdown and water softener blowdown from the potable water treatment system,
6. Sanitary wastewater, and
7. Laboratory wastewater.

Each waste stream will be discussed in the following sections. The characteristics and flow rates of waste streams and surface runoff which are discharged to the Combination Stream

Drain are presented in Section 6.0, Combination Stream Drain Investigation.

3.4.3.2 Fluoride Treatment System Waste Streams

The hydrogen fluoride (HF) scrubber wastewater originates from the off-gas scrubber which removes hydrogen fluoride (HF) vapors from several process gas streams. Process gasses exiting the secondary cold traps during UF_6 recovery consist of a small amount of fluorine, traces of UF_6 , and non-condensables, such as nitrogen. Nitrogen enters the system at a variety of points, such as shaft seals and instrument purges. Gasses are continuously pumped from the secondary cold traps to the hydrogen/fluorine burner. The hydrogen/fluorine burner also receives hydrogen gasses from the fluorine production cell room. The combined gasses are burned to produce HF and water vapors. Flue gas from the hydrogen/fluorine burner and the DUF_4 waste gas burner enters the off-gas scrubber system, forming a weak HF. The scrubber also receives weak HF off-gasses/condensed liquids from hydrofluorination and vapors from vent systems for the anhydrous HF storage tanks.

The HF scrubber system consists of a countercurrent water scrubber which is fed with softened, potable water. The weak HF present in the scrubber feed gasses is absorbed by the water spray, forming a weak aqueous HF wastewater stream. The

non-condensable gasses are vented from the scrubber to the atmosphere.

The weak HF, i.e., HF scrubber wastewater from the scrubber system, is piped to the fluoride treatment system where it is treated with lime to neutralize the acid. The neutralization also results in the precipitation of fluoride ions as calcium fluoride. The wastewater is passed through fluoride sludge settling basins before being polished in the fluoride clarifier basin. Settled sludge is managed in three (3) fluoride sludge holding basins. The clarified wastewater is piped to manhole CD-3 where it is discharged to the Combination Stream Drain and subsequently to surface waters through permitted Outfall 001.

3.4.3.3 Fluorine Production Waste Stream

The fluorine production process also produces a waste stream, which is sludge from the fluorine production cells. On-site fluorine production supplies the elemental fluorine necessary to convert UF_4 to UF_6 through the fluorination reaction. Fluorine is produced at the Sequoyah Facility by electrically decomposing HF into elemental fluorine and hydrogen in potassium bifluoride electrolyte. The reaction is carried out in jacketed tanks known as cells. The byproduct hydrogen is burned in the hydrogen/fluorine burner.

Cell maintenance is periodically required to reestablish the efficiency of the electrolytic reaction. Sludge buildup in the cell is removed during cell rework. The waste sludge is drummed and sent to a permitted hazardous waste disposal site. The sludge contains arsenic as a result of arsenic impurity in the HF supply. Scale buildup in the HF vaporizer contains less than one percent arsenic, copper, and nickel.

3.4.3.4 Cooling Water System Waste Streams

There are two separate cooling water systems utilized at the Sequoyah Facility. Both systems produce wastewater streams. The first type of cooling water system is once-through cooling water. The second type of cooling system is recirculated cooling water. Each of these two (2) cooling systems are discussed in the following paragraphs. The types of cooling water system used in the various units in the process are shown on Drawing 2. Routing of cooling water at the Sequoyah Facility is complex.

Untreated water from Lake Tenkiller is used as once-through cooling water for the Sequoyah Facility. The once-through cooling water system is referred to as the "cooling water emergency" (CWE) water. Originally, all uses of CWE water were for cooling of non-uranium containing media. Although most uses of CWE water are still for cooling non-uranium containing media, there are a few heat exchangers which have

the potential to contact uranium-containing media. Two (2) of these are the hydrofluorination off-gas condenser and the wet-scrub heat exchanger for denitration.

CWE water is used extensively throughout such Sequoyah Facility operations as: digestion, solvent extraction, denitration, boildown, nitric acid recovery, hydrofluorination, and in air compressors, pump seals, and rectifiers. CWE water is returned to the cooling tower make-up manway and subsequently to the cooling tower equalization basin. The equalization basin can provide makeup water to the "hot-side basin" under certain conditions, such as circulation pump start-up or shutdown, but under normal operation receives overflow from the "hot-side basin". Under either condition, the cooling tower equalization basin will continuously discharge excess water to the Combination Stream Drain and subsequently through permitted Outfall 001.

In addition to use as a cooling water, there are several other uses for CWE water. The uses occur before the CWE water has been used as cooling water. Other uses for CWE water are decontamination and cleanup, general washdown throughout the Sequoyah Facility, and makeup water for digestion or in other units as needed.

The second cooling water type, recirculating cooling water or "cooling water supply" (CWS), is circulated through the cooling tower continuously. As mentioned earlier, the cooling tower equalization basin can provide make-up water to the cooling tower hot-side basin under certain conditions, such as circulation pump start-up or shutdown, but normally receives overflow from the hot-side basin. From the cooling tower hot-side basin, the cooling water enters the cooling tower. The CWS water is then distributed to the MPB, SX building, and DUF₄ building.

CWS water is used for many cooling purposes. Most CWS water is used to cool uranium-containing media by way of cooling coils in heat exchangers. CWS water is also used for cooling in the Sequoyah Facility for digestion, solvent extraction, boildown, fluorine generation, fluorination, heating and air conditioning, air compressors, rectifiers, refrigeration, and in the DUF₄ plant.

The cooling water returning to the cooling tower hot-side basin is referred to as "cooling water supply return" (CWSR) water. High pressure steam return lines from some of the solvent extraction and digestion steam lines also discharge condensate into the CWSR water prior to discharge into the hot-side basin. As mentioned previously, certain CWE water is also discharged into the CWSR water and hot-side sump.

Therefore, the CWS system typically has an excess of water and normally overflows into the equalization basin.

The cooling tower hot-side basin has the capability to periodically blowdown to prevent excessive salt build-up in the cooling water. When necessary, the blowdown operation is manually performed by a valve system. During normal operation, blowdown is not required due to overflow from the hot-side basin. The blowdown can be discharged to the North Ditch or the Combination Stream Drain and subsequently through permitted Outfall 001.

3.4.3.5 Steam System Waste Streams

High pressure steam from the boilers is distributed throughout the Sequoyah Facility. Steam is used for heating, cooling, and ejectors. The used steam is managed in a variety of ways, depending on the original steam use. Each steam handling method will be discussed in the following paragraphs.

High pressure steam used in the Anhydrous Hydrogen Fluoride (AHF) superheater is discharged into the MPB roof drains and subsequently to the Combination Stream Drain and permitted Outfall 001.

High pressure steam used in the boildown tanks, fluorination, heating, tracing and miscellaneous facility services, and some steam in solvent extraction is discharged to a hot well and subsequently used as boiler feed water. Therefore, this steam condensate does not discharge directly as wastewater.

The high pressure steam used in the recompression evaporator is discharged to the North Ditch and subsequently enters the Combination Stream Drain and permitted Outfall 001.

As mentioned in the previous section on cooling water systems, high pressure steam return lines from some of the solvent extraction and digestion steam lines discharge into the CWSR water prior to the hot-side basin of the cooling tower.

High pressure steam used in hydrofluorination and fluorination returns as super heated steam and is used along with excess high pressure steam to produce the low pressure steam. Low pressure steam is used throughout the Sequoyah Facility for various purposes. Some of the low pressure steam is used in heating, tracing, and miscellaneous facility services. This low pressure steam is returned to a hot well where the condensate is used as boiler feed. Also, some of the low pressure steam is used in the DUF_4 building, returned to the sanitary treatment plant and is subsequently discharged to the Combination Stream Drain and permitted Outfall 001. The

remaining low pressure steam is used in the fluorine cell rework, fluorine generation, fluorination, AHF vaporizer, UF₆ shipping, heating, tracing and miscellaneous facility services. This low pressure steam is discharged as low temperature steam condensate to the roof drain sewer and manhole CD-6 and subsequently through the Combination Stream Drain and permitted Outfall 001.

3.4.3.6 Potable Water Treatment System Waste Streams

The potable water treatment system is a source of wastewater. Raw water from Lake Tenkiller is treated and used for various purposes throughout the facility. Water from the lake enters the raw water basin before solids are removed in the sedimentation basin. The sedimentation basin blowdown is discharged to the North Ditch for settling and solids separation. The North Ditch ultimately discharges to the Combination Stream Drain to permitted Outfall 001. Following sedimentation, the water is chlorinated and passed through a sand filter. The treated potable water is then used for domestic purposes, lab purposes, and firewater storage. Water to be used as HF scrubber water and boiler feedwater passes through an additional water softening unit. Water softener blowdown is discharged to the roof drain sewer and into manhole CD-6 of the Combination Stream Drain and subsequently through permitted Outfall 001.

3.4.3.7 Sanitary Wastewater

Sanitary wastewater is normally treated in the sanitary treatment plant. Sources of sanitary wastewater include laboratories, restrooms, drinking fountains, showers, laundry and washrooms. Treatment consists of aerobic treatment and filtration. The wastewater can also be treated and/or held in the sanitary lagoon. After treatment, wastewater is discharged to the sanitary distribution box, then to manhole CD-9 of the Combination Stream Drain, and finally through permitted Outfall 001.

3.4.3.8 Laboratory Wastewater

Two (2) laboratories serve the Sequoyah Facility. The Environmental Lab is an off-site lab which performs most of the environmental analyses. Impacted wastewater and samples from the Environmental Lab are transported by truck to the raffinate clarifiers. A septic tank and lateral field are used at the Environmental Lab for nonimpacted rinsewater.

The second lab, the Process Lab, is located in the MPB and performs the process-related analyses. Process Lab wastes having significant uranium content can be reprocessed through the miscellaneous digester. Process Lab wastewater from sources such as sink drains, cooling water, and scrubber water is discharged into the HF scrubber water for lime treatment and subsequently discharged through permitted Outfall 001.

4.0 FACILITY-WIDE SURFACE WATER INVESTIGATION (TASK 1)

4.1 Introduction

4.1.1 Background

Surface water traverses the entire Sequoyah Facility and exits at well-defined outfalls. The surface water routes, discharge points, and monitoring program are discussed below. SFC currently has six (6) EPA National Pollutant Discharge Elimination System (NPDES) outfalls, five (5) of which are also Oklahoma Water Resources Board (OWRB) Waste Disposal Permit outfalls. The six (6) outfalls are identified by NPDES permit designations as: 01A, 001, 004, 005, 007, and 008. Outfall 01A, an NPDES permitted outfall, is treated sanitary wastewater only and discharges into the Combination Stream Drain. Outfall 001, known as the Combination Stream Drain, is discussed in detail in Section 6.0 of this report. The discharge from Outfall 001 is piped underground to receiving waters identified as ephemeral streams which flow into headwaters of the Robert S. Kerr Reservoir, as stated in the OWRB permit, attached in Appendix A.

In June 1990 SFC constructed a drainage ditch around the Sequoyah Facility that diverts all surface water runoff from the northern and western portions of the Sequoyah Facility into Outfall 008. This drainage ditch effectively eliminated separate discharges from Outfalls 004, 005, and 007. Although all three (3) are still NPDES and OWRB permitted outfalls,

these outfalls are classified as inactive and are not monitored by SFC.

In addition to the permitted outfall, SFC monitors two (2) additional monitoring points. These additional monitoring points are not new discharges, but are simply internal monitoring points by SFC and are not required by the OWRB or NPDES permits. Surface water discharging past these two (2) monitoring points, designated Outfall 009 and Outfall 010 by SFC, eventually arrives at receiving waters identified as ephemeral streams which flow into headwaters of the Robert S. Kerr Reservoir. These SFC outfalls are located southeast of the Decorative Pond (Outfall 009) and southeast of the Fluoride Settling Basins (Outfall 010).

The locations of the monitored outfalls and inactive outfalls are presented in Figure 12. This Figure also shows the general area in which the surface water investigation was conducted.

Throughout the years of SFC operation, a number of outfalls have been added to and deleted from the monitoring program. A summary of all past and present outfalls, the approximate location of each outfall, the purpose of each outfall, and the current outfall status is presented in Table 5.

4.1.2 NPDES and OWRB Permit Conditions

The NPDES permit, Permit No. OK0000191, became effective on November 15, 1988, and expires November 14, 1993. A copy of this permit is attached in Appendix B. The OWRB Waste Disposal Permit, OWRB Permit No. WD-75-074, became effective on October 1, 1988, was revised on December 13, 1988, and expires on September 30, 1993. A copy of this permit is attached in Appendix A. The monitoring requirements for each outfall, for both the NPDES and the OWRB permits, are summarized in Table 6. The discharge limitations for each outfall, for both the NPDES and OWRB permits, are summarized in Table 7. A discontinued outfall is no longer regulated by the OWRB and NPDES permits. The inactive outfalls no longer discharge since all flow is diverted to Outfall 008 for monitoring.

Effluent limitations and monitoring requirements for total uranium are not included in the NPDES nor OWRB permits since the Sequoyah Facility is regulated by the Nuclear Regulatory Commission (NRC), and uranium is a source material subject to NRC regulation. An EPA referenced memorandum states to the OWRB that according to the U.S. Supreme Court decision of June 1, 1976 (Train v. Colorado PIRG, No. 74-1270), the EPA has no authority to regulate discharges of nuclear waste material subject to regulation by the Atomic Energy Commission (AEC) or its successor, the NRC (Marusak, 1976). The discharge

limitation for uranium is contained in 10 CFR 20, Appendix B, Table 2 and is equivalent to 45 mg/L (CFR, 1991). This limit is applicable to all surface water outfalls.

4.1.3 Surface Water Environmental Investigation Areas

The area of investigation is generally the area occupied by the past and present operational units and coincides with the approximate 85-acre Sequoyah Facility operating area. The operational units are defined and discussed in Section 2.0. Some of these operational units contribute stormwater runoff directly to the surface water, while stormwater from most of the other operational units is routed to the Combination Stream Drain, known as Outfall 001. The operational units that contribute to surface water outfalls other than Outfall 001 are presented in Table 8.

4.2 Scope and Objectives

An initial objective of the surface water investigation was to develop a detailed understanding of flow paths of surface water at the Sequoyah Facility in order to identify potential licensed material pathways. After identification of potential pathways, a comprehensive surface water sampling plan was established for all surface water which exits the Sequoyah Facility to allow identification of areas potentially contributing significant concentrations of licensed materials to runoff.

Two (2) monitoring events were planned and implemented. Monitoring of the flow rate at monitoring sites was performed to estimate the loading of licensed material being transported by the surface water.

4.3 Investigation Activities

4.3.1 Initial Investigation and Planning

An aerial photograph of the Sequoyah Facility was taken on October 31, 1990, by Aerial Data Services of Tulsa, Oklahoma (Figure 2). Aerial Data Services then developed a topographic map with one foot contours from the aerial photograph. This topographic map was used for a variety of tasks, including analyzing flow patterns, identifying surface water pathways, choosing monitoring sites, and defining drainage sub-basins.

After analyzing flow patterns and identifying surface water pathways, monitoring sites were chosen by RSA and SFC personnel. Monitoring sites were developed to sample surface water from all major contributing areas and at the exit points from the Sequoyah Facility. The surface water pathways and monitoring sites were checked in the field, and slight location revisions were made based on field observations. A map showing monitoring sites and outlining drainage basins associated with these sites was developed from the topographic map. This map is presented in Drawing 3. The drainage basins contributing surface water to each monitoring site are also

defined on Drawing 3. Areas that do not contribute to a monitoring site either discharge into the Combination Stream Drain or, in the case of Units 17 and 18, which are impoundments, to the lined fertilizer ponds.

The flow paths are also defined on Drawing 3. Runoff from some drainage basins flow into other basins. Basins SW4, SW6, SW8, and SW10 are the basins which discharge from the Sequoyah Facility. The other basins contribute directly or indirectly to these four (4) basins.

The geometry at the monitoring sites varies from grass-lined channels to weirs to culverts. An understanding of the geometry and slope of each monitoring site was needed to estimate flows. The geometry of the channels was determined by a survey. In addition to cross-sections of the channels, elevations were taken upstream and downstream of monitoring sites to determine the channel slope. The configuration of each of the twenty (20) monitoring sites is described in Table 9.

In accordance with the FEI Plan, two (2) sampling and flow measurement events were conducted. The analytical parameters selected as the test parameters for the surface water runoff investigation were fluoride, total uranium, nitrate (as N), pH, and specific conductivity. After review of the test data,

selected samples were analyzed for gross alpha, gross beta, and radium-226, also in accordance with the FEI Plan.

4.3.2 Surface Water Sampling

Samples and measurements were taken manually by SFC personnel during two (2) different rainfall events. Rainfall during these events was sufficient to produce runoff at all monitoring sites. The first sampling event occurred on January 15, 1991, with rainfall beginning at 4:30 a.m. Sampling started at 10:00 a.m. and ended at 12:14 p.m. The second sampling event occurred on March 1, 1991, with rainfall beginning at 5:00 a.m. Sampling began at 9:55 a.m. and concluded at 1:20 p.m. Samples were taken by SFC personnel and analyses were performed by the SFC on-site laboratory. Gross alpha, gross beta, and radium-226 were analyzed by Barringer Laboratories Inc., of Golden, Colorado.

Two (2) rainfall gauges exist on the SFC property, one at the south guard house and one at the MPB. Rainfall is recorded daily for each gauge. A listing of the amount of rainfall in inches and for the period of time between December 16, 1990, and March 2, 1991 is presented in Table 10.

There is a difference in the amount of rainfall recorded for the guard house and MPB, which partially results from difference in the time at which the rainfall amount is recorded. Rainfall at the guard house is recorded every day at 12:00 a.m. while the rainfall at the MPB is recorded every day at 7:00 a.m. The rainfall recorded for the first sampling event was 0.74 inches at the guardhouse and 0.32 inches at the MPB. The rainfall recorded for the second sampling event was 0.55 inches at the guardhouse and a total of 0.43 inches at the MPB, over a 26-hour period beginning at 5:00 a.m. on March 1, when the rainfall began, and ending at 7:00 a.m. on March 2, 1991, when the rainfall was measured the following day. The average rainfall amounts are 0.53 inches and 0.49 inches for the January and March events, respectively.

4.4 Investigation Results

4.4.1 Sampling Event No. 1 - January 15, 1991

Flow rates were calculated using Manning's Equation for open channel flow for all monitoring sites except the weirs (Chow, 1959). The flow through the weirs was calculated using the equation provided by the weir manufacturer. The flows calculated for each monitoring site are instantaneous flows referred to as point flows. A drainage basin for each monitoring site has been topographically defined and is presented in Drawing 3. The point flow at a monitoring site results from surface runoff from the monitoring site's

drainage basin plus the upstream drainage basins. For simplicity, herein, the drainage basin corresponding to a monitoring site will be referred to with the same symbol used for the monitoring site (e.g., monitoring site SW1 and its drainage basin will both be designated SW1). The point flow rates calculated for Event No. 1 are presented in Table 11. The flows measured vary from 20.2 to 3462.5 gallons per minute (gpm).

As appropriate, constituent concentrations in surface water samples can be compared to the discharge limits, the SFC environmental action levels (EAL), and other water quality criteria. The fluoride concentrations obtained during Event No. 1 are presented in Table 11. These concentrations ranged from 0.7 mg/L to 2.9 mg/L. The maximum allowable fluoride concentration stated in the OWRB discharge permit is 1.6 mg/L. There is no surface water discharge limit for fluoride in the NPDES permit. However, the EPA Maximum Contaminant Level (MCL) for fluoride in drinking water is 4.0 mg/L. From Table 11, all concentrations measured during Event No. 1 (e.g., maximum Event No. 1 fluoride concentration = 2.9 mg/L) were well below the MCL of 4.0 mg/L. Four monitoring sites, SW5, SW6, SW10, and SW16, had fluoride concentrations above the SFC EAL of 1.6 mg/L. The concentration at monitoring site SW10 (2.3 mg/L), which is also Outfall 008 and is the only permitted outfall, exceeded the OWRB discharge limit (1.6

mg/L), but was well below the MCL. Overall, the fluoride concentrations detected in Event No. 1 are low and do not pose significant environmental concern. The drainage areas which are the sources of the measurable fluoride concentrations are presented in Figure 13.

Based on the physical boundaries of the drainage basins and the location of the operation units (which are presented in Figure 6), in relation to the fluoride concentrations observed, the potential unit sources of the measurable fluoride appear to be Unit 5, Unit 15, Unit 18, and/or Unit 23. From historical data, which is summarized in Section 2.0, it is known that Unit 15 has a total of 96,830 cubic feet of fluoride sludge placed within three (3) unlined pits. Also, a 1986 UF₆ release impacted approximately 457 cubic yards of soil with an average fluoride concentration of 210 µg/g. This soil was placed in Unit 23 but is encapsulated in high density polyethylene and is unlikely to be a source. No documented history of fluoride presence was discovered for Units 5 or 18.

The maximum limit on nitrate concentration in the SFC OWRB discharge permit is 20.0 mg/L. The NPDES permit does not have a discharge limit for nitrate at surface water outfalls. The nitrate concentrations from Event No. 1 ranged from 0.6 mg/L to 57.6 mg/L. Only four monitoring sites (SW9, SW12, SW13, and SW17) of the twenty (20) monitoring sites had nitrate

concentrations above the SFC EAL of 20.0 mg/L. The drainage areas that are potential sources of the nitrate are presented in Figure 14. There is no correlation with the drainage areas associated with measurable fluoride concentrations (Figure 13). The nitrate concentration at SW10 (12.8 mg/L), which corresponds to permitted Outfall 008, was well below the SFC EAL (20 mg/L) and the OWRB discharge limit. There are no monitoring sites that exit the Sequoyah Facility operating area that had concentrations above the Sequoyah Facility EAL.

The potential sources of nitrate appear to be Unit 8, Unit 11, and/or Unit 18. From historical information documents referenced in Section 2.0, in a June 1989 meeting of SFC and OWRB, it was agreed that Unit 8 contributes to nitrate discharge concentrations at Outfall 008. In the same June 1989 meeting, SFC indicated that Unit 18 was the major contributor to nitrate levels at Outfall 008 and Outfall 004. There is no history of elevated nitrate levels noted for Unit 11.

The maximum permissible concentration (MPC) for uranium in effluents to unrestricted areas is governed by NRC and is equivalent to 45.0 mg/L (45,000 $\mu\text{g/L}$). The uranium concentrations for Event No. 1 ranged from < 5.0 $\mu\text{g/L}$ to 7860 $\mu\text{g/L}$. There were no surface monitoring sites with uranium concentrations above the NRC MPC. Concentrations at four (4)

monitoring sites (SW7, SW11, SW14, and SW16) exceeded the SFC EAL for uranium of 225 $\mu\text{g/L}$ (0.225 mg/L). Monitoring site SW14, which is downstream from SW16, and site SW16 (see Figure 15) uranium concentrations were 6840 $\mu\text{g/L}$ and 7860 $\mu\text{g/L}$, respectively. Monitoring site SW11 is downstream of the other sites (SW7, SW14, SW16) and the data indicates (weighted averages) drainage area SW11 was not a significant source of the uranium measured at SW11 during Event No. 1. Monitoring site SW7 uranium concentration (227 $\mu\text{g/L}$) was not significantly above the SFC EAL for uranium (225 $\mu\text{g/L}$). Both drainage area SW14 and SW16 are sources of the elevated concentrations of uranium as presented in Figure 15. It is significant to note that at the permitted Outfall 008 (SW10) and all other Sequoyah Facility exit monitoring sites (SW4, SW6, and SW8, Drawing 3), uranium concentrations were well below the Sequoyah Facility EAL of 225 $\mu\text{g/L}$. Finally, there is no correlation with the drainage areas associated with measurable nitrate concentrations.

The potential sources of uranium appear to be Units 5, 10 and/or 11. Historical research for Unit 5 indicates estimated total uranium content in Unit 5 to be more than 1000 kilograms. However, the licensed material at Unit 5 is below grade and there is no apparent migration pathway to surface water. Soil sampling from 1985 indicates uranium levels up to 3500 $\mu\text{g/g}$ were measured in Unit 10. Analysis of water samples

taken in 1985 from Unit 11 detected uranium concentrations ranging from 117 to 10,970 $\mu\text{g/L}$.

The effluent limitation for radium 226 from 10 CFR 20 is 30 pCi/L. The SFC EAL for surface water is 3 pCi/L. Three surface water samples were analyzed for radium 226, and results were all considerably below 30 pCi/L and below 3 pCi/L as presented in Table 11, even through the range of associated uranium for the same samples is from $<5.0 \mu\text{g/L}$ to 7,860 $\mu\text{g/L}$, the maximum concentration. Therefore, it can be inferred with significant confidence that the effluent limitation for radium is not exceeded at the Sequoyah Facility.

There are no discharge limits for gross alpha or gross beta. However, an SFC EAL in surface water for gross alpha of 15 pCi/L has been established. Two (2) of the samples (from monitoring sites SW16 and SW18) had gross alpha concentrations above the EAL. The maximum gross alpha and gross beta concentrations measured correspond to the maximum uranium concentrations measured. Also, there is good correlation between the other two (2) gross alpha and gross beta concentrations and the uranium concentrations (Table 11). Therefore, uranium appears to be a good indicator parameter for assessing the gross alpha and gross beta parameters.

The pH of discharged water is limited (by the OWRB and NPDES permits) to a range between 6.0 and 9.0 standard units for discharge from the Sequoyah Facility. The pH at all twenty (20) monitoring sites was within the allowable range for both events.

4.4.2 Sampling Event No. 2 - March 1, 1991

The flow rates measured during Event No. 2 were all lower than the rates during Event No. 1 because the rainfall amount was less. The flow rates measured for Event No. 2 are presented in Table 12. The flows measured vary from 0.2 to 941.5 gpm.

The Event No. 2 fluoride concentrations, which are presented in Table 12, ranged from 0.6 mg/L to 1.8 mg/L. Only monitoring site SW15 (1.8 mg/L) fluoride concentration slightly exceeded the SFC EAL of 1.6 mg/L. Although the fluoride concentration during Event No. 2 (1.8 mg/L) was higher at SW15 than during Event No. 1 (1.4 mg/L), the difference is not significant and does not pose any significant environmental impact potential. None of the monitoring sites that exceeded the SFC EAL during Event No. 1 were above the EAL during Event No. 2. The discharge limit of 1.6 mg/L was not exceeded at the permitted Outfall 008 (SW10). There were no monitoring sites that exceeded the fluoride MCL for drinking water (i.e., 4.0 mg/L) during Event No. 2.

Fluoride poses no environmental concern to surface water at the Sequoyah Facility.

The nitrate concentrations for Event No. 2 ranged from 0.9 mg/L to 179.0 mg/L. With decreasing flows from Event No. 1 to Event No. 2, the general associated trend is increasing nitrate concentrations. Nine (9) different monitoring sites exceeded the SFC EAL of 20 mg/L compared to four (4) in Event No. 1. A weighted average analysis for monitoring site SW10 downstream of drainage basins SW9, SW12, and SW13, that had much higher nitrate concentrations, and SW11, that had a lower nitrate concentration, indicates that significant nitrate concentrations were not contributed from drainage area SW10. The eight (8) drainage basins that appear to be the sources of nitrate concentrations in Event No. 2 are SW9, SW12, SW13, SW14, SW17, SW18, SW19, and SW20. These drainage basins include the four (4) drainage basins from Event No. 1 with nitrate concentrations above the SFC EAL (i.e., SW9, SW12, SW13, and SW17). Nitrate concentrations for the other four (4) basins (i.e., SW14, SW18, SW19, and SW20), although above the SFC EAL, are not appreciably greater than Event No. 1. The drainage areas that are the potential sources of the nitrate concentrations exceeding the SFC EAL measured in Event No. 2 are presented in Figure 16. Monitoring site SW10, which is Outfall 008, the only permitted outfall monitored, had nitrate concentrations (28.2 mg/L) only slightly above the

discharge limit (20 mg/L) and SFC EAL (20 mg/L). As indicated above, the SW10 nitrate concentrations are a result of conditions in upstream drainage areas. Concentrations at all other monitoring sites exiting the Sequoyah Facility (SW4, SW6, and SW8) were well below the SFC EAL.

Based on Event No. 2 results, the unit sources of nitrate appear to be Unit 8, Unit 11, Unit 18, and/or Unit 25. This correlates well with the potential unit sources identified in Event No. 1 (e.g., Unit 8, Unit 11, and Unit 18). As discussed in Section 4.4.1, Unit 8 and Unit 18 have histories of elevated nitrate concentrations, while none was noted for Unit 11. However, Unit 11 is the drainage area around Unit 8 and is a potential nitrate source. Unit 25 is identified as a potential source because of the SW19 nitrate concentration.

The uranium concentrations for Event No. 2 ranged from < 5.0 $\mu\text{g/L}$ to 1970 $\mu\text{g/L}$. As with nitrate, the general trend was that of increasing uranium concentrations associated with decreasing flows. This was most notably not true for SW14 and SW16, the monitoring sites with the greatest uranium concentrations for both events. At SW14 and SW16, the uranium concentration significantly decreased in Event No. 2 compared to Event No. 1. None of the monitoring sites had concentrations of uranium that exceeded the discharge limit of 45.0 mg/L (45,000 $\mu\text{g/L}$). There were monitoring sites that had

uranium concentrations above the SFC EAL of 225 $\mu\text{g/L}$. These sites were SW3, SW6, SW7, SW10, SW11, SW14, SW15, SW16, and SW18. These sites include the four (4) sites (SW7, SW11, SW14, and SW16) with Event No. 1 uranium concentrations above the SFC EAL. Monitoring sites SW16 and SW14 had the greatest Event No. 2 uranium concentrations of 1,970 $\mu\text{g/L}$ and 1,710 $\mu\text{g/L}$, respectively. These same sites had the greatest Event No. 1 uranium concentrations. As in Event No. 1, drainage areas SW14 and SW16 are the potential significant sources of elevated uranium concentrations. Drainage areas SW10 and SW11 are downstream of areas (SW7, SW14, SW15, and SW16) that had higher uranium concentrations and the data indicates SW10 and SW11 are not the sources of the uranium concentrations. Uranium concentrations for drainage areas SW7, SW15, SW18, SW3 and SW6 (288 $\mu\text{g/L}$, 355 $\mu\text{g/L}$, 293 $\mu\text{g/L}$, 284 $\mu\text{g/L}$, and 262 $\mu\text{g/L}$, respectively) were only slightly above the SFC EAL of 225 $\mu\text{g/L}$. The drainage areas that are the sources of the Event No. 2 uranium concentrations are shown in Figure 17. Uranium concentrations for the other two (2) monitoring sites (SW4 and SW8) exiting the Sequoyah Facility were well below the SFC EAL as with Event No. 1.

As with Event No. 1, the principal potential sources of uranium appear to be Units 5, 10, and 11.

4.4.3 Overall Event Comparison Summary

The flow rates for all monitoring sites were higher during Event No. 1 than during Event No. 2 due to higher rainfall intensities and/or amounts. In most cases, the flow rate difference was significant. There is a general trend in the relationship between constituent concentration and flow rate. For both uranium and nitrate, as the flow rate decreased, the concentration of these constituents generally increased. As discussed previously, this trend was reversed for the two (2) monitoring sites with the greatest uranium concentrations (SW14 and SW16). For fluoride, a trend was not evident, a result of low fluoride concentrations in runoff. This indicates fluoride is not a significant constituent for surface water runoff considerations. Only five (5) of the monitoring sites had increased fluoride concentrations during Event No. 2, when the flow rates decreased.

4.4.4 Constituent Loading

Another pertinent surface water evaluation is a loading analysis. A relative loading assessment assisted in evaluating total contributions of constituents and relative contributions from the individual drainage areas within the previous discussion. This section expands on some observations which can be made from review of loadings.

A constituent loading at a point is calculated by multiplying the point flow rate by the constituent concentration to convert to a loading or mass/time unit. A constituent concentration could therefore be relatively high but a low flow rate could result in a low loading. This evaluation helps place the significance of the concentrations in proper perspective. Since the investigation determined instantaneous or point flow rates during a rainfall event, an instantaneous or point loading unit of kilogram per minute (kg/min) is calculated.

Calculated fluoride loadings for Event No. 1 and 2 are presented in Table 13. The loadings for fluoride decreased considerably from Event No. 1 to Event No. 2. Since the concentration discussion indicates fluoride to not pose significant environmental concern, further assessment of fluoride loading relationships is not warranted.

Nitrate loadings for Event No. 1 and 2 are presented in Table 14. Because of lesser flows, the loadings for nitrate generally decreased (90% of monitoring sites) significantly from Event No. 1 to Event No. 2, even though the nitrate concentrations generally increased significantly. The higher loadings of nitrate during Event No. 1 were measured in drainage areas SW4, SW9, SW10, SW11, SW12, SW13, and SW14. Three (3) (SW9, SW12, and SW13) of these seven (7) drainage

areas had Event No. 1 nitrate concentrations above the EAL discussed in Section 4.4.1. The loading analysis shows that although the nitrate concentrations for SW9, SW12, and SW13 exceeded the SFC EAL, the loadings are similar to loadings from drainage basins with much lower concentrations (SW4, SW10, SW11, and SW14). Further, the other drainage area that had an Event No. 1 concentration above the SFC EAL (SW17) had a low flow rate, resulting in a loading significantly below the loading from basins with lower nitrate concentrations (e.g. SW4 and SW11). Similar observations can be made from the Event No. 2 loading calculations in Table 14. In particular, it is significant to note that three (3) of the drainage areas (SW17, SW18 and SW19) with Event No. 2 nitrate concentrations above the SFC EAL had corresponding low nitrate loadings in comparison to the other drainage areas. This loading analysis provides insight into why the discharge limit at Outfall 008 (SW10) was not exceeded in Event No. 1 and only slightly exceeded in Event No. 2.

Uranium loadings for Event No. 1 and 2 are presented in Table 15. Unlike nitrate, the uranium loadings generally did not decrease (only 65% of monitoring sites compared to 90% for nitrate) from Event No. 1 to Event No. 2, even though the concentrations generally increased. The highest uranium loadings during Event No. 1 were measured in basins SW11 and SW14. It should be observed that the other drainage area with

the greatest uranium concentrations (SW16) had a much lower loading than SW14. Also, as indicated in the previous concentration discussion, SW11 is not a major contributor to the Event No. 1 uranium loading. Therefore, the combined observation is that, in terms of loadings, the most significant source of uranium contribution is from SW14. All other drainage basins have significantly less loadings than SW14 or SW11. A similar evaluation of the Event No. 2 loadings indicates that for monitoring sites with concentrations greater than the SFC EAL, SW11 and SW14 are the most significant contributors of uranium loadings during Event No. 2 with SW15 to a lesser extent. Also, as for Event No. 1, the significant uranium contributions are not from drainage area SW11 but are from the upstream drainage areas.

5.0 FACILITY-WIDE UNDERGROUND UTILITY INVESTIGATION (TASK 4)

5.1 Introduction

Underground utility lines at SFC are used for the transport of laundry wastewater, sanitary wastewater, electricity, communications, security monitoring, cooling water supply and return, cooling water emergency supply and drain, fire water supply, and domestic and potable water supply. All active process streams are located in above ground piping. Other utilities not identified above are present in both above ground and underground utilities.

Many underground utilities are installed in excavated trenches using a porous backfill, such as sand, to immediately surround the utility. At the Sequoyah Facility, the porous backfills are much more conductive than the surrounding natural soils; therefore, utility trenches act as preferential drainage routes for shallow subsurface water (porewater). The Facility-Wide Underground Utility Investigation (Utility Investigation) focuses on assessing the underground utilities' backfill as a potential migration pathway for licensed material.

Two (2) phases of underground utilities investigations have been performed at the Sequoyah Facility. The first investigation phase, the MPB and SX Utilities Investigation, was conducted under an NRC Order Modifying License (OML)

issued September 19, 1990, and focused on identifying potential uranium migration pathways away from the MPB and SX Buildings. The second investigation phase expanded the scope of the previous investigation to include other Sequoyah Facility utilities site-wide. Activities and findings of both underground utility investigation phases are presented in this Section and are collectively referred to as the Facility-Wide Underground Utility Investigation (Utility Investigation).

5.2 Scope and Objective

An objective of the Utility Investigation was the construction of accurate and complete utility drawings identifying all active and inactive underground utilities at the Sequoyah Facility which can be updated and revised by SFC personnel. Also, all construction drawings were reviewed relative to the Sequoyah Facility subsurface geology. This activity allowed identification of potential migration pathways for licensed material.

Another objective of the Utility Investigation was to characterize the quantity and locations of licensed material in the subsurface fill soils. During the investigation, SFC personnel actively installed hydraulic barriers and trench monitors in underground utility trenches to preclude further migration and to recover licensed material in the trenches. Since the pathway and migration potential is not necessarily

a function of the active status of a utility, active, inactive, and/or abandoned utilities are addressed in the investigation.

During the Utility Investigation, the Sequoyah Facility Combination Stream Drain utility trench was identified as a major potential migration pathway due to its location in a known impacted area, its trench size and depth, and its route. The Combination Stream Drain has been identified as a Past and Present Operational Unit (FEI Unit 27). Due to the magnitude of the Combination Stream Drain Investigation, the reporting of its investigation is presented separately in Section 6.0 of this report.

5.3 Investigation Activities

5.3.1 Records/Drawing Search

A review of an estimated 500 Sequoyah Facility construction and as-built utilities drawings was performed to evaluate and locate potential utility migration pathways. The drawings reviewed dated from 1968 pre-construction drawings to 1990 as-built drawings. Data collected from FEI Task 3 (Past and Present Operations, Historical Information Investigation) were also utilized to determine areas where licensed material may exist in the shallow subsurface soils or fill relative to underground utilities. This included an evaluation of construction elevations, and also the nature and thickness of

soils and/or fill beneath the foundation and floors of the MPB and SX Buildings which could be potential areas for the localization of licensed material. Interviews with Sequoyah Facility process engineering, project engineering, and design personnel were also conducted to evaluate and locate potential migration pathways.

5.3.2 SX and MPB Utility Drawing Development

During investigations conducted under the OML, Sequoyah Facility construction and utility drawings in the MPB and SX Building area were reviewed. An underground utility drawing was developed from Sequoyah Facility construction drawings and identified various utility lines in the vicinity. This drawing was developed for and presented in the MPB Final Findings Report (Roberts/Schornick & Associates, Inc., 1990).

5.3.3 Facility-Wide Underground Utility Drawing Development

The Utility Investigation expanded the scope of the MPB and SX Building Utility Investigations to include all Sequoyah Facility underground utilities. In order to develop the Facility-Wide Underground Utility drawings, facility construction and as-built drawings were reviewed to locate underground utilities. Aerial and ground survey data collected during the FEI was also reviewed for use in preparation of the drawings.

The Utility Investigation drawings are presented as Drawings 4 through 12. The underground utility drawings have been verified through field investigations and reviewed by SFC personnel for accuracy, completeness, and consistency with Sequoyah Facility nomenclature.

5.3.4 MPB and SX Utility Investigations

An investigation of utility trenches associated with the MPB and SX Buildings was conducted by SFC personnel. The investigation was in response to Actions 2 and 3 of the OML, which require the determination of potential pathways for migration of licensed material beneath and beyond the MPB, as well as the direction and extent of migration of licensed material via excavated intercept trenches.

Twenty-five (25) utility trench excavations were performed during the MPB and SX Utility Investigations. Sixteen (16) concrete hydraulic barriers and twenty-one (21) trench monitors (TM) were installed in the utility excavations to stop continued migration of licensed material along the sand fill in the utility backfill trenches. Five (5) trench monitors (TM-1, TM-2, TM-9, TM-12, and TM-22) were installed without hydraulic barriers. The locations of the various trench excavations and constructed hydraulic barriers are also depicted on Drawings 4 through 12. Trench excavation cross-sections are presented on Drawing 13 for both the SX Building

and MPB investigations. Drawing 13 was developed by RSA from SFC personnel field notes collected during the excavations.

Drawing 14 presents a detailed plan and cross-section of a typical utility trench hydraulic barrier and trench monitor. The hydraulic barriers are designed and constructed to prevent the migration of water in the porous sand fill surrounding a utility line and to collect migrating water upgradient of the barrier. The trench monitor or collection sump design includes perimeter gravel backfill around the trench monitor to provide local storage capacity and allow efficient removal of the porewater. The frequency and volume of pumping from the trench monitors is dictated by the hydrogeological properties of the subsurface and by surface-related influences such as stormwater infiltration. Trench monitors are normally inspected weekly by SFC personnel. Pumping from the trench monitors is typically performed by SFC personnel on a weekly frequency to recover licensed material and porewater in the trench backfill materials, thus preventing possible further migration.

Soil and water samples collected in the utility trench excavations during the Utility Investigation in the vicinity of the MPB and SX Building have been previously reported (Roberts/Schornick & Associates, Inc. 1990, 1991). The discussion and results of these two (2) investigations have

been revised and updated, and are presented later in this Section.

5.3.5 Other Sequoyah Facility Utility Investigations

During the Utility Investigation, additional utilities and/or segments identified as potential migration pathways were investigated. The inactive hydrogen fluoride scrubber effluent pipeline which was routed to the Initial Lime Neutralization Area (FEI Unit 3) was excavated north of the Decorative Pond and south of the port road and was abandoned by grouting the inside of the pipeline closed with a non-porous cement. In addition, two (2) hydraulic barriers and two (2) trench monitors (TM-25 and TM-26) were installed along this utility pipeline excavation at the locations shown on Figure 18 and Drawing 10.

An extensive investigation of the Combination Stream Drain was performed (See Section 6.0). Two (2) recovery wells (MW-RW-1T and MW-RW-3T) were installed in the Combination Stream Drain utility trench, in addition to trench monitor TM-9T, which had previously been used as a fluid recovery sump. Trench monitor TM-9T was replaced with MW-RW-3T because TM-9T did not fully penetrate the sand backfill around the Combination Stream Drain pipeline. Additionally, the Utility Investigation information was utilized in assisting in the determination of

locations for lithologic borings and monitoring wells. This program is defined in detail in Section 7.0.

The Utility Investigation continued the identification and verification of potential pathways that could contribute to the migration of licensed material away from the Past and Present Operational Units being investigated, and also away from the Sequoyah Facility. The results of this investigation are presented later in this Section.

5.3.6 Foundation and Construction Drawing Review

A review of Sequoyah Facility construction and as-built foundation drawings of the MPB and SX Building was performed to identify and locate potential uranium migration pathways in porous fill material beneath the building foundations. The facility foundation drawings were also reviewed to assess potential vertical uranium migration pathways created by the installation of the building foundations during construction of the MPB and SX Buildings. During this review, the geometry and depth of the piers was analyzed to determine the potential for communicating licensed materials to subsurface geological units. The results of this review are presented later in this Section.

5.4 Investigation Results

5.4.1 Utility Drawings Review

The review of Sequoyah Facility drawings and interviews with SFC personnel culminated with the development of a set of Sequoyah Facility underground utility plan drawings (Drawings 4 through 12). Facility coordinate data, dimensioned data, plan scale data, and pertinent land survey data were used in the construction of the utility drawings. The utility drawings produced from this investigation included active and abandoned underground utilities.

5.4.1.1 MPB and SX Building Foundation Drawings Analysis

As previously stated, MPB and SX Building construction and as-built drawings were reviewed during the Utility Investigation to identify and locate potential uranium migration pathways in porous fill material beneath building foundations. Analysis of the drawings showed that the MPB is supported on shallow drilled piers, founded at elevation 555.0 feet above mean sea level (AMSL). Some of these piers are belled piers. The finished floor elevation of the MPB is elevation 566.0 feet AMSL.

Based on a review of SFC drawings 110-C-161, -162, and -163, the near surface materials consist of silt with clay and sand, underlain by shale at elevations ranging from approximately 555 to 560 feet AMSL. Sandstone underlies the shale. The

design for the drilled piers generally calls for the piers to be founded six (6) inches below the top of the shale. It appears that the drilled pier foundations extend less than approximately five (5) feet into the shale, and do not penetrate the shale into the underlying sandstone.

The administration and laboratory section of the MPB, located in the southwestern portion of the building, contains a tunnel that extends to elevation 557.0 feet AMSL. The subsurface information in this area, taken from the above referenced SFC drawings, shows that this tunnel does not penetrate the silt (terrace deposits) or extend to the shale.

A scale pit is located in the northwestern part of the MPB, from column lines 6 to 6.9, and A to A.6. The bottom of the scale pit is at elevation 556.0 feet AMSL. The subsurface information referenced above indicates that this scale pit extends less than five (5) feet into the shale, but does not extend to the sandstone.

The SX Building is supported on shallow drilled piers, founded a minimum of six (6) inches into shale, based on a review of SFC drawings 000-C-201, 240-C-201, 202, 209, and 401. The finished floor elevation of the SX Building is 566.5 feet AMSL. The average subfloor sand base is approximately six (6) inches thick. Based on a review of RSA borings BH-26, BH-27,

BH-28, and BH-29, the near subsurface materials beneath the SX Building consist of silty or sandy clay underlaid by shale. The top of the shale occurs at elevations ranging from approximately 557 to 560 feet AMSL in the SX Building area. Sandstone underlies the shale and was encountered in these borings at depths below approximately elevation 548 feet AMSL. Although the exact information is unavailable, it is considered unlikely that the piers penetrate the shale into the underlying sandstone.

Tank foundations in and around the SX Building extend as deep as elevation 552 feet AMSL. These elevations are above the highest sandstone elevation (547.7 feet AMSL) noted on the borings drilled in the SX Building area. Therefore, it appears that some of these foundations extend into the uppermost shale but do not extend to the first sandstone unit. A pulse column and generator foundation extends to elevation 558 feet AMSL. This elevation appears to be close to the top of the shale in this area but does not penetrate shale.

In summary, the shallow drilled piers supporting the MPB extend less than approximately five (5) feet into the shale and do not penetrate the shale into the underlying sandstone. The MPB tunnel apparently does not extend to the surface of the shale. The MPB scale pit extends less than five (5) feet into the shale, but does not extend to the sandstone. It does

not appear that the SX Building drilled piers penetrate the shale or extend to the sandstone. Other tank foundations and equipment foundations in the SX Building may extend into the shale, but do not extend to the sandstone. Based on this information, it does not appear that any of the SX or MPB foundation elements provide a potential for communicating licensed materials to the sandstone unit.

5.4.2 Utility Trench Excavation Findings

Numerous underground utility lines exist in the vicinity of the SX Building and MPB and were identified as potential pathways for migration of licensed material. Many of these utility lines were excavated to determine if there was a potential for licensed material migration along the utility line backfill. Visual lithological observations were made, and soil and water samples were obtained for analyses. Soil descriptions and water levels in the excavations were also recorded. Data generated from various monitoring programs are described in the following sections. The utility trench excavations are shown on Drawings 4 through 12.

5.4.2.1 Excavation Lithological Observations

Soils in the utility excavations were noted to consist of a clayey gravel backfill material underlain by clay and shale. In addition, most utility trenches were observed to contain a sand backfill around utility lines.

Clayey gravel backfill was observed to range in thickness from approximately 2 to 8 feet. The clay in the fill is reddish in color, and the gravel ranges in size up to 1.5 inches.

The clay underlying the clayey gravel fill is typically mottled and ranges in color from yellowish brown to gray and red. The clay reaches thicknesses up to six (6) feet. The lower boundary of the clay grades abruptly into an underlying shale bedrock. Typically, a fine quartz sand backfill completely surrounded the utility line. Water was noted in all trench excavations except for Trenches 4, 6, 8, 10, 18, and 19.

5.4.2.2 Trench Soil Analyses

Grab samples of soil and sand fill material from the utility excavations were obtained by SFC personnel between August 30 and October 19, 1990, and analyzed by SFC laboratories for uranium and nitrate. The analytical results for these trench soil/fill samples are presented in Table 16.

Elevated concentrations of uranium (ie., greater than the Sequoyah Facility EAL of 40 $\mu\text{g/g}$) were detected in soils from all utility trenches associated with the SX Building, which are Trenches 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, and 15A. Soil sample analyses for uranium ranged from a

low of 9.4 $\mu\text{g/g}$ in sample 3A3 from Trench 3, to a high of 8950 $\mu\text{g/g}$ in a soil sample from Trench 13.

Soil samples collected from utility trench excavations in the MPB area (Trenches 16, 17, 18, 19, 20, 21, 22, 23, and 24) were also analyzed for nitrate and total uranium, and the results are also presented in Table 16. Trenches 16, 17, and 23 were the only excavations where soil uranium levels were above the SFC EAL of 40 $\mu\text{g/g}$. Trench 16 had uranium levels that ranged from 66 $\mu\text{g/g}$ to 790 $\mu\text{g/g}$. Utility Trench 17 had uranium levels ranging from <5.0 $\mu\text{g/g}$ to 98.8 $\mu\text{g/g}$. Trench excavation 23 had uranium levels that varied from 58.0 $\mu\text{g/g}$ to 224.7 $\mu\text{g/g}$.

Trenches 25 and 26 were installed along an old line to the Initial Lime Neutralization Area (Unit 3). Soil samples collected from these trenches and analyzed for uranium were below the SFC EAL of 40 $\mu\text{g/g}$ uranium. The soil analytical data for Trenches 25 and 26 are also shown in Table 16. A detailed explanation of the utility trench excavation program for Trenches 16, 17, 18, 19, 20, 21, 22, 23, and 24 in the MPB area is presented in Appendix C and was part of the MPB Final Findings Report (Roberts/Schornick & Associates, Inc., 1990).

There were also fifteen (15) hand auger soil borings that were drilled adjacent to and/or through the floor slab of the MPB and into and through the sand backfill that underlies the concrete floor. The soil and water analytical results for these fifteen (15) borings are presented in Table 17, and drilling details showing concrete floor slab thickness, sand fill thickness beneath concrete, clay/shale depth, and if water was encountered are shown on Table 18. Analytical results from the MPB hand auger (HA) borings were discussed in detail in the MPB Final Findings Report (Roberts/Schornick & Associates, Inc., 1990). These borings delineated an area beneath the northwest corner of the MPB where uranium levels exceeded the SFC EAL of 40 $\mu\text{g/g}$ uranium. A map showing this area (approximately 14,900 square feet) is presented in Drawing 15.

5.4.2.3 Trench Water Analyses

Water samples were also collected from all SX Building and MPB area trench excavations or hand auger borings which encountered water. These samples were collected by SFC personnel and analyzed in the SFC process or environmental laboratory for total uranium, nitrate, fluoride, pH, and specific conductance. Water was encountered in all utility trench excavations except for Trenches 4, 6, 8, 10, 18, and 19, which were dry. Porewater collected from these open trench excavations exceeded the SFC EAL of 225 $\mu\text{g/L}$ uranium in

all trenches except Trenches 22 and 25. The porewater samples from the open trench excavations ranged from $<5.0 \mu\text{g/L}$ in Trench 22 to 1.2 g/L in Trench 14. Table 19 presents the analytical results from porewater samples collected from the open trench excavations.

Water was encountered in only three (3) of the fifteen (15) hand auger borings in the MPB area (HA-2, HA-12, and HA-13). No water sample was obtained from HA-2; however, total uranium levels in HA-12 and HA-13 were $40 \mu\text{g/L}$ and $30 \mu\text{g/L}$, respectively.

5.4.2.4 Utility Trench Monitoring Programs and Results

Since the installation of the trench monitors or recovery sumps, RSA and SFC have actively been monitoring: 1) porewater quality (total uranium, nitrate, pH, fluoride, specific conductance, and a special sampling event for total arsenic) in each trench monitor, 2) water level fluctuations in each trench monitor, 3) the volume of liquids removed and the quantity of uranium recovered from each trench monitor, and 4) the effectiveness of each trench hydraulic barrier in stopping continued fluid migration. There will be no discussion of the extensive utility trench monitoring program for the Combination Stream Drain in this section. However, a thorough evaluation of this utility line is presented in Section 6.0.

Water quality data for the twenty-three (23) trench monitors, the electrical vault, and French Drains A and B are presented in Table 20. These monitoring sites have been typically sampled on a weekly basis since about September 11, 1990. SFC personnel sampled the trench monitors, electrical vault, and French Drains A and B from September 11, 1990, to February 4, 1991. RSA personnel sampled these monitoring stations from February 12, 1991, to present (June 17, 1991). Referring to Table 20, the average concentration for total uranium, nitrate, pH, fluoride, specific conductance, and total arsenic is shown along with each individual analytical sample result. The long-term (September 1990 to June 1991) total uranium averages ranged from a low of 18.0 $\mu\text{g/L}$ in trench monitor TM-25T to a high of 253 mg/L in TM-2T. The nitrate long-term averages ranged from a low of 0.22 mg/L in TM-20T to a high of 92.9 mg/L in TM-2T. Long-term average fluoride levels ranged from 0.84 mg/L in TM-21T to 132.9 mg/L in TM-23T. The pH averages ranged from 5.5 in TM-2T to 8.2 in trench monitors TM-3T and TM-24T. A single sampling of all trench monitors for total arsenic showed a low of <0.005 mg/L in TM-1T, TM-3T, TM-5T, TM-9T, TM-16T, TM-18T, TM-22T, and TM-24T and a high of 0.356 mg/L in French Drain A. There is no specific chemical trends in any of the trench monitoring data that is apparent during the time period monitored.

In addition to the water quality monitoring programs, all trench monitors except TM-17T, TM-18T, TM-20T, TM-21T, TM-22T, TM-25T, and TM-26T are pumped on a weekly frequency to remove fluids and to recover uranium. This weekly pumping program began on September 11, 1990, and is continuing at present (June 18, 1991). From September 11, 1990, to June 18, 1991, SFC removed approximately 95,719 gallons of liquid and 6.6 kilograms of uranium from the utility trench monitors. This recovered liquid is being managed appropriately based upon the analysis of the recovered liquid. Management includes reprocessing some water back through the SX process for uranium recovery. The fluid recovery and concentration from each monitor has been tabulated as shown in Table 21. The source of the uranium, nitrate, and fluoride found in the trench monitors was primarily from accidental spills and releases onto the MPB and SX Building floors and the migration of this material through cracks in concrete (concrete repaired and sealed in about 1983) into underlying utility line trenches. To a lesser degree, some of the material present in the trenches may come from leaky pipelines; however, this contribution is thought to be small in most cases.

Water levels have also been measured on a weekly frequency since September 11, 1990 in all trench monitoring stations. All water level and piping depth measurements are shown in Table 22 for the trench monitors. Hydrographs for trench

monitors TM-2T, TM-20T, and TM-23T are shown in Figure 19. In general, porewater levels in the trench monitors have shown an overall decline since pumping began.

RSA also conducted a study in the SX Building and MPB area on February 12, 13, 14, and 15, 1991 to determine if there was any interconnection between utility trenches and to evaluate the effectiveness of the hydraulic barriers. The water level monitoring data for this study is summarized in Table 23. This investigation consisted of pumping each trench monitor at different times and monitoring for drawdowns in other nearby trench monitors. All trench monitors were pumped at various times on February 13 or 14, 1991. Water levels were monitored in nearby trench monitors for a period of several hours to determine if any drawdown was noted which could indicate interconnection between the utility trenches. The monitoring data appears to indicate that no hydraulic communication was noted between any of the utility trench monitors, thus suggesting that there are no significant fluids migrating beyond the concrete barriers installed across the utility trenches.

5.4.3 Quantification of Licensed Materials in Shallow Subsurface Environment

5.4.3.1 Uranium in Water Under the SX Building Floor

Water in the sand fill material under the SX Building was calculated to be approximately 14,000 gallons. The volume was calculated using a conservative porosity of 40% for the sand fill material, a conservative saturated thickness of 1.0 feet for the sand, building slab dimensions of 85.0 by 55.0 feet, and a conversion factor of 7.48 gallons of water per cubic foot of volume.

Based on a concentration of 7.14 g/L uranium in a single water sample from the sand backfill from beneath the SX Building floor, the total accumulation of uranium in one (1) porewater volume beneath the SX Building was calculated at approximately 378 kilograms.

5.4.3.2 Uranium in Soil Beneath the SX Building

Based upon building dimensions of 85.0 feet long and 55.0 feet wide, and with a very conservative average sand subbase thickness of 2.0 feet, the sand fill bulk volume under the SX Building is estimated at 9350 cubic feet or 2.65×10^8 cubic centimeters. Based upon an estimated sand dry bulk density of 115 pounds per cubic foot and an average concentration of uranium in the soil at 4000 $\mu\text{g/g}$, the total weight of uranium in the soil is conservatively estimated at 1960 kilograms.

5.4.3.3 Uranium in Soil in the Utility Trenches

The amount of uranium lost to the soils in the utility trenches was conservatively calculated at 3293 kilograms. This conservative estimate is based on the volume of sand in the potential pathway trenches in the vicinity of the SX Building and along 1383 feet of the Combination Stream Drain trench, and the average concentrations of the uranium determined from the soil samples.

5.4.3.4 Uranium in Water in the Utility Trenches

The amount of uranium currently present in the water in the utility line trenches and along 1383 feet of the Combination Stream Drain trench was conservatively estimated at 9.8 kilograms. This is based on the length of the utility trenches potentially contaminated, the average water thicknesses in the trenches, and the concentrations of uranium in the water. This estimate calculates the amount of uranium in one (1) porewater volume in the utility trenches.

5.4.3.5 Uranium in Water and Soil Under the MPB

Immediately after receipt of the OML, SFC managers initiated actions to characterize the quantity (volume and activity) and location of licensed material under the MPB floor and adjoining area. SFC managers also initiated actions to identify and investigate utility trenches in the MPB area through which licensed material could potentially migrate.

RSA and SFC initiated an investigation to evaluate soils under the MPB by collecting soil samples from fifteen (15) soil borings hand augered adjacent to or through the MPB floor. These soil borings penetrated the sand backfill beneath the MPB and generally extended one (1) foot into native undisturbed soils. Results of this investigation identified an area of approximately 14,900 square feet beneath the MPB where licensed material was present. This area is generally located in the northwest portion of the MPB. Based upon analytical test results for soils, the total quantity of uranium in the fill materials (principally sand) beneath the MPB was estimated to be 3260 kilograms.

SFC has also evaluated nine (9) utility lines in the MPB area. This evaluation consisted of excavating the trenches and constructing cutoff walls and recovery sumps in the utility trenches that represented migration pathways. The amount of uranium present in sand fill surrounding the MPB utility lines, and water contained within this fill, was also estimated. Based upon soil and water samples collected from the excavated trenches in the MPB area, it is estimated that 728 kilograms of uranium is present in soil backfill in utility line trenches associated with the MPB. An additional 0.92 kilograms of uranium is estimated to be present in water in these utility line trenches.

5.4.4 Uranium Recovery Programs

5.4.4.1 SX Hexane Tank Vault Liquids Monitoring and Recovery Program

During the construction of the hexane tank concrete vault in August 1990, SFC installed a french drain dewatering system consisting of gravel that surrounded the concrete below-ground vault. In addition, a subfloor recovery/dewatering system was installed approximately four (4) feet below the floor grade near the center of the concrete vault. The location of the SX vault subfloor monitor is shown on Figure 18. A pump was installed into the subfloor monitor, and fluids containing licensed materials are being recovered on an almost daily basis since August 16, 1990. Since August 16, 1990, approximately 108,295 gallons of liquid and approximately 322 kilograms of uranium have been removed from the subsurface waters in the SX Building area. A summary of the SX vault analytical data, liquid removal volumes, and quantities of uranium removed is shown in Table 24. The analytical data from the SX vault monitoring program have also been plotted in graphical form as shown on Figure 20. Referring to Figure 20, the total uranium levels in liquids recovered from the SX vault remained fairly constant at around 1.0 g/L of uranium from August 16, 1990 to about November 29, 1990, at which time a decreasing trend in uranium concentration became evident. This trend of decreasing total uranium concentration continued to about January 20, 1991. From about January 20, 1991 to about January 27, 1991 the total uranium concentration increased from about 0.5 g/L to about 1.0 g/L, where it

remained relatively constant until March 7, 1991. Since March 7, 1991, the concentration of uranium in liquids in the SX vault have steadily decreased to about 0.6 g/L in June 1991.

On May 1, 1991, SFC personnel collected liquids from the SX vault and conducted total and dissolved uranium analyses on the sample. The sample results are shown in Table 25. The results indicate that of the uranium noted in the sample, approximately 95 to 98 percent of the uranium was insoluble uranium and 2 to 4 percent of the uranium was dissolved or soluble uranium. These results are probably caused by precipitation of uranium minerals due to oversaturation of the water with uranium at this location.

The source of the uranium found in the SX Building area is likely from historical (mainly pre-1983) releases of process fluids or washdown water onto concrete floors which were cracked and leaking. Other potential sources include releases directly onto the ground surface from accidental spills of process fluids in the area. In about 1983, the floors in the SX Building were repaired, and a floor inspection program was initiated as part of the OML in October 1990. SFC will continue to recover fluids from the SX vault and reprocess these liquids back into the process stream to recover uranium.

5.4.4.2 Digestion Floor Area Recovery Program

The digestion area is located in the southwest section of the MPB. During the inspection and repair of the digestion area floors in mid-to-late September 1990, SFC identified liquid containing licensed materials between the stainless steel floor and the underlying concrete floor. Since liquid was present, SFC installed a water-tight and leak-proof 4-inch steel flange or pipe through the stainless steel floor for the purposes of extracting the liquid between the liner and concrete floor. The liquid between the floor and liner probably has resulted from the migration of process liquids or washdown water through flaws in the stainless steel floor. These potential leak sites were repaired as part of the OML actions initiated in September and October 1990.

Upon identifying liquid was present, SFC initiated a liquid recovery program on September 22, 1990. Between September 22, 1990 and September 29, 1990, approximately 132 gallons and 5.9 kilograms of uranium was recovered. The subfloor monitor was dry between September 29, 1990, until January 8, 1991, when an additional 0.24 gallons of liquid and 4.8 grams of uranium was recovered. The subfloor monitor is checked on a weekly basis and has been dry from January 8, 1991, to present (June 17, 1991). This subfloor monitor will continue to be inspected and fluid recovered as required. A summary of the fluids recovered from this subfloor monitor is presented in Table 26.

5.4.4.3 Denitration Subfloor Monitoring and Recovery Program

In the general vicinity of the denitration unit (NW corner of MPB), a 10-inch diameter stainless steel pipe (denitration sump) extends beneath the floor of the MPB to a depth of approximately 6.45 feet. A small pump has been installed into this subfloor monitor, and water is recovered and routed back through the process. It is not known when or precisely for what purpose this subfloor monitor was originally installed. It is thought to have been installed in the mid-to-late 1970's. However, there is analytical data collected from the subfloor monitor dating back to December 1987, as shown in Table 27. This data indicates that fluids containing uranium and nitrate are present beneath the MPB floor in this area. The location of the denitration subfloor monitor is shown in Figure 18.

RSA attempted to sample the soils found beneath this subfloor monitor by drilling hand auger borings (HA-14 and HA-14A) directly through the bottom and into the underlying soil. RSA attempted on two (2) occasions (October 11 and 23, 1990) to drill through soils found beneath the bottom of the subfloor monitor. RSA was successful in penetrating only about 2.35 feet until auger refusal was encountered. However, there was a marked decline in uranium levels in soil from 10,410 $\mu\text{g/g}$ at the soil surface (5.8 to 6.15 feet) to 700 $\mu\text{g/g}$ at the last sampling depth (7.8 to 8.15 feet). Based upon this data, it appears that the uranium levels in soils are decreasing with

depth at this location. The soil analytical data collected from the denitration subfloor monitor on October 11 and 23, 1990 are shown in Table 17. Drilling details for HA-14 are shown on Table 18. It is thought that the uranium found in the soils and water beneath the MPB floor slab in this area resulted from the migration of process fluids through cracks in the concrete floor when process spills or leaks occurred in this area prior to the installation of the stainless steel floor liners and concrete sealants in about 1983.

Since about December 26, 1990, the denitration subfloor monitor has been inspected daily for the presence of fluid. If fluids are noted, the subfloor monitor is pumped, the volume of fluid recovered is noted, and a sample of the recovered water is analyzed for total uranium. This monitoring data has been tabulated in Table 28. Table 28 summarizes the total volume of liquid recovered and the cumulative weight of uranium removed from the denitration subfloor monitor. As of June 14, 1991, approximately 675 gallons of liquid and 5.5 kilograms of uranium have been recovered.

The concentration of total uranium from the denitration subfloor monitor has been plotted in graphical form as shown on Figure 21. Referring to Figure 21, there was a steady increasing trend in uranium concentrations from December 1990 to about April 25, 1991. On approximately April 21, 1991, the pump suction in the denitration subfloor was lowered about one

(1) foot in an attempt to improve recovery. The result was an increase in fluid recovery, but a decrease in uranium concentration. This dramatic decrease in total uranium concentration is evident on Figure 21. It is thought that lowering the pump suction improved the water recovery and probably decreased the turbidity of the sample, both of which could cause the total uranium concentration to decline.

6.0 COMBINATION STREAM DRAIN INVESTIGATION

6.1 Introduction

The function of the Combination Stream Drain (CD) is to transport various discharges to Outfall 001. These discharges include contact and non-contact overflow water from the recirculating cooling water system, cooling water emergency system effluent, MPB roof drain stormwater, fire water drains, steam boiler blowdown, decanted water softener blowdown, Yellowcake Pad stormwater runoff, treated sanitary wastewater, excess raw water, fluoride treatment effluent, and other miscellaneous stormwater from the process area.

The main line of the CD at the Sequoyah Facility is approximately 2334 feet of gravity-flow reinforced concrete pipe ranging in size from 12 to 30 inches nominal diameter. Drawing 16 presents the Plan View of the CD, while Drawings 17 through 20 show plan and profile views of the CD. The CD ranges in depth from approximately 5 to 30 feet below the ground surface. The CD consists of two major segments as shown on Drawing 16. CDU-1 (12 and 15-inch reinforced concrete pipe, Drawing 16) begins at the raw water basin and continues to Outfall 001. CDU-2 (30-inch reinforced concrete pipe, Drawing 16) begins at the northeast corner of the MPB and continues to a discharge point located at the emergency basin. Under normal operating conditions, flow in CDU-2 is routed through the main sump and into CDU-1, which continues to Outfall 001. During high flow conditions in CDU-2, a portion of the flow is diverted by an existing weir to the

emergency basin in addition to the normal operating condition flow path.

Major flow contributions are made at ten (10) junction manholes at various locations along the CD. A major flow contribution occurs at the equalization basin overflow weir into the main sump located on the southeast side of the cooling water tower. Smaller flow contributors are plumbed directly into portions of the CD, such as in section CDU-2, which is routed east to west, north of the MPB. The discharge from the CD at Outfall 001 is routed by underground pipeline (a small segment is actually above ground for a short distance) southwest to the receiving waters identified as ephemeral streams which flow into headwaters of the Robert S. Kerr Reservoir.

The effluent at Outfall 001 is subject to Federal regulation (10 CFR Part 20), as well as NPDES and OWRB permit conditions. The MPC of total uranium in the discharge effluent is defined in 10 CFR Part 20, Appendix B, Table 2, as 3×10^{-5} $\mu\text{Ci/ml}$, which is equivalent to 45 mg/L total uranium, assuming an activity ratio between U^{238} and U^{234} of unity or a mass conversion of 1.5 g/ μCi (Jelinek, 1989). All other regulated constituents of the discharge effluent have been discussed previously and are listed in Table 7 along with the associated permit limits. As also indicated previously, Table 6 presents the monitoring parameters and frequencies required by the NPDES and OWRB permits.

Monthly flow proportional samples of effluent discharged at Outfall 001 were reviewed for the time period of January 1985 to October 1990. The average total uranium concentration of these samples is 0.538 mg/L.

Two (2) concurrent CD investigations were performed during the FEI. First, an external CD Investigation was performed to assess the potential of uranium migration along the CD pipeline trench backfill. During October and November 1990, three (3) trench monitor wells (MW-33T, MW-34T, and MW-44T) were installed into the CD trench backfill. Two (2) trench porewater recovery wells (MW-RW-1T installed in November 1990 and MW-RW-3T installed in March 1991) were also installed into the CD trench backfill during the FEI. Recovery well MW-RW-1T is located inside the restricted area fence on the south side of the yellowcake storage pad. Recovery well MW-RW-3T is located northwest of the SX Building, downgradient of manhole CD-9. This recovery well is located near trench monitor TM-9T, which was also installed into the CD backfill. The CD trench monitoring well and recovery well locations are shown on Drawing 16.

A second internal CD Investigation was performed during the FEI to determine the CD dynamics of uranium loadings and flows and to identify the potential for infiltration/exfiltration along the CD. This investigation also assessed constituent concentrations along the CD and its contributing streams. Both CD investigations are presented in this Section.

6.2 Scope and Objectives

6.2.1 External Investigation

Several investigations have been conducted to evaluate the sand backfill material that surrounds the CD. The purpose of these investigations was to develop a detailed understanding of how fluids may be migrating through this backfill material, as well as defining the amount of licensed material (uranium) that may be present in soils and porewater within the CD backfill. Other objectives included the evaluation of whether fluids in the CD trench sand backfill were infiltrating into the CD, or whether the CD was leaking and adding fluids to the trench backfill.

6.2.2 Internal Investigation

An objective of the internal CD Investigation was to develop a detailed understanding of streams contributing flow to the CD. After the contributing streams were identified, a flow and constituent quantification and characterization investigation of the CD was performed so the relative potential for uranium infiltration and exfiltration to and from the CD and surrounding environment could be determined. Also, from data collected during the flow quantification and characterization investigation, individual contributing stream total uranium loadings were determined, and major uranium contributing streams were identified.

6.3 Investigation Activities

6.3.1 External Investigation Activities

Following a detailed review of the utility drawings that show the CD, RSA and SFC initiated a program to install several trench monitoring and recovery wells. The initial response activity (initiated on September 1, 1990) was the attempt to excavate (Trench 9) the CD and to install a hydraulic barrier and sump across the CD trench northwest of the SX Building as shown on Drawing 19. A hydraulic barrier was not installed due to the depth of the CD (>17 feet) and safety concerns over an unstable excavation.

In lieu of a hydraulic barrier in Trench 9, SFC installed a 16-inch diameter perforated Drisco pipe (Trench Monitor TM-9T) in a gravel fill at the location shown on Figure 18 and Drawing 18. The gravel surrounding the pipe was in direct hydraulic communication with the CD sand backfill material. However, this trench monitor (TM-9T) did not fully penetrate the sand backfill, due to the reasons mentioned earlier. Soil samples were also collected during Trench 9 excavation and analyzed for uranium and nitrate with the results being shown on Table 16. Uranium levels in soil collected from this trench ranged from 283 $\mu\text{g/g}$ to 710 $\mu\text{g/g}$.

SFC initiated fluid recovery from TM-9T on September 11, 1990. The volumes of fluid recovered and quantities of uranium removed are shown in Table 21. The volume of fluid removed from TM-9T from September 11, 1990, to June 18, 1991, was

10,688 gallons of water and 1358 grams of uranium. Trench Monitor TM-9T is shown on Figure 18.

A second monitoring well in the CD trench backfill, MW-33T, was installed on October 11, 1990. This trench monitoring well was installed near the southeast corner of the yellowcake sump (Unit 16) at the location shown on Figure 22. Total uranium levels (average 7875 $\mu\text{g/L}$) in this trench monitoring well were above the SFC EAL of 225 $\mu\text{g/L}$. Soil samples from trench monitor well MW-33T boring (BH-37) were also analyzed for uranium with the results shown in Table 29. The detectable uranium levels ranged from 60 $\mu\text{g/g}$ to 130 $\mu\text{g/g}$ in the 10 to 11 foot depth interval.

On October 30, 1990, a second CD trench monitoring well, MW-34T, was installed approximately 200 feet south of MW-33T as shown on Figure 22. Water quality data from this CD trench monitoring well (MW-34T) showed uranium levels (average of 101 $\mu\text{g/L}$) that were under the SFC EAL but over background values. Soil samples from this borehole (BH-44) were analyzed for uranium, fluoride, and nitrate with the results shown in Table 29. No uranium was detected in any of the soil samples collected from 0 to 10.5 feet (total well depth). Because uranium was detected in MW-44T, SFC installed a third CD trench monitoring well (November 12, 1990), MW-44T, located approximately 300 feet southwest of MW-34T as shown on Figure 22. Uranium in the CD trench backfill porewater at MW-44T was near background levels, averaging about 19 $\mu\text{g/L}$. Soil samples

were collected from the MW-44T borehole (BH-56T) and analyzed for uranium, fluoride, and nitrate, with the results shown in Table 29. No uranium was detected in soils from MW-44T (BH-56T).

Following an evaluation of the water quality data from wells MW-33T, MW-34T, and MW-44T, SFC decided to install a CD trench porewater recovery well (MW-RW-1T) on November 14, 1990, at the location where the CD leaves the restricted area as shown on Figure 22. A pump was subsequently placed into this well in January 1991, and recovery of fluids began from the CD utility trench. The total uranium present in porewater recovered from this well has averaged about 43,878 $\mu\text{g/L}$. Details on the fluid recovery from MW-RW-1T will be discussed in Section 6.4. Soil samples were also collected from borehole BH-61T (MW-RW-1T) and analyzed for uranium, nitrate, and fluoride. The uranium levels were at background ($<5.0 \mu\text{g/g}$), except for the 0.0 - 0.5 foot interval at $6.3 \mu\text{g/g}$, until a depth of 15.0 feet where uranium levels varied from 28 $\mu\text{g/g}$ to 754 $\mu\text{g/g}$ to the total borehole depth of 17 feet.

RSA and SFC also initiated a program (February 13 to 19, 1991) to evaluate the trench backfill sands surrounding the CD to determine if the CD was leaking and adding fluids to the trench backfill material, or determine if porewater in the trench was flowing into the CD. This investigation consisted of placing a pressure transducer and data logger in trench well MW-33T and recording water levels on a 30-minute

frequency from February 13 to 19, 1991. The CD discharge at Outfall 001 was also continuously monitored as part of SFC's NPDES permit. A comparison of the water level changes versus discharge rate was then made to determine if there were any changes in the water level in the trench which could be correlated to changes in the CD discharge rate. The results of this study will be discussed more fully in Section 6.4.

A second CD trench backfill recovery well, MW-RW-3T, was installed near TM-9T on March 5, 1991. This utility trench recovery well fully penetrates the sand backfill that surrounds the CD trench in the SX Building area. A pump will be installed into this recovery well, and recovery of fluids started in mid-to-late summer 1991.

Beginning on September 11, 1991, RSA began monitoring the water levels in trench monitoring wells MW-33T, MW-34T, MW-44T, MW-RW-1T, MW-RW-3T, and TM-9T on a daily or every other day frequency (except weekends) from September 11, 1990, to about January 3, 1991. From about January 3, 1991 to present (June 17, 1991), water levels are being measured on an approximate weekly frequency. The water level data for the CD trench monitoring wells is summarized in Table 30. Well completion details (except TM-9T) for each of the CD trench monitoring or recovery wells are presented in Table 31 and Appendix D. All of the CD trench monitoring wells have been sampled on an approximate weekly sampling frequency since February 15, 1991, to present (June 17, 1991). Prior to

February 15, 1991, these CD trench monitoring wells (except TM-9T) and recovery wells were sampled during previous Facility-wide groundwater sampling events. Trench monitor TM-9T has been sampled on a weekly frequency since September 11, 1990. The combination trench monitoring wells have been analyzed for total uranium, pH, specific conductance, nitrate as N, fluoride, and a special sampling event for arsenic. The trench porewater analytical data for these trench monitors is shown on Table 32.

6.3.2 Internal Investigation Activities

The initial step in the investigation was to develop an accurate understanding of the dynamics of the CD and contributing streams. This initial step was performed during the months of January through March 1991. SFC utility drawings were reviewed, and SFC personnel were interviewed to determine the location of the CD, contributing streams, and access points to the CD. After these points had been identified, a field inspection was performed to confirm the dynamics and locate sampling and/or flow monitoring stations. Also during the field inspection, the dimensions of CD manholes (entry/exit piping, depth to piping, and total depth) and weirs were measured. Flow could not be measured at all sampling locations because of the nature of the sampling point and structural interferences.

Two (2) separate sampling/flow monitoring events were subsequently performed. Sampling/flow monitoring Event No. 1 was performed on March 22, 1991. Twenty-five (25) sampling and/or flow monitoring stations were selected for Event No. 1. Table 33 describes the sampling/flow monitoring stations, and Figure 23 presents a schematic layout of the sampling/flow monitoring stations selected for Event No. 1. With the exception of the monitoring station located at Outfall 001, grab samples were collected concurrently with flow measurements at locations identified for both sampling and flow measurement. Grab samples were collected at Outfall 001 on a more frequent 30-minute interval. All grab samples were analyzed for total uranium, fluoride, radium-226, ammonia, nitrate, total suspended solids, pH, and conductivity. Sampling during Event No. 1 spanned approximately seven (7) hours during a typical Sequoyah Facility operational day. It should be noted that on the day prior to Event No. 1, between 7:00 a.m. on March 21, 1991, and 7:00 a.m. on March 22, 1991, 2.0 inches of rainfall were recorded at the MPB. The effects of the stormwater runoff were apparent from the steadily decreasing flow rates in contributing streams observed during the sampling.

Data collected from Event No. 1 indicated that significant diurnal flow and constituent concentration variations occurred over the sampling/flow monitoring period. These fluctuations were observed to be due to both the continually decreasing stormwater runoff and to the normal dynamics of the facility

processes and CD relationships. Because of these variations, the sampling and flow monitoring plan was re-evaluated, revised, and intensified for Event No. 2. The sampling and flow measurement strategies were intensified to better detect concentrations and flow rate variations, and also to allow a more accurate loading analysis. Event No. 2 was also planned to occur when rainfall was not influencing flow rates.

Sampling/flow monitoring Event No. 2 was performed on April 16, 1991. Twenty-nine (29) sample collection stations and fourteen (14) flow monitoring stations were selected for Event No. 2. Table 34 describes the sampling/flow monitoring stations, and Figure 24 presents a schematic sampling/flow monitoring layout of the stations selected for Event No. 2.

During Event No. 2, grab samples were collected on 30-minute intervals at sampling stations (Monitoring Stations 001 to 011) on the main segment of the CD. Samples at all other monitoring stations (Monitoring Stations 012 to 029) were collected on hourly intervals. Flow measurements were performed at least twice at each flow monitoring station. The first and last grab samples collected at each sampling location were analyzed for total uranium, fluoride, radium-226, ammonia, nitrate, total suspended solids, pH, and conductivity. All other samples were analyzed for total uranium, pH, and conductivity. Event No. 2 was more intensive and spanned a shorter time interval of approximately four (4) hours.

During both Events, a Marsh-McBirney Flo-Tote Model 260 (Flo-Tote) was used as the principal flow measurement device. The Flo-Tote was used to measure the flow velocity and flow depth at the selected stations. Calibration of the Flo-Tote was verified by comparison of the flow rate determined by the instrument and the flow rate determined by the depth of water at the Parshall flume located at Outfall 001.

6.4 Investigation Results

6.4.1 External Investigation Results

The results of the external CD investigation indicate that licensed material (uranium) has migrated into the backfill sands surrounding the CD. Referring to Figure 22, the average uranium, fluoride, nitrate, and total arsenic concentrations found in the trench monitoring wells are shown. The average total uranium concentration in the porewater from CD trench recovery well MW-RW-3T was 45,539 $\mu\text{g/L}$. Moving downstream or south along the trench to TM-9T, the average total uranium concentration decreased slightly to 35,954 $\mu\text{g/L}$. The average total uranium concentration at the location (MW-RW-1T) where the CD crosses the restricted area boundary is 43,878 $\mu\text{g/L}$. Moving southward from MW-RW-1T, the average total uranium concentrations are 7,875 $\mu\text{g/L}$ in trench well MW-33T, 101 $\mu\text{g/L}$ in trench well MW-34T, and 19 $\mu\text{g/L}$ in trench well MW-44T. The average fluoride levels in porewater along the CD are slightly elevated as compared to background, but show no definite trend or pattern. The total arsenic levels in the CD trench monitoring wells are all below EPA Primary Drinking Water

Standards for arsenic of 0.05 mg/L, except for MW-44T. The total arsenic level in MW-44T (0.412 mg/L) is thought to originate from the nearby calcium fluoride sludge holding ponds. The average nitrate levels noted in porewater from the trench monitors varied from 0.7 mg/L in MW-44T to 81.1 mg/L in MW-RW-1T. Based upon the data available to RSA, it appears that the uranium and nitrate found in the CD backfill porewater principally originated in the vicinity of the SX Building due to historical releases and spills in the SX process areas and not from the CD itself. The analytical data for CD trench wells are summarized in Table 32.

The total uranium concentrations in trench monitoring wells MW-33T, MW-34T, MW-44T, MW-RW-1T, MW-RW-3T, and TM-9T are shown in graphical form versus time in Figures 25 through 30, respectively. A review of these graphs of total uranium concentrations plotted against time indicates no specific long-term trends in the analytical data based upon the data collected from September 1990 to June 1991. Hydrographs of the Combination Stream Drain trench monitoring wells (TM-9T, MW-34T, and MW-33T) are plotted in Figure 31. A review of this drawing shows no significant change in the CD trench porewater levels from September 1990 to June 1991.

The volumes of fluids and quantities of uranium recovered from CD trench monitoring wells MW-RW-1T and TM-9T are shown in Tables 35 and 21, respectively. As discussed earlier, the volume of porewater removed from TM-9T between September 11,

1990, and June 18, 1991, was 10,688 gallons, and the quantity of uranium removed was 1358 grams. The volume of porewater and uranium recovered from MW-RW-1T (Table 35) between January 31, 1991, and June 17, 1991, were 9,223.2 gallons and 1.5 kilograms, respectively.

The hydrograph study of trench monitor well MW-33T and the CD discharge indicate that there is no apparent correlation between changes in water levels in the CD trench and discharge rates at Outfall 001 from the CD. This appears to indicate that there is no significant influx of porewater from the trench into the CD pipeline or an efflux of fluids flowing inside the CD into the trench backfill materials. A plot of the water level changes in the CD trench backfill materials versus the Outfall 001 discharges is shown on Figure 32. Although there appears to be no correlation between the CD discharge out Outfall 001 and water level changes in the CD trench porewater, SFC is investigating the cause of the porewater level changes noted between February 13-19, 1991. The preliminary focus of the investigation is the firewater lines in the SX Building area which have a pressure-pump that cycles on and off to maintain proper pressure in the lines. It is believed that there may be leaks in the firewater lines and when the pressure-maintaining pump is operated, the firewater lines slowly leak, eventually dropping in pressure until the next cycle is initiated. This may be the cause of the gradual porewater level changes noted in the CD trench backfill material.

Another very important observation about the CD trench backfill material is that porewater levels are several feet lower in the CD trench than the natural groundwater surface adjacent to the CD trench from the middle of the yellowcake storage pad northward toward the cooling water tower, as shown on Drawings 18 and 19. From the middle of the yellowcake storage pad southward, the porewater fluid level falls to the CD pipeline depth or slightly above the CD pipeline as shown on Drawing 18. This indicates that in areas where uranium impacts to soils and shallow utility trench porewater are known (i.e., the SX Yard), there is limited possibility of infiltration of these fluids into the CD pipeline. It is also possible that groundwater may be discharging into this utility trench, and the CD trench acts as a groundwater line sink which may prevent fluids from migrating significantly beyond this point, at least in the upper shallow water-bearing zones.

RSA has also evaluated the geochemistry of the CD trench porewater. This study will be presented in Section 7.0.

6.4.2 Internal Investigation Results

The plan view of the CD is presented on Drawing 16. The plan and profile views of the CD (Drawings 17 through 20) show the ground surface elevation, CD flow line invert elevation, the groundwater table elevation, and the CD trench backfill porewater surface elevation along the CD routing. The groundwater surface elevation is obtained from data collected from Sequoyah Facility groundwater monitoring wells on April

18 and April 19, 1991. The porewater surface elevation is obtained from data collected in trench monitors along the CD on April 18 and 19, 1991.

Analytical results from grab samples collected during the CD Investigation Events No. 1 and 2 are presented in Tables 36 and 37. Only one grab sample and one flow measurement was obtained at most monitoring stations for Event No. 1. In addition, rainfall occurred prior to Event No. 1, and the flows therefore included surface water runoff and were not indicative of a typical operational day without rainfall. The results from Event No. 1 are informative and indicate concentrations for all constituents were within the limits applicable to Outfall 001. The Event No. 1 data also indicate the potential sources for uranium include wastewater from the south yellowcake sump, cooling water system, sanitary sump, north yellowcake sump, and yellowcake unloading dock sump. The Event No. 1 data also indicated that due to the number of uranium contribution sources and flow variability observed, a greater intensity of sampling and flow measurement was necessary to evaluate the CD at the detailed level desired. Therefore, the sampling/flow monitoring program was intensified for Event No. 2. The following discussion focuses primarily on the CD Investigation results obtained during Event No. 2. Unless stated otherwise, the monitoring station numbers herein refer to stations identified in Event No. 2 (the numbering system for Event No. 2 is different from Event No. 1).

During both events, frequent sampling was performed at Outfall 001 (Monitoring Station 001). Review of Events No. 1 and 2 results from Outfall 001 shows that no uranium concentrations exceeded the NRC permissible discharge limit of 45 mg/L. During Event No. 1, the average uranium concentration measured at Outfall 001 was 519 $\mu\text{g/L}$, or 1.2 percent of the permissible discharge limit.

During Event No. 2, the average uranium concentration measured at Outfall 001 was 279 $\mu\text{g/L}$, or 0.6 percent of the permissible discharge limit. Other monitoring stations having uranium concentration generally at the concentrations measured at Outfall 001 or greater during Event No. 2 include the Combination Stream Drain at Manhole CD-3 (002), CD at the south yellowcake sump (005), the south yellowcake sump (006), the main drain (Manhole CD-9, 007), the main sump (008), CD at Manhole CD-10 (010), the sanitary sump east (011), the SX cooling water emergency drain (012), the hot side basin (016), the SX cooling water supply return (017), the MPB cooling water supply return (018), the cooling water supply at the cooling water supply meter south of the cooling water tower (019), the sanitary lagoon (024), and the sanitary wastewater treatment plant effluent (025). As can be seen in Table 37, the SX and MPB cooling water supply returns (017 and 018), the hot side basin (016), and the cooling water supply (019) consistently exhibited uranium concentrations of similar magnitude. This result occurs since the cooling water supply system is a recirculating system and suggests there is not a

great amount of make-up flow from the equalization basin to the hot-side basin at the cooling water tower.

Monitoring stations identified as having consistently low uranium concentrations include the decorative pond (004), equalization basin (009), make-up manway (013), MPB cooling water emergency drain (014), raw water basin overflow (015), MPB fire water drain at CD manhole CD-7 east (020), Combination Stream Drain at CD-7 (021), and the recompression evaporator stream effluent (029).

Radium-226, nitrate, fluoride, and ammonia concentration levels obtained during the two events (Tables 36 and 37) did not exceed the discharge permit levels at Outfall 001 (Table 7). The maximum radium-226 level measured at Outfall 001 was 5.1 pCi/L, which is significantly less than the maximum NPDES permit level of 30.0 pCi/L. For Event No. 1 and Event No. 2, all but two (2) of the samples obtained were below 2.0 pCi/L. Also, all fluoride and nitrate concentrations measured at Outfall 001 were below the MCL values for drinking water (4.0 mg/L and 10 mg/L respectively) and OWRB discharge permit levels (1.6 mg/L and 20 mg/L respectively). The pH measured at Outfall 001 was also within the permit range.

Except for the sanitary sump east (011) and the sanitary wastewater treatment plant effluent (025), all other samples obtained for nitrate during the two events were below the MCL of 10 mg/L for drinking water.

The fluoride clarifier effluent stream (002), the north ditch at sanitary sump east, and the emergency basin at sanitary sump east (018) slightly exceeded the MCL for fluoride of 4.0 mg/L for drinking water during Event No. 1. In no cases did the fluoride concentrations exceed the MCL for fluoride for drinking water during Event No. 2.

Tables 38 and 39 present flow data collected during Events No. 1 and 2, respectively. During Event No. 1, overflow from the decorative pond (004) contributed flow to the CD at CD manhole CD-3 (002). During Event No. 2, no overflow from the decorative pond (004) occurred. Based on flow measurements during Event No. 2, the major flow contributor to the CD is the overflow from the cooling tower equalization basin (009). The other principal flow source (yellowcake sump, sanitary sump, fluoride clarifier, roof drains) were small in comparison to the cooling tower system.

A real time continuous recording flow meter is installed on the CD at Outfall 001. Data from the flow meter is recorded by a strip-chart recorder located in the MPB for permanent documentation. Figure 33 presents the flow data recorded during the duration of Event No. 2. An analysis of this data shows flow rates during Event No. 2 at Outfall 001 (001) ranged from 1155 to 1540 gallons per minute.

Analysis of the continuously recorded data at Outfall 001 (001) (Figure 33) and the overflow from the equalization basin (009) (Table 39) which is primarily once-through cooling water, shows that the overflow from the equalization basin (009) is the largest contributor to the total flow at Outfall 001 (001).

The Event No. 2 flow data (Table 39) indicates the major source of flow into the equalization basin (009) is from the make-up manway (013), which in turn has major contributions of flow from the raw water basin overflow (015) and the MPB cooling water emergency drain (014). Figure 34, a plan and elevation view of the cooling water tower, identifies streams contributing to the flow dynamics of the equalization basin (009), and also the equalization basin's relation to the CD. The function of the equalization basin (009) is to provide automatic make-up of water to the hot side basin (016) and help balance flows. Under normal operating conditions, the equalization basin's (009) effluent flows into the main sump (008) and, to a lesser extent, to the hot side basin (016). The primary flow into the equalization basin (009) is from the make-up manway (013). Under certain surge conditions in the hot side basin (016), flow from the hot side basin (016) to the equalization basin (009) occurs as well. The cooling water system is discussed in Section 3.0 in relation to the overall Sequoyah Facility process.

Identifying major sources of uranium contribution to the CD is most accurately accomplished by combining both the uranium concentration and flow rate at each monitoring station. These elements collectively are referred to as loadings. For Event No. 2, the time period of 11:00 a.m. to 2:30 p.m. was selected as being most informative for a loading analysis. The loadings at sampling/flow monitoring locations during Event No. 2 are presented in Table 40 and on Figure 35.

The uranium loadings at Outfall 001, during Event No. 2, varied from 0.0005 kg/minute to 0.0033 kg/minute. As presented in Figure 35, uranium loadings generally decrease from Outfall 001 (001) upgradient to various main trunk CD junctions. The largest contributing uranium loadings were found at the main trunk junction from the cooling water system. At this point, the loading contributor to the CD is from the overflow from the equalization basin (0.0009 kg/minute, (019)). Again, the major flow contribution to the equalization basin is from the make-up manway (013). Also, the uranium loadings in the cooling water return and supply system ranged from 0.036 kg/minute (MPB cooling water supply return (018)) to 0.045 kg/minute (cooling water supply (019)) but do not directly contribute a major flow to the CD as explained previously.

It is significant to note that although the equalization basin (009) contributed the largest loading to the CD, all samples collected at the equalization basin (009) during Event No. 2

contained low uranium concentrations. Therefore, the fact that the equalization basin was the largest Event No. 2 loading contributor to the CD is a direct result of its flow rate into the CD.

The sanitary sump east (011) was also found to be a significant uranium loading contributor to the CD. The sanitary sump east (011) contained a uranium loading of 0.00029 kg/min. In contrast to the equalization basin, the sanitary sump had high uranium concentration and low flows.

As part of the internal CD Investigation, an analysis of flow data collected during Event No. 2 was made in an effort to determine the possibility of infiltration of groundwater or trench porewater, or of exfiltration of effluent from the CD concrete reinforced piping. An analysis of flow data collected during Event No. 2 was performed for two (2) time intervals. The analysis compared the difference between the sum of inflows and the outflow at Outfall 001 to the estimated accuracy of the flow measurement equipment. During the time interval between 11:00 a.m. and 12:45 p.m., the difference between the measured inflows to the CD (003, 006, 007 sanitary sump east, 009, 010, 1461 gpm) and measured outflow at Outfall 001 (001, 1365 gpm) was 96 gpm or 6.6 percent of the inflow and 7.0 percent of the Outfall 001 outflow. Similarly, between the time interval of 12:32 p.m. and 2:33 p.m., the difference between the same inflows (1432 gpm) and flow at Outfall 001 (1295 gpm) was 137 gpm or 9.6 percent of the

inflows and 10.6 percent of 001 flow. The percent differentials presented are well within the estimated accuracy of flow measurement equipment (15 percent). Both analyses presented indicate no detectable net infiltration or exfiltration occurred during Event No. 2.

7.0 FEI UNIT SOIL AND GROUNDWATER INVESTIGATIONS (TASKS 5 AND 6)

7.1 Introduction

SFC has planned and completed a detailed investigation of soils and groundwater in all areas of the 85-acre Sequoyah Facility. The investigation was initiated, completed, and reported in phases. The first investigative phase was initiated (August 1990) in response to releases detected in the vicinity of the SX Building. The effort was expanded (September 1990) to include investigations in the MPB area. The investigations in the MPB area encompassed the OML (September 19, 1990) response requirements. The SFC investigations in the SX Building and MPB areas were completed and reported on previously (Roberts/Schornick and Associates, Inc., 1990 and 1991).

The next phase of investigation, defined by the FEI Plan (October 15, 1990), expanded the scope of work to the entire 85-acre Sequoyah Facility (Figure 36). The FEI Plan was also required by the OML (Item 6). The FEI Plan has been fully implemented. Section 7.0 presents the activities and results of all phases of the soils and groundwater investigations completed to date at the Sequoyah Facility. Section 7.0 also presents a detailed description of the investigation methodology and rationale.



PAST AND PRESENT OPERATION UNITS

- 1 MAIN PROCESS BUILDING AREA
- 2 SOLVENT EXTRACTION AREAS
- 3 INITIAL LIME NEUTRALIZATION AREA (1970)
- 4 SURFACE WATER, ENTIRE FACILITY
- 5 CONSTRUCTION EQUIPMENT BURIAL AREA
- 6 EMERGENCY BASIN
- 7 SANITARY LAGOON
- 8 POND 1 SPOILS PILE
- 9 NORTH DITCH
- 10 ASH RECEIVERS, CONTAMINATED EQUIPMENT AREA
- 11 DRAINAGE AREAS AROUND EMERGENCY BASINS, SANITARY LAGOON INCINERATOR AND OLD RAFFINATE LINES
- 12 FLUORIDE SLUDGE BASIN #2
- 13 FLUORIDE SLUDGE STORAGE POND
- 14 FLUORIDE SETTLING BASINS
- 15 FLUORIDE SLUDGE BURIAL AREA
- 16 YELLOWCAKE SUMP AREA
- 17 CLARIFIER POND AREA
- 18 POND 2
- 19 DITCH, WEST OF POND 2
- 20 CONTAMINATED EQUIPMENT STORAGE
- 21 YELLOWCAKE STORAGE PAD
- 22 DITCH FROM UF₆ CYLINDER COOL DOWN AREA
- 23 CONTAMINATED SOIL FROM 1986 RELEASE
- 24 AMMONIUM NITRATE LINED PONDS
- 25 AREAS OF OPERATIONAL SPILLS
- 26 DECORATIVE POND
- 27 COMBINATION STREAM DRAIN
- 28 PRESENT LIME NEUTRALIZATION AREA

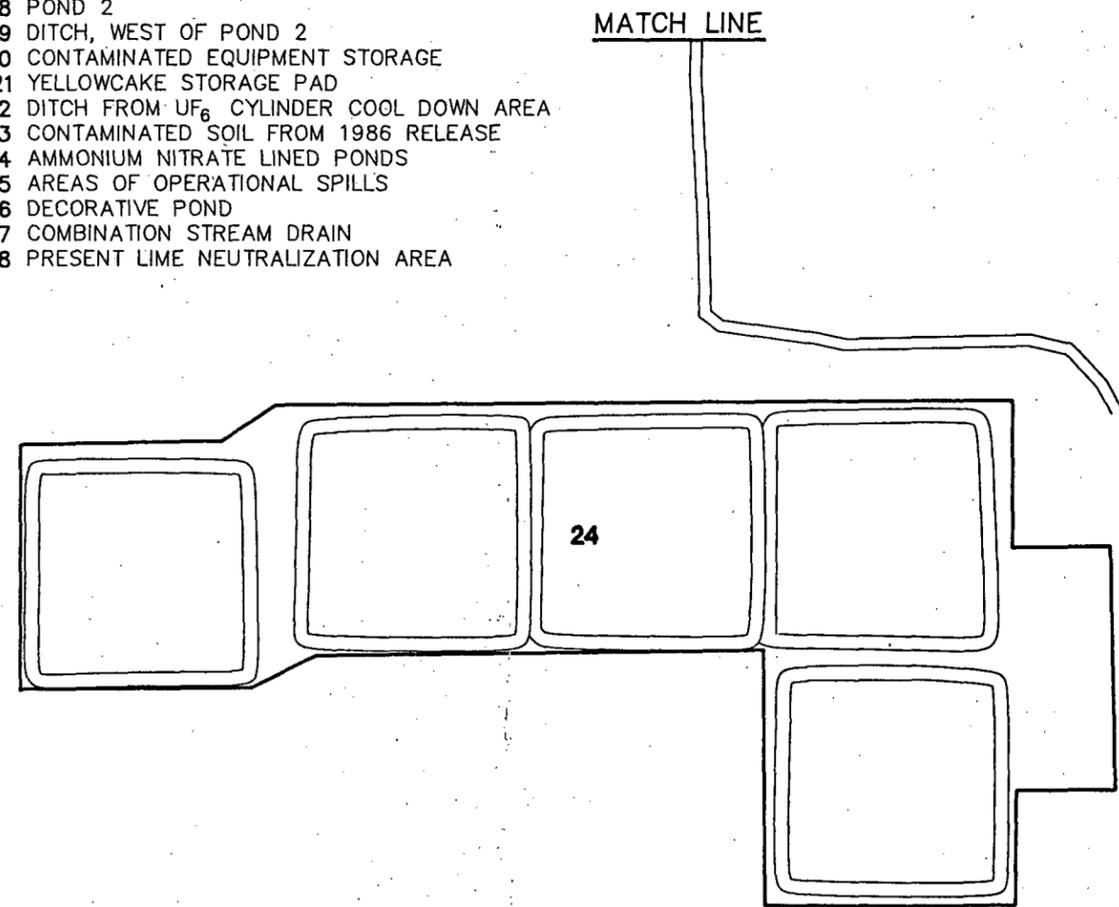
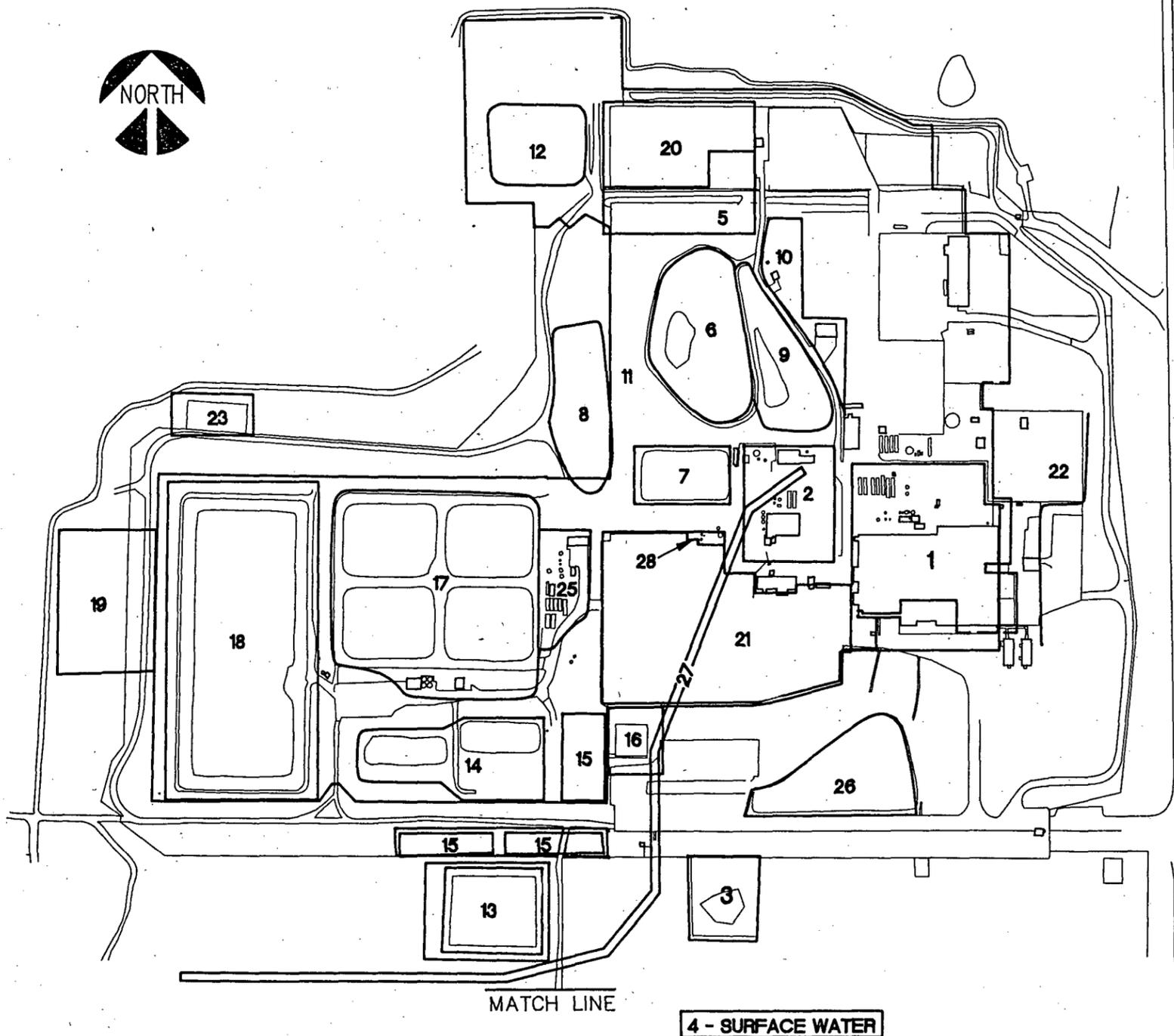


Figure Title:	PAST AND PRESENT OPERATION UNITS	Client:	SEOUYAH FUELS CORPORATION
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ROBERTS/SCHORNICK & ASSOCIATES, INC. Environmental Consultants <small>3700 West Robinson, Suite 200 Norman, Oklahoma 73072 (405) 321-3895</small>		DATE:	6/11/91
		SCALE:	N.T.S.
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		PREPARED BY:	D.B.
		CHECKED BY:	H.M.S.
		DRAFTED BY:	RML
		FIGURE NO.:	6

7.2 Scope and Objectives

The scope of the FEI soils and groundwater investigation included:

1. a review of pre-existing environmental monitoring data for all areas at the facility;
2. a review of land uses and general features, including facility processes;
3. a review of geological data from the area;
4. a detailed soils and groundwater investigation of the uppermost groundwater systems present in the restricted area and adjacent areas of the Sequoyah Facility, which includes soil borings, monitor well installation, groundwater sampling and analysis, soil sampling and analysis, impoundment sediment and water sampling, groundwater flow hydraulic property evaluation, and process waste stream evaluation; and
5. an evaluation of the subsurface geology and soil chemical quality.

The objectives of the FEI soils and groundwater investigations included:

1. Determining if releases of licensed material and other constituents have occurred from all past and present operational areas to the groundwater and define the extent of any releases detected,

2. Performing soils investigations of past and present operational areas which are determined to be potential sources of releases to the environmental and which require additional characterizational information to supplement existing historical information,
3. Fully defining the geological conditions which control the occurrence and movement of groundwater and any associated licensed material or other constituents in the subsurface soils and groundwater at the Sequoyah Facility,
4. Installing a comprehensive groundwater monitoring system capable of detecting releases of licensed material to the uppermost groundwater system,
5. Identifying areas where potential corrective action responses should be considered, and
6. Developing information useful for the definition of potential corrective action responses in the areas identified for consideration.

SFC identified twenty-eight (28) past and present operation unit areas on the facility property where the detailed investigations were completed. The scope of work and objectives of the FEI, stated above, were achieved. SFC now has in place a comprehensive groundwater monitoring system that is capable of detecting releases from all restricted areas and from all past and present FEI units located at the

Sequoyah Facility. As of June 17, 1991, SFC has installed a total of 163 monitoring wells which include 79 shallow shale/terrace groundwater monitoring wells, 78 deep sandstone/shale groundwater monitoring wells, 1 groundwater recovery well, 2 Combination Stream Drain (CD) trench recovery wells, and 3 CD trench monitoring wells. Approximately 210 soil borings have been drilled as part of the MPB, SX Building, and FEI unit investigations to characterize the extent and quantity of licensed materials and other constituents in the groundwater and soils beneath the Sequoyah Facility. The following subsections present the activities and results of the FEI effort.

7.3 Facility-Wide FEI Field Investigation Activities

7.3.1 Shallow Lithological Soil Borings

RSA drilled ninety-nine (99) machine-augered shallow soil borings across the Sequoyah Facility for the purpose of evaluating the subsurface stratigraphy/hydrogeology and to delineate the horizontal and vertical extent of possible licensed material impacts to shallow soils/groundwater. The final boring, BH-99, was drilled with rotary air methods and was placed downgradient of the surface water retention pond. This final boring was completed as a deep sandstone/shale monitor well, MW-90A. Five (5) of the borings, BH-37T, BH-44T, BH-56T, BH-61T, and MW-RW-3T, were drilled into the backfill surrounding the Combination Stream Drain underground

pipings and were completed as trench backfill monitor wells (MW-33T, MW-34T, MW-44T) and trench porewater recovery wells (MW-RW-1T and MW-RW-3T), respectively. These five (5) wells were installed to monitor and to recover porewater in the sand backfill of the Combination Stream Drain trench. The location of the lithological soil borings are shown on Figure 37. All ninety-nine (99) machine-augered soil borings (BH-1 to BH-98 and MW-RW-3T) were drilled by Professional Services Industries, Shepherd Engineering and Testing Division, under the professional supervision of a hydrogeologist from RSA (Roberts/Schornick and Associates, Inc., Norman, Oklahoma). The soil borings were all drilled between September 24, 1990 and March 12, 1991, utilizing hollow stem auger drilling methods and a CME 750 drilling rig. All borings were drilled to depths of between 1.9 feet to 30.4 feet. The shallow shale/terrace deposit soil borings were advanced until the underlying sandstone bedrock was encountered. The borings were then terminated at this contact and the borehole grouted to surface with a cement-bentonite grout mix. The purpose of boreholes BH-1 to BH-98 (except BH-37T, BH-44T, BH-56T, BH-61T, and MW-RW-3T) was to define the thickness and vertical extent of the upper shale and terrace deposits and to collect continuous soil samples for chemical characterization purposes. Borings BH-37T, BH-44T, BH-56T, BH-61T, and MW-RW-3T were drilled to monitor and recover porewater in the combination stream pipeline trench. Soil samples were also

collected from borings BH-37T, BH-44T, BH-56T, and BH-61T and analyzed for uranium.

A second machine-augered boring was drilled near each initial borehole (BH-1 to BH-98) location (except BH-37T, BH-44T, BH-56T, BH-61T, and MW-RW-3T), but was approximately five (5) feet from the first boring. This second boring was completed as a groundwater monitoring well. The reason two (2) separate boreholes were drilled was to prevent the possible communication of groundwater in the second borehole (which was completed as a shallow shale/terrace well) into the uppermost sandstone unit. The second borehole was typically terminated 1 to 2 feet from the top of the first sandstone unit to prevent potential cross contamination of the shallow shale/terrace system into the deeper sandstone/shale lithological sequence. A summary of the machine-augered soil boring drilling details is presented in Table 41.

Soil samples were collected continuously to the total boring depths in BH-1 to BH-98 and the CD trench wells utilizing a CME, 3 inch diameter, continuous tube sampling system. The CME sampler provided five (5) foot long continuous soil samples. Lithological descriptions of the soil samples were visually made by the on-site hydrogeologist according to the Unified Soil Classification System (ASTM D-2488 and ASTM D-2049). All remaining core and soil samples from the borings

not used for analytical testing programs were wrapped in cellophane and aluminum foil, labelled, oriented, and placed in waxed, water-proof core boxes for on-site storage. The soil boring logs are presented in Appendix E.

The hollow-stem augers and all downhole sampling equipment were decontaminated prior to use in each boring utilizing a high temperature/pressure washer at decontamination areas designated by SFC. All other sampling equipment was also washed between each sampling event. Augered cuttings from all boreholes were retained on site and were placed in DOT approved 55-gallon drums for storage until testing can be performed to determine disposal criteria.

All initial boreholes (BH-1 to BH-98) were backfilled to approximately one (1) foot from ground surface with a bentonite cement grout mix. The grout slurry consisted of approximately 94 pounds of Portland cement (one bag) mixed with approximately 6.5 gallons of water and about five (5) pounds of bentonite powder. All boreholes were rechecked the day after grout placement and those boreholes where the grout had subsided were "topped off". The remainder of the borehole was filled with concrete to ground level in all areas except the grassy areas. In the grassy areas, the top one (1) foot was filled with topsoil. The borehole was then surveyed by an

Oklahoma registered land surveyor for vertical elevation (\pm 0.01 foot) and location (\pm 1 foot).

7.3.2 Deep Sandstone/Shale Soil Borings

At every location where a shallow shale/terrace soil boring was drilled (except BH-1, BH-18, BH-24, BH-24, BH-34, BH-35, BH-36, BH-37, BH-38, BH-39, BH-40, BH-41, BH-44T, BH-55, BH-56T, BH-61T, BH-62, BH-63, BH-64, and BH-84), a deep sandstone/shale borehole was also drilled. The deep sandstone/shale boring was typically located 5 to 10 feet away from the lithological borehole and shallow shale/terrace deposit monitoring well. The deep sandstone/shale boring was typically drilled through the overlying upper shale/terrace deposit sequence using a 12 1/4 inch rock bit and air rotary drilling methods. The 12 1/4 inch borehole was drilled into the upper 6 inches to 2 feet of the underlying sandstone unit. A precleaned, screw-threaded, Schedule 40, 8-inch PVC surface conductor fitted with a water-tight, drillable cap was then placed into the borehole and cemented in place using a cement-bentonite grout mix as previously described. The 8-inch PVC conductor casing was installed to prevent possible contamination of deeper zones (deep sandstone/shale soils and groundwater) from soil or groundwater which was found in the shallow shale/terrace deposits.

The deep sandstone/shale soil borings were then advanced through the 8-inch PVC surface conductor casing. These borings were advanced using a 6-inch bit and air rotary drilling methods (a hydrocarbon filter was used to filter the air). Soil samples were collected continuously from soil cuttings and logged for lithological characteristics. Lithological logs were prepared from the top of the uppermost sandstone to total boring depth. Select boreholes were cored using a 3-inch NX corebarrel to provide additional lithological control. All cuttings and water were captured and placed in DOT approved 55-gallon drums for storage until testing can be performed to determine disposal criteria. All deep sandstone/shale borings were drilled by Pool Drilling, Clinton, Oklahoma, between September 1990 and April 1991. A total of seventy-eight (78) deep sandstone/shale borings were drilled, with depths ranging from 17.8 feet (BH-49A) to 53.3 feet (BH-83A). All deep sandstone/shale borings were completed as deep sandstone/shale groundwater monitoring wells, which are designated by an "A" after the well number (i.e., MW-50A). The deep sandstone/shale boreholes have also been designated by the letter "A" following the borehole number (i.e., BH-2A). The lithological logs for the deep sandstone/shale borings are shown in Appendix E.

7.3.3 Soil Sample Collection from Lithological Borings

Soil samples from the ninety-eight (98) machine-augered boreholes were collected continuously in five-foot lengths to total borehole depth. Soil samples were composited in the field into 6-inch increments for analysis for uranium, nitrate, and fluoride for most boreholes. The 5-foot long continuous tube soil cores were split into 6-inch increments and composited over each 6-inch interval. Approximately 200 grams of soil from the composited 6-inch interval was placed in precleaned, properly labeled, glass jars and submitted under chain-of-custody control to the SFC environmental laboratory for analyses. Additional soil samples were composited for soil vapor headspace gas readings as described in Section 7.3.9. All remaining soil was wrapped in cellophane and aluminum foil, labeled, oriented, and placed in waxed core boxes for permanent storage. The soil analytical data and composite intervals are shown in Table 29 and the analytical data will be discussed in detail in Section 7.4.5.

Soil samples were collected from the deep sandstone/shale borings over each two (2) foot interval (by collecting cuttings from air rotary drilling) and placed in precleaned, properly labeled, glass jars, for analysis of uranium, nitrate, and fluoride. These samples were handled in the same way as the augered soil samples. The soil analyses from the deep sandstone/shale intervals are also shown in Table 29 and

identified by the letter "A" designation behind the borehole number (i.e., BH-21A). A total of approximately 2160 soil samples were collected from these borings.

Approximately 885 soil samples from boreholes BH-1 to BH-41 were collected and generally analyzed for uranium, nitrate, and fluoride. Soil samples collected from BH-42 to BH-98 were collected on 6-inch intervals but only every other soil sample was analyzed for nitrate, uranium, and fluoride. Approximately 1278 samples were collected from BH-42 to BH-98 and about 840 were analyzed. The remaining 438 samples are being retained for possible future testing. The analytical data from the deep sandstone/shale borings will also be discussed in Section 7.4.5.

7.3.4 FEI Unit Soil Characterization Activities

Based upon a review of the chemical characterization results from the lithological characterization borings, the groundwater quality data, and data identified during the FEI unit historical document review, soils in several Units were investigated. The Units investigated were: Unit 1 (the MPB area), Unit 2 (SX Building area), Unit 3 (initial lime neutralization area), Unit 4 (surface water runoff areas), Unit 5 (construction equipment burial area), Unit 6 (emergency basin area), Unit 7 (sanitary lagoon area), Unit 9 (north ditch area), Unit 10 (ash receivers, contaminated equipment

area), Unit 11 (drainage areas around the emergency basin, sanitary lagoon, and north ditch), Unit 16 (south yellowcake sump area), Unit 20 (contaminated equipment storage area), Unit 21 (yellowcake storage pad), Unit 25 (the area of operation and spills), Unit 26 (decorative pond area), and the UF₆ cylinder storage area. The location of the FEI investigation units are shown in Figure 6. These units were investigated because analytical data or operational history indicated there was a possibility that licensed materials and associated constituents may have created impacts to shallow soils in these FEI Units. SFC's objective of these unit soil investigations was to determine the extent and quantity of any licensed materials and associated constituents in the soils. This data was required to plan future corrective actions in these areas, if required, and understand the potential migration pathways and sources of these constituents.

From March 5, 1991 to April 16, 1991, RSA and SFC drilled ninety (90) shallow soil borings to depths of between 1.5 feet to 5.0 feet in several of the FEI units. Most borings were drilled using a CME 750 drilling rig equipped with a 3-inch diameter, CME continuous tube sampling system. There were approximately twenty-four (24) soil sample sites that were drilled using a 4-inch diameter stainless-steel hand auger due to accessibility problems for the CME drilling rig. Most borings were taken to depths of 5 feet except in areas where

auger refusal occurred. All unit soil characterization borings were backfilled to surface with a cement-bentonite grout mix and the borehole was surveyed for vertical elevation (± 0.01 feet) and location (± 1 foot). Drilling details for the FEI unit soil characterization borings are shown in Table 42, and a map showing the location of these soil characterizations boring is shown on Figure 38.

Soil samples were collected from each unit characterization boring, composited over six (6) inch intervals, and placed in properly labeled precleaned glass jars. The soil samples were then given under chain-of-custody to the SFC laboratory for analysis of uranium, nitrate, and fluoride. The SFC laboratory typically analyzed every other six (6) inch depth interval (i.e., 0-0.5 foot analyzed, 0.5-1.0 foot not analyzed, 1.0-1.5 foot analyzed, etc.) but is retaining all the composited soil intervals not analyzed for possible future testing. A total of 610 soil samples were collected from the unit characterization soil borings associated with the units listed earlier. Out of the 610 six (6)-inch composite soil samples, 332 samples were analyzed for the parameters noted above. The analytical data for this unit soil sampling program are presented in Tables 43 and 44, and a detailed review of this data will be provided in Section 7.4.5. The unit soil characterization lithological boring logs are shown in Appendix F.

In addition to the soil samples taken for uranium, nitrate, and fluoride analyses, RSA collected soil samples for organic vapor monitor (OVM) headspace gas analyses. The OVM headspace gas measurement methodology is discussed in Section 7.3.9 and the results of the OVM survey will be discussed in Section 7.4.5.5. In general, soils from the unit soil investigation were composited over 2 foot intervals and placed in clean glass jars, covered with aluminum foil, and then sealed. Approximately 24 hours later (samples stored at ambient temperatures), the lid was unscrewed and the aluminum foil was pierced, thus obtaining an OVM headspace gas reading. All OVM headspace soil gas readings are summarized in Table 45.

7.3.5 Miscellaneous Soil Investigations

In addition to the unit soil characterizations mentioned above, RSA and SFC also collected soil samples from miscellaneous areas at the Sequoyah Facility. On November 7, 1990, RSA collected soil and water samples from the backfill material adjacent to the concrete on the east side of the south yellowcake sump (Unit 16). These soil samples were collected with a hand auger to a depth of 5.3 feet. A water sample was also collected by SFC from the open hand auger borehole (HA-22) on November 8, 1990 prior to plugging the boring with a cement-bentonite grout mix. The analytical results of this sampling event are presented in Table 46 and

a detailed description of these results will be presented in Section 7.4.5.1.

There were several other miscellaneous areas where soil samples were collected by SFC and analyzed for uranium, fluoride, nitrate, and pH. These included a firewater line southeast of the MPB, the scale in a laundry sewer pipe, soils near TM-23T, soils in the north storage pad area, soils north of the clarifiers, soils in the NOX roadway drainage to SX yard, and soils near the french drain pump west of the Pond 2 discharge routing line. This data is presented in Table 47. Most of these soil samples were collected from open excavations and were part of SFC projects which required excavation into soils at the Sequoyah Facility. A more detailed discussion of the results will be presented in Section 7.4.5.1.

7.3.6 Impoundment Investigations

SFC environmental personnel collected sediment samples from the Sequoyah Facility decorative pond (Unit 26), the sanitary lagoon (Unit 7), the emergency basin (Unit 6), the north ditch (Unit 9), and the ammonium nitrate lined ponds (Unit 24) at the locations shown on Figure 38 and Drawing 21 (except Unit 24).

On October 4, 1990, SFC collected four (4) sediment and four (4) water samples (water samples collected at each pond sediment sample site) from the Sequoyah Facility Decorative Pond (Unit 26). The upper six (6) inches of sediment was collected from the locations shown on Figure 37 and Drawing 21. These sediment and water samples were analyzed by the SFC environmental laboratory for total uranium. The analytical results are presented in Table 48 and will be discussed in detail in Section 7.4.5.3.

Sediment and water samples were also collected from the sanitary lagoon (Unit 7), the emergency basin (Unit 6), and the north ditch (Unit 9) on April 11, 1991 by SFC environmental personnel. The sediment samples were collected from the upper six (6) inches of sediment in each impoundment and analyzed for total uranium, fluoride, nitrate, and pH. In addition, a water sample was collected from each sediment sample site and analyzed for the above listed parameters and specific conductance. The location of the sediment sample sites are shown on Figure 37 and Drawing 21. The analytical results are presented in Table 49. These results will be discussed in detail in Section 7.4.5.3.

In addition, sediment samples were collected from ammonium nitrate lined pond 3E (Unit 24 area) and analyzed for uranium, fluoride, nitrate, radium-226, and thorium-230. These samples

were collected on June 20, 1991 by RSA and SFC by sampling the sediment that accumulated on the liner. The analytical results for this sampling of Pond 3E are presented in Table 50 and will be discussed more fully in Section 7.4.5.3.

7.3.7 Stream Sediment Sampling

On June 10, 1991, NRC, RSA, and SFC personnel collected sediment or soil samples from the intermittent drainages associated with Outfalls 001, 004, and 005. A sample of soil was also obtained from the bank of the Robert S. Kerr Reservoir. The soil samples were collected from about the upper three (3) inches of soil with a stainless steel hand trowel. The samples were split between the NRC and SFC for analyses of radium-226, thorium-230, and uranium. The soil sample sites (SFC-A through SFC-J) are shown on Figure 39. Also shown on this Figure are soil sample sites from a 1986 sampling event on these drainages. The analytical data for the 1991 sampling and soil samples taken in 1986 from areas near the 1991 sample sites are summarized in Table 51. A more detailed description of the analytical results will be presented in Section 7.4.5.2.

7.3.8 MPB Floor Investigation (Unit 1)

Soil samples were collected from fifteen (15) hand auger sample sites that were drilled through the MPB floor or areas immediately adjacent to the MPB floor. The hand auger borings

were drilled in September and October 1990 as part of the OML actions. These soil samples were collected to define the extent and quantity of uranium that may be present beneath the MPB floor. The results of this investigation were discussed in Section 5.4.2.2 and will not be discussed further.

7.3.9 Soil Headspace Gas Survey Activities

A soil headspace gas survey typically is the measurement of relative or specific volatile hydrocarbon concentrations in soil pores in the unsaturated and saturated zone at various points, distributed vertically and horizontally. In the unsaturated zone, hydrocarbons can exist in the vapor phase in soil pores, adsorbed onto soil particles, and as free hydrocarbon liquid in soil pores. Hydrocarbons in the saturated zone are typically adsorbed onto soil particles over the zone of groundwater fluctuations or may exist as free liquid in the soil pores. By obtaining soil headspace gas data at vertically and horizontally distributed points, the extent of subsurface hydrocarbon impact can be defined.

The ambient temperature headspace (ATH) method (Van Zyl, 1987) was utilized for the soil vapor survey for samples collected at the Sequoyah Facility. This method consists of collecting discrete (or composite) soil samples from a borehole and placing the soil in a glass container, leaving a vacant headspace in the glass container. The headspace gas in each

glass sample container is then analyzed for organic vapors approximately twenty-four hours later, using a portable organic vapor monitor (OVM) after storing at ambient air temperatures.

Soil samples from the ninety-nine (99) borings drilled across the Sequoyah Facility were collected in continuous 5-foot lengths using a 3-inch diameter, CME continuous tube sampler. Samples were collected continuously over the entire depth of each boring. The individual 5-foot long soil samples were often "shaved" to remove the outer layer of soil with the remaining soil composited over either one (1)-foot or two (2)-foot lengths and placed in glass jars (the jars were filled to 3/4 full). A layer of aluminum foil was placed over the top of the jar and the cap screwed in place, sealing the jar. After waiting approximately twenty-four hours (samples were stored at ambient air temperatures), the lid was unscrewed and the OVM detector probe was used to pierce the aluminum foil and an organic vapor headspace reading was obtained. The resulting OVM headspace gas readings are in parts per million (ppm) of total ionizable hydrocarbon based upon an isobutylene standard. The OVM detector was calibrated to a known isobutylene gas standard prior to the headspace gas readings. The OVM detector has a limit of detection of 0.1 parts per million of total ionizable hydrocarbon. Results of the OVM ambient temperature headspace gas readings are recorded (and

presented in graphical form) on the soil boring logs presented in Appendix E. A summary of all OVM soil gas readings has been prepared and is presented in Tables 45 and 52. The OVM soil gas readings provide an important insight into both the vertical and areal extent of hydrocarbon occurrence in the subsurface soils across the Sequoyah Facility. A soil headspace gas survey was not conducted on the deep sandstone/shale rock samples since they were collected via air rotary drilling methods which greatly affect any volatile hydrocarbons which may be present. The soil gas headspace survey was conducted to provide a gross evaluation of whether any organic impacts to Sequoyah Facility soil were evident. The headspace soil gas survey results will be discussed in Section 7.4.5.5.

7.3.10 Monitor Well Installation Activities

7.3.10.1 Shallow Shale/Terrace Deposit Wells

Seventy-nine (79) of the ninety-nine (99) machine-augered borehole locations were completed as groundwater monitoring wells in order to monitor shallow shale/terrace groundwater quality beneath the Sequoyah Facility, test the formations' physical properties, and measure groundwater elevations for hydraulic gradient/flow direction and seasonal water-level fluctuations. Trench monitoring wells (MW-33T, MW-34T, MW-44T) and recovery wells (MW-RW-1T and MW-RW-3T) were installed into the Combination Stream Drain trench sand backfill

material. Groundwater recovery well MW-RW-2 was also installed adjacent to BH-9. The location of the shallow shale/terrace deposit wells are shown on Figure 40.

All shale/terrace deposit and trench monitor wells were constructed with precleaned, 2-inch, screw-coupled, tri-lock, PVC casing and 0.010-inch slot, 2 to 10 foot long, PVC screens. Screen placement was chosen by placing the screen across and above the groundwater level observed at the time of drilling as well as fully screening the saturated portion of the terrace deposits and/or uppermost weathered shale. Placing the screen at this level in the zone of saturation allowed for the monitoring of potential immiscible layers or lighter-than-water organics on the groundwater surface as well as monitoring the uppermost saturated terrace deposits and/or weathered shale zone. Placing the screen above the existing saturated zone allows for monitoring a greater saturated thickness in the event the water-level rises. Special care was taken to avoid penetration of the underlying sandstone zone with the shallow/shale zones. The entire screen length annulus was surrounded with a clean 8-20 silica sand filter pack. A 0.15 to 0.80 foot long fines-catchment sump was placed below the screen interval and the bottom was fitted with a screw plug or a slip-cap held in place by stainless-steel screws. The sand filter pack extended from the bottom of the well to approximately 2.0 feet above the top of the

screen. A 2-foot thick sodium bentonite seal was placed above the top of the sand pack and hydrated with distilled water. The well annulus from the top of the bentonite seal to approximately 1.5 feet below ground level was filled with a bentonite/cement grout mix. All completion materials (screen, sump, riser, plugs, protectors and caps) were thoroughly precleaned before entering the borehole. Above-grade or at-grade steel casing protectors were placed over the PVC casing and concrete was placed in the remaining 1.5 feet of the borehole and a 2 foot diameter by 1 foot thick surface concrete pad poured for all above-grade completions. All at-grade completions have double, water-tight seals. The protector seal is watertight and a water-tight cap is also placed over the top of the PVC riser. Well completion diagrams for all shallow shale/terrace deposit wells are shown in Appendix G. A summary of shallow shale/terrace monitoring well completion details is shown in Table 53.

7.3.10.2 Fluid Recovery Wells

A total of three (3) recovery wells were installed during the investigation: MW-RW-1T, MW-RW-2, and MW-RW-3T. Recovery wells MW-RW-1T and MW-RW-3T were installed into the sand backfill of the Combination Stream Drain trench to recover porewater contained within the trench. Recovery well MW-RW-2 was installed to recover groundwater from the shallow shale/terrace system near the southwest corner of the MPB.

The locations of MW-RW-1T, MW-RW-2 and MW-RW-3T are shown on Figure 22. MW-RW-1T is located on the south side of the yellowcake storage pad at the location where the combination stream leaves the restricted area. Well MW-RW-2 is located in the vicinity of BH-9 at the southwest corner of the MPB, and MW-RW-3T is located northwest of the SX Building (between the SX Building and the sanitary lagoon and is located in the Combination Stream Drain trench).

Recovery well MW-RW-1T was constructed with precleaned 6-inch, screw-coupled, tri-lock, PVC casing and factory slotted 0.020-inch PVC screen, ten (10) feet in length. Screen placement was chosen by placing the base of the screen as close to the base of the combination stream as possible. This provides a maximum amount of screen saturation for maximum water recovery potential.

Recovery well MW-RW-2 was constructed with 6-inch, screw-coupled, tri-lock, PVC casing and factory slotted 0.020-inch PVC screen, ten (10) feet in length. Placement of the screen was chosen by placing the base of the screen as close to the underlying Unit 1 sandstone as possible.

Recovery well MW-RW-3T was constructed with precleaned 5-inch, screw-coupled, tri-lock, PVC casing and factory slotted 0.020-inch PVC screen, fifteen (15) feet in length. Screen

placement was chosen by placing the base of the screen as close to the base of the trench backfill material as possible. The well construction diagrams for these fluid recovery wells are presented in Appendix D. The locations of these wells are shown on Figure 22 and Drawing 21. Well construction details for these wells are presented in Table 31.

7.3.10.3 Deep Sandstone Conductor Casing

In order to prevent possible cross-contamination during drilling between groundwater and soil contained in the shallow shale/terrace unit and deeper groundwater bearing zones (sandstones and interbedded shales), RSA and SFC installed 8-inch PVC conductor casings through the entire extent of the uppermost groundwater bearing zone (shallow shale/terrace deposits). The conductor casings were set approximately 6-inches to 2.0 feet into the underlying sandstone. The conductor casing consisted of precleaned, 8-inch, Schedule 40 PVC, screw threaded, fitted with a drillable, water-tight bottom cap. The inside of the 8-inch conductor casing was filled with potable water and/or sand prior to placement into the borehole and cementing. The casing was set into a 12.25 inch borehole that was either drilled by rotary wash or air rotary methods. The casing was cemented in place by using a tremie line to place a cement-bentonite grout mix between the casing and borehole annulus. The cement-bentonite grout mix consisted of mixing 6 gallons of water to 3-5 pounds of

powdered bentonite per one (1) 94 pound bag of Portland cement. The cement was allowed to set-up over a minimum period of 24 hours prior to drilling through the casing bottom plug. The potable water and/or sand was placed into the casing was removed prior to drilling through the casing bottom plug.

The conductor casings were all installed by Pool Drilling of Clinton, Oklahoma under the professional supervision of an RSA hydrogeologist. Seventy-eight (78) conductor casings were installed between September 30, 1990 and April 1, 1991. A summary of the conductor casing drilling details is presented in Table 54.

7.3.10.4 Deep Sandstone Monitor Wells

Prior to drilling through the 8-inch conductor casings, all potable water and/or sand was removed from the inside of the casing. The bottom cap was then drilled out using a 6-inch bit and the borehole advanced using air-rotary drilling methods (a hydrocarbon filter was used to filter the drilling air). The boreholes were advanced into an interbedded sandstone and shale sequence referred to as the deep sandstone/shale groundwater system. The borings were generally terminated when a continuous sandstone unit that generally occurred between depths of 30 to 35 feet across the Sequoyah Facility was fully penetrated. The deep sandstone

monitor wells were advanced to depths of between 17.8 feet (BH-49A, north of Pond 2) to 53.3 feet (BH-83A, northeast of MPB area). The deep sandstone/shale wells were drilled and installed between October 5, 1990 and April 2, 1991 by Pool Drilling and supervised by a hydrogeologist from RSA. A total of seventy-eight (78) deep sandstone/shale wells were installed, and the location of the deep sandstone/shale wells are shown in Figure 41. The deep sandstone/shale wells were constructed of 2-inch, tri-lock, screw-threaded PVC casing and 0.010 slot screen. The screen interval generally extended from about 1 to 2 feet below the conductor casings to the bottom of the second or lower sandstone (generally, 30 to 35 foot depth interval). A seal of bentonite pellets was placed into the bottom of the borehole if the underlying shale was penetrated. This seal extended only to the bottom of the sandstone unit. A sand pack was placed around the screen and extended 1.5 to 2.0 feet above the top of the screen. A bentonite pellet seal was then placed on top of the sand pack (the top of sand typically was 6 inches to 1 foot below the conductor casing) and extended 1 to 2 feet into the conductor casing. The inside of the 8-inch conductor casing was then filled with a volclay grout to 1.5 feet from ground and an above ground or below-ground protector installed in the same manner as described in the shallow shale/terrace monitor well section. A summary of the deep sandstone/shale monitoring well drilling and completion details is presented in Table 55.

Monitor well completion records for the deep sandstone/shale wells are presented in Appendix H.

The shallow shale/terrace and deep sandstone/shale monitor wells were developed periodically between September 26, 1990 and May 20, 1991, using clean dedicated PVC bailers or a precleaned centrifugal pump. The wells were purged until the water visibly cleared of fine-grained sediment and the pH, temperature, and specific conductance of the developed groundwater stabilized. Monitor well development details for the shallow and deep wells are presented in Tables 56 and 57, respectively.

7.3.11 Hydraulic Conductivity Tests, Water-Level Measurements, and Well Depth Measurements

Hydraulic conductivity is a numerical description of the capability of an aquifer to transmit a volume of groundwater under a known hydraulic gradient through a unit cross-section of the aquifer over a known period of time. Hydraulic conductivity tests (falling and/or rising head tests) of the uppermost groundwater systems were conducted in most of the wells installed in the SX Building and MPB area in November and December, 1990, utilizing the slug test method (Bouwer and Rice, 1976). The hydraulic conductivity tests were conducted in wells which were constructed under rigid dimensional controls in order to provide representative values of

horizontal hydraulic conductivity for the upper shale/terrace and deeper sandstone/shale groundwater systems.

With the slug test method, the hydraulic conductivity of an aquifer is determined from the rate of rise or decline of the water level in a well after a certain volume or "slug" is suddenly inserted or removed from the well. Slug test results were evaluated in accordance with the methods presented by Bouwer and Rice (1976).

To provide useful data, slug tests in moderately permeable material are conducted using an automatic data logger and a pressure transducer to measure groundwater levels. Groundwater fluctuations were measured using an In-Situ Hermit SE-1000B Environmental Data Logger and a 10 psi downhole pressure transducer. In sandy or other permeable aquifers, the useful portion of the recovery curve occurs within the first few seconds of the test. A log-type measurement frequency is necessary to allow very frequent measurements (0.5 second or less) in the first several seconds and less frequent measurements after about 10 to 20 seconds.

In-situ field slug tests were conducted on several shallow shale/terrace and several deep sandstone/shale monitoring wells in November and December, 1990, to obtain measurements of horizontal hydraulic conductivity in each groundwater

horizon. The hydraulic conductivity values provide valuable insight into the transport velocity of the groundwater in the upper groundwater systems beneath the Sequoyah Facility. The slug test data is presented in Appendix I. The results of the slug tests are tabulated in Table 58 and are discussed in detail in Section 7.4.2.2.

Water level and well depth measurements have been periodically measured on all FEI installed groundwater monitoring wells at the Sequoyah Facility from September 1990 to June 1991. Water level measurements were generally taken on a two (2) or three (3) day frequency (from September 1990 to January 1991) in all wells except for seven (7) wells which were slow to reach equilibrium. In these wells (MW-3, MW-6, MW-15, MW-20, MW-21, MW-23, and MW-25), water levels were measured daily Monday through Friday beginning November 5, 1990 to about December 20, 1991. In January, 1991, RSA began to measure water levels on an approximate monthly frequency. The water level measurements were taken to accurately determine the hydraulic gradient and groundwater flow direction in the Sequoyah Facility area. Measurements taken at different time intervals also provide information on the extent of seasonal fluctuation of the groundwater surface. The water level measurements taken in the shallow shale/terrace deposits and deep sandstone/shale monitoring wells are summarized in Tables 59 and 60, respectively.

Well depth measurements were also taken periodically in the groundwater monitoring wells. The well depth measurements provide information necessary to assess the condition of a well (i.e., if the wells are experiencing silt build-up) and to provide the necessary purge volumes during groundwater sampling events. The well depth measurements for the shallow shale/terrace deposits and deep sandstone/shale wells are tabulated in Tables 59 and 60, respectively.

7.3.12 Groundwater Sampling Activities

Between September 28 and May 17, 1991, groundwater from the shallow shale/terrace and deep sandstone/shale wells was sampled on several occasions. The groundwater was sampled for the purpose of characterizing the chemical quality of the uppermost and next deeper groundwater systems upgradient and downgradient from the MPB and SX Building areas as well as other FEI units. The first Facility-wide groundwater sampling event was conducted between September 28, 1990 and October 11, 1990. Wells sampled during this time period were all in the SX Building or MPB area and were all installed as part of the OML. A second groundwater sampling event was conducted between December 5 to 10, 1990 and included sampling of all (including SX Building sandstone wells) wells in the SX Building and MPB areas. A third groundwater sampling event was conducted between February 4 to 8, 1991 and included all monitoring wells installed by RSA to February 8, 1991. A

special groundwater sampling event was conducted on March 7 and 8, 1991 in which eight (8) select wells were sampled for 19 heavy metals and volatiles and semi-volatile priority pollutant organics. A full description of this sampling event is discussed in Sections 7.4.3.13 and 7.4.3.14. The fourth Facility-wide groundwater sampling event was conducted between April 17 and May 17, 1991. As part of this fourth sampling event, groundwater from all wells was field analyzed for dissolved oxygen, Eh (oxidation/reduction potential), temperature, pH, specific conductance, and total alkalinity (carbonate, bicarbonate, and hydroxide). Several wells (21) were selected for analyses of the major anions and cations and other parameters that were required to construct a geochemical model of the groundwater systems. This sampling also included all utility trench monitoring stations and four (4) of these were tested for the major anions and cations. A limited groundwater sampling event was also conducted on the twelve (12) monitor wells installed, (MW-83 through MW-89A), on April 4-5, 1991. All wells were sampled by RSA personnel during all sampling events.

Prior to sampling, all wells were measured to determine groundwater level and well depth. In addition, the groundwater surface was generally inspected to determine if any floating immiscible liquids were present. Following these measurements, attempts were made to purge the wells of at

least three casing/sand pack volumes of groundwater in order to eliminate stagnant fluids within the well casing and sand filter pack. If the wells did not yield three (3) casing volumes prior to being bailed dry, the wells were allowed to recover for 12 to 24 hours prior to obtaining a sample. However, in a few cases, some of these wells would take longer before enough sample could be obtained for analyses. Purging was accomplished by bailing with precleaned dedicated PVC bailers. All bailers were fitted with clean monofilament line. All fluids purged from the wells were collected in 55 gallon drums and were retained for analysis.

Groundwater samples were collected with dedicated precleaned PVC bailers. The groundwater samples were carefully poured directly into the appropriately preserved sample bottles. Special care was exercised during sampling to avoid excess aeration of the sample. All samples were hand carried under chain-of-custody control to the appropriate SFC laboratory by RSA personnel.

The groundwater collected from all of the wells installed around the Sequoyah Facility was typically analyzed for uranium, fluoride, nitrate, pH, and specific conductance. The uranium, fluoride, nitrate, pH, and specific conductance parameters were chosen because they are major environmental indicator constituents for material used at the Sequoyah

Facility. During the final sampling event, an additional parameter (total arsenic) was added based upon results from the March 7 and 8 sampling event. Tables 61 and 62 summarize the time sequence over which groundwater samples were taken and the analytical test results for the shallow shale/terrace and deep sandstone/shale wells, respectively. All samples were analyzed by the SFC process or environmental laboratory except those collected for metal analyses, priority pollutant organic analyses, or major anions or cation analysis. Barringer Laboratory of Golden, Colorado conducted these analyses.

7.3.13 Area-Wide Water Well Survey Activities and Results
SFC and the Oklahoma State Department of Health (OSDH) initiated a survey to identify any water wells which may exist within an approximate 2-mile radius from the MPB. This survey consisted of contacting landowners who live approximately within this 2-mile radius area and requesting permission to sample any water well that may have existed on that property. In addition, SFC did an extensive search of old home sites located on SFC property to determine if there are any water wells on these properties. SFC and RSA also reviewed the U.S. Geological Survey water well database for Sequoyah County, the Oklahoma Water Resources Board (OWRB) files, wells identified in the Reconnaissance of the Water Resources of the Fort Smith Quadrangle, Hydrological Atlas 1, and wells identified by a

visual inspection of properties in the 2-mile radius area. No water well records were on file with the OWRB for wells within 2 miles of the Sequoyah Facility. Correspondence to this effect has been received from the OWRB and is presented in Appendix J.

All water wells identified through the above-described survey and their current use are shown on Figure 42. In addition, details about the water wells identified on SFC property and off-site residence (OR) water wells are presented on Tables 63 and 64, respectively. Information indicated on Tables 63 and 64 include well depth, casing size, casing type, water level, current well use, and well location. There were a total of ten (10) water wells identified on SFC property. Nine (9) of these wells are not in use and one (1) well, SFC-4, is used for lawn watering only.

A total of twenty-three (23) off-site water wells were sampled. The OSDH sampled seven (7) off-site wells on September 6, 1990. The OSDH and SFC sampled eighteen (18) off-site wells on May 9 and 10, 1991 (including two (2) wells previously sampled by the OSDH on September 6, 1990). The off-site residence well sampling program, performed jointly by OSDH and SFC, characterized the eighteen (18) wells sampled to include ten (10) wells currently in use for either livestock

or domestic purposes, seven (7) wells that are no longer in use and one (1) well that has an unknown current use.

The water wells located on SFC property vary in depth from 12.8 feet (SFC-6) to 132.7 feet (SFC-8). Most wells are constructed of 6-inch PVC. All known completion information is listed on Table 63. The off-site residence water wells vary in depth from 26.4 feet to greater than 200 feet, and are generally constructed of 6-inch PVC. All known well completion information for the off-site residence wells is listed in Table 64.

On September 6, 1990, the OSDH sampled seven (7) domestic groundwater supply wells in the general vicinity of the Sequoyah Facility. The sampling effort was initiated at the request of the landowners. These samples were collected by OSDH personnel and analyzed at the State of Oklahoma Environmental Laboratory, Radiochemistry Laboratory, for analyses of gross alpha, gross beta, and in one case, for uranium and radium-226. The results of these analyses are presented in Table 65. The analytical results indicate that all water well samples were below the EPA Primary Drinking Water limit established for gross alpha of 15 pCi/L, gross beta of 50 pCi/L, and radium-226 of 5.0 pCi/L.

The analytical report is presented in Appendix K. The analytical results for the on-site water wells are presented in Table 66. The on-site water wells were sampled by SFC personnel on April 9, 1991, and analyzed for total uranium, nitrate as N, fluoride, pH, gross alpha, gross beta, radium-226, and thorium-230.

The analytical results from the on-site well sampling indicate that fluoride and nitrate are at background levels in all wells and well below EPA drinking water standards. Total uranium was at background levels in all wells except SFC-1 which has uranium levels slightly higher than background at 11.0 $\mu\text{g/L}$ (April 9, 1991 sample) and 18.0 $\mu\text{g/L}$ (May 24, 1991 sample).

The pH in all wells were within EPA Secondary Drinking Water Limits of 6.5 - 8.5 except in well SFC-1 where the pH was 5.5 (April 9, 1991) and 5.8 (May 24, 1991).

Gross alpha, gross beta, and radium-226 were below drinking water standards in all wells except SFC-1, where gross alpha (270 pCi/L), gross beta (220 pCi/L), and radium-226 (10 pCi/L) have exceeded drinking water standards.

Well SFC-1 is an old abandoned water well located on SFC property approximately one-quarter mile due north of the MPB, as shown on Figure 42. This well is 86 feet deep and the water level on April 9, 1991 was measured at 2.1 feet from ground level. The well is uncased with only a short section of five (5) inch tin pipe at the surface. The well is abandoned and not in use. The specific conductance of the water from SFC-1 was 124 $\mu\text{mhos/cm}$. A specific conductivity of 124 $\mu\text{mhos/cm}$ is much lower than would be expected for groundwater in this area, which typically ranges from about 350 to 600 $\mu\text{mhos/cm}$ in shallow (upper 40 feet) area bedrock wells. This particular well was not purged to remove stagnant fluids prior to sampling. It is suggested that, based upon the pH values (5.5 - 5.8) being similar to rainwater, the low specific conductivity, and the fact that this well was not purged, surface water has flowed into this well.

SFC was unable to locate an abandoned water well which may have existed on the adjoining property to the north. The landowner believed there was once a well on the property, but was unable to find it. The location where the well was believed to be present is shown on Figure 42.

As part of the off-site residence sampling program, eighteen (18) off-site wells were sampled on May 9 and 10, 1991 by SFC and the OSDH, with split samples taken by SFC and OSDH for

analyses at their respective laboratories. The analytical results for the split samples collected by SFC are shown in Table 67. The OSDH results have not yet been reported. The SFC analytical data indicates that no uranium was detected in any of the off-site well samples. Fluoride concentrations were near or at expected background levels and no fluoride concentrations exceeded EPA drinking water limits. Nitrate levels were elevated over drinking water limits (10 mg/L) in wells OR-4 (19.2 mg/L), OR-6 (22.5 mg/L), and OR-8 (44.9 mg/L). These nitrate levels are very likely elevated due to impacts from landowner septic tanks and/or barnyard animals, and are not elevated due to Sequoyah Facility operations. None of these wells are in current use for any purpose. In addition, nitrate levels were elevated in wells OR-7 (9.8 mg/L) and OR-18 (3.3 mg/L), and are also likely due to septic tanks, and/or barnyard animals. Well OR-7 is in current use and well OR-18 is not in use. The gross alpha, gross beta, and radium-226 levels in all wells were all below EPA drinking water limits and did not appear to be elevated over background levels. Total coliform bacteria analyses indicated that fourteen (14) of the eighteen (18) wells exceeded the EPA drinking water limit set for coliform bacteria in drinking water. This is probably due to septic tank impacts, or the fact that many were not in use and not properly sealed at the surface. No additional follow-up work is necessary for wells

sampled during the off-site residence well sampling program on September 5, 1990 or May 9 and 10, 1991.

There were no identifiable groundwater users between the Sequoyah Facility and the Illinois and Arkansas Rivers, the likely groundwater discharge point for the shallow groundwater system. No apparent or known impacts to current or past groundwater users have occurred as a result of the Sequoyah Facility operation.

7.4 Results of Hydrogeological and Soil Assessments

7.4.1 Geology

7.4.1.1 Site Soils

According to the U.S.D.A. Soil Conservation Service, the MPB and SX Building are located over soils of the Pickwick Series. Other soils in the immediate process area include soils of the Hector Series, Linker Series, Stigler Series, Mason Series, Spiro Series, Ender Series, and Vian Series. A soils map of the Sequoyah Facility process area is shown on Figure 43.

According to the U.S.D.A. Soil Conservation Survey Map of Sequoyah County, Oklahoma (Abernathy, 1970), the Pickwick loam (PcC2), 2 to 5 percent slopes, eroded of the Pickwick Series directly underlies the MPB and SX Building. The Pickwick Series (PcB, PcC, PcC2) consists of deep, moderately permeable, well-drained soils on uplands that form in

weathered material from sandstone. Soil of the Pickwick Series typically have a surface layer of loam that is light brownish gray in the upper part and very pale brown in the lower part. A typical profile consists of light brownish-gray loam from 0 to 4 inches, followed by a very pale brown loam from 4 to 10 inches. Beneath this is a reddish-yellow light clay loam from 10 to 14 inches underlain by a reddish-yellow clay loam to 28 inches. From 28 inches to about 68 inches is a coarsely mottled reddish-yellow clay loam followed by a mottled light gray and reddish-yellow clay loam. Soils of the Pickwick Loam (PcC2) are typically eroded. Generally, the surface soil layer is 7 to 11 inches thick. This soil is suited to growing of small grain crops, sorghum, and tame pasture. This soil has a moderate corrosivity to uncoated steel and a high corrosivity to unprotected concrete. The individual mapping units PcB, PcC, and PcC2 were identified in this Series. The units PcB and PcC are both similar to the description provided above for the Series, with PcB occurring on 1 to 3% slopes and PcC occurring on 3 to 5% slopes.

The Vian Series (VaB and VaC) soils consist of deep, moderately slowly permeable, moderately well drained soils on uplands and form in loamy alluvium or loess. Soils of the Vian Series typically have a surface layer of silt loam. The upper part of the subsoil is typically a very pale brown silt loam. Below this is a brownish-yellow silty clay loam, and

below this, coarsely mottled light-gray, very pale brown and yellow silty clay loam. Two (2) mapping units (VaB and VaC) of Vian silt loam are found in the project area. Soil unit VaB occurs on 1 to 3% slopes and VaC occurs on 3 to 5% slopes.

The Stigler Series soils are deep, very slowly permeable, somewhat poorly drained soils on uplands. These soils typically have a surface layer that is light brownish-gray silt loam about 10 inches thick in the upper part with the lower part being a very pale brown silt loam to 18 to 20 inches. The subsoil is a very pale brown silty clay loam that grades to a brownish-yellow mottled silty clay loam or clay at 45 to 60 inches. The mapping unit present in the project area (LoD3) consists of Linker and Stigler soils with 2 to 8% slopes and is severely eroded. This mapping unit (LoD3) is typical of the descriptions given for the Linker and Stigler Series soils.

The Mason Series soils (Ma) consist of deep, moderately permeable, well drained soils in bottomlands. This Series typically has a surface layer of brown silt loam about 12 inches thick. The subsoil is brown silty clay loam extending to 72+ inches. The mapping unit, Mason silt loam (Ma), has 0 to 2% slopes and is typical of the Series.

The mapping unit Hector-Linker-Binder Complex (HCF), 5 to 40% slopes, was identified in the project area. The soils in the complex range from stony and very shallow to deep. Hector and Linker soils make up 75% of the total area. The soil characteristics for the mapping unit are described below.

The Hector Series soils consist of shallow, rapidly permeable, excessively drained soils on uplands that form in material weathered from sandstone. These soils are typically fine sandy loam to about 14 inches.

Soils of the Enders Series are deep, slowly permeable, moderately well drained and occur on sloping uplands. The soil has a fine sandy loam surface that is grayish-brown in the upper part and very pale brown in the lower part, with a combined thickness of 10 inches. The subsoil is red clay with mottling in the lower part and shale depth ranges from 30 to 55 inches.

The Linker Series soils consist of moderately deep to deep, moderately permeable, well drained soils on uplands that formed in material weathered from sandstone. These soils are typically loam and clay loam to about 30 inches.

7.4.1.2 Regional Geology

The Sequoyah Facility is located on the southwest flank of the Ozark Uplift, a major tectonic feature extending from east-central Missouri to northwest Arkansas and northeast Oklahoma. The Arkoma Basin lies immediately to the south and southeast, while the Ouachita Mountains are about 50 miles south of the Sequoyah Facility. The geology in the region consists of Quaternary-age alluvial and terrace deposits along and adjacent to the major rivers in the region. Bedrock formations present in the region consist of Pennsylvanian, Mississippian, Devonian, Silurian, and Ordovician-age shale, limestone, siltstone, and sandstone formations. The geologic formations regionally dip to the southwest at 2 to 3 degrees toward the Arkoma Basin. The bedrock formation present in the Sequoyah Facility area is the Pennsylvanian-age. A regional geological map showing the Sequoyah Facility is presented in Figure 44. An explanation for this map and a regional stratigraphic column is presented in Figure 45. An area stratigraphic column is also shown in Figure 46 for bedrock units present in the Arkoma Basin and adjacent areas.

7.4.1.3 Site Geology

The 85-acre Sequoyah Facility process area (including the MPB and SX Building areas), shown in Figure 36, is underlain by a thin layer of Quaternary-age terrace deposits which are underlain by about 390 feet of the Pennsylvanian-age Atoka

formation. The Atoka is underlain by the Pennsylvanian-age Wapanoka Limestone Formation. In areas, small amounts of fill materials are also present.

Fill Material

Small amounts of fill are present in select areas at the SFC Facility. Most of the fill materials occur in the MPB and SX Building areas immediately adjacent to buried utility lines and as subbase to concrete floors, concrete and asphalt roads, and concrete storage pad areas. The fill material in the buried utility line trenches immediately surrounding the utility lines consists mostly of silty sand and silty gravel. The fill materials in the utility trenches area, adjacent to but not immediately surrounding the utility line, consist mostly of silty sand, sandy gravel, silty clays, and weathered shale. The fill materials beneath the concrete floors, concrete storage pads, and roadways consist mostly of silty sand and sandy clay that reach a maximum thickness of about 1.5 feet. A silty clay and/or weathered shale fill material typically overlies the coarser sands and gravels in the utility line trenches. The fill material in the buried utility line trenches occurs from depths of about 0 to 20 feet but averages 5 to 7 feet in thickness and depth.

Terrace Deposits

A thin veneer of Quaternary-age Pleistocene terrace deposits covers most of the Sequoyah Facility area surface where fill materials are not present. The terrace deposits consist mostly of silts, sandy silts, silty clays, sandy gravelly clays, silty sandy clays, and clays that overlie shale and sandstone units of the Atoka formation. The terrace deposits are remnants of extensive terrace deposits laid down during high water stages of the Illinois and Arkansas Rivers. Downcutting by these rivers has left these deposits high above the present day river valley. From their maximum thickness on the hill tops in the area (including the MPB and SX Building areas), the terrace deposits thin rapidly in all directions. The terrace deposits in the Sequoyah Facility area range in thickness from about 0 to 16.4 feet (average about 6.7 feet) and occur between depths from 0 to 16.4 feet. The terrace deposits are thickest (16.4 feet) near the southwest corner of the MPB and thin in all directions away from this area. Beneath the MPB, the terrace deposits thicken southward from the north side of the MPB where the terrace deposits range from about 0 to 2 feet in thickness, to about 8 feet on the southeast side and about 16 feet on the southwest side of the MPB. The terrace deposits range in thickness from 5.0 to 8.7 feet in the SX Building area and occur from depths of 0 to 8.7 feet in this area. The terrace deposits exceed 10 feet in thickness near the southwest corner of Pond 2, the south

Yellowcake Sump area, the Emergency Basin, North Ditch, Sanitary Lagoon area, and the southwest corner of the MPB. The terrace deposits are less than 5 feet thick immediately north of the MPB, northwest of the Fluoride Pond #2, south of Pond 2, north of Pond 2, and in the initial lime neutralization area (Unit 3). An isopach map showing the thickness of the terrace deposits in the Sequoyah Facility area is shown on Figure 47. This map also shows the depth to the top of the Atoka bedrock surface, which are shales and sandstones in the Sequoyah Facility area. The thickness of the terrace deposits and their relationship to the underlying shales and sandstones of the Atoka formation is also shown on the geological cross-sections presented in Figures 48, 49, 50, 51, 52, and 53. The location of these geological cross-sections are shown on Figure 54. These geological cross-sections were prepared across several areas of the Sequoyah Facility and provide valuable information on the stratigraphic relationships between each lithological unit.

Atoka Formation

Immediately underlying the terrace deposits is the Pennsylvanian-age Atoka formation. The Atoka formation is characterized by very irregularly bedded discontinuous units of sandstone, siltstone, and shale with thin limestones in the lower part. Approximately 390 feet of the Atoka formation are present beneath the Sequoyah Facility. The base of the Atoka

formation (390 feet below the surface), rests on the unconformity at the top of the Wapanoka limestone formation. The Wapanoka outcrops about 10 miles northeast of the Sequoyah Facility and the top of the Atoka, marked by the Hartshorne sandstone, outcrops about 6 miles southwest of the Sequoyah Facility. Regional dip is generally to the southwest, which is also the direction of thickening of the Atoka. The members of the Atoka exposed at the Sequoyah Facility are about in the middle of the formation.

In the Sequoyah Facility area, the top of the Atoka formation occurs from about 0 to 16.4 feet below ground level as shown on Figure 47. The top of the Atoka present in the Sequoyah Facility area consists of an upper shale unit (Unit 1) which is present in areas shown on the bedrock surface geological map presented in Figure 55. This geological map presented in Figure 55 shows the geological units that subcrop beneath the terrace deposits at the Sequoyah Facility. This map is useful to identify the stratigraphic sequence beneath a given area at the Sequoyah Facility. This subcrop map shows that Unit 1 shale underlies the MPB and SX Building areas, the UF₆ storage pad, the yellowcake storage pad, the emergency basin, sanitary lagoon, the north ditch, the DUF₄ building, and portions of the clarifier and calcium fluoride sludge ponds. An isopach map showing the thickness of this upper Unit 1 shale is shown in Figure 56. The thickness of this uppermost (Unit 1) shale

ranges from a maximum of 20.1 feet near the northwest corner (BH-4) of the MPB to zero in the areas shown on Figure 56. The thickest areas of the Unit 1 shale are found in the yellowcake storage pad area, the SX Building area, the MPB area, and the area north of the MPB. The shale thins to zero feet west, north, and south from the MPB area. The thickness of this uppermost Unit 1 shale beneath the MPB ranges from about 6 feet in the southwest corner to about 18 feet near the northwest corner. The thickness of this shale unit ranges from about 12.5 to 20 feet in the SX Building area. The uppermost shale Unit 1 is typically dark grayish brown, fissile, and silty and sandy near the contacts with adjacent sandstone units. This unit is laterally continuous at the Sequoyah Facility until it is no longer present in the stratigraphic sequence due to its removal by erosion. The thickness of this shale unit is important since it is essentially an aquitard which inhibits the downward or upward movement as well as the horizontal movement of groundwater or associated contaminants.

A structure map showing the elevation of the surface of the Atoka bedrock is shown in Figure 57. This structure map of the Atoka bedrock surface indicates that the bedrock slopes toward the northwest, west, and south-southwest from the bedrock high located in the MPB area. The total relief noted on the bedrock in the Sequoyah Facility area is about 42.3

feet ranging from elevation 564.7 feet AMSL in BH-83 to 522.4 feet AMSL in BH-42. This represents a slope of 2.7 percent or a vertical drop of about 2.7 feet per 100 feet of distance. This map was prepared since the bedrock surface appears to have a "perched" groundwater system partially developed on its surface and the groundwater flow of the "perched" system will typically follow the slope of the bedrock surface.

A structure map showing the elevation of the uppermost Unit 1 shale was also prepared and is presented in Figure 58. This map indicates that the elevation of the Unit 1 shale unit is highest near BH-12 on the north side of the MPB and BH-83 (NE of MPB) and slopes away from these points to the north, south, and west. The maximum elevation of the Unit 1 shale surface noted was 564.7 feet AMSL in BH-83 and the minimum elevation observed was 541.0 feet AMSL in BH-62 which is northwest of the sanitary lagoon. A review of a structure map of this type is important since shale typically will exhibit a low vertical permeability and recharging water will tend to flow vertically until this shale unit is encountered and then becomes perched upon its surface. Groundwater flow of this perched system is then controlled by the slope or configuration of the shale surface. This structure map was also examined for the presence of erosional "valleys" or paleo-channels on the bedrock surface which often control the movement of groundwater and may also exhibit higher flow permeabilities

than adjacent materials. A possible eroded paleo-channel surface on the Unit 1 shale was noted to begin near the southwest corner of the MPB and trend south-southwesterly as shown on Figure 58. This possible paleo-channel is found at the same location where an intermittent drain was once located (Figure 43) and is likely related to this old stream channel. No other definite major paleo-channels were found at the Sequoyah Facility.

Located beneath the uppermost Unit 1 shale is a highly cemented, very fine to medium-grained, pale brown to dark gray, sandstone. This sandstone, referred to as Unit 1 sandstone, is laterally continuous across most areas of the Sequoyah Facility (Figure 55) and ranges in thickness from 0 to 12.5 feet (averages about 4 feet in thickness) and occurs between depths of about 2 feet to 27.5 feet. This sandstone unit is essentially impermeable (except for joints or fractures) due to its highly cemented nature. This unit would also be considered an aquitard in the Sequoyah Facility area. An isopach map showing the thickness of the Unit 1 sandstone is shown in Figure 59. This sandstone ranges in thickness from 0 to about 12.5 feet in BH-7 at the southeast corner of the MPB. The Unit 1 sandstone is thickest near the southeast and northeast corners of the MPB and generally thins towards the west where it is eventually removed from the section through erosion. A map showing the depth to the top of the

first sandstone (Unit 1 or Unit 2 sandstone) encountered in the Sequoyah Facility area is shown on Figure 60. This map shows that the depth to the top of the first sandstone unit ranges from 29.5 feet at the west end of the yellowcake storage pad (BH-86) to 1.9 feet (BH-84) on the east side of FEI Unit 3, etc. The depth to the uppermost sandstone typically decreases to the south, north, and west from the MPB and yellowcake storage pad area. This map is important since it also shows the combined thickness of the terrace deposits and any underlying shale. These deposits consist mostly of silts, clays, and weathered shales (clay minerals) which may inhibit downward migration of licensed material and also provide adsorption sites for licensed material. A structure map (Figure 61) of the top of the Unit 1 sandstone was also prepared to evaluate its surface configuration and possible paleo-channel systems. This map was prepared to aid in the evaluation of the groundwater data since the sandstone appears to be very tight and relatively impermeable. The Unit 1 sandstone surface elevation is highest along the north and east sides of the MPB and generally slopes toward the west, northwest, and southwest away from these areas. A possible southwest trending paleo-channel was identified on the sandstone surface south of the SX Building.

Beneath the uppermost Unit 1 sandstone in the MPB and SX Building area is an alternating sequence of laterally continuous sandstone and shale units which have been numbered sequentially as shale Unit 2, sandstone Unit 2, sandstone Unit 3, etc. These individual units have been characterized to a depth of about 40 feet in the MPB and SX Building areas and are shown on the lithological cross-sections shown in Figures 48 through 53.

In general, those units that have been penetrated by drilling are laterally continuous beneath the SX Building and MPB areas. The shale layer Unit 2 ranges in thickness from 2.6 to 9.8 feet (average 5.2 feet) and occurs between depths of 8 to 32.5 feet. This shale and sandy shale Unit 2 is dark gray to light brownish gray, fissile, silty, and contains thin laterally discontinuous silty sandstone lenses. Sandstone Unit 2 is dark gray to very dark gray, very fine grained, quartzose, well cemented sandstone. This laterally continuous unit in the SX Building and MPB areas contains laterally discontinuous beds of silty shale. This sandstone Unit 2 ranges in thickness from 3 to 10.3 feet (averages 5.0 feet) and occurs between depths of 12.5 to 38 feet below ground level in the MPB and SX Building areas. Shale Unit 3 underlies sandstone Unit 2. This shale is very dark gray, sandy to silty, carbonaceous, and contains thin discontinuous sandstone layers. Shale Unit 3 is laterally continuous across

the MPB and SX Building area and varies in thickness from 1 to >8 feet (average 2.5 feet) and is found between depths of 17.0 to >40.5 feet. Sandstone Unit 3 was penetrated by only five (5) borings in the MPB and SX Building areas. Based upon this data, this sandstone unit varied in thickness from 1.5 to 3.0 feet (average 2.5 feet) and was found between depths of 30 to 37 feet. This sandstone unit is highly cemented, very fine grained, very dark gray, and very hard. The last shale (Unit 4) was partially penetrated in only three (3) borings in the MPB and SX Building areas. This shale Unit 4 is greater than 4 feet in thickness and occurs between depths of 27.5 to 35.5 feet. A more detailed description of the terrace deposits and the individual shale and sandstone units (in the MPB and SX Building areas) is presented in the Sequoyah Facility specific stratigraphic column shown in Figure 62. Detailed stratigraphic cross-sections in the MPB and SX Building areas were presented in the Main Process Building, Final Findings Report, Revision 2, December 15, 1990. The individual shale and sandstone units described above are shown on these cross-sections but only shale Unit 1 and sandstone Unit 1 are identified on cross-sections presented in Figures 48 to 53. All other sandstones and shales are identified only as lower sandstone and lower shale units due to the apparent discontinuous nature of these units outside the immediate area of the MPB and SX Building areas.

The Atoka bedrock formation penetrated by drilling in the Sequoyah Facility area generally dips to the south-southwest from 0.5 to 4 percent (average 2 percent). Jointing and fracturing are present in this bedrock formation to varying degrees but do not appear to be a prominent feature in these rocks. The silty and sandy shales are much less conspicuously jointed than the purer clay shale, and the observable joints are wavy, irregular, and short. Most of the sandstone beds also lack prominent jointing; where observed, they are short and irregular.

The Carlile School fault (approximately 2800 feet southeast of MPB) is the most prominent structural feature in the immediate area and is located near the Carlile School in the NW Section of 22, T12N and R21E as shown on Figure 42. The plane of the fault is not exposed, but its presence is revealed by vertical beds of sandstone which form low hummocky parallel ridges south of the Carlile School. The ridges stretch for a couple of hundred meters across a pasture. They are about 150 feet apart, and are the surface indication of sandstone beds at 1 to 2 feet thick. Data collected during the drilling program in the MPB area did not indicate the definite presence of any faults or lithological offsets. However, some difficulty was encountered in correlation of lithological data south of the Decorative Pond, which could indicate a small fault or most probably a lithological facies change.

The area of East Central Oklahoma, where the Sequoyah Facility is located, lies in a quiet seismic region of the United States. Although distant earthquakes may produce shocks strong enough to be felt in this area, the region is considered to be one of minor seismic risk.

The most recent documented subsurface movement to have occurred within the SFC area occurred along the Meers Fault system an estimated 2,000 years ago. This system is located in south central Oklahoma. Other tectonic movements have occurred along the El Reno-Nemaha Ridge, which extends from central Oklahoma through Kansas and into Nebraska. Both of these systems are considered seismically dormant. The most recent significant regional tectonic movement occurred in the New Madrid area of Missouri. The probability of significant damage to the Sequoyah Facility from earthquakes is remote.

Minerals in the area consist of coal, limestone/sandstone, and sand/gravel from the Arkansas River floodplain, and clay and shale. The nearest coal production is approximately nine (9) miles west of the Sequoyah Facility. Coal is being mined from a depth of 1400 feet at Stigler in Haskell County, 18 miles south of the Sequoyah Facility. There are no known oil or gas fields in the area.

7.4.2 Hydrogeology

7.4.2.1 Regional Hydrogeology

Usable groundwater in the region occurs principally in the thicker alluvial and terrace deposits of the Arkansas, Illinois, and Canadian Rivers. Groundwater also occurs to minor degrees in the Pennsylvanian-age bedrock formations. A major bedrock aquifer (the Keokuk and Rush Springs formations of Mississippian-age) occurs approximately 10 miles northeast of the Sequoyah Facility. This aquifer is capable of yielding between 3 to 50 gallons per minute of good quality water. The location of the Sequoyah Facility with respect to major bedrock aquifers is shown in Figure 63. An explanation for this map is shown in Figure 64. The Sequoyah Facility is located near the edge of a major alluvial and terrace aquifer deposited along the Arkansas and Illinois Rivers. Site specific data indicate that only a thin veneer of terrace deposits exist at the Sequoyah Facility and these are not capable of yielding usable or sustainable quantities of groundwater due to their limited saturated thickness and areal extent. The terrace deposits in the Sequoyah Facility area yield very little to no groundwater and much of the terrace deposits in the MPB, SX Building, and overall Sequoyah Facility area are unsaturated and therefore are not capable of yielding groundwater. A map showing the Sequoyah Facility area with respect to major alluvial aquifers is shown in Figure 65.

A map showing the availability of groundwater in the area shows that the Sequoyah Facility is located over geological units which are considered least favorable for development of groundwater supplies. The map showing the availability of groundwater in the SFC area is shown in Figure 66. An explanation for this map is shown in Figure 67. The Sequoyah Facility is also located in an area where the chemical quality of groundwater contained in underlying lithological units is described as poor to fair. A map showing the general quality of groundwater in the Sequoyah Facility area is shown as Figure 68. An explanation for this map is presented in Figure 69.

Regional flow of groundwater in the Sequoyah Facility area is west and south toward the Arkansas or Illinois Rivers, the likely discharge point for shallow groundwater beneath the Sequoyah Facility. Groundwater may also discharge through springs, evapotranspiration, or recharge to other strata. The Atoka formations and terrace deposits of the area are likely recharged from precipitation falling over their outcrop areas, and to a lesser degree from recharge from underlying formations.

The only significant fresh water aquifer in the immediate SFC Facility area is the alluvium of the Arkansas River Valley. The lower part of the alluvium consists of up to 15 feet of

coarse sand with a productivity of as much as 900 gpm. The water is classified as "hard to very hard" (greater than 180 mg/L total hardness) but is suitable for irrigation and watering stock.

7.4.2.2 Site Hydrogeology

The hydrologic conditions in the immediate area of the Sequoyah Facility are typical of those described for the Atoka formation discussed below. This formation is considered to be a very poor aquifer because the soil cover is thin and has poor permeability thus limiting recharge, and the underlying sandstone and shale beds require fracturing to provide storage capacity. Water quality is poor and yields average only 0.5 gpm. It is estimated that because of the very low permeability of the Atoka rocks, a high percentage of the rainfall is lost by surface runoff.

The only local area capable of supporting a marginal well is adjacent to the Carlile School fault (Figure 42), where fracturing of the Atoka formation is sufficient to provide a reservoir of limited areal extent. The best water well on the Sequoyah Facility area is located in the belt of fracturing and has a depth of 84 feet, a static water level at 29 feet, and a yield of 1 gpm. The water quality of this well is better than average for the Atoka formation, having approximately 460 mg/L total dissolved solids. This well was

located at an old home site in the NW1/4, NW1/4 of Section 27, T12N, R21E. This well is abandoned and was not found during the area-wide off-site groundwater sampling conducted May 9-10, 1991. In contrast, water wells drilled at the three former home sites of State Highway 10 did not supply adequate water for domestic purposes. There are a few domestic/stock wells in the area that were used prior to the rural water district service. However, most of these wells are no longer in use. A complete description of area water wells and usage is provided in Section 7.3.13. The Sequoyah County Rural Water Association now supplies rural water to most area residents.

The Sequoyah Facility does not use groundwater resources but obtains water from the Tenkiller Reservoir located about 7 miles to the north.

Groundwater in the Sequoyah Facility area occurs in limited quantities in the Quaternary-age terrace deposits and within the deeper interbedded sandstones and shales in the Atoka formation. There appear to be two (2) hydraulically separate groundwater flow systems at the Sequoyah Facility. The uppermost groundwater system is a shallow fractured/weathered shale that is in hydraulic communication with groundwater contained in overlying terrace deposits. This uppermost groundwater system is referred to as the shallow shale/terrace

deposits groundwater system. Beneath this upper groundwater system, but hydraulically separated by a dense, highly cemented, non-porous sandstone is an interbedded shale and sandstone sequence referred to as the deep sandstone/shale groundwater system. The shallow shale/terrace groundwater system generally occurs from depths of 0 to 20 feet and the deep sandstone/shale groundwater system typically occurs between depths of 10 to 40 feet, depending upon the location at the Sequoyah Facility. In general, the terrace deposits northward from the middle of the MPB were unsaturated and did not contain groundwater at the time of water level measurements made on April 18 and 19, 1991. Southward from this area, the terrace deposits were saturated over a portion of their thickness. There were several other areas at the Sequoyah Facility where the terrace deposits were not saturated, specifically south and west of Pond 2 and all along the northern portion of the Sequoyah Facility near the restricted area boundary. A map showing the saturated thickness of the terrace deposits for April 18 and 19, 1991 is presented in Figure 70. The portion of the terrace deposits where the groundwater saturation is the thickest is in the southwest corner of the MPB in the area of the paleo-channel developed in Unit 1 shale surface. This map (Figure 70) also shows the depth that the first groundwater would be encountered (in areas where the terrace deposits are unsaturated) beneath the bedrock surface.

A map showing the depth to groundwater on April 18 and 19, 1991 in the shallow shale/terrace deposits is shown in Figure 71. The depth to groundwater on April 18 and 19, 1991 varied from -0.43 feet (above ground level) at MW-32 near the Decorative Pond to 21.09 feet below ground level at MW-73 along the northeast boundary of the Sequoyah Facility. The depth to groundwater varies from about 10 to 11 feet beneath the SX Building and 5 to 10 feet beneath the MPB. The depth to groundwater at the Sequoyah Facility is variable, but generally decreases from northeast of the MPB toward the south, west, and northwest.

The groundwater potentiometric surface for groundwater in the uppermost or shallow shale/terrace deposits is shown in Figure 72. As indicated in the map, groundwater flows radially away from the front entrance of the MPB. The groundwater potentiometric surface appears to be greatly affected by the trench well pumping program in the SX Building (where 15 trench sumps are pumped weekly) and adjacent areas. Except for the area in front of the MPB, the groundwater flow in the shallow shale/terrace deposits is toward the west, northwest, and southwest. The configuration of the shallow shale/terrace deposit potentiometric surface map is nearly identical on the Atoka bedrock surface configuration. This suggests that the configuration of the bedrock surface greatly influences the groundwater flow and suggests that groundwater found in the

shallow shale/terrace deposits may be partially perched upon the bedrock surface. A groundwater depression has been created near the SX Building due to the pumping of the trench sumps in this area. Preparation of a static potentiometric surface map for the shallow shale/terrace deposits was not possible due to pumping of the trench sumps and SX Building vault in the area. The groundwater in the uppermost shale/terrace deposits is under unconfined conditions and generally is perched on the bedrock surface in most areas.

The potentiometric surface map for the deeper sandstone and interbedded shale sequence for April 18 and 19, 1991 was prepared and is presented in Figure 73. This map shows that groundwater in formations underlying the shallow shale/terrace deposits generally flows to the southwest, west, and northwest from the MPB area. A comparison of this map to the structure maps of the top of the Unit 1 sandstone (Figure 61) and the bedrock surface structure map shows a good degree of correlation. The interbedded sandstone and shale bedrock sequence beneath the uppermost Unit 1 shale is under confined conditions and there appears to be no major communication with the groundwater contained within the overlying shale or terrace deposits. In fact, the uppermost Unit 1 sandstone unit may likely act as an impermeable barrier on which groundwater contained within the overlying shale and terrace deposits is partially perched. This sandstone is very highly

cemented, very fine grained, and has very little primary porosity through which groundwater can move.

A groundwater head difference map between the terrace deposits/uppermost shale unit and the lithological units beneath the uppermost shale has been prepared and is presented in Figure 74. This map shows that there is a significant difference in groundwater potentiometric surfaces between these water bearing formations monitored which is excellent evidence for hydraulic separation of the two (2) water bearing zones monitored. There was three (3) areas identified at the Sequoyah Facility where groundwater from the deep sandstone/shale sequence is at a higher vertical potentiometric surface elevation than the shallow shale/terrace groundwater. In these areas, groundwater from the deep sandstone/shale sequence has an upward flow gradient. These areas where this occurs are shown on Figure 74 and include the emergency basin and north ditch area, the Sequoyah Facility decorative pond area, and an area near well MW-73 and MW-83 at the northeast corner of the Sequoyah Facility. These areas appear to be associated with the old drainages or low topographical areas that were present naturally. It is significant to note that because there is an upward flow gradient in these areas, groundwater in the shallow shale/terrace deposits should not move vertically and recharge lower groundwater zones. However, over most of the Sequoyah

Facility, there is a slight downward gradient from the shallow shale/terrace groundwater system towards the deep sandstone/shale groundwater system.

Hydrographs of select wells in the Sequoyah Facility area have also been prepared and are presented in Figures 75 and 76. These hydrographs show short-term groundwater fluctuations and the relationship between the groundwater potentiometric surfaces in the two (2) water bearing formations monitored. In general, there is very little fluctuation noted in the deep sandstone/shale groundwater system, as evidenced by Figures 75 and 76. There appears to be an overall increase in groundwater levels for the shallow shale/terrace system for most wells, although this increase is small.

Slug tests were conducted on fourteen (14) shallow shale wells and twenty-one (21) deep sandstone wells at the Sequoyah Facility. The permeability or horizontal hydraulic conductivity of the shallow shale formations and terrace deposits ranged from a maximum of 1.28×10^{-2} cm/sec to a minimum of 2.07×10^{-7} cm/sec. The geometric mean from the fourteen (14) shallow shale wells was 2.02×10^{-5} cm/sec. The hydraulic gradient on April 18 and 19, 1991 in groundwater contained in the shallow shale/terrace deposits is variable over the Sequoyah Facility and ranges from about 0.005 to 0.04 feet/foot and averages 0.014 across the Sequoyah Facility.

The hydraulic gradient averages about 0.04 feet/foot on the south side of the MPB and about 0.005 feet/foot in the vicinity of the MPB and SX Building. The effective porosity for the fractured shale unit is estimated at 0.05 or 5 percent. Based upon these values, the average groundwater flow velocity was calculated using Darcy's flow equation:

where: $V = KI/n$
V = average flow velocity, cm/sec
K = hydraulic conductivity, cm/sec
I = hydraulic gradient, feet/foot
n = effective porosity, dimensionless

The average groundwater flow velocity in the shallow shale/terrace unit at the Sequoyah Facility is variable and largely dependent upon the degree and interconnection of fracturing present in the uppermost shale and the extent of the saturated portion of the terrace deposits. The average groundwater flow velocity in the shallow shale/terrace groundwater was calculated at 0.016 feet/day or about 5 feet/year, but may vary locally from about 2 feet per year to 16 feet/year.

The slug test results conducted on the deep sandstone/shale sequence indicated that the horizontal hydraulic conductivity of this geologic sequence ranged from a minimum of 4.47×10^{-6} cm/sec to a maximum of 3.49×10^{-4} cm/sec. The geometric mean from the slug tests conducted on the twenty-one (21) deep

sandstone wells was 6.76×10^{-5} cm/sec. The horizontal hydraulic gradient in the deep sandstone/shale groundwater system averaged 0.019 feet/foot but ranged from 0.08 feet/foot to 0.006 feet/foot in the MPB and SX Building areas. The effective porosity for the fractured shale/sandstone sequence was estimated at 0.05 or 5 percent. Based upon these values, the average groundwater flow velocity in the deep sandstone unit was calculated at 0.073 feet/day or about 27 feet/year but may locally vary from 8 to 112 feet/year. The results of the horizontal hydraulic tests (slug tests) are presented in Table 58 and the slug test data are presented in Appendix I.

7.4.3 Groundwater Quality Results

7.4.3.1 Introduction

Groundwater quality data has been collected from Sequoyah Facility wells installed as part of the unit FEI since September 1990. There have been four (4) Facility-wide groundwater sampling events as noted in an earlier section of this report. The first two (2) of these sampling events were conducted prior to the installation of all wells planned in the FEI. The third (February 4-8, 1991) and fourth (April 23-May 17, 1991) sampling events were conducted after all wells had been installed at the Sequoyah Facility. The analytical data collected from the April 23 to May 17, 1991 sampling event will be presented in the following series of isopleth maps that will show the distribution of total uranium, nitrate

as N, fluoride, total arsenic, hydroxide alkalinity, bicarbonate alkalinity, carbonate alkalinity, dissolved oxygen, pH, Eh, and specific conductance in the shallow shale/terrace and deep sandstone/shale groundwater systems. The analytical data from these sampling events are presented in Tables 61, 62, 68, and 69 for the shallow shale/terrace and deep sandstone/shale groundwater systems.

7.4.3.2 Total Uranium Isopleth Maps

Isopleth maps showing the total uranium concentration in the shallow shale/terrace and the deep sandstone/shale groundwater systems on April 23 to May 17, 1991 are presented in Figures 77 and 78, respectively. The data from the April and May time period is the most comprehensive and recent data set available from the FEI. Referring to Figure 77, the total uranium found in the shallow shale/terrace groundwater system varied from $<5.0 \mu\text{g/L}$ in several wells to $36,500 \mu\text{g/L}$ in well MW-10, which is located southwest of the MPB outside the restricted area boundary (RAB). The only other area where uranium levels outside the RAB occurred above the Sequoyah Facility EAL of $225 \mu\text{g/L}$ was at well MW-35 (located west of the emergency basin) where uranium was found at $395 \mu\text{g/L}$. Other wells at the Sequoyah Facility that exceeded the Sequoyah Facility EAL for uranium were wells MW-12 ($2330 \mu\text{g/L}$), MW-14 ($19,700 \mu\text{g/L}$), MW-18 ($4160 \mu\text{g/L}$), MW-24 ($442 \mu\text{g/L}$), and MW-25 ($31,600 \mu\text{g/L}$). These wells are all located within the RAB. In addition to a

comparison of the uranium levels detected in the uppermost shale/terrace deposits to Sequoyah Facility EAL, a comparison was made to background uranium levels which range from <5.0 to 10 $\mu\text{g/L}$. The uranium isopleth map (Figure 77) indicates that uranium was detected in groundwater southwest of the MPB, north and west of the SX Building, northeast of the MPB, west of the emergency basin, the emergency basin and sanitary lagoon area, south of the calcium fluoride sludge ponds, and along the northeast side of Pond 2.

The total uranium isopleth map (Figure 78) for the deep sandstone/shale groundwater indicates there are no areas outside the restricted area boundary where uranium exceeded the Sequoyah Facility uranium EAL. There are only two (2) wells outside the restricted area boundary (RAB) where the total uranium exceeded the background uranium levels of 5 to 10 $\mu\text{g/L}$. These were wells MW-2303A at 14 $\mu\text{g/L}$ and well MW-81A at 11.0 $\mu\text{g/L}$. Inside the RAB, there were four (4) wells where uranium in groundwater exceeded the Sequoyah Facility EALs. These wells were MW-12A (14,200 $\mu\text{g/L}$), MW-25A (1420 $\mu\text{g/L}$), MW-50A (587 $\mu\text{g/L}$), and MW-87A (321 $\mu\text{g/L}$). Referring to Figure 78, the total uranium isopleth map indicates that uranium was encountered in groundwater at the northwest corner of the MPB, north and west of the SX Building, the contaminated equipment burial area, and north of fluoride sludge Pond #2.

There is no data to indicate that uranium has migrated beyond the Sequoyah Facility property boundary. The uranium in the groundwater appears to be contained mostly in a small area centered near the MPB and SX Building areas. The FEI investigation has defined the extent of uranium in the groundwater at the Sequoyah Facility.

7.4.3.3 Nitrate Isopleth Maps

Isopleth maps showing the concentration of nitrate as N in the shallow shale/terrace groundwater and the deep sandstone/shale groundwater are shown in Figures 79 and 80, respectively. The nitrate levels found in the shallow shale/terrace groundwater system ranged from <0.1 mg/L to 2040 mg/L in well MW-25. The Sequoyah Facility EAL for nitrate is 20 mg/L. This level was exceeded in nine (9) wells outside the RAB and in seven (7) wells inside the RAB. The nitrates are found above the Sequoyah Facility EAL on the east side of the MPB, the southwest corner of the MPB, north and west of the SX Building, north of the MPB, west of the Pond 1 spoils pile, and in the area of the clarifier ponds and Pond 2 as shown in Figure 79. The background level for nitrate appears to be about 1.0 mg/L or less.

The nitrate levels found in the deep sandstone/shale groundwater (Figure 80) range from 0.1 mg/L to 4210 mg/L in well MW-58A south of Pond 2. There are fifteen (15) wells

outside the RAB where nitrate exceeds the Sequoyah Facility EAL of 20 mg/L, mostly located adjacent to Pond 2, or west of the Pond 1 spoils pile. There are eleven (11) wells inside the RAB where nitrate exceeds 20 mg/L. The nitrates are found in the groundwater inside the RAB in the SX Building area, the north ditch, emergency basin, and sanitary lagoon area, and in the Pond 2 area. The background nitrate levels in the deep sandstone/shale groundwater appear to range from less than 1 to about 2 mg/L.

Most of the nitrate found in the Sequoyah Facility groundwater probably originated from process leaks and spills in the SX Building area, historical leakage from Pond 2, and from the Pond 1 spoils pile. SFC will undertake a program to further define the extent of the nitrate plume in the groundwater systems found beneath the Sequoyah Facility. In particular, additional well placement will need to be determined for locations west and south of Pond 2 in areas accessible at the Sequoyah Facility.

7.4.3.4 Fluoride Isopleth Maps

Fluoride concentrations in the shallow shale/terrace and deep sandstone/shale groundwater systems are also presented as isopleth maps as shown in Figures 81 and 82, respectively. The isopleth map for the shallow shale/terrace groundwater (Figure 81) shows fluoride levels that range from 0.2 mg/L in

well MW-77 to 9.7 mg/L in well MW-40. The Sequoyah Facility EAL for fluoride is 1.6 mg/L and the drinking water MCL is 4.0 mg/L. The background fluoride levels appear to be 1.0 mg/L or less. There are nine (9) wells where the fluoride exceeds the Sequoyah Facility EAL outside the RAB and five (5) areas inside the RAB where fluoride exceeds the Sequoyah Facility EAL of 1.6 mg/L. The fluoride is found in groundwater above the EAL southwest of the MPB, northeast of the SX Building, north of the clarifier pond (north of old fluoride sludge pond #1), in the south yellowcake sump area, and south of the calcium fluoride sludge ponds and sludge burial areas.

The fluoride found in the deep sandstone/shale groundwater ranged from 0.2 mg/L in well MW-24A to 4.2 mg/L in well MW-64A. Referring to Figure 82, there were eight (8) wells where the fluoride exceeded the EAL of 1.6 mg/L outside the RAB and one (1) well where the fluoride exceeded the EAL inside the RAB. The fluoride background levels appear to be 1.0 mg/L or less for the deep sandstone/shale groundwater. The fluoride levels in the deep sandstone/shale groundwater are above the Sequoyah Facility EAL south of Pond 2, in the vicinity of the calcium fluoride sludge ponds, and on the east side of the yellowcake storage pad. The fluoride concentrations are less than the fluoride MCL (4.0 mg/L) with the exception of MW-64A (4.2 mg/L).

7.4.3.5 Total Arsenic Isopleth Maps

The total arsenic isopleth maps for the shallow shale/terrace groundwater and the deep sandstone/shale groundwater are described in the metals groundwater analytical Section 7.4.3.13 and thus will not be discussed here.

7.4.3.6 Carbonate Alkalinity Isopleth Map

The alkalinity of the groundwater is very important in determining the mobility of various species of uranium in the groundwater. Isopleth maps have been prepared for carbonate, hydroxide, and bicarbonate alkalinity found in the two (2) groundwater systems.

An isopleth map showing the carbonate alkalinity (CaCO_3) isopleth map for the deep sandstone/shale groundwater is shown on Figure 83. There was no carbonate alkalinity present in the shallow shale/terrace groundwater system. Carbonate alkalinity as CaCO_3 was found in groundwater from wells MW-8A (40 mg/L), MW-10A (40 mg/L), and MW-19A (80 mg/L). The carbonate alkalinity is related to the elevated pH of 9.0 or greater for these three (3) wells. The carbonate levels, as CaCO_3 , are thought to have originated from soda ash (Na_2CO_3) once stored on the ground east of the MPB.

7.4.3.7 Hydroxide Alkalinity Isopleth Map

An isopleth map (Figure 84) showing the hydroxide alkalinity for the deep sandstone/shale groundwater system is nearly identical in configuration to the carbonate alkalinity isopleth map (Figure 83), suggesting that they are related. The hydroxide alkalinity ranged from 300 mg/L in MW-8A to 280 mg/L in MW-10A to 180 mg/L in MW-19A to 180 mg/L in well MW-22A. There was no hydroxide alkalinity found in the shallow shale/terrace groundwater system. The hydroxide alkalinity is also thought to be associated with the storage of soda ash east of the MPB.

7.4.3.8 Bicarbonate Alkalinity Isopleth Maps

Isopleth maps showing the bicarbonate alkalinity as CaCO_3 in the shallow shale/terrace and deep sandstone/shale groundwater systems are shown on Figure 85 and 86, respectively. The bicarbonate alkalinity of the shallow shale/terrace groundwater ranges from 20 mg/L at wells MW-5 and MW-40 to 680 mg/L at well MW-78. The lowest bicarbonate levels are found in the MPB area, the initial fluoride neutralization area (Unit 3), in the Pond 1 spoils pile area, and north and west of the SX Building. The highest bicarbonate levels are found near the calcium fluoride sludge ponds, the area north of the sanitary lagoon, an area east of the north ditch, and near the contaminated equipment burial area. There seems to be a general correlation between low bicarbonate levels and high

uranium levels in the shallow shale/terrace groundwater system.

The isopleth map showing bicarbonate alkalinity as CaCO_3 in the deep sandstone/shale groundwater is shown in Figure 86. The bicarbonate alkalinity ranges from zero in wells MW-8A, MW-10A, MW-19A, and MW-22A to 660 mg/L in wells MW-41A and MW-2330 west of Pond 2. The bicarbonate levels are lowest in the MPB and SX Building areas and typically increase to the north, south, and west from these areas. The bicarbonate levels are highest in the calcium fluoride sludge pond areas, the clarifier pond area, and the southwest corner of Pond 2.

7.4.3.9 Dissolved Oxygen Isopleth Maps

The dissolved oxygen in the groundwater system is also important in defining the mobility of uranium species in groundwater. Various uranium species will have different mobilities depending on the oxidation/reduction potential of the groundwater, which is related to the dissolved oxygen content. The dissolved oxygen isopleth map for the shallow shale/terrace deposit groundwater system is shown in Figure 87. The dissolved oxygen ranged from 1.33 mg/L in well MW-42 (south of south yellowcake sump) to 9.2 mg/L in well MW-70. The dissolved oxygen was typically found to be lowest in the south yellowcake sump area, south-southwest from the MPB, and northeast from the MPB. There appeared to be no definite

correlation of dissolved oxygen to uranium levels or any other parameters measured.

The dissolved oxygen isopleth for the deep sandstone/shale groundwater system is shown on Figure 88. The dissolved oxygen ranged from 2.52 mg/L in well MW-9A to 7.83 mg/L in well MW-2330. The lowest dissolved oxygen levels were found east of the Pond 1 spoils pile, south of the fluoride sludge Pond 2, and south-southwest of the MPB. The dissolved oxygen content of the deep sandstone/shale groundwater did not vary much over the Sequoyah Facility and there was no definite correlation to other parameters measured in groundwater. The dissolved oxygen levels were generally higher in the shallow shale/terrace groundwater system when compared to the deeper sandstone/shale groundwater system.

7.4.3.10 Eh Isopleth Maps

Isopleth maps showing the oxidation/reduction potential, Eh, of the Sequoyah Facility groundwater system are shown in Figures 89 and 90. The Eh isopleth maps were prepared because the oxidizing or reducing potential of the groundwater will greatly affect the solubility and mobility of various uranium species in groundwater. The Eh isopleth map shown in Figure 89 shows that the Eh levels in the shallow shale/terrace groundwater varied from -180.1 millivolts (MV) in well MW-21 to 545.0 MV in MW-30. The lowest Eh levels generally occurred

in the south yellowcake sump area, the areas northeast and south-southwest of the MPB, and near the southeast corner of the contaminated equipment burial area. There appears to be no definite correlation between Eh and total uranium levels found in the shallow shale/terrace groundwater.

The Eh isopleth map (Figure 90) for the deep sandstone/shale groundwater shows values that range from -105.1 MV in MW-8A to 364.8 MV in well MW-57A. The lowest Eh levels in the groundwater occur in the MPB area and the highest levels occur at the southwest corner of Pond 2. There appears to be no direct correlation between the Eh levels and uranium levels in deep sandstone/shale groundwater.

A graph (Figure 91) has been prepared that shows the Eh plotted against dissolved oxygen for groundwater and trench porewater. This graph also identifies the wells or trench monitors where uranium levels were greater than 50 $\mu\text{g/L}$. Referring to Figure 91, there is a definite pattern to the dissolved oxygen and Eh values. The shallow shale/terrace groundwater tends to have the highest dissolved oxygen and Eh values followed by the deep sandstone/shale wells. An unexpected result, however, was that the utility trench porewaters typically had the lowest dissolved oxygen and Eh levels, possibly indicating that anaerobic conditions may be occurring in these waters. There was only one shallow

shale/terrace well (MW-18) that had uranium levels over 50 $\mu\text{g/L}$ and an Eh of less than 100 MV. No deep sandstone/shale wells had uranium present greater than 50 $\mu\text{g/L}$ and Eh levels below 100 MV. Most of the groundwater monitoring wells where uranium was detected had Eh levels between 200 MV to 300 MV and dissolved oxygen levels between 4.0 mg/L to 7.0 mg/L.

7.4.3.11 pH Isopleth Maps

Isopleth maps showing the pH of the shallow shale/terrace groundwater and the deep sandstone/shale groundwater are shown on Figures 92 and 93, respectively. Referring to Figure 92, the pH of the shallow shale/terrace groundwater ranged from 4.63 in MW-40 to 7.51 in well MW-59. The areas of lowest pH occur near the southwest corner of the MPB, north of the SX Building, and north of the clarifier ponds. There are no areas of unusually high pH noted in the shallow shale/terrace groundwater system.

The pH isopleth map (Figure 93) for the deep sandstone/shale groundwater varies from 11.58 in well MW-10A to 4.19 in well MW-2326. The highest pH values are associated with wells in the MPB area and the lowest pH wells are located in the southwest corner of Pond 2.

The pH of the groundwater system is also an important parameter in determining the solubility, mobility, and species of uranium present in groundwater at the Sequoyah Facility.

7.4.3.12 Specific Conductance Isopleth Maps

Isopleth maps were prepared for the shallow shale/terrace groundwater system and the deep sandstone/shale groundwater system as shown on Figures 94 and 95, respectively. In the shallow shale/terrace groundwater, the specific conductance ranged from 160 $\mu\text{mhos/cm}$ in well MW-5 to 13,580 $\mu\text{mhos/cm}$ in well MW-24. The highest areas of specific conductance are associated with the SX Building, the north fluoride sludge pond 2 area, Pond 2 area, and the area north of the clarifier ponds. These areas typically show the highest nitrate impacts and the specific conductivity isopleth maps are similar in configuration to the nitrate isopleth map for the shallow shale/terrace groundwater.

The specific conductivity isopleth map (Figure 95) for the deep sandstone/shale groundwater shows that the conductivity varied from 18,900 $\mu\text{mhos/cm}$ in well MW-58A to 334 $\mu\text{mhos/cm}$ in well MW-30A. The specific conductance levels are highest in the SX Building area, the north fluoride sludge basin 2 area, and Pond 2 area. Again, the specific conductivity isopleth map is similar in configuration to the nitrate isopleth map for the deep sandstone/shale groundwater.

7.4.3.13 Metals in Sequoyah Facility Groundwater

Since yellowcake can have impurities in the form of heavy metals such as vanadium, molybdenum, arsenic, lead, and iron, among others, SFC implemented a program to test select areas of the Sequoyah Facility groundwater for nineteen (19) heavy metals. Prior to selecting the location of the wells to be sampled, SFC and RSA reviewed quality control and quality assurance information supplied by various vendors for 1989 yellowcake shipments to determine possible metal parameters. Table 70 is a list of the metal impurities found in the yellowcake product received by SFC in 1989. SFC also reviewed historical information from 1970 to 1989 showing the amount of metal impurities received in the yellowcake, as shown on Table 71. Based upon a review of Tables 70 and 71, SFC and RSA determined that the following metals could potentially be present in Sequoyah Facility process waters: molybdenum, vanadium, magnesium, thallium, calcium, iron, arsenic, and phosphorus. Additional review of Sequoyah Facility processes indicated that barium was also used as barium chloride in the sanitary lagoon. Based upon this review, three (3) of the most highly affected wells (MW-10, MW-25, and MW-59A) and background well MW-7 were analyzed for nineteen (19) total metals which included: antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, thallium, uranium, vanadium, and zinc.

On March 7 and 8, 1991, RSA collected groundwater samples from wells MW-7, MW-10, MW-25, and MW-59A for analyses of the nineteen (19) total metals noted above. The total metals analyses were conducted by Barringer Laboratories of Golden, Colorado. The analytical data is summarized in Table 72 and the laboratory sheets are presented in Appendix L.

The results indicated that in background well MW-7, total iron in groundwater at 1.66 mg/L was over the EPA recommended secondary drinking water standard of 0.3 mg/L. The only other metals detected in background well MW-7 were barium at 0.15 mg/L, magnesium at 13.3 mg/L, selenium at 0.004 mg/L, uranium at 0.0093 mg/L, vanadium at 0.01 mg/L, and zinc at 0.051 mg/L.

Total metal results for groundwater from well MW-10 indicated that: arsenic at 0.127 mg/L exceeded the primary standard of 0.05 mg/L, lead at 0.10 exceeded the primary standard of 0.05 mg/L, silver at 0.06 mg/L exceeded the primary standard of 0.05 mg/L, and total iron exceeded the secondary standard of 0.3 mg/L at 4.44 mg/L. Other metals detected in groundwater from well MW-10 were barium at 0.69 mg/L, beryllium at 0.03 mg/L, cadmium at 0.007 mg/L, copper at 0.09 mg/L, magnesium at 28.4 mg/L, mercury at 0.0002 mg/L, molybdenum at 0.02 mg/L, nickel at 0.72 mg/L, thallium at 0.001 mg/L, uranium at 49.9 mg/L, vanadium at 0.14 mg/L, and zinc at 0.578 mg/L.

Groundwater from well MW-25 exceeded the EPA primary drinking water standard for barium of 1.0 mg/L at 2.26 mg/L. The total iron level in groundwater from MW-25, at 1.68 mg/L, exceeded the EPA secondary drinking water standard for iron of 0.3 mg/L. Other metals detected in groundwater from well MW-25 include arsenic at 0.004 mg/L, cadmium at 0.006 mg/L, magnesium at 378 mg/L, nickel at 0.03 mg/L, silver at 0.04 mg/L, uranium at 21.0 mg/L, vanadium at 0.03 mg/L, and zinc at 0.009 mg/L.

Total metal analysis of groundwater from MW-59A indicated that arsenic at 3.71 mg/L exceeds the 0.05 mg/L primary drinking water standard, cadmium at 0.022 mg/L exceeds the EPA primary drinking water standard of 0.01 mg/L, and selenium at 0.015 mg/L exceeds the EPA primary drinking water standard of 0.01 mg/L. The EPA recommended secondary drinking water standard for iron of 0.3 mg/L is exceeded in groundwater from MW-59A which was measured at 3.75 mg/L. The other metals detected in well MW-59A were barium at 0.25 mg/L, magnesium at 590 mg/L, nickel at 0.02 mg/L, uranium at 0.0424 mg/L, vanadium at 0.04 mg/L, and zinc at 0.008 mg/L.

The metal results indicated that arsenic, barium, uranium, and magnesium were the only metals that were found to be elevated appreciably in the Sequoyah Facility groundwater. The uranium originates from the yellowcake and the magnesium also occurs

as an impurity in the yellowcake. The analytical results of the March 7 and 8, 1991 special groundwater sampling for metals are tabulated in Table 72. The locations of the wells sampled for metals on March 7 and 8, 1991 are shown on Figure 96.

Because total arsenic was detected in well MW-59A at 3.71 mg/L, SFC initiated a program to sample groundwater from every FEI monitoring well and to also sample porewater contained in the utility trenches. Between April 23 and May 17, 1991, RSA sampled all wells and utility trench monitors for total arsenic. Based upon these analytical results, the total arsenic levels in SFC wells ranged from <0.005 mg/L in several wells to 5.599 mg/L in well MW-42. Approximately 154 wells were sampled for total arsenic and, of these 154 wells, a total of 66 had arsenic levels in groundwater below the test method analytical detection limit of 0.05 mg/L. A total of 44 wells had arsenic levels in groundwater between 0.005 mg/L and 0.05 mg/L; 13 wells had total arsenic levels between 0.05 mg/L and 0.1 mg/L; 24 wells had total arsenic levels between 0.1 mg/L and 1.0 mg/L; and 6 wells had total arsenic levels greater than 1.0 mg/L with the highest arsenic level found in well MW-42 (south of yellowcake sump) at 5.599 mg/L. The total arsenic analytical results are shown in Tables 61 and 62.

In addition to the monitoring wells, porewater samples from all utility trench monitors was collected and tested for total arsenic. Out of 24 tested, 10 utility trench porewater samples showed total arsenic levels of less than the detection limit of 0.005 mg/L. A total of 14 trench monitors showed arsenic levels between 0.005 mg/L and 0.05 mg/L. One (1) trench monitor (TM-21) was not tested for arsenic due to it being dry. Arsenic was also tested in fluids from the SX Building vault which measured 0.09 mg/L. Arsenic in the Combination Stream Drain trench backfill varied from <0.005 mg/L in TM-9T to 0.412 at MW-44T.

The laboratory results indicate five (5) general areas of measurable total arsenic levels: 1) south and west of Pond 2, ranging from 0.012 to 3.71 mg/L, 2) south and east of the fluoride sludge basins and fluoride sludge burial areas, ranging from 0.21 to 3.52 mg/L, 3) south of the south yellowcake sump area, ranging from 0.45 mg/L to 5.6 mg/L, 4) the MPB area, ranging from 0.052 mg/L to 0.206 mg/L, and 5) west of the Pond 1 Spoils Pile, ranging from 0.013 mg/L to 0.195 mg/L. These areas are shown by the arsenic isopleth maps presented in Figures 97 and 98 for the shallow shale/terrace groundwater and deep sandstone/shale groundwater, respectively.

The wells with the two highest arsenic concentrations are shallow shale/terrace wells MW-42 (south of the south yellowcake sump) at 5.599 mg/L and MW-64 (east of the fluoride sludge storage pond) at 3.518 mg/L. Typically, the shallow wells tend to show measurable levels of total arsenic more frequently than the deep wells.

Three deep sandstone/shale wells have total arsenic concentrations over 2.0 mg/L. These wells, MW-57A (2.033 mg/L), MW-58A (2.25 mg/L), and MW-59A (3.71 mg/L) are located at the southwest corner of Pond 2. The remaining groundwater samples show total arsenic concentrations below 0.8 mg/L.

7.4.3.14 Organic Analytical Results

On March 7 and 8, 1991, SFC initiated a program to sample select monitoring wells at the Sequoyah Facility and analyze the groundwater for a wide range of volatile and semi-volatile organic compounds. Prior to sampling, RSA and SFC initiated a program to identify locations where organic chemicals may have been stored or used in the Sequoyah Facility process. Based upon this review, a total of eight (8) groundwater monitoring wells were selected (including upgradient well MW-7) for analyses of volatile and/or semi-volatile organic compounds. The locations of the wells selected for organic analyses of groundwater are shown on Figure 96. In addition to the Sequoyah Facility review, RSA and SFC evaluated the

types of organic chemicals used in the Sequoyah Facility process to determine if additional organics were identified that did not appear on a typical priority pollutant volatile or semi-volatile parameter lists. Based upon this review, it was determined that n-hexane and tributylphosphate should be analyzed in addition to the priority pollutant volatile and semi-volatile parameter list.

The groundwater samples were collected on March 7 and 8, 1991 by RSA personnel using strict EPA groundwater sampling protocol for organics. The groundwater samples were analyzed for priority pollutant organics by Barringer Laboratories of Golden, Colorado using EPA gas chromatograph/mass spectrophotometer (GC/MS) test methods 624 (volatile organics) and 625 (semi-volatile organics). The priority pollutant organics parameter list includes thirty-eight (38) volatile organic compounds and sixty-five (65) semi-volatile compounds that are commonly monitored in effluent and waste streams under the Clean Water Act. The GC/MS test methods used provide reliable identification for a wide range of organic compounds and are best suited for analysis of a long or complex parameter list, when significant interferences are present or when little is known about a sample.

Volatile Organics

The results of the priority pollutant volatile scan on eight (8) wells (MW-7, MW-10, MW-12, MW-14, MW-25, MW-50A, MW-59A, and MW-2301B) at the Sequoyah Facility show that a total of four (4) volatile organics were detected, as shown in Table 73. Methylene chloride (dichloromethane) was detected in groundwater from wells MW-10 and MW-25 at levels of 3.73 $\mu\text{g/L}$ or parts per billion and 0.82 $\mu\text{g/L}$, respectively. Methylene chloride is a very common laboratory contaminant and the levels noted in groundwater from wells MW-10 and MW-25 fall within the ranges commonly seen for laboratory contamination by methylene chloride. These levels of methylene chloride, if actually present in the groundwater, are very low and represent no environmental hazard at the Sequoyah Facility. Chloroform was detected in well MW-10 at a level of 0.95 $\mu\text{g/L}$. Again, chloroform is a common laboratory contaminant and the level noted at 0.95 $\mu\text{g/L}$ is well within ranges commonly associated with laboratory contamination. This level of chloroform, if actually present in the groundwater, is very low and represents no environmental hazard at the Sequoyah Facility. A third volatile organic detected in the groundwater (well MW-12) was trichlorofluoromethane (Freon 11) at 219.1 $\mu\text{g/L}$. This compound was found in the well (MW-12) nearest the above ground storage area where this compound was stored. This compound is thought to have migrated into the shallow groundwater system in the immediate area of well MW-12

from minor surface spills. There is no maximum contaminant levels (MCLs) promulgated under the Safe Drinking Water Act for these three (3) compounds (methylene chloride, chloroform, and trichlorofluoromethane) and these compounds represent no known environmental hazard to the Sequoyah Facility. The fourth volatile organic compound found in the Sequoyah Facility groundwater was 1,1,1-trichloroethane at 2.02 $\mu\text{g/L}$ in well MW-12 and 226.5 $\mu\text{g/L}$ in well MW-14. These two (2) wells are located near the area where 1,1,1-trichloroethane was historically stored (in 55-gallon drums) in an above ground storage shed. The 1,1,1-trichloroethane is believed to have impacted the groundwater only in the immediate area of this storage shed and was likely caused by minor spillage onto the ground surface. A maximum contaminant level for 1,1,1-trichloroethane has been established that applies to community, non-transient, and non-community water systems. This MCL level is 200 $\mu\text{g/L}$ for 1,1,1-trichloroethane. The level found in well MW-14 slightly exceeds the MCL; however, there is no immediate environmental hazard to the Sequoyah Facility. There were no other volatile organics (including hexane) which were detected in the Sequoyah Facility groundwater systems.

Semi-volatile Organics

Groundwater samples were collected from three (3) groundwater wells at the Sequoyah Facility and tested for the priority

pollutant semi-volatile parameter list of about 65 organic parameters and tributylphosphate. Three (3) priority pollutant semi-volatile compounds were detected in groundwater at the Sequoyah Facility, as shown in Table 73. These three (3) compounds were di-n-butylphthalate at 0.96 $\mu\text{g/L}$ in upgradient and background well MW-7; benzo(a)anthracene at 2.66 $\mu\text{g/L}$ in well MW-7; and bis(2-ethylhexyl)phthalate at 1.82 $\mu\text{g/L}$ in well MW-10. The phthalates found in the groundwater at the Sequoyah Facility are very low and are also common laboratory contaminants. Phthalates are found as plasticizers in numerous plastic products and are often found in groundwater at very low parts per billion levels. These phthalate levels, if actually present, represent no potential environmental hazard at the Sequoyah Facility. There is no MCL established for di-n-butylphthalate or bis(2-ethylhexyl)phthalate. The benzo(a)anthracene was detected in upgradient and background well MW-7 at very low parts per billion levels (2.66 $\mu\text{g/L}$). There is no MCL for this compound and this constituent poses no potential environmental hazard at the Sequoyah Facility. This constituent may have come from asphalt used to pave a nearby state highway. No other semi-volatile priority pollutant organics were detected in the Sequoyah Facility groundwater. However, tributylphosphate used in the SX Building process was found in groundwater from wells MW-10 at 42.01 $\mu\text{g/L}$ and in well MW-25 at 39.56 $\mu\text{g/L}$. The tributylphosphate found in the groundwater likely

originated from historical spills (pre-1983) of process fluids onto the SX Building floor and seepage of these fluids through cracks in concrete (prior to being repaired) and into the subsurface. There is no MCL for this constituent and the low parts per billion levels represent no immediate environmental hazard at the Sequoyah Facility. Groundwater recovery programs have been implemented in the area of well MW-10 and the SX Building (SX Building vault area) and should contain and recover the tributylphosphate in the shallow groundwater system in these areas.

7.4.3.15 Stiff Diagrams

Stiff diagrams present groundwater quality data in a simple pattern analysis that can be used to make a quick visual comparison of individual chemical analyses. Stiff diagrams are prepared by plotting as milliequivalents per liter, the major cations (Na, K, Ca, and Mg) and major anions (Cl, HCO₃, SO₄, and CO₃) typically found in groundwater to create a polygonal shape. Stiff diagrams were prepared for twenty-one (21) groundwater monitoring wells and four (4) utility trench porewater sampling sites and are shown on Figure 99. It should be noted that nitrate was found to be a major anion in groundwater in several of the wells; however, this anion is not presented on the stiff diagrams. Referring to Figure 99, the stiff diagrams indicate that there is a distinct difference in background groundwater quality type between the

deep sandstone/shale and the shallow shale/terrace groundwater systems as evidenced by the lack of a close pattern match between background and upgradient monitoring wells MW-7 (shallow) and MW-7A (deep), and MW-73 (shallow) and MW-73A (deep). This supports other data which suggest that the deep and shallow groundwater systems are hydraulically separate and not in major communication with each other.

The stiff diagrams prepared from groundwater analyses of each of the twenty-one (21) wells and the other four (4) utility trench porewater samples were compared to each other to determine if there was a visual pattern match which could indicate similar groundwater chemistry and source areas. There appears to be a general pattern match between groundwater in wells MW-12A and MW-25A suggesting a similar groundwater chemistry and a similar impact source. These two (2) wells, MW-12A and MW-25A, are both located near the SX Building. A general pattern match is noted between groundwater from wells MW-25, MW-35, MW-57A, and MW-59A, which may suggest a similar groundwater impact constituent source. Similar patterns are also noted between wells MW-18, MW-18A, MW-63, and MW-63A; between MW-12 and combination trench well MW-34T; and between wells MW-50 and MW-50A. The stiff diagrams were prepared to better visualize the major ion chemistry that is present in the groundwater at the Sequoyah

Facility. The analytical data used to prepare the stiff diagrams is presented in Table 72.

7.4.3.16 Piper Trilinear Diagrams

One of the most common ways to visually depict groundwater chemical data is through the use of trilinear diagrams. This method of visually depicting chemical data shows the relative concentrations of the major cations (Na, K, Ca, and Mg) and major anions (Cl, HCO₃, SO₄, and CO₃) as they are plotted on a series of three (3) triangles. The trilinear diagram is convenient for showing the effects of mixing two waters from different sources. The mixture of two different waters will plot on the straight line joining the points. Groundwater samples collected from twenty one (21) monitoring wells and four (4) utility trench porewater monitor wells were analyzed for the major anions and cations. Based upon these analyses, three (3) separate trilinear diagrams were prepared as shown on Figures 100, 101, and 102. Figure 100 is a Piper trilinear diagram showing the major anion/cation chemistry of the shallow shale/terrace deposits. There is no overall dominant anion or cation consistently present in the shallow shale/terrace groundwater system. The trilinear diagram for the deep sandstone/shale groundwater system also shows no consistent dominant groundwater type. However, groundwater from background and upgradient monitoring wells MW-7A and MW-73A indicate that bicarbonate is the major anion. A review of

Figure 101 indicates that most of the deep sandstone/shale groundwater samples fall on a straight line running from the bottom to the top of the page. This may indicate that the groundwater types are a result of mixing of water similar to that found in groundwater from well MW-73A (background) with other waters found at the Sequoyah Facility.

Water found in the utility trench backfill generally has calcium as the dominant cation and bicarbonate as the dominant anion. The trilinear diagram for the utility trench porewater is shown in Figure 102.

The trilinear diagrams were prepared to determine if there were any specific patterns in the groundwater chemistry between the shallow shale/terrace deposits groundwater, deep sandstone/shale groundwater, and the utility trench porewaters. Although there are some similarities between the water systems, there appears to be no dominant pattern between the water systems tested.

7.4.3.17 Miscellaneous Groundwater Samples

Water samples were also taken from six (6) open boreholes in the MPB area. These results are presented in Table 74 but will not be discussed here since they are considered unreliable due to the likely affects of surface soil contamination. Also, monitor wells have been installed near

each of these locations and provide more reliable data. Water samples were collected from these open boreholes per direction of the NRC on-site representative. RSA had previously recommended against sampling groundwater from open boreholes due to possible cross contamination and the unreliability of the data.

7.4.4 Geochemical Modelling of Sequoyah Facility Groundwater and Utility Trench Porewater

7.4.4.1 Introduction

The purpose of this part of the investigation is to determine the relative mobility and species of uranium contained in groundwater, soils, and utility trench porewater at the Sequoyah Facility. The objectives include: 1) characterization of dissolved uranium concentrations in trench backfill porewater, shallow shale/terrace groundwater, and deep sandstone/shale groundwater; 2) define the migration potential of uranium; and 3) evaluate uranium geochemistry along the groundwater-flow path.

Porewater samples were collected from four (4) trench monitors and monitor wells completed within utility trenches, including the combination stream trench. In addition, twenty-one (21) groundwater samples were collected from the shallow shale/terrace groundwater system and the deep sandstone/shale groundwater system. A map showing the locations of the wells

sampled is presented as Figure 103. These samples were analyzed for major cations and anions and trace elements, including uranium and other solutes. Parameters measured in the field included pH, Eh, temperature, carbonate, bicarbonate and hydroxide alkalinity, specific conductance, and dissolved oxygen. The analytical data from the field measurements are presented in Table 69. The major anion and cation analytical results are shown in Table 72.

Geochemical modeling, using the computer code PHREEQE (Parkhurst et al., 1980), was used to evaluate the transport and fate of dissolved uranium at the Sequoyah Facility. The program solves simultaneous equations describing equilibrium-chemical reactions that may occur in a given water. From the input of solution analyses, PHREEQE computes the activities of complexed and free ionic species, neutral ion pairs, and distribution of ionic species. The model then calculates ion-activity products (IAP) and compares the IAP to the solubility products (Kt) for the minerals and solid compounds contained in the database. The relative degree of saturation is measured by the saturation index (SI), which is defined as the $\log_{10}(IAP/Kt)$. These calculations are useful to determine solution-mineral equilibria for dissolved uranium species.

For meaningful model simulations, it is important that the thermochemical database is accurate and internally consistent. The database contained in PHREEQE is the same as the database developed for WATEQ2 (Ball et al., 1980). This database has been critically reviewed (Noronha and Pearson, 1983).

7.4.4.2 Geochemistry Study

Geochemical modeling using PHREEQE was performed to assess the mobility of uranium at the Sequoyah Facility. Groundwater samples were collected from the following monitor wells and utility line trenches (T): MW-7, MW-7A, MW-10, MW-10A, MW-12, MW-12A, MW-18, MW-18A, TM-20T, MW-25, MW-25A, MW-34T, MW-35, MW-50A, MW-57A, MW-59A, MW-63, MW-63A, MW-65, MW-73, MW-73A, and MW-RW-1T. An additional sample was also collected from the SX Building vault. Samples obtained from these locations were used as input to PHREEQE.

7.4.4.3 Investigation Results

Results of water quality data are reported in Tables 75 and 76. Dissolved concentrations of calcium, fluoride, iron, phosphate, sulfate, silica, and uranium were used as input analytes for geochemical model simulations. Field parameters including carbonate alkalinity, pH, Eh, and temperature were also used in the simulations. The Eh, pH, temperature, and dissolved uranium and ligand (fluoride, sulfate, carbonate, phosphate) concentrations are required input parameters for

PHREEQE for calculating the distribution of uranium (U(IV) and U(VI)) species. Lindberg and Runnells (1984) discuss the difficulties associated with Eh measurements in natural waters due to the lack of internal equilibrium between redox couples. Therefore, the field Eh measurements are considered as an approximation of redox conditions at the Sequoyah Facility.

Results of speciation calculations for uranium are provided in Table 75 in which uranyl carbonate and uranyl phosphate complexes are predicted to dominate. These anionic complexes are soluble (Langmuir, 1978; Longmire, 1991) and have been observed to undergo limited adsorption onto ferric oxyhydroxides under laboratory conditions (Tripathy, 1984; Hsi and Langmuir, 1985).

Precipitation of U(VI) minerals results in partial removal of uranium from solution. This partial removal is due to the relatively high solubilities of U(VI) minerals. Results of saturation index calculations are summarized in Table 76. In most instances, the groundwater samples are predicted to be undersaturated with respect to uraninite, amorphous UO_2 , U_4O_9 , U_3O_8 , coffinite, UF_4 , $\text{UF}_4 \cdot 2 \cdot 5\text{H}_2\text{O}$, $\text{U}(\text{HPO}_4)_2$, ningyoite, UO_3 , gummite, $\text{B-UO}_2(\text{OH})_2$, schoepite, rutherfordine, H-autunite, uranophane, bassetite. Therefore, these minerals generally are not expected to precipitate from solution, based on results of the computer simulations. Subsequently, elevated

concentrations of uranium persist in groundwater at the Sequoyah Facility. Groundwater samples obtained from MW-10, MW-12A, and MW-RW-1T, however, are predicted to be in near equilibrium ($SI = \pm 1$) or oversaturated with respect to U_3O_8 , U_4O_9 , $B-UO_2(OH)_2$, schoepite, rutherfordine, uraninite, and $USiO_4$. Groundwater from well MW-25 is near equilibrium ($SI = \pm 1$) with respect to $B-UO_2(OH)_2$, schoepite, and rutherfordine. Results of the SI calculations for these monitor wells (MW-10, MW-12A, MW-25, and MW-RW-1T) suggest that uranium is possibly being removed from solution through precipitation processes. A sample taken from the SX Building vault is predicted to be at near equilibrium, or oversaturated with respect to $B-UO_2(OH)_2$, rutherfordine, schoepite, UO_2AM , U_4O_9 , U_3O_8 , and uraninite according to the geochemical simulations. It appears that in areas where high dissolved uranium concentrations are found, such as groundwater from wells MW-10, MW-12A, MW-25, MW-RW-1T, and the SX Building vault, there will likely be some precipitation of uraninite, U_4O_9 , U_3O_8 , $B-UO_2(OH)_2$, schoepite, and rutherfordine.

Most groundwater samples are predicted to be oversaturated with respect to ferric oxyhydroxide, a strong adsorbent for uranium. Partial removal of uranium from solution through adsorption reactions is possible in the presence of ferric oxyhydroxide at the Sequoyah Facility. Further investigations, however, are required to quantify this removal

process. Other potential adsorbents include clay minerals and solid organic matter. Further petrographic analyses are required to establish the presence of these adsorbents.

Results of the saturation index calculations indicate that groundwater generally is undersaturated with respect to uranyl minerals and that dissolution of these minerals is predicted to occur. Since these uranyl minerals have a high solubility, it is likely that elevated concentrations of uranium will remain in the solution.

Groundwater is predicted to be oversaturated with respect to $\text{Fe}(\text{OH})_3$, which is an important adsorbent for uranium. It is possible that uranium may be partly removed from solution through adsorption processes at the Sequoyah Facility. Further laboratory leach studies and mineralogical characterization are required to quantify uranium removal due to adsorption.

7.4.5 Results of Soil Characterization Activities

7.4.5.1 FEI Unit Characterization Results

Based upon soil samples collected from boreholes BH-1 through BH-98 and the ninety (90) unit soil characterization borings, isopleth maps of the uranium content in soils were prepared for the 0 to 1.0, 1.0 to 5.0, 5.0 to 10.0, 10.0 to 15.0, 15.0 to 20.0, 20.0 to 25.0, and 25.0 to 30.0 foot depth intervals.

The soil analytical data is summarized in Tables 29, 43, and 44. The locations of all chemical characterization borings are shown in Figure 38.

The isopleth maps showing the total uranium levels in soil were conservatively prepared by taking the highest uranium levels detected in soils over the specific soil interval and contouring this number. There is a Sequoyah Facility EAL for uranium in soils of 40 $\mu\text{g/g}$ and this value and the background uranium level of less than 5 $\mu\text{g/g}$ will be used in comparisons to analytical data.

The soil uranium isopleth map (Figure 104) for the 0 to 1 foot depth interval indicates that there is impact over the Sequoyah Facility EAL centered mainly in the SX Building, sanitary lagoon, north ditch, and emergency basin areas. There is also uranium detected above the EAL south of the MPB and near the initial lime neutralization area (Unit 3). Most of the uranium is found in the upper six (6) inches of soil and most is found within the RAB.

Figure 105 shows the soil uranium isopleth map for the 1 to 5 foot depth interval. This map generally shows that the uranium levels tend to decrease in concentration from the uranium levels measured in the 0 to 1 foot interval. The 1 to 5 foot soil uranium isopleth map indicates that there is only

one (1) area outside the RAB where uranium was detected over 40 $\mu\text{g/g}$ across this depth interval and this was in the Unit 3 initial lime neutralization area. There were several areas where uranium levels in soils exceeded the EAL of 40 $\mu\text{g/g}$ within the RAB. These were mainly in the MPB area, the SX Building area, and the areas around the emergency basin, sanitary lagoon, and north ditch.

There is a dramatic decrease in the areal extent and the levels of uranium found in the soils in the 5 to 10 foot depth interval. There are no areas outside the RAB where uranium was detected above 40 $\mu\text{g/g}$ as shown on Figure 106. The uranium found in soils in this depth interval were located in the SX Building area, the MPB area, the incinerator and contaminated equipment burial area, and the area west of the emergency basin near BH-47. The only areas where uranium was detected above 40 $\mu\text{g/g}$ was in BH-16 (225-1561 $\mu\text{g/g}$), BH-17 (13-966 $\mu\text{g/g}$) and BH-27 (828-7940 $\mu\text{g/g}$). These borings are all within the RAB.

The uranium isopleth map for soil found in the 10 to 15 foot depth interval is shown in Figure 107. This isopleth map indicates that uranium occurs in soils over 40 $\mu\text{g/g}$ outside the RAB at BH-9 (southwest of the MPB). The only other areas where uranium in soils exceeded the 40 $\mu\text{g/g}$ levels were in BH-3, BH-16, and BH-27, all within the RAB.

Figure 108 is an isopleth map showing maximum uranium levels found in soils across the 15 to 20 foot depth interval. Uranium was detected in three (3) borings over the 40 $\mu\text{g/g}$ level. These borings are BH-9 (southwest corner of the MPB and located outside the RAB), BH-3 (southwest corner of MPB), and BH-97 (northwest corner of cooling tower). BH-3 and BH-97 are located within the RAB.

The isopleth map showing uranium levels in soils in the 20 to 25 foot depth interval is shown in Figure 109. This isopleth map indicates that there was only one (1) borehole at the Sequoyah Facility (BH-3) where uranium exceeded 40 $\mu\text{g/g}$ and this was located inside the RAB at the southwest corner of the MPB. Uranium was also detected above background levels in the cooling tower areas and northeast of the contaminated equipment storage area.

Soil samples collected from the 25 to 30 foot depth interval and analyzed for uranium are presented in the isopleth map shown in Figure 110. This isopleth map for total uranium indicates that there are no areas outside the RAB where uranium was detected in soil. Uranium was detected in soil borings west of the MPB and in the cooling tower/SX Building area, which are all located within the RAB. There was one (1) location where uranium exceeded the 40 $\mu\text{g/g}$ level and this was in BH-96 at 60 $\mu\text{g/g}$.

Based upon the results of the soil analyses for uranium, the lateral and vertical extent of uranium within the 85-acre Sequoyah Facility has been defined. These seven (7) isopleth maps are useful in defining areas where uranium may be present in subsurface soils.

There are two (2) additional areas where SFC has requested RSA to further characterize licensed material in Sequoyah Facility soils. One (1) area is within FEI Unit 10 (incinerator area) and the second area is north of Unit 10. RSA has prepared work plans to investigate soils in these areas.

7.4.5.2 Soil Analytical Data from Stream Drainages

The soil analytical data collected by the NRC and SFC from the stream drainages west and south of the SFC process and impoundment areas on June 10, 1991 are shown in Table 51. The soil samples were collected from the ten (10) sites (SFC-A to SFC-J) shown on Figure 39. Five (5) of the soil sample sites were in an intermittent drainage associated with Outfall 005. Three (3) soil samples were collected from the intermittent drainage associated with Outfall 001. There was one (1) soil sample collected from the intermittent drainage associated with Outfall 004, and one (1) sample was collected from soils along the headwaters of Robert S. Kerr Reservoir. Based upon these results, there were two (2) soil samples, SFC-D (46 $\mu\text{g/L}$) and SFC-E (220 $\mu\text{g/L}$), where uranium levels exceeded the

Sequoyah Facility EAL of 40 $\mu\text{g/g}$. Both of these samples are in the intermittent drainage associated with Outfall 005.

The soil samples collected in June 1991 were also compared to previous soil samples collected in 1986. The results of this comparison indicate that the uranium levels have decreased substantially when compared to uranium levels found in soils collected in 1986 at nearly the same locations.

SFC has requested that RSA prepare a Technical Work Plan to further evaluate the soils in all of the intermittent drainages.

7.4.5.3 Soil Analytical Data From Miscellaneous Areas

There were several miscellaneous areas where soil samples were collected and analyzed for uranium, nitrate, and fluoride. One (1) of these areas was near the south yellowcake sump (Unit 16). Soil samples were collected from the east side of the south yellowcake sump within the fill that is adjacent to the concrete. These soil samples had uranium levels that ranged from 8.7 $\mu\text{g/g}$ to 230 $\mu\text{g/g}$, which exceed the EAL of 40 $\mu\text{g/g}$. The analytical data for Unit 16 is presented in Table 46.

There were several other areas at the Sequoyah Facility where soil samples were collected (by SFC personnel) and analyzed for uranium, fluoride, and nitrate. These areas are listed in Table 47. The most significant finding was that high uranium levels were found on the inside scale of the laundry pipe at levels of 134 mg/g.

7.4.5.4 Pond Sediment Sample Results

The results of the impoundment sediment sampling program for the sanitary lagoon, emergency basin, north ditch, decorative pond, and ammonium nitrate lined pond 3E are discussed in this section.

The analytical data for sediment and water found in the Sequoyah Facility Decorative Pond is presented in Table 48. These data indicate that uranium was detected in the pond sediments at levels ranging from 10 $\mu\text{g/g}$ to 25.5 $\mu\text{g/g}$, and the water at these same locations had uranium concentrations that ranged from 6.4 $\mu\text{g/L}$ to 11.5 $\mu\text{g/L}$. The low levels of uranium in the water suggest that the uranium in the sediments is not being solubilized into the water and may be adsorbed onto organics in the pond sediments.

The uranium in the sediments from the sanitary lagoon has uranium levels ranging from 10.7 mg/g to 24.2 mg/g and water samples collected at these same locations ranged from 2.85

mg/L to 4.17 mg/L. The pH of the sanitary lagoon water ranged from 9.2 to 9.3. The uranium in sediments from the emergency basin ranged from 4.7 mg/g to 7.9 mg/g and the uranium in water at these sample sites ranged from 11.2 mg/L to 11.7 mg/L. The pH ranged from 10.7 to 10.8. The uranium in sediments in the north ditch ranged from 0.9 mg/g to 1.5 mg/g and the uranium in water ranged from 7.75 mg/L to 8.24 mg/L. The pH of water in the north ditch ranged from 8.9 to 9.1.

Surface water samples and sediments obtained from the decorative pond, emergency basin, sanitary lagoon, and north ditch contain variable amounts of uranium, which may be the result of the adsorption/desorption processes. For example, the sediment:water ratio of uranium varies from 1563 to 2365 for samples taken from the decorative pond. These surface water samples are characterized by near neutral pH values. Conversely, samples from the emergency basin and north ditch contain sediment:water ratios of uranium from 116 to 705. These samples are characterized by alkaline pH values ranging from 9 to 11. This suggests that uranium adsorption onto sediments is greatly enhanced at near neutral pH values, which is in agreement with experimental results reported by Hsi and Langmuir (1985) and Longmire (1991). Adsorbents may include solid organic matter, clay minerals, and $\text{Fe}(\text{OH})_3$. Also, due to the alkaline pH in the sanitary lagoon, north ditch, and emergency basin, uranyl carbonate complexes may dominate at

the higher pH and the uranium in the sediments may be desorbing into the water.

The analytical results from the ammonium nitrate lined pond 3E sediment sampling are presented in Table 50. These data indicate that relatively high levels of fluoride, uranium, and nitrate are contained in the pond sediments. The uranium varies from 0.99 mg/g to 5.15 mg/g, fluoride varies from 0.35 mg/g to 0.82 mg/g, and nitrate varies from 2.16 mg/g to 7.7 mg/g. The radium was low at 0.5 to 1.6 pCi/g and the thorium-230 varied from 1.4 pCi/g to 22 pCi/g.

7.4.5.5 Comparison of Uranium in Soil and Groundwater

RSA and SFC evaluated groundwater analytical data for total (insoluble) and dissolved (soluble) uranium and compared these levels to uranium levels found in soils for both the shallow shale/terrace and deep sandstone/shale groundwater systems. This comparison involved calculating ratios of total and dissolved uranium in groundwater to soil uranium levels. The uranium levels in groundwater and soil was also plotted in graphic form as total uranium levels in groundwater versus the highest uranium level in soil observed in the saturated zone for groundwater in the shallow shale/terrace wells and the deep sandstone/shale wells. Graphs were also prepared evaluating the average levels of uranium in soils in the zone of saturation; however, these graphs were very similar to

those prepared for the highest levels which are shown in Figures 111 and 112. These graphs are shown in Figure 111 for the shallow shale/terrace groundwater and in Figure 112 for the deep sandstone/shale groundwater. There was no specific ratio observed between uranium levels in soils and dissolved or soluble uranium in groundwater. There was also no apparent relationship shown on Figures 111 and 112 between total uranium in groundwater and uranium levels in soils.

7.4.5.6 Soil Headspace Gas Survey Results

Soil headspace gas measurements were taken on most of the soil samples collected during the Sequoyah Facility unit soil characterization program and during the lithological boring program. The soil gas survey data was collected to provide initial screening of soils to determine if hydrocarbon impacts were evident. Referring to Table 52, there were fourteen (14) borings where hydrocarbon vapors were detected above background levels. These borings were BH-18, BH-19, BH-24, BH-25, BH-43, BH-45, BH-50, BH-52, BH-53, BH-57, BH-62, BH-86, BH-88, and BH-92. The hydrocarbon detected in borings BH-18, BH-19, BH-24, BH-25, BH-86, and BH-88 are likely from asphalt roadways or pavement which was currently or historically present in these areas. The low OVM readings recorded in borings BH-43, BH-45, BH-50, BH-52, BH-53, BH-57, BH-62, and BH-92 are generally present in the upper 2 to 3 feet of the soil profile. The highest OVM reading in these borings occurs

in borehole BH-43 at 6.3 ppm at the 2.0 to 2.9 foot interval (the soil intervals above and below the 2.0 to 2.9 foot depth were zero). The levels noted in the above-listed borings are very low and are very near background levels recorded in the Sequoyah Facility air and, therefore, do not represent any significant organic impacts.

Soil from the unit soil characterization borings was also analyzed for the presence of volatile organics. Volatile organics were detected in five (5) of the ninety (90) unit soil characterization borings. These were borings SC-101, SC-115, SC-212, SC-283, and SX-B and the OVM soil gas hydrocarbon levels were all below 3.0 ppm (except SX-B) and typically were found in the upper one (1) to three (3) feet of soil. The highest soil gas hydrocarbon readings were detected in unit characterization boring SX-B at 117 ppm from the 2.5 to 5.0 foot depth interval. This well is located south of the cooling tower in a roadway. It is possible that vehicles could have caused a minor hydrocarbon impact in this area. No organic impact to soils/groundwater in the SX Building and MPB area was evident based upon OVM soil gas readings. They are the most likely areas where hydrocarbon impacts could have occurred; however, none were found. The OVM soil gas data for the vault characterization borings are presented in Table 45.

7.4.6 Pre-Existing Sequoyah Facility-Wide Groundwater Monitoring System Review

This section summarizes the response to Item No. 4 of the OML which requires examination of groundwater monitoring well data existing prior to September 24, 1990 and determination of the adequacy of the associated monitoring well program to identify licensed material migration from the MPB. This response was accomplished by completing Tasks 4.1, 4.2, and 4.3 of the FEI Work Plan. In addition, RSA and SFC have gone well beyond the OML and have conducted a review of the pre-existing groundwater monitoring program at all areas in the Sequoyah Facility process area, which includes the ammonium nitrate lined pond areas (Unit 24).

A review of all available groundwater quality, geological, and monitoring well completion records was performed to evaluate the suitability of the pre-existing (i.e., prior to MPB investigation being initiated on September 24, 1990) groundwater monitoring well network and associated groundwater quality data for use in monitoring the groundwater in the MPB and SX Building areas. In addition, RSA and SFC reviewed similar data for other areas of the Sequoyah Facility, particularly data from those monitoring wells associated with the various FEI units.

Approximately 115 pre-existing groundwater monitoring wells had been installed at the Sequoyah Facility since the late 1970's. A vast majority (approximately 93) of the monitoring wells were in the surface impoundment areas (Pond 2 and the ammonium nitrate lined ponds) located west and south of the SX Building and MPB. Approximately 42 of the 115 wells have been plugged for a variety of reasons. Of the approximately 73 pre-existing groundwater monitoring wells remaining, there are no wells located within 650 feet of the MPB. The nearest pre-existing monitoring well to the SX Building is well number MW-2302A, which is located approximately 400 feet to the northwest. Well MW-2302A is also the nearest well to the MPB and is located approximately 650 feet to the northwest. None of the pre-existing groundwater monitoring wells can be used to directly monitor and detect potential groundwater quality impacts occurring in the SX Building or MPB areas. Therefore, in response to Action 4 of the OML, it is concluded that the pre-existing groundwater monitoring well program was not one that would have identified migration from the MPB and SX Building. As a result, during the MPB and FEI investigation, SFC has installed a groundwater monitoring system adequate to identify migration of licensed material and other constituents from the MPB and SX Building. This system is described in detail in Section 7.3.10. A map showing all wells installed (existing and plugged) prior to September 24, 1990 is shown in Drawing 22.

Other FEI units identified that had pre-existing monitoring wells associated with them included FEI Unit 6 (Emergency Basin) and Unit 11 (Drainages around north ditch, emergency basin, and sanitary lagoon), in which eight (8) monitoring wells existed prior to September 24, 1990. There were four (4) pre-existing monitoring wells associated with Unit 17 (Clarifier Pond Area); three (3) monitoring wells associated with Unit 13 (Fluoride Sludge Storage Pond) and Unit 15 (Fluoride Sludge Burial Areas); thirty-four (34) wells associated with Unit 24 (Ammonium Nitrate Lined Ponds); and about forty-four (44) wells associated with Pond 2. Out of these 93 wells, there are presently (June 17, 1991) 63 wells in existence, and the remaining wells have been plugged. Most other wells at the Sequoyah Facility are associated with the fertilizer spreading operations.

A review of the pre-existing groundwater analytical data from wells associated with the above-listed FEI units indicates that there was generally close agreement of this data to groundwater quality data collected from wells installed since September 24, 1990 into the same zone in the same general areas as the pre-existing wells. It appears that most of the pre-existing wells did an adequate job of monitoring the groundwater quality near the FEI units noted above. However, there were deficiencies with some wells having inadequate surface and borehole annulus seals which may have caused cross

communication between surface water runoff and the groundwater. Many of these wells also lacked either well completion details, lithological details, or both, and therefore proper written documentation was not maintained as to which zones these wells were monitoring. Following drilling of the lithological borings and installation of wells since September 24, 1990, it was determined that most of the pre-existing wells were installed into either the deep sandstone/shale lithological sequence or the shallow shale/terrace deposits. These are the same zones into which the post September 24, 1990 wells were installed. Based upon this review, most of the pre-existing wells installed around FEI Units 2, 6, 11, 13, 15, 17, 18, and 24 were adequate for water-quality monitoring; however, many of these wells lacked good annular seals and proper construction and lithological documentation and, therefore, were upgraded and replaced as part of the FEI unit investigations. The pre-existing monitoring well network installed around Unit 24 (ammonium nitrate lined ponds) presently appears to be adequate; however, this monitoring well network is currently undergoing review.

7.4.7 "SX Sand Wells" Data Review

In early March 1991, RSA was asked by SFC to review the data presented in SFC file "R-16, SX Sand Well Results". In addition to this review, RSA conducted a field survey on March

11, 1991 to identify the location and construction details of the "SX sand wells".

The "SX sand wells" are actually 2-inch diameter steel pipes that were apparently installed into the utility trench backfill sand surrounding the firewater pipe lines that surround the SX Building. Based upon historical records, it appears that four (4) of these steel pipes (open only at bottom) were placed into the firewater trench sand backfill prior to January 22, 1976. The locations of the firewater pipeline trench monitors are shown on Figure 37 and Drawing 21 and are designated as Fire Station 2 (NE from SX Building, Fire Station 3 (NW of SX Building), Fire Station 4 (SW of SX Building), and Fire Station 5 (SE of SX Building). There were no records to indicate that Fire Station 1 was ever installed or monitored. The monitoring pipes were installed into the sand backfill surrounding the firewater pipelines and extended to depths of between 2.93 to 5.08 feet below ground as measured on March 11, 1991. Fire Station 2 (NE of SX Building) was removed in November 1987 during construction activities in the area and, therefore, the exact depth of this monitoring pipe is not known precisely, but should have been installed to similar depths as the other monitoring pipes. The water levels measured on March 11, 1991 in the three (3) remaining monitoring pipes all indicated that there was water in the firewater line trench backfill sands and that the water

levels varied from 2.72 to 3.3 feet from ground level. Details of the monitoring pipe depths and water level measurements are shown in Table 77.

Records indicate that water samples have been collected from all four (4) monitoring pipes on a monthly frequency beginning on January 22, 1976 and ending on May 4, 1989 for all fire station monitoring pipes except Fire Station 2, which was monitored on a monthly frequency beginning on January 22, 1976 but ending on September 30, 1987 due to its removal during Sequoyah Facility construction activities on November 2, 1987. The water samples collected from these monitoring pipes were analyzed for total uranium, nitrate as N, and pH. The sampling data for these fire station monitoring pipes have been summarized in Table 78. In addition, all analytical data on total uranium and nitrate have been plotted out in graphical form for the purpose of evaluating potential trends in the data over time. These graphs are presented in Figures 113, 114, 115, 116, 117, 118, 119, and 120. In general, there appeared to be a sudden increase in uranium levels in porewater in these monitoring pipes during mid to late 1978. It is believed that this increase correlated to a specific release that occurred in the MPB Building area during this time period. The uranium levels appear to have generally increased or stayed level to about 1981 when they started to show a decreasing trend in uranium concentration to about

early 1986. At that time the uranium again indicated an increasing trend. This trend of increasing uranium began in about January 1986, increased briefly over the next couple of months, then declined steadily. This increase in uranium in January 1986 is thought to be related to the January 1986 UF₆ cylinder release.

The nitrate levels in the "SX sand wells" (except Fire Station 4) generally indicated elevated nitrate levels since records of monitoring began on January 1976 and continued until about 1984, when the nitrate levels declined. However, at Fire Station 4 the nitrate levels increased again in January 1986, possibly in relation to the UF₆ cylinder release response actions.

Based upon RSA's review of the "SX sand well" data, prior knowledge of this data by RSA would not have significantly influenced or changed the scope of the environmental investigations initiated by RSA on September 6, 1990 in the SX Building and MPB areas.

The "SX sand wells" are not currently being monitored. SFC has installed several utility trench monitoring stations in the SX Building yard and these are currently being sampled and fluid is being recovered on a weekly frequency. Some of the utility trench monitoring stations (TM-10T, TM-11T, and TM-

23T) installed in August and September 1990 monitor the same firewater line as the "SX sand wells". These trench monitors provide access to the firewater pipeline trench backfill porewater and therefore the "SX sand wells" are no longer needed. SFC will properly plug and abandon the "SX sand wells" upon obtaining approval from the NRC.

8.0 FEI CONCLUSIONS AND FINDINGS SUMMARY

8.1 Introduction

SFC finalized the comprehensive FEI Work Plan on October 15, 1990. Comprehensive environmental investigations were performed at the Sequoyah Facility during the subsequent nine (9) month time period through July, 1990. The FEI activities and findings have been presented in detail in the previous sections of this report. This section provides a summary of the principal FEI findings reported.

8.2 Past and Present Operations, Historical Information Review

The FEI identified 28 past or present operational units at the Sequoyah Facility for investigation. These units are all located on an approximate 85-acre parcel of land, well within the SFC property boundaries. The historical information obtained from file searches and interviews was presented. The units include process areas and buildings; the surface water management system; impacted soils, materials, and discarded equipment storage areas; active and inactive impoundments; impacted drainage areas; and underground utilities. These units have the potential for releasing licensed material to the environment at the Sequoyah Facility.

8.3 Facility Process Flow and Process Stream Characterization

A detailed Sequoyah Facility process flow and process stream evaluation was completed to provide a reference for assessing releases identified in the FEI and for identifying potential release sources and constituents.

The primary process at the Sequoyah Facility is the conversion of uranium ore concentrate to uranium hexafluoride (UF_6). The uranium ore concentrate is dissolved into solution and processed to extract and concentrate uranium. The uranium is transformed to various oxidized states throughout the process. Other chemical compounds, including principally nitric acid, hexane, tributylphosphate, and hydrogen fluoride, are utilized in the production process. A secondary process at the Sequoyah Facility is the production of depleted uranium tetrafluoride (DUF_4).

A complete process flow diagram was developed and verified for the Sequoyah Facility. From the process flow assessment, seven (7) waste streams (i.e. solids/sludges) or liquids (wastewaters) were identified. These seven waste streams include:

1. Hydrogen fluoride scrubber wastewater treated in the fluoride treatment system and the resulting sludge solids,
2. Sludge solids produced in the fluorine production cells,

3. Overflow or excess cooling water,
4. Steam condensate,
5. Sedimentation basin and water softener blowdown from the potable water treatment system,
6. Sanitary wastewater, and
7. Laboratory wastewater.

The SFC management practices for these waste streams are defined and reported.

Other constituents were identified to be present at the facility with potential for release to the environment. Most notable are the miscellaneous constituents present in the uranium ore concentrate processed at the Sequoyah Facility.

8.4 Facility-Wide Surface Water Investigation

The surface water management system was identified as a specific operational unit for investigation in the FEI (Unit 4). The surface water exits the Sequoyah Facility at well-defined outfalls which are monitored by SFC. Surface water, which is collected, routed to the Combination Stream Drain in conjunction with the Sequoyah Facility waste streams, and subsequently discharged through permitted Outfall 001, was investigated separately in the FEI (see Subsection 8.6 for summary).

For purposes of the FEI, a comprehensive network of 20 monitoring stations was defined to characterize the surface water at the Sequoyah Facility. These monitoring sites included all pertinent outfalls plus additional sites selected at key transitional drainage locations based on a detailed areal topographic survey and site map developed in the FEI.

Two (2) sampling events were performed during separate rainfall events to characterize the surface water. These events occurred on January 15, 1991 (Event No. 1) and March 1, 1991 (Event No. 2).

The concentrations of fluoride measured for all monitoring sites during both Event No. 1 and Event No. 2 were below the MCL for drinking water (4.0 $\mu\text{g/L}$). The data indicate fluoride does not pose an environmental concern for the Sequoyah Facility surface water system.

Nitrate concentrations did not exceed the permit limit for the surface water outfall (008) in Event No. 1 and only slightly exceeded the permit limit in Event No. 2. All other Sequoyah Facility exit points (SW4, SW6, and SW8) for surface water were below the SFC EAL (20 mg/L) for nitrate in both events. Nitrate concentrations did consistently exceed the SFC EAL in drainage areas generally around Unit 18, Unit 25, and Unit 8. The maximum nitrate concentration was 179 mg/L.

Uranium concentrations for all monitoring sites were below the allowable 10 CFR 20 discharge limit for both events. The Event No. 1 uranium concentrations for all four (4) Sequoyah Facility exit point monitoring sites were well below the Sequoyah Facility EAL (225 $\mu\text{g/L}$). The Event No. 2 uranium concentrations for two (2) Sequoyah Facility exit point monitoring sites were below the SFC EAL and slightly above the SFC EAL at the other two (2) exit point monitoring sites. Uranium concentrations did generally exceed the SFC EAL in the Unit 10 and Unit 11 drainage areas during Event No. 2. Uranium concentrations also exceeded the SFC action limits in two (2) FEI defined drainage areas (SW7 and SW18).

Recently, SFC has constructed a small swale in a subarea of Unit 10 to divert flow from this subarea to the North Ditch (Unit 9). The Unit 10 subarea is believed to have impacted surface soils present which contributed to the uranium concentrations documented by the surface water investigation.

8.5 Facility-Wide Underground Utility Investigation

The Facility-Wide Underground Utility Investigation characterized the quantity and location of licensed materials in the subsurface fill soils in the SFC underground utility trenches. Utility trenches backfilled with more porous material provide a potential migration pathway for transporting licensed material away from the Sequoyah Facility.

From this FEI effort, a complete set of utility drawings which locate past and present utilities at the Sequoyah Facility was generated. This effort also included review of the SX Building and MPB construction drawings relative to site geology and documented that no construction foundations or piers penetrate the underlying upper shale unit. Twenty-seven (27) utility trench excavations were performed to investigate migration potential. Eighteen (18) hydraulic barriers and twenty-three (23) trench monitors were installed. The FEI findings document that varying levels of licensed materials are present in the utility trench soil and porewater. SFC has implemented an aggressive corrective action program which, to date, has resulted in removal of 3,081 kilograms of uranium in excavated soils, recovery of 95,719 gallons of soil porewater containing 6.6 kilograms of uranium from utility trench monitors, recovery of 108,295 gallons of water from the SX Tank Vault drain containing 322 kilograms of uranium, recovery

of 145.1 gallons of water from the MPB digestion subfloor monitor containing 5.9 kilograms of uranium, and recovery of 675 gallons of water from the MPB denitration subfloor monitor containing 5.5 kilograms of uranium.

8.6 Combination Stream Drain Investigation

The investigation of the Combination Stream Drain (CD) was not one of the original principal FEI Work Plan Tasks but emerged during the FEI as a major component of the Facility-Wide Underground Utility Investigation. Two (2) extensive investigations of the CD were performed during the FEI, one internal and one external.

The internal investigation identified all contributing waste streams to the CD and clarified the operational dynamics of the CD. Two (2) flow and sampling events were completed to characterize the CD. The CD characterization investigation determined that the major uranium loading is from the cooling tower equalization basin. Along the CD, the potential sources of inflow with the greatest uranium concentration include the sanitary sump and cooling water hot side basin sump. The internal investigation also determined no measurable infiltration or exfiltration was occurring into or out of the CD, respectively. The uranium limit applicable to the CD permitted outfall (001) was never exceeded during the FEI investigation.

The external investigation of the CD trench backfill material has included the installation of three (3) trench backfill monitoring wells and two (2) porewater recovery wells. The trench backfill monitoring program has defined the levels of uranium along the CD trench backfill. The uranium levels fall below the EAL of 225 $\mu\text{g/L}$ outside the restricted area in the area south of the yellowcake sump but north of Outfall 001. The external investigation identified the SX Building area as the probable major contributor area of uranium to the CD trench. A porewater recovery well was installed where the CD exits the restricted area boundary and this well has recovered approximately 1.5 kilograms of uranium. There appears to be no major infiltration or exfiltration of fluids into or out of the CD pipeline. The porewater levels in the CD trench are below the invert of the pipeline from the cooling tower area to the middle of the yellowcake pad. Therefore, there cannot be any infiltration of fluids into the CD pipeline across this area.

8.7 Unit and Groundwater Investigations

SFC initiated a detailed Facility-wide groundwater and soils investigation to determine the quantity and extent of licensed material and other constituents in Sequoyah Facility groundwater and soils. As of July 15, 1991, SFC has installed seventy-nine (79) shallow shale/terrace groundwater monitoring wells, seventy-eight (78) deep sandstone/shale wells, one (1) groundwater recovery wells, and two (2) CD recovery wells, and three (3) CD trench monitoring wells. In addition, approximately ninety-nine (99) lithological characterization borings and approximately 210 soil chemical characterization borings were drilled for the purpose of defining the extent and quantity of licensed material and associated constituents in soils at the facility.

The results of the groundwater and lithological characterization programs indicate that the Sequoyah Facility is underlain by a thin veneer of Quaternary-age terrace deposits (silts and clays) that vary in thickness from 0 to about 16 feet. These terrace deposits are underlain by the Pennsylvanian-age Atoka formation which consists of an alternating interbedded sequence of shale and sandstone. A shale unit approximately 6 to 20 feet thick underlies the MPB and SX Building areas. This shale is underlain by a thin sandstone unit.

There are two (2) hydraulically separate groundwater flow system present in the upper fifty (50) feet at the Sequoyah Facility. The uppermost groundwater system, referred to as the shallow shale/terrace groundwater, is found in the weathered and fractured shale that is in hydraulic communication with groundwater contained in overlying terrace deposits. Beneath the uppermost shale/terrace groundwater system, but hydraulically separated by a dense, highly cemented, non-porous sandstone, is an interbedded shale and sandstone sequence referred to as the deep sandstone/shale groundwater system. The groundwater in both of these systems flows towards the west, northwest, and southwest from the eastern portion of the Sequoyah Facility near the MPB. The groundwater flow rates vary from 5 to 16 feet per year in the shallow shale/terrace groundwater and from 8 to 112 feet per year in the deep sandstone/shale groundwater. The groundwater flow in the shallow shale/terrace groundwater systems is nearly identical to the slope of the bedrock surface indicating that the bedrock surface configuration controls the groundwater movement at the Sequoyah Facility.

There is limited groundwater usage in the Sequoyah Facility area. No major bedrock or alluvial aquifers underlie the Sequoyah Facility. An area-wide water well survey conducted by SFC indicated that no impacts to groundwater from Sequoyah Facility operations have occurred on area water wells. Most

of the water wells identified in the off-site well survey were not in current use. There were no groundwater users noted downgradient of the Sequoyah Facility process area.

Isopleth maps showing the levels of nitrate, fluoride, uranium, and total arsenic in Sequoyah Facility groundwater were prepared. The uranium isopleth maps indicated that limited areas of groundwater at the Sequoyah Facility were impacted and the impacts were generally in the MPB and SX Building areas. The uranium was fully defined in the shallow shale/terrace and deep sandstone/shale groundwater at the Sequoyah Facility and no uranium has migrated through the groundwater beyond the Sequoyah Facility property boundary. The extent of nitrate, fluoride, and arsenic in the two (2) groundwater systems was also evaluated. The limits of these constituents at the Sequoyah Facility (nitrate, fluoride, and arsenic) in the groundwater were fully defined in the MPB and SX Building areas. SFC intends to expand the FEI scope and drill additional wells west and south of Pond 2 to fully characterize the extent of these constituents (nitrate, fluoride, and arsenic) in the groundwater.

Metal analyses of the facility groundwater indicated that the only metals that were significantly higher than EPA primary drinking water standards were arsenic and barium. Organic analyses of groundwater indicated that 1,1,1-trichloroethane,

tributylphosphate, and trichlorofluoromethane were found in groundwater at the facility. These organics were detected at slightly elevated levels and further investigation will be conducted to define the extent of the 1,1,1-trichloroethane. The 1,1,1-trichloroethane is thought to be limited in areal extent. The geochemical modelling study indicated that uranium in groundwater exists mainly as uranyl carbonate and uranyl phosphate complexes. These anionic complexes are soluble in the facility groundwater. The results of the saturation index calculations indicate that groundwater should be unsaturated with respect to uraninite, amorphous UO_2 , U_4O_9 , U_3O_8 , coffinite, UF_4 , $\text{UF}_4 \cdot 2 \cdot 5\text{H}_2\text{O}$, $\text{U}(\text{HPO}_4)_2$, ningyoite, UO_3 , gummite, $\text{B-UO}_2(\text{OH})_2$, schoepite, rutherfordine, H-autunite, uranophane, and bassetite. These minerals are generally expected not to precipitate from solution. However, there were several areas where uranium is predicted to be oversaturated with respect to U_3O_8 , U_4O_9 , $\text{B-UO}_2(\text{OH})_2$, schoepite, rutherfordine, uraninite, and USiO_4 . These wells are mostly in the MPB, SX Building, and Combination Stream Drain trench areas. Uranium is likely being removed from solution through a precipitation process in these areas. Partial removal of uranium from solution through adsorption with ferric oxyhydroxide, a strong adsorbent for uranium, is also predicted to occur naturally at the Sequoyah Facility.

A soil isopleth map completely defines the location of uranium in soils within the 85-acre Sequoyah Facility boundary. Most of the uranium found in the soils is in the upper 5 feet and is found mainly in the MPB and SX Building areas.

9.0 CORRECTIVE ACTIONS

9.1 Introduction

Throughout the course of FEI activities, several corrective actions have been defined and implemented, in addition to others currently being considered. Most of the corrective actions considered were deemed necessary based on knowledge gained as a result of the material characterization and investigation activities described earlier in this report. The implemented or considered corrective actions are:

- Impacted Soils Removal, Transfer, and Storage, with Possible Uranium Recovery;
- Combination Stream Drain Trench Migration Pathway Mitigation; and
- Utility Trench Pore Water and Groundwater Recovery.

Brief corrective action summaries appear in Sections 9.2 through 9.7 and include status reports for each corrective action.

SFC is currently developing a comprehensive facility corrective action plan for submission to the NRC in 1991. This comprehensive corrective action plan will include the corrective actions described in this report, as well as any new corrective actions defined as a result of information from the FEI activities.

9.2 Impacted Soils

SFC has initiated several corrective action responses in relation to impacted soils during the FEI. Initially, in August 1990, SFC performed soil excavations in the SX Building area to remove a large quantity of impacted soil encountered during environmental investigations. Based on uranium concentrations in the impacted soils, this corrective action response accounted for the removal of approximately 3,081 kilograms of uranium.

Also, based on investigation findings for Unit 3 - Initial Limestone Neutralization Area, SFC determined that a corrective action response to remove impacted soil at Unit 3 was warranted. SFC has finalized a plan to excavate and transfer impacted soils from Unit 3 to a storage area inside the Sequoyah Facility restricted area boundary. At present, SFC has completed design of the storage area.

Additionally, SFC is performing a technical review of options to remove and recover uranium from impacted soils. This review will assess the feasibility, results achievable, and costs for existing technologies which offer potential for remediation of soils of the type present and impacted at the Sequoyah Facility. As part of this assessment, SFC is evaluating the possibility of obtaining a research and

development grant to assess removal and recovery of uranium from impacted soils.

9.3 Combination Stream Drain Trench Migration Pathway Mitigation Project

Another SFC corrective action response was initiated from the FEI investigation of the Combination Stream Drain's (CD) potential to act as a uranium migration pathway. SFC has evaluated the geochemistry of the porewater from the CD in order to ascertain the porewater's uranium mobility potential (Section 7.0). As a corrective action response, two (2) trench recovery wells have been installed in the CD trench backfill, and SFC is currently evaluating the need for an additional recovery well. Operational performance data, dating from January 14, 1991 to May 23, 1991, have been developed for one (1) of the trench recovery wells (Section 7.0).

As a possible additional mitigation action, SFC has evaluated the feasibility of lining the CD even though the FEI identified no measurable infiltration or exfiltration association with the CD.

9.4 Utility Trench Pore Water and Groundwater Recovery Program

Early in the course of the FEI, the Sequoyah Facility utility trenches were identified as potential pathways for uranium migration. This investigation is discussed in the report (Section 5.0). SFC has enacted a comprehensive corrective action program for recovery of the utility trench porewater. SFC has installed 25 cutoff walls and/or trench monitors in the SX Building and MPB utility trench excavations. Also, an SX vault subfloor monitor and three (3) groundwater recovery wells have been installed to date. As of June 18, 1991, these corrective action water recovery systems had removed approximately 772,240 liters (204,014 gallons) of liquid and 327,953 grams (723 pounds) of uranium. SFC will continue to implement these corrective action activities.

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May 21, 1992

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CERTIFIED
REGISTERED MAIL

Mr. John W. N. Hickey, Chief
Fuel Cycle Safety Branch,
Division of Industrial and
Medical Nuclear Safety, NMSS
U.S. NUCLEAR REGULATORY COMMISSION
Washington, D.C. 20555

Re: Addendum Facility Environmental Investigation

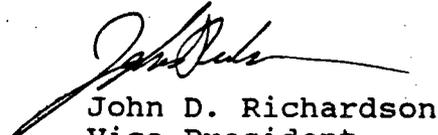
Dear Mr. Hickey:

Enclosed please find six (6) copies of the Sequoyah Fuels Corporation Addendum Facility Environmental Investigation Findings Report, dated May 21, 1992. This information completes all related investigations that were outstanding when the original FEI, dated July 31, 1991, was submitted.

This additional information was utilized in developing the SFC Action Plan submitted January 10, 1992. Subsequently, this information does not require additions or modifications to the Action Plan.

If you require further information or have any questions regarding this submittal, please contact me at (918) 489-3207.

Sincerely,


John D. Richardson
Vice President,
Regulatory Affairs

JR:tb

xc: File

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