Industrial Wastewater Closure Module for the High-Level Waste Tank 20 System

Savannah River Site

Construction Permit Number: 17,424-IW

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ACRONYMS AND ABBREVIATIONS

ACI	American Concrete Institute
AEA	Atomic Energy Act
ALARA	as low as reasonably achievable
Bq	becquerel
BSRI	Bechtel Savannah River, Inc.
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	curie
CLSM	controlled low-strength material
CTL	Construction Testing Laboratory
CTS	concentrate transfer system
CWA	Clean Water Act
DCF	dose conversion factors
DOE	U.S. Department of Energy
DOE-HQ	U.S. Department of Energy-Headquarters
DWPF	Defense Waste Processing Facility
EA	environmental assessment
Eh	oxidation potential
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
ESP	Extended Sludge Processing
ETF	F/H Effluent Treatment Facility
FFA	Federal Facility Agreement
FONSI	Finding of No Significant Impact
FTF	F-Area Tank Farm
g	gram
GSA	General Separations Area
GTCC	greater-than-class-C
GTS	groundwater transport segment
HEPA	high efficiency particulate air (filter)
HLW	high-level waste
HQ	hazard quotient

HWMF	hazardous waste management facility
ICRP	International Commission on Radiological Protection
ITP	In-Tank Precipitation Facility
L	liter
LDR	Land Disposal Restrictions
LLW	low-level waste
LOAEL	lowest-observed-adverse-effect-level
m^3	cubic meters
µCi	microcurie (10^{-6} Ci)
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MEPAS	Multimedia Environmental Pollutant Assessment System
µg	microgram (10^{-6} gram)
mg	milligram (10^{-3} gram)
mrad	millirad
mrem	10^{-3} rem
MSL	mean sea level
mSv	milliSievert (10^{-3} Sievert)
mV	millivolt
NEPA	National Environmental Policy Act
NERP	National Environmental Research Park
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOAEL	no-observed-adverse-effect-level
NPDES	National Pollutant Discharge Elimination System
NRC	U.S. Nuclear Regulatory Commission
O&M	Operations and Maintenance
PCB	polychlorinated biphenyl
pCi	picocurie (10^{-12} Ci)
ppm	parts per million
psi	pounds per square inch
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
rem	roentgen equivalent man
RFI/RI	RCRA Facility Investigation/Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
SCDHEC	South Carolina Department of Health and Environmental Control

SCHWMR	South Carolina Hazardous Waste Management Regulations
SCPCA	South Carolina Pollution Control Act
SDWA	Safe Drinking Water Act
SMDF	Saltstone Manufacturing and Disposal Facility
SPCC	Spill Prevention Control and Countermeasure
SRS	Savannah River Site
SRTC	Savannah River Technology Center
SWMU	solid waste management unit
TEDE	total effective dose equivalent
TOC	total organic carbon
TSS	total suspended solids
UMTRA	Uranium Mill Trailings Remedial Action Program
UTS	Universal Treatment Standards
VOC	volatile organic compound
WSRC	Westinghouse Savannah River Company

EXECUTIVE SUMMARY

Since the Savannah River Site (SRS) began operations in the early 1950s, its uranium and plutonium recovery processes have generated liquid high-level radioactive waste, which currently amounts to 34 million gallons stored in 51 underground tanks in the F- and H-Areas. The U.S. Department of Energy (DOE) intends to remove these high-level waste (HLW) tanks from service as they complete their missions. Because the tank systems are permitted under the South Carolina Pollution Control Act, they will be closed under South Carolina Regulation R.61-82, "Proper Closeout of Wastewater Treatment Facilities." DOE has submitted a general plan (DOE 1996a) for the closure of all 51 tank systems, which the South Carolina Department of Health and Environmental Control (SCDHEC) approved on July 31, 1996.

The purpose of this tank-specific closure module is to set forth the plan by which DOE intends to close the Tank 20 system in accordance with South Carolina Regulation R.61-82 and in a manner consistent with the ultimate remediation of the HLW tank farms under the SRS Federal Facility Agreement (FFA) (EPA 1993). Because this module tiers from DOE's general closure plan and the Program Plan (DOE 1996b), its objectives are consistent with those two documents; Chapter 1 describes these objectives.

Tank 20 is a Type IV tank (see general closure plan, Chapter 2) in the F-Area Tank Farm, grouped in a depression with Tanks 17, 18, and 19. These four tanks, known as a "four-pack," will undergo bulk waste removal and spray water washing; however, a small amount of sludge will remain. Tank 20 has already undergone bulk waste removal and spray water washing. Although there are small cracks in the Tank 20 wall, there is no evidence that waste has leaked out.

The F-Area Tank Farm is a heavy industrial use area. DOE anticipates that F-Area will remain under industrial use for 10,000 years, the entire period of analysis for this module. Tanks 17 through 20 were placed well below the original site grade. The bottoms of the tanks are currently about 3 feet above the water table. The groundwater under the tanks discharges to Upper Three Runs to the north and Fourmile Branch to the south.

Just upgradient of Fourmile Branch toward the tank farms, the groundwater in the Water Table Aquifer and the Barnwell-McBean Aquifer outcrops in a broad band known as the seepline, which would be the primary point of exposure to any contaminants leaching from Tank 20. The outcropping at the seepline is approximately 1 mile from Tank 20.

The closure configuration for Tank 20 includes filling the tank with a "sandwich" of grouts. The first layer would consist of a minimum of 24 inches of chemically reducing grout. The fill material would be formulated with chemical properties that retard the movement of some radionuclides and chemical constituents from the closed tank. On top of the reducing grout would be a layer of Controlled Low-Strength Material (CLSM), which is a self-leveling fill material. CLSM provides sufficient strength to support the overbearing weight. The CLSM layer would be about 32 feet deep, to within 6 inches of the top of the vertical wall of the tank (spring line). The final layer would be a free-flowing, strong grout similar in strength to normal concrete (2,000 pounds per square inch). The purpose of the strong grout would be to fill the voids around the risers and to discourage an intruder from possibly accessing the waste. The risers will also be filled with a layer of reducing grout and a layer of strong grout (5,000 pounds per square inch).

In addition to filling the tank with grout, DOE will isolate the tank and its systems. Chapter 5 describes the equipment to be removed and the equipment that will remain after closure. DOE would use grout to fill some of the equipment that remains with the tank. The tank's top truss and equipment would be left in a safe and orderly state.

Closure of the Tank 20 system under R.61-82 must not preclude any potential FFA remedial activities pursuant to the Resource Conservation and Recovery Act (RCRA) or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Therefore, DOE has identified known and potential contamination sites within Tank 20's groundwater transport segment that are subject to the RCRA Facility Investigation/Remedial Investigation or Site Evaluation processes. Preliminary fate and transport modeling shows that the contaminants known or expected to be in these units will not produce any impacts concurrent with Tank 20 closure impacts.

DOE will defer soil assessment in the vicinity of Tank 20 until it can isolate all related tanks and associated systems from the operational parts of the tank farm. A soils assessment and post-closure strategy for the operational grouping (Tanks 17 through 20, the 242-F evaporator, the concentrate transfer system, and the 241-1F control room) will be provided to the SCDHEC and the U.S. Environmental Protection Agency in the last of the tank-specific closure modules.

During and after closure of Tank 20, DOE will continue routine operational monitoring and inspection, environmental surveillance, physical security, and stormwater system maintenance. After the closure of the four-pack grouping and after completion of soils assessments/remediation, the four-pack depression will be backfilled to grade level, and DOE will design a monitoring and inspection program specifically suited to the four tanks. Although DOE's fate and transport modeling does not indicate that a cap is needed to satisfy performance modeling, a low permeability cap may be placed over the area, depending on the outcome of the remedial investigation and feasibility study for the area.

In accordance with the methodology outlined in Chapter 6 and illustrated in Appendixes D and E of the general closure plan (as slightly modified in Chapter 1 of this module), DOE has evaluated the impacts of closing Tank 20 in accordance with the configuration described in Chapter 4 of this module. Additional modeling or other evaluations were performed on nearby tanks and nontank systems to determine collective impacts at the point of exposure (the seepline at Fourmile Branch). DOE determined that the collective impacts from closing every tank in the F-Area tank farm are below the various performance objectives. For example, the Tank 20 contribution to the maximum F-Area tank farm dose from drinking groundwater at the seepline is 0.0055 millirem per year out of a total impact of 1.9 millirem per year. This is well within the performance objective of 4 millirem per year.

Based on these results, the proposed closure strategy for Tank 20 will protect human health and the environment and will comply with applicable regulations. In addition, DOE has assessed the Tank 20 closure using the nine evaluation criteria of CERCLA Section 121 (see Chapter 9). The assessment concludes that the closure of Tank 20 will provide overall protection of human health and the environment.

REFERENCES

DOE (U.S. Department of Energy), 1996a, *Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Tank Systems, Savannah River Site, Construction Permit Numbers 14,338, 14,520, 17,424-IW*, Revision 1, Savannah River Operations Office, Aiken, South Carolina, July 10.

DOE (U.S. Department of Energy), 1996b, *High-Level Waste Tank Closure Program Plan*, Rev. 0, Savannah River Operations Office, Aiken, South Carolina, December 16.

EPA (U.S. Environmental Protection Agency) 1993, *Federal Facility Agreement between U.S. Environmental Protection Agency Region IV, U.S. Department of Energy, and the South Carolina Department of Health and Environmental Control*, Docket No. 89-05-FF, August 16.

CHAPTER 1. INTRODUCTION

The U.S. Department of Energy (DOE) received approval on July 31, 1996, from the South Carolina Department of Health and Environmental Control (SCDHEC) of a general plan (DOE 1996a) to close 51 high-level radioactive waste (HLW) tank systems at the Savannah River Site (SRS) in accordance with South Carolina Regulation R.61-82, "Proper Closeout of Wastewater Treatment Facilities." The overall strategy in the plan calls for SCDHEC approval of detailed closure modules for individual SRS tank systems. This document is the first in the series of closure modules that tier from the general plan. It addresses the Tank 20 system, which is in the F-Area Tank Farm and which SCDHEC has permitted as an industrial wastewater treatment facility under Construction/Operating Permit No. 17,424-IW. This module includes a description of the Tank 20 system and proposed closure methods, and a performance evaluation that demonstrates that the proposed closure will protect human health and the environment in accordance with the requirements of South Carolina Regulation R.61-82.

1.1 Purpose and Objectives

The purpose of this closure module is to set forth the plan by which DOE intends to close the Tank 20 system in accordance with South Carolina Regulation R.61-82 and in a manner consistent with the ultimate remediation of the HLW tank farms under the SRS Federal Facility Agreement (FFA; EPA 1993), and to obtain from SCDHEC approval to proceed with this closure. Because this module tiers from DOE's approved general closure plan and the Program Plan (DOE 1996b), its objectives are consistent with those of the general closure plan and the Program Plan as they apply to closure of the Tank 20 system.

The specific objectives of this module are as follows:

- Define and describe the Tank 20 system planned for closure under this module and other HLW tank systems that could affect or be affected by closure of the Tank 20 system.
- Identify and describe the resources (e.g., human populations, land use, natural and cultural resources) potentially affected by the Tank 20 closure, and information used to demonstrate that the proposed closure will protect these resources (i.e., will meet performance objectives).
- Describe the proposed configuration of the Tank 20 system after closure, including the isolation from operational systems, disposition of major tank system components, and physical and chemical stabilization of the residual waste and the tank system itself.

- Describe specific measures DOE has taken and plans to take under this plan to achieve the proposed closure configuration, and provide an implementation schedule for planned closure activities.

- Describe measures to ensure consistency of the Tank 20 closure with ultimate remediation of the HLW tank farms in accordance with provisions of the FFA, and DOE's plan and schedule for associated post-closure activities.

- Demonstrate by means of a detailed performance evaluation supported by appropriate modeling results that the planned Tank 20 closure configuration will comply with performance objectives pertinent to the closure.

- Demonstrate that the planned Tank 20 closure will conform substantially to other relevant and appropriate criteria.

1.2 Tank 20 Closure Plan

The activities detailed for the Tank 20 system in this closure module implement the strategy set forth in Chapter 4 of the approved general closure plan (DOE 1996a), as modified in Figure 1-1 (see modifications from the general closure plan described in Section 1.4). Under this strategy, DOE has: (1) removed waste from the tank system using bulk waste removal followed by spray water washing and (2) selected a protective closure configuration (residual contaminant level/stabilization combination) on the basis of a performance evaluation to determine compliance with pertinent performance objectives (i.e., exposure pathway/concentration or dose/point of compliance combinations). As discussed in Section 6.1 of the general closure plan, the groundwater pathway is the limiting exposure pathway. Therefore, the performance evaluation uses an interpretive construct known as a groundwater transport segment (GTS) to account for other potential sources of contamination (e.g., other HLW tank systems) that might contribute to the same point of compliance as the Tank 20 system. As discussed in more detail in Section 6.4 of the Program Plan, the use of the GTS in conjunction with groundwater fate and transport modeling (using conservative assumptions) facilitates the accounting of individual tank closure impacts against performance objectives. In this manner, DOE can ensure compliance with performance objectives not only for the Tank 20 system, but also for the overall closure of the tank farms.

This tank system-specific module is narrowly focused to document the results of DOE activities to implement the approved general closure strategy for the Tank 20 system. The module references the

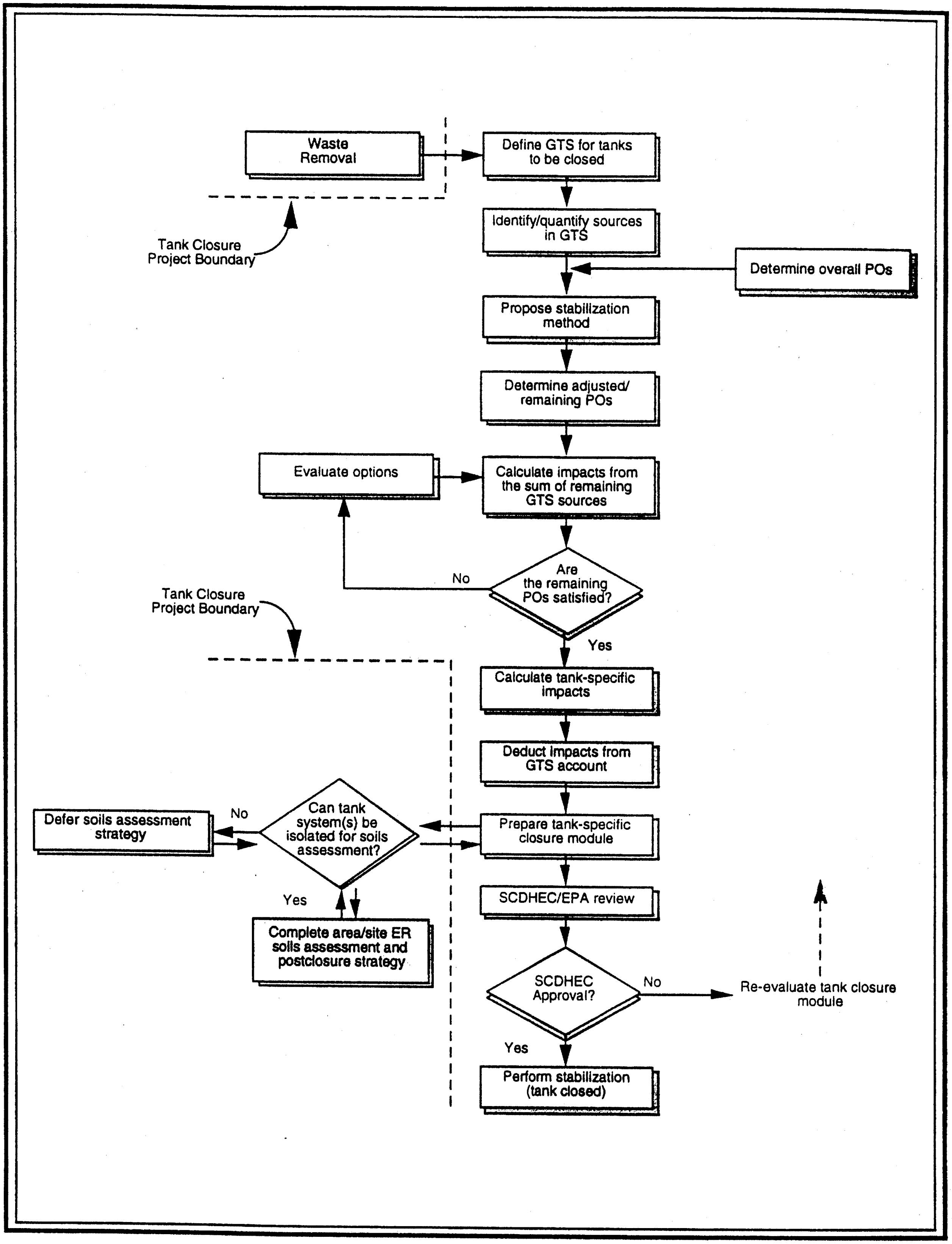

Figure 1-1. Flow sheet for HLW tank closure.

general closure plan where appropriate. The organization of the module demonstrates its conformance with the general closure plan and the specific objectives listed in Section 1.1, as follows:

- Chapter 2 describes the Tank 20 system DOE has selected for closure under this module and other HLW tank systems that could affect or be affected by the Tank 20 system closure.

- Chapter 3 describes the natural and human resources that could affect or be affected by the Tank 20 system closure to support the performance evaluation in Chapter 8 and conformance with overall closure criteria in Chapter 9.

- Chapter 4 describes the proposed closure configuration for the Tank 20 system, including the isolation from operational systems, planned disposition of major components, waste removal activities undertaken and planned, characterization of waste residuals in the Tank 20 system and other pertinent tank systems, planned features to stabilize the Tank 20 system and associated waste residuals, and other features designed to ensure tank system stability during the post-closure period.

- Chapter 5 describes planned methods and activities to achieve the proposed closure configuration described in Chapter 4 and a milestone schedule for closure activities.

- Chapter 6 provides information demonstrating that DOE will undertake closure activities in a manner that ensures overall protection of human health and the environment.

- Chapter 7 describes measures undertaken and proposed to ensure consistency of the Tank 20 system closure with ultimate remedial actions for the HLW tank farms and the strategy for soil and groundwater remedial activities under the FFA, including monitoring and maintenance during the post-closure period.

- Chapter 8 describes the methods and results of the performance evaluation to determine compliance of the proposed Tank 20 system closure configuration with pertinent performance objectives, including identification of those standards, demonstration of compliance with those performance objectives, and accounting of closure impacts against the performance objective budget.

- Chapter 9 summarizes conformance of the proposed closure of the Tank 20 system with relevant and appropriate criteria, specifically the nine criteria used to evaluate Comprehensive

Environmental Response, Compensation, and Liability Act remedial action options [as described in 40 CFR 300.430(e)(9)], including compliance with requirements not evaluated in Chapter 8 (implementability, cost, and other factors).

- Appendix A describes the groundwater fate and transport modeling methods and results that DOE uses to support the performance evaluation in Chapter 8.

- Appendix B describes the application of the GTS methodology to account for closure impacts against the performance objectives budget.

1.3 Identification of Tank 20's Operational Grouping

Although DOE intends to perform soils assessment and potential remedial action in the vicinity of Tank 20, such activities would not occur until all operationally related tanks are closed as well. This is to ensure that intrusive characterization or remediation does not release contamination or interfere with operation of other tank systems.

The following tank systems are operationally related to Tank 20 and will be closed in the listed order: Tank 20, Tank 17, Tank 19, and Tank 18 (see Figure 1-2). The 242-F evaporator, the 241-1F control room, and the Concentrate Transfer System will be closed near the end of the sequence. The rationale for this sequence is purely practical. Tank 20 had waste removal completed in the late 1980's and ballast water removed late last year. Tanks 17 and 19 are interchangeable in the closure sequence and are planned to be closed in quick succession. Tank 18 will be the last tank closed since all wastewater must be transferred out of the grouping through the Tank 18 system. The 242-F evaporator, control room, and Concentrate Transfer System can be closed independently of the tank closures. This group of tanks is scheduled to be closed by 1998.

1.4 Modification of the General Closure Plan

DOE set forth the general methodology for closing tanks in the general closure plan. Since the general closure plan was approved, DOE has improved the process somewhat, although the general approach has not changed. This section describes changes in the closure methodology to be employed for the Tank 20 closure. DOE will modify the general closure plan in 1997 to reflect these changes. Figure 1-1 depicts the modified process.

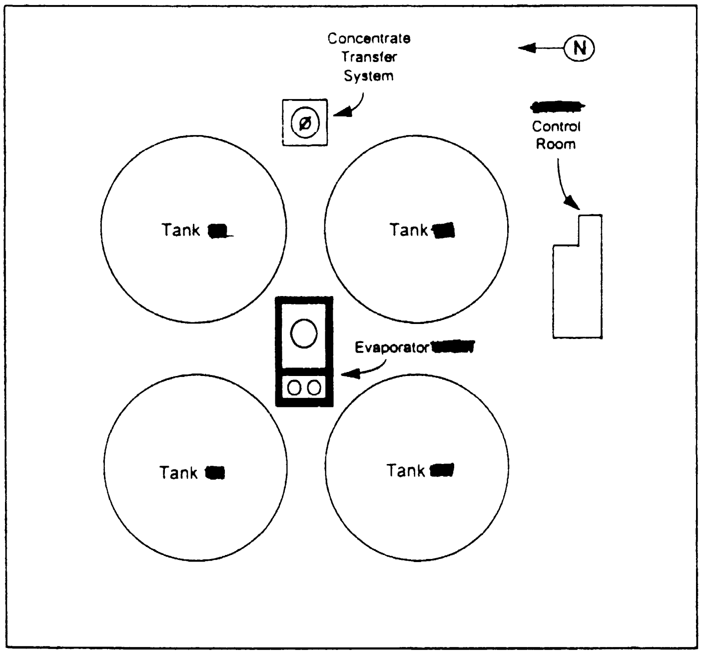

Figure 1-2. Tank 20 in its operational grouping.

1.4.1 CHANGES RELATED TO ACCOUNTING AGAINST PERFORMANCE OBJECTIVES

The DOE closure methodology has matured to the point that there is no need to calculate tank-specific performance objectives. Once it is determined that the sum of the sources in a GTS satisfy the overall performance objectives, each individual source would be expected to consume no more than its share of the performance objective. Therefore, calculation of tank-specific performance objectives is being abandoned in favor of a system that maintains an accounting of individual tank closure impacts against the overall adjusted performance objective. As tanks are closed, their closure impacts are calculated and subtracted from the overall performance objectives. The remainder is recorded and the next tank's closure impacts are then subtracted from that remainder.

DOE must still be careful to not overshoot the overall performance objective. This is because the determination of closure impacts for the sum of all the GTS sources is based on an estimated source term. As tanks are closed, sampling and analysis of the residual contamination provides a more accurate source term for those tanks. Some tanks might have more or less contamination than assumed for the total GTS impacts calculation. Therefore, after each tank is characterized for closure, the impacts of all the remaining unclosed tanks in the GTS would be calculated to ensure all performance objectives are satisfied. DOE would also separately calculate the impacts of the tank to be closed and deduct the impacts from the remaining performance objective budget. Should the new calculation indicate an overshoot in the performance objectives, DOE would have to evaluate whether to further clean the tank under consideration for closure or commit to more rigorous cleaning on future tanks. DOE's decision would be placed in the closure module for SCDHEC concurrence.

1.4.2 CHANGES RELATED TO POST CLOSURE SOILS ASSESSMENT/REMEDIAL ACTION

These changes are reflected in the shaded portion of Figure 1-1, outside the tank closure project boundary. The primary difference is a redrawing of the flowchart to more effectively reflect the intent of the process and to reflect improved SRS integration of post-closure management with tank system closure activities.

1.5 References

DOE (U.S. Department of Energy), 1996a, *Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Tank Systems, Savannah River Site, Construction Permit Numbers 14,338, 14,520, 17,424-IW*, Revision 1, Savannah River Operations Office, Aiken, South Carolina, July 10.

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CHAPTER 2. DESCRIPTION OF HIGH-LEVEL WASTE TANK 20 SYSTEM

2.1 Tank 20 History

Tank 20 is located in the F-Area Tank Farm (See Figures 2-1, 2-2, and 2-3 of the general closure plan). This tank was constructed in 1958 and was subsequently placed into service as an evaporator concentrate receipt tank in 1960. The supernate and salt were removed from the tank in several operations occurring in the mid 1980s. In 1988, the interior, including the dome and sides, was spray water washed. After spray water washing, photographs of the tank showed approximately 12,000 gallons (3.5 inches) of wash water and no observable solids. In 1990, additional water was added as ballast, bringing the total liquid volume up to approximately 22,000 gallons. The purpose of the ballast water is to prevent uplift of the bottom of the tank in the event that groundwater or surface water collecting in the leak detection sump was not pumped out in a timely manner. The ballast water in the tank was pumped out in late 1996. The amount of solids remaining in the tank has been confirmed to be approximately 1,000 gallons.

Photographic inspections have identified three corrosion penetrations in the walls of Tank 20; however, monitoring of the leak detection sump for contamination has shown no evidence that waste leaked through these penetrations into the environment. In addition, there are two piping penetrations on the tank walls, approximately 30 feet from the tank bottom, at the 90° and 210° tank coordinates. Each of these penetrations extends beyond the tank wall; each has been capped with a steel plate. No known releases have occurred as a result of operations involving these penetrations. Tank 20 closure activities will place a video camera in the tank to account for all penetrations. Backfill material will seal these penetrations as the tank is closed, eliminating the potential for future releases through them.

2.2 Tank 20 Construction

Tank 20, like all Type IV tanks (see Figure 2-5 of the general closure plan), is a steel-lined single-shell cylindrical tank with a 1.3 million gallon capacity, concrete walls, a concrete domed roof without support columns, and a dome ring. Tank 20 has no annular containment nor cooling coils. The walls and floor were constructed of $^{3}/_{8}$ -inch thick carbon steel plates. The $^{7}/_{16}$ -inch knuckle plates at the junction between the tank bottom and the sidewalls rest on a concrete tank ring. The tank steel conforms to

ASTM A285-54T Grade B (firebox quality) standards. All welds on the tank were radiographically inspected, and the completed steel tank was leak-tested prior to waste storage. Concrete was built up around the exterior walls by employing the "shotcrete" technique. This technique employs a pneumatic method of applying concrete to a surface by blowing a thick semifluid concrete mixture through a nozzle. The "shotcrete" concrete wall is 11 inches thick at the base of the wall and tapers to 6 inches at the top. The "shotcrete" forms a dense, high-strength concrete wall which enhances the load-bearing capacity of the tank system. This high-strength concrete wall was prestressed with embedded girths of steel under tension in the primary tank shell. The concrete mat beneath the tank is 4 inches thick and rests on undisturbed earth. Above the mat is a 3-inch layer of concrete containing a grid of channels which drain to a sump for leak detection via a bubbler tube. The reinforced concrete tank dome is 7 inches thick with a minimum of 32 inches of earth cover for radiation shielding. The domed roof contains above-grade riser openings (Figure 2-1) where various instruments and waste transfer equipment are installed. Although the dome itself is not lined, the riser openings are lined with 1/4 -inch steel plates. Tank 20 also has several pieces of ancillary equipment associated with it. These include a slurry pump, a transfer jet, a thermowell, a leak detection system, and transfer piping into and out of the tank (WSRC 1991).

2.3 Other Equipment

Galvanized steel platforms and support steel for pumps are installed on the tank top. Service piping and conduit are mounted to the steel girders.

The slurry pump, transfer jet, and thermowell associated with Tank 20 and the transfer line between Tanks 18 and 20 will be closed under this module.

Other tanks and equipment in the vicinity of Tank 20 include Tanks 17, 18, and 19 and associated transfer piping, the 242-F evaporator, the concentrate transfer system (CTS), CTS ventilation building, and the 241-1F control room. The closure of these items is outside the scope of this module. However, the closure of Tank 20 must be conducted in such a way that the closure of the other equipment can be expeditiously performed.

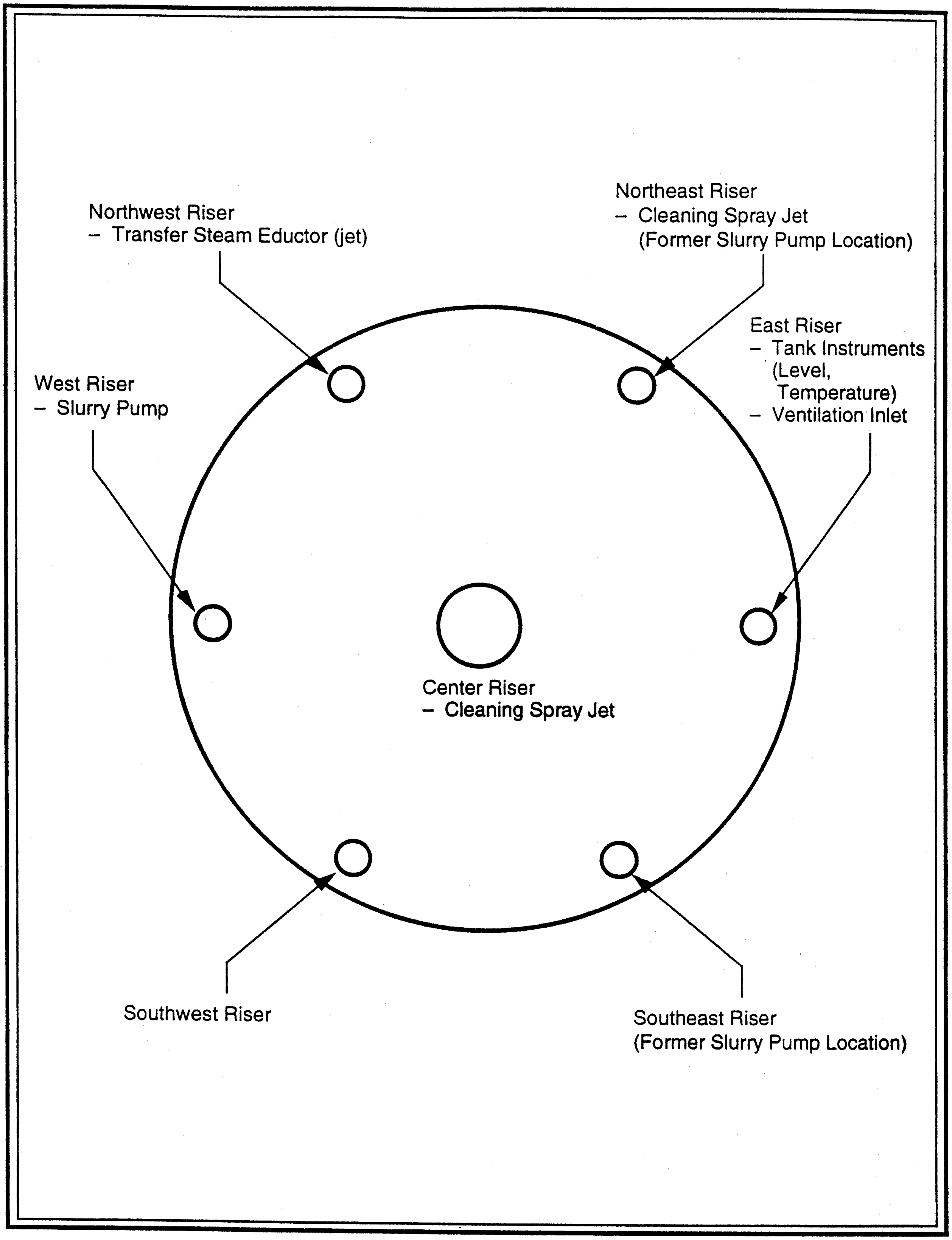

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Figure 2-1. Tank 20 riser locations (plan view).

2.4 References

WSRC (Westinghouse Savannah River Company), 1991, *As-Built Construction Permit Application for an Industrial Wastewater Treatment Facility for the F/H-Area High-Level Radioactive Waste Tank Farms*, Rev. 0, Aiken, South Carolina, April 16.

CHAPTER 3. ENVIRONMENTAL CONDITIONS

This chapter describes the natural and cultural resources in the vicinity of the F-Area Tank Farms that could affect or be affected by the proposed closure of the Tank 20 system. The information emphasizes the environmental features of F-Area that are important to the performance evaluation discussed in Chapter 8 and Appendix A. Most of the information is from existing Savannah River Site (SRS) documents that address F-Area and the F-Area Tank Farm.

3.1 Land Use and Demographics

3.1.1 CURRENT LAND USE

Land use in the F-Area, including the tank farm, is heavy industrial, as shown in Figure 3-1. This aerial photograph from south to north shows the high-level waste (HLW) tanks in F-Area. Land use within a mile of F-Area is classified as woodlands with the exception of the E-Area Solid Waste Disposal Facility and H-Area to the east that makeup the remainder of the SRS General Separations Area (GSA). Section 3.1 of the general closure plan (DOE 1996a) contains more information on land use and demographics related to the F-Area Tank Farm.

3.1.2 FUTURE LAND USE

The U.S. Department of Energy (DOE) has determined that the area affected by the proposed HLW tank closure would continue to be under institutional control for the next 100 years, after which it would be zoned industrial for an indefinite period with deed restrictions on the use of groundwater (DOE 1996b). DOE has designated the SRS as a National Environmental Research Park (NERP). A current initiative in the U.S. House of Representatives would designate the SRS as a NERP under Federal law. The significance of this initiative is that the lands of the SRS would be under Federal control in perpetuity.

In response to the DOE Headquarters (DOE-HQ) direction, SRS prepared a *Land Use Baseline Report* (WSRC 1995a) which describes SRS and the surrounding area in terms of its physical and natural features and its environmental conditions to facilitate development of appropriate future land use plans and controls.

3.2 Topography, Geology, and Soils

The topography of the F-Area Tank Farm varies from a high of approximately 295 feet to a low of approximately 288 feet above mean sea level (MSL); however, the ground surface elevation in the depression around Tanks 17 to 20 is approximately 271 feet above MSL, as shown in Figure 3-2.

Tanks 17 through 20 were placed below the original site grade to facilitate gravity feed of waste. The area around the tanks was backfilled with clay and topsoil to the top of the tanks. Figure 3-3 is a general cross-section of the F-Area Tank Farm from north to south. The base elevation of Tanks 17 and 18 is 229 feet MSL and 228 feet MSL for Tanks 19 and 20, respectively (Morris 1979). Neighboring Tanks 25 and 28 have base elevations of 249 feet MSL (O'Neal 1981). Table 3-1 lists the base elevation of the F-Area tanks. The modeling described in Appendices A and B use the base elevations of the F-Area tanks as points of reference for modeling purposes.

Table 3-1. Base elevations of F-Area tanks.

Tank	Elevation of tank base (ft.)
1	244
2	244
3	243
4	243
5	242
6	242
7	241
8	241
17	229
18	229
19	228
20	228
25	249
26	250
27	250
28	249
44	248
45	250
46	250
47	248

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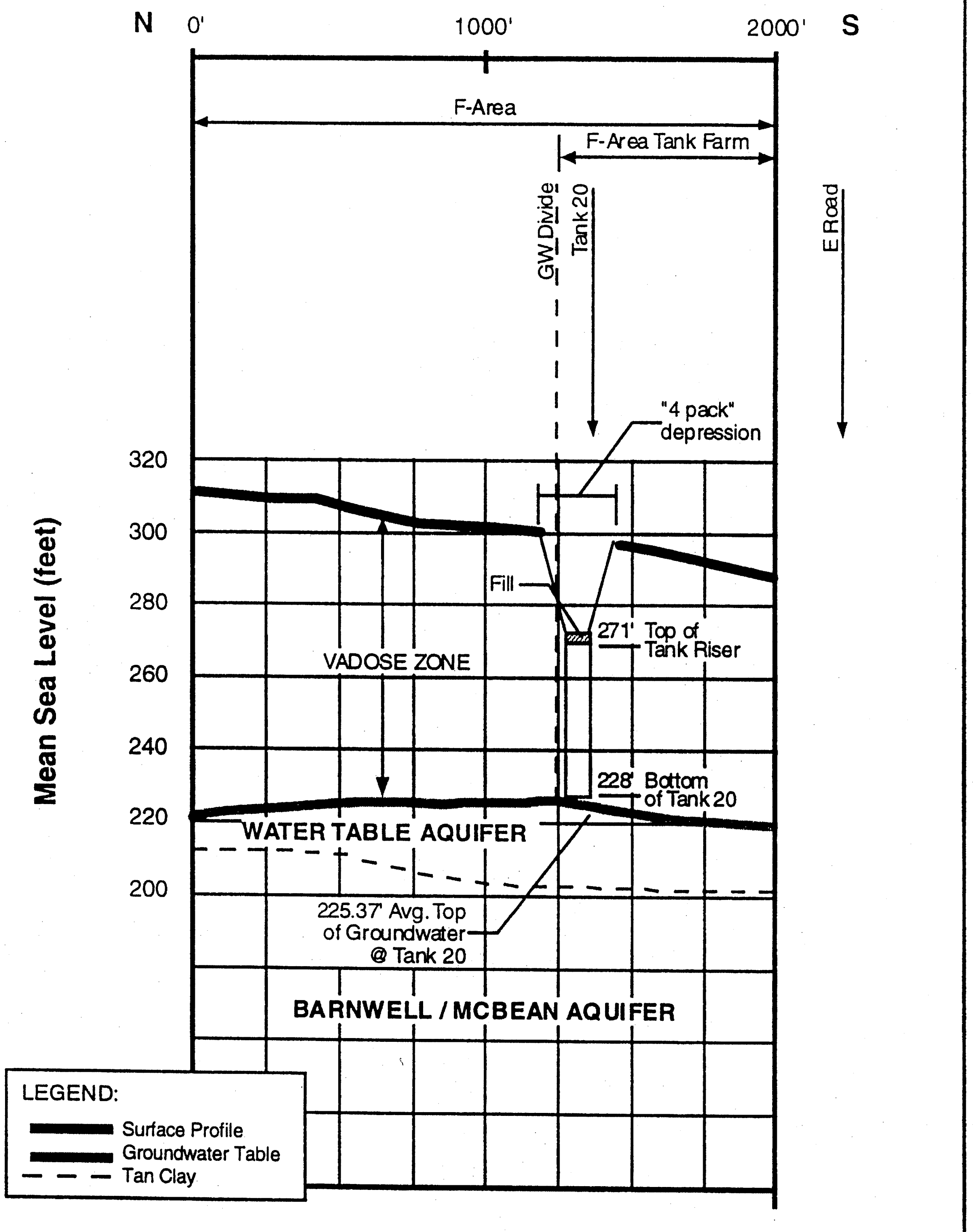
Figure 3-2. F-Area Tank Farm topography map.



Source: Water level based on data from WSRC (1995b).
Top of Tan Clay based on lithologic picks in "FSL" wells due west of F-Area Tank Farm.
Placement of Tank and its elevation based on Tank Farm maps and data from O'Neal (1981).

PK38-12PC

Figure 3-3. Generalized north-south cross section through the F-Area Tank Farm.

The geology and soils beneath the F-Area Tank Farm are known as the "Upland Unit." This unit is known for its variable composition of clay, sand, and sandy clay lenses. DOE built the F-Area Tank Farm on or in the native soils of the site. In the mid 1970's, site preparation for the construction of Tanks 25 to 28 and Tanks 44 to 47 required subsurface grouting of a calcareous deposit. The calcareous deposit was found intermittently at a depth of 130 feet below the ground surface (approximately 289 feet above MSL) and is suspected to be approximately 10 to 30 feet in thickness. A uniform grid pattern (50 feet by 75 feet) was placed in the footprint of the eight tanks as well as an area to the west of Tank 44 to 47 (25 feet by 75 feet) for future tank construction. Grout was pumped into the ground to minimize potential tank subsidence.

Soils that make up the vadose zone in this region of the SRS and the F-Tank Farm area in particular belong to the Fuquay-Blanton-Dothan Association (along the ridges) and the Vaucluse-Ailey Association (along the slopes of drainages). The former are well-drained sloping soils characterized by a thick sandy surface and a loamy subsoil. The latter soils are sloping to strongly sloping and occur in long narrow areas, in this case along the drainage of Fourmile Branch. Vaucluse soils are loamy on the surface and the subsurface whereas the Ailey soils are moderately thick and sandy at the surface and in the subsurface. Both of these soils have a brittle loamy subsoil (WSRC 1993; USDA 1990).

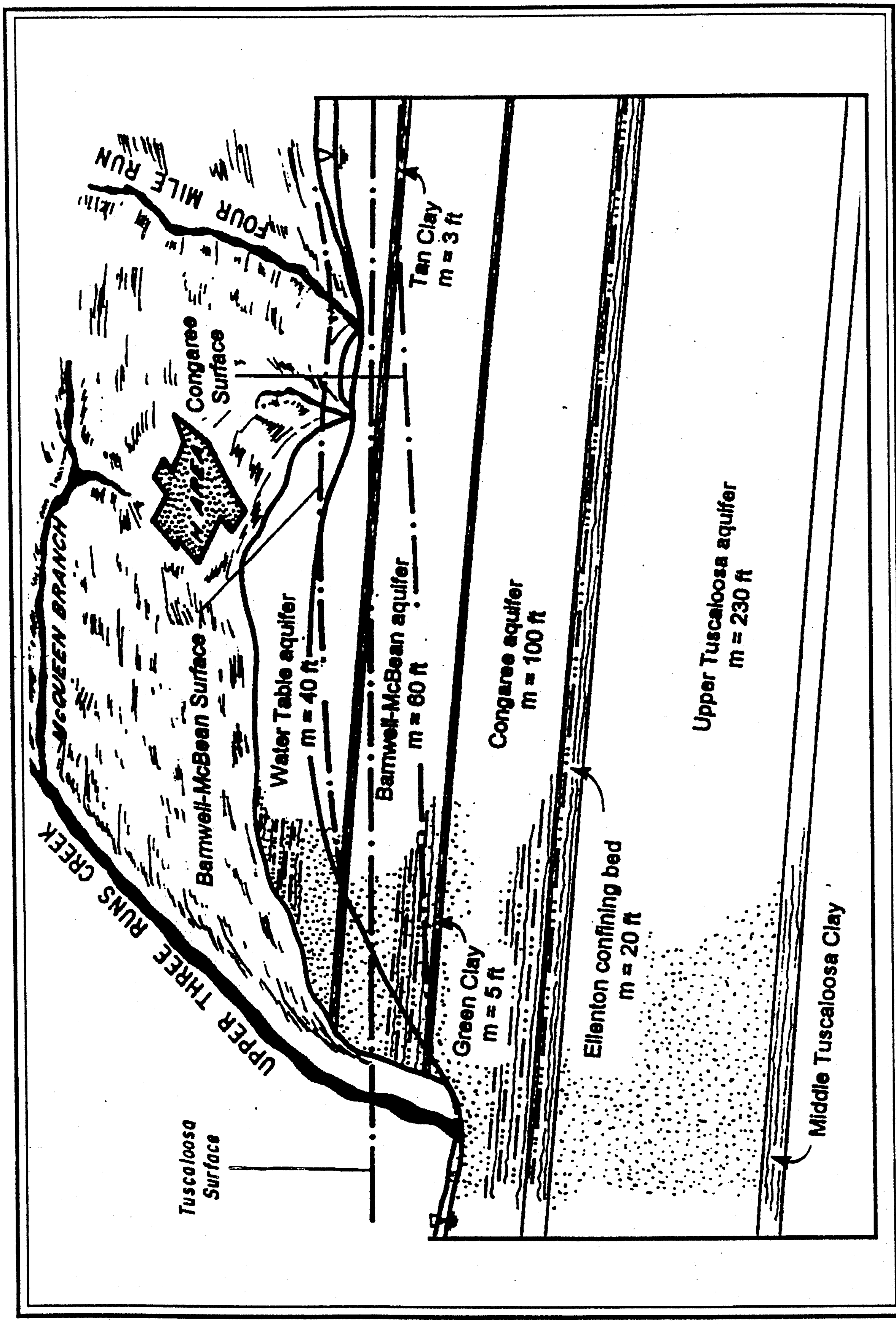
Section 3.2 of the general closure plan (DOE 1996a) describes more of the geology and soils related to the F-Area Tank Farm.

The F- and H-Area Tank Farms have incurred minor spills and releases of waste materials from the tank systems over the years of operation. In addition, spills and releases have occurred in and around F-Area as a result of facility operations. The quality of groundwater in F-Area is discussed in Section 3.3.2. SRS Operating Departments (i.e., such as the F-Area Tank Farms) that have experienced spills and releases operate in accordance with an SRS Operations and Maintenance (O&M) Plan. The SRS O&M Plan provides direction to departments on spill response, removal actions, and O&M activities consistent with the SRS National Contingency Plan and Federal Facility Agreement (EPA 1993; WSRC 1996a, 1996b).

3.3 Groundwater

3.3.1 HYDROGEOLOGY

The hydrogeologic system in the GSA consists of vertically stacked aquifer units separated by intervening confining units (see Figure 3-4). The uppermost aquifer, the Water Table, consists of an



Source: GeoTrans (1987).

Figure 3-4. Summary of the hydrogeologic system for the GSA.

upper unit of clayey sand with clay and silt lenses and a lower unit of silty and poorly graded sand. This aquifer is underlain by the Tan Clay confining unit, which is not generally recognized as a continuous confining unit in this area. Recharge to the Water Table results primarily from infiltration of precipitation, but a small portion occurs as underflow from areas upgradient of the GSA. Locally, some recharge likely occurs due to seepage from basins and other man-made facilities. Discharge from the Water Table flows to the underlying Barnwell-McBean and to surface waters. The ratio of lateral to vertical flow from this aquifer in the GSA is a function of: (1) distance from incising streams, (2) variability of the Tan Clay layer, (3) magnitude of the potentiometric head elevation difference between the Water Table and underlying Barnwell-McBean, and (4) presence of faults and localized high permeability zones. Discharge to surface waters occurs south of the F- and H-Area Tank Farms along the upper reaches of Fourmile Branch predominantly east of the intersection of Road C with Fourmile Branch, and for a short distance west of Road C. North of the tank farms, the saturation zone of the Water Table pinches out and drains downward to the Barnwell-McBean before discharging to the seepline of Upper Three Runs.

The Barnwell-McBean Aquifer zone, which underlies the Tan Clay, consists of clayey sand and poorly graded sand in its upper part and clayey and silty sand in its lower part. The Barnwell-McBean aquifer is underlain by the Green Clay confining unit. This aquifer is confined for most of its areal extent in the GSA; however, it becomes locally unconfined due to topography (stream incision), structural dip (i.e., rises to the northwest), and downward leakage along Upper Three Runs. Recharge occurs as leakage from the overlying Water Table and as underflow from areas upgradient of the GSA. Discharge from the Barnwell-McBean flows to the underlying Congaree and to surface waters. Similar to the Water Table, the ratio of lateral to vertical flow from the Barnwell-McBean is a function of: (1) distance from incising streams, (2) variability of the Green Clay layer, (3) magnitude of the potentiometric head elevation difference between the Barnwell-McBean and underlying Congaree, and (4) presence of faults. Discharge to surface waters occurs south of the F- and H-Area Tank Farms along the lower reaches of Fourmile Branch predominantly west of the intersection of Road C with Fourmile Branch. North of the tank farms, the unit discharges in limited areas of unnamed tributaries to Upper Three Runs. Along most of Upper Three Runs the saturation zone of the Barnwell-McBean is thought to pinch out and drain downward to the Congaree before directly discharging to the creek.

The Congaree underlies the Green Clay layer and is composed of a coarsening upward sequence of clays, silts, and sand, the upper part of which consists of poorly sorted sand. Recharge to the Congaree occurs as underflow from the southeast (i.e., upgradient of the GSA) and leakage from the overlying Barnwell-McBean. Discharge from the Congaree in the GSA occurs along Upper Three Runs and also as underflow to the northwest. The Congaree is underlain by the Ellenton Clay confining unit which prevents significant upward leakage from the underlying aquifer, which has a greater potentiometric head than the Congaree Aquifer zone.

Groundwater flow beneath the F- and H-Areas occurs in a porous medium consisting of sedimentary deposits of clay, silt, sand, and mixtures thereof. The direction and velocity of flow is controlled by a complex interaction between (1) recharge to the aquifers via precipitation, underflow from upgradient portions of the aquifer, and man-made structures; (2) the physical properties of the aquifers such as the grain size, sorting, and fractures that control fluid transmission and storage properties; (3) the depositional setting of the sediments and tectonics that dictate geologic boundaries; and (4) topography and geomorphology that result in physical boundaries to the flow system. Both geologic and physical boundaries may result in areas of no flow or areas of discharge in the form of leakage to adjacent aquifer units (vertical flow) and outcropping to local stream channels (lateral flow) from any given aquifer unit. In the F- and H-Areas, groundwater flow in the Shallow Aquifer has both lateral and vertical components because the confining layers between aquifers are typically thin and discontinuous, the hydraulic gradient between aquifers is typically downward, and local streams (i.e., Fourmile Branch and Upper Three Runs) have incised these hydrostratigraphic units. Since the clays of the Ellenton formation provide a tight and consistent aquitard and the potentiometric head of the underlying aquifer is greater than that of the Congaree Aquifer zone, groundwater flow in the Intermediate and Deep Aquifers is thought to have little influence on, or to be significantly unaffected by, groundwater flow in the Shallow Aquifer in the F- and H-Areas.

3.3.2 GROUNDWATER QUALITY

The F-Area Tank Farm is situated on a near-surface groundwater divide between Upper Three Runs and Fourmile Branch. The groundwater flows toward and discharges to both Upper Three Runs and Fourmile Branch. A potentiometric map of groundwater in F- and H-Areas that depicts groundwater flow is found as Figures 8-1, 8-2, and 8-3 of this module.

As discussed in Section 3.2, in the F-Area Tank Farm and in the vicinity of the southern part of F-Area, a number of spills and releases of waste material have occurred. A representative list of constituents present in the Water Table Aquifer adjacent to selected sources has been compiled in Table 3-2. The table includes the maximum concentration values for constituents taken from the first quarter 1995 groundwater monitoring program data (WSRC 1995b). The constituent data was compiled to present the groundwater quality conditions and the potential contributing sources. The maximum data were selected based on the highest constituent values above EPA drinking water standards from some of the wells associated with the major potential sources. Figures 3-5 and 3-6 depict the location of the monitoring wells in the vicinity of the F-Area Tank Farm. The monitoring well numbers are denoted in Tables 3-2 and 3-3 (WSRC 1995c).

The contaminants include the following:

- Various radionuclides
- Metals
- Nitrates
- Chlorinated volatile organics

Potential major source locations in the immediate area of F-Area and Tank 20 are the:

- F-Area Tank Farm
- Coal Pile Runoff Basin
- Ash Basins (portions)
- Seepage Basins

Table 3-3 provides the F-Area background groundwater quality data for the same representative list of constituents presented in Table 3-2. To present the background conditions of the F-Area Water Table Aquifer, Table 3-3 provides the most recent groundwater quality monitoring data (WSRC 1995b) for a background well (FSB-108D) utilized in the postclosure permit for the F-Area Seepage Basins.

Appendix A provides a discussion of the contaminant contributions used in the Tank 20 modeling.

Table 3-2. F-Area representative groundwater constituents of concern (Water Table Aquifer).[a]

Constituent	First Quarter 1995 Concentration	Well	Location
Iron	261,000 μg/l	FTF 7	F-Area HLW Tank Farm
Manganese	4,240 μg/l	FTF 6	
Aluminum	20,100 μg/l	FTF 13	
Chromium	65 μg/l	FTF 7	
Mercury	4.6 μg/l	FTF 2	
Nitrate (as N)	10,400 μg/l	FTF 24A	
Lead	6,500 μg/l	FTF 2	
Gross alpha	1.1E-07±5.6E-09 μCi/ml	FTF 5	
Gross beta	5.1E-07±1.5E-08 μCi/ml	FTF 7	
Iron	462 μg/l	FCB 4	Coal Pile Runoff Basin
Manganese	28 μg/l	FCB 4	
Aluminum	259 μg/l	FCB 6	
Lead	26 μg/l	FCB 6	
Gross alpha	5.3E-09±1.3E-09 μCi/ml	FCB 3	
Iron	1,960 μg/l	FAB 2	Ash Basins
Manganese	43 μg/l	FAB 2	
Nickel	14 μg/l	FAB 4	
Aluminum	434 μg/l	FAB 2	
Chromium	9.5 μg/l	FAB 1	
Mercury	2.9 μg/l	FAB 1	
Silver	<0.65 μg/l	FAB 1	
Nitrate (as N)	3,450 μg/l	FAB 1	
Phosphate	830 μg/l	FAB 2	
Chloride	4,540 μg/l	FAB 2	
Fluoride	655 μg/l	FAB 2	
Lead	8.4 μg/l	FAB 4	
Gross alpha	1.2E-08±2.3E-09 μCi/ml	FAB 1	
Gross beta	9.9E-09±1.2E-09 μCi/ml	FAB 1	
Iron	46 μg/l	FSB 78	Former F-Area Seepage Basins
Manganese	1,350 μg/l	FSB 78	
Nickel	29 μg/l	FSB 78	
Aluminum	38,200 μg/l	FSB 78	
Chromium	4.5 μg/l	FSB 78	
Mercury	0.52 μg/l	FSB 78	
Silver	0.99 μg/l	FSB 78	
Copper	41 μg/l	FSB 78	

Table 3-2. (continued)

Constituent	First Quarter 1995 Concentration	Well	Location
Nitrate (as N)	143,000 μg/l	FSB 78	
Phosphate	<100 μg/l	FSB 78	
Chloride	1,380 μg/l	FSB 78	
Fluoride	<500 μg/l	FSB 78	
Lead	1.0 μg/l	FSB 78	
Strontium-90	2.1E-06±3.2E-08 μCi/ml	FSB 78	
Technetium-99	5.5E-08±1.1E-08 μCi/ml	FSB 78	
Cesium-137	2.8E-07±1.3E-08 μCi/ml	FSB 78	
Europium-154	-2.4E-09±2.2E-08 μCi/ml	FSB 78	
Plutonium-239	2.0E-11±5.7E-11 μCi/ml	FSB 78	

a. Sources: WSRC (1995b,c).

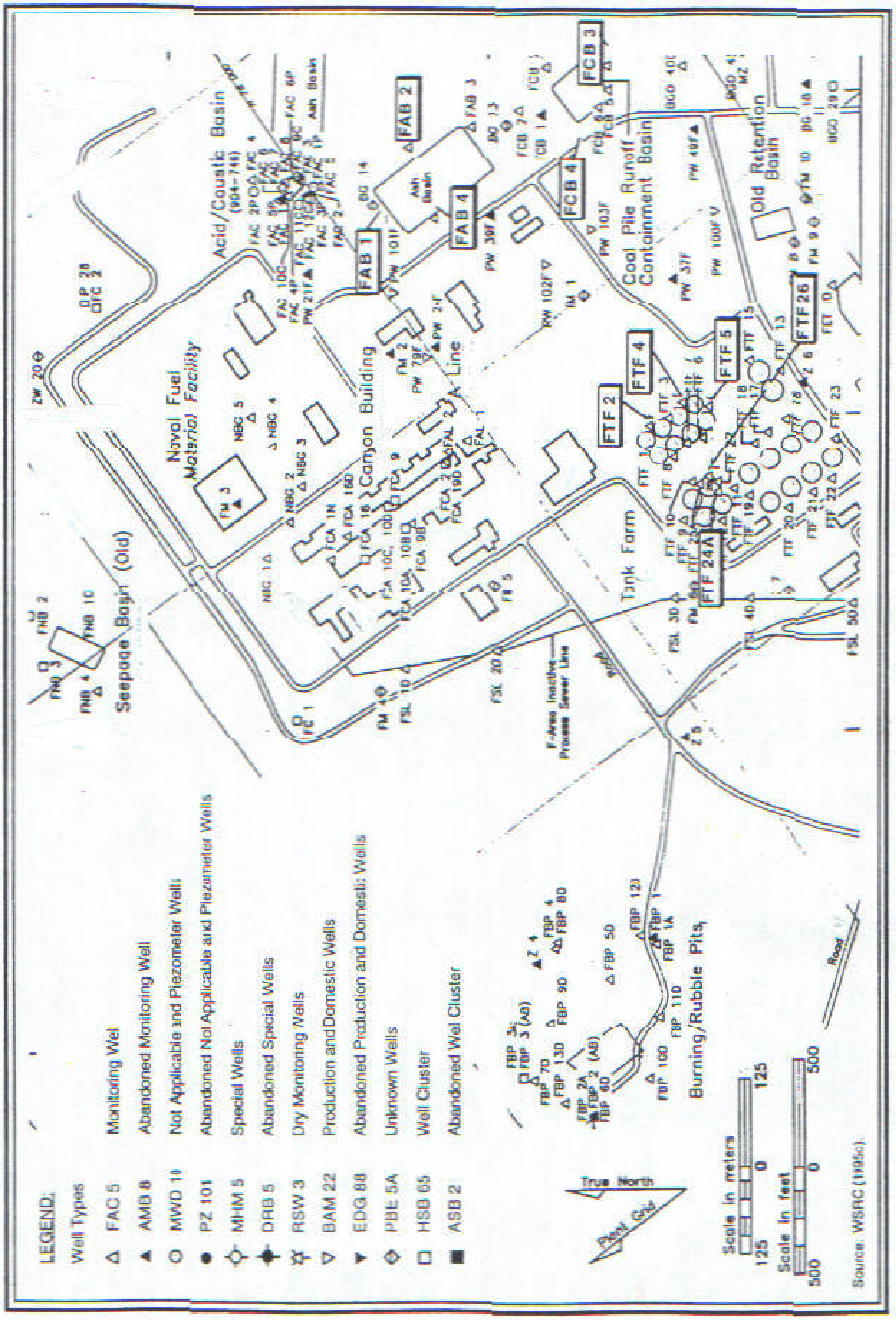


Figure 3-5. Wells at and near F-Area: the Canyon Building, Tank Farm, Naval Fuel Material Facility, Acid/Caustic Basin, Coal Pile Runoff Containment Basin, Seepage Basin (Old), Old Retention Basin, and Burning/Rubble Pits.

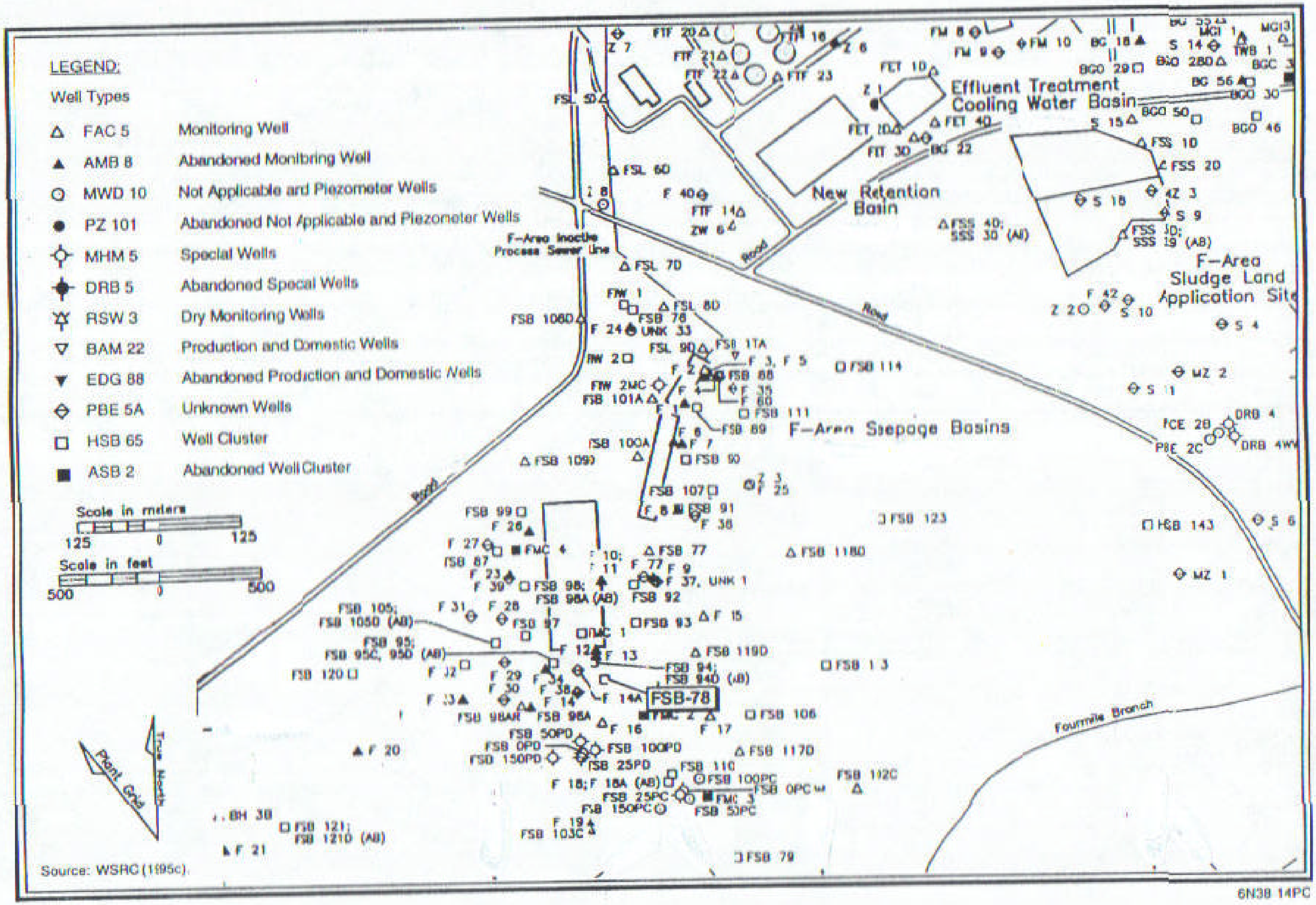


Figure 3-6. Wells at and near F-Area: Seepage Basin, Effluent Treatment Cooling Water Basin, F-Area Sludge Land Application Site, and New Retention Basin.

Table 3-3. F-Area representative background groundwater constituents (Water Table Aquifer).[a]

Constituent	First Quarter 1995 Concentration	Well	Location
Aluminum	123 μg/l	FSB-108D	F-Area Seepage Basins
Chloride	2,900 μg/l		
Chromium	<4.0 μg/l		
Copper	7.2 μg/l		
Fluoride	<50 μg/l		
Iron	87 μg/l		
Manganese	13 μg/l		
Mercury	0.058 μg/l		
Nickel	4.0 μg/l		
Nitrate (as N)	813 μg/l		
Phosphate	<83 μg/l		
Silver	<3.3 μg/l		
Zirconium-95	2.9E-9±5.0E-9 μg/l		
Selenium-79	NA[b]		
Strontium-90	-6.5E-10±2.7E-10 μCi/ml		
Technetium-99	-1.0E-08±6.6E-09 μCi/ml		
Tin-126	NA[b]		
Cesium-135	NA[b]		
Cesium-137	-2.7E-10±1.9E-09 μCi/ml		
Samarium-151	NA[b]		
Europium-154	-1.3E-09±7.1E-09 μCi/ml		
Plutonium-239	-1.3E-11±1.8E-11 μCi/ml		

a. Sources: WSRC (1995b,c).
b. No data available.

3.4 Other Resources

Information pertaining to surface water, biota, air quality, and cultural resources can be found in Sections 3.4 through 3.7 of the general closure plan (DOE 1996a).

3.5 References

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CHAPTER 4. PROPOSED CLOSURE CONFIGURATION

4.1 Disposition of Major Components

In addition to the approximately 1,000 gallons of waste solid at the bottom of Tank 20, residual contamination remains on some equipment inside and near the tank. This equipment includes a slurry pump, a transfer jet, a thermowell, a leak detection system, and pumps and transfer piping into and out of the tank. In addition, steel tapes, electrical wiring, cable, rubber hose, and a small sample extraction apparatus will remain in the tank after closure. All penetrations will be physically separated from the tank system at closure, thereby isolating the tank. These penetrations will be filled with backfill material during the Tank 20 closure. Drawing W2017868 (Figure 4-24 in the permit application for Construction/Operating Permit No. 17,424-IW), annotated to highlight planned isolation of the Tank 20 system, is included with this closure module (see map sleeve).

4.2 Waste Residual Characteristics

Waste removal activities (consisting of bulk waste removal and spray water washing) have been completed for Tank 20, and approximately 22,000 gallons of ballast water (0.1 Ci/gal) has been transferred from Tank 20 into Tank 18. Based on U.S. Department of Energy's (DOE's) characterization of waste residuals remaining (presented in this section) and results of DOE's performance evaluation (Chapter 8), no further waste removal activities are considered necessary.

DOE conducted a remote visual inspection and sampling and analysis of the residual waste in Tank 20. Following removal of ballast water from the tank to the extent practicable, DOE obtained visual images of the tank interior on videotape and photographs to ascertain visual appearance (e.g., color) and spatial distribution of the waste. The volume of the waste in the tank was estimated using photographs taken through the center riser. This was accomplished by estimating the depth of the waste at points on the tank bottom with respect to the thickness of steel lifting plates welded to the tank floor. These plates, distributed throughout the tank floor, are 12-inch squares, 3/8 inch thick, and are welded to the floor with a 1/4-inch weld bead. As such, they provide a convenient reference for estimating depth. The volume of the waste solids in the bottom of the tank is estimated to be about 1,000 gallons from observed horizontal distribution and depths of the observed waste (d'Entremont and Hester 1996).

DOE estimated the concentration of contaminants in the waste from process knowledge. For radionuclides, the process knowledge consisted of (1) the known distribution of fission product radionuclides from uranium fission and (2) Savannah River Site (SRS) accountability records for plutonium and neptunium products. For chemicals, the process knowledge consisted of summaries of samples that were collected for design of the Defense Waste Processing Facility flowsheet and samples of residual waste liquids in the tank.

DOE also sampled the waste solids in Tank 20 to verify the process knowledge estimates. The samples demonstrated that the process knowledge estimates were reasonable. The inventories of contaminants reported in Appendix A are process knowledge estimates with the exception of the estimates for Tc-99 and fluoride. The inventories of these two contaminants were adjusted upward based on the sample data (d'Entremont and Hester 1996).

DOE used three methods to collect samples from Tank 20 based on practical considerations associated with the amount of waste residuals present. The first method involved lowering an absorbent swipe attached to a weight through the southeast riser to the tank bottom. The swipe was maneuvered along the tank bottom to collect a sample, raised from the tank, surveyed for radiation, and placed into a plastic bag. The bag was surveyed for contamination, placed into an approved shipping container, and transported to DOE's onsite Savannah River Technology Center (SRTC) for sample preparation and analysis. The second method was used to collect samples from observed accumulations of waste solids. In this method a "mud snapper" sampler was lowered to the tank floor through a riser and was used to obtain grab samples. The entire sampler, once retrieved from the tank, was placed in an approved shipping container and transported to SRTC facilities for sample removal, preparation, and analysis. The third sampling technique involved use of a "scrape sampler" designed to scrape thin deposits of solids from the floor of the tank. The sampler was maneuvered in the tank with a hinged fiberglass rod and scraped across the bottom. Once retrieved from the tank, scrape samples were processed in a manner similar to that described for the mud snapper sample. Sample transport was conducted according to established procedures and in a manner that ensured that control of sample identification was maintained.

SRTC has previously developed analytical methods for the characterization of high-level waste and has implemented these methods for many years using trained personnel in accordance with routine procedures. The samples of residual waste from Tank 20 were received and prepared for analysis at the SRTC Shielded Cells Facility and were then transported to the SRTC Analytical Development Section laboratory where they were analyzed.

Following preparation of the swipe sample by dissolution in acid, SRTC analyzed for the constituents listed in Table 4-1. Since the mass of waste obtained by this swipe sampling method was unknown, this analysis does not provide a definitive quantitative amount of constituents present but rather an estimate. However, ratios of constituents can be obtained and useful results are obtainable by comparison of these

Table 4-1. Tank 20 residual waste constituents selected for analysis and analytical methods.

Constituent	Analytical Method
Radioactive constituents	
^{137}Cs, ^{79}Se, ^{241}Am, other gamma-emitting radionuclides	Gamma spectrometry
^{90}Sr	Liquid scintillation
^{99}Tc, ^{239}Pu, ^{241}Pu	Inductively coupled plasma/mass spectrometry
^{238}Pu	Inductively coupled plasma/mass spectrometry/alpha spectroscopy
Gross beta	Beta scan
Alpha-emitting radionuclides	Alpha spectroscopy
Nonradioactive Constituents	
Al, As, B, Ba, Ca, Cd, Cr, Cu, Fe, La, Li, Mg, Mn, Mo, Na, Ni, Pb, Se, Sn, Sr, Ti, V, Zn, Zr	Inductively coupled plasma/atomic emission spectrometry
Ag	Inductively coupled plasma/mass spectrometry
Hg	Atomic absorption spectroscopy
F, NO_3, NO_2, SO_4	Ion chromatography
Specific gravity	Standard methods

results to analytical results obtained from grab samples or other swipe samples. The waste samples obtained using the mud snapper and scraper were dried, weighed, dissolved in acid, and analyzed for the constituents listed in Table 4-1 to obtain a quantitative measure of the species present.

Table 4-1 is a list of radioactive and nonradioactive analytes for the Tank 20 residual waste samples and the analysis methods used. Analysis of Tc-99, Se-79, and Pu-239 were included because these radionuclides are predicted to have potentially notable dose contributions from the closed tank system (Chapter 8). Analysis of the other radionuclides were included to establish the accuracy of process knowledge estimates of tank waste composition. Of these, Sr-90 and Cs-137 are the two radionuclides predicted to be present at the highest concentrations. The plutonium isotopes and americium are associated with separations processes, so measurement of these radionuclides will establish the amount of product that was sent to Tank 20 as waste. The list of inorganic constituents includes abundant species likely to be present and contaminants of concern that are likely to be of greatest concern (e.g., RCRA metals).

4.3 Tank System Stabilization

DOE will use a reducing grout, selected from results of studies on three proposed mixes, to stabilize the residual waste in the tank (Figure 4-1). The purpose of this grout is to provide long-term chemical durability against leaching of the residual waste by aggressive agents in the environment such as groundwater and acid rain. Approximately 500 cubic yards of this specially formulated grout will be placed in at least two pours to provide a minimum of 24 inches of covering over the interior bottom portion of the tank. This reducing grout is a self-leveling backfill material which will encapsulate not only the residual waste, but also some of the equipment described in Section 4.1 that will remain inside the tank. The reducing grout is composed primarily of cement, blast furnace slag, masonry sand, and silica fume.

On top of the reducing grout, and constituting the bulk of the tank's fill material, will be the placement of approximately 7,500 cubic yards of controlled low strength material (CLSM). This material is an inexpensive, self-leveling fill material composed of sand and cement formers which is readily available from local concrete suppliers. The CLSM will be pumped into the tank in a manner similar to that used for the reducing grout, up to a level of approximately 6 inches below the tank's springline (Figure 4-1). The compressive strength of the CLSM is equivalent to normal backfills at SRS.

From the springline area up to the bottom of the tank top riser ports, a strong grout will be poured on top of the CLSM. This strong grout is a low viscosity, free-flowing grout with a compressive strength in the normal concrete range of 2,000 to 3,000 pounds per square inch and is beneficial for filling void spaces. In addition, this relatively strong grout will discourage an intruder from inadvertently accessing the waste.

A reducing grout will be poured into the lower section of each riser; the high flowability of the reducing grout is effective in filling small voids in riser openings. In the upper section of each riser, a 5,000 pounds per square inch grout will be used to finish off the top of the riser. The reducing grout will be injected in the remaining equipment to ensure that such voids are filled to the fullest extent practical.

Finally, metal or wooden formwork will be installed around each of the riser ports. Riser fill material caps (grout or concrete) will then be poured at these locations, which will effectively seal both the riser ports and the concrete plugs currently used to seal the riser openings.

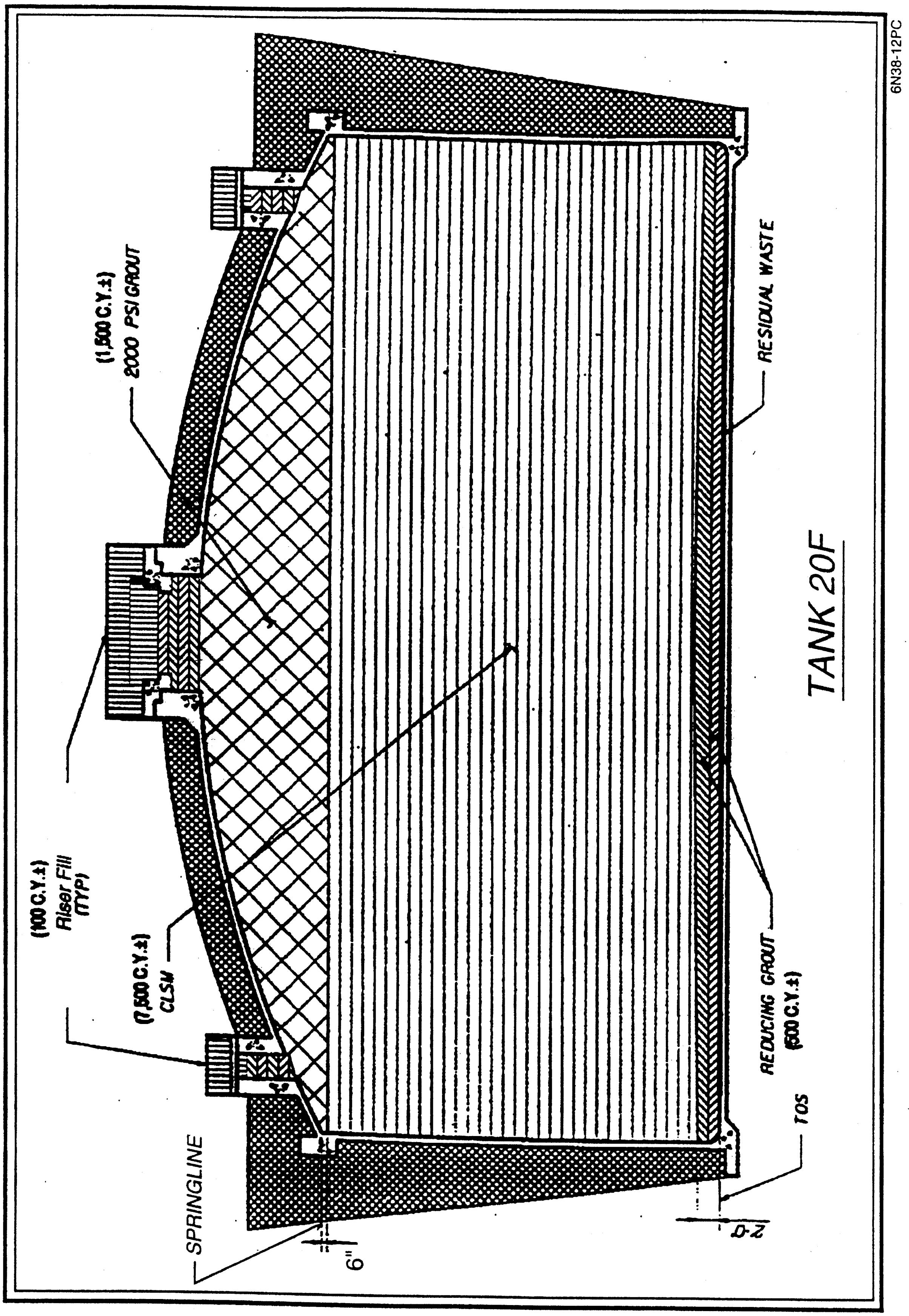

Figure 4-1. Tank stabilization materials.

4.4 Tank Stabilization Uncertainties

Several uncertainties remain regarding the tank stabilization activities. These uncertainties and the precautions to be taken to mitigate the associated risks are listed below.

- There is the risk of spills of backfill material during injection. This material may pose a personnel hazard by producing slippery or spray conditions. Spray of the grouts and CLSM under pressure poses an ingestion hazard and an eye hazard. Vehicular and pedestrian traffic will be restricted during filling operations to reduce the risk. Any waste generated from spill cleanup activities will be evaluated for hazardous and radioactive characteristics to determine appropriate waste handling and disposal.

- The large number of mixer trucks needed for a complete tank fill (1,300 to 1,400 trucks at 6 cubic yards each) will require approximately 75 to 90 trucks in the vicinity of F-Tank Farm each day. The increased heavy equipment traffic poses a traffic risk to resident workers. DOE will take measures to route the trucks along less traveled routes while in the tank farm.

- Tripping hazards will be prevalent during installation of backfill material. Postings and barricades will limit personnel access to the construction area.

- Though the possibility of overflowing the backfill to the adjacent operating tank (Tank 18) is small, the risk does exist. Tanks 18 and 20 share a common ventilation system. The vent for the system is mounted on Tank 18 and the two tanks are connected via a 6-inch line. Overflow can occur via this cross-connect line, which will be left open for venting during most of the backfilling process. However, DOE will establish specific procedures to assure that the existing valve in this cross-connect line is closed when fill operations reach the line elevation to prevent overflow to Tank 18. Positive verification of valve closure can be accomplished by checking ventilation flows (i.e., by ensuring that there is no vent flow in Tank 20 while flow is verified for Tank 18). Inadvertent overflow of backfill material would pose no personnel or nuclear hazard. However, an overflow would need to be addressed when waste removal and tank closure is performed on the Tank 18 system.

- During tank finishing, the dome will be filled with a low viscosity grout (strong grout). This grout is likely to seep out of the crevices around the risers. The personnel and process hazards associated with this are very low. However, the inadvertent spread of low level contamination could slow cleanup and decontamination operations. Therefore, precautions will be taken to either contain the seepage or prevent its occurrence. Any waste generated from cleanup of the seepage will be evaluated for hazardous and radioactive characteristics to determine appropriate waste handling and disposal.

- During curing of the backfill material, a small amount of bleed water may rise to the top. The risers and the vent equipment will be prepared to contain the bleed water. Bleed water will be collected and expeditiously returned to the tank farm system for processing. Backfill material additions will be managed such that bleed waste is minimized.

- The tank will be filled slowly, which will allow for the continual curing (hardening) of the fill material, so that any pressures associated with the fill material will not damage the tank. The cautious placement of the fill material will also serve to eliminate or mitigate any potential overflow conditions involving either bleed water or backfill material at the riser ports.

- There is a possibility that some interior voids will not be completely filled. The volumes of the installed equipment and tank are known and will be compared to the amount of fill material used. This amount will be used to determine the extent of potential voids.

- Attempts have been made to locate each tank penetration. These penetrations have been identified by using a video camera placed in the tank interior. The chance of an overlooked penetration is small. However, if there is a small penetration in the tank or riser opening that is not in drawings or visible to the camera, it will be filled with backfill material. Flow of the fill material into such a penetration will eventually harden, posing no risk.

- After tank closure, the superstructure and some piping will remain on top of the tank and will not be encapsulated in grout. Tank farm personnel will be able to maintain the aesthetic appearance of the equipment remaining on the tank top. Furthermore, inhibited water lines on the tank top are connected to an active system and are currently operable. Therefore, freeze protection and other maintenance support will be available until these lines are removed.

- Tank farm operations must not be adversely affected by this closure operation. Therefore, alarms and equipment will be decommissioned in such a way to eliminate hazardous energy, alarms, and surveillance on this tank.

4.5 Backfill Requirements and Grout Testing

4.5.1 BACKFILL REQUIREMENTS

Chemical and mechanical requirements for the backfill materials DOE will use for stabilization of the Tank 20 system are described below and listed in Table 4-2.

Table 4-2. Mechanical and chemical requirements for Tank 20 backfill material.

	Requirement			
Attribute	Reducing Grout	CLSM	Strong Grout	Riser Fill
Mechanical Requirements				
Rheology	Flow Cone < 20 seconds	ACI 227 > 10 inches	No requirement	No requirement
Set time	<72 hours	<72 hours	<72 hours	<72 hours
Compressive Strength at 3 days	>50 p.s.i.	No requirement	No requirement	No requirement
Compressive Strength at 28 days	No requirement	50 p.s.i.	2,000 p.s.i.	5,000 p.s.i.
Leveling Quality	Flow Table >10 inches	Flow Table >10 inches	No requirement	No requirement
Segregation	Minimal	No requirement	No requirement	No requirement
Chemical Requirements				
Eh	<0 mV	No requirement	No requirement	No requirement
pH	>9.5	No requirement	No requirement	No requirement

Reducing Grout

The purpose of the reducing grout is to provide a chemically stable environment in which key waste constituents will be immobilized. This will be accomplished by introducing a reducing agent to the tank so that permeated water infiltration is chemically altered to have a low oxidation potential (Eh). The reducing agent must be deployed evenly across the tank bottom. The mechanical properties of the grout mix and the final set state will have properties necessary to ensure even distribution of the reducing components.

The reducing grout mix must be flowable, pumpable, and self-leveling. These characteristics are primarily to facilitate placement since the grout will be placed in the tank from a single pour point. It is also desirable that the reducing grout have a set time no greater than 72 hours, also to facilitate emplacement. A compressive strength of greater than 50 p.s.i. is desired to ensure that long-term settling does not occur. Bleed water will be kept to a minimum to reduce the need for handling contaminated water as the backfill material approaches the top of the tank. Table 4-2 lists important mechanical requirements for the reducing grout.

Chemically, the reducing grout must be required to set. Setting occurs as the unhydrated cement pozzolanic and other hydraulic components (slag and silica fume) react with water to form insoluble phases. These components form the matrix that binds the sand aggregate into a solid, cohesive material. The reducing grout is also required to have an Eh<0 mV to chemically reduce technetium, selenium, and certain other constituents of concern. For example, a reducing grout with Eh<0 mV will reduce Tc^{+7} to Tc^{+4} and consequently precipitate the Tc^{+4} as TcS. Protechnitate (Tc^{+7}) reduction and subsequent precipitation in basic waste forms has been documented for the SRS Saltstone Manufacturing and Disposal Facility. Table 4-2 lists required chemical properties of the reducing grout.

The reducing grout formulation selected for placement was tested for compliance with criteria set forth in Table 4-2, results of which are provided in a technical report (CTL 1996). The reducing grout formulation will be manufactured by a batch plant supplier in accordance with specifications provided by DOE. These specifications are consistent with the laboratory test mixes and the criteria listed in Table 4-2. Manufacturing, delivery, and placement parameters directly affecting the criteria in Table 4-2 will be verified and tested in accordance with the SRS Quality Assurance Program.

Controlled Low Strength Material (CLSM)

The main purpose of the CLSM is to fill the majority of space in the empty tank. No specific chemical requirements other than to set have been established. The mechanical requirements, provided in Table 4-2, are established to ensure flowability for ease of placement and to ensure sufficient compressive strength. It is desirable to minimize bleed water simply from an as low as reasonably achievable (ALARA) standpoint.

Strong Grout

The strong grout is intended to fill the empty space of the tank dome. It also is intended to provide a physical barrier to discourage intruders, and thus a requirement for a higher compressive strength than the CLSM has been established. The strong grout will meet the mechanical and chemical properties in Table 4-2.

Riser Fill

The purpose of the riser fill material is to fill voids in the riser and to "cap" the riser in a neat, orderly, and cosmetically desirable state. The lower section of each riser will be filled with a highly flowable reducing grout similar to the first layer of fill and the riser tops will be capped with 5,000 psi (nominal) grout. This provides sufficient void-filling and shrink-resistant properties (see Table 4-2).

4.5.2 TESTING OF THE REDUCING GROUT

DOE employed Construction Technology Laboratories, Inc. (CTL) to determine the emplacement, chemical, and mineralogical properties of three reducing grout formulations, each designed to have an oxidational potential (Eh) less than zero and a pH greater than 9.5.

CTL formulated the mixes with various parameters and desired properties, including (listed in decreasing priority): reducing conditions, alkalinity, flowability, self-leveling capability, compressive strength, cohesiveness, low water/cement ratio, low permeability, chemical composition, engineering properties (setting time, set strength), and minimal bleeding. The three grouts, termed mix 1, mix 2, and mix 3, each had the same basic ingredients except for the type of cement used. Each grout contained sand, ground blast boiler slag, silica fume, water, water reducing agents (also known as super-plasticizers), set retarders, and sodium thiosulfate. Mix 1 was a Type I cement-based grout, mix 2 was a Type I/K cement-based grout, and mix 3 was a Type V cement-based grout. The sand, silica fume, and slag amounts were slightly adjusted to account for the different amounts of cements used for each mix.

CTL designed a battery of tests intended to examine each of the properties previously listed. Several of these tests allowed CTL to observe several of these parameters simultaneously. To approximate the application of stabilizing sludge, CTL used a simulated sludge originally used for DWPF cold chemical testing. CTL added nonradioactive surrogates that are chemically similar to the radioactive elements of concern such as plutonium and technetium.

Large Scale Pour Test - This test was designed to simulate an actual grout pour under tank conditions. The test allowed the grout to be poured into the center of an 85-foot long by 8-foot wide form coated with sludge simulant to determine if a reducing grout can actually flow and self level to the edges of the tank. Because of the size and expense of the test, only one grout mix was used for this experiment.

Mix 2 was chosen because it more closely represented the rheological properties of the other two mixes. It was expected from preliminary bench scale testing that mix 1 and mix 3 would behave similarly under the test conditions. CTL concluded from this test that the material was self leveling; however, the grout demonstrated some thixotropic flow behavior (i.e., once in motion the grout flowed quite well but once the flow halted, some shear force was needed to re-establish flow). CTL also observed that some of the grout incorporated with the sludge.

Vertical Drop Test - Each grout was poured into 2-foot by 2-foot forms from various heights to evaluate the function of "free fall" on segregation. The grout was allowed to cure and cores were taken for laboratory analysis. Stereomicroscopic analysis concluded that there was not a strong correlation between drop height and segregation and each grout possessed good cohesiveness.

Horizontal Pour Test - Each grout was gently poured into the sides of 2-foot by 2-foot forms. The bottoms of the forms had a thin layer (½-inch thick) of sludge. This test was designed to further investigate the degree of sludge incorporation in the grout. Cores of the cured grout revealed that sludge incorporation did occur, with mix 2 having slightly more incorporation than the other two mixes. The quantity of incorporation was not determined.

Physical Property Testing - Compressive strength, volume stability, and setting time were determined. CTL concluded that shrinkage for all three grouts were low, and each grout obtained at least 500 psi compressive strength within 3 days.

Sludge Leaching and Sequential Batch Leaching of Grouted Sludges - A series of leaching tests were conducted to determine the chemical durability under adverse conditions. These tests help determine which grout formulation is the most chemically resistant. Therefore, leaching properties were determined using non radioactive sludge simulant. A homogeneous mixture of grout and simulated sludge was prepared and allowed to cure for 14 days. The cured material was then crushed and leached in simulated acid rain (prepared from sulfuric and nitric acid to achieve pH 5) and 0.1 M acetic acid. The liquid was periodically changed and evaluated for leached constituents. The results are detailed in the CTL report which concluded that each grout possessed additional chemical durability other than pH and Eh.

Grout Diffusion Tests - The purpose of this test was to determine the degree of sludge migration into a layer of grout with diffusion as the only transport mechanism. Grout was placed onto a layer of undisturbed sludge and allowed to cure. It was concluded, using electron microscopic analysis, that there was no immediate diffusion of the sludge into the grout, and such mechanisms would have to be observed over a long period of time.

Heat of Hydration Tests - Heat of hydration was determined using conduction calorimetry. CTL determined that only 5 to 10 percent of the heat generated occurred during the first hour of curing. This amount of heat would not be detrimental to the flowability and chemical properties during grout transport. CTL concluded that there are no adverse thermal effects resulting from grout hydration for any of the three grouts.

Oxalate and Sulfate Effects Testing - During grout testing, SRS discovered the presence of oxalates and sulfates in the sludge of Tank 20. This could have an adverse effect on grout placement. This is because the calcium hydroxide in the grout could react with the oxalates and sulfates in the sludge to form calcium oxalate and calcium sulfate. The calcium oxalate and sulfate are insoluble and could form microscopic crystals in the grout mix thereby prematurely "setting" the mix. This would have an adverse effect on grout placement because it could severely affect the self-leveling capability. Bench flow tests were conducted and mix 3 was determined to be the most resistant to the oxalate and sulfate reaction.

CTL in conjunction with Savannah River Technology Center developed a pretreatment solution to be placed on top the sludge to eliminate or significantly lessen the chemical effects of these compounds. A slurry of 10 weight percent calcium hydroxide would be placed on the sludge prior to grout placement. The intent is to allow the calcium hydroxide and oxalate/sulfate reaction to occur before pouring the grout. To test this concept, three forms were built to simulate various field conditions. The forms were essentially one tenth scale (8-foot long with ends 2 feet and 4 feet to form a trapezoid). A thin layer of sludge was placed in each form with a two-inch supernate placed on top of the sludge. The first form was the "control" case and contained no oxalates and sulfates. The second form was the "field" case and was spiked with sodium oxalate and sodium sulfate. The third form was set up similar to the second form except that a calcium hydroxide slurry was added on top of the sludge and supernate. Mix 3 was selected because of its superior flow performance under oxalate and sulfate conditions. The results revealed that the grout poured in the first and second forms behave similarly and with flow characteristics consistent with previous tests. However, the grout poured into the third form showed a marked improvement over flowability and self leveling capability. It was therefore concluded that the presence of oxalate and sulfates had no detrimental placement effects; however, the use of a pretreatment greatly improved placement capability.

CTL concluded in their report that all the grouts satisfied the criteria set forth in Table 4.2. They all possessed high cohesiveness, good strength, volume stability, reasonable setting times, and good chemical stabilization characteristics. Mix 3 was chosen because of its superior resistance to oxalate and sulfate compounds.

4.6 Other Features

Following the completion of the grout pouring operations, the Tank 20 system will be completely isolated from the remainder of the tank systems. However, area security measures and access controls will remain strictly enforced. Groundwater monitoring and monitoring of the process sewer and stormwater lines serving the area around Tank 20 will continue to be performed.

As discussed in Chapter 7, the proposed closure configuration for the Tank 20 system includes backfilling the area with soil to the original grade to eliminate ponding over the closed tank system. However, this backfilling will be conducted after DOE completes closure activities of all tank systems in this grouping (i.e., all systems in the Tank 17-20 area). DOE does not anticipate a need to install a low-permeability cover (e.g., asphalt or clay cap) over the closed Tank 20 system on the basis of the performance evaluation presented in Chapter 8. However, the proposed backfilling configuration is compatible with the installation of such a cap if one is determined to be necessary as a result of assessments of the tank grouping.

4.7 References

CTL (Construction Technology Laboratories, Inc.), 1996, "Development of Reducing Grout for Closure of SRS Tank #20," Construction Technology Laboratories, Inc., Skokie, Illinois, October.

d'Entremont, P. D. and J. R. Hester, 1996, *Characterization of Tank 20 Residual Waste*, WSRC-TR-96-0267, Westinghouse Savannah River Company, Aiken, South Carolina, September.

CHAPTER 5. CLOSURE ACTIVITIES AND SCHEDULE

5.1 Pre-Closure Activities

Prior to initiating formal closure activities under this module, which consist primarily of backfill material installation, the U.S. Department of Energy (DOE) will have completed several pre-closure activities. These activities include physical and functional isolation of the Tank 20 system, removal and disposition of some system components, and certain modifications to the Tank 20 system to prepare for installation of backfill material, as discussed in the following subsections.

5.1.1 TANK 20 SYSTEM ISOLATION

Mechanical and electrical services will be isolated from the tank such that future use is prohibited. Tank isolation is an activity that must be performed regardless of the closure option. Accessible piping and conduit will be removed and pulled back from each riser so that a physical break is made from the tank. However, the Tank 20 to Tank 18 transfer line will not be removed. Instead, the transfer line isolation valve will be removed, thereby providing a physical break between Tank 20 and Tank 18, and that portion of the line leading from Tank 20 will be filled with grout as part of the closure under this module (Figure 5-1). The common ventilation system will be separated by closing the cross-tie isolation valve. This line will be filled with backfill material during the tank filling operation under this closure module. Annotated Drawing W2017868 included with this closure module (map jacket) depicts the isolation of the Tank 20 system from other major tank farm facilities.

5.1.2 COMPONENT REMOVAL, DECONTAMINATION, AND REUSE OR DISPOSAL

DOE plans to leave the tank structure intact. No support steel will be removed unless it is necessary to be removed to disconnect services from the tank risers. Equipment already installed in the tank (such as a slurry pump, a steam eductor, steel measuring tapes, spray cleaning heads, and small debris on the tank bottom) and equipment directly used in tank closure operations (such as a submersible pump, cable, backfill transfer pipes or tremmies, and a steel level marker) will be entombed in the backfill material as part of the closure process. Items removed in preparation for closure under this module, such as reel tapes, slurry pump motors, instrument racks, piping, and insulation, may be decontaminated to such

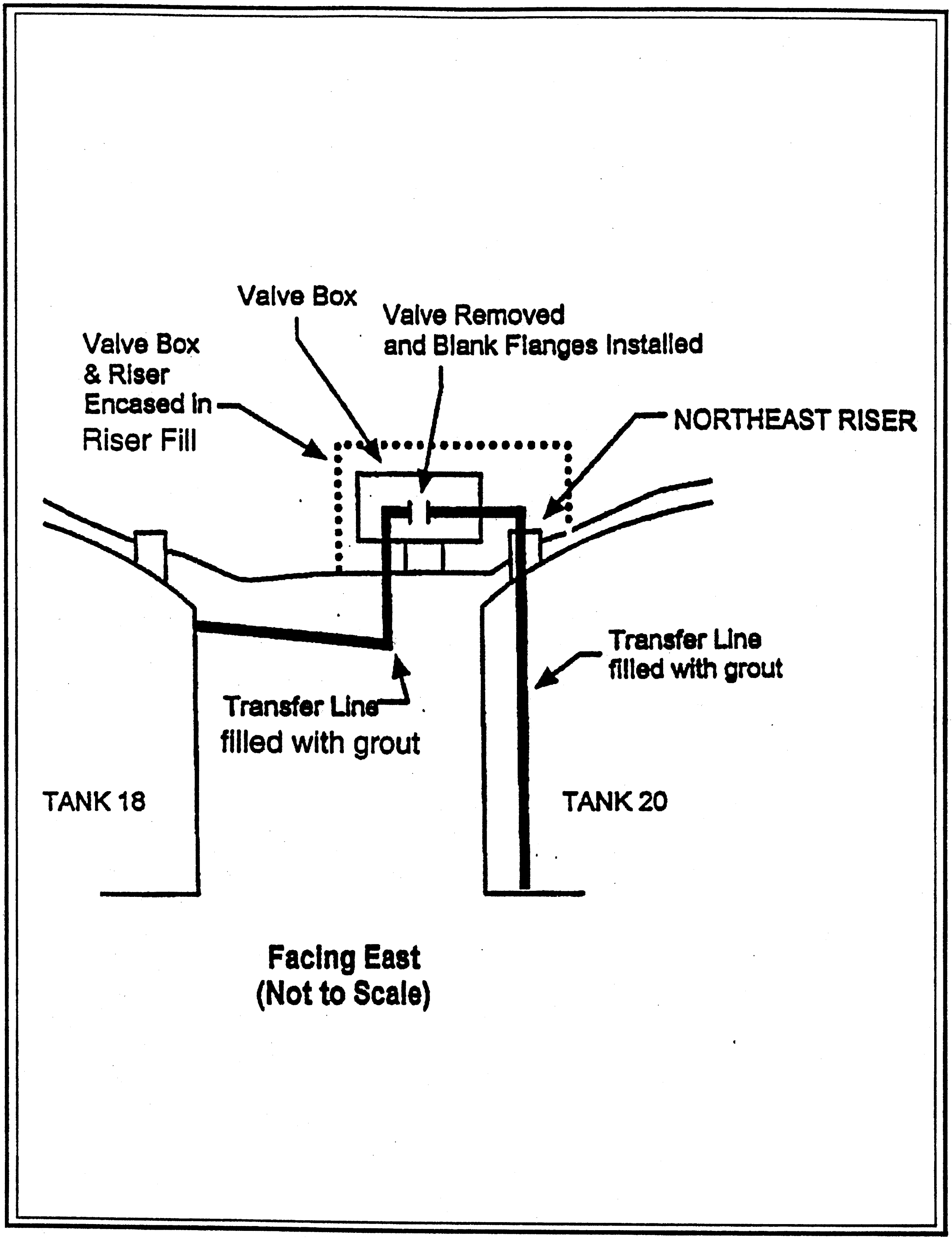

Figure 5-1. Tank 20 transfer line closure.

levels that they may be sent to the Solid Waste Department's facilities as scrap. Otherwise, they will be appropriately characterized and shipped to Solid Waste (e.g., as low level radioactive waste).

5.1.3 TANK MODIFICATIONS FOR INSTALLATION OF BACKFILL MATERIAL

The tank risers will be modified to permit backfill material to be placed into the tank. Provisions will be made to provide a delivery point into the tank, to manage air displacement, to address bleed water build-up, and to handle any tank top overflow.

The center riser will be prepared to allow addition of the backfill material. Equipment located at the riser will be disconnected. A backfill transfer line (or "tremmie") will be inserted through an access port to allow introduction of the backfill into the tank. Tank venting will be predominately through the existing permanently installed ventilation system until the backfill material reaches approximately 6 inches below the springline of the tank. However, a newly constructed vent device, equipped with a breather high-efficiency particulate filter, will be supplied for the final dome filling operation.

During the filling process, excess water (bleed water) is expected to float to the top of the grout and controlled low-strength-material (CLSM). The amount of bleed water will be minimized during the actual closure operation by limiting the amount of water in the grout and CLSM, and by specifying the fill material cure times. It is expected that any bleed water produced will be re-absorbed back into the fill material. The amount of re-absorption will be dictated by the cure times. Any bleed water not absorbed will be removed from the tank and returned to the tank farm systems by siphoning it off and transferring it through a temporary aboveground line to another waste tank. The possible overflow of bleed water and grout from around the riser joints will be controlled by constructing forms around the risers and sealing those forms for watertightness as part of pre-closure preparation for riser grouting operations. Each riser will be prepared for local filling and venting to ensure that the top void spaces are filled.

5.1.4 RESIDUAL WASTE PRE-TREATMENT

An aqueous solution of calcium hydroxide, sodium thiosulfate, and calcium sulfide will be added to Tank 20 to pretreat the residual waste as part of pre-closure activities. The sodium thiosulfate and calcium sulfide creates a desirable chemically reducing environment prior to addition of reducing grout.

The calcium hydroxide in the solution reacts with the oxalates and sulfates to form the insoluble compounds calcium oxalate and calcium sulfate. This pretreatment ensures that there are no conflicting chemical reactions between the grout and sludge that would occur during placement. In particular, the calcium hydroxide present in the grout mix might react with the oxalate anion in the sludge to form $Ca(COO)_2$ which has been shown in the laboratory to possibly reduce grout flow. Also, the formation of $Ca(COO)_2$ and $CaSO_4$ during grout placement may create a physical barrier which would impede transport of the reducing agents to the constituents of concern. The pre-treatment will allow these potentially undesirable reactions to take place before the grout is poured, and therefore remove these contaminants as a grout placement risk.

Laboratory testing using actual Tank 20 sludge was performed at SRTC's onsite laboratories to determine the quantity and concentrations of the pre-treatment solution to sufficiently react with the sludge contaminants. In addition, flume testing was conducted at an offsite laboratory, Construction Technologies Laboratories, Inc., (CTL) to demonstrate the effectiveness of the planned pre-treatment. For this test, the grout mix was poured down test flumes that had been laced with treated and untreated nonradioactive sludge simulant to determine effects on flow characteristics, oxalate and sulfate formation, and Eh/pH maintainability (CTL 1996). The testing determined that the 10 wt percent calcium hydroxide pretreatment solution was effective in improving grout flowability without adverse effects to Eh/pH.

5.2 Closure Activities

The following subsections detail backfill material installation and related activities DOE plans to conduct under this closure module.

5.2.1 BACKFILL MATERIAL PROCUREMENT AND DELIVERY

Based on the estimated waste inventory, the closure strategy is to fill the tank in a layered regime as discussed in Chapter 4. A portable pumping skid with a concrete unloading hopper will be placed to allow access to pump fill material directly into Tank 20. The fill materials will be routed to the center riser of Tank 20 through hard piping for grout and CLSM pours. Mixer trucks with material from an offsite production facility or an onsite batch plant will unload the fill material and concrete into the unloading hopper. The grout or CLSM will then be pumped into the tank for tank fill and to each riser for riser closure.

An area close to the location of the concrete unloading hopper will be designated for concrete chute washdown and emergency grout dumping. This area will be located on a flat section of ground greater than 300 feet from any stormwater ditches or drains. The area will consist of a bermed, plastic lined section next to which concrete trucks can park. The bermed, plastic lined section will receive 1 to 2 gallons of water from each concrete truck, created from spraying excess reducing grout material off of the chute area of the truck. Excess water from the inside (barrel) of the concrete trucks will not be excessed at this location; rather, it will be disposed of properly offsite at the concrete vendors concrete plant. Savannah River Site (SRS) experience with this practice indicates that this small amount of excess water will soak into and solidify along with excess backfill material in the bermed, lined section. As needed, this solidified backfill material will be removed from the bermed area and disposed of as concrete rubble at the SRS Burma Road construction disposal area, in compliance with SRS procedures. This entire area will be dismantled at the conclusion of the Tank 20 backfilling process.

5.2.2 BACKFILL MATERIAL INSTALLATION

The actual backfill material installation will be governed by SRS procedures in accordance with Design Engineering requirements as outlined in the construction and subcontractor work packages. The filling progress will be monitored by an in-tank video camera. The exact backfill material level will be measured using visual indications with a remaining level indicator (ruler) placed in the tank. During riser closure operations, containment provisions will be made to restrict or contain grout overflows. Entombed tank components such as the slurry pump, transfer jet, wiring, cable, steel tapes, hose, and sample collection apparatus will be encapsulated during tank grouting operations.

The risers and void spaces in the installed equipment remaining in the tank will be filled with highly flowable reducing grout material to ensure that all voids are filled to the fullest extent possible. The tank fill and riser backfilling operations will be performed in such a way as to eliminate rainwater intrusion into the tank. Upon completion of the tank closure, the riser tops will be left in a clean and orderly condition. There will be no remaining connections (mechanical or electrical) to the risers. Risers will be encapsulated in concrete using forms constructed of rolled steel plates or removable wooden forms previously installed around each riser. The riser encapsulation will be completed at the end of the tank dome fill operation. No excavation will be performed as a tank closure activity under this module.

5.2.3 RISER CLEANUP

Piping and conduit at each of the risers that is not removed will be entombed in the riser filling operations. Each riser will be encased in concrete and decontamination of the remaining riser formwork structures and adjacent areas will be performed, if necessary. The tank appurtenances, such as the riser inspection port plugs, riser plug caps, and the transfer valve box covers, which will have been removed to ensure complete backfilling of the tank, will be entombed at the same time as the associated risers are filled and backfilled.

5.2.4 ALARMS AND ELECTRICAL

Alarms associated with Tank 20 will be disabled and evaluated for future use as spare equipment. Electrical breakers and cables will be disconnected and left in place.

5.2.5 UNDERLINER SUMP

The underliner sump will be filled to the fullest extent possible with grout and any aboveground portions removed and entombed in concrete.

5.2.6 OTHER EQUIPMENT

The tank radiation monitor will be disconnected, removed, and evaluated for future use. If decontamination and re-use are not feasible, then the equipment will be managed as low level radioactive waste in accordance with applicable regulations and procedures.

5.2.7 CONSTRUCTION EQUIPMENT DECONTAMINATION

Construction equipment used in the Tank 20 closure activities will be decontaminated to acceptable limits and used for future tank closings where practicable. If such equipment is unusable, then it will be managed as waste.

5.3 Deferred Activities

As discussed in Section 7.3, the tank areas around Tanks 17, 18, 19, and 20 will be backfilled to grade with soil upon final closure activities of these tank systems and other facilities in this grouping, including the 242-F High Level Waste Evaporator and the Concentrate Transfer System.

5.4 References

CTL (Construction Technology Laboratories, Inc.), 1996, "Development of Reducing Grout for Closure of SRS Tank #20," Construction Technology Laboratories, Inc., Skokie, Illinois, October.

CHAPTER 6. GENERAL PROTOCOLS FOR ENSURING PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT DURING CLOSURE

The U.S. Department of Energy (DOE) is fully committed to the protection of human health and the environment during all tank closure activities. Environmental controls and programs have been formalized which allow the closure of the tank to proceed in a manner which ensures appropriate protection of the environment and human health. These programs, addressed in more detail in the following sections, are designed to ensure that personnel comply with the established environmental requirements for preventing, minimizing, or controlling releases of contaminants during pre-closure and closure operations. These activities have been reviewed to ensure that worker exposure to radiation are maintained as low as reasonable achievable (ALARA). Since the work involved in this tank closure program is expected to be of such relatively low risk as a result of the bulk waste removal and cleaning activities performed earlier, a project-specific health and safety plan is not required by DOE. However, a work package describing the activities to be accomplished provides detailed information on the personal protective equipment necessary to complete the various tasks. The work package also provides other general safety requirements that enable each worker to safely and confidently perform assigned tasks.

6.1 Best Management Practices Plan

The means to identify and control any potential discharge or release of hazardous or toxic substances into the navigable waters of the United States is an important step in the tank closure process. Accordingly, the existing Savannah River Site (SRS) Best Management Practices Plan (WSRC 1995a) is used to identify those potential sources of a release which would require immediate action by facility personnel or the incorporation of special conditions into the work plan for this closure activity such as construction of dikes or diversionary structures. The sources, which have been identified, include the aboveground transfer lines (both primary and secondary) used in the pumping operations from Tank 20 into Tank 18, and potential tank top overflows of bleed water or grout during the tank filling operations. Steps taken as a result of these reviews include the diversion of the stormwater gates to discharge into a basin on the south end of the tank farm during all pumping operations, and the continuous monitoring of the transfer lines when in use.

6.2 Spill Prevention, Control, and Countermeasure Plan

The objective of the SRS Spill Prevention, Control, and Countermeasures (SPCC) Plan (WSRC 1995b) is to prevent the discharge of oil in harmful quantities into navigable waters of the United States. This objective requires a review of the SPCC Plan as it relates to the number of trucks accessing the site and tank farm during the delivery of grout and controlled low-strength material for distribution into the tank. This review significantly reduces the likelihood of a spill event from the facility.

6.3 Environmental Compliance

SRS has in place written procedures (WSRC 1996a) that provide both guidance and detailed information regarding activities prescribed by Federal, state, and local laws and regulations; DOE Orders; and WSRC policies. These procedures pertain to water protection, air quality, and the protection of the land and its inhabitants and are applicable to contractor and subcontractor organizations at the SRS.

The procedures require a documented evaluation of the proposed activity effects upon the air, groundwater, and domestic water, as well as to waste generation, identification, and management. From these evaluations, any permit modifications or new applications needed are disclosed and prepared. If the proposed activity generates a waste, that waste is characterized as to whether it was hazardous, toxic, or radioactive, and appropriate treatment and disposal methods are identified.

6.4 Management of Waste

All construction activities have been evaluated for the impacts of any generated waste. In the case of the tank closure program, it is recognized that some construction equipment and materials used to close the tanks may not be reusable and therefore might be considered as waste. Such waste would then be managed, treated, if necessary, and disposed of in accordance with applicable laws and regulations.

The majority of the waste generated during tank closure is expected to fall into one of two waste categories, either clean (neither hazardous nor radioactive) solid waste or a low-level radioactive waste. It is not expected that any waste will be classified as mixed waste (i.e., waste having the attributes of both a hazardous component and a radioactive component). Potentially generated waste has also been reviewed for asbestos and polychlorinated biphenyl (PCB) contamination, but neither is expected to be present. Regardless of classification, the waste will be treated as appropriate, properly stored, and safely disposed in accordance with written procedures (WSRC 1996b). These procedures encompass a program of waste certification and acceptance criteria that will ensure protection of human health and safety consistent with applicable regulatory standards.

6.5 DOE Order Requirements

Department of Energy Order 5400.5, *Radiation Protection of the Public and the Environment*, (soon to be promulgated as Title 10 (Energy) of the Code of Federal Regulations, Part 834) sets forth, among other standards, public and environmental protection standards against undue radiological risks applicable to DOE operations. This Order, as will the above referenced Code, prescribes dose limits for the general public that are consistent with radiation protection standards recommended by the International Commission on Radiological Protection (ICRP) contained in ICRP Publications 26 and 30. Under the tank closure program, compliance with this Order will be demonstrated by monitoring and surveillance analyses performed in accordance with both the Order and the requirements and recommendations provided in the Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE 1991). In addition, all doses to the tank closure workers and to the public will be kept ALARA.

6.6 South Carolina Pollution Control Act Requirements

Pursuant to the South Carolina Pollution Control Act, the Tank 20 System has been operating under an industrial wastewater treatment facility permit. Closure of this tank for purposes of complying with the permitting regulations under this Act will be in accordance with a plan and schedule approved by the South Carolina Department of Health and Environmental Control (SCDHEC). Once the plan and schedule have been approved by SCDHEC, then authority to proceed with closure activities under this module will be issued and closure will commence. Once the closure has been completed, then SCDHEC offices in both Aiken and Columbia will be notified and an opportunity for inspection of the facilities will be extended. The final as-closed drawings will be provided to SCDHEC. Upon approval of the closure activities a closeout letter for the Tank 20 system will be issued by SCDHEC.

6.7 Clean Air Act Requirements

SRS has evaluated emissions from Tank 20 in accordance with Appendix D of 40 CFR 61. This evaluation assumed that all radioactive air pollutants from the tank will be emitted into the atmosphere at one time. However, since the residual waste radioactivity is low, no adverse impacts were found in the evaluation.

Tank 20 is currently exempted from existing nonradioactive air toxic permit regulations. Under the closure activity, no increase in nonradioactive emissions is expected. The SRS Title V air permit application identifies the tank as an insignificant source by virtue of its emission potential. Since the tank will be transitioned from operation to closure, the Title V permit application will require revision to reflect the aforementioned changes. The results from this evaluation will be utilized in a notification to SCDHEC to remove Tank 20 from the application. The closure activities are not contingent on the permit application revision; however, the evaluation and notification will be submitted to SCDHEC as soon as practicable.

6.8 References

DOE (U.S. Department of Energy), 1991, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0137T, January.

WSRC (Westinghouse Savannah River Company), 1995a, *Savannah River Site Best Management Practices Plan*, WSRC IM-90-49, Section 4.5, F-Area Risk Identification and Assessment, Rev. 3, November 30.

WSRC (Westinghouse Savannah River Company), 1995b, *Savannah River Site Spill Prevention Control and Countermeasure Plan*, WSRC IM-90-48, Rev. 2, Section 7.0, F-Area, Rev. 3, November 30.

WSRC (Westinghouse Savannah River Company), 1996a, *Procedure Manual 3Q, Environmental Compliance Manual*, Aiken, South Carolina.

WSRC (Westinghouse Savannah River Company), 1996b, *Procedure Manual 1S, Savannah River Site Waste Acceptance Criteria*, Aiken, South Carolina.

CHAPTER 7. POST-CLOSURE ACTIVITIES

7.1 Environmental Restoration Program Interface - An Overview

The U.S. Department of Energy (DOE) has identified other potential sources of contamination in the General Separations Area that it will consider to ensure the consistency of high-level waste (HLW) tank system closure activities with the overall remediation of the F- and H-Area Tank Farms. Chapter 3 of the general closure plan for the HLW tank systems (DOE 1996) identifies potential contributors of contamination to the Upper Three Runs and Fourmile Branch watersheds. The general closure plan includes the Resource Conservation and Recovery Act (RCRA)/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) units associated with those watersheds, as identified in Appendix C of the Federal Facility Agreement (FFA, EPA 1993). DOE will conduct the RCRA Facility Investigation/Remedial Investigation (RFI/RI) for those units in accordance with Section XI of the FFA to determine the appropriate remedial measures, if any, needed to achieve remedial goals.

The RCRA/CERCLA units within the groundwater transport segment (GTS) that encompasses the Tank 20 system include the closed F-Area Seepage Basins and the F-Area Groundwater. Due to differences in the degree of isolation and location of contaminants from the F-Area Tank Farm and the F-Area Seepage Basins, it is not likely that contaminants from both units will impact groundwater or surface-water quality at Fourmile Branch at the same time. This is described in the accounting for Tank 20 environmental impacts in Section 8.2 and Appendix B.

The F- and H-Area Tank Farms include areas subject to Site Evaluation in accordance with Section X of the FFA; a short description of the areas in and near the Tank 20 GTS can be found in the *Savannah River Site Plan for Performing Maintenance in Federal Facility Agreement Areas (O&M) Plan* (WSRC 1996). These areas include several locations of contamination associated with the historic operations of the HLW tank systems that comprise this grouping. The principal radiological contaminants of concern associated with these areas are strontium-90 and cesium-137. The fate and transport modeling (Chapter 8) indicates that these radioisotopes will not contribute significantly to the projected dose levels resulting from releases to groundwater and surface water from the closed HLW tank systems. The proposed closure configuration will retain these relatively short-lived isotopes within the tank systems until they decay to the point that they will not contribute to the projected beta-gamma dose level. Therefore, DOE does not expect contaminated soils in these areas to contribute significantly to the projected dose levels for the closed tank systems.

Based on historical knowledge and radiological surveys, the releases associated with these areas of contamination do not currently pose a significant threat to human health or the environment. When work is performed within these areas, a site-specific health and safety plan is written to protect worker safety and to address constituents of concern. Additional information regarding the nature and extent of contamination present will be collected during soils assessment activities.

7.2 Soils Assessment Activities

Due to the proximity of Tank 20 to the other tank systems in its grouping (Tanks 17 through 19, the 242-F evaporator and the associated concentrate transfer system), DOE cannot practicably isolate this tank system for soil assessment and potential remedial activities at this time. DOE will remove from service a minimum of the transfer piping and mechanical (inhibited water lines, ventilation, instrument air, etc.) and electrical services in this area as part of the Tank 20 closure activities. Personnel safety and radiation exposure considerations associated with ongoing operations of the remaining tank systems make it impractical to start intrusive characterization efforts while most components in that grouping remain in service.

DOE will defer the soils assessment and potential remedial activities associated with Tank 20 until it completes closure for all tank systems in its grouping and all operational support services (transfer lines, chemical piping, electrical systems, etc.) are removed from service and it has been verified that the area can be safely sampled. The DOE schedule (see Appendix B of the Program Plan) calls for closure of two additional tank systems (Tanks 17 and 19) in Fiscal Year 1997 and five tanks systems (including Tank 18) by Fiscal Year 2000. Therefore, as stated in Section 1.3, DOE intends to close the tanks in Tank 20's operational grouping in the following order: Tank 20, Tank 17, Tank 19, and Tank 18.

DOE will submit a strategy and schedule for both the soils assessment and post-closure activities to the South Carolina Department of Health and Environmental Control (SCDHEC) and U.S. Environmental Protection Agency (EPA)-Region IV for review and approval within the submittal of the tank-specific closure module for the last of the HLW tank systems in this grouping. Assessment activities will start in accordance with the schedule to be developed as part of that strategy.

The soils assessment and potential remedial activities associated with the grouping will commence after SCDHEC approves the as-built conditions of the last unit in the Tank 20 grouping and it has been deemed safe and non-impactive to tank farm operations to perform the assessment. All work activities associated with soils assessment and potential remedial actions will be scheduled and controlled in such a way to ensure such activities are conducted safely in conjunction with existing HLW operations.

7.3 Other Post-Closure Activities

Because not all the tank systems in the F-Area Tank Farm will undergo closure at the same time, there will be an interim period where some tank systems will remain operational, while others will be closed. During this interim period, security will continue to be maintained to restrict access to the closed tanks by unauthorized personnel. The existing stormwater system providing drainage for the area encompassing Tanks 17 through 20 will be maintained (including monitoring and surveillance activities) to channel rainwater away from the tanks until all four tanks are closed and the soil assessment/remedial activity phase is completed.

Investigation, determination of remediation requirements, and implementation of potential remedial actions related to soil and groundwater contamination in the F-Area Tank Farm will be conducted in accordance with RCRA/CERCLA requirements pursuant to the FFA. The proposed closure configuration for Tank 20 includes backfilling the area immediately surrounding the operational grouping to eliminate ponding over the closed tank system. Backfilling will occur after closure of the last tank system in the grouping and completion of the tank grouping soils assessment and any remedial activities. The proposed backfilling configuration will be designed to be compatible with the installation of a cap, if the assessment of the grouping determines that a low-permeability cap is necessary. This determination will be made with SCDHEC concurrence.

Existing monitoring systems will identify releases from the closed Tank 20 system. Figures 3-5 and 3-6 show the locations of the 27 monitoring wells in the F-Area Tank Farm (noted as "FTF"). These wells are monitored for pH, specific conductance, gross alpha, nonvolatile beta, and tritium (WSRC 1995). Results of this monitoring are reported to SCDHEC and EPA-Region IV in the annual SRS Environmental Report.

The groundwater monitoring aspects of the Tank 20 closure will be dealt with through the creation of a groundwater operable unit, in accordance with the FFA, which will address the F-Area Tank Farm groundwater. The SRS will determine details of the monitoring systems and sampling/analysis protocols as part of this activity. The post-closure monitoring system may include, as appropriate, the installation and operation of additional wells to detect and monitor contaminants of concern from the closed HLW tank systems. These monitoring wells will enable DOE to determine when releases occur and their impact on the shallow aquifer. Results from this monitoring will be correlated with the fate and transport model predictions used in the tank-specific closure modules to determine compliance with the groundwater protection standards at the seepline and surface-water quality standards in the receiving stream.

7.4 References

DOE (U.S. Department of Energy), 1996, *Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Tank Systems, Savannah River Site, Construction Permit Numbers 14,338, 14,520, 17,424-IW*, Revision 1, Savannah River Operations Office, Aiken, South Carolina, July 10.

EPA (U.S. Environmental Protection Agency), 1993, *Federal Facility Agreement between U.S. Environmental Protection Agency Region IV, U.S. Department of Energy, and South Carolina Department of Health and Environmental Control*, Docket No. 90-05-FF, August 16.

WSRC (Westinghouse Savannah River Company), 1995, *The Savannah River Site's Groundwater Monitoring Program, First Quarter 1995*, ESH-EMS-950393, Savannah River Site, Aiken, South Carolina.

WSRC (Westinghouse Savannah River Company), 1996, *Savannah River Site Plan for Performing Maintenance in Federal Facility Agreement Areas (O&M) Plan*, Draft, WSRC-RP-96-5, Savannah River Site, Aiken, South Carolina.

CHAPTER 8. PERFORMANCE EVALUATION

This chapter describes the methods the U.S. Department of Energy (DOE) will use to determine if the Tank 20 closure satisfies the performance standards discussed in the *Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Tank Systems* (DOE 1996).

8.1 Applicable Performance Standards

Tables C-4 through C-6 of the general closure plan list performance standards applicable to high-level waste (HLW) tank system closure. In general, these standards can be divided into four categories:

1. Air quality performance standards
2. Groundwater and surface-water protection performance standards
3. Performance standards that pertain to radiation protection of hypothetical human receptors (i.e., intruder, worker, resident farmer)
4. Performance standards related to protection of biota

This section discusses the performance standards that DOE considers pertinent to the closure of Tank 20.

As discussed in Appendix A, the Tank 20 closure configuration, which entails filling the tank with grout, would not result in exposure to receptors by the atmospheric pathway. Therefore, the air quality performance standards listed in Appendix C of the general closure plan are not applicable to the closure of Tank 20.

The groundwater and surface-water performance standards generally apply drinking water standards as a limit at various points of compliance, depending on the source of the requirement. For example, the Maximum Contaminant Level is applied as a limit in groundwater at locations 1 meter and 100 meters downgradient from the edge of the tank farm. Previous modeling for closure of a group of tanks in the F-Area Tank Farm (DOE 1996) showed that compliance with drinking water standards at these locations might not be achievable, given the current state of technology for waste removal from tanks. DOE will ensure that the SRS defense processing and environmental management areas (including the F- and H-Area Tank Farms) will be zoned "industrial" for an indefinite period with deed restrictions on the use of the groundwater. In addition, DOE is actively seeking Congressional designation for the SRS National Environmental Research Park, which would strengthen institutional control of the site. Therefore, for the closure of the tank system, the performance standard related to protection of water resources will be compliant with South Carolina Department of Health and Environmental Control (SCDHEC) water quality criteria, criteria to protect aquatic life, or Maximum Contaminant Levels, whichever is more restrictive, applied at the point where groundwater discharges to the surface (the seepline).

As shown in Tables A-13 through A-15 in Appendix A, the calculated doses to an intruder and to the postulated worker at the seepline after HLW tank closure would be much less than the calculated dose from consumption of water at the seepline. Similarly, the calculated doses to the hypothetical adult and child resident and from consumption of water from Fourmile Branch would be much less than the calculated dose from consumption of water at the seepline. Section A.4.2 of Appendix A also demonstrates that the calculated impacts to biota residing on or near the F-Area Tank Farm would be well within the performance standards for both radiological and nonradiological constituents. For these reasons, DOE is confident that if it meets drinking water standards at the seepline, then it would also meet the performance standards for the hypothetical human receptors (i.e., intruder, worker, resident farmer) and for biota.

Therefore, the remainder of this chapter will discuss the performance of the Tank 20 closure in relation to the following performance standards: (1) compliance with the SCDHEC Primary Drinking Water Standards for radionuclides (i.e., 4 mrem/year beta-gamma dose and 15 pCi/L total alpha concentration) at the seepline, and (2) compliance with the SCDHEC water quality criteria, criteria to protect aquatic life, or Maximum Contaminant Level, whichever is more restrictive, for nonradiological constituents at the seepline. These performance standards are listed in Table 8-1.

8.2 Accounting for Tank 20 Closure Against Performance Objectives

The overall process for accounting a tank's closure impacts against the performance objectives consists of:

1. Defining a groundwater transport segment (GTS) for the tank system to be closed.
2. Identifying and quantifying sources within the GTS.
3. Developing "adjusted" performance objectives to account for non-tank sources in the GTS.
4. Conducting fate and transport modeling to determine if adjusted performance objectives for the GTS are satisfied.

Table 8-1. Nonradiological groundwater and surface-water performance standards applicable to high-level waste tank system closure.

Constituents of Concerns	Maximum Contaminant Level (40 CFR §141.62) (mg/L)[a]	Maximum Contaminant Level Goal (40 CFR §141.51) (mg/L)[b]	Maximum Contaminant Levels (SC R.61-58.5.B(2)) (mg/L)[c]	Water Quality Criteria for Protection of Human Health (SC R.61-68, Appendix 2) (mg/L)[d,e]	Criteria to Protect Aquatic Life (SC R.61-68, Appendix 1) (mg/L)[d,f]	
					Average	Maximum
Aluminate						
Aluminum					0.087	0.750
Barium			2.0		50	100
Boron						
Calcium						
Carbonate						
Chloride						
Chromium III				637.077	0.120[g]	0.980[g]
Chromium VI				0.050	0.011[g]	0.016[g]
Total chromium	0.1	0.1	0.1		0.011	0.016
Copper		1.3			0.0065[g]	0.0092[g]
Hydroxide						
Fluoride	4.0	4.0	4.0			
Iron					1.000	2.000
Lead		zero[h]		0.050	0.0013[g]	0.034[g]
Lithium						
Magnesium						
Manganese					1.0	2.0
Mercury	0.002	0.002	0.002	1.53×10^{-4}	1.2×10^{-5}[g]	0.0024[g]
Molybdenum						
Nickel			0.1	4.584	0.088[g]	0.790[g]
Nitrate	10 (as N)	10 (as N)	10 (as N)			
Nitrite	1 (as N)	1 (as N)	1 (as N)			
Total nitrate & nitrite	10 (as N)	10 (as N)	10 (as N)			
Oxalate						
Phosphate						
Potassium						
Selenium	0.05	0.05	0.05	0.010	0.0050[g]	0.020[g]
Silicon						
Silver				0.050		0.0012[g]
Sodium						
Sulfate						
Titanium						
Tributylphosphate						
Zinc					0.059	0.065
Zirconium						

a. Safe Drinking Water Act (SDWA) - The MCLs (§141.62) for inorganic contaminants apply to community water systems, nontransient noncommunity water systems, and transient noncommunity water systems.

b. SDWA - The MCLGs (§141.50) are nonenforceable health goals corresponding to the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and that allows an adequate margin of safety.

c. SC SDWA - The MCLs for inorganic contaminants specified in R.61-58.5.B(2) apply to all public water systems.

Table 8-1. (continued).

d. SC Water Classifications and Standards - The water quality standards are applicable to both surface waters and groundwaters unless indicated otherwise (R.61-68.C).
   - With the exception of human health criteria listed in Section E(8), the numeric standards of this regulation are applicable to any flowing waters when the flow rate is equal to or greater than the minimum 7-day average flow rate that occurs with an average frequency of once in 10 years (7Q10). State water quality standards for human health protection will be applicable to surface waters at average annual flow conditions or a average tidal dilution conditions, whichever is appropriate (R.61-68.E(8)).
   - Numeric criteria for all class surface waters are adopted for toxic pollutants for which EPA has published national criteria to protect aquatic life pursuant to Section 304(a) for the Federal CWA and for ammonia and chlorine. No numeric criteria are listed in this regulation; however, the national numeric criteria developed and published by EPA are incorporated by reference. If the State develops site-specific criteria for any substances for which EPA has developed national criteria, the site-specific criteria will supersede the national criteria. If metal concentrations for national criteria are hardness-dependent, the chronic and acute concentrations shall be based on 50 mg/L hardness if the ambient hardness is less than 50 mg/L and based on the actual mixed stream hardness if it is greater than 50 mg/L (R.61-68.E(7)(a)(3)).
   - Freshwater standards for toxic pollutants listed in Section 307 of the Federal CWA and for which EPA has developed national criteria are subject to the standards prescribed in Sections E(7) and E(8) of this regulation (R.61-68.G(3)).
   - It is policy of the Department to maintain the quality of groundwater consistent with its highest potential uses. For this reason, all South Carolina groundwater is classified GB effective on June 28, 1995. Quality standards for inorganic chemicals in Class GB Groundwaters are those set forth in the State Primary Drinking Water Regulations R.61-58.5.B(2) (R.61-68.H(2)).

e. SC Water Classifications and Standards - State water quality standards for human health protection specified in Section 8(a) will be applicable to surface waters at average annual flow conditions or at average tidal dilution conditions, whichever is appropriate (R.61-68.E(8)(b)).

f. Average and maximum values for water quality to protect aquatic life identified in spreadsheet obtained from M. Vickers of SCDHEC.

g. Denotes compounds with national criteria to protect aquatic life identified in R.61-68.E(7).

h. Action level for lead is 0.015 mg/L.

5. Conducting fate and transport modeling to determine impacts for the tank to be closed.
6. Accounting for the tank-specific impacts against the remaining adjusted performance objectives.

Appendix B describes in detail the methodology for accounting for tank closure impacts and applies the methodology to Tank 20 closure.

8.2.1 DEFINING THE TANK 20 GTS

A careful examination of the F-Area tank farm in the context of its hydrogeological setting (section 3.3.1) reveals that the F-Area tank farm has only one GTS. Due to the three-dimensional nature of groundwater flow and leakage between the stacked aquifer layers beneath the F-Area tank farm, the GTS will contain three layers. The boundaries of the Water Table Aquifer layer of the GTS, which is the first aquifer layer impacted by any future releases from the tank farms, is used to define the boundaries of the underlying Barnwell-McBean Aquifer layer. In turn, the Barnwell-McBean Aquifer layer will control the boundaries of the underlying Congaree Aquifer layer of the GTS. Therefore, the fate and transport modeling includes components for each of the aquifer layers within the GTS. Figures 8-1, 8-2, and 8-3 show the boundaries of the GTS layers for both of the tank farm areas.

6N38-12PC

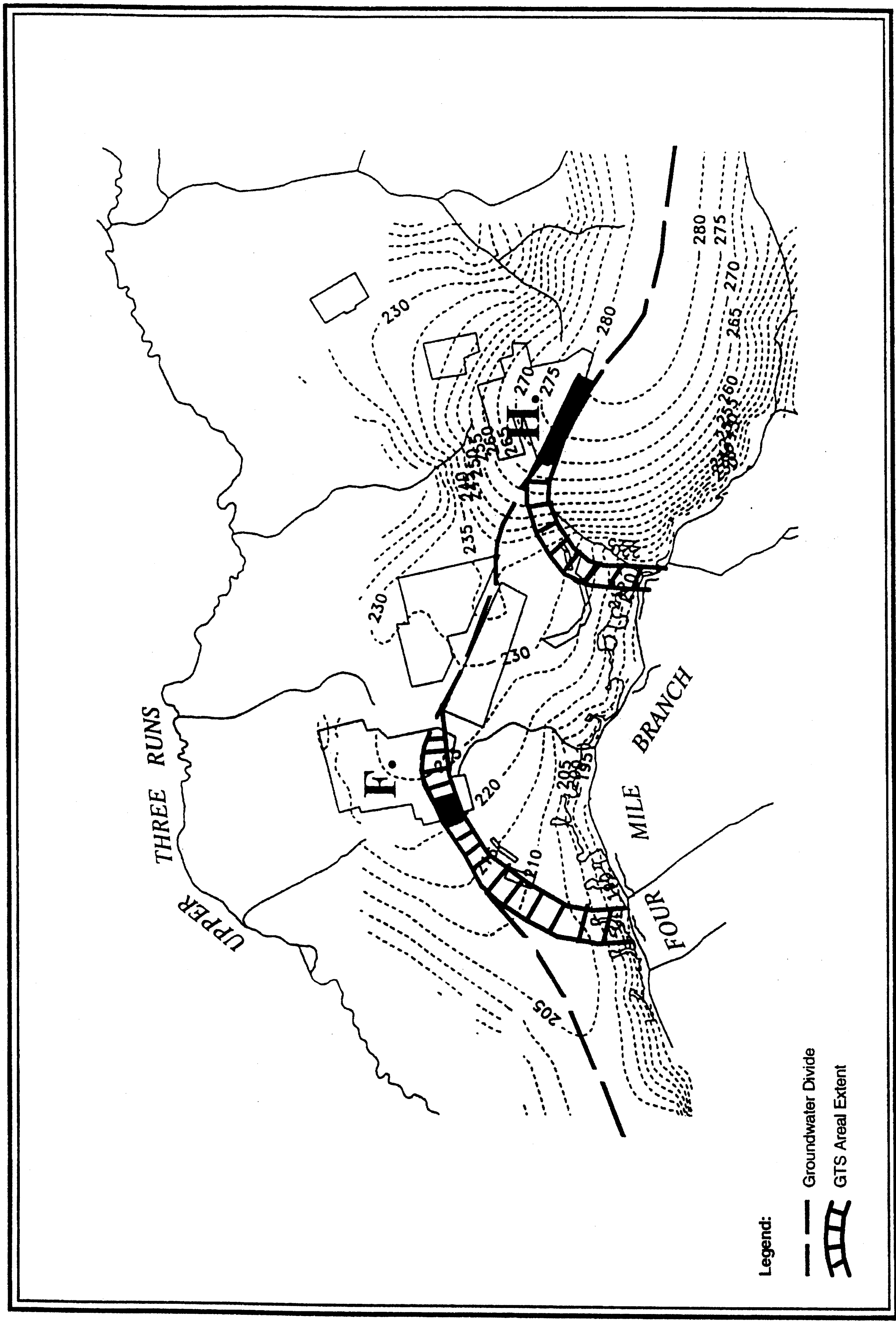

Figure 8-1. Calibrated potentiometric surface (ft) for the Water Table aquifer.

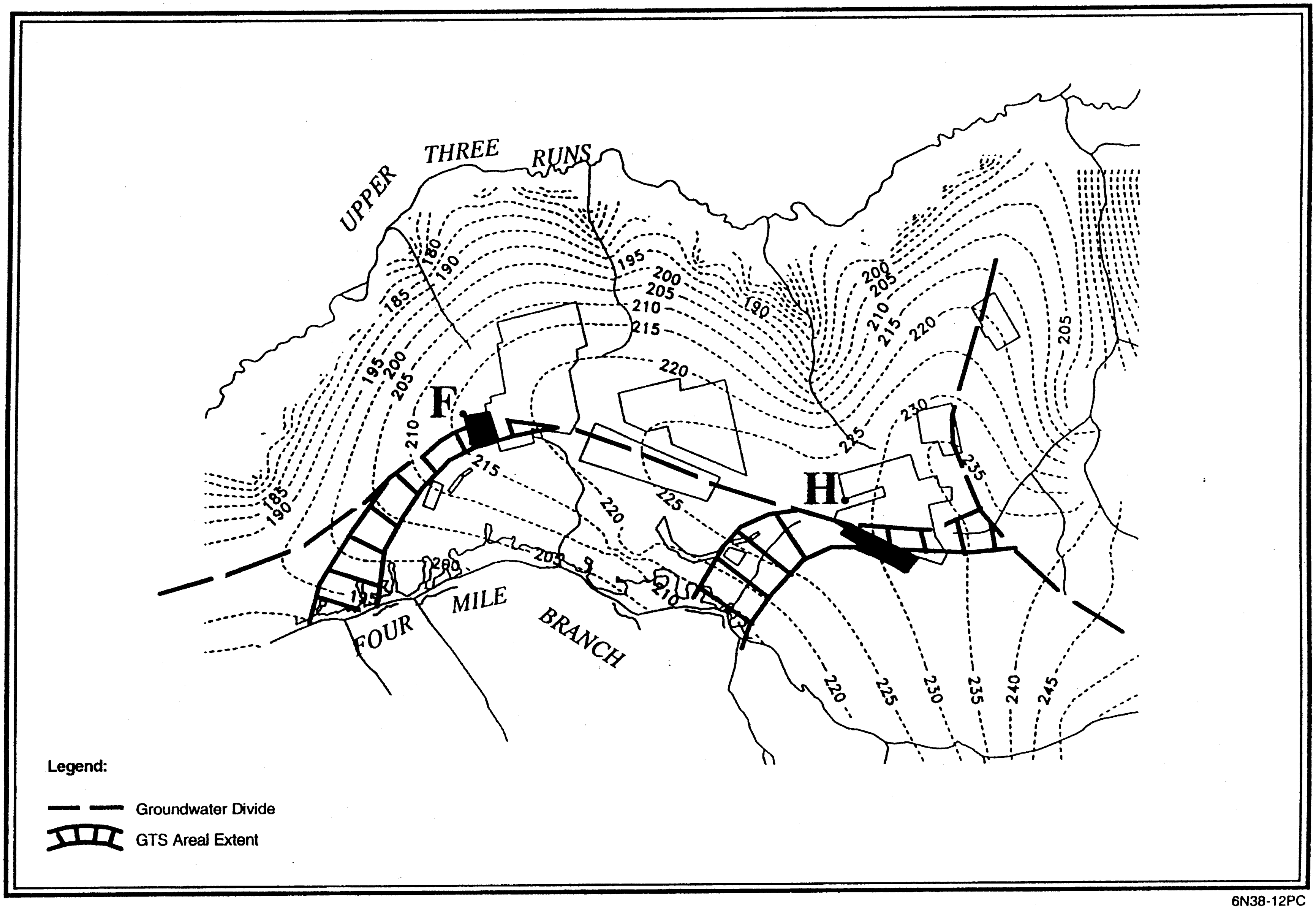

Figure 8-2. Calibrated potentiometric surface (ft) for the Barnwell/McBean aquifer.

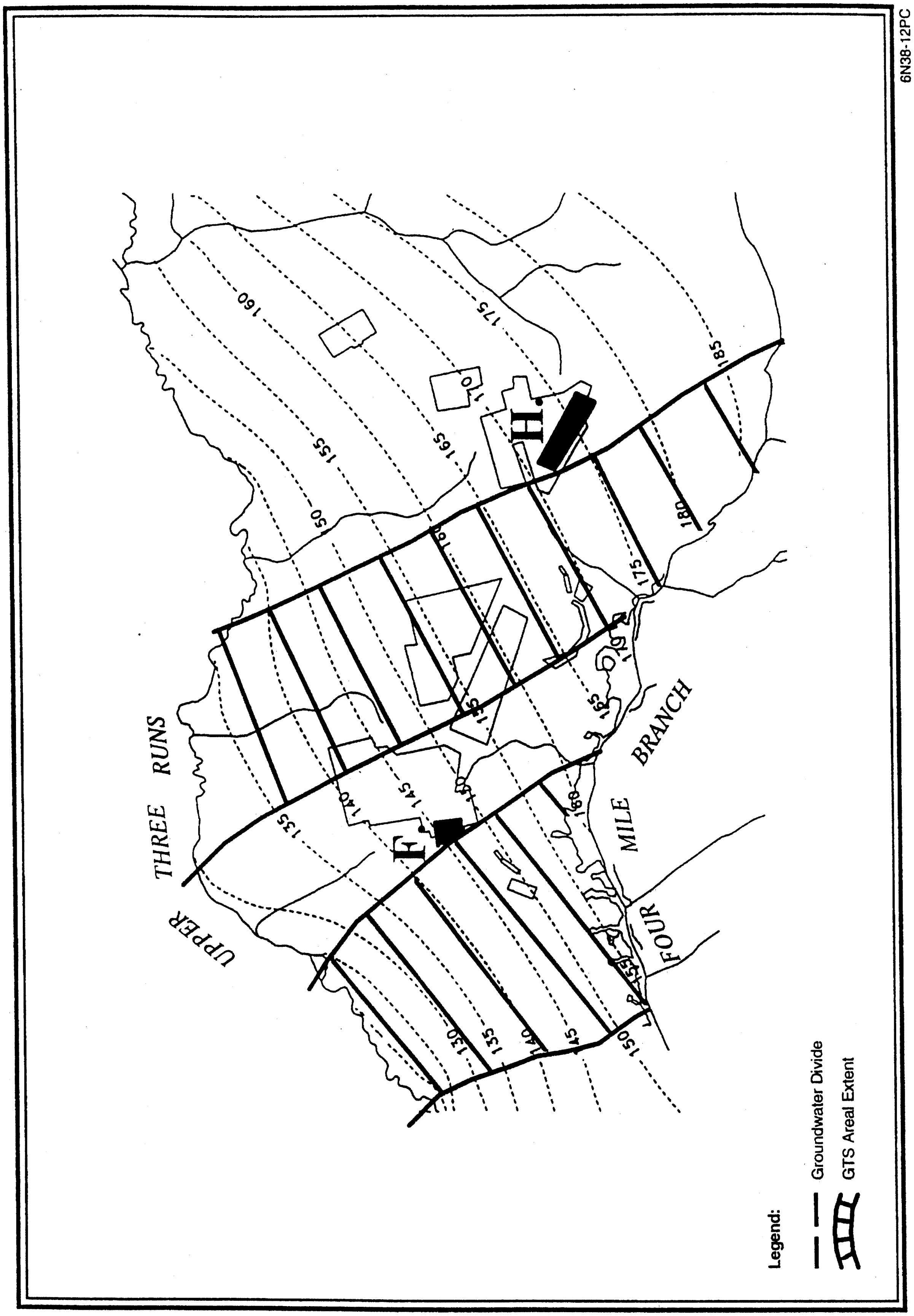

Figure 8-3. Calibrated potentiometric surface (ft) for the Congaree aquifer.

8.2.2 IDENTIFYING AND QUANTIFYING SOURCES WITH THE GTS

The entire F-Area tank farm, comprised of 22 HLW tanks, is within the Tank 20 GTS. Except for Tank 20, the source term for the GTS is based on process knowledge and scattered historical sample results. The Tank 20 source term is based on process knowledge, modified by recent sampling and analysis. The only non-tank-farm source within the GTS with potential for significant and measurable impacts is the F-Area Seepage Basins.

8.2.3 DEVELOPING ADJUSTED PERFORMANCE OBJECTIVES

DOE considered previous evaluations of the F-Area Seepage Basins to determine their contributions to environmental impacts. These evaluations determined that none of the constituents of concern from the F-Area Seepage Basins will be detected at the seepline concurrent with Tank 20 impacts. Therefore, the adjusted performance objectives are identical in magnitude to the overall performance objectives. The adjusted performance objectives for the parameters identified in section 8.1 are presented in Table 8-2.

8.2.4 MODELING TO DETERMINE IF ADJUSTED PERFORMANCE OBJECTIVES ARE SATISFIED

DOE modeled the impacts of closing every tank in the F-Area tank farm (the F-Area GTS) using the methodology illustrated in Appendix A (Appendix A applies to Tank 20 modeling only). Appendix B provides more detailed results of the GTS modeling. Results for comparison against the performance objectives identified in section 8.1 are provided in Table 8-2. Appendices A and B demonstrate that seepline concentrations in the Barnwell-McBean Aquifer provide the limiting cases. Therefore, the Table 8-2 results pertain to concentrations of contaminants in the Barnwell-McBean Aquifer at the seepline. Although water in the Barnwell-McBean Aquifer mixes with water from the Water Table Aquifer at the seepline, the degree of mixing is uncertain. Any mixing would reduce the reported concentrations. Therefore, the values reported in Table 8-2 assume no mixing. Examination of Table 8-2 reveals that all performance objectives are satisfied for the F-Area GTS.

8.2.5 MODELING TO DETERMINE TANK 20 IMPACTS

Appendix A contains complete details of the modeling for Tank 20 impacts. The results are presented in Table 8-2 for the selected parameters. Concentrations and doses are for the Barnwell-McBean Aquifer at the seepline, assuming no mixing with other waters. The results represent the Tank 20 contribution to the overall GTS impacts at the time the GTS impacts are maximum. Maximum Tank 20 impacts occur

Table 8-2. Comparison of modeling results to performance objectives at the seepline.[a]

Constituent/Effect	Adjusted PO	F-Area GTS Impact	Tank 20 Impact	Remaining PO
Radiological				
Beta-gamma dose (mrem/yr)	4	1.9	5.5E-03	3.99
Alpha concentration (pCi/L)	15	3.9E-02	(b)	15
Non-Radiological				
Nickel (mg/L)	1E-01	(c)	(c)	1.0E-01
Chromium (mg/L)	1E-01	6.0E-05	5.0E-06	1.0E-01
Mercury (mg/L)	2E-03	(c)	(c)	2E-03
Silver (mg/L)	5E-02	2.2E-03	1.9E-04	5E-02
Copper (mg/L)	1.3	(c)	(c)	1.3
Nitrate (as N) (mg/L)	10	1.5E-02	1.3E-03	10
Fluoride (mg/L)	4	1.5E-03	1.3E-04	4
Lead (mg/L)	1.5E-02	(c)	(c)	1.5E-02
Barium (mg/L)	2.0	(c)	(c)	2.0

a. Values taken from Table B-8 of Appendix B.
b. Value is less than 1E-13.
c. Value is less than 1E-06.

later than the maximum GTS impacts and are reported in Appendix A. Maximum Tank 20 impacts are also well below performance objectives.

8.2.6 ACCOUNTING FOR TANK 20 IMPACTS

The last column of Table 8-2 provides the remaining budget of adjusted performance objectives after closure of Tank 20. Future closures will be compared to these values. The reported values are the difference between the adjusted performance objective and the Tank 20 impacts.

8.3 References

DOE (U.S. Department of Energy), 1996, *Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Tank Systems, Savannah River Site, Construction Permit Numbers 14, 338, 14, 520, 17, 424-IW*, Revision 1, Savannah River Operations Office, Aiken, South Carolina, July 10.

CHAPTER 9. CONFORMANCE WITH CLOSURE CRITERIA

As noted in Chapter 1 of the approved general closure plan (DOE 1996a), the U.S. Department of Energy (DOE) intends that the evaluation and selection of a proposed closure configuration by the process described in that general plan be consistent with evaluation against the nine Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria set forth in 40 CFR 300.430(e)(9). The evaluation of major closure configuration alternatives provided in the general closure plan (in particular, analyses provided in Appendices A and D), the closure strategy set forth in Chapter 4 of the general plan, and the associated National Environmental Policy Act (NEPA) process substantially fulfills this intent with respect to DOE's choice of generic "selected alternative" (see the general closure plan, Appendix A). This Chapter provides DOE's summary demonstration of conformance with the CERCLA nine criteria for the Tank 20 system closure as specifically proposed in this closure module. The demonstration is provided in subsections corresponding to these criteria, as follows.

9.1 Overall Protection of Human Health and the Environment

As discussed in the following subsections of this chapter, DOE's proposed closure of the Tank 20 system will ensure overall protection of human health and the environment by implementing a closure configuration that will be effective in reducing and immobilizing residual wastes left in place, by providing for effective post-closure monitoring and maintenance and consistency with final tank farm remediation, and by committing to implement appropriate land use controls for the long term. Fate and transport modeling and risk analyses presented in this module provide reasonable assurance that the Tank 20 system closure, in consideration of other sources of contamination that could affect the same receptors, will be highly protective of potential human and ecological receptors that may be present under reasonable land use controls. For the 10,000 year period of analysis, maximum lifetime excess cancer risk for a human receptor (Appendix A) was calculated to be 2.8×10^{-7}; the maximum calculated hazard quotient (HQ) for animal receptors was calculated to be 1.4×10^{-2}, indicative of no expected adverse impacts in the long term. In the short term, implementation of the Tank 20 system closure will be undertaken in a manner that is protective of workers, the public and the natural environment through compliance with applicable requirements and guidance; use of formal work controls and a competent, experienced workforce; and application of As Low As Reasonably Achievable (ALARA) principles.

9.2 Compliance with Requirements; Conformance with Relevant and Appropriate Guidance

DOE's determination of applicable requirements and relevant and appropriate guidance for high level waste (HLW) tank system closure, including the Tank 20 system closure, is provided in Appendix C of the general closure plan (DOE 1996a) and associated Tables C-1 through C-6. Table C-2 includes a complete list of these requirements and guidance, annotated to include rationale for including or excluding guidance entries (categorized as Relevant and Appropriate or To-Be-Considered Materials) from further consideration. In general, such guidance is included for further consideration in cases where it is more stringent than an applicable requirement, and excluded from further consideration in cases where it is less stringent than an applicable requirement or where conformance with the guidance is met by adherence to provisions of the general closure plan. The consolidated list of requirements and guidance resulting from application of the rationale (i.e., Table C-2 less exclusions) is provided in Table C-3. These requirements and guidance are of two types: those expressed as numerical performance standards (generally allowable contaminant release concentrations or doses), and those that are not. The former are tabulated in Tables C-4 (nonradiological air), C-5 (nonradiological groundwater and surface water) and C-6 (radiological, all pathways) of the general closure plan. The remaining requirements and guidance except those pertinent only to high-level waste, which are not considered further in view of DOE's incidental waste determination for Savannah River Site (SRS) HLW tank residuals, are listed in Table 9-1 of this module.

DOE's performance evaluation presented in Chapter 8 addresses compliance with the numerical performance standards listed in Tables C-4, C-5, and C-6. As demonstrated in Section 8.1, contaminant releases to the air, surface water, and accessible soils are expected to comply with corresponding performance standards. DOE's analysis also indicates that all pertinent performance standards for the groundwater pathway (for both radiological and nonradiological contaminants) would be met where this water outcrops to surface water (Fourmile Branch and Upper Three Runs).

Table 9-1 provides summary evaluations of conformance with non-numerical requirements and guidance. Many of these requirements, particularly DOE Order requirements and proposed regulations that address radiological performance of the closure, closely parallel numerical standards and will be met as described above. The remaining criteria, including DOE Order requirements and the Resource Conservation and Recovery Act (RCRA) requirements, primarily address environmental requirements and guidance associated with planning and implementing the closure (e.g., compliance with NEPA, management of generated wastes, adherence to ALARA principles, etc.). DOE has complied with or is complying with planning and approval requirements, and will ensure compliance with implementation requirements through existing sitewide plans and procedures and associated Westinghouse Savannah River Company (WSRC)-HLW procedures, as described in Chapter 6 of this module.

9.3 Long-Term Effectiveness and Permanence

DOE's planned closure configuration, post-closure monitoring and maintenance, ultimate tank farm remediation, and appropriate land use controls will ensure long-term effectiveness and permanence of the Tank 20 system closure. As discussed in Chapter 4, spray water washing has effectively reduced waste residuals in the tank system, and effective physical and chemical stabilization of the waste and tank system structures left in place will be provided by grouting (combination of "reducing grout," controlled low-strength material (CLSM), and high strength grout). Physical integrity of this configuration, which provides protection from inadvertent intrusion, is expected to be maintained for at least 1,000 years (see Appendices A and D of the general closure plan). Specially formulated reducing grout is expected to be highly effective in immobilizing waste residuals as determined from Savannah River Site (SRS) experience in other similar applications, especially in the development of the SRS saltstone manufacturing and disposal process, and specific grout formulation verification studies using nonradioactive HLW simulant.

Fate and transport modeling and risk analyses (Chapter 8, Appendices A and B) provide reasonable assurance that the Tank 20 system closure, in consideration of other sources of contamination that could affect the same receptors, will be highly protective of potential human and ecological receptors that may be present under reasonable land use controls to be established by DOE. For the 10,000 year period of analysis, maximum lifetime cancer risk for a human receptor under the scenarios examined is calculated to be 2.8×10^{-7}, corresponding to predicted maximum radiation dose at the seepline, predicted to occur 1,855 years after closure (Appendix A). The maximum HQ for animal receptors is calculated to be 1.4×10^{-2} (indicative of no expected adverse impacts), predicted to occur 1,365 years after closure (Appendix A). DOE will establish post-closure release monitoring and maintenance plans and will effect ultimate tank farm remediation, including a cap if appropriate, in accordance with RCRA and CERCLA as implemented by the Federal Facility Agreement (FFA; EPA 1993) (see Chapter 7 of this module).

9.4 Reduction of Toxicity, Mobility, or Volume through Treatment

The methods DOE has established for treating wastes removed from the Tank 20 system and waste residuals remaining at closure are designed to effectively immobilize radiological and nonradiological contaminants of concern. Wastes removed from the Tank 20 system and associated wash water have been transferred to operational HLW tanks and ultimately will be immobilized as glass in the Defense

Waste Processing Facility (DWPF) vitrification facility or as saltstone at the Saltstone Manufacturing and Disposal Facility as necessary to meet applicable Atomic Energy Act requirements and RCRA land disposal restriction treatment standards. Tank farm evaporator overheads are treated in the F-/H-Area Effluent Treatment Facility. Treated wastewater from this facility is disposed of via an National Pollutant Discharge Elimination System (NPDES) permitted outfall, and low-level waste fraction residuals are stabilized and disposed of at the Saltstone Manufacturing and Disposal Facility. The effectiveness of these SRS treatment systems, all of which are permitted and operational, is well demonstrated. Any additional wastes removed from the Tank 20 system and associated wash water, as well as any bleed water generated during the grouting process, will be transferred to Tank 18 and treated in like manner using these same facilities.

Waste residuals remaining in the Tank 20 system will be effectively immobilized through the use of reducing grout, and by the physical and chemical stabilization and reduced infiltration provided by the proposed reducing grout, CLSM, and strong grout stabilization scheme. The specific performance of the reducing grout with respect to Tank 20 waste residuals is demonstrated by testing using nonradioactive HLW simulants (Chapter 4).

9.5 Short-Term Effectiveness

DOE will undertake the proposed closure of the Tank 20 system in a manner that is protective of the public, workers, and the environment. Individual doses to workers implementing the proposed closure will be maintained ALARA through the use of appropriate personal protective equipment and radiation work practices and controls. Associated air emissions (e.g., from high efficiency particulate air filtered tank system vents) would be maintained within currently allowable limits, providing protection to both workers and the public. No permit modifications are believed to be necessary. DOE has estimated that aggregate radiation dose to workers implementing stabilization under the "selected closure alternative" would be 10 to 11 person-rem averaged over 37 workers, or about 300 mrem per worker (DOE 1996b). The current SRS administrative control level is set at 700 mrem/year. DOE anticipates that no additional waste removal activities will be necessary for the Tank 20 system closure, so additional worker radiation doses associated with that operation would not be incurred. Other process-related risks are expected to be small, and consist primarily of hazards associated with increased heavy truck traffic, spills of grout material, tripping hazards, etc. DOE will conduct a thorough process hazards review and technical review to document associated risks and determine actions necessary to ensure protection of human health and the environment. Actions and recommendations from these reviews will be integrated into the closure operation. Job-specific protocols will be established as necessary to augment SRS standard plans and procedures for ensuring protection of human health and the environment (see Chapter 6)

9.6 Implementability

DOE's proposed closure of the Tank 20 system can be readily implemented using standard construction techniques applied for other projects at the tank farm facilities and at other SRS radiological facilities. Waste removal from SRS HLW salt tanks using hydraulic methods followed by spray water washing has already been accomplished for Tank 20, so additional spray water washing, although not expected, can be readily undertaken. Tank system component isolation and grout handling and placement (e.g., concrete, CLSM, saltstone) are routine, reliable operations at SRS. Therefore, the Tank 20 stabilization would represent a large scale, but relatively conventional SRS construction operation with a low likelihood of serious technical problems in its implementation. As discussed in Chapter 7, the Tank 20 closure operation is being planned and will be undertaken in a manner that ensures consistency with requirements for monitoring, maintenance, and remediation of the HLW tank farm soils.

DOE has coordinated with SCDHEC, Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission (NRC) throughout the development of the general closure plan and this Tank 20 system closure module. In response to the general closure plan, SCDHEC requested additional information, which DOE provided to SCDHEC in the Program Plan (DOE 1996b) on December 16, 1996. DOE has also prepared an environmental assessment and issued a Finding of No Significant Impact (FONSI) for closure of the HLW tanks in accordance with requirements of NEPA (DOE 1996c, 1996d). Finally, SCDHEC (1996) has approved the general closure plan for these tank closures. No permit modifications or new permits are believed to be necessary for closure of the Tank 20 system. Once this Tank 20 system closure module has been approved by SCDHEC, DOE will proceed with closure of this tank system.

All materials and services necessary to implement the Tank 20 system closure are readily available. The closure will involve use of construction staff and craft personnel, mostly existing SRS personnel. Similarly, existing support infrastructure, including roads, water supply, wastewater treatment, and waste management facilities and services at SRS are adequate to support the proposed Tank 20 system closure (see Chapter 5 and DOE 1996c).

9.7 Cost

DOE has determined that no additional waste removal will be required for the proposed Tank 20 system closure. In addition, costs for post-closure monitoring and maintenance may be incurred upon development and implementation of these activities. DOE considers costs for closure activities under this module to be primarily attributable to stabilization of the Tank 20 system. DOE's cost estimate for stabilization for the generic "selected closure alternative" is $2.5 million, which DOE has demonstrated to be highly cost effective in relation to other major closure alternatives (general closure plan, Appendices A and D). DOE's corresponding cost estimate for the Tank 20 closure is $2.2 million, which includes approximately $1.0 million for construction materials (tank fill material, hopper, delivery support, etc.), $1.1 million for other construction costs, and $0.1 million for design costs.

9.8 Federal and State Acceptance

DOE has coordinated closely with EPA, NRC, and SCDHEC in the development of the SRS HLW tank closure strategy. Acceptability of this general strategy by SCDHEC is demonstrated by approval of the general closure plan by SCDHEC, working in close cooperation with EPA-Region IV (SCDHEC 1996). SCDHEC's approval of this module will signify state acceptance of DOE's proposed closure of the Tank 20 system.

9.9 Community Acceptance

Community acceptance of DOE's proposed Tank 20 System closure is indicated by response of the public to DOE's environmental assessment (EA) for HLW tank closure (DOE 1996c) and by the FONSI subsequently issued by DOE (DOE 1996d). Comments on the draft EA received by the public in writing and at a public meeting held on June 11, 1996, were considered in development of the final EA. Public acceptance is also indicated by support of general closure plan development by the SRS Citizens Advisory Board (CAB 1996).

Table 9-1. Conformance assessment for HLW tank system closure requirements and guidance not expressed as numerical performance standards.[a]

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
South Carolina Pollution Control Act (SCPCA) R.61-82, Section IV	Proper Closeout of Waste Treatment Facilities Not Defined As Lagoons or Package Plants - Waste treatment units shall be closed out in accordance with guidelines issued by SCDHEC on an individual basis. These guidelines shall be designed to prevent health hazards and to promote safety in and around the abandoned sites.	DOE has coordinated closely with SCDHEC to develop the scope and contents of the general closure plan (DOE 1996a) and this module, including requirements and guidance pertinent to HLW tank closure. Approval by SCDHEC and implementation by DOE of the general closure plan and this module will achieve compliance with this requirement.	A
CERCLA SRS FFA WSRC-05-94-42 - DOE, EPA & SCDHEC, 8/16/93	The agreement directs the comprehensive remediation of SRS and also delineates the relationship between its requirements and the requirements for corrective measures being conducted under RCRA Section 3004 (u) and (v) according to the conditions of the Federal and state RCRA permit. Section IX - High-Level Radioactive Waste Tank System(s) Section IX.E.1 - DOE has submitted a waste removal plan and schedule for the waste tank system. DOE shall remove the tanks from service according to the approved plan(s) and schedule(s). Waste tanks deemed unsuitable by SCDHEC shall not receive additional waste prior to schedule approval for such receipt and only if waste receipt is approved as part of the plan associated with such schedule. Section IX.E.2 - The DOE waste tank system(s) removal plan(s) shall provide for the removal or decontamination of all residues, contaminated containment systems components (liners, etc.), contaminated soils and structures and equipment contaminated with hazardous and/or radioactive substances. If DOE demonstrates that it cannot practicably remove or decontaminate soils or structures and equipment, then DOE shall conduct all necessary response actions under Section XI through XVI of this Agreement for those waste tank system(s).	DOE has developed this closure module in accordance with the approved general closure plan (DOE 1996a) and requirements of the SCPCA. DOE developed a High-Level Waste Tank System Program Plan which sets forth the anticipated sequence and schedule for closure of specific HLW tank systems, and the process for coordinating soils assessments. Chapter 5 of the Program Plan describes this protocol in general terms. DOE developed the High-Level Waste Tank System Program Plan in a manner that ensures its consistency with the general closure plan and the FFA, as modified.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
CERCLA SRS FFA WSRC-05-94-42 - DOE, EPA & SCDHEC, 8/16/93 (cont.)	<u>Section IX.E.3</u> - DOE will submit to EPA and DHEC an annual report on the status of the tanks being removed form service under Subsection E.1. <u>Section IX.E.4</u> - For waste tank system(s) that DOE decides to remove from service that have been issued an industrial wastewater permit under SCPCA, the DOE shall remove such waste tank system(s) from service in accordance with the SCPCA and all applicable regulations promulgated pursuant to the SCPCA. For any waste tank systems(s) for which closure or removal from service is or has been conducted under the SCPCA, DOE shall conduct a site evaluation in accordance with Section X of the FFA.		
CERCLA Waste Removal Plan and Schedule for the HLW Tank Farms, WSRC-RP-93-1477, Rev. 0, 11/9/93	Waste removal plan and schedule for the HLW tank system(s) and/or component(s) that do not meet secondary containment standards or that leak or have leaked as required by Section IX.E of the SRS FFA. <u>III. HLW Facility Descriptions and Operating Plans - Tank Farm Waste Tanks & Waste Removal Operations</u>: (1) Type III tanks will be reused while the Type I, II, and IV tanks will be removed from service. (2) The tanks to be removed will undergo a water washing operation in the primary vessel and an annulus cleaning if waste is present in the annulus. (3) Salt will be removed from the new style tanks first, and these tanks will be reused to support Tank Farm evaporator operations and processing of DWPF recycle. (4) The first sludge tanks to be emptied will be old-style tanks, which will be removed from service. <u>Operating Plans</u>: Each waste tank will be fitted with special waste removal equipment. (1) Tanks containing sludge will have four slurry pumps and one transfer pump installed to	DOE has developed this closure module in accordance with the approved general closure plan (DOE 1996a) and requirements of the SCPCA, and is generally consistent with these provisions of the Waste Removal Plan and Schedule. However, DOE has developed a High-Level Waste Tank System Program Plan which sets forth the anticipated sequence and schedule for closure of specific HLW tank systems, and the process for coordinating soils assessments. The Program Plan information on post-closure monitoring and soils assessment supersedes that provided in the Waste Removal Plan and Schedule. Chapter 5 of the Program Plan describes this protocol in general terms. DOE has developed the High-Level Waste Tank System Program Plan in a manner that ensures its consistency with the general closure plan and the FFA, as modified.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
CERCLA Waste Removal Plan and Schedule for the HLW Tank Farms, WSRC-RP-93-1477, Rev. 0, 11/9/93 (cont.)	suspend the settled sludge into a pumpable slurry for transfer to Extended Sludge Processing (ESP). (2) Tanks containing salt will have three slurry pumps and one transfer jet installed to dissolve the salt and transfer it to In-Tank Precipitation Facility. IV. Assumptions - Waste Removal: (1) Each tank's waste removal schedule is based upon a typical construction-through-startup authorization task duration of 22-30 months. (2) As waste removal and water washing/annulus cleaning operations are completed for each old-style tank, that tank will be transitioned to SRS's Environmental Restoration Division for decommissioning and closure in accordance with applicable permits and other regulatory requirements.		

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
CERCLA Waste Removal Plan and Schedule for the HLW Tank Farms, WSRC-RP-93-1477, Rev. 0, 11/9/93 (cont.)	VI. Waste Removal Description/Definition: For the purposes of this plan, "removal from service" is defined as: (1) As much high level waste (salt, sludge and/or supernate) as practical is removed from the tank primaries and any annulus that had received waste via mechanical agitation (slurry pumps and eductor jets). (2) All tanks primaries and any annulus that received waste will be washed with inhibited water and as much waste as practical removed via installed systems (eductor jets and pumps). (1) Upon further evaluation, it may be decided that an additional chemical cleaning step may occur on some tanks as necessary. (2) A closure plan will be developed per SC Regulation R.61-82, Proper Closeout of Wastewater Treatment Facilities and submitted to DHEC for review and approval. (3) Upon approval, it is anticipated that the tank system/component will be turned over to the RCRA/CERCLA Program for decommissioning. (4) It may also be necessary to maintain a heel of inhibited water in some of the tanks to prevent structural damage to the tank bottom caused by upward groundwater pressure.	DOE has developed this closure module in accordance with the approved general closure plan (DOE 1996a) and requirements of the SCPCA, and is generally consistent with these provisions of the Waste Removal Plan and Schedule. DOE developed a High-Level Waste Tank System Program Plan which sets forth the anticipated sequence and schedule for closure of specific HLW tank systems, and the process for coordinating soils assessment. Chapter 5 of the Program Plan describes this protocol in general terms.	
National Environmental Policy Act 42 U.S.C. 4321 et seq.), 10 CFR 1021	Requirements of NEPA to evaluate SRS HLW tank closure options would be fulfilled in accordance with DOE implementing regulations (10 CFR 1021). NEPA evaluation will address impacts, including occupational exposure to site personnel, associated with various closure alternatives.	DOE has fulfilled these requirements via preparation of an Environmental Assessment and issuance of a FONSI (DOE 1996c, 1996d)	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
Endangered Species Act of 1973 (16 U.S.C. 1531 *et seq*); 50 CFR 402 and related statutes (Anadromous Fish Conservation Act, Bald Eagle Protection Act, South Carolina Nongame and Endangered Species Conservation Act, Migratory Bird Treaty Act, Fish and Wildlife Coordination Act)	Prohibits federally-authorized actions that would likely jeopardize the existence of any threatened or endangered or otherwise protected species or result in the destruction or adverse modification of critical habitat.	As noted in DOE's EA for HLW tank closure (DOE 1996c), no adverse impacts to threatened or endangered species is expected to result from proposed closure activities.	A
National Historic Preservation Act, 16 U.S.C. 470 et seq. and related legislation (e.g., Antiquities Act, Historic Sites Act, Archeological and Historic Preservation Act, Archaeological Resources Protection Act, American Indian Religious Freedom Act).	Impact potential on cultural resources for HLW tank closure options, if any, would be formally evaluated in the context of NEPA.	As noted in DOE's EA for HLW tank closure (DOE 1996c) no adverse impacts to cultural resources is expected to result from proposed closure activities	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
RCRA 40 CFR 262 R.61-79.262	<u>Standards Applicable to Generators of Hazardous Waste</u> - Generators of hazardous waste are required to do the following: • Determine if the waste is hazardous waste and; identify requirements for management of hazardous waste as set forth in §§264, 265, and 268; and obtain an EPA identification number (Subpart A) • Comply with manifest requirements for transport of hazardous waste offsite (Subpart B) • Comply with pre-transport requirements for hazardous waste packaging, labeling, marking, placarding, and accumulation; comply with storage facility requirements of §§264/265 and 270 if hazardous waste is stored for more than 90 days (Subpart C) • Comply with recordkeeping and reporting requirements for hazardous waste generation, offsite transport, treatment, storage, and disposal (Subpart D)	Wastes generated as a result of closure activities described in this module will be characterized and managed in accordance with RCRA generator requirements using the methods and procedures described in Chapters 5 and 6 of this module. Any additional spray wash water, waste removed from the Tank 20 system, and bleed water generated during grouting activities will be conservatively managed to effect RCRA Land Disposal Restrictions (LDR) compliant treatment in the HLW system [F-/H-Area Effluent Treatment Facility (ETF), DWPF, Saltstone Manufacturing and Disposal]. RCRA compliant characterization and management of wastes generated during closure will be ensured via sitewide procedures (including SRS Environmental Compliance Manual, Procedure 3Q; SRS Waste Acceptance Criteria Manual, Procedure 1S; SRS Waste Disposal Manual, WSRC-IM-90-138; SRS Site Treatment Plan, WSRC-TR-94-060) and associated WSRC-HLW procedures as described in Chapter 6.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
RCRA 40 CFR 264.101 (Subpart F) R.61-79.264.101 (Subpart F)	<u>Corrective Action for Solid Waste Management Units</u> - An owner/operator seeking a permit for the treatment, storage, or disposal of hazardous waste must institute corrective action as necessary to protect human health and the environment for all releases of hazardous waste or constituents from any solid waste management unit at the facility, regardless of the time at which the waste was placed in such unit. Corrective action will be specified in the permit application in accordance with this section and subpart S. The owner/operator must implement corrective action beyond the facility property boundary, where necessary to protect human health and the environment, unless he demonstrates that he was unable to obtain the necessary permission to undertake such actions. This section also sets forth standards for monitoring well installation.	DOE will ensure compliance with this requirement by implementing provisions of the approved general closure plan and this module, which have been developed in close coordination with SCDHEC and EPA to ensure consistency with RCRA corrective action requirements as implemented under the FFA. Chapter 7 of this module describes measures DOE will take in the Tank 20 system closure to ensure consistency with these requirements.	A
RCRA 40 CFR 268 R.61-79.268	<u>Land Disposal Restrictions</u> - Specifies standards to which hazardous waste must be treated prior to land disposal and prohibits storage of untreated hazardous waste except under specified conditions. Subpart D sets forth the treatment standards and Subpart E identifies prohibitions on storage applicable to restricted wastes.	RCRA LDR requirements will be met by implementing sitewide plans and procedures and associated WSRC-HLW procedures as described below.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
RCRA 40 CFR 268.40 (Subpart D) R.61-79.268.40 (Subpart D)	<u>Applicability of Treatment Standards</u> - A waste identified in the table "Treatment Standards for Hazardous Wastes" in this section may be land disposed only if it meets the requirements found in the table. For each waste, the table identifies one of three types of treatment requirements: (1) all hazardous constituents in the waste or in the treatment residues must be at or below the levels found in the table ("total waste standards"); (2) the hazardous constituents in the extract of the wastes or the treatment residue must be at or below the levels found in the table ("waste extract standards"); or (3) the waste must be treated using the technology specified in the table ("technology standard"). These standards are established for two types of waste: "wastewaters" which are generally wastes containing less than 1 percent by weight total organic carbon (TOC) and less than 1 percent by weight total suspended solids (TSS) and "nonwastewaters" (§268.2(d) and (f)). The table includes entries specific to certain mixed wastes: "Radioactive high level wastes generated during the reprocessing of fuel rods" (nonwastewaters only) that are D002 or D004-D011 hazardous wastes are subject to the HLVIT standard. "Radioactive lead solids" (nonwastewaters only) that are D008 hazardous wastes are subject to the MACRO standard. "Elemental mercury contaminated with radioactive materials" (nonwastewaters only) that are D009 hazardous wastes are subject to the AMLGM standard.	Hazardous wastes removed from the Tank 20 system or generated as a result of closure activities described in this module will be treated as appropriate to ensure compliance with applicable LDR treatment standards using the methods and procedures described in Chapters 5 and 6 of this module. Any additional spray wash water, waste removed from the Tank 20 system, and bleed water generated during grouting activities will be conservatively managed to effect RCRA LDR compliant treatment in the HLW system (F-/H-Area ETF, DWPF, Saltstone Manufacturing and Disposal). RCRA compliant characterization and management of wastes generated during closure will be ensure via sitewide procedures (including SRS Environmental Compliance Manual, Procedure 3Q; SRS Waste Acceptance Criteria Manual, Procedure 1S; SRS Waste Disposal Manual, WSRC-IM-90-138; SRS Site Treatment Plan, WSRC-TR-94-060) and associated WSRC-HLW procedures.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
RCRA 40 CFR 268.40 (Subpart D) R.61-79.268.40 (Subpart D) (cont.)	In the Third rule, EPA indicated that the HLVIT standard would apply to the "high-level fraction of the mixed waste generated during the reprocessing of fuel rods" exhibiting the characteristics of corrosivity and toxicity for metals (see 55 FR 22627). Incidental wastes associated with HLW tank closure which are also mixed wastes would not require treatment by vitrification, but may nevertheless require treatment in accordance with the applicable LDR treatment standards for any hazardous characteristics, including standards for any underlying hazardous constituents. In addition to a specified technology or waste-specific concentration standard, wastes may also be subject to LDR treatment standards for underlying hazardous constituents set forth in §268.48. For example, a corrosive characteristic waste (D002) would need to be deactivated (i.e., rendered no longer corrosive) and treated to achieve the Universal Treatment Standards (UTS) concentration limits for any underlying hazardous constituents.		
RCRA 40 CFR 268.45 R.61-79.268.45	Treatment Standards for Hazardous Debris - Hazardous debris may be treated in accordance with the waste-specific standards or, alternatively, the debris may be treated in accordance with the standards set forth in Table 1 of this section. The alternative standards for hazardous debris include extraction, destruction, and immobilization technologies. Debris that is treated using one of the specified extraction or destruction technologies, and which does not exhibit a hazardous waste characteristic, is no longer subject to regulation as hazardous waste. Debris that is treated using one of the specified immobilization technologies may be excluded (e.g., debris that, after immobilization, no longer exhibits the characteristic for which the debris was hazardous waste).	Potentially hazardous debris generated as a result of Tank 20 closure activities, if any, may be treated in accordance with waste-specific standards or in accordance with standards set forth in Table 1 of 40 CFR 268.45 in accordance with sitewide plans and procedures as described above. Debris amenable to decontamination in a manner that meets an extraction standard (clean debris surface) may be treated in the SRS 299-H facility which qualifies as a containment building.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
RCRA 40 CFR 268.48 R.61-79.268.48	Universal Treatment Standards - Table UTS in this section identifies the hazardous constituents and their nonwastewater and wastewater treatment standard levels. For determining compliance with the treatment standards for underlying hazardous constituents as defined in §268.2(i), these constituent-specific treatment standards may not be exceeded.	Compliance with LDR treatment standards, including UTS constituents, as required, will be ensured by sitewide plans and procedures and associated WSRC-HLW procedures as described above.	A
RCRA 40 CFR 268.50 (Subpart E) R.61-79.268.50 (Subpart E)	Prohibitions on storage of restricted wastes - Storage of hazardous wastes restricted from land disposal is prohibited unless such storage is in tanks, containers, or containment buildings solely for the purpose of accumulating such quantities of hazardous waste as necessary to facilitate proper recovery, treatment, or disposal.	Compliance with the LDR storage prohibition will be ensured by sitewide plans and procedures and associated WSRC-HLW procedures as described above.	A
Atomic Energy Act (AEA) 10 CFR 834.306(e) (Proposed)	Control and Disposition of Residual Radioactive Material - . . . (4) In the development of controls and waste management plans, where appropriate, the impacts of alternative disposal modes shall be evaluated beyond the 1,000-year design requirement, to 10,000 years. (5) For wastes containing a high specific activity (e.g., $\geq$1 nCi/g) of radium or thorium, alternative disposal methods, such as deep land disposal, protective covers (e.g., riprap), concrete vaults, or geologic repositories that provide additional protection from possible inadvertent intrusion shall be evaluated and employed if justified by potential risk considerations.	DOE evaluated alternative closure configurations for HLW tanks to 10,000 years (general closure plan, Appendix D).	TBC

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA 10 CFR 20.1405(b) (Proposed)	Criteria for License Termination Under Restricted Conditions: A site will be considered acceptable for license termination under restricted conditions if the licensee has made provisions for institutional controls that provide reasonable assurances that the total effective dose equivalent (TEDE) from residual radioactivity distinguishable from background to the average member of the critical group will not exceed 15 mrem (0.15 mSv) TEDE per year. Institutional controls must be enforceable by a responsible government entity or in a court of law in response to suits by affected parties.	DOE will ensure that appropriate land use controls will be established as necessary to ensure that potential doses from residual radioactivity are protective. Results of modeling presented in Appendix A indicate that exposures would be less than the cited limit for the proposed closure configuration under reasonable residential, worker, and intruder scenarios.	TBC
AEA 40 CFR 196.23(c) (Proposed)	Environmental Standards for Groundwater Protection - Compliance with §196.23(a) of this subpart will not be required, if the implementing agency determines compliance to be technically impracticable from an engineering perspective. In this situation, the implementing agencies shall: (1) select active control measures that ensure members of the public will not be exposed to groundwater that is drinking water, in which the levels of radioactivity exceed the limits specified in 40 CFR part 141; (2) select and perform remedial actions that limit to the greatest extent, contamination of groundwater that is not already contaminated, as is reasonable under the circumstances; (3) select and perform remedial actions that restore to the greatest extent, groundwater that is already contaminated, as is reasonable under the circumstances; (4) comply with the public notice and comment requirements of §196.03(a) of subpart A; and (5) comply with the periodic verification requirements of §196.24 of this subpart.	DOE considers these provisions are or will be substantially met for the Tank 20 closure in that: (1) DOE will institute appropriate land use control measures for affected groundwater in excess of radiological limits of 40 CFR 141, (2) has selected a closure configuration for the Tank 20 system that limits to the extent practicable contamination of groundwater (general closure plan, Appendix A; Chapters 4 and 8 of this module), (3, 5) has provided for post closure monitoring and integration with the SRS environmental restoration in accordance with the FFA (Chapter 7), and (4) has incorporated public involvement in the NEPA process.	TBC

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5820.2A, Chapter III, 2.a	<u>Low-Level Waste Management</u> - DOE low-level waste (LLW) operations shall be managed to protect the health and safety of the public, preserve the environment of the waste management facilities, and ensure that no legacy requiring remedial action remains after operations have been terminated.	The Tank 20 system closure as proposed by DOE in this module will comply with this requirement.	A
AEA DOE 5820.2A, Chapter III, 2.b	<u>Low-Level Waste Management</u> - DOE LLW shall be managed on a systematic basis using the most appropriate combination of waste generation reduction, segregation, treatment, and disposal practices so that the radioactive components are contained and the overall system cost effectiveness is maximized.	DOE will ensure compliance with this requirement for the Tank 20 system closure by managing of wastes generated during closure in accordance with sitewide procedures (including SRS Environmental Compliance Manual, Procedure 3Q; SRS Waste Acceptance Criteria Manual, Procedure 1S; SRS Waste Disposal Manual, WSRC-IM-90-138; SRS Site Treatment Plan, WSRC-TR-94-060 and associated WSRC-HLW procedures as described in Chapter 6. DOE's proposed closure configuration (Chapter 4), integration of the closure with soils assessment activities (Chapter 7), and implementation of appropriate land use controls for the long term (Chapter 3).	A
AEA DOE 5820.2A, Chapter III, 2.c	<u>Low-Level Waste Management</u> - DOE LLW shall be disposed of on the site at which it is generated, if practical, or if on-site disposal capability is not available, at another DOE disposal facility.	DOE plans to treat and dispose of all LLW generated as a result of Tank 20 closure operations at SRS treatment and disposal facilities, including F-/H-Area ETF and associated National Pollutant Discharge Elimination System outfall, Saltstone Manufacturing and Disposal Facility, and Solid Waste Disposal Facility in E-Area.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5820.2A, Chapter III, 3.a(1-2)	Low-Level Waste Management - DOE LLW that has not been disposed of prior to issuance of this Order shall be managed on the schedule developed in the Implementation Plan to protect public health and safety in accordance with standards specified in applicable EH Orders and other DOE Orders. . . Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment ALARA.	DOE will ensure compliance with this requirement for the Tank 20 system closure by managing of wastes generated during closure in accordance with sitewide procedures (including SRS Environmental Compliance Manual, Procedure 3Q; SRS Waste Acceptance Criteria Manual, Procedure 1S; SRS Waste Disposal Manual, WSRC-IM-90-138; SRS Site Treatment Plan, WSRC-TR-94-060. Maintaining radiological releases and exposure of workers and the public ALARA is a fundamental principle of SRS operations. DOE will ensure adherence to this principle during implementation of the closure via the SRS Radiological Control Manual (5Q) and WSRC Procedure 3Q ECM 18.2, "Radiological Effluent Monitoring Reporting and ALARA Release Guides," and other procedures as discussed in Chapter 6. DOE considers that the proposed Tank 20 system closure configuration as described in Chapter 4 and evaluated in Chapter 8 implements ALARA in the long term.	A
AEA DOE 5820.2A, Chapter III, 3.i(1)	Low-Level Waste Management - LLW shall be disposed of by methods appropriate to achieve the performance objectives stated in paragraph 3a, consistent with the disposal site radiological performance assessment in paragraph 3b.	DOE will ensure that appropriate land use controls will be established for the long term as necessary to ensure that potential doses from residual radioactivity are protective. Results of the performance evaluation presented in Chapter 8 (based on modeling presented in Appendix A) indicate that exposures would be less than the cited limit for the proposed closure configuration under reasonable residential, worker, and intruder scenarios.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5820.2A, Chapter III, 3.i(2)	Low-Level Waste Management - Engineered modifications (stabilization, packaging, burial depth, barriers) for specific waste types and for specific waste compositions (fission products, induced radioactivity, uranium, thorium, radium) for each disposal site shall be developed through the performance assessment model. In the course of this process, site specific waste classification limits may be developed if operationally useful in determining how specific wastes should be stabilized and packaged for disposal.	The engineered closure configuration proposed for the Tank 20 system closure (Chapter 4) is based on a comparison of alternative configurations (general closure plan) and specific accommodation of Tank 20 waste residuals as determined from specific studies of the grout proposed as fill, and is supported by modeling and a performance evaluation in a manner that substantially meets this requirement.	A
AEA DOE 5820.2A, Chapter III, 3.I(4)	Low-Level Waste Management - Disposition of waste designated as greater-than-class C (GTCC), as defined in 10 CFR 61.55, must be handled as special cases. Disposal systems for such waste must be justified by a specific performance assessment through the NEPA process and with the concurrence of DP-12 for all DP-1 disposal facilities and of NE-20 for those disposal facilities under the cognizance of NE-1.	DOE has justified closure of the Tank 20 system as proposed in this tank-specific closure module on the basis of the performance evaluation discussed in Chapter 8, and has complied with the NEPA process via an Environmental Assessment and issuance of a FONSI (DOE 1996c, 1996d).	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5820.2A, Chapter III, 3.i(5)(a-c)	Low-Level Waste Management - The following disposal requirements are intended either to improve stability of the disposal site or to facilitate handling and provide protection of the health and safety of personnel at the disposal site. Waste must not be packaged for disposal in cardboard or fiberboard boxes, unless such boxes meet Department of Transportation requirements and contain stabilized waste with a minimum of void space. For all types of containers, void spaces within the waste and between the waste and its packaging shall be reduced as much as practical. Liquid wastes, or wastes containing free liquid, must be converted into a form that contains as little freestanding and noncorrosive liquid as is reasonably achievable, but, in no case, shall the liquid exceed 1 percent of the volume of the waste when the waste is in a disposal container, or 0.5 percent of the volume of the waste processed to a stable form. Additionally, waste must not be readily capable of detonation or of explosive decomposition or reaction at normal pressures and temperatures or of explosive reaction with water.	Tank 20 system waste residuals to be left in place at closure do not exhibit the cited characteristics.	A
AEA DOE 5820.2A, Chapter III, 3.i(5)(d-e)	Low-Level Waste Management - Waste must not contain, or be capable of generating quantities of toxic gases, vapors, or fumes harmful to persons transporting, handling, or disposing of the waste. This does not apply to radioactive gaseous waste packaged at a pressure that does not exceed 1.5 atmospheres at 20 degrees centigrade.	Tank 20 system waste residuals to be left in place at closure do not exhibit the cited characteristics.	A
AEA DOE 5820.2A, Chapter III, 3.i(5)(f)	Low-Level Waste Management - Waste must not be pyrophoric. Pyrophoric materials contained in waste shall be treated, prepared, and packaged to be nonflammable.	Tank 20 system waste residuals to be left in place at closure do not exhibit the cited characteristics.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5820.2A, Chapter III, 3.i(8)(b)	Low-Level Waste Management - Disposal units shall be designed consistent with disposal site hydrology, geology, and waste characteristics and in accordance with the NEPA process.	DOE has designed the Tank 20 system closure in consideration of site hydrology, geology, and waste characteristics as documented in this closure module, and in accordance with NEPA as evidenced by DOE's preparation of an EA for HLW tank closure and issuance of a FONSI (DOE 1996c, 1996d).	A
AEA DOE 5820.2A, Chapter III, 3.i(9)(b)	Low-Level Waste Management - Permanent identification markers for disposal excavations and monitoring wells shall be emplaced.	DOE will ensure that installation of permanent markers and monitoring wells will be emplaced in accordance with this requirement as part of post-closure activities.	A
AEA DOE 5820.2A, Chapter III, 3.i(9)(d)	Low-Level Waste Management - Waste placement into disposal units should minimize voids between containers.	Tank 20 system waste residuals to be left in place are not containerized.	A
AEA DOE 5820.2A, Chapter III, 3.j(2)	Low-Level Waste Management - During closure and post closure, residual radioactivity levels for surface soils shall comply with existing DOE decommissioning guidelines.	The proposed Tank 20 system closure configuration will preclude contamination of surface soils by use of grout fill and, depending on the final remediation scheme for the HLW tank farms to be decided in accordance with the FFA, substantial cover (e.g., soil backfill and clay cap). No soil contamination is expected to result from implementation of the closure. Any radioactive contaminant spills that occur during closure would be cleaned up and any resulting contamination would be remediated in accordance with the SRS Spill Prevention Control and Countermeasure (SPCC) Plan and procedures established under the FFA. Existing soil contamination would be remediated under the FFA as discussed in Chapter 7 of this module.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5820.2A, Chapter III, 3.j(4)	Low-Level Waste Management - Inactive disposal facilities, disposal sites, and disposal units shall be managed in conformance with RCRA, CERCLA, and Superfund Amendments and Reauthorization Act (SARA), or, if mixed waste is involved, may be included in permit applications for operation of contiguous disposal facilities.	Compliance of the proposed Tank 20 system closure with this requirement is achieved by the integration of these activities with RCRA/CERCLA compliant remediation of the site under the FFA as described in the general closure plan and Chapter 7 of this module.	A
AEA DOE 5400.5, Chapter II, 1.a(4)(a)	Dose Limits - Operations Office may request from EH-1, specific authorization for a temporary public dose limit higher than 100 mrem (1 mSv), but not to exceed 500 mrem (5 mSv), for the year.	As noted in Chapter 8 of this module, DOE does not expect that dose to the public as a result of the Tank 20 closure would exceed 100 mrem/yr under the proposed closure configuration and reasonable land use controls to be established by DOE.	A
AEA DOE 5400.5, Chapter II, 5.a	Residual Radioactivity - Release of real property (land and structures) shall be in accordance with the guidelines and requirements for residual radioactive material presented in Chapter IV. These guidelines and requirements apply to both DOE-owned facilities and to private properties that are being prepared by DOE for release. Real properties owned by DOE that are being sold to the public are subject to the requirements of Section 120(h) of CERCLA, as amended, concerning hazardous substances, and to any other applicable Federal, state, and local requirements. The requirements of 40 CFR 192 are applicable to properties remediated by DOE under Title I of the Uranium Mill Trailings Remedial Action Program (UMTRA).	See specific entries below for conformance assessment with respect to these provisions. DOE does not currently contemplate release of property potentially affected by the Tank 20 system closure. DOE will ensure appropriate land use controls are established for the long term as necessary to ensure that potential doses from residual radioactivity are protective, and would comply with requirements of CERCLA 120(h) or other comparable requirement in effect in the event affected property is sold.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5400.5, Chapter IV, 5.a	Residual Radioactivity - The authorized limits for each property shall be set equal to the generic or derived guidelines unless it can be established, on the basis of specific property data (including health, safety, practical, programmatic and socioeconomic considerations), that the guidelines are not appropriate for use at the specific property. The authorized limits shall be established to (1) provide that, at a minimum, the basic dose limits in paragraph IV.3, will not be exceeded under the "worst-case" or "plausible-use" scenarios, consistent with the procedures and guidance provided in DOE/CH-8901, or (2) be consistent with applicable generic guidelines. The authorized limits shall be consistent with limits and guidelines established by other applicable Federal and state laws. The authorized limits are developed through the project offices in the field and are approved by the Headquarters Program Office.	The applicable generic or derived guideline as set forth in DOE Order 5400.5 is 100 mrem/yr, all pathways, with additional requirements to comply with federal and state laws applicable to air and water. For purposes of closure of HLW tank systems, DOE considers that the performance standard relating to protection of water resources will be compliance with these standards at the seeplines, and will establish appropriate land use controls to ensure protectiveness with respect to upgradient groundwater resources.	
AEA DOE 5400.5, Chapter IV, 5.b	Residual Radioactivity - Remedial action shall not be considered complete until the residual radioactive material levels comply with the authorized limits, except as authorized pursuant to paragraph IV.7 for special situations where the supplemental limits and exceptions should be considered and it is demonstrated that it is not appropriate to decontaminate the area to the authorized limit or guideline value.	The applicable generic or derived guideline as set forth in DOE Order 5400.5 is 100 mrem/yr, all pathways, with additional requirements to comply with federal and state laws applicable to air and water. For purposes of closure of HLW tank systems, DOE considers that the performance standard relating to protection of water resources will be compliance with these standards at the seeplines, and will establish appropriate land use controls to ensure protectiveness with respect to upgradient groundwater resources.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5400.5, Chapter IV, 6.b(1)	Residual Radioactivity - Control and stabilization features shall be designed to provide, to the extent reasonably achievable, an effective life of 50 years with a minimum life of at least 25 years.	As discussed in the general closure plan, Appendix D, DOE expects the selected closure alternative, the configuration proposed for the Tank 20 Closure, to be stable for at least 1000 years. DOE has included an upper layer of "strong grout" in the fill for this design configuration to discourage penetration of the closed tank (Chapter 4) and will ensure appropriate land use controls are established to minimize unauthorized public access or use of the area that may breach this containment.	A
AEA DOE 5400.5, Chapter IV, 6.b(4)	Residual Radioactivity - Access to a property and use of onsite material contaminated by residual radioactive material should be controlled through appropriate administrative and physical controls such as those described in 40 CFR Part 192. These control features should be designed to provide, to the extent reasonable, an effective life of at least 25 years.	As discussed in the general closure plan., Appendix D, DOE expects the selected closure alternative , the configuration proposed for the Tank 20 Closure, to be stable for at least 1000 years. DOE has included an upper layer of "strong grout" in the fill for this design configuration to discourage penetration of the closed tank (Chapter 4) and will ensure that appropriate land use controls are established for the long term as necessary to ensure that potential doses from residual radioactivity (e.g., groundwater contamination) are protective. Results of the performance evaluation presented in Chapter 8 (based on modeling presented in Appendix A) indicate that exposures would be less than the cited limit for the proposed closure configuration under reasonable residential, worker, and intruder scenarios.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5400.5, Chapter IV, 6.c	<u>Interim Management</u> - A property may be maintained under an interim management arrangement when the residual radioactive material exceeds the guideline values if the residual radioactive material is in accessible locations and would be unreasonably costly to remove provided that administrative controls are established by the responsible authority (Federal, state, or local) to protect members of the public and that such controls are approved by the appropriate Program Assistant Secretary or Director. The administrative controls include but are not limited to periodic monitoring as appropriate; appropriate shielding; physical barriers to prevent access; and appropriate radiological safety measures during maintenance, renovation, demolition, or other activities that might disturb the residual radioactive material or cause it to migrate. The owner of the property should be responsible for implementing the administrative controls, and cognizant Federal, state, and local authorities should be responsible for enforcing them.	DOE does not currently contemplate release of property potentially affected by the Tank 20 system closure. However, DOE will ensure appropriate land use controls are established for the long term as necessary to ensure that potential doses from residual radioactivity are protective. In the event an interim management arrangement is undertaken in regard to affected property, DOE would obtain the necessary DOE approvals in effect at that time.	A

Table 9-1. (continued)

Citation	Requirement/Guidance Summary	Conformance Assessment	Requirements/ Guidance Category[b]
AEA DOE 5400.5, Chapter IV, 6.d(1)	Residual Radioactivity - For uranium, thorium, and their decay products: (a) Control and stabilization features shall be designed to provide, to the extent reasonably achievable, an effective life of 1,000 years with a minimum life of at least 200 years . . . (c) Before any potentially biodegradable contaminated wastes are placed in a long-term management facility, such wastes shall be properly conditioned so that the generation and escape of biogenic gases will not cause the requirement in paragraph IV.6d(1)(b) to be exceeded and that biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph IV.6d(1)(a) . . . (e) Access to a property and use of onsite material contaminated by residual radioactive material should be controlled through appropriate administrative and physical controls such as those described in 40 CFR, Part 192. These controls should be designed to be effective to the extent reasonable for at least 200 years.	Tank 20 residual waste to be left in place at closure is not biodegradable and does not include appreciable amounts of uranium, thorium, or their byproducts. However, as discussed in the general closure plan, Appendix D, DOE expects the selected closure alternative , the configuration proposed for the Tank 20 Closure, to be stable for at least 1,000 years. DOE has included an upper layer of "strong grout" in the fill for this design configuration to discourage penetration of the closed tank (Chapter 4) and will ensure appropriate land use controls are established to minimize unauthorized public access or use of the area that may breach this containment and otherwise ensure that potential doses from residual radioactivity (e.g., groundwater contamination) are protective.	A
AEA DOE 5400.5, Chapter IV, 7	Residual Radioactivity - If specific property circumstances indicate that the guideline or authorized limits established for a given property are not appropriate for any portion of that property. supplemental limits or an exception may be requested. Any supplemental limits shall achieve the basic dose limits set forth in Chapter II of this Order for both current and potential unrestricted uses of a property. Exceptions to the authorized limits defined for a property may be applied to any portion of the property when it is established that the authorized limits cannot reasonably be achieved and that restrictions on use of the property are necessary. It shall be demonstrated that the exception is justified and that the restrictions will protect members of the public within the basic dose limits of this Order.	The applicable generic or derived guideline as set forth in DOE Order 5400.5 is 100 mrem/yr, all pathways, with additional requirements to comply with federal and state laws applicable to air and water. For purposes of closure of HLW tank systems, DOE considers that the performance standard relating to protection of water resources will be compliance with these standards at the seeplines, and will establish appropriate land use controls to ensure protectiveness with respect to upgradient groundwater resources.	A

Table 9-1. (continued)

a. Entries in this table include applicable requirements, relevant and appropriate guidance, and To-Be-Considered materials as listed in Table C-3 of the general closure plan (DOE 1996a), except those expressed as numerical performance standards (separately listed in Tables C-4, C-5, and C-6 of the general closure plan) and those pertinent to high level or transuranic wastes.

b. Categories are defined as follows:
   - A = Applicable (Substantive Federal and State environmental protection requirements, criteria, or limits that directly apply to SRS high-level waste tank system closure operations.)
   - RA = Relevant and Appropriate (Substantive Federal and State environmental protection requirements, criteria, or limits which, while not directly applicable, are judged to be well suited for use for SRS high-level waste tank system closure operations based on their applicability to similar operations.)
   - TBC = To-be-Considered Materials (Advisories, guidance, proposed rules and the like issued by Federal or State government that are not legally binding, but which are judged to be useful in establishing environmental protection protocols and performance objectives or in evaluating closure options with respect to protectiveness of human health and the environment.)

9.10 References

CAB (SRS Citizen Advisory Board), 1996, Recommendation No. 15 regarding Savannah River Site High-Level Waste Tank Farm Closure, January 23.

DOE (U.S. Department of Energy), 1996a, *Industrial Wastewater General Closure Plan for F- and H-Area High-Level Waste Tank Systems, Savannah River Site, Construction Permit Numbers 14,338, 14,520, 17,424-IW*, Revision 1, Savannah River Operations Office, Aiken, South Carolina, July 10.

DOE (U.S. Department of Energy), 1996b, *High-Level Waste Tank Closure Program Plan*, Rev. 0, Savannah River Operations Office, Aiken, South Carolina, December 16.

DOE (U.S. Department of Energy), 1996c, *Environmental Assessment for the Closure of the High-Level Waste Tanks in F- & H-Areas at the Savannah River Site*, DOE/EA-1164, Savannah River Operations Office, Savannah River Site, July.

DOE (U.S. Department of Energy), 1996d, *Finding of No Significant Impact for the Closure of the High-Level Waste Tanks in F- and H-Areas at the Savannah River Site*, U.S. Department of Energy, Savannah River Operations Office, July 31.

EPA (U.S. Environmental Protection Agency), 1993, *Federal Facility Agreement between the U.S. Environmental Protection Agency Region IV, the U.S. Department of Energy, and the South Carolina Department of Health and Environmental Control*, Docket No 89-05-FF, August 16.

SCDHEC (South Carolina Department of Health and Environmental Control), 1996, letter from M. G. Vickers to J. W. Cook approving the Closure Plan for the Savannah River Site F- and H-Area High-Level Waste Tank Systems, July 31.

APPENDIX A

FATE AND TRANSPORT MODELING

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APPENDIX A. FATE AND TRANSPORT MODELING

This appendix describes the methodology and results of the fate and transport modeling that the U.S. Department of Energy (DOE) performed to support the closure of high-level waste (HLW) Tank 20 at the Savannah River Site (SRS). This modeling estimates potential human health and ecological impacts of residual contamination remaining in Tank 20 after closure. It also estimates the groundwater concentrations and dose levels at the groundwater outcropping (seepline), which is the established point of exposure.

The modeling assumed (1) institutional control for 100 years and subsequent industrial land use; (2) the area immediately around the F-Area Tank Farm remains in commercial/industrial use for the entire 10,000-year period of analysis; (3) the area of commercial/industrial land use extends between Fourmile Branch and Upper Three Runs in the vicinity of the F-Area Tank Farm.

Potential impacts to the following receptors were analyzed:

- *Worker*: an adult who has authorized access to, and works at, the tank farm and surrounding areas but is considered to be a member of the public for compliance purposes. This analysis assumes that the worker remains on the shores of Fourmile Branch or Upper Three Runs during working hours.

- *Intruder*: a teenager who gains unauthorized access to the F-Area Tank Farm and is potentially exposed to contaminants.

- *Nearby adult resident*: an adult who lives in a dwelling across Fourmile Branch downgradient of the F-Area Tank Farm, near the location of the seepline.

- *Nearby child resident*: a child who lives in a dwelling across Fourmile Branch downgradient of the F-Area Tank Farm, near the location of the seepline.

For informational purposes, concentration and dose levels were also calculated at 1 meter and 100 meters downgradient from the edge of F-Area Tank Farm.

The identity and level of residual contaminants in Tank 20 were derived from data provided in d'Entremont (1996a). The calculated impacts from the residual contamination in this tank can be used in conjunction with results from modeling of other sources in the Groundwater Transport Segment to account for Tank 20 impacts against the GTS performance objectives as discussed in Chapter 8.

A.1 Analyzed Scenario

In the analyzed scenario, the mobile contaminants in the tank will gradually migrate downward through unsaturated soil to the hydrogeologic units comprising the Shallow Aquifer underlying the F-Area Tank Farm. The first hydrogeologic unit encountered will be the Water Table Aquifer. Some contaminants will be transported by groundwater through the Water Table Aquifer to the seepline and subsequently to Fourmile Branch. Upon reaching the surface water, the contaminants will contaminate the seepline, sediments at the bottom of Fourmile Branch, and the shoreline. Aquatic organisms in the streams and plants along the shoreline will become exposed to the contaminants. Terrestrial organisms might ingest the contaminated vegetation and obtain their drinking water from the contaminated stream. Human receptors could be exposed to contaminants through various pathways associated with the surface water.

Due to vertical leakage through the Tan Clay layer, a portion of the contaminants will migrate further downward into the underlying Barnwell-McBean Aquifer which predominantly discharges along Fourmile Branch. These contaminants will affect organisms and human receptors in and along Fourmile Branch in the same manner as those contaminants transported through the Water Table Aquifer.

Variability in the Green Clay layer underlying the Barnwell-McBean Aquifer results in flow from the Barnwell-McBean down to the Congaree Aquifer. Thus, a portion of those contaminants reaching the Barnwell-McBean Aquifer will move further downward into the Congaree Aquifer which predominantly discharges along Upper Three Runs. However, since there is minimal interchange between these two aquifers and the volume of water in the Congaree is quite large, impacts to humans and aquatic and terrestrial organisms at this location will be negligible. More details on the hydrogeology of the tank farm area can be found in Appendix E of the High-Level Waste Tank Closure Program Plan (DOE 1996a).

The closure scenario assumes that the tank will be filled with grout and no engineered structures will be used to reduce the infiltration of rain water. Based on the E-Area Vaults radiological performance assessment (WSRC 1994a), the concrete tank structure could enter a period of degraded performance due to cracking at around 1,400 years. Assuming that the approximately 34 feet of grout continues to support the tank roof and provide an additional barrier to infiltration for an indefinite period of time [Z-Area radiological performance assessment (WSRC 1992)], water infiltration should occur much later than

1,400 years. For this scenario, the conservative assumption is made that the tank top, grout, and basemat will fail at 1,000 years, with a corresponding increase in their respective hydraulic conductivities.

Previous modeling of tank closure scenarios (DOE 1996b) has demonstrated that placing a cap over a grout-filled tank has little effect on the magnitude of the impact at the point of exposure. The cap does succeed in detaining the movement of contaminants until failure of the cap occurs. Thus, impacts due to leaching contaminants from a grout-filled tank with a cover can be assumed to be the same as for a grout-filled tank with no cover but occurring later in time. For this reason, separate modeling runs were not performed for a closure with an engineered cover. Impacts can be assumed to be equivalent to those from the analyzed scenario but separated by 500 years.

A.2 Methodology

A.2.1 HUMAN HEALTH ASSESSMENT

A.2.1.1 General Methodology

Utilizing the Multimedia Environmental Pollutant Assessment System (MEPAS) computer code (Droppo et al. 1995), a multipathway risk model developed by Pacific Northwest Laboratory, this assessment performed calculations to assess the impacts of the leaching of contaminants to the groundwater for the tank closure scenario. To model the grout-filled tank, an infiltration rate was selected that represents the vertical moisture flux passing through the tank bottom. The infiltration rate depends on the chemical and physical characteristics of the tank and the fill material.

Based on the calculated inventories of chemical and radioactive contaminants remaining after bulk waste removal and spray washing in the tank (d'Entremont 1996a), the model was set up to simulate the transport of contaminants from the contaminated zone (residual waste layer), through the concrete basemat, the vadose zone directly beneath the basemat, and into the underlying Shallow Aquifer. As previously stated, the Shallow Aquifer is comprised of three interacting aquifers, the Water Table, the Barnwell-McBean, and the Congaree. Model runs were completed for contaminant transport through each of these aquifers for both early (before failure) and late (after failure) conditions.

Modeling was also performed for contaminants remaining in the ancillary equipment and piping above the tank. In this calculation, the piping and equipment were considered to be the contaminated zone while the partially saturated (vadose) zone was defined as the layer of soil extending from the surface to the saturated zone.

For both the Water Table and Barnwell-McBean Aquifers, calculated contaminant concentrations, dose levels, and peak times of occurrence are provided at 1 meter and 100 meters downgradient from the edge of the F-Area Tank Farm, at the seepline, and at Fourmile Branch for the receptors discussed in Section A.2.1.2. Results for the Congaree Aquifer are reported at the seepline of Upper Three Runs.

A.2.1.2 Receptors

Potential receptors and exposure pathways are identified in the following sections and illustrated in Figure A-1.

Worker

The worker is assumed to be in the area including and surrounding the F-Area Tank Farm. Because institutional controls are in place, the potential for exposure of the worker to the primary source (residual at the bottom of the tanks) will be minimal due to the barrier provided by the cover over the tank, the structural integrity of the tank, the lack of any industrial work over the tanks, and safety measures that DOE will take to reduce potential exposure further. Therefore, this analysis assumes that the worker is constantly at the nearest place where contaminants will be accessible (i.e., on the banks of Fourmile Branch or Upper Three Runs as part of his work duties). The assumption is conservative because the worker has a greater potential for exposure to contaminants at the seepline. For compliance purposes, the worker is assumed to be a member of the public at all points in time, which means the dose limits applicable to members of the public will be applied to the worker. However, the fact that he is a worker limits, and hence, eliminates pathways that might be considered if he were considered a resident. The potential exposure pathways for the seepline worker are:

- Direct irradiation from shoreline deposits (radioactive contaminants only)
- Incidental ingestion of the soil from shoreline deposits
- Dermal contact with dust from shoreline deposits

The assessment did not evaluate exposure from the inhalation of resuspended soil because the soil conditions at the seepline (i.e., the soil is very damp) are such that the amount of soil resuspended and potentially inhaled would be minimal.

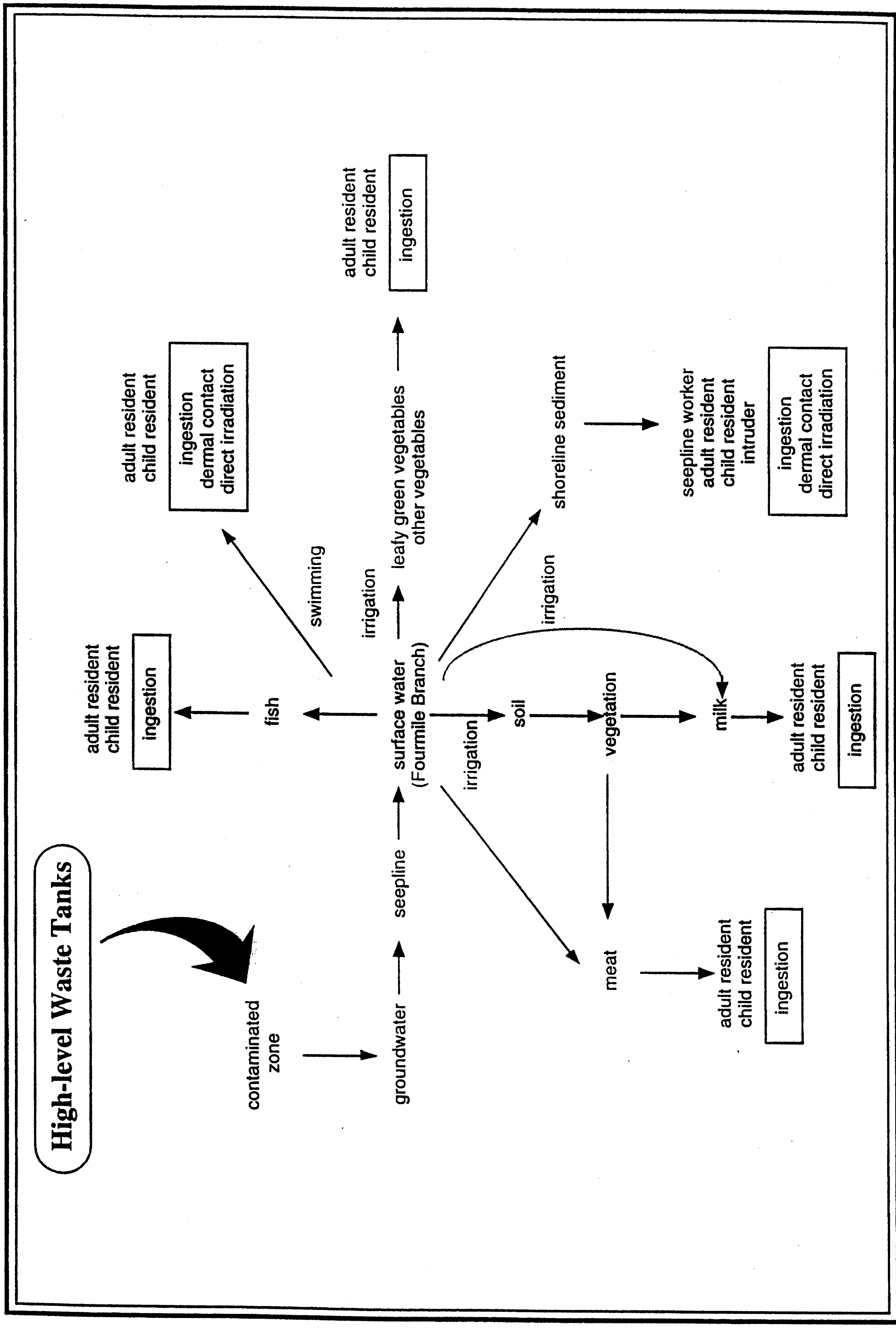

Figure A-1. Potential exposure pathways for human receptors.

Intruder

Another potential receptor is the intruder, a person who gains unauthorized access to the tank farm site and becomes exposed to the contaminants. The intruder scenario is analyzed as if institutional controls have ceased. Because the intruder will not have residential habits, he will not have exposure pathways similar to those of a resident (the intruder does not build a house, grow produce, etc.); rather, the intruder could be exposed to the same pathways as the seepline worker but for a shorter duration (4 hours per day, as noted in Section A.3.2.5).

Nearby Adult Resident/Nearby Child Resident

Nearby residents could be exposed to contaminants from the F-Area Tank Farm. Under this scenario, members of the public are assumed to construct a dwelling near (but outside) the tank farm and surrounding industrial land use area. The dwelling is assumed to be downgradient near Fourmile Branch on the side opposite the F-Area Tank Farm 100 meters downstream of the groundwater outcropping in Fourmile Branch. The residents of this dwelling will include adults and children. The adult resident will be modeled separately from the child because of different body weights and consumption rates. A residential scenario was not analyzed for Upper Three Runs since the impacts from Fourmile Branch are greater and thus more limiting, as evidenced by the results at the seeplines.

The resident is assumed to use Fourmile Branch for recreational purposes; to grow and consume produce irrigated with water from Fourmile Branch; to obtain milk from cows raised on the residential property; and to consume meat from cattle that was fed contaminated vegetation from the area. Therefore, the potential exposure pathways for both the nearby adult and nearby child resident would be the following:

- Incidental ingestion of contaminated soil from shoreline deposits
- Inhalation of contaminated soil from shoreline deposits
- Direct irradiation from shoreline (radioactive contaminants only)
- Direct irradiation from surface water (radioactive contaminants only - recreation)
- Dermal contact with surface water
- Incidental ingestion of surface water
- Ingestion of contaminated meat
- Ingestion of produce grown on contaminated soil irrigated with water from Fourmile Branch
- Ingestion of milk from cows that are fed contaminated vegetation
- Ingestion of aquatic foods (e.g., fish) from Fourmile Branch

Atmospheric Pathway Receptors

The analyzed scenario does not present a credible mechanism for material to be released from the tank to the atmosphere. Therefore, the direct transport of material via the atmospheric pathway was not analyzed.

A.2.1.3 Computational Code

Groundwater and surface-water concentrations and human health impacts were calculated using the MEPAS computer code. MEPAS integrates source term, transport, and exposure models for contaminants. In the MEPAS code, contaminants are transported from a contaminated area to potential human receptors through various transport pathways (groundwater, surface water, soils, food, etc.). Human receptors receive doses, both chemical and radiation, through exposure or intake routes (ingestion, dermal contact, inhalation, etc.) and numerous exposure pathways (drinking water, leafy vegetables, meat, etc.).

MEPAS includes models that estimate human health impacts from radiation exposure (radionuclides and direct radiation), carcinogenic chemicals, and noncarcinogenic chemicals. Health effects resulting from radiation and radionuclide exposures are calculated as annual dose (mrem/yr). Cancer incidence rates are calculated for carcinogens.

The MEPAS code is widely used and accepted throughout the DOE complex and has been presented to and accepted by regulatory agencies, such as the U.S. Environmental Protection Agency (EPA). Examples of its use by DOE include the EH-Environmental Survey Risk Assessment and the Complex-Wide Programmatic Waste Management EIS Impact Analysis. This code has been used to demonstrate environmental impacts in Resource Conservation and Recovery Act (RCRA)-Subpart X permit applications to various EPA regions; these analyses were accepted and permits based on them were issued.

A.2.1.4 Calculational Methodology

The modeling results presented in this appendix are based on the amount of contaminants remaining in Tanks 20 after bulk waste removal and spray washing. The inventory assumed is based on 1,000 gallons of residual solids remaining in the tank (d'Entremont 1996a). For purposes of modeling, the inventory is distributed over a square with area corresponding to that of the tank bottom. The results can generally be scaled to differing amounts of residual contaminants in a tank.

Because MEPAS was not specifically designed to model rainwater runoff efficiencies afforded by engineered caps or thick covers such as the grout fill, analyses were performed specifying infiltration rates that relate to the closure scenario. For example, an infiltration rate of 2 centimeters per year relates to an intact engineered cap such as those previously designed and evaluated at SRS (WSRC 1993). Since the grout fill in this closure scenario would hinder infiltration but to a lesser degree than a grout and cap combination, an infiltration rate of 4 centimeters per year was chosen to represent before failure conditions. Similarly, an infiltration rate of 40 centimeters per year (average infiltration rate for SRS soils) would correspond to the infiltration rate occurring after grout and basemat failure (WSRC 1994a).

MEPAS runs were performed for early (before structural failure) and late (after structural failure) conditions for Tank 20. As previously discussed, a failure time was assumed based on the anticipated performance of the tank fill material and concrete basemat. Failure would be catastrophic: that is, the tank fill and basemat would fail simultaneously. For modeling purposes, failure was simulated by increasing the infiltration rate to 40 cm/yr and increasing the hydraulic conductivity of the concrete basemat to that of sand. Because radionuclide and chemical pollutants could leach though imperfections in the concrete before catastrophic failure occurs, the original source term was reduced by an amount equal to the quantities released to the Water Table Aquifer during the prefailure period. In addition, radionuclides continually decay, further diminishing the source term. Thus, for late runs, in addition to changing the infiltration rates and hydraulic conductivities, the source term concentrations were adjusted to reflect losses and decay occurring before failure.

In the groundwater transport pathway, infiltration causes leaching of pollutants from the tank through distinct media below the waste unit down to the groundwater in the three uppermost aquifers. To model the movement of the pollutants from the waste unit to the aquifers, MEPAS requires identification of the distinct strata that the pollutants encounter.

To model Tank 20, the residual solids remaining at the bottom of the tank were considered to be the contaminated zone.. Between the contaminated zone and the Water Table Aquifer, two discernible layers were identified: the concrete basemat of the tank and the unsaturated (vadose) zone. Parameters describing the concrete layer were defined for both pre- and postfailure conditions because values for such parameters as porosity, field capacity, and hydraulic conductivity change with degradation state. Flow through the vadose zone is complicated in that movement varies with soil-moisture content and wetting and drying conditions. Therefore, soil parameters values (e.g., density, porosity) for the Water Table Aquifer were conservatively used to describe the unsaturated zone.

Once contaminants reach the Water Table Aquifer, they may follow one of three possible routes: (1) they will be transported through the water table and outcrop at the seepline and Fourmile Branch; (2) they will leak from the Water Table Aquifer through the underlying Tan Clay layer into the Barnwell-McBean Aquifer which also outcrops at the seepline and Fourmile Branch; or (3) they will continue downward from the Barnwell-McBean Aquifer though the Green Clay layer, into the Congaree, and appear in Upper Three Runs.

The total flux to each aquifer indicates the distribution of contaminants among the three aquifers. Hydrologic studies (WSRC 1994b) indicate that the water budget or percent flow to each aquifer below the F- and H-Tank Farm areas is 31 percent to the Water Table Aquifer, 65 percent to the Barnwell-McBean Aquifer, and 4 percent to the Congaree Aquifer. Thus, 31 percent of the leachate from Tank 20 will remain in the Water Table Aquifer, while 65 percent is transferred through the Barnwell-McBean Aquifer, and 4 percent will reach the Congaree Aquifer.

In MEPAS, only one of these groundwater paths may be analyzed at a time; thus, three separate runs were performed both for early and late conditions. In MEPAS, the aquifer being analyzed in a particular run is considered to be the saturated zone; all the layers between the contaminated zone and this saturated zone are recognized by the code as partially saturated zones. For example, in modeling contaminant transport through the Barnwell-McBean Aquifer, the Barnwell-McBean is identified as the saturated zone while the concrete basemat, vadose zone, Water Table Aquifer, and Tan Clay layer are all modeled as partially saturated zones. Thus, depending on whether an aquifer is being recognized as the saturated zone or a partially saturated zone for a particular run, parameters may change or additional ones may be necessary. The parameters used for modeling the various strata in the model are further discussed in Section A.3.2.

For each of the eight layers modeled (contaminated zone, concrete basemat, vadose zone, Water Table Aquifer, Tan Clay layer, Barnwell-McBean Aquifer, Green Clay layer, and Congaree Aquifer), surface distribution coefficients, K_ds, were selected for each radionuclide and chemical. Because distribution coefficients are a chemical property, the K_d values were not changed for degraded or failed materials. The identification and derivation of the K_d values is described in Section A.3.2.1.

As contaminants are transported from the contaminated zone to the seepline, they are dispersed longitudinally (along the streamline of fluid flow), vertically, and transversely (out sideways) by the transporting medium. MEPAS incorporates longitudinal dispersivity of pollutants moving downward through the partially saturated zone layers (i.e., concrete basemat and vadose zone) into concentration calculations. In the saturated zone, MEPAS includes into concentration calculations the three-dimensional dispersion along the length of travel. Dispersion distances were calculated through each of the layers encountered by the contaminants. As expected, dispersion increases with longer travel distances.

Groundwater concentrations and doses due to ingestion of water were calculated at hypothetical wells at 1 meter and 100 meters downgradient from the edge of the F-Area Tank Farm, at the seeplines of Fourmile Branch and Upper Three Runs, and in Fourmile Branch. No human receptors would be exposed to the groundwater pathway at these locations, but the calculations were performed for information purposes.

Impacts to adult and child residential receptors were evaluated at a point 100 meters downstream of the groundwater outcropping in Fourmile Branch. The concentrations of contaminants in Fourmile Branch were also calculated. Based on the dimensions, flow rate, and stream velocity of Fourmile Branch, MEPAS accounts for the mixing of the contaminant-containing water from the aquifer with stream water and other groundwater contributions. For both adult and child residents, ingestion rates were based on site-specific parameters. Parameters and associated assumptions used in calculating human impacts are presented in Section A.3.2.5.

In addition to Tank 20, MEPAS runs were performed to determine the impacts of residual pollutants contained in ancillary equipment and piping. The piping and other outside equipment were assumed to be filled with grout (where possible). For modeling in MEPAS, the ancillary equipment was considered to be the contaminated zone, and the entire distance between the contaminated zone and the saturated zone was characterized as one layer of typical SRS soil. Therefore, no credit was taken for the additional reduction of leachate afforded by the tank structure in its closed configuration, thus, providing conservative results.

A.2.2 ECOLOGICAL RISK ASSESSMENT

A.2.2.1 General Methodology

Several potential scenarios were considered for assessing ecological risks associated with tank closure. These included contamination of runoff water during rainstorms, soil contamination from air emissions following tank collapse, and contamination of groundwater. Inspection showed that the tank tops are considerably (4 to 7 meters) below the surrounding, original land surface. Therefore, runoff or soil contamination was not a reasonable assumption. Groundwater contamination was selected to be the basis of the analyzed scenario, which includes seepage of the groundwater at a downgradient outcrop (seepline) and subsequent mixing in Fourmile Branch. The groundwater pathway, together with potential routes of entry into ecological receptors, is shown in the conceptual site model (Figure A-2).

The habitat in the vicinity of the seepline is bottomland hardwood forest, which grades into marsh around the channels of Fourmile Branch and its tributaries. On the upslope side of the bottom land, the forest becomes a mixture of pine and hardwood.

The analyzed scenario includes potential impacts to terrestrial receptors at the seepline and aquatic receptors in Fourmile Branch. For the assessment of risk due to toxicants, the aquatic receptors are treated as a group because water quality criteria have been derived for protection of aquatic life in general.

These criteria, or equivalent values, are used as threshold concentrations. For the radiological risk assessment, the redbreast sunfish was selected as an indicator species due to its abundance in Fourmile Branch.

There are no established criteria for the protection of terrestrial organisms from toxicants. Receptor indicator species are usually selected for risk analysis and the results extrapolated to the populations, communities, or feeding guilds (e.g., herbivores, predators) they represent. Two terrestrial animal receptors, the southern short-tailed shrew and the mink, were selected in accordance with EPA Region IV guidance, which calls for investigation of small animals with small home ranges. The guidance also calls for investigation of predators when biomagnifying contaminants are being studied, such as mercury. The southern short-tailed shrew is small and one of the most common mammals on the SRS; the mink is a small-bodied predator associated with waterways. These indicator species are also used in the radiological assessment.

The seepage area is estimated to be small, about 0.5 hectare, so risk to plant populations would be negligible even if individual plants were harmed. The only case in which harm to individual plants might be a concern in such a small area would be if protected plant species are inhabitants. Because no protected species were seen or are known to live in this area, risks to terrestrial plants are not treated further in the risk assessment.

The following exposure pathways were chosen for calculating absorbed radiation dose to the terrestrial mammals of interest (shrew and mink) located on or near the seepline: ingestion of food (earthworms, slugs, insects and similar organisms for the shrew, and shrews for the mink); ingestion of soil; and ingestion of water. The following exposure pathways were chosen for calculating absorbed dose to

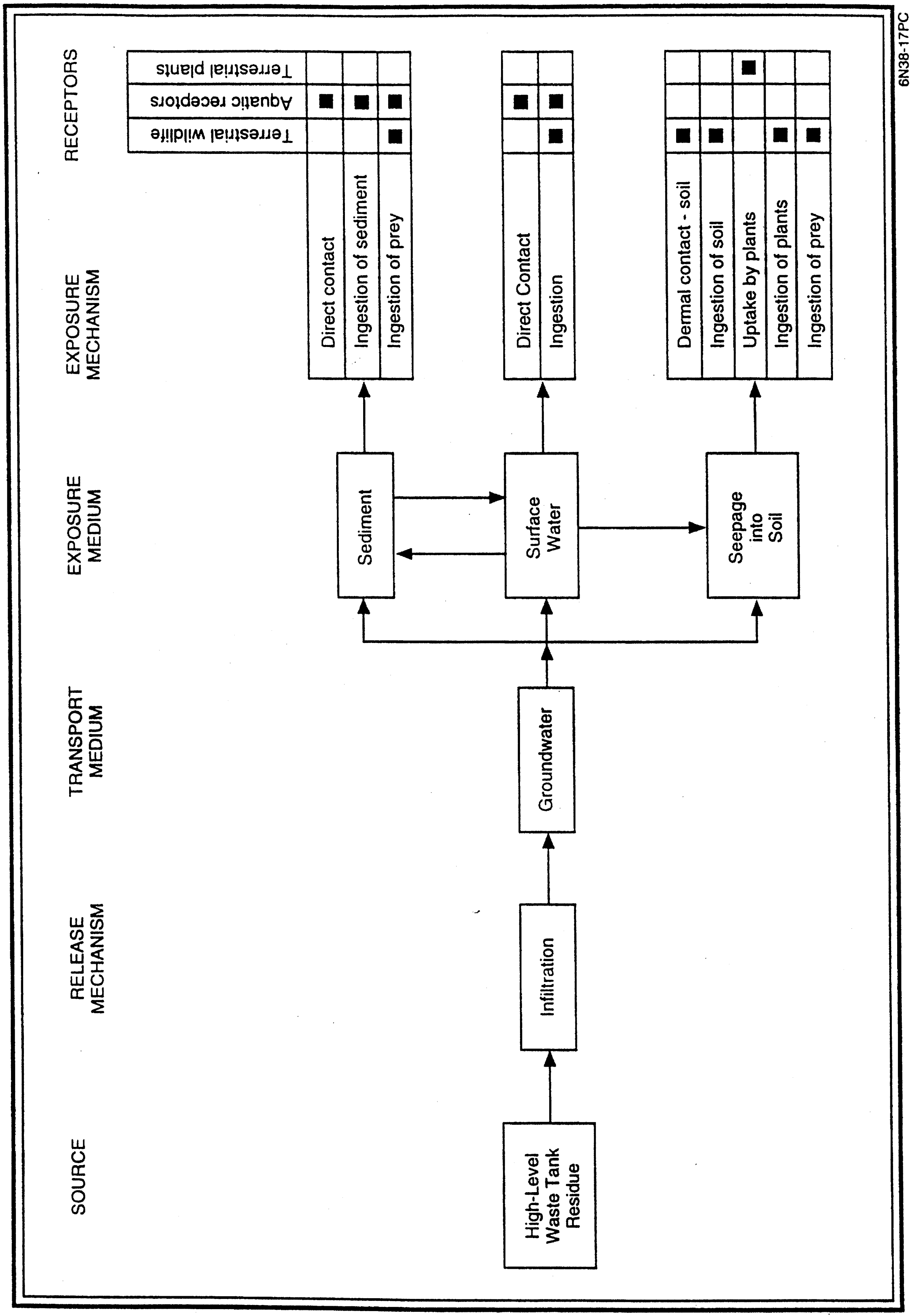

Figure A-2. Conceptual site model for ecological risk assessment, Tank 20 closure.

aquatic animals of interest (sunfish) living in Fourmile Branch: uptake of contaminants from water and direct irradiation from submersion in water. Standard values for parameters such as mass, food ingestion rate, water ingestion rate, soil ingestion rate, and bioaccumulation factors were used.

A.2.2.2 Exposure and Toxicity Assessment

A.2.2.2.1 Exposure to Chemical Toxicants

Exposure for aquatic receptors is simply expressed as the concentration of contaminants in the water surrounding them. This is the surface-water exposure medium shown in the conceptual site model (Figure A-2). The conceptual model also includes sediment as an exposure medium; sediment can become contaminated from the influence of the surface water or from seepage that enters sediment directly. However, this exposure medium was not evaluated because estimating sediment contamination from surface-water inputs would be highly speculative and seepage into sediment is not considered in the groundwater model; all of the transported material is assumed to come out at the seepline.

Exposure for terrestrial receptors is based on dose, expressed as milligrams of contaminant per kilogram of body mass per day. The routes of entry used for estimating dose were ingestion of food and water. Dermal absorption is a possibility, but the fur of shrews and minks was considered to be an effective barrier against this route. The food of shrews is mainly soil invertebrates, and the mink eats small mammals, fish, and a variety of other small animals. Contaminants in seepage water were considered to be directly ingested as drinking water (shrew), ingested as drinking water after dilution in Fourmile Branch (mink), ingested in aquatic prey (mink), and transferred to soil, soil invertebrates, shrews, and to mink through a simple terrestrial food chain.

A.2.2.2.2 Chemical Toxicity Assessment

The goal of the toxicity assessment is to derive threshold exposure levels which are protective of the receptors (Table A-1). For aquatic receptors, most of the threshold values are ambient water quality criteria for chronic exposures. Others include the concentration for silver, which is an acute value (no chronic level was available).

For terrestrial receptors, toxicity thresholds are based on the lowest oral doses found in the literature that are no-observed-adverse-effect-levels (NOAELs) or lowest-observed-adverse-effect-levels (LOAELs) for chronic endpoints that could affect population viability or fitness (Table A-2). Usually the endpoints

Table A-1. Threshold toxicity values.

Contaminant	Aquatic receptors (mg/L)	Terrestrial receptors (mg/kg-d) Shrew	Mink
Aluminum	0.087	27.7	6.4
Barium	0.0059	1.78	0.41
Chromium	0.011	11.6	2.7
Copper	0.0014[a]	52.2	12
Fluoride	NA[b]	8.3	2.5
Iron	1.0	NA	NA
Lead	0.00013[a]	0.012	0.003
Manganese	NA	52.9	12.1
Mercury	0.000012	0.082	0.019
Nickel	0.019[a]	29.7	6.8
Nitrate (as N)	NA	(c)	-
Silver	0.000055[a]	0.33	0.077
Uranium	0.00187	4.48	1.01
Zinc[a]	0.0127	14.0	3.17

a. Based on a hardness of 8.2 mg $CaCO_3$/L.
b. NA: Not applicable (not normally a toxin for this type of receptor).
c. Screening for MCL level (10 mg/L) in seep water considered protective for nitrate.

are adverse effects on reproduction or mice, and indicator species are made by applying a factor based on relative differences in body size: body surface area ratios.

A.2.2.3 Calculational Design

A.2.2.3.1 Chemical Contaminants

For terrestrial receptors, the exposure calculation is a ratio of total contaminant intake to body mass, on a daily basis. This dose is divided by the toxicity threshold value to obtain a hazard quotient. Modeled concentrations in Fourmile Branch were divided by aquatic threshold levels to obtain a ratio. Although this ratio is not considered a hazard quotient, it is used to help identify concentrations indicating potential risk.

Table A-2. Toxicological basis of NOAELs for indicator species.

Analyte	Surrogate Species	LOAEL (mg/kg/d)	Duration	Effect	NOAEL (mg/kg/d)	Reference	Notes
Inorganics							
Aluminum	Mouse	-	13 mo	Reproductive system	19	Ondreicka et al. (1966) in ATSDR (1990)	
Barium	Rat	5.4	16 mo	Systemic	0.54	Perry et al. (1983) in Opresko et al.. (1994)	
Chromium VI	Rat	-	1 y	Systemic	3.5	Mackenzie et al. (1958) in ATSDR (1991)	
Copper	Mink	15	50 w	Reproductive	12	Aulerich et al. (1982) in Opresko et al. (1994)	
Fluoride	Rat	5	60 d	Reproductive	-	Araibi et al. (1989) in ATSDR (1993)	
	Mink	5	382 d	Systemic	-	Aulerich et al. (1987) in ATSDR (1993)	Systemic LOAEL < reproductive
Iron							Data inadequate; essential nutrient
Lead	Rat	0.28	30 d	Reproductive	0.014	Hilderbrand et al. (1973)	
Manganese	Rat	-	100-224 d	Reproductive	16	Laskey et al. (1982)	
Mercury	Mink	0.25	3 mo	Death; devel.	0.15	Wobeser et al. (1976) in Opresko et al. (1994)	
Nickel	Rat	18	3 gens	Reproductive	-	Ambrose et al. (1976)	Based on first-generation effects
Nitrate (as N)							MCL of 10 mg/L at seepline is protective
Silver	Mouse	23	125 d	Behavioral	-	Rungby & Danscher (1984)	
Uranium	Mouse	-	~102 d	Reproductive	3.07	Paternain et al. (1989) in Opresko et al. (1994)	
Zinc	Mouse	96	9-12 mo	Systemic	-	Aughey et al. (1977)	Small data base

A.2.2.3.2 Radioactive Contaminants

Animal ingestion dose conversion factors (DCFs) for both terrestrial animals (shrew and mink) were estimated, for purposes of these calculations, by assuming that the animals possess similar metabolic development. Uncertainty factors are applied to these doses to extrapolate from LOAELs to NOAELs and from subchronic or acute to chronic study durations. The derivation of these values is listed in Table A-3. Adjustments for differences in metabolic rates between experimental animals, usually rats or processes as humans with regard to retention and excretion of radioisotopes; the chemistry of radioisotopes in the animals' bodies is assumed to be similar to that of humans. This assumption is appropriate because much of the data used to determine the chemistry of radioisotopes in the humans' bodies was derived from studies of small mammals. Equations from International Commission on Radiological Protection (ICRP) Publication 2 (ICRP 1959) were used to predict the uptake rate and body burden of radioactive material over the lifespan of the animals. All isotopes were assumed to be uniformly distributed throughout the body of the animal. Dose conversion factors for the aquatic animal, sunfish, were calculated by assuming a steady-state concentration of radioactive material within the tissues of the animal and a uniform concentration of radioactive material in the water surrounding the sunfish.

The quantity of radioactivity ingested by the organisms of interest was estimated by assuming that the organisms live their entire lives in the contaminated region (the seepline area for the terrestrial organisms and Fourmile Branch near the seepline for the sunfish). The shrews are assumed to drink seepline waterat the maximum calculated concentrations of radioactivity and to eat food that lives in the soil/sediments near the seepline. The concentrations of radioactivity in these media were derived from the calculated seepline and Fourmile Branch concentrations. The mink is assumed to drink Fourmile Branch water and eat only shrews that live near the seepline.

The estimated amount of radioactivity that the terrestrial organisms would ingest, through all postulated pathways, was then multiplied by the dose conversion factors to calculate an annual radiation dose to the organism. For the sunfish, the concentration of radioactivity in the surface water was multiplied by the submersion and uptake dose conversion factors to calculate an annual radiation dose. These radiation doses are compared to the limit of 1.0 rad per day (365 rad per year).

Table A-3. Derivation of NOAELs for indicator species.

Contaminant of concern	Surrogate species	NOAEL or LOAEL in surrogate species (mg/kg/d)	UF[a]	Body surface area conversion factor	Indicator species	Indicator species NOAEL (mg/kg/d)	Notes
Inorganics							
Aluminum	Mouse	19	1	0.33	Mink	6.4	
	Mouse	19	1	1.46	Shrew	27.7	
Barium	Rat	0.54	1	0.76	Mink	0.41	
	Rat	0.54	1	3.30	Shrew	1.78	
Chromium VI	Rat	3.5	1	0.76	Mink	2.7	
	Rat	3.5	1	3.30	Shrew	11.6	
Copper	Mink	12	1	1.00	Mink	12.0	
	Mink	12	1	4.35	Shrew	52.2	
Fluoride	Mink	5	2	1.00	Mink	2.5	UF from less serious LOAEL
	Rat	5	2	3.30	Shrew	8.3	UF from less serious LOAEL
Iron							Data inadequate; essential nutrient
Lead	Rat	0.014	4	0.76	Mink	0.003	UF for study duration
	Rat	0.014	4	3.30	Shrew	0.012	UF for study duration
Manganese	Rat	16	1	0.76	Mink	12.1	
	Rat	16	1	3.30	Shrew	52.9	
Mercury	Mink	0.15	8	1.00	Mink	0.019	UF for study duration
	Mink	0.15	8	4.35	Shrew	0.082	UF for study duration
Nickel	Rat	18	2	0.76	Mink	6.8	UF from LOAEL: NOAEL in 2nd and 3rd generations
	Rat	18	2	3.30	Shrew	29.7	UF from LOAEL: NOAEL in 2nd and 3rd generations
Nitrate (as N)							MCL of 10 mg/L at seepline is protective
Silver	Mouse	23	100	0.33	Mink	0.077	UF for LOAEL and nature of study
	Mouse	23	100	1.46	Shrew	0.33	UF for LOAEL and nature of study
Uranium	Mouse	3.07	1	0.33	Mink	1.01	
	Mouse	3.07	1	1.46	Shrew	4.48	
Zinc	Mouse	96	10	0.33	Mink	3.17	UF: LOAEL to NOAEL
	Mouse	96	10	1.46	Shrew	14.0	UF: LOAEL to NOAEL

a. UF = Uncertainty factor.

A.3 Assumptions and Inputs

A.3.1 SOURCE TERM

A.3.1.1 Radionuclides

The radioactive material inventory for Tank 20 and residuals in the ancillary piping and equipment used for the modeling are listed in Table A-4. Both the radioactive and chemical inventories relate to quantities rėmaining after bulk waste removal and spray water washing which estimated to be 1,000 gallons of residuals (d'Entremont 1996a). DOE conservatively assumed that an additional 20 percent of the radioactive contaminants remaining in Tank 20 after bulk waste removal and spray washing will be distributed in the ancillary equipment and piping associated with the tank system (d'Entremont 1996b).

Table A-4. Tank 20 residuals inventory of radionuclides after waste removal and spray washing (curies).[a]

Radionuclide	
Se-79	3.19E-03
Tc-99	5.53E-02
C-14	6.56E-04
I-129	2.62E-07
Pu-239	3.42E+00
Pu-240	7.64E-01
Pu-241	4.98E+01
Pu-242	1.58E-03
Cm-244	1.73E-04
Cm-245	9.13E-11

a. d'Entremont (1996a).

A.3.1.2 Chemicals

The chemical source inventory used in this modeling is listed in Table A-5. As with the radioactive source term, the ancillary piping and evaporator residuals were conservatively estimated to be equal to 20 percent of the tank inventory. In addition, the 3,000 pounds of lead in the tank top risers (500 pounds per riser, six risers per tank) was modeled.

Table A-5. Tank 20 residuals inventory of chemical constituents after waste removal and spray washing (kilograms).[a]

Constituent	Tank 20
Aluminum	5.09E+01
Barium	1.79E+00
Chromium VI	2.16E+00
Copper	1.53E+00
Fluoride	6.31E-01
Iron	1.66E+01
Manganese	1.14E+01
Mercury	6.31E-01
Nitrate[b]	1.66E+01
Lead	2.56E+00
Uranium	1.74E+01
Zinc	3.07E+00

a. d'Entremont (1996a).

A.3.2 CALCULATIONAL PARAMETERS

The modeling is designed to be specific to Tank 20; this is accomplished by utilizing site-specific data where available. For the hundreds of MEPAS input parameters, default values were used only for the distribution coefficients for chemical constituents. The following sections discuss some of the most important parameters.

A.3.2.1 Distribution Coefficients

The distribution coefficient, K_d, is defined for two-phased systems as the ratio of the constituent concentration in the solid (soil) to the concentration of the constituent in the interstitial liquid (leachate). For a given element, this parameter can vary over several orders of magnitude depending on such conditions as soil pH and clay content. Experiments (Bradbury and Sarott 1995) have demonstrated that strong oxidizing or reducing environments tend to affect the K_d values markedly. Because this parameter is highly sensitive in relation to breakthrough and peak times (but not necessarily peak concentration), careful selection is imperative to achieve reasonable results. For this reason, several literature sources were used to ensure that the most current and appropriate K_d s were selected.

For purposes of modeling the transport of contaminants from the tank bottom though the three affected aquifers, a maximum of eight distinct strata were identified. These eight strata are (1) the contaminated zone, (2) the concrete basemat, (3) the vadose zone, (4) the Water Table Aquifer; (5) the Tan Clay layer;

(6) the Barnwell-McBean Aquifer; (7) the Green Clay layer; and (8) the Congaree Aquifer. Distribution coefficients for each of these zones differ depending on the chemical and physical characteristics of the material comprising the layer.

The modeling of the ancillary equipment/piping and Tank 20 was similar, except in modeling the piping the concrete basemat was conservatively assumed to have no effect on reducing the transport rate of contaminants to the saturated zone. In this instance, the grout-filled equipment/piping is the modeled as the contaminated zone and the thickness of the vadose zone was increased to 52 feet to reflect the higher elevation of the piping in relation to the Water Table.

Distribution coefficients for each stratum under various conditions are listed in Table A-6.

Under the analyzed scenario, both the tank and piping will be filled with a strongly reducing grout. Therefore, the K_ds selected for the contaminated zone and the tank basemat reflect this reducing environment; these are listed in columns II and III, respectively. The vadose zone, Water Table Aquifer, and Congaree Aquifer distribution coefficients are assumed to have K_ds which are characteristics of typical SRS soil as listed under Column I of Table A-6. The Tan Clay layer and Green Clay layer are assumed to have physical and chemical characteristics of clay with K_ds provided under Column 4.

Similarly, for the piping model, K_ds for the contaminated zone and the vadose zone are given in Columns II, and I, respectively. The vadose zone, Water Table Aquifer, Barnwell-McBean Aquifer, and Congaree Aquifer distribution coefficients are listed under Column 1 of Table A-6. The Tan Clay layer and Green Clay layer K_ds are provided under Column 4.

A.3.2.2 <u>MEPAS Groundwater Input Parameters</u>

Table A-7 lists the input parameters used for the partially saturated zones.

Table A-8 lists input parameters for the saturated zone. The aquifer in which contaminant movement is being analyzed will be the saturated zone for that run.

A.3.2.3 <u>Hydraulic Conductivities</u>

Because leach rate is ultimately limited by the lowest hydraulic conductivity of the strata and structures above and below the contaminated zone, this parameter is highly sensitive in its effect on breakthrough times and peak concentrations at the receptor locations. Table A-9 lists the changes in hydraulic

Table A-6. Radionuclide and chemical distribution coefficients (cm^3/gram).

	I		II		III		IV	
Constituent	SRS soil	Note	Reducing contaminated zone	Note	Reducing concrete	Note	Clay	Note
Carbon-14	2	a	0.1[b]	c	0.1[b]	c	1	d
Curium-244, -245	150	a	5,000	c	5,000	c	8,400	d
Iodine-129	0.6	a	2	c	2	c	1	d
Plutonium-239, -240, -241, -242	100	a	5,000	c	NA	j	5,100	d
Selenium-79	5	a	0.1	c	0.1	c	740	d
Technetium-99	0.36	a	1,000	c	1,000	c	1	d
Aluminum	35,300	e	353	f	353	f	35,300	g
Barium	530	e	1[h]	c	1[h]	c	16,000	g
Chromium VI[i]	16.8	e	7.9	f	7.9	f	360	g
Copper	41.9	e	33.6	f	33.6	f	336	g
Fluoride	0	e	0	f	0	f	0	g
Iron	15	e	1.5	c	1.5	f	15	g
Lead	234	e	500	c	500	c	1,830	g
Manganese	16.5	e	100	c	100	c	36.9	g
Mercury	322	e	5,280	f	5,280	f	5,280	g
Nickel	300	e	100	c	100	c	650	g
Nitrate	0	e	0	f	0	f	0	g
Silver	0.4	e	1	c	1	c	40	g
Uranium	50	a	NA	c	5,000	j	1,600	d
Zinc	12.7	e	1,460	f	1,460	f	1,460	g

a. WSRC (1994a), Table 3.3-2, page 3-69, value for soil.
b. Characteristics similar to selenium (Bradbury and Sarott 1995, Table 3, page 16).
c. Bradbury and Sarott (1995), Table 4, Region 1, page 42.
d. WSRC (1994a), Table 3.3-2, page 3-69, value for clay.
e. MEPAS default for soil <10% clay and pH from 5-9.
f. MEPAS default for soil >30% clay and pH >9.
g. MEPAS default for soil >30% clay and pH from 5-9.
h. Characteristics similar to strontium (Bradbury and Sarott 1995, Table 3, page 16).
i. For conservatism, all chromium modeled as VI valence.
j. Solubility limit of 4.4E-13 M/liter used, E-Area RPA (WSRC 1994a, page D-32).

Table A-7. MEPAS input parameters for partially saturated zones.

	Concrete Basemat						
	Intact	Failed	Vadose zone	Water Table Aquifer	Tan Clay layer	Barnwell-McBean Aquifer	Green Clay layer
Strata thickness (ft)	0.58[a]	0.58[a]	5.4[b]	40.0[c]	3.0[c]	60.0[c]	5.0[c]
Bulk density (g/cm^3)	2.21[d]	1.64[e]	1.59[d]	1.59[d]	1.36[e]	1.59[d]	1.39[e]
Total porosity	15%[d]	38%[e]	35%[f]	35%[f]	40%[f]	35%[f]	40%[f]
Field capacity	15%[d]	9%[e]	12%[e]	35%[e]	33.4%[e]	35%[e]	32.5%[e]
Longitudinal dispersion (ft)	0.0058[g]	0.0058[g]	0.054[g]	0.40[g]	0.030[g]	0.60[g]	0.050[g]
Vertical hydraulic conductivity (cm/s)	9.6E-09[d]	6.6E-03[e]	7.1E-03[h]	7.1E-03[h]	1.6E-06[h]	5.6E-04[h]	4.4E-09[h]

a. WSRC, Drawing #W202091, 1991.
b. Based on distance between bottom of tank (elevation from WSRC, Drawing #202091, 1991) to groundwater.
c. GeoTrans (1987).
d. WSRC (1994a).
e. Droppo (1995), Table 2.1.
f. Aadland (1995).
g. Calculated using MEPAS formula for longitudinal dispersivity.
h. GeoTrans (1993).

Table A-8. MEPAS input parameters for saturated zone.

	Water Table Aquifer	Barnwell-McBean Aquifer	Congaree Aquifer
Thickness (ft)	40[a]	60.0[a]	100.0[a]
Bulk Density (g/cm^3)	1.59[b]	1.59[b]	1.64[c]
Total Porosity	35%[d]	35%[d]	34%[d]
Effective Porosity	20%[d]	20%[d]	25%[d]
Pore Velocity (ft/day)	0.12	0.064	0.23

a. Geotrans (1987).
b. WSRC (1994a).
c. Droppo (1995).
d. Aadland (1995).

Table A-9. Concrete basemat hydraulic conductivities (centimeters per second).

Time (yrs)	Hydraulic conductivity
0-1000	9.6E-09
1000-10000	6.6E-03

conductivities due to failure as a function of time for the concrete basemat. The modeling assumed that excess water has a place to run off (over the sides of the basemat or cover) and that ponding above the contaminated zone does not occur.

A.3.2.4 Infiltration Rates

As discussed in Section A.2.1.1, infiltration rates are a function of time to failures of the tank top, grout, and concrete basemat. The infiltration rates as a function of time are listed in Table A-10.

Table A-10. Infiltration rates (centimeters per year).

Time (yrs)	Rate
0-1000	4
1000-10000	40 (failure at 1000 years)

A.3.2.5 Human Health Exposure Parameters and Assumed Values

Because the impact on a given receptor depends in large part on the physical characteristics and habits of the receptor, stipulation of certain values is necessary to obtain meaningful results. Some of these values are included as default values in MEPAS; however, others must be specified so the receptors are modeled appropriately for the scenario being described. For this modeling effort, site-specific values were used as much as possible; that is, values that had been used in other modeling efforts for the SRS were incorporated when available and appropriate.

Table A-11 lists the major parameters that were used in assigning characteristics to the receptors used in the calculations.

A.3.3 ECOLOGICAL RISK ASSESSMENT

The exposure factors used in calculating doses to the shrew and mink are listed in Table A-12. An important assumption of the exposure calculation is that no feeding or drinking takes place outside the influence of the seepage, even though the home range of the shrew is about twice as large as the seep area and the mink's home range is more than 10 times larger than the seep area. The bioaccumulation factor for soil and soil invertebrates is 1 for all metals, as is the factor for soil invertebrates and shrews. K_d values for estimating contaminant concentrations in soil due to the influence of seepage are from Baes et al. (1984). Bioconcentration factors for estimating contaminant concentrations in aquatic prey items are from the EPA Region IV water quality criteria table. For contaminants with no listing in the Region IV table for a bioconcentration factor, a factor of 1 is used. The mink was modeled as obtaining half of its diet from shrews at the seep area and the other half from aquatic prey downstream of the seepline.

A.4 Results

A.4.1 HUMAN HEALTH ASSESSMENT

For each scenario, the maximum concentration or dose was identified for each receptor and for each contaminant along with the period during which the maximum occurred within a 10,000-year performance period. In addition, for radiological constituents, the total dose was calculated to enable the evaluation of the impacts of all radiological constituents. Because the maximum doses for each radionuclide do not necessarily occur simultaneously, it is not appropriate to add the maximum doses. Rather, it is more appropriate to assess the doses as a function of time, sum the doses from all

Table A-11. Assumed human health exposure parameters.

Parameter	Applicable receptor	Value	Comments
Body mass	Adult	70 kg	This value is taken directly from ICRP (1975). In radiological dose calculations, this is the standard value in the industry.
	Child	30 kg	This value was obtained from ICRP (1975). Both a male and female child of age 9 have an average mass of 30 kg.
Exposure period	All	1 year	This value is necessary so MEPAS will calculate an annual radiation dose. Lifetime doses can be calculated by multiplying the annual dose by the assumed life of the individual.
Leafy vegetable ingestion rate	Adult	21 kg/yr	This value was taken from Hamby (1993), which was used in other modeling work at SRS.
	Child	8.53 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC (1977).
Other vegetables ingestion rate	Adult	163 kg/yr	This value was taken from Hamby (1993), which was used in other modeling work at SRS.
	Child	163 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC (1977).
Meat ingestion rate	Adult	43 kg/yr	This value was taken from Hamby (1993), which was used in other modeling work at SRS.
	Child	16 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC (1977).
Milk ingestion rate	Adult	120 L/yr	This value was taken from Hamby (1993), which was used in other modeling work at SRS.
	Child	128 L/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC (1977).
Water ingestion rate	All	2 L/day	This value is standard in MEPAS and is consistent with maximum drinking water rates in NRC (1977).
Finfish ingestion rate	Adult	9 kg/yr	This value was taken from Hamby (1993), which was used in other modeling work at SRS.
	Child	2.96 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC (1977).
Time spent at shoreline	Adult resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC (1977).
	Child resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC (1977).
	Seepline worker	2080 hrs/yr	This value is based on the assumption of continuous exposure of the seepline worker during each working day.
	Intruder	1040 hrs/yr	This value is based on the conservative assumption of half-time exposure during each working day.
Time spent swimming	Adult resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC (1977).
	Child Resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC (1977).

Table A-12. Parameters for foodchain model ecological receptors.

Receptor	Guild	Parameter	Value	Notes; Reference
Southern short-tailed shrew (*Blarina carolinensis*)	Insectivore	Body weight	9.7 grams	Mean of 423 adults collected on SRS; Cothran et al. (1991)
		Water ingestion	2.2 grams/day	0.223 g/g.day X 9.7g; EPA (1993)
		Food ingestion	5.2 grams/day	0.541 g/g/day X 9.7g; Richardson (1973) cited in Cothran et al. (1991)
		Soil ingestion	10% of diet	Between vole (2.4%) and armadillo (17%); Beyer et al. (1994)
		Home range	0.96 ha	Mean value on SRS; Faust et al. (1971) cited in Cothran et al. (1991)
Mink (*Mustela vison*)	Carnivore	Body weight	800 grams	"Body weight averages 0.6 to 1.0 kg"; Cothran et al. (1991)
		Water ingestion	22.4 grams/day	0.028 g/g/day X 800g; EPA (1993)
		Food ingestion	110 grams/day	Mean of male and female estimates; EPA (1993)
		Soil ingestion	5% of diet	Between red fox (2.8%) and raccoon (9.4%); Beyer et al. (1994)
		Home range	variable	7.8-20.4 ha (Montana), 259-380 ha (North Dakota; EPA 1993) Females: 6-15 ha, males:18-24 ha (Kansas; Bee et al. 1981)

radionuclides for each time increment, and then select the maximum total dose from this compilation. Therefore, the total dose reported in Tables A-13 through A-15 for radiological constituents might not correlate to the maximum dose or period for any individual radionuclide because of the contributions from all radionuclides at a given time. In addition to total dose, the gross alpha concentration , the beta-gamma dose, and the lifetime risk of incidence of excess cancer were calculated to allow comparisons to the appropriate performance objectives.

Nonradiological constituent concentrations in the various water bodies were calculated to enable direct comparisons to performance objectives. For each constituent, the maximum concentration was calculated along with the period during which the maximum concentration occurred. None of the nonradiological constituents are known ingestion carcinogens; therefore, cancer risk was not calculated for these contaminants.

Tables A-13 through A-18 list impact estimates due to transport of contaminants in the three aquifers described in Section A.2. All contaminants listed in Tables A-4 and A-5 were used in the calculations; however, contaminants with exceedingly small impacts at the locations of interest were not listed in Tables A-13 through A-18. The tables that list radiological impacts include doses for postulated receptors (i.e., Adult Resident, Child Resident, Seepline Worker, and Intruder) and at the seepline. Additional calculations were performed for groundwater locations close to the tank farm (i.e., the 1 m well and the 100 m well) for informational purposes. For nonradiological constituents, the maximum concentration of each contaminant is listed for each water location.

Although calculational results are presented for the three aquifers, the maximum concentration of a contaminant to which a person could potentially be exposed is the highest among the three aquifers (i.e., the doses and concentrations from the three aquifers are not additive). For example, the maximum dose a person could get by ingesting water at the seepline location is due to the contaminant transport in the Barnwell-McBean aquifer. In reality, the water at the seepline may be a mixture of the groundwater that outcrops from the Barnwell-McBean aquifer and the water table aquifer, resulting in an average seepline concentration. DOE did not take credit for this possibility but has instead assumed that a person could ingest the maximum contaminant concentration from a single aquifer.

Inspection of Tables A-13 through A-15 shows that Tc-99 is the dominant radiation dose contributor. These tables show dose estimates from some of the other constituents; however, it is apparent that Tc-99 is the limiting constituent. The tables also indicate that gross alpha concentration in the groundwater and surface water will be much less than any of the performance objectives during the 10,000 year period.

Table A-13. Tank 20 radiological results due to contaminant transport in the water table aquifer.

Location		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Gross alpha concentration (pCi/L)	Lifetime risk
Adult resident	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
Child resident	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
Seepline worker	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
Intruder	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
1-meter well	Maximum value	1.4E+01	6.8E+01	5.5E-01	2.6E-02	6.8E+01	6.8E+01	3.4E+00	1.5E-03
	Time of maximum (yr)	1015	1645	1015	1015	1645	1645	6965	
100-meter well	Maximum value	7.0E-02	4.0E-01	3.1E-03	(a)	4.0E-01	4.0E-01	3.7E-01	8.9E-06
	Time of maximum (yr)	1085	315	1015	(a)	315	315	9625	
Seepline	Maximum value	(a)	4.9E-03	(a)	(a)	5.0E-03	5.0E-03	4.0E-09	1.1E-07
	Time of maximum (yr)	(a)	1715	(a)	(a)	1785	1785	9975	
Surface water	Maximum value	(a)	(a)	(a)	(a)	(a)	(a)	4.0E-11	(b)
(drinking)	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	9975	

a. Radiation dose is less than 0.001 mrem/yr.
b. Risk is less than 1×10^{-7}.

Table A-14. Tank 20 radiological results due to contaminant transport in the Barnwell-McBean aquifer.

Location		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Gross alpha concentration (pCi/L)	Lifetime risk
Adult resident	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
Child resident	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
Seepline worker	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
Intruder	Maximum value	(a)	(a)	(a)	(a)	NA	(a)	NA	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	NA	(a)	NA	
1-meter well	Maximum value	1.9E+00	1.6E+02	1.1E+00	9.9E-02	1.6E+02	1.6E+02	1.2E-11	3.5E-03
	Time of maximum (yr)	3395	1645	1085	1015	1645	1645	9975	
100-meter well	Maximum value	1.8E-02	1.4E+00	1.1E-02	(a)	1.4E+00	1.4E+00	5.6E-18	3.0E-05
	Time of maximum (yr)	3605	1715	1155	(a)	1715	1715	9975	
Seepline	Maximum value	(a)	1.3E-02	(a)	(a)	1.3E-02	1.3E-02	7.0E-29	2.8E-07
	Time of maximum (yr)	(a)	1855	(a)	(a)	1855	1855	9975	
Surface water	Maximum value	(a)	(a)	(a)	(a)	(a)	(a)	0.0E+00	(b)
(drinking)	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	35	

a. Radiation dose is less than 0.001 mrem/yr.
b. Risk is less than 1×10^{-7}.

Table A-15. Tank 20 radiological results due to contaminant transport in the Congaree aquifer.

Location		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Gross alpha concentration (pCi/L)	Lifetime risk
Seepline	Maximum value	(a)	(a)	(a)	(a)	(a)	(a)	0.0E+00	(b)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	35	

a. Radiation dose is less than 0.001 mrem/yr.
b. Risk is less than 1×10^{-7}.

Table A-16. Tank 20 nonradiological results due to contaminant transport in the water table aquifer.

Receptor		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
1-meter well	Maximum concentration (mg/L)	1.3E+00	(a)	5.1E-02	5.1E-01	1.1E+00	5.1E-01	1.6E+02	9.8E-03	5.1E+00	5.3E+00	(a)	1.5E-01	4.4E-05	1.9E-01
	Time of maximum (yr)	1015	(a)	4515	1015	1085	1295	1085	6685	1015	1155	(a)	2905	4165	1855
100-meter well	Maximum concentration (mg/L)	7.5E-03	(a)	9.2E-05	2.9E-03	3.5E-03	1.0E-03	3.9E-01	3.4E-05	3.0E-02	1.7E-02	(a)	3.1E-04	5.4E-06	1.3E-03
	Time of maximum (yr)	1015	(a)	9975	1015	1295	1785	1295	9905	1015	1365	(a)	5495	9485	1925
Seepline	Maximum concentration (mg/L)	6.2E-05	(a)	(a)	3.8E-05	3.3E-06	(a)	4.2E-04	(a)	3.9E-04	1.8E-05	(a)	(a)	(a)	5.9E-06
	Time of maximum (yr)	1085	(a)	(a)	1015	4585	(a)	4165	(a)	1015	4515	(a)	(a)	(a)	4725
Surface water	Maximum concentration (mg/L)	(a)	(a)	(a)	(a)	(a)	(a)	2.9E-06	(a)	2.7E-06	(a)	(a)	(a)	(a)	(a)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	4235	(a)	1015	(a)	(a)	(a)	(a)	(a)

a. Concentration is less than 1×10^{-6} mg/L.

Table A-17. Tank 20 nonradiological results due to contaminant transport in the Barnwell-McBean aquifer.

Receptor		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
1-meter well	Maximum concentration (mg/L)	4.1E+00	(a)	(a)	2.6E+00	3.5E-01	1.8E-01	1.0E+02	(a)	2.6E+01	4.0E+00	(a)	(a)	6.3E-05	1.5E-01
	Time of maximum (yr)	1155	(a)	(a)	1015	3045	4375	1855	(a)	1015	2065	(a)	(a)	9975	7035
100-meter well	Maximum concentration (mg/L)	4.0E-02	(a)	(a)	2.2E-02	2.7E-03	1.2E-03	6.2E-01	(a)	2.2E-01	2.6E-02	(a)	(a)	(a)	1.4E-03
	Time of maximum (yr)	1155	(a)	(a)	1015	3395	5215	2205	(a)	1015	2485	(a)	(a)	(a)	7175
Seepline	Maximum concentration (mg/L)	1.9E-04	(a)	(a)	1.3E-04	5.0E-06	(a)	6.4E-04	(a)	1.3E-03	2.7E-05	(a)	(a)	(a)	2.8E-06
	Time of maximum (yr)	1365	(a)	(a)	1015	9485	(a)	7455	(a)	1015	8155	(a)	(a)	(a)	9975
Surface water	Maximum concentration (mg/L)	(a)	(a)	(a)	(a)	(a)	(a)	3.5E-06	(a)	7.0E-06	(a)	(a)	(a)	(a)	(a)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	7665	(a)	1015	(a)	(a)	(a)	(a)	(a)

a. Concentration is less than 1×10^{-6} mg/L.

Table A-18. Tank 20 nonradiological results due to contaminant transport in the Congaree aquifer.

Receptor		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
1-meter well	Maximum concentration (mg/L)	(a)	(a)	(a)	(a)	(a)	(a)	2.7E-06	(a)	6.2E-06	(a)	(a)	(a)	(a)	(a)
	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	6335	(a)	1085	(a)	(a)	(a)	(a)	(a)

a. Concentration is less than 1×10^{-6} mg/L.

Tables A-16 through A-18 indicate that the seepline concentrations of all nonradiological contaminants will be quite low throughout the 10,000 year period. None of the contaminants are projected to exceed any known performance objectives.

A.4.2 ECOLOGICAL ASSESSMENT

A.4.2.1 Nonradiological Analysis

Hazard quotients for the shrew and the mink indicated that no contaminants pose potential risk to those receptors. In general, Scenario 1, grout filled-no cap Barnwell McBean Aquifer, resulted in the highest HQs (Table A-19). Under that scenario, HQs for fluoride ranged from 1.3×10^{-3} for the shrew to 5.4×10^{-4} for the mink, and HQs for silver ranged from 1.4×10^{-2} for the shrew to 7.6×10^{-3} for the mink. The remaining HQs for all contaminants under all scenarios were lower. HQ values were lowest under the grout filled-no cap Congaree Aquifer scenario.

Contaminant concentrations in Fourmile Branch and Upper Three Runs downstream of the seep line were well below threshold values at all modeled time periods for all closure scenarios. HQs for aquatic contaminants were summed for each period to investigate potential additive effects. The highest value was 1.8×10^{-2} for the grout filled-no cap Barnwell McBean Aquifer scenario (Fourmile Branch), which occurred 1,365 years after closure. This is the same period in which silver reached its maximum terrestrial HQ for this closure option (Table A-19). The low HQs indicate that the likelihood of aquatic effects is remote.

A.4.2.2 Radiological Analysis

Calculated absorbed doses to the referenced organisms are listed below. All calculated doses are below the regulatory limit of 365,000 mrad per year (365 rad per year).

Aquifer	Sunfish dose (mrad/yr)	Shrew dose (mrad/yr)	Mink dose (mrad/yr)
Water Table	1.84E-04	0.7	0.1
Barnwell-McBean	3.61E-04	1.7	0.2

Table A-19. Results of terrestrial risk assessment.

Analyte	Barnwell-McBean Aquifer			Congaree Aquifer			Water Table Aquifer		
	Maximum HQ		Time of	Maximum HQ		Time of	Maximum HQ		Time of
	Mink	Shrew	maximum HQ[a]	Mink	Shrew	maximum HQ	Mink	Shrew	maximum HQ
Aluminum	(b)	(b)	NA	(b)	(b)	NA	(b)	(b)	NA
Barium	(b)	(b)	NA	(b)	(b)	NA	(b)	(b)	NA
Chromium	1.1E-04	2.0E-04	9,485	2.2E-10	3.9E-10	10,955	7.2E-05	1.3E-04	4,585
Copper	3.6E-09	6.5E-09	10,955	1.4E-11	2.4E-11	10,955	1.9E-07	3.5E-07	10,185
Fluoride	5.4E-04	1.3E-03	1,015	2.5E-06	6.0E-06	1,085	1.6E-04	3.7E-04	455
Lead	(b)	(b)	NA	(b)	(b)	NA	6.7E-12	5.2E-12	10,955
Manganese	9.9E-06	1.8E-05	8,155	2.1E-08	3.9E-08	8,295	6.7E-06	1.2E-05	4,515
Mercury	(b)	(b)	NA	(b)	(b)	NA	(b)	(b)	NA
Nickel	(b)	(b)	NA	(b)	(b)	NA	(b)	(b)	NA
Silver	7.6E-03	1.4E-02	1,365	6.4E-07	1.2E-06	4,235	2.5E03	4.6E-03	1,085
Uranium	4.3E-19	7.5E-19	10,955	(b)	(b)	NA	7.1E-08	1.2E-07	10,955
Zinc	4.7E-06	8.4E-06	10,955	(b)	(b)	NA	5.2E-06	9.1E-06	4,795

a. Years after closure.
b. HQ is less than ~ 1×10^{-2}.
NA = Not applicable.

A.4.3 SUMMARY OF RESULTS

Radiological doses at the seepline (the point of exposure) were calculated to be 0.15 mrem/year. Essentially all of this dose is due to selenium-79 and technetium-99 because the other radionuclides either decay en route or do not migrate at a sufficient rate to reach the seepline within the 10,000-year period of analysis. The calculated gross alpha concentration at the seepline demonstrates that appreciable amounts of plutonium-239 do not arrive at the seepline within the 10,000-year period, regardless of the analyzed scenario. For nonradiological constituents, none of the contaminants reach the seepline in quantities that could exceed the maximum contaminant level.

A.5 Uncertainty/Sensitivity Analysis

A.5.1 HUMAN HEALTH ANALYSIS

The principal parameters that affect modeling results are the following:

- **Inventory:** The amount of material in the tank directly affects the concentrations at any given location, unless the amount of material is so great that the solubility limit is exceeded. Once the solubility limit is exceeded, greater amounts of source material do not necessarily result in increased concentrations at receptor locations. In this modeling effort, only plutonium-239 was assumed to be limited by solubility.

- **Hydraulic conductivity:** The actual rate of water movement through the material is ultimately affected by the hydraulic conductivity of the strata underneath the source. For both scenarios, the concrete basemat is the limiting layer with regard to water infiltration. At the time of basemat failure, the hydraulic conductivity is increased dramatically, making more water available to carry contaminants to the aquifer. In general, this will result in greater doses/concentrations due to the increased movement of material.

- **Distribution coefficient:** The distribution coefficient (Kd) affects the rate at which contaminates moves through strata. Large K_d values provide significant holdup time for short-lived radionuclides.

- **Vadose zone thickness:** The thickness of the strata between the contaminated region and the aquifer does not necessarily reduce the concentration so much as it slows the progress toward the aquifer. Therefore, for shorter-lived radionuclides, extra time granted by thicker strata can decrease the activity before they reach the aquifer.

- **Dispersion coefficient:** The dispersion coefficient affects the degree to which the plume "spreads" as it moves toward receptor locations. Less dispersion would understandably cause greater concentrations to be calculated for a given point, while greater dispersion would result in lower concentration estimates.

- **Distance downgradient to receptor location:** The distance to a given receptor location affects (a) the time at which contaminants will arrive at the location and (b) how much dispersion occurs. For greater distances, longer travel times will be encountered, resulting in lower activity values for short-lived radioactive constituents and greater dispersion for all constituents.

As described in Sections A.2 and A.3, a number of conservative assumptions were included as part of this modeling effort. This has the effect of providing dose/concentration estimates that may be greater than values that might actually be measured. The relative lack of sensitivity of the magnitude of the results to many of the parameters listed above, however, suggests that the estimates depend on a limited few key parameters, such as source term, assumed strata layering, and the amount of dispersion. Therefore, the impact estimates in this appendix could be high by an order of magnitude (or more). That is, it is expected that the "true" value is less than the estimates presented in this document because of the conservative assumptions. The uncertainties associated with this modeling are comparable to those typically performed elsewhere to estimate potential environmental impacts. This modeling underwent an independent sensitivity and uncertainty analysis by Sandia National Laboratories. An evaluation of the Sandia analysis (Cook 1996a) concluded that the results were "... similar enough to conclude that the problem has been addressed properly."

A.5.2 ECOLOGICAL RISK ASSESSMENT

Most of the data and assumptions used in the exposure calculations (exclusive of the exposure concentrations, which were calculated by the groundwater model) are average or midpoint values. Uncertainty for these values is largely a question of precision in measurement or variability about these points. However, two assumptions are conservative, meaning that they are likely to overestimate risk.

The relationship between seep area and home range has already been mentioned; the lack of correction for home range is likely to overestimate risk to an individual shrew by a factor of two and to an individual mink by a factor greater than ten. The other assumption is that when contaminants in seepage adhere to the soil, they are not removed from the water. In other words, the seepage concentration is used to predict soil concentrations and downstream water concentrations without adjustment for losses.

Uncertainty in the toxicity assessment includes the selection of a particular dose and the factors applied to ensure that it is protective. The fluoride dose selected as a threshold, a LOAEL of 5 mg/kg·d associated with relatively less serious effects in rats and minks, could have been a higher dose based on effects more likely to cause decreased fitness. The data base available for silver toxicity is not good, and this is reflected in the high uncertainty factor (100X) used to lower the selected dose.

Because toxicity data is mostly limited to individual responses, a risk assessment is usually limited to the probability of risk to an individual. This makes the evaluation of risk to populations, communities, and ecosystems a speculative and uncertain undertaking, even though characterization of risks to populations is the typical goal of an ecological risk assessment. In the case of the seep, it is reasonable to assume that terrestrial effects will be limited to this area, because the contaminants have not been shown to bioaccumulate in terrestrial systems. Surface water is the only likely pathway for contaminants to exit the seep area. (Mercury is known to accumulate in aquatic food chains, but no mercury or lead is transported to the seepline during the 10,000 year modeled time period.)

A.6 References

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APPENDIX B

ACCOUNTING FOR TANK 20 IMPACTS AGAINST PERFORMANCE OBJECTIVES

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APPENDIX B. ACCOUNTING FOR TANK 20 IMPACTS AGAINST PERFORMANCE OBJECTIVES

The U.S. Department of Energy (DOE) has developed a method to budget performance objectives applicable to groundwater in the F- and H-Area Tank Farms at the Savannah River Site (SRS). This appendix explains the application of the method described in Chapter 6 of the *Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Tank Systems* (DOE 1996a) (as revised in Section 1.4 of this module). The modeling methods used to develop this appendix are based on the hydrogeological model presented in Appendix E of the Program Plan (DOE 1996b).

Under the concept of the groundwater transport segments (GTSs) described in Section 6.3 of the Program Plan, DOE has performed three types of calculations for the F-Area GTS pertaining to the high-level waste tanks:

- An *a priori* calculation of the projected impact of the entire GTS using assumptions on the degree of tank cleaning achievable

- An evaluation of the contribution of non-tank-farm sources to groundwater impacts

- A tank-specific calculation for Tank 20 using sampling results available following cleaning

The *a priori* calculational results are used to project whether the GTS will meet the overall performance objectives. This process helps to address the cumulative effect of all the tanks in the tank farm whose plumes may intersect. In the following sections, results of the F-Area GTS modeling and the non-tank-farm source evaluation will be used with the Tank 20 results presented in Appendix A to ensure that the performance objective "budget" is not exceeded.

B.1 F-Area GTS Impacts

B.1.1 SOURCE TERM IDENTIFICATION

To determine the source term for the *a priori* calculation of F-Area GTS impacts, DOE reviewed information pertaining to transfers of liquids to the high-level waste tanks since their placement in the tank farms. This includes log books showing the data regarding transfers as well as sampling results, reel tape measurements and photographs that provided information on the solids content in the tanks.

Based on all this information, DOE estimated the current inventory of solids in each tank and the concentrations of radiological and nonradiological constituents in the solids.

To determine the inventory of contaminants after cleaning of the tanks is accomplished, DOE assumed that the concentration of constituents in the solids remains unchanged. This assumption is realistic based on the fact that the presence of constituents in the solids indicates that the constituents are relatively insoluble and would be expected to remain insoluble throughout the tank cleaning process, which includes bulk removal of solids followed by water washing. Thus, the cleaning actions are expected to remove the more soluble constituents and reduce the volume of solids in the tanks; however, the cleaning may not necessarily change the concentration of constituents in the solids.

Based on available cleaning technology, DOE assumed that the cleaning process would still leave behind a nominal amount of solids in each tank. The density of the solids is relatively low (1.95 lbs./gal.); this value is used to determine the total inventory of constituents in each tank.

Based on this discussion, the process of quantifying the source term concentration and total inventory can be summarized as follows:

1. Current concentrations in the solids in each tank are estimated based on sampling results, logs of transfers, and other measurements

2. Concentrations in the solids remain constant after the tank cleaning process

3. Each tank is cleaned with a nominal amount of solids remaining in each tank with a density of 1.95 lbs./gal.

4. The total inventory in each tank is based on the assumed concentration and the calculated mass per unit tank based on the information in Step 3 above.

Under the assumptions given above, DOE estimated the radiological and nonradiological constituent inventories as presented in Tables B-1 and B-2 below.

The radioactive material inventory for the F-Area Tank Farm and residuals in the ancillary piping and equipment used for the modeling are listed in Table B-1. Both the radioactive and chemical inventories relate to quantities remaining after bulk waste removal and spray water washing (d'Entremont 1996). DOE conservatively assumed that an additional 20 percent of the radioactive contaminants remaining in

Table B-1. F-Area Tank Farm residual inventory of radionuclides after waste removal and spray washing (curies).[a]

Radionuclide	F-Area Tank Farm
Se-79	1.18E+00
Tc-99	2.75E+02
C-14	3.32E-02
I-129	9.71E-05
Pu-239	1.43E+02
Pu-240	3.25E+01
Pu-241	6.84E+02
Pu-242	1.49E-02
Cm-244	6.18E-02
Cm-245	3.34E-08

a. d'Entremont (1996).

Table B-2. F-Area Tank Farm residual inventory of chemical constituents after waste removal and spray washing (kilograms).[a]

Constituent	F-Area Tank Farm
Aluminum	9.75E+02
Barium	2.25E+01
Chromium VI	2.64E+01
Copper	1.83E+01
Fluoride	1.90E+01
Iron	2.98E+03
Manganese	2.75E+02
Mercury	8.13E+00
Nitrate[b]	1.98E+02
Lead	3.14E+01
Uranium	5.23E+02
Zinc	3.64E+01

a. d'Entremont (1996).
b. Includes nitrite (as N). Due to the oxidizing properties of groundwater, all nitrite will be converted to nitrate prior to appearance at the seepline.

tank farm after bulk waste removal and spray washing will be distributed in the ancillary equipment and piping associated with the tank system (d'Entremont 1996).

The chemical source inventory used in this modeling is listed in Table B-2. As with the radioactive source term, the ancillary piping and evaporator residuals were conservatively estimated to be equal to 20 percent of the tank farm inventory.

B.1.2 SOURCE CONFIGURATION

For the F-Area GTS *a priori* calculation, DOE calculated the impacts at the point of exposure from groups of tanks that were similar in location and structure. In F-Area, all Type I tanks (Tanks 1-8) were grouped together, all the Type III tanks (Tanks 25-28, 33,34, and 44-47) were grouped together, and all the Type IV tanks (Tanks 17-20) were grouped together. These groupings were appropriate because the tanks in each grouping have approximately the same basemat thickness (an important consideration in calculating the retardation effects on contaminants). DOE also performed a sensitivity analysis to ensure that the distance between tanks within a grouping (e.g., all the Type III tanks in F-Area Tank Farm are not adjacent to each other) did not affect substantially the projected results at the point of exposure for a given GTS. The results of this analysis indicate that the distance from F-Area Tank Farm to the point of exposure is relatively large compared to the dimensions of the tank farm so that projected impacts at the point of exposure vary little as the source term is moved within F-Area Tank Farm.

DOE performed a separate MEPAS calculation for each grouping of tanks. For each calculation, DOE entered the source term data (in both concentration and total inventory) for the grouping distributed over a square with area equal to that of the tank bottoms in the grouping. For instance, for the Type I tanks, the source term for the MEPAS calculation would consist of the total inventory of the affected tanks and the concentration of contaminants in the grouping (i.e., the total inventory of the affected tanks divided by the total solids in these tanks) distributed over a square with area equal to the area of the eight Type I tanks.

To account for overlapping of the contaminant plumes from the three separate groupings of tanks, DOE performed the calculations with the three groupings at the same initial physical location (as discussed above, location of the source within the F-Tank Farm boundary has little influence on the calculated concentration at the point of exposure). DOE also summed the centerline concentrations from each plume at the point of exposure to ensure that the highest concentration is reported. Therefore, although the plumes from the groupings may not overlap entirely, DOE's calculation methodology provides an upper estimate for the projected impacts.

B.1.3 RESULTS OF F-AREA GTS *A PRIORI* CALCULATION

As discussed in Section B.1.2, DOE summed the concentrations of each constituent at the centerline of the plume for the F-Area GTS at the point of exposure. Then DOE identified the maximum concentration during the 10,000 year period following closure to determine compliance with performance objectives. For nonradiological constituents, these concentrations can be compared directly to the performance objectives. For the radiological constituents, the total effective dose equivalent is reported in addition to gross alpha concentration. The results of the F-Area GTS *a priori* calculation are provided in Tables B-3 and B-4.

B.2 Contribution of Nontank Sources

DOE used the F-Area GTS represented in Figures 8-1, 8-2, and 8-3 to identify non-tank-farm sources with potential to impact groundwater at the point of exposure (seepline). The F-Area Seepage Basin proved to be the only non-tank-farm source with potentially significant and quantifiable impacts within the GTS.

DOE recently performed a performance assessment (PA) (Cook 1997) for the F-Area Seepage Basin to evaluate potential contributions of radiological and nonradiological constituents to the peak doses for the F-Area GTS presented in Tables B-3 and B-4. This PA was performed to model current conditions at the seepage basin (excluding effects of the pump-and-treat activities) using best currently available source term and hydrogeologic data. The results of this PA for constituents identified in the seepage basin are presented in Tables B-5 and B-6 for the radiological and nonradiological constituents, respectively.

Table B-5 shows that of the radionuclides that have been identified as present in the seepage basin, only Tc-99 and H-3 have peaks within the 10,000 year period of interest for tank closure. Because of its relatively short radiological halflife (12.3 years) and the fact that it does not exist in measurable quantities in tank residuals, groundwater impacts of H-3 resulting from tank closure activities are expected to be inconsequential.

However, Table B-3 shows that Tc-99 has been determined to be the limiting radionuclide with respect to tank closure impacts at the point of exposure (Barnwell-McBean aquifer at the Fourmile Branch seepline). The F-Area GTS *a priori* calculation has predicted a Tc-99 peak dose of 1.9 mrem per year in 805 years after tank closure. Table B-5 shows that Tc-99 resulting from closure of the seepage basin is expected to peak at 0.18 mrem per year in 1,495 years. Since the F-Area GTS Tc-99 peak has been determined to be the limiting radiological impact, the time-dependent behavior of the seepage basin Tc-99 was reviewed to determine if meaningful quantities would be expected to be present during the GTS peak (805 years). This review determined that the dose contribution from Tc-99 at year 805 for groundwater located 490 meters from the seepage basin was insignificant. Therefore, because the seepage basin peak occurs much later than the tank farm peak, the Tc-99 releases from the F-Area seepage basin do not effect the radiological performance objectives of the F-Area GTS. This temporal relationship is shown in Figure B-1.

Table B-3. F-Area GTS *a priori* radiological results at the seepline due to contaminant transport in the three aquifers.

Aquifer		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Gross alpha concentration (pCi/L)	Lifetime risk
Water table	Maximum Value	3.4E-02	1.0E+00	(a)	(a)	1.0E+00	1.0E+00	2.6E-02	2.2E-05
	Time of Maximum (yr)	2205	385	(a)	(a)	385	385	3815	
Barnwell-McBean	Maximum Value	3.6E-02	1.9E+00	(a)	(a)	1.9E+00	1.9E+00	3.9E-02	4.1E-05
	Time of Maximum (yr)	5705	805	(a)	(a)	805	805	6405	
Congaree	Maximum Value	(a)	6.5E-03	(a)	(a)	6.5E-03	6.5E-03	3.7E-05	1.4E-07
	Time of Maximum (yr)	(a)	5495	(a)	(a)	5495	5495	9275	

a. Value is less than 0.001mrem/yr

Table B-4. F-Area *a priori* nonradiological results at the seepline due to contaminant transport in the three aquifers.

Aquifer		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
Water table	Maximum concentration (mg/L)	9.0E-04	(a)	(a)	2.6E-04	4.0E-05	1.1E-05	5.1E-03	(a)	2.7E-03	4.3E-04	(a)	(a)	(a)	3.6E-05
	Time of Maximum (yr)	1085	(a)	(a)	105	4795	9905	4445	(a)	105	5145	(a)	(a)	(a)	4585
Barnwell-McBean	Maximum concentration (mg/L)	2.2E-03	(a)	(a)	1.5E-03	6.0E-05	(a)	7.7E-03	(a)	1.5E-02	6.4E-04	(a)	(a)	(a)	1.7E-05
	Time of Maximum (yr)	1365	(a)	(a)	1015	9555	(a)	7735	(a)	1015	8925	(a)	(a)	(a)	9975
Congaree	Maximum concentration (mg/L)	(a)	(a)	(a)	7.5E-06	(a)	(a)	3.3E-05	(a)	7.9E-05	1.4E-06	(a)	(a)	(a)	(a)
	Time of Maximum (yr)	(a)	(a)	(a)	1085	(a)	(a)	6475	(a)	1085	8365	(a)	(a)	(a)	(a)

a. Concentration is less than 0.000001mg/L

Table B-5. F-Area Seepage Basin performance assessment results for radiological constituents of concern.

Nuclide	Maximum concentration (pCi/l)	Time of maximum concentration (years)	Average dose at peak time (mrem/yr)
Cs-137	-	>1,700,000	-
I-129	2.5E+00	37,785	5.1E-01
Tc-99	1.9E+02	1,495	1.8E-01
H-3	1.7E+00	180	7.8E-05
U-234	6.5E-01	150,496	1.2E-01
U-235	3.5E-01	150,567	6.3E-02
U-238	1.7E+00	150,567	2.9E-01
Pu-239	2.1E-06	368,726	6.5E-06
Am-241	-	345,152	-
Sr-90	-	27,674	-
Y-90	-	27,674	-

Table B-6. F-Area Seepage Basin performance assessment results for nonradiological constituents of concern.

	Maximum concentration (mg/l)	Time of maximum concentration (years)	Average dose at time of maximum concentration (mg/kg/day)
Cadmium	1.1E-04	22,783	3.3E-06
Chromium	-	>101,000	-
Lead	-	>101,000	-
Mercury	-	>101,000	-
Nitrate	7.0E+00	198	2.0E-01
Phosphate	1.5E+00	13,370	4.4E-02
Sodium	1.4E+01	198	4.0E-01

Of the nonradiological constituents with defined performance objectives identified in the F-Area Seepage Basin, only nitrate, nickel, and lead were determined to also exist in significant quantities in the F-Area tank farm GTS. The F-Area Tank Farm fate and transport modeling demonstrates that residual nickel and lead would not appear at the point of exposure (Fourmile Branch seepline) in appreciable concentrations within the 10,000 year period of interest. Further, because these elements have large distribution coefficients in SRS soil, their peak concentrations at the seepline would not be expected to occur for several hundred thousand years after tank closure.

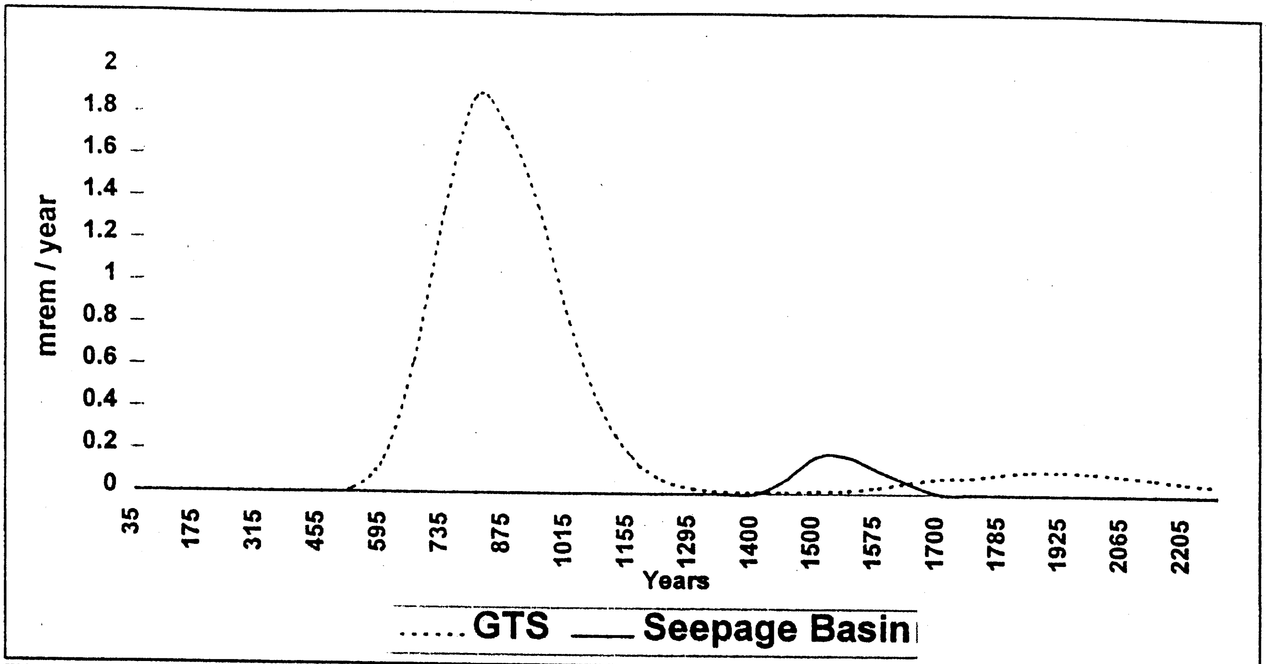

Figure B-1. GTS and Seepage Basin Tc-99 doses in the Barnwell-McBean aquifer at the seepline.

Nitrate is the only nonradiological constituent of concern common to both the F-Area GTS and the F-Area seepage basin that is expected to peak within the 10,000 year period of interest. The temporal relationship is shown below in Figure B-2. This figure shows that although the F-Area GTS and the seepage basin have overlapping peaks at 200 years, the GTS peak (0.0019 mg/l) is only 0.03 percent of the seepage basin maximum value of 7 milligram per liter. Therefore, the GTS nitrate early peak (due to releases from ancillary piping) will not affect the seepage basin maximum value appreciably.

The figure also shows graphically that the limiting peak for the F-Area GTS occurs at 1,015 years at a value of 0.015 milligrams per liter. The graph shows that at this point in time, effects of the seepage basin nitrate on the GTS peak would be minimal.

Because of the reasons given above, fate and transport modeling of the seepage basin and the GTS has determined that the impacts of all common constituents of concern within the two waste units are separated in time or magnitude to such an extent that they are not additive in nature.

B.3 Adjusted Performance Objectives

DOE evaluated performance standards to determine the overall performance objectives. Table B-7 lists the GSA overall performance objectives at the seepline and stream, which are the points of exposure.

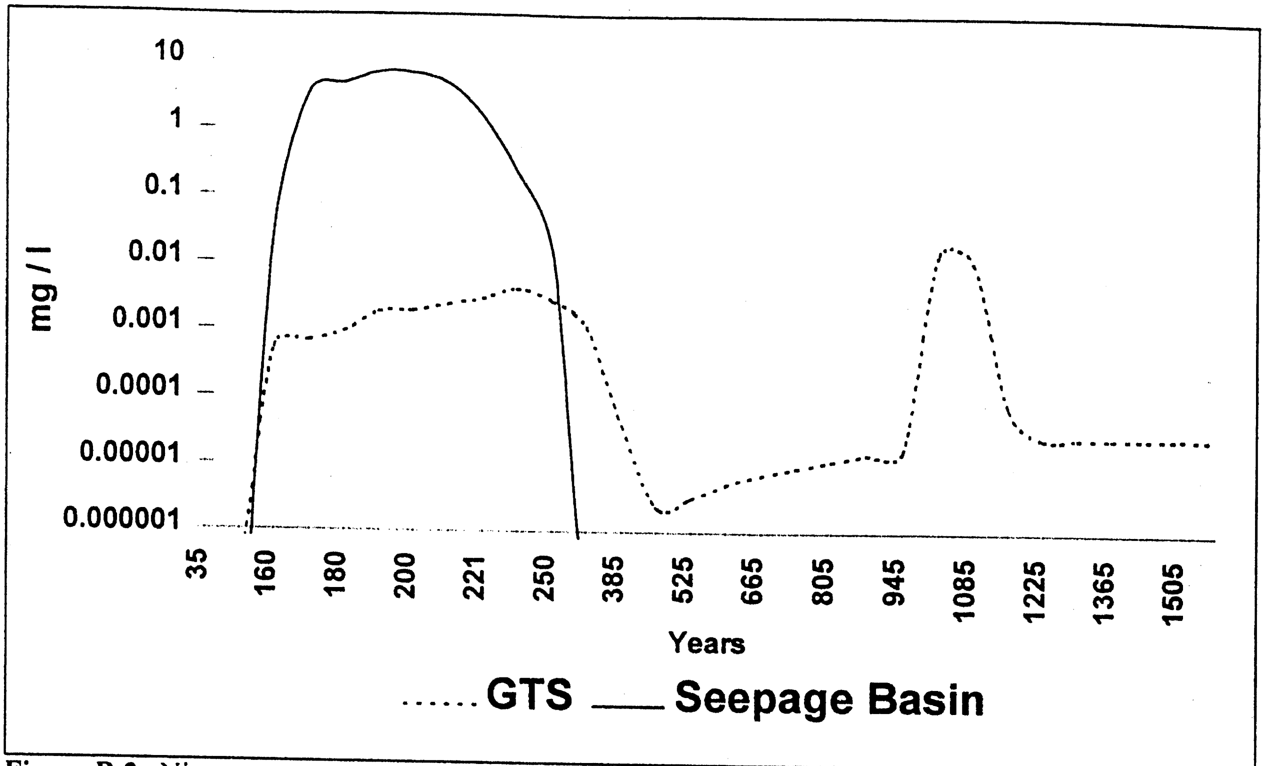

Figure B-2. Nitrate concentration in the Barnwell-McBean Aquifer at the seepline.

Table B-7. Seepline and stream performance objectives for the F-Area GTS.

Constituent	Units	Seepline	Stream
Radiological			
Beta-gamma dose	mrem/yr	4	4
Alpha concentration	pCi/L	15	15
Total dose[a]	mrem/yr	4	4
Nonradiological			
Iron	mg/L	-	1
Aluminum	mg/L	-	0.087
Nickel	mg/L	0.1	0.088
Chromium[b]	mg/L	0.1	0.011
Mercury	mg/L	0.002	1.20E-05
Silver	mg/L	0.05	0.0012
Copper	mg/L	1.3	0.0065
Nitrate (as N)	mg/L	10	-
Fluoride	mg/L	4.0	-
Lead	mg/L	0.015	0.0013
Barium	mg/L	2.0	50
Manganese	mg/L	-	1.0
Zinc	mg/L	-	0.059

a. Total dose (combined alpha and beta-gamma radioactivity) limit used for comparison with performance standards in Appendix C of the general closure plan (DOE 1996a).
b. Total chromium (chromium III and VI).

DOE calculated adjusted performance objectives based on the contributions of sources within the GTS upgradient from the seepline. Based on the source identification, the sources used to calculate adjusted performance objectives were the HLW tank systems and F-Area seepage basins.

As discussed in Section B.2, due to differences in peak times or relative magnitudes, DOE assumes that the seepage basins do not contribute constituents during the F-Area GTS peaks at the seepline in the limiting aquifer (Barnwell-McBean). Therefore, the adjusted performance objectives for the point of exposure are equal to the overall performance objectives listed in Table B-7. The following equation expresses this determination:

$$PO_a = PO - C_{os}$$

where:
- PO_a = Adjusted performance objective
- PO = Overall performance objective
- C_{os} = Contribution of other sources at peak contribution from the HLW tank system

Since C_{os} = 0 (zero):

PO_a = PO - 0 (zero)

PO_a = PO

The adjusted performance objective is analogous with the performance objective for all tank systems in F-Area GTS.

B.4 Calculation of Remaining Performance Objectives

Fate and transport modeling of the F-Area tank farm *a priori* calculation has determined that the overall performance objectives for the GSA will be satisfied. Therefore, DOE must calculate impacts due to closure of Tank 20 for individual constituent contribution at the GTS constituent peak times and subtract this impact from the adjusted performance objectives to determine the remaining overall performance objective. For example, the GTS radiological peak has been predicted to occur in the limiting aquifer (Barnwell-McBean) 805 years after tank farm closure (Table B-3) but the Tank 20 peak in this aquifer has been predicted to occur 1,855 years after closure. The 805 year peak is limiting because the Tank 20 peak is two orders of magnitude smaller (1.9 versus 0.013 mrem per year) and, therefore, the Tank 20 contribution to the GTS peak at 805 years post closure must be calculated and subtracted from the GTS peak to determine the remaining performance objective. The same calculation must be performed for nonradiological constituents.

The remaining performance objective relationship for the F-Area GTS is given by the following expression:

$$PO_r = PO_a - D_{20}$$

where: PO_r = Remaining performance objective

PO_a = Adjusted performance objective

D_{20} = Contribution of Tank 20 at peak contribution from the F-Area Tank Farm

The performance objectives (based on dose equivalent limits) for radiological constituents are additive for different radionuclides. Therefore, the dose performance objective remainder calculation must consider the contribution of each radionuclide at the time the total peak from all radionuclides reaches each point of exposure. This is done by examining the MEPAS output results for each radionuclide and determining the fraction of the total peak attributable to each radionuclide.

To determine the remaining performance objectives, the Tank 20-specific modeling results (evaluated at the time of maximum GTS impacts) were subtracted from the F-Area GTS *a priori* results (provided in Tables B-3 and B-4) for the Barnwell-McBean aquifer. Table B-8 lists these results for the seepline location in the Barnwell-McBean aquifer.

To determine the Tank 20 impacts and the remainder performance objective for chemical constituents, DOE had to determine the relative contribution to the F-Area GTS peak concentration attributable to Tank 20. DOE used a method similar to that described for radiological constituents, except it derived peak contributions for each contaminant because concentrations of the different contaminants are not additive.

DOE derived the GTS remaining chemical constituent performance objectives by subtracting the Tank 20 peak impact from the adjusted GTS performance objective. For example, the chromium contribution attributable to Tank 20 at the GTS peak time is 5.0E-6 milligram per liter. Therefore, the remaining GTS performance objective is 0.1 minus 5.0E-06 or 0.099995 or effectively 0.1. Table B-8 lists the Tank 20 impacts results for all chemical constituents of concern.

Table B-8. Tank 20 impacts and remaining performance objectives for the F-Area GTS.[a]

	Units	Seepline	Stream
Radiological			
Beta-gamma dose	mrem/yr	0.0055 (4.0)	3.0E-05 (4.0)
Alpha concentration	pCi/L	0 (15)	0 (15)
Total dose	mrem/yr	0.0055 (4.0)	3.0 E-05 (4.0)
Nonradiological[b]			
Iron	mg/L	-	3.5E-06 (1.0)
Nickel	mg/L	0 (0.1)	0 (0.088)
Chromium[c]	mg/L	5.0E-06 (0.1)	2.7E-08 (0.010)
Mercury	mg/L	0 (0.002)	0 (1.2E-5)
Silver	mg/L	1.9E-04 (0.05)	1.0E-06 (0.0012)
Copper	mg/L	0 (1.3)	0 (.0065)
Nitrate	mg/L	1.3E-03 (10)	-
Lead	mg/L	0 (0.015)	0 (1.3E-3)
Fluoride	mg/L	1.3E-04 (4.0)	-
Barium	mg/L	0 (2.0)	0 (50)
Manganese	mg/L	-	1.5E-07 (1.3E-3)
Zinc	mg/L	-	1.5E-08 (0.059)
Uranium	mg/L	0	0

a. Values in parentheses represent remaining performance objectives for the F-Area GTS tank sources.
b. Aluminum does not reach seepline in 10,000 years.
c. Total chromium (chromium III and VI).

B.5 Summary

Establishing remaining performance objectives using the method described in this appendix will provide reasonable assurance that the impacts of future closure activities do not exceed overall performance objectives. As tanks are closed, sampling and analysis of the residual contamination provides a more accurate source term for these tanks. Since tanks may contain more or less contamination than assumed for the *a priori* F-Area GTS calculation, after each tank is characterized for closure, the impacts of all the remaining unclosed tanks in the GTS will be calculated to ensure all performance objectives are satisfied.

In using this method, DOE takes credit for the fact that constituents of concern from various areas impact compliance points at different times due to varying closure scenarios and geological conditions. In addition, the method can determine the level of resources required for future site remediation activities.

B.6 References

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