- The Charleston, South Carolina, earthquake of 1886 had an estimated Richter magnitude of 6.6; it occurred approximately 90 miles from the SRS area, which experienced an estimated peak horizontal acceleration of 8 percent of gravity (0.08g) (Lee, Maryak, and McHood 1997). Lee, Maryak, and McHood (1997) re-evaluated historical data for the 1886 event and for other earthquakes in the Charleston area and determined that the Charleston epicentral zone could produce a magnitude 7.5 earthquake.

- As summarized by Geomatrix (1991), the Union County, South Carolina, earthquake of 1913 had an estimated magnitude of 4.5 and occurred 90 to 100 miles from SRS. The Union County earthquake is included in a group of historical epicenters that form a diffuse northwesterly trending zone from the Charleston region to the Appalachian tectonic province. Within that zone, Geomatrix (1991) concluded that an earthquake of up to magnitude 6.0 could theoretically occur.

In recent years, the following three earthquakes occurred inside the SRS boundary, as reported by local print media and cited in DOE (2000a):

- On May 17, 1997, with a Richter magnitude of 2.3 and a focal depth of 3.38 miles; its epicenter was southeast of K Area

- On August 5, 1988, with a Richter magnitude of 2.0 and a focal depth of 1.6 miles; its epicenter was northeast of K Area

- On June 8, 1985, with a Richter magnitude of 2.6 and a focal depth of 3.7 miles; its epicenter was south of C Area and west of K Area.

Existing information does not relate these earthquakes conclusively with known faults under the Site. In addition, the focal depth of these earthquakes is currently being reevaluated. Figure 3-6 shows the locations of the epicenters of these earthquakes.

Outside the SRS boundary, an earthquake with a Richter scale magnitude of 3.2 occurred on August 8, 1993, approximately 10 miles east of the City of Aiken near Couchton, South Carolina. People reported feeling this earthquake in Aiken, New Ellenton (immediately north of SRS), North Augusta (approximately 25 miles northwest of the SRS), and on the Site (Aiken Standard 1993).

3.2 Water Resources

This section describes surface and subsurface water in the area potentially affected by the proposed action. Surface water and groundwater are characterized in terms of flow and quality (physical properties and concentrations of chemicals and contaminants).

3.2.1 SURFACE WATER

The Savannah River bounds SRS on its southwestern border for about 20 miles, approximately 160 river miles from the Atlantic Ocean. Five upstream reservoirs – Jocassee, Keowee, Hartwell, Richard B. Russell, and Strom Thurmond – minimize the effects of droughts and the impacts of low flow on downstream water quality and fish and wildlife resources in the river. River flow averages about 10,000 cubic feet per second at SRS (DOE 1995b).

Approximately 130 river miles downstream of SRS, the river supplies domestic and industrial water for Savannah, Georgia, and Beaufort and Jasper Counties in South Carolina through intakes at about River Mile 29 and River Mile 39, respectively (DOE 1995b).

The SRS streams that could be affected by the alternatives are blackwater streams, which means that the water has a dark coloration due to the dissolution of natural organic matter from soils and decaying vegetation. Three SRS streams potentially could be affected by salt processing alternatives: McQueen Branch, Upper Three Runs, and Fourmile Branch

(Figure 3-7). Of the three, only Fourmile Branch ever received the high flows and elevated temperatures associated with thermal discharges from nuclear reactors. McQueen Branch, which lies east of the proposed facilities, receives surface runoff from both proposed sites (Figures 3-1 and 3-2) and potentially could be affected by land-disturbing construction activities. Process wastewater from salt processing operations would be treated in the Effluent Treatment Facility (ETF) and discharged to Upper Three Runs via National Pollutant Discharge Elimination System (NPDES) outfall H-16. Sanitary wastewater from salt processing facilities would be treated in the Centralized Sanitary Wastewater Treatment Facility and discharged to Fourmile Branch via NPDES outfall G-10 (WSRC 1999b).

McQueen Branch flows approximately 3 miles from its headwaters east of H Area to its confluence with Tinker Creek (see Figure 3-7). Tinker Creek flows west for several hundred feet before entering Upper Three Runs, approximately 1 mile north of Z Area. McQueen Branch is a shallow blackwater stream with an average width of approximately 6 feet. For most of its length, it lies in a bottomland hardwood forest.

Upper Three Runs, the longest of the SRS streams, is a large blackwater stream in the northern part of SRS that discharges to the Savannah River. It drains an area of over 195 square miles and is approximately 25 miles long, with its lower 17 miles within SRS boundaries. This creek receives more water from underground sources than other SRS streams and is the only stream with headwaters arising outside the Site. It is the only major tributary on SRS that has not received thermal discharges from nuclear reactors; however, it does receive NPDES-permitted wastewater discharges from other SRS facilities (Halverson et al. 1997).

Fourmile Branch is a blackwater stream that originates near the center of SRS and flows southwest for 15 miles before emptying into the Savannah River (Halverson et al. 1997). It drains an area of about 22 square miles, including much of F, H, and C Areas. In its lower reaches, Fourmile Branch broadens and flows via braided channels through a delta formed by the disposition of sediments eroded form upstream during high flows associated with reactor operations. Downstream from the delta, the channels rejoin into one main channel. Most of the flow discharges into the Savannah River, while a small portion flows west and enters Beaver Dam Creek (DOE 1995b).

From 1974 to 1995, the mean flow of Upper Three Runs at Road A was 245 cubic feet per second, and the 7Q10 (minimum 7-day average flow rate that occurs with an average frequency of once in 10 years) was 100 cubic feet per second (Halverson et al. 1997). The *SRS Ecology Environmental Information Document* (Halverson et al. 1997) and the *Final Environmental Impact Statement for the Shutdown of the River Water System at the Savannah River Site* (DOE 1997a) contain detailed information on flow rates and water quality of the Savannah River and SRS streams.

The South Carolina Department of Health and Environmental Control (SCDHEC) regulates the physical properties and concentrations of chemicals and metals in SRS effluents under the NPDES program. A comparison of 1997 Savannah River water quality analyses showed no significant differences between stations up- and down-stream of SRS (Arnett and Mamatey 1998a). Table 3-1 summarizes the water quality of Fourmile Branch and Upper Three Runs for 1997. Occasionally, reported concentrations in Table 3-1 exceed water quality criterion (see, for example, aluminum). An exceedance suggests the potential for adverse effects to aquatic biota, but should not be construed as an actual risk. Water quality criteria are based on laboratory studies that do not take into account site-specific ameliorative or mediating factors in the environment that reduce or limit the bioavailability of a chemical. Concentrations that exceed water quality criteria may have natural or anthropogenic origins.

In 1997, major releases of radionuclides from the SRS to surface waters amounted to 8,950

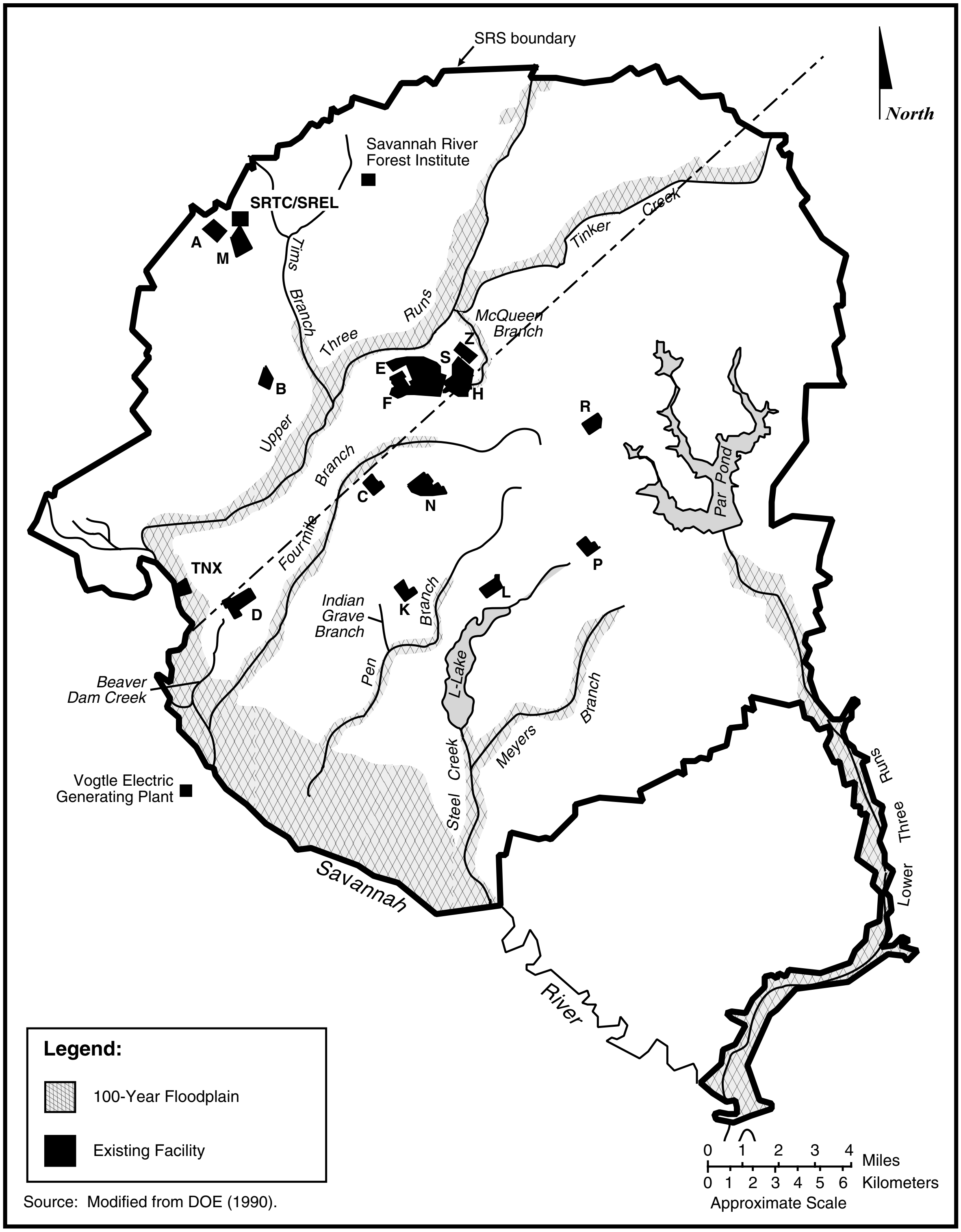

Figure 3-7. Savannah River Site, showing 100-year floodplain and major stream systems.

Table 3-1. SRS stream water quality (onsite downstream locations).

Parameter[a]	Units	Upper Three Runs (U3R-4) (average)	Water Quality Standard[b]	
Aluminum	mg/L	0.274[c]	0.087	
Cadmium	mg/L	ND[d]	0.00066	
Calcium	mg/L	1.62	NA[e]	
Cesium-137	pCi/L	0.67	120[f]	L4-5
Chromium	mg/L	ND	0.011	
Copper	mg/L	0.036[c]	0.0065	
Dissolved oxygen	mg/L	8.2	≥5	
Iron	mg/L	0.586	1	
Lead	mg/L	ND	0.0013	
Magnesium	mg/L	0.385[c]	0.3	
Manganese	mg/L	0.026	1	
Mercury	mg/L	ND	0.000012	
Nickel	mg/L	0.012	0.088	
Nitrate	mg/L	0.24	10[g]	
pH	pH	6.3	6-8.5	
Plutonium-238	pCi/L	ND	1.6[f]	
Plutonium-239	pCi/L	0.0005	1.2[f]	
Sodium	mg/L	1.58	NA	
Strontium-89,90	pCi/L	0.061	8[g]	
Suspended solids	mg/L	14.1	NA	
Temperature[h]	°C	17.3	32.2	
Total dissolved solids	mg/L	36	500[i]	
Tritium	pCi/L	4.260	20,000[g]	
Uranium-234	pCi/L	0.093	20[f, j]	
Uranium-235	pCi/L	0.046	24[f, j]	
Uranium-238	pCi/L	0.110	24[f, j]	
Zinc	mg/L	0.028	0.059	

Source: Arnett and Mamatey (1998a).
a. Parameters DOE routinely measures as a regulatory requirement or as part of ongoing monitoring programs.
b. Water Quality Criteria for aquatic life unless otherwise indicated.
c. Concentration exceeded WQC; however, these criteria are for comparison only. WQCs are not legally enforceable.
d. ND = Not detected.
e. NA = Not applicable.
f. MCL = Maximum Contaminant Level; State Primary Drinking Water Regulations.
g. DCG = DOE Derived Concentration Guides for Water (DOE Order 5400.5). DCG values are based on committed effective dose of 100 millirem per year; however, because drinking water MCL is based on 4 millirem per year, value listed is 4 percent of DCG.
h. Shall not be increased more than 2.8°C (5°F) above natural temperature conditions or exceed a maximum of 32.2°C (90°F) as a result of the discharge of heated liquids, unless appropriate temperature criterion mixing zone has been established. L4-5 L4-6
i. Secondary MCL; State Drinking Water Regulations. L8-9 L11-7
j. EPA MCL for uranium is 30 µg/L, which is equivalent to 27 pCi/L. Because the DCG is a lower concentration, DOE uses it for the uranium standard.

curies of tritium, 0.262 curie of strontium-89 and -90, and 0.177 curie of cesium-137 (Arnett and Mamatey 1998b). Table 3-2 lists radioactive liquid releases by source for 1997; Table 3-3 lists radioactive liquid releases by outfall or facility and compares annual average radionuclide concentrations to DOE concentration guides. Figure 3-8 shows outfall and facility locations for radioactive surveillance. The resulting dose to a downriver consumer of river water from radionuclides released from the Site was less than 2 percent of the U.S. Environmental Protection Agency (EPA) and DOE standards for public water supplies (40 CFR Part 141 and DOE Order 5400.5, respectively) and less than 0.1 percent of the DOE dose standard from all pathways (DOE 1990; Arnett and Mamatey 1998b). Table 3-4 lists potential contributors of contamination to Upper Three Runs and Fourmile Branch.

3.2.2 GROUNDWATER RESOURCES

3.2.2.1 Groundwater Features

In the SRS region, the subsurface contains two hydrogeologic provinces. The uppermost, consisting of a wedge of unconsolidated Coastal Plain sediments of Late Cretaceous and Tertiary age, is the Atlantic Coastal Plain hydrogeologic province. Beneath the sediments of the Atlantic Coastal Plain hydrogeologic province are rocks of the Piedmont hydrogeologic province. These rocks consist of Paleozoic igneous and metamorphic basement rocks and Upper Triassic Age lithified mudstone, sandstone, and conglomerates of the Upper Triassic Dunbarton basin. Sediments of the Atlantic Coastal Plain hydro

Table 3-2. Annual liquid releases by source for 1997 (including direct and seepage basin migration releases).

		Curies					
Radionuclide[a]	Half-life (years)	Reactors	Separations[b]	Reactor materials	TNX	SRTC	Total
H-3 (oxide)	12.3	2.91×10^{3}	5.24×10^{3}		4.02×10^{2}	1.82	8.55×10^{3}
Sr-89,90[c]	29.1	6.46×10^{-2}	1.40×10^{-1}		5.09×10^{-3}	4.10×10^{-3}	2.14×10^{-1}
I-129[d]	1.6×10^{7}		7.82×10^{-2}				7.82×10^{-2}
Cs-137	30.2	2.86×10^{-3}	4.49×10^{-2}				4.78×10^{-2}
U-234	2.46×10^{5}	4.45×10^{-3}	2.30×10^{-2}	2.68×10^{-5}	1.52×10^{-6}	1.06×10^{-4}	2.76×10^{-2}
U-235	7.04×10^{8}	4.91×10^{-5}	7.23×10^{-4}		1.37×10^{-7}	3.44×10^{-6}	7.76×10^{-4}
U-238	4.47×10^{9}	3.83×10^{-3}	2.57×10^{-2}	5.71×10^{-5}	9.19×10^{-6}	1.11×10^{-4}	2.97×10^{-2}
38	87.7	4.24×10^{-5}	9.57×10^{-4}		7.68×10^{-7}	1.78×10^{-6}	1.00×10^{-3}
Pu-239[d]	24,100	1.10×10^{-2}	3.39×10^{-2}	1.14×10^{-3}	1.12×10^{-3}	3.38×10^{-3}	5.05×10^{-2}
Am-241	432.7		7.81×10^{-6}	2.11×10^{-6}			9.92×10^{-6}
Cm-244	18.1		2.93×10^{-6}	4.14×10^{-7}			3.34×10^{-6}

Notes: Blank spaces indicate no quantifiable activity.
Source: Arnett and Mamatey (1998a).
a. H = hydrogen (H-3 = tritium), Sr = strontium, I = iodine, Cs = cesium, U = uranium, Pu = plutonium, Am = americium, Cm = curium.
b. Includes separations, waste management, and tritium facilities.
c. Includes unidentified beta.
d. Includes unidentified alpha.
TNX = a technology development facility adjacent to the Savannah River.
SRTC = Savannah River Technology Center.

Table 3-3. Liquid radioactive releases by outfall/facility and comparison of annual average radionuclide concentrations to DOE derived concentration guides.[b]

Outfall or Facility	Radionuclide[a]	Quantity of Radionuclides Released during 1997 (curies)	Average Effluent Concentration during 1997 (microcuries per milliliter)	DOE DCGs[b] (microcuries per milliliter)
F Area (Separations and Waste Management)				
F-01	H-3	5.03×10^{-2}	2.54×10^{-7}	2.00×10^{-3}
	Sr-89,90	Below MDL[d]	1.02×10^{-11}	1.00×10^{-6}
	Cs-137	Below MDL	1.32×10^{-9}	3.00×10^{-6}
F-012 (281-8F Retention Basin)	H-3	7.6710^{-1}	9.83×10^{-6}	2.00×10^{-3}
	Sr-89,90	Below MDL	3.01×10^{-9}	1.00×10^{-6}
	Cs-137	1.58×10^{-3}	2.07×10^{-8}	3.00×10^{-6}
F-013 (200-F Cooling Basin)	H-3	1.73×10^{-2}	1.63×10^{-6}	2.00×10^{-3}
	Sr-89,90	3.13×10^{-5}	4.39×10^{-9}	1.00×10^{-6}
	Cs-137	5.92×10^{-4}	2.30×10^{-8}	3.00×10^{-6}
Fourmile Branch-3 (F-Area Effluent)	H-3	1.32	7.80×10^{-7}	2.00×10^{-3}
	Sr-89,90	Below MDL	4.16×10^{-10}	1.00×10^{-6}
	Cs-137	Below MDL	8.97×10^{-10}	3.00×10^{-6}
Upper Three Runs-2 (F Storm Sewer)	H-3	1.66×10^{-1}	8.78×10^{-7}	2.00×10^{-3}
	Sr-89,90	Below MDL	8.56×10^{-11}	1.00×10^{-6}
	Cs-137	Below MDL	5.13×10^{-10}	3.00×10^{-6}
	U-234	6.86×10^{-5}	3.48×10^{-10}	6.00×10^{-7}
	U-235	5.15×10^{-6}	3.02×10^{-11}	6.00×10^{-7}
	U-238	1.90×10^{-4}	9.15×10^{-10}	6.00×10^{-7}
	Pu-238	1.54×10^{-5}	9.10×10^{-11}	4.00×10^{-8}
	Pu-239	7.73×10^{-6}	4.66×10^{-11}	3.00×10^{-8}
	Am-241	7.77×10^{-6}	3.98×10^{-11}	3.00×10^{-8}
	Cm-244	2.92×10^{-6}	1.74×10^{-11}	6.00×10^{-8}
Upper Three Runs F-3 (Naval Fuel Effluent)	H-3	3.45×10^{-2}	1.46×10^{-6}	2.00×10^{-3}
	Sr-89,90	Below MDL	1.16×10^{-10}	1.00×10^{-6}
	Cs-137	Below MDL	2.47×10^{-10}	3.00×10^{-6}
	U-234	1.62×10^{-5}	8.95×10^{-10}	6.00×10^{-7}
	U-235	5.86×10^{-6}	2.30×10^{-9}	6.00×10^{-7}
	U-238	3.04×10^{-6}	1.76×10^{-10}	6.00×10^{-7}
	Pu-238	1.61×10^{-7}	6.23×10^{-12}	4.00×10^{-8}
	Pu-239	2.60×10^{-8}	5.04×10^{-12}	3.00×10^{-8}
	Am-241	4.49×10^{-8}	7.07×10^{-13}	3.00×10^{-8}
	Cm-244	9.54×10^{-9}	-6.84×10^{-11}	6.00×10^{-8}
H Area (Separations and Waste Management)				
Fourmile Branch-1C (H-Area Effluent)	H-3	3.85	9.22×10^{-6}	2.00×10^{-3}
	Sr-89,90	7.93×10^{-5}	7.05×10^{-10}	1.00×10^{-6}
	Cs-137	6.77×10^{-4}	3.27×10^{-9}	3.00×10^{-6}
H-017 (281-8H Retention Basin)	H-3	7.17×10^{-1}	1.02×10^{-5}	2.00×10^{-3}
	Sr-89,90	5.21×10^{-4}	7.91×10^{-9}	1.00×10^{-6}
	Cs-137	1.04×10^{-2}	1.11×10^{-7}	3.00×10^{-6}

Table 3-3. (Continued).

Outfall or Facility	Radionuclide[a]	Quantity of Radionuclides Released during 1997 (curies)	Average Effluent Concentration during 1997 (microcuries per milliliter)	DOE DCGs[b] (microcuries per milliliter)
H-018 (200-H Cooling Basin)	H-3	1.44×10^{-1}	2.27×10^{-5}	2.00×10^{-3}
	Sr-89,90	2.75×10^{-4}	4.58×10^{-8}	1.00×10^{-6}
	Cs-137	2.21×10^{-4}	3.71×10^{-7}	3.00×10^{-6}
HP-15 (Tritium Facility Outfall)	H-3	1.74	1.55×10^{-5}	2.00×10^{-3}
	Cs-137	Below MDL	7.75×10^{-11}	3.00×10^{-6}
HP-52 (H-Area Tank Farm)	H-3	2.43	1.30×10^{-6}	2.00×10^{-3}
	SR-89,90	Below MDL	7.67×10^{-11}	1.00×10^{-6}
	Cs-137	1.58×10^{-4}	1.92×10^{-9}	3.00×10^{-6}
McQueen Branch at Road F	H-3	1.20×10^{1}	1.05×10^{-5}	2.00×10^{-3}
	Cs-137	Below MDL	4.85×10^{-10}	3.00×10^{-6}
Upper Three Runs – 2A (Effluent Treatment Facility Outfall at Rd C)	H-3	3.82×10^{2}	4.72×10^{-3}	2.00×10^{-3}
	Sr-89,90	1.28×10^{-5}	2.24×10^{-9}	1.00×10^{-6}
	Cs-137	1.79×10^{-2}	2.16×10^{-7}	3.00×10^{-6}
S Area	H-3	9.18×10^{-1}	1.57×10^{-5}	2.0×10^{-3}
S-004 (Defense Waste Processing Facility)	Sr-89,90	2.98×10^{-6}	1.43×10^{-10}	1.00×10^{-6}
	Cs-137	Below MDL	6.30×10^{-10}	3.00×10^{-6}
	U-234	2.63×10^{-7}	1.74×10^{-11}	6.00×10^{-7}
	U-238	7.80×10^{-7}	3.13×10^{-11}	6.00×10^{-7}
	Pu-238	1.17×10^{-7}	7.08×10^{-13}	4.00×10^{-8}
	Pu-239	6.15×10^{-8}	2.79×10^{-12}	3.0×10^{-8}

Notes: MDL denotes "minimum detectable level."
Source: Arnett and Mamatey (1998a).
a. H = hydrogen (H-3 = tritium), Sr = strontium, I = iodine, Cs = cesium, U = uranium, Pu = plutonium, Am = americium, Cm = curium.
b. DCG = Derived Concentration Guide. Source: DOE Order 5400.5. In cases where different chemical forms have different DCGs, the lowest DCG for the radionuclide is given. DCGs are defined as the concentration of that radionuclide that will give a 50-year committed effective dose equivalent of 100 mrem under conditions of continuous exposure for one year. DCGs are reference values only and are not considered release limits or standards.

geologic province are divided into three aquifer systems: the Floridan Aquifer System, the Dublin Aquifer System, and the Midville Aquifer System as shown in Figure 3-4 (Aadland, Gellici, and Thayer 1995). The Meyers Branch Confining System and/or the Allendale Confining System, as shown in Figure 3-4, separate the aquifer systems.

Groundwater within the Floridan System (the shallow aquifer beneath the Site) flows slowly toward SRS streams and swamps and into the Savannah River. The depth to which onsite streams cut into soils, the lithology of the soils, and the orientation of the soil formations control the horizontal and vertical movement of the groundwater. The valleys of smaller perennial streams allow discharge from the shallow saturated geologic formations. The valleys of major tributaries of the Savannah River (e.g., Upper Three Runs) drain formations of intermediate depth, and the river valley drains deep formations.

Groundwater flow in the shallow (Floridan) aquifer system is generally horizontal, but does have a vertical component. In divide areas between surface-water drainages, the vertical component of the hydraulic gradient typically is downward. In the lower reaches of streams, groundwater again moves generally in a horizontal direction, but may have an upward vertical component.

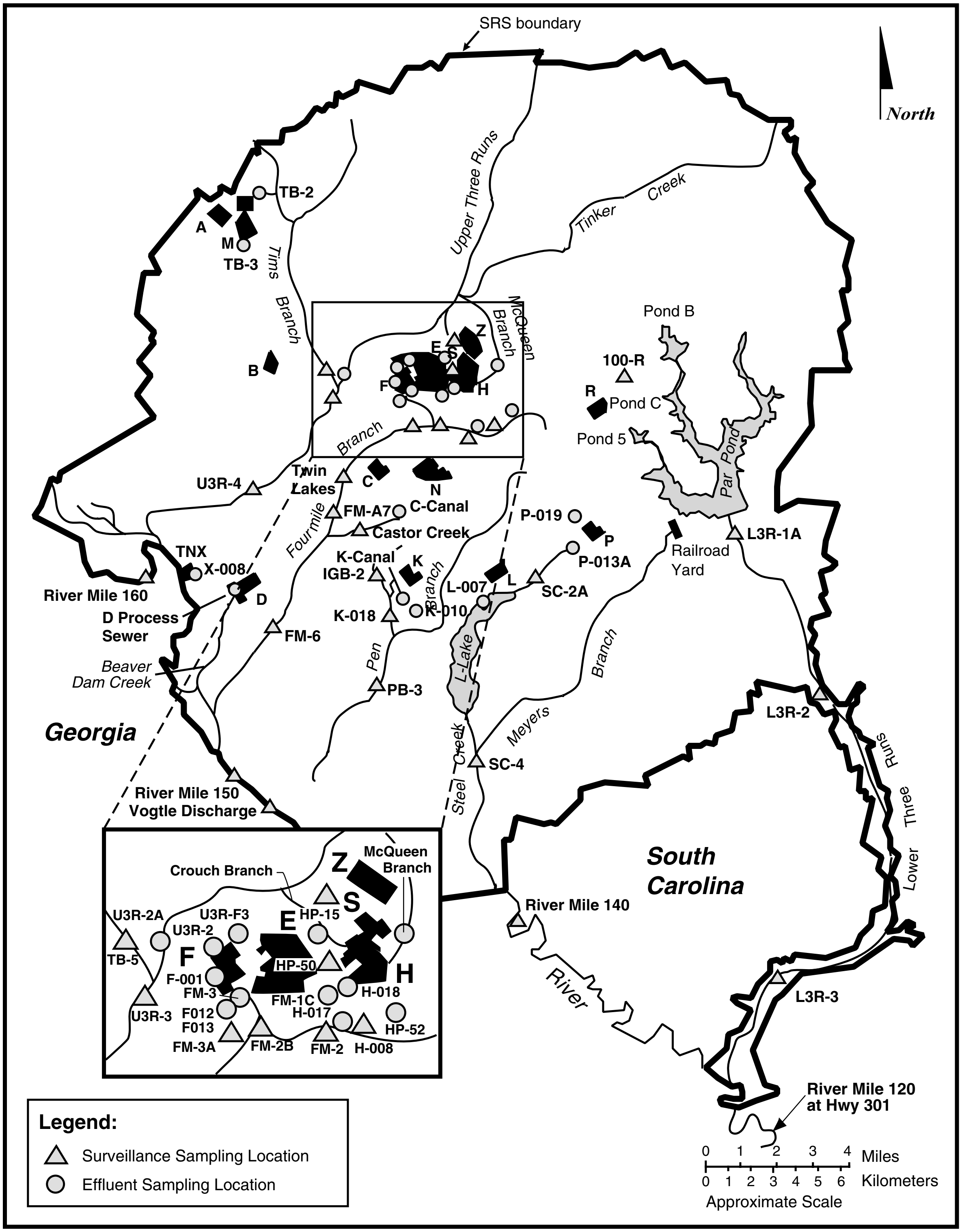

Figure 3-8. Radiological surface water sampling locations.

Table 3-4. Potential F and H Area contributors of contamination to Upper Three Runs and Fourmile Branch.

Fourmile Branch Watershed	Upper Three Runs Watershed
Burial Ground Complex Groundwater[a]	Burial Ground Complex Groundwater[a]
Burial Ground Complex: the Old Radioactive Waste Burial Ground (643-E) and Solvent Tanks S01-S22 portions	Burial Ground Complex: the Low-Level Radioactive Waste Disposal Facility (643-7E) portion
F-Area Coal Pile Runoff Basin, 289-F	Burma Road Rubble Pit, 231-4F
F-Area Hazardous Waste Management Facility, 904-41G, -42G, -43G	F-Area Burning/Rubble Pits, 231-F, -1F, -2F
F-Area Inactive Process Sewer Lines from Building to the Security Fence[a], 081-1F	F-Area Inactive Process Sewer Lines from Building to the Security Fence[a], 081-1F
F-Area Retention Basin, 281-3F	
F-Area Seepage Basin Groundwater Operable Unit	H-Area Coal Pile Runoff Basin, 289-H
H-Area Hazardous Waste Management Facility, 904-44G, -45G, -46G, -56G	
H-Area Inactive Process Sewer Lines from Building to the Security Fence[a], 081-H	H-Area Inactive Process Sewer Lines from Building to the Security Fence[a], 081-H
H-Area Retention Basin, 281-3H	Old F-Area Seepage Basin, 904-49G
H-Area Seepage Basin Groundwater Operable Unit	211-FB Plutonium-239 Release, 081-F
H-Area Tank Farm Groundwater	
Mixed Waste Management Facility, 643-28E	
Warner's Pond, 685-23G	

Source: WSRC (1996)
a. Units located in more than one watershed.

With the release of water to the streams, the hydraulic head of the aquifer unit releasing the water can become less than that of the underlying unit. If this occurs, groundwater has the potential to migrate upward from the lower unit to the overlying unit. For example, to the south of H Area, Fourmile Branch cuts into the Upper Three Runs Aquifer, but does not cut into the Gordon Aquifer; the hydraulic head is greater in the Gordon Aquifer than in the overlying Upper Three Runs Aquifer. At such a location, contaminants in the overlying aquifer system would be prevented from migrating into deeper aquifers by the upward hydraulic gradient.

Shallow groundwater flow in S and Z Areas is to the southwest toward Crouch Branch, to the northeast toward McQueen Branch, and to the northwest toward Upper Three Runs. North-west-flowing Crouch and McQueen Branches are tributaries to Upper Three Runs, which flows southwest to the Savannah River. Groundwater flow in deeper aquifers (e.g., Crouch Branch and McQueen Branch Aquifers) is generally to the southwest. Thus, at some depth there is a reversal of flow from that of the shallow aquifers.

Based on data in the SRS groundwater geochemical database, no groundwater plumes are mapped as emanating from S- or Z-Area sources. However, a preliminary review of groundwater monitoring data for S Area indicates tritium contamination in one monitoring well. The contamination is likely from the tritium facility in H Area. This well is located just south of Site B. No tritium contamination was noted in groundwater monitoring data for Z Area. Within the immediate vicinity of Site