Chapter 8
Groundwater

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To Read About . . . See Page . . .

DURING the past 40 years, scientists have begun to understand the complexity of the hydrologic system. Water on the land surface and in the atmosphere is easily studied, but water existing in pores and fractures beneath the surface is less accessible. Water infiltrates into soils and rock beneath the ground, then moves along pressure gradients—sometimes for short distances before emerging in streams and lakes; sometimes across hundreds of miles over many years. While water in a surface stream may flow many miles in a day, groundwater may move only a few hundred feet in a year.

As scientists have come to understand the phenomenon of groundwater, they have come to appreciate the risks that come from contamination finding its way into this dynamic system. During the 20th century, waste from industrial and public activities was discovered in groundwater, and scientists found that cleaning water underground was much more difficult than removing contaminants from surface water. As a result, federal and state governments enacted statutes designed to protect the groundwater and to clean up contamination found in groundwater. Understanding, using, protecting, and cleaning up groundwater are significant aspects of the Savannah River Site (SRS) groundwater program.

SRS is located atop sediments of the Atlantic Coastal Plain composed predominantly of sand and clay. Water flows easily through the sand layers but is retarded by less permeable clay beds, creating a complex system of aquifers. Operations during the life of SRS have resulted in contamination migrating into groundwater at various locations on the site (figure 8–1), predominantly in the central areas of the site. The ongoing movement of water into the ground, through the aquifer system, and then into streams and lakes—or even into deeper aquifers—continues to carry contamination along with it, resulting in spreading plumes.

To address this problem, the site has developed, over several decades, a comprehensive network of monitoring wells that have helped SRS scientists understand the physical groundwater system, locate plumes of contamination in groundwater, and monitor the progress of cleanup efforts. In addition to monitoring, the site has a comprehensive groundwater protection and remediation program that will be described later in this chapter. The chapter also will describe SRS's physical groundwater system; its monitoring, protection, and remediation programs; and—in summary form—the monitoring results.

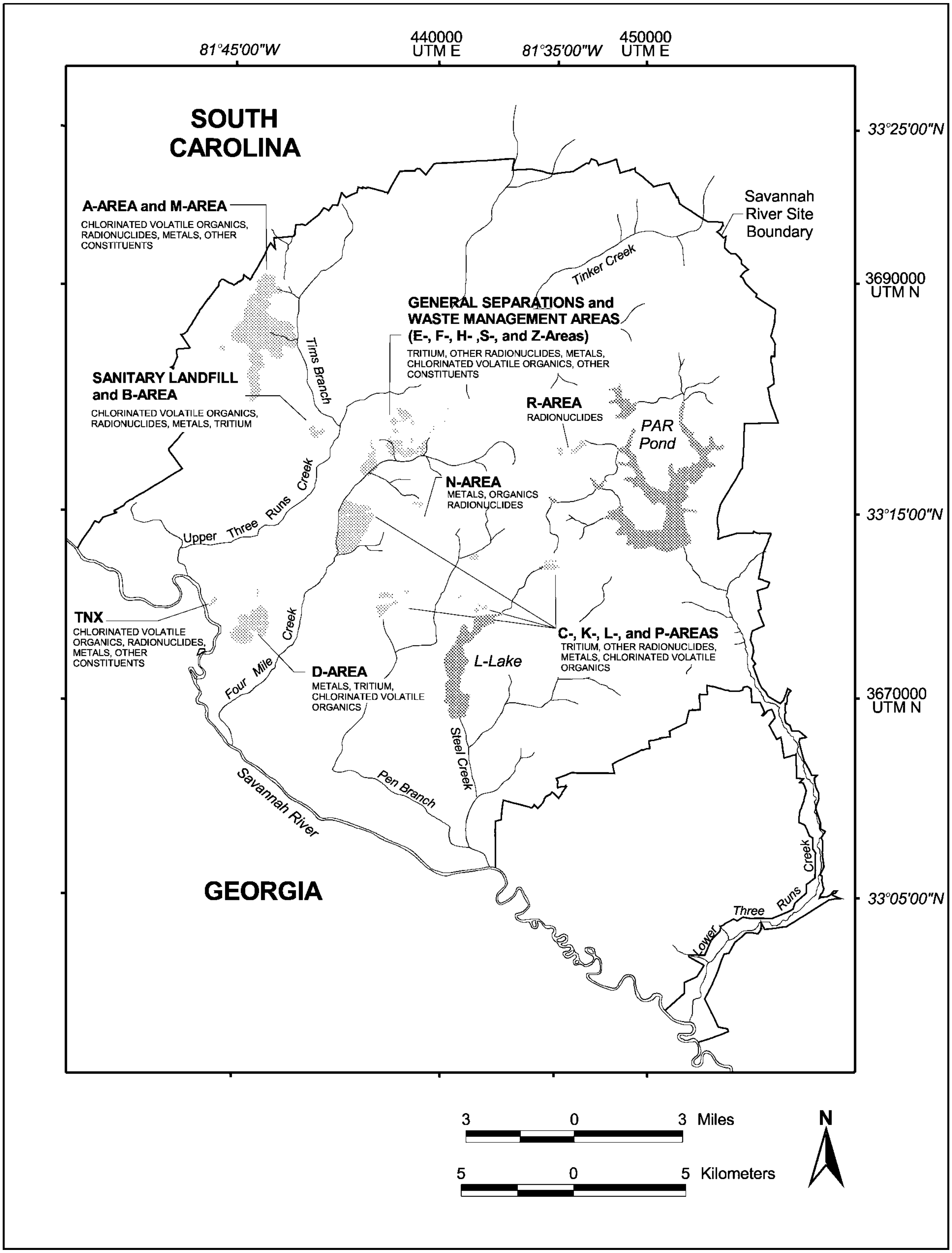
This chapter provides an overview of the groundwater monitoring program at SRS; more detailed groundwater monitoring results can be obtained by contacting the manager of the Westinghouse Savannah River Company (WSRC) Environmental Protection Department (EPD) at 803–725–1728.

The *Environmental Protection Department's Well Inventory* (ESH–EMS–2000–470), which is available to the public, contains detailed maps of the wells at each monitored location.

Groundwater at SRS

SRS is underlain by sediment of the Atlantic Coastal Plain. The Atlantic Coastal Plain consists of a southeast-dipping wedge of unconsolidated sediment that extends from its contact with the Piedmont Province at the Fall Line to the edge of the continental shelf. The sediment ranges from Late Cretaceous to Miocene in age and comprises layers of sand, muddy sand, and clay with subordinate calcareous sediments. It rests on crystalline and sedimentary basement rock.

The hydrostratigraphy of SRS has been subject to several classifications. The hydrostratigraphic classification established in Aadland et al., 1995, and in Smits et al., 1996, is widely used at SRS and is



SRTC/ER Map

Figure 8–1 Facilities Monitored by the SRS Monitoring Well Network; Shaded Areas Indicate Extent of Groundwater Contamination in 2001.

Key for Figure 8–1

A-Area/M-Area
- A-Area/M-Area Recovery Well Network
- A-Area Background Well Near Firing Range
- A-Area Burning/Rubble Pits/A-Area Ash Pile
- A-Area Coal Pile Runoff Containment Basin
- A-Area Metals Burning Pit
- A–014 Outfall
- M-Area Hazardous Waste Management Facility & M-Area Plume Definition
- Metallurgical Laboratory Seepage Basin
- Miscellaneous Chemical Basin
- Motor Shop Oil Basin
- Savannah River Laboratory Seepage Basins
- Silverton Road Waste Site

General Separations/Waste Management (E-Area, F-Area, H-Area, S-Area, & Z-Area)
- Burial Grounds Perimeter
- Burma Road Rubble Pit
- E-Area Vaults near the Burial Grounds
- F-Area Ash Basin
- F-Area Burning/Rubble Pits
- F-Area Canyon Building/A-Line Uranium Recovery Facility
- F-Area Coal Pile Runoff Containment Basin
- F-Area Effluent Treatment Cooling Water Basin
- F-Area Retention Basins
- F-Area Sanitary Sludge L& Application Site
- F-Area Seepage Basins/Inactive Process Sewer Line
- F-Area Seepage Basins Remediation Extraction Wells/ Tank
- F-Area Seepage Basins Remediation Injection Wells/ Tank
- F-Area Tank Farm
- H-Area Auxiliary Pump Pit
- H-Area Canyon Building
- H-Area Coal Pile Runoff Containment Basin
- H-Area Effluent Treatment Cooling Water Basin
- H-Area Retention Basins
- H-Area Seepage Basins/Inactive Process Sewer Line
- H-Area Seepage Basins Remediation Extraction Wells & Tank
- H-Area Seepage Basins Remediation Injection Wells & Tank
- H-Area Tank Farm/Tank Farm Groundwater Operable Unit
- Hazardous Waste/Mixed Waste Disposal Facility
- HP-52 Outfall/Warner's Pond Area
- Old Burial Ground
- Old F-Area Seepage Basin
- Old H-Area Retention Basin
- S-Area Defense Waste Processing Facility
- S-Area Low-Point Pump Pit
- S-Area Vitrification Building
- Waste Solidification/Disposal Facility
- Wells Between the F-Area Canyon Building & the Naval Fuel Material Facility
- Z-Area Low-Point Drain Tank
- Z-Area Saltstone Facility Background Wells

C-Area
- C-Area Burning/Rubble Pit
- C-Area Coal Pile Runoff Containment Basin
- C-Area Disassembly Basin
- C-Area Reactor Seepage Basins
- Injection Wells of the C-Area Reactor

K-Area
- K-Area Ash Basin
- K-Area Bingham Pump Outage Pit
- K-Area Burning/Rubble Pit
- K-Area Coal Pile Runoff Containment Basin
- K-Area Disassembly Basin
- K-Area Reactor Seepage Basin
- K-Area Retention Basin
- K-Area Tritium Sump

L-Area
- Chemicals, Metals, & Pesticides Pits
- L-Area Acid/Caustic Basin/L-Area Oil & Chemical Basin
- L-Area Bingham Pump Outage Pits
- L-Area Burning/Rubble Pit
- L-Area Disassembly Basin
- L-Area Reactor Seepage Basin
- L-Area Research Wells

P-Area
- P-Area Bingham Pump Outage Pit
- P-Area Burning/Rubble Pit
- P-Area Coal Pile Runoff Containment Basin
- P-Area Disassembly Basin
- P-Area Reactor Seepage Basins

R-Area
- R-Area Acid/Caustic Basin
- R-Area Bingham Pump Outage Pit
- R-Area Burning/Rubble Pits
- R-Area Coal Pile
- R-Area Disassembly Basin
- R-Area Reactor Seepage Basins

Sanitary Landfill & B-Area
- B-Area Microbiology Wells
- Sanitary Landfill/Interim Sanitary Landfill

Central Shops (N-Area)
- Ford Building Seepage Basin
- Hazardous Waste Storage Facility
- Hydrofluoric Acid Spill
- N-Area Diesel Spill
- N-Area Burning/Rubble Pits
- N-Area (Central Shops) Sludge Lagoon
- N-Area Fire Department Training Facility
- N-Area Heavy Equipment Wash Basin and Burning/ Rubble Pit

D-Area & TNX-Area
- D-Area Burning/Rubble Pits
- D-Area Oil Seepage Basin
- D-Area Coal Pile, Coal Pile Runoff Containment Basin, & Ash Basins
- New/Old TNX Seepage Basins
- Road A Chemical Basin (Baxley Road)
- TNX-Area Assessment Wells
- TNX-Area Background Wells
- TNX-Area Points along Seepline
- TNX-Area Operable Unit Wells
- TNX-Area Floodplain Wells
- TNX-Area Recovery Wells
- TNX Burying Ground
- TNX Intrinsic Remediation Piezometers
- TNX Permeable Wall Demonstration Well Installation
- TNX Outfall Delta

Other Sites
- Accelerator for Production of Tritium Area
- SREL Flowing Springs Site

regarded as the current SRS standard. This system is consistent with the one used by the U.S. Geological Survey (USGS) in regional studies that include the area surrounding SRS [Clarke and West, 1997]. Figure 8–2 is a chart that indicates the relative position of hydrostratigraphic units and relates hydrostratigraphic units to corresponding lithologic units at SRS and to the geologic time scale. This chart was modified from Aadland et al., 1995, and Fallaw and Price, 1995.

The hydrostratigraphic units of primary interest beneath SRS are part of the Southeastern Coastal Plain Hydrogeologic Province. Within this sequence of aquifers and confining units are two principal subcategories, the overlying Floridan Aquifer System and the underlying Dublin-Midville Aquifer System. These systems are separated from one another by the Meyers Branch Confining System. In turn, each of the systems is subdivided into two aquifers, which are separated by a confining unit.

In the central to southern portion of SRS, the Floridan Aquifer System is divided into the overlying Upper Three Runs Aquifer and the underlying Gordon Aquifer, which are separated by the Gordon Confining Unit. North of Upper Three Runs Creek, these units are collectively referred to as the Steed Pond Aquifer, in which the Upper Three Runs Aquifer is called the M-Area Aquifer zone, the Gordon Aquifer is referred to as the Lost Lake Aquifer zone, and the aquitard that separates them is referred to as the Green Clay confining zone [Aadland et al., 1995]. The Upper Three Runs Aquifer/Steed Pond Aquifer is the hydrostratigraphic unit within which the water table usually occurs at SRS; hence, it is informally referred to as the “water table” aquifer.

The Dublin-Midville Aquifer System is divided into the overlying Crouch Branch Aquifer and the underlying McQueen Branch Aquifer, which are separated by the McQueen Branch Confining Unit. The Crouch Branch Aquifer and McQueen Branch Aquifer are names that originated at SRS [Aadland et al., 1995]. These units are equivalent to the Dublin Aquifer and the Midville Aquifer, which are names originating with the USGS [Clarke and West, 1997].

Figure 8–3 is a three-dimensional block diagram of the hydrogeologic units at SRS and the generalized groundwater flow patterns within those units. These units are from shallowest to deepest: the Upper Three Runs/Steed Pond Aquifer (or water table aquifer), the Gordon/Lost Lake Aquifer, the Crouch Branch Aquifer, and the McQueen Branch Aquifer.

Groundwater recharge is a result of the infiltration of precipitation at the land surface; the precipitation moves vertically downward through the unsaturated zone to the water table. Upon entering the saturated zone at the water table, water moves predominantly in a horizontal direction toward local discharge zones along the headwaters and midsections of streams, while some of the water moves into successively deeper aquifers. The water lost to successively deeper aquifers also migrates laterally within those units toward the more distant regional discharge zones. These typically are located along the major streams and rivers in the area, such as the Savannah River. Groundwater movement within these units is extremely slow when compared to surface water flow rates. Groundwater velocities also are quite different between aquitards and aquifers, ranging at SRS from several inches to several feet per year in aquitards and from tens to hundreds of feet per year in aquifers.

Potentiometric contour maps for this report were contoured using 2000 data. An exception is the Crouch Branch Aquifer; its contours were updated during 2001 based on measurements in new wells in the northwestern part of the site and offsite wells near Jackson, South Carolina. However, the current potentiometric surfaces of the aquifers are not significantly different from those depicted in maps in this report.

Figure 8–4 illustrates the water table configuration at SRS for second quarter 2000; the contours were initially taken from the SRS long-term mean water table configuration [Hiergesell, 1998]. Water level measurements obtained in second quarter 2000 then were posted on this map and contours then were adjusted to be consistent with time-specific measurements. Horizontal groundwater movement in the water table aquifer is in a direction that is perpendicular to the contours, proceeding from areas of higher fluid potential (recharge areas) to areas of lower fluid potential, where it discharges along the reaches of perennial streams at SRS.

The potentiometric level contours for the Gordon/Lost Lake Aquifer, Crouch Branch Aquifer, and McQueen Branch Aquifer are illustrated in figures 8–5, 8–6, and 8–7, respectively. These contours are based on water level measurements obtained from SRS regional cluster wells in second quarter 2000; however, additional water level measurements obtained from monitoring wells also were used to construct the Gordon/Lost Lake Aquifer contours in A-Area, M-Area, and the general separations area of SRS. As with the water table, horizontal groundwater movement is in a direction perpendicular to the contours and proceeds from

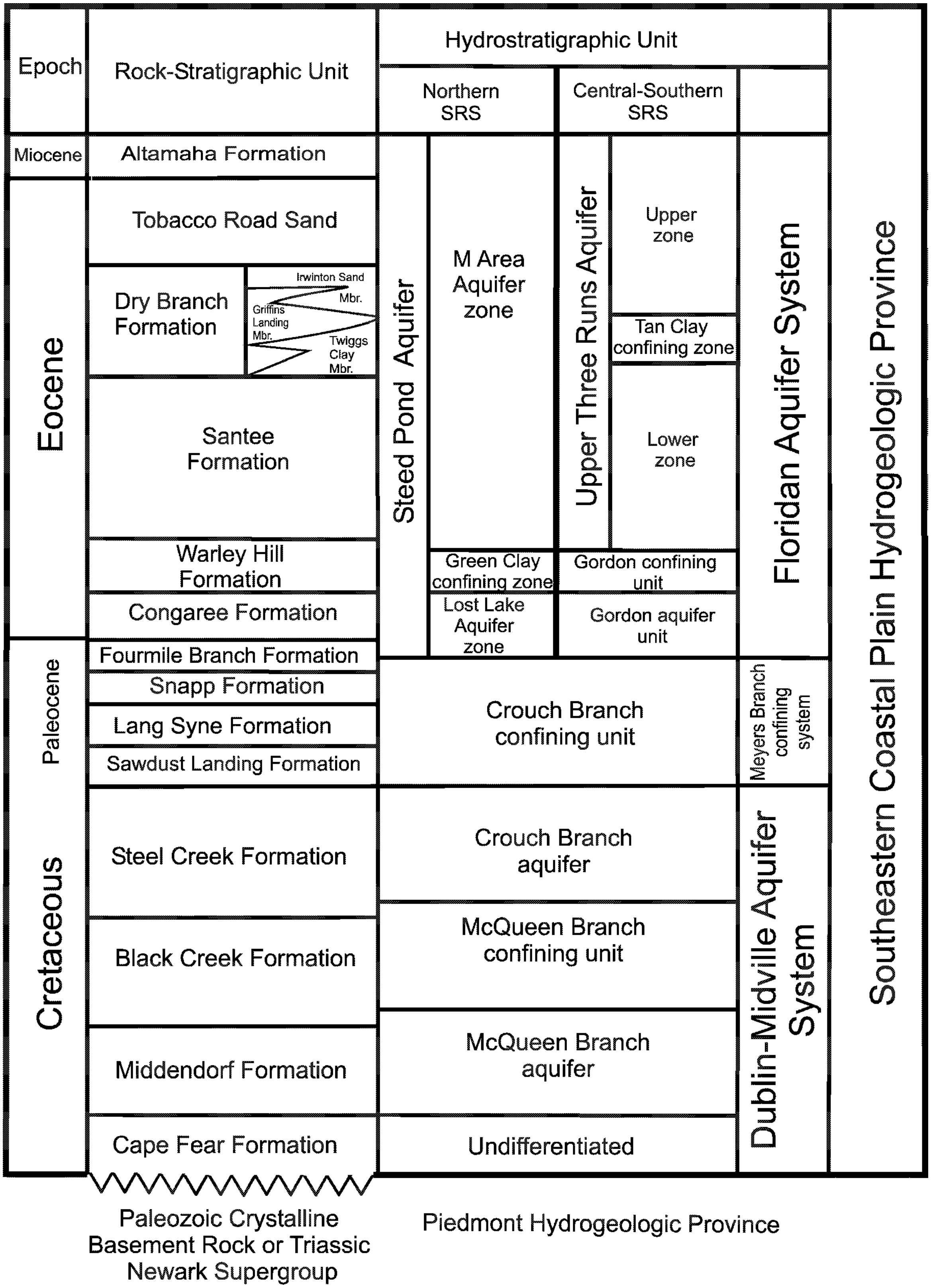


Figure 8–2 Hydrostratigraphic Units at SRS

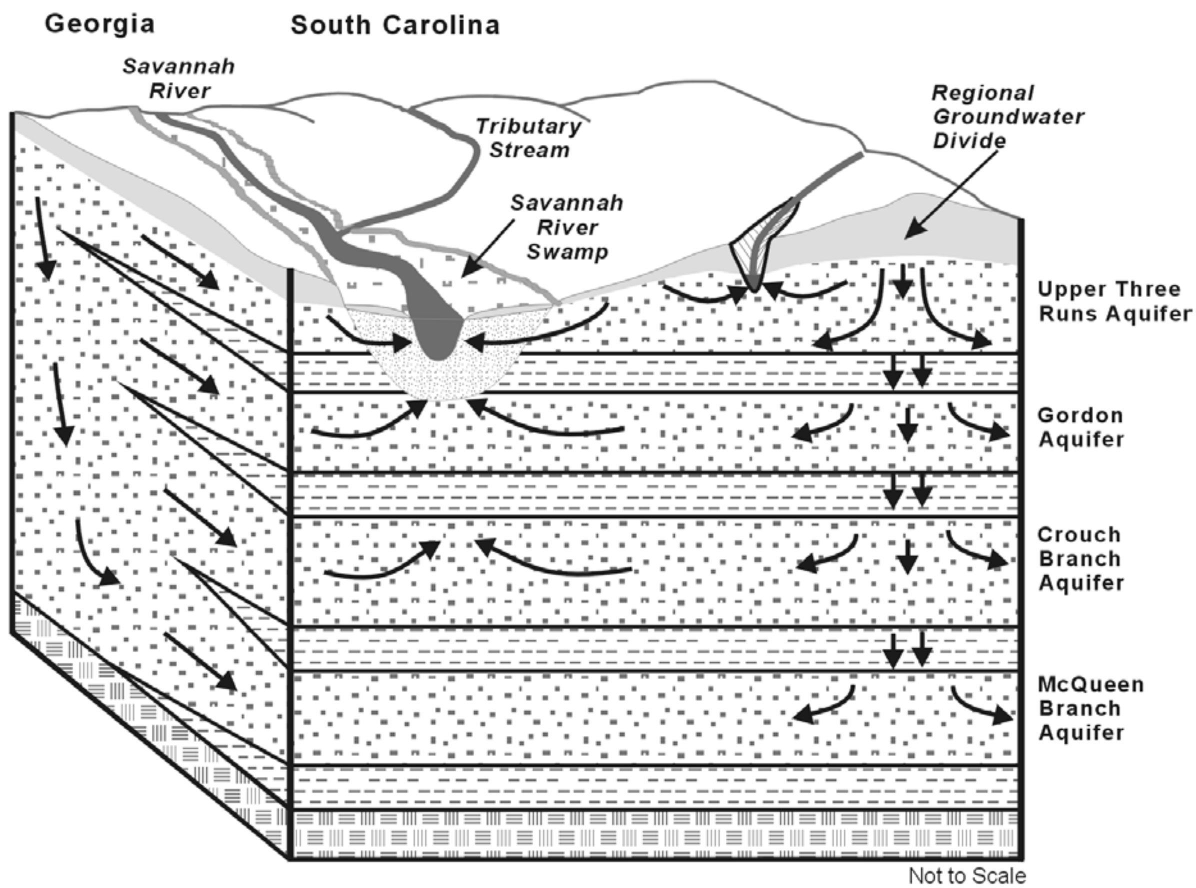


Figure 8–3 Groundwater at SRS

The groundwater flow system at SRS consists of four major aquifers separated by confining units. Flow in recharge areas generally migrates downward as well as laterally—eventually either discharging into the Savannah River and its tributaries or migrating into the deeper regional flow system.

Modified from Clarke and West, 1997

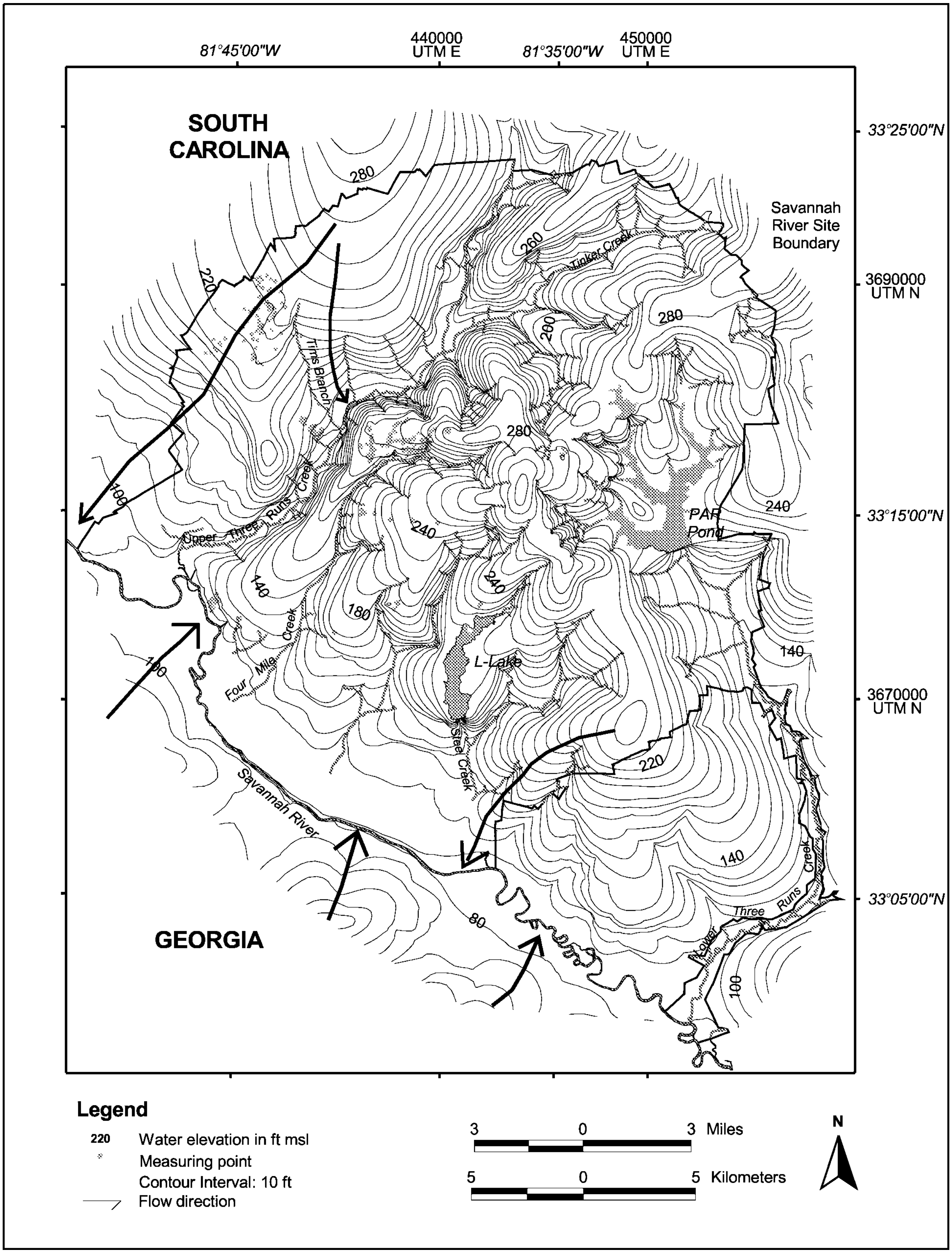
areas of higher fluid potential to areas of lower fluid potential.

Monitoring wells are used extensively at SRS to assess the effect of site activities on groundwater quality. Most of the wells monitor the upper groundwater zone, although wells in lower zones are present at the sites with the larger groundwater contamination plumes. Groundwater in areas indicated on figure 8–1 contains one or more constituents at or above the levels of the DWS of the U.S. Environmental Protection Agency (EPA).

Groundwater Protection Program at SRS

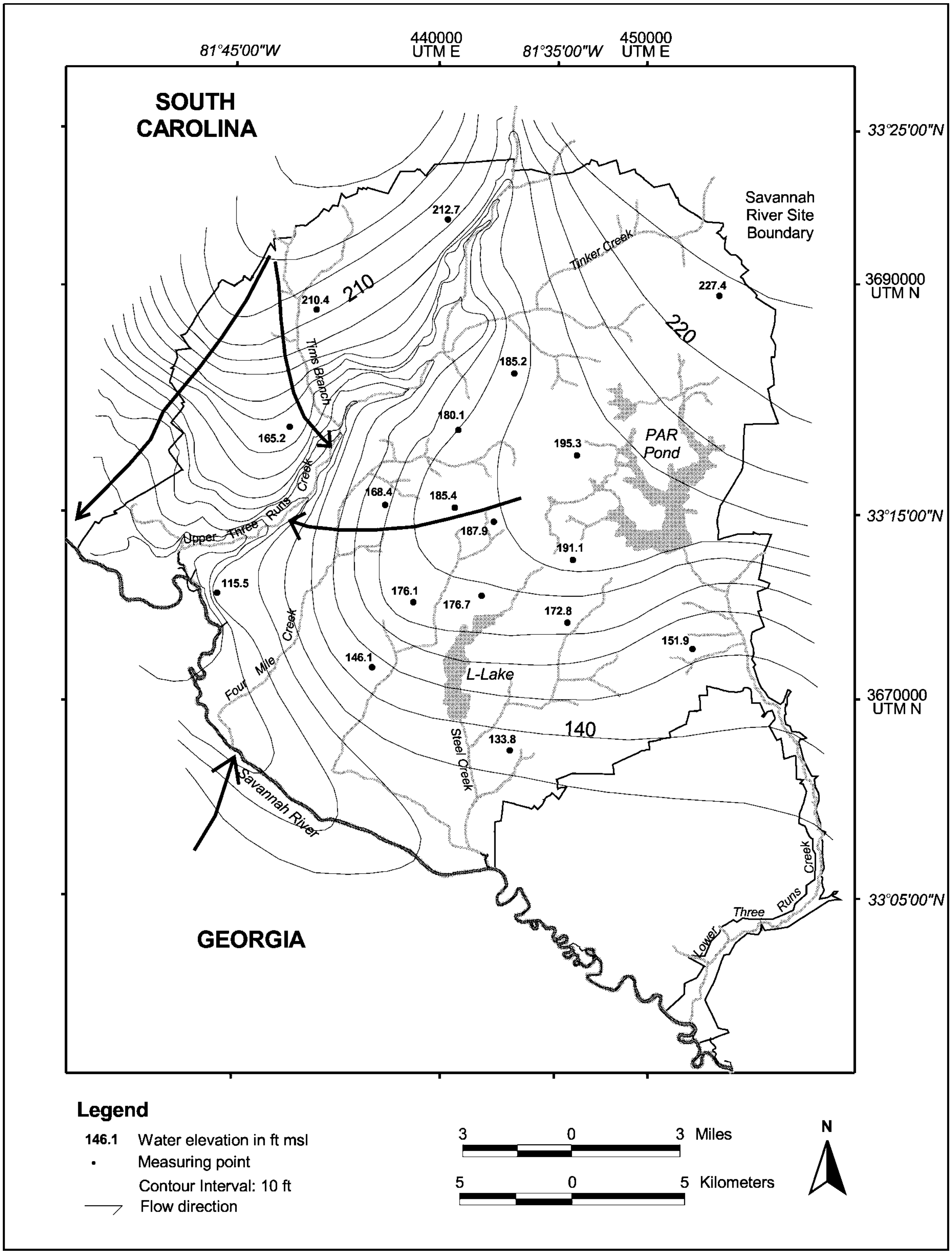
The SRS groundwater program was audited by both the U.S. Department of Energy (DOE) and WSRC during 2000 and 2001. Findings of these assessments resulted in the early revision of the site Groundwater Protection Management Program Plan (GPMP; WSRC–TR–2001–00379) to codify improvements to the program. The GPMP described five function elements of the SRS program that are designed to meet federal and state laws and regulations, DOE orders, and site policies and procedures. These elements include

- investigating site groundwater
- using site groundwater
- protecting site groundwater
- remediating contaminated groundwater
- reporting the results of these efforts to stakeholders



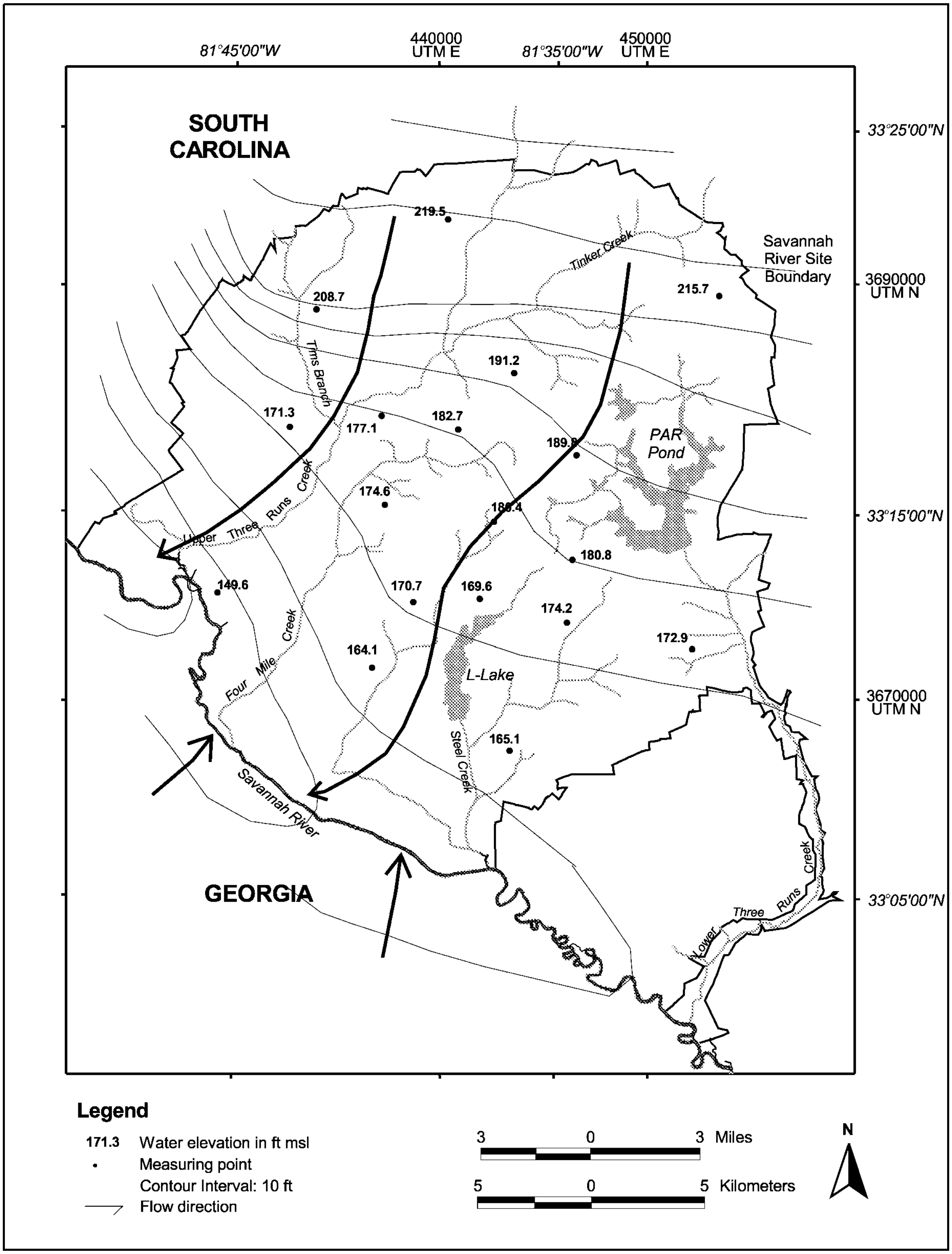
SRTC/EST Map

Figure 8–4 Water Table Contours at SRS



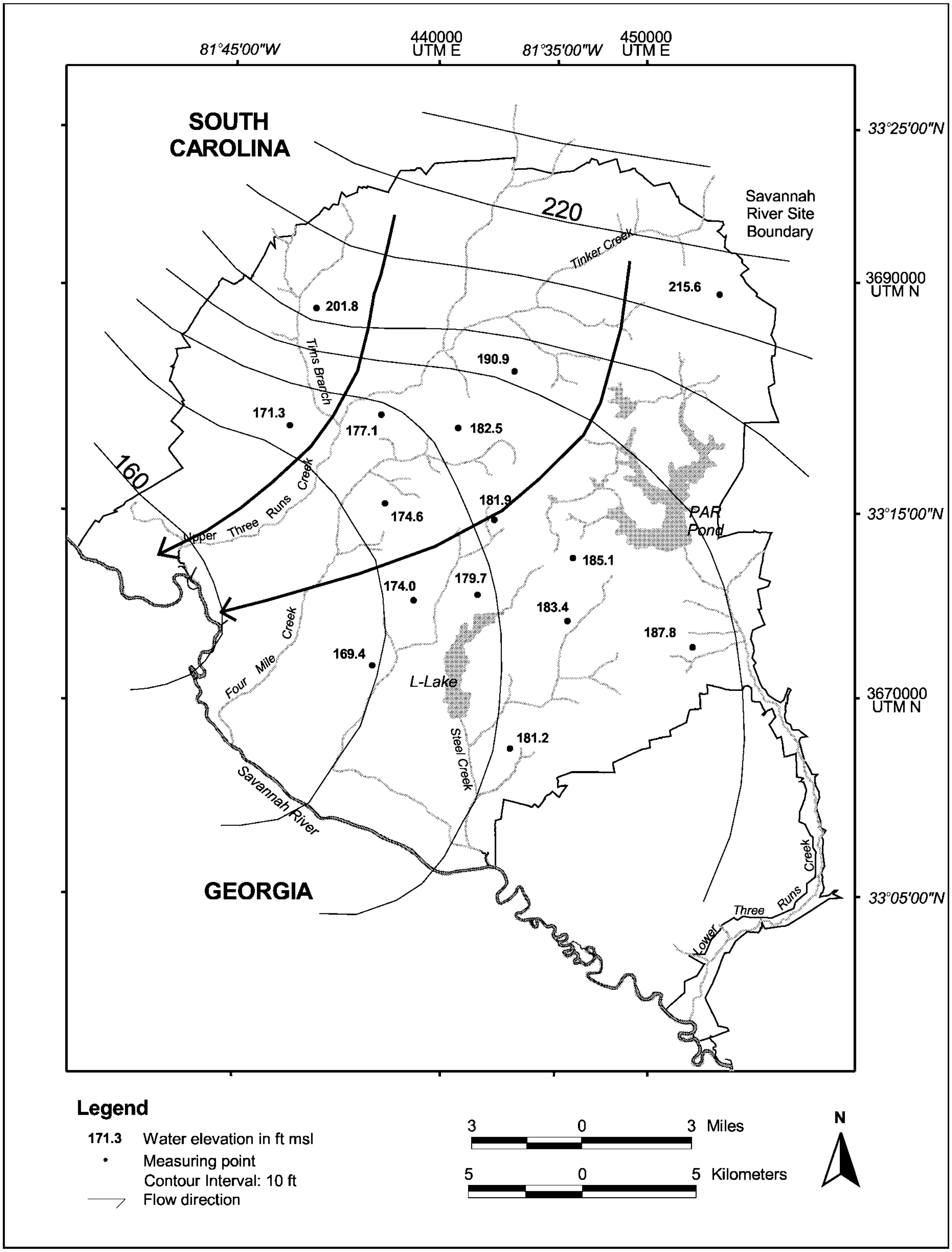
SRTC/EST Map

Figure 8–5 Potentiometric Surface of the Gordon Aquifer at SRS



SRTC/EST Map

Figure 8–6 Potentiometric Surface of the Crouch Branch Aquifer at SRS



SRTC/EST Map

Figure 8–7 Potentiometric Surface of the McQueen Branch Aquifer at SRS

SRS identified specific program goals in each of these areas to maintain its commitment to a groundwater program that protects human health and the environment. Groundwater monitoring is a key tool used in each of the first four elements, and monitoring results form the basis for evaluations that are reported to site stakeholders.

Investigating SRS Groundwater

An extensive program is in place at SRS to acquire new data and information on the groundwater system. This program is multifaceted and is conducted across departmental boundaries at the site because of the different charters and mandates of these organizations. Investigations include both the collection and analysis of data to understand groundwater conditions on regional and local scales at SRS. Research efforts at the site generally are conducted to obtain a better understanding of subsurface processes and mechanisms or to define new approaches to subsurface remediation.

Investigative efforts focus on the collection and analysis of data to characterize the groundwater flow system. Characterization efforts at SRS include the following activities:

- the collection of geologic core material and the performing of seismic profiles to better delineate subsurface structural features
- the installation of wells to allow the periodic collection of both water levels and groundwater samples at strategic locations
- the development of water table and potentiometric maps to delineate the direction of groundwater movement in the subsurface
- the performance of various types of tests to obtain *in situ* estimates of hydraulic parameters needed to estimate groundwater velocities

Analysis of data on the regional scale is needed to provide a broad understanding of groundwater movement patterns at SRS that can be used as a framework to better understand the migration of contaminants at the local scale near individual waste units. Surface water flow characteristics also are defined at the site on the regional scale and are significant to risk analyses because perennial streams are the receptors of groundwater discharge—some of which contains contaminants from SRS waste units. Because the site boundary does not represent a groundwater boundary, regional studies are helpful in understanding the movement of groundwater both onto the site from the surrounding area and vice versa.

The collection and analysis of data describing subsurface hydrogeologic conditions at or near individual waste units is needed to design effective remediation systems. Characterization embraces both traditional and innovative technologies to accomplish this goal. The installation of monitoring wells and piezometers is a traditional investigative method to allow the collection of (1) water levels, which are used to define flow directions, and (2) groundwater samples, which are analyzed to monitor contaminant plume migration within the groundwater flow system. Electric logs acquired during well installation are used to delineate the subsurface hydrostratigraphy. Examples of newer technologies include the use of

- direct-push technology, such as the cone penetrometer, to collect one-time groundwater samples at investigation sites and to help establish hydrostratigraphic contacts
- the “rotosonic” method for bore holes to collect core and install wells

Various tests are also conducted, as needed, to obtain *in situ* estimates of subsurface hydraulic properties that can be used to calculate groundwater velocities.

Numerical models have been used extensively as an analytical tool at SRS for both regional- and local-scale investigations. Models have been utilized for a variety of reasons, but primarily to (1) define the regional groundwater movement patterns at SRS and the surrounding areas, (2) enhance the understanding of contaminant migration in the subsurface, and (3) support the design of remediation systems. At SRS, major groundwater modeling efforts have focused on A/M-Area, F-Area, H-Area, the Burial Ground Complex, and several of the reactor areas where the most extensive subsurface contamination is known to exist.

Research on groundwater issues is conducted at SRS to obtain a better understanding of subsurface mechanisms, such as (1) the interaction of contaminants with the porous media matrix, and (2) the factors that impact the rate of migration of contaminants within the groundwater flow system. Research to address relevant issues often is conducted through cooperative studies with investigators at various public universities and private companies, while other efforts are conducted exclusively by SRS employees.

Using SRS Groundwater

SRS derives its own drinking and production water supply from groundwater. The site ranks as South Carolina’s largest self-supplied industrial consumer of groundwater, utilizing approximately 5.3 million gallons per day. SRS domestic and process water systems are supplied from a network of approximately 40 site groundwater wells in widely scattered locations across the site, of which eight supply the primary drinking water system for the site. Treated well water is supplied to the larger site facilities by the A-Area, D-Area and K-Area domestic water systems. Each system has wells, a treatment plant, elevated storage tanks, and distribution piping. The wells range in capacity from 200 to 1,500 gallons per minute.

These three systems supply an average of 1.1 million gallons per day of domestic water to customers in these areas. The domestic water systems supply site drinking fountains, lunchrooms, restrooms, and showering facilities with water meeting state and federal drinking water quality standards. Process water is used for equipment cooling, facility washdown water, and as makeup water for site cooling towers and production processes.

The South Carolina Department of Health and Environmental Control (SCDHEC) periodically samples the large- and small-system wells for Safe Drinking Water Act contaminants. An unscheduled biannual SCDHEC sanitary survey also is performed.

In 1983, SRS began reporting its water usage annually to the South Carolina Water Resources Commission (and later to SCDHEC). Since that time, the amount of groundwater pumped on site has dropped by 50 percent—from 10.8 million gallons per day during 1983–1986 to 5.3 million gallons per day during 1997–2000. The majority of this decrease is attributable to the consolidation of site domestic water systems, which was completed in 1997. Thirteen separate systems, each with its own supply wells, were consolidated into three systems located in A-Area, D-Area, and K-Area. Site facility shutdowns and reductions in population were also contributing factors. The amount of groundwater pumped at SRS has had only localized effects on water levels in the Cretaceous aquifers, and it is unlikely that water usage at the site ever will cause drawdown problems that could impact surrounding communities.

The process water systems in A-Area, F-Area, H-Area, K-Area, L-Area, S-Area and TNX-Area meet site demands for boiler feedwater, equipment cooling water, facility washdown water, and makeup water for cooling towers, fire storage tanks, chilled-water-piping loops, and site test facilities. These systems are supplied from dedicated process water wells ranging in capacity from 100 to 1,500 gallons per minute. In K-Area, the process water system is supplied from the domestic water wells. At some locations, the process water wells pump to ground-level storage tanks, where the water is treated for corrosion control. At other locations the wells directly pressurize the process water distribution piping system without supplemental treatment.

The site groundwater protection program integrates information learned about the properties of SRS aquifers with site demand for drinking and process water. SRS ensures a high level of drinking water supply protection by performing (1) monitoring above and beyond SCDHEC monitoring and (2) periodic evaluations of production wells. Additional protection will be realized under a site wellhead protection program that meets the requirements of the South Carolina Source Water Assessment Program described below.

Protecting SRS Groundwater

SRS is committed to protecting the groundwater resource beneath the site. A variety of activities contribute to this goal, including

- construction, waste management, and monitoring efforts to prevent or control sources of groundwater contamination
- monitoring programs (both groundwater and surface water) to detect contamination
- a strong groundwater cleanup program through the Environmental Restoration Division (ERD)

Monitoring provides the best means to detect and track groundwater contamination. To ensure that no unknown contamination poses a risk, SRS depends on a sitewide groundwater monitoring and protection effort—the site Groundwater Surveillance Monitoring Program (GSMP). This new program is an upgraded replacement of the site screening program.

Because aquifer conditions and groundwater quality vary in the temporal domain, an ongoing groundwater surveillance monitoring program is a fundamental part of any groundwater protection effort. SRS is continually improving its surveillance program, which meshes with the regulatory program that addresses contaminated groundwater.

Whereas the remediation monitoring program is performed for the purpose of regulatory compliance (e.g., defining contamination in a hazardous waste management facility or solid waste management unit, assessing the effectiveness of corrective action, etc.), the GSMP addresses sitewide groundwater protection in accordance with DOE Order 5400.1, “General Environmental Protection Program.”

One goal of the GSMP is to protect potential offsite receptors from contamination by detecting contamination in time to apply appropriate corrective actions. SRS is a large site, and most groundwater contamination is located in the central site areas (figure 8–1). However, the potential for offsite migration exists, and the consequences of such an outcome are serious enough to warrant a comprehensive prevention program.

SRS has evaluated groundwater flow and determined, for each aquifer, where groundwater flows across the site boundary, since the location of groundwater flow would be a conservative surrogate for any potential contaminant migration. Monitoring at those locations is being strengthened by the addition of several new well clusters to ensure early detection of any contamination migrating toward the site boundary. If contamination is ever detected, appropriate reporting and remediation efforts can be initiated by DOE.

Another pathway for existing groundwater contamination to flow offsite is by discharge into surface streams and subsequent transport into the Savannah River. SRS monitors site streams for contamination, and new wells have been installed in recent years along several site streams to detect contamination before it enters the stream and to assess its concentration in groundwater.

Another function of the groundwater protection program is to monitor groundwater around operating facilities to ensure that any potential contamination emanating from any facility is detected in a timely manner. This monitoring includes the tank farms and canyon facilities in the central site area. In addition, surveillance monitoring is performed at various wells around the site to detect any new or previously undetected contaminant plumes.

A major challenge of the site groundwater program is the careful evaluation of the hundreds of thousands of new data records generated each year. The GSMP includes analysis using a combination of new computer automation tools and “hands on” groundwater expertise to screen all the recent records in the site groundwater database each year. This evaluation seeks unexpected results in any site wells that might indicate new or changing groundwater contamination.

SRS is cooperating with SCDHEC to develop and implement source water assessment and protection programs. After an assessment program has been approved and implemented, the SRS groundwater protection program will focus on protection efforts. The primary aspect of the source water assessment and protection programs will be wellhead protection, given that SRS derives its drinking water exclusively from groundwater. Other aspects will include strategies for preventing contamination and controlling existing contamination through the SRS program. The program will evaluate waste minimization, spill prevention and control, well abandonment, and future land use. More information about this initiative can be found at http//www.epa.gov/safewater/protect.html.

Remediating Contaminated SRS Groundwater

SRS has maintained an environmental restoration effort for many years. ERD personnel manage groundwater cleanup of contaminated groundwater associated with Resource Conservation and Recovery Act (RCRA) hazardous waste management facilities or Federal Facility Act units. ERD’s mission is to aggressively manage the inactive waste site and groundwater cleanup program so that

- schedules for environmental agreements are consistently met
- the utilization of financial and technology resources are continually improved
- the overall risk posed by existing contaminated sites is continually reduced

The strategy of ERD, which has developed a management action plan for groundwater, revolves around developing an appropriate regulatory framework for each waste site, assessing the degree and extent of contamination, and remediating the contaminated groundwater to its original beneficial use. In cases where that remediation goal is impractical, ERD intends to prevent plume migration and exposure and to evaluate alternate methods of risk reduction.

Reporting Results of Groundwater Program Activities

In addition to its annual environmental report, SRS publishes several reports related to the site groundwater program. Some of these are referenced in this chapter, including (1) compliance and investigation reports developed for groundwater remediation activities, (2) a sampling schedule describing annual monitoring activities (3) various site-specific groundwater monitoring reports for regulatory compliance (4) quarterly groundwater monitoring reports, and (5) the biannual well inventory. Beginning in 2002, an annual report of the site Groundwater Surveillance Monitoring Program also will be issued.

Description of the Groundwater Monitoring Program

The groundwater monitoring program at SRS gathers information to determine the effect of site operations on groundwater quality. The program is designed to

- assist SRS in complying with environmental regulations and DOE directives
- provide data to identify and monitor constituents in the groundwater
- permit characterization of new facility locations to ensure that they are suitable for the intended facilities
- support basic and applied research projects

The groundwater monitoring program at SRS is conducted by the Environmental Geochemistry Group (EGG) of EPD's Environmental Monitoring Section (EMS). To assist other departments in meeting their responsibilities, EGG provides the services for installing monitoring wells, collecting and analyzing samples, and reporting results.

The *WSRC Environmental Compliance Manual* (WSRC–3Q1) provides details about the following aspects of the groundwater monitoring program:

- well siting, construction, maintenance, and abandonment
- sample planning
- sample collection and field measurements
- analysis
- data management
- related publications, files, and databases

The remainder of this chapter presents overviews of several of these topics, along with information specific to 2001.

Sample Scheduling and Collection

EMS schedules groundwater sampling either in response to specific requests from SRS personnel or as part of its ongoing groundwater monitoring program. These groundwater samples provide data for reports required by federal and state regulations and for internal reports and research projects. The groundwater monitoring program schedules wells to be sampled at intervals ranging from quarterly to triennially.

Personnel outside EMS may request sample collection as often as weekly. Constituents that may be analyzed are commonly imposed by permit or work plan approval. Those include metals, field parameters, suites of herbicides, pesticides, volatile organics, and others. Radioactive constituents that may be analyzed by request include gross alpha and beta measurements, gamma emitters, iodine-129, strontium-90, radium isotopes, uranium isotopes, and other alpha and beta emitters.

Groundwater samples are collected from monitoring wells, generally with either pumps or bailers dedicated to the well to prevent cross–contamination among wells. Occasionally, portable sampling equipment is used; this equipment is decontaminated between wells.

Sampling and shipping equipment and procedures are consistent with EPA, SCDHEC, and U.S. Department of Transportation guidelines. EPA–recommended preservatives and sample–handling techniques are used during sample storage and transportation to both onsite and offsite analytical laboratories. Potentially radioactive samples are screened for total activity (alpha and beta emitters) prior to shipment to determine appropriate packaging and labeling requirements.

Deviations (caused by dry wells, inoperative pumps, etc.) from scheduled sampling and analysis for 2001 are enumerated in the SRS quarterly groundwater monitoring reports cited previously in this chapter.

Analytical Procedures

In 2001, General Engineering Laboratories of Charleston, South Carolina; Recra LabNet Philadelphia of Lionville, Pennsylvania; and Sanford Cohen and Associates of Montgomery, Alabama, performed most of the groundwater analyses. In addition, the General Engineering Mobile Laboratory performed onsite analyses of volatile organics and semivolatile organics and metals. EMAX Laboratories, Inc., of Torrance, California, performed analyses for several sampling projects, and MicroSeeps of Pittsburgh, Pennsylvania, performed natural attenuation analyses. The contracted laboratories are certified by SCDHEC to perform specified analyses.

The EMS laboratory at SRS screened potentially radioactive samples for total activity prior to shipment. General Engineering Laboratories performed radiological analyses, and Thermo NUtech of Oak Ridge, Tennessee, subcontracted radiological analyses from Recra LabNet Philadelphia.

Full lists of constituents analyzed, analytical methods used, and the laboratories' estimated quantitation limits are given in the SRS quarterly groundwater reports referenced earlier.

Evaluation of Groundwater Data

EMS receives analytical results and field measurements as reports and as ASCII files that are loaded into databases at SRS. For 2001, logbooks track receipt and transfer of data to the Geochemical Information Management System (GIMS) database or to the Environmental Restoration Data Management System (ERDMS), and computer programs present the data in a format that can be validated.

Quality control practices include the following:

- verification of well names and sample dates for field and analytical data
- verification that all analyses requested on the chain-of-custody forms were completed by each laboratory
- identification of data entry problems (e.g., duplicate records, incorrect units)
- comparison of analytical data to historical data and review of the data for transcription, instrument, or calculation errors
- comparison of blind replicates and laboratory in-house duplicates for inconsistencies
- identification of laboratory blanks and blind blanks with elevated concentrations

Possible transcription errors and suspect results are documented and submitted to the appropriate laboratory for verification or correction. No changes are made to the database until the laboratory documents the problem and solution. Changes to the database are recorded in a logbook.

The quarterly groundwater monitoring reports identify queried results verified by the laboratory and list groundwater samples associated with blanks having elevated results. These reports also present the results of intralaboratory and interlaboratory quality assurance comparisons (chapter 9, “Quality Assurance”).

Changes to the Groundwater Monitoring Program during 2001

Well Abandonments and Additions; Changes to the Sampling Schedule

During 2001, two wells were abandoned—one in A-Area/M-Area and another in the A-Area burning/rubble pits.

The following 212 wells were scheduled to be monitored for the first time in 2001:

- Fifty-one new wells in the chemicals, metals, and pesticides pits in order to determine the nature and extent of contamination
- Two wells in the Jackson Wells project as wells added to the GSMP.
- Thirteen wells in the miscellaneous chemical basins for an Inductively Coupled Plasma/Remedial Action Implementation Plan
- Fifteen wells in the southern sector for the Groundwater Effectiveness Monitoring Strategy for the proposed Southern Sector Phase 1 Groundwater Corrective Action
- Twenty wells in the A-Area burning/rubble pits for Interim Corrective Measures Implementation/Remedial Action Implementation Plan
- Twenty-four wells in the D-Area expanded operable unit for the RCRA Facility Investigation/Remedial Investigation Workplan Addendum
- Twelve wells in the F-Area Seepage Basins Injection Study to provide information to be utilized in the evaluation of the Base Injection Study
- Seventeen wells for the A-Area/M-Area Cretaceous Wells project for A-Area/M-Area groundwater
- Nine wells at the R-Reactor seepage basins to provide additional field data to support the development of the Corrective Measures Study/Feasibility Study
- Six wells at the H-Area groundwater treatment unit to establish decontamination factors to facilitate remedial decision making
- Thirteen wells at the Mixed Waste Management Facility for RCRA compliance sampling
- Fourteen wells in the General Site for the GSMP
- Thirteen wells in the sanitary landfill for compliance with South Carolina Hazardous Waste Management Regulations, Solvent Rag Settlement (91–51–SW), GWQAP 1995; and comprehensive monitoring evaluation audit ESH–CGP–2000–00136
- Three wells in A-Area/M-Area for production well sampling at SCDHEC request

Groundwater Monitoring Results at SRS

This section summarizes groundwater monitoring results during 2001 for each of the following areas at SRS:

- A-Area and M-Area
- C-Area
- D-Area and TNX-Area
- General separations and waste management areas (E-Area, F-Area, H-Area, S-Area, and Z-Area)
- K-Area
- L-Area and chemicals, metals, and pesticides pits
- N-Area
- P-Area
- R-Area
- Sanitary landfill

Additional information about groundwater contamination, monitoring, and cleanup in most of these areas can be found at the following internet address: http://www.srs.gov/general/pubs/fulltext/fulltext–2001.htm.

Groundwater Contamination at A-Area and M-Area

The administration and manufacturing areas (A-Area and M-Area) are located in the northwestern part of SRS and include a number of facilities associated with the site's groundwater cleanup and monitoring programs (figure 8–1). The area contains facilities that were used for the manufacture of reactor fuel and target assemblies, support services, laboratories, and administration. The manufacturing facilities were operational from the 1950s into the early 1980s. Major contaminants include volatile constituents, particularly trichloroethylene and tetrachloroethylene, used as degreasers in old manufacturing processes. Wastewater from the manufacturing operations flowed into the M-Area Settling Basin and the Lost Lake, a shallow body of water that received runoff from the settling basin; these two units make up the hazardous waste management facilities (HWMF). Additional details about the A-Area and M-Area groundwater cleanup and monitoring programs can be found in the SRS RCRA permit application and FFA documents.

Cleanup activities, focusing on both groundwater and the overlying soil column, have substantially altered the groundwater flow and spread of contamination. These efforts have included the capping of basins and the extraction of contaminants from groundwater. To contain the trichloroethylene and tetrachloroethylene plumes in groundwater, SRS installed groundwater recovery systems in A-Area and M-Area. These systems include pumping wells installed in the Steed Pond aquifer and air stripper units for treating the water. The clean water is discharged through a permitted outfall to an SRS stream. Groundwater monitoring and numerical modeling tasks have demonstrated the effectiveness of the groundwater recovery systems in controlling migration of the trichloroethylene and tetrachloroethylene plumes associated with the HWMF. Since the system began operating in 1984, almost a million pounds of solvents have been recovered via the groundwater recovery systems in A-Area and M-Area. The corrective action plan, approved by SCDHEC in 1987, requires groundwater cleanup operation and monitoring in A-Area and M-Area for 30 years.

Other technologies are in use at A-Area and M-Area to recover chlorinated solvent plumes and perform *in situ* remediation. These plumes are associated with individual operable units or facilities, but also may commingle or be in hydraulic communication with the larger trichloroethylene and tetrachloroethylene plume in the Steed Pond aquifer beneath A-Area and M-Area. Twenty-three vertical recirculation wells are in use at the miscellaneous chemical basin and in the southern sector of A-Area and M-Area. Also, phytoremediation is in use at the southern sector to recover the distal (low concentration) area of the groundwater plume. Air sparging wells and shallow soil vapor extraction units are operating at the A-Area burning/rubble pits. Soil vapor extraction is in use at the A–014 outfall, M-Area settling basin, and miscellaneous chemical basin.

In September 2000, SRS began operation of a technology known as dynamic underground stripping (DUS). DUS was deployed at the M-Area solvent storage tank area, which was known to have a dense nonaqueous phase liquid source that released volatile organic compounds (VOCs) to the A-Area and M-Area groundwater plume. The DUS technology vaporizes VOCs in the permeable zones of the treatment area by injecting steam into the subsurface soil and heating the VOC contaminants above their boiling points. Contaminants are removed by physical transport to extraction wells and by *in situ* destruction of contaminants with a thermally accelerated oxidation process. When DUS operations were discontinued in September 2001, more than 70,000 pounds of VOCs had been removed from the treatment area.

Groundwater Contamination at C-Area

Several groundwater contaminant plumes have been characterized by data collected from numerous monitoring wells and cone penetrometer locations in the C-Area groundwater operable unit (figure 8–1). Significant plumes of tritium and trichloroethylene have been identified in the area. Two distinct tritium plumes have been identified—a northern tritium plume and a southern tritium plume. These plumes are derived from several separate sources, some of them undetermined at this time. In addition, two distinct plumes of trichloroethylene have been identified: a northern trichloroethylene plume, and a southern trichloroethylene plume. The source location of the northern trichloroethylene plume has been identified at the C-Area burning/rubble pit, and the source of the southern trichloroethylene plume is an undefined area inside of the C-Area reactor fence.

The two tritium plumes and the southern trichloroethylene plume, which emanates from the C-Area reactor, are administratively associated with the C-Area groundwater operable unit. The trichloroethylene plume from the C-Area burning/rubble pit is administratively associated with the C-Area burning/rubble pit operable unit.

As indicated by the field-derived plume configuration, groundwater originating from just beneath the C-Reactor building (105–C) appears to be flowing south, southwest with eventual discharge to Castor Creek and Fourmile Branch. Groundwater migrating from potential source locations of the C-Area burning/rubble pit trichloroethylene and tritium plumes appears to be flowing to the west, with eventual discharge to Fourmile Branch.

Groundwater Contamination at D-Area and TNX-Area

D-Area, located in the southwest part of SRS, includes a large coal-fired power plant and decommissioned heavy water facilities. TNX-Area, also located in the southwest part of the site, was used to test equipment and develop new designs. Several units are associated with groundwater monitoring and cleanup in these two areas (figure 8–1).

Contamination at D-Area and TNX-Area occurs in the Upper Three Runs aquifer, a shallow water table (figure 8–3). Volatile organic constituents, particularly trichloroethylene, are the primary contaminants. In D-Area, there is substantial contamination of the groundwater near the coal pile, coal pile runoff containment basin, and ash basins. This contamination is consistent with low-pH conditions, the leaching of coal and coal ash, and the discharge of chlorinated degreasing solvents. The most widespread contaminant at D-Area is trichloroethylene; other contaminants include heavy metals and tritium. A phytoremediation system is being tested for the treatment of groundwater contaminated by trichloroethylene. A separate plume of volatile organics (especially trichloroethylene) and lead has been associated with disposal activities at the D-Area oil seepage basin. A groundwater mixing zone application was approved by SCDHEC in 1998 for chlorinated solvents.

There is a shallow plume of contaminated groundwater beneath much of TNX-Area and downgradient into the Savannah River Swamp. Contaminants in the groundwater include radionuclides, heavy metals, and VOCs—especially trichloroethylene. The highest concentrations of trichloroethylene are found northwest and southeast of the TNX burying ground. A separate plume appears to be moving to the southwest of the TNX outfall delta toward the X–08 ditch. Groundwater cleanup at TNX-Area utilizes a groundwater recovery system and a soil vapor extraction system. Geosiphon wells have been installed in the lower swamp area for recovering trichloroethylene that is moving toward the Savannah River.

Groundwater Contamination at the General Separations and Waste Management Areas

The separations and waste management areas, which include E-Area, F-Area, H-Area, S-Area, and Z-Area, are located in the center of SRS. Reactor-produced materials are processed in the chemical separations plants, or "canyons," at F-Area and H-Area. The separations and waste management areas, also called the General Separations Area (GSA), contain many units associated with the groundwater monitoring and cleanup programs (figure 8–1).

Both surface and groundwater divides run from east to west between Upper Three Runs Creek and Fourmile Branch. In the Upper Three Runs aquifer (figure 8–3), groundwater in the northern GSA flows north into Upper Three Runs Creek, while groundwater in in the southern GSA flows into Fourmile Branch. The flow dynamics change in the Gordon aquifer, where flow is to the northwest over most of the GSA.

The most extensive groundwater monitoring and cleanup programs in these areas are associated with three RCRA-regulated facilities—the F-Area HWMF, the H-Area HWMF, and the Burial Ground Complex. Tritium is the most common contamination at all three facilities, but metals, other radionuclides, and volatile organic constituents also are present. A complex groundwater cleanup system has been operating at the F-Area and H-Area HWMFs for several years, but work at the Burial Ground Complex now is directed toward plume characterization. Much of the cleanup emphasis is on constraining the flow of contaminant plumes into Fourmile Branch.

Groundwater Contamination at K-Area

There are four known plumes of groundwater contamination in K-Area (figure 8–1). Primary contaminants include trichloroethylene, tetrachloroethylene and tritium. A small, isolated plume of trichloroethylene and tetrachloroethylene is associated with the K-Area burning/rubble pit and rubble pile, on the northeast side of the K-Area reactor. There is no continuing source, and the plume is not discharging to surface water. A groundwater mixing zone application has been approved for this operable unit.

A tritium plume, termed "tritium anomaly plume," is located northwest of the reactor (figure 8–1). This plume has not been fully characterized, but extends at least 2,000 feet from somewhere inside the reactor fence to a surface discharge point in Indian Grave Branch. It has been named the tritium anomaly plume because especially high tritium values have been measured in monitoring wells and surface water. This plume is slated to be investigated under the K-Area groundwater operable unit. In addition, the K-Area Groundwater Operable Unit will include another tritium plume emanating from the vicinity of the retention basin and discharging into surface water and a trichloroethylene plume intermingled with the tritium anomaly plume. These plumes will be investigated under the site RCRA/Comprehensive Environmental Response, Compensation, and Liability Act program.

Groundwater Contamination at L-Area and the Chemicals, Metals, and Pesticides Pits

L-Area groundwater contamination is associated with several units, including the chemicals, metals, and pesticides pits, the L-Area burning/rubble pit, and several units located next to and in the L-Area reactor area (figure 8–1).

Contaminants above the maximum contaminant limit from the chemicals, metals, and pesticides pits include tetrachloroethylene, trichloroethylene, and daughter products; lindane; carbon tetrachloride; and chloroform. Groundwater flows north, northwest from the pits toward Pen Branch. Groundwater modeling in this area is under way.

At the L-Area burning/rubble pit, carbon tetrachloride is the only groundwater constituent of concern. Groundwater in this area flows west toward Pen Branch, downstream of the chemicals, metals, and pesticides pits. Groundwater flow and transport modeling in this area has been completed. Contamination will not discharge to surface water based on modeling predictions. There is also an approved groundwater mixing zone.

Contamination in the reactor area includes trichloroethylene, tetrachloroethylene and tritium. Groundwater in this area flows south toward L Lake. Groundwater modeling will begin for these plumes in fiscal year 2002.

Groundwater Contamination at N-Area

N-Area, also called the Central Shops area, is located in the central part of SRS and provides supply, maintenance, and other support services for the site (figure 8–1). Groundwater contamination in N-Area is associated with organic compounds, including chlorinated solvents (trichloroethylene), as well as heavy metals.

Chlorinated solvents have been used throughout N-Area. It is believed that most of the solvents ended up in floor drains that emptied into a drainage ditch near the center of the area. Groundwater contamination in N-Area has been detected only at the SRL oil test site and at the heavy-equipment wash basin and Central Shops burning/rubble pit (631–5G). An effort is under way to administratively create a new groundwater operable unit in N-Area because it is believed that the source of the groundwater contamination is the drainage ditch, not the surface units.

At the SRL oil test site, groundwater contamination (tetrachloroethylene, trichloroethylene, and carbon tetrachloride) has been detected in both shallow and deep zones of the Upper Three Runs aquifer (figure 8–2). The SRL oil test site was developed (1975–1977) to evaluate the natural biodegradation of petroleum waste or waste oil.

The heavy-equipment wash basin and Central Shops burning/rubble pit was used to clean and maintain equipment until 1981. The highest concentrations of trichloroethylene (6,500 parts per billion) exist in the shallow Upper Three Runs aquifer near the outfall. In this area, a competent clay layer just beneath the surface supports a perched-water zone, which flows toward the drainage ditch. The trichloroethylene plume exists in two "lobes." One moves downgradient on top of a clay layer in the Upper Three Runs aquifer; the other has been drawn deeper into the lower part of the Upper Three Runs aquifer toward a shallow groundwater production well (now abandoned).

Groundwater Contamination at P-Area

Groundwater in P-Area is discharging in the Steel Creek watershed (figure 8–1). The area is still in the early stages of characterization, and groundwater modeling has not yet begun. Current data suggest that tritium and trichloroethylene plumes exist above the maximum contaminant limit. No site-specific groundwater modeling documents are available yet for this area.

Groundwater Contamination at R-Area

Groundwater contamination exists at concentrations above maximum contaminant limits in R-Area (figure 8–1). Contamination includes tritium, strontium-90, tetrachloroethylene, and trichloroethylene. Three operable units in R-Area are geographically associated with groundwater contamination—the R-Area reactor seepage basins, the R-Area Bingham pump outage pits, and the R-Area burning/rubble pits.

The tritium plume is widespread, exceeds the maximum contaminant limit, and is poorly defined. This contaminant will be characterized under the R-Area groundwater operable unit. Strontium-90 contamination has been discovered adjacent to the R-Area Reactor seepage basins in the very shallow groundwater. Vadose zone modeling and flow and transport modeling are in progress for this plume, which is not discharging to surface water. Final reports are expected June 2002. The tetrachloroethylene and trichloroethylene plumes are associated with the R-Area Bingham pump outage pit and with the R-Area burning/rubble pits and rubble pile. These plumes will be addressed under the R-Area groundwater operable unit. The nearest possible discharge area for the R-Area Bingham pump outage pits plume is Joyce Branch, upstream from PAR Pond. The likely discharge point for the plume near the R-Area burning/rubble pits and rubble pile is Pond 4 of PAR Pond.

Groundwater Contamination at the Sanitary Landfill

The sanitary landfill is located in B-Area, south of Road C, about halfway down the slope of the Aiken Plateau to Upper Three Runs Creek (figure 8–1). The landfill received general SRS wastes for disposal—such as paper, cafeteria wastes, plastics, wood, cardboard, rags, scrap metal, pesticide bags, asbestos (in bags), and sludge from SRS wastewater treatment facilities—beginning in 1974. The “trench and fill” method of waste disposal was used, and the wastes were covered by natural soil or a fabric substitute. The natural water table is in or near the bottom of the waste trenches. The sanitary landfill ceased operations in 1994.

Sanitary landfills are intended to receive only nonradioactive, nonhazardous waste. However, until October 1992, some hazardous wastes (specifically, solvent-laden rags and wipes used for cleaning, decontamination, and instrument calibration) were buried in portions of SRS’s original 32-acre landfill and its southern expansion. Groundwater contamination consists of low concentrations of VOCs, but tritium, metals, and other radionuclides also are present.

Several remediation activities have been successful in addressing groundwater contamination at the sanitary landfill. A RCRA-style cap was installed over the main and southern expansion sections in 1996–1997. The cap has been effective in eliminating (1) the recharge effects of precipitation through the landfill trenches and (2) the mobility of contaminants in the wastes.

A biosparging system consisting of two horizontal wells began operation in 1999. These wells are installed south and southwest of the landfill and intercept the vinyl chloride plume that extends beyond the point-of-compliance wells south of the landfill. This remediation system involves the injection of air and nutrients resulting in the volatilization and degradation of trichloroethylene and vinyl chloride.

Groundwater monitoring results have shown that the landfill cap has reduced the migration of contaminants into the groundwater under the sanitary landfill and has facilitated the reductive dechlorination of chlorinated solvents. Also, the biosparging system has proven effective in groundwater cleanup.