Savannah River Site
Groundwater Management Strategy and Implementation Plan (U)

Aiken, South Carolina

WSRC-RP-2006-4074

Updated October 2020
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ac</td>
<td>acre</td>
</tr>
<tr>
<td>ACL</td>
<td>alternate concentration limit</td>
</tr>
<tr>
<td>ABRP</td>
<td>A-Area Burning/Rubble Pits and Rubble Pit</td>
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<tr>
<td>BGC</td>
<td>Burial Ground Complex</td>
</tr>
<tr>
<td>CAGW</td>
<td>C-Area Groundwater</td>
</tr>
<tr>
<td>CBRP</td>
<td>C-Area Burning/Rubble Pit</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act</td>
</tr>
<tr>
<td>CMP Pits</td>
<td>Chemicals, Metals, and Pesticides Pits</td>
</tr>
<tr>
<td>CSGW</td>
<td>Central Shops Groundwater</td>
</tr>
<tr>
<td>DOSB</td>
<td>D-Area Oil Seepage Basin</td>
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<tr>
<td>DNAPL</td>
<td>dense non-aqueous phase liquid</td>
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<tr>
<td>DUS</td>
<td>Dynamic Underground Stripping</td>
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<tr>
<td>EC&amp;ACP</td>
<td>Environmental Compliance and Area Completion Projects</td>
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<tr>
<td>ERH</td>
<td>Electrical Resistance Heating</td>
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<tr>
<td>FFA</td>
<td>Federal Facility Agreement</td>
</tr>
<tr>
<td>FMB</td>
<td>Fourmile Branch</td>
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<tr>
<td>FY</td>
<td>Fiscal Year</td>
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<tr>
<td>GSA</td>
<td>General Separations Area</td>
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<tr>
<td>GSACU</td>
<td>General Separations Area Consolidated Unit</td>
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<tr>
<td>ha</td>
<td>hectare</td>
</tr>
<tr>
<td>HWMF</td>
<td>Hazardous Waste Management Facility</td>
</tr>
<tr>
<td>IOU</td>
<td>Integrator Operable Unit</td>
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<tr>
<td>KAGW</td>
<td>K-Area Groundwater</td>
</tr>
<tr>
<td>KBRP</td>
<td>K-Area Burning/Rubble Pit</td>
</tr>
<tr>
<td>LANG</td>
<td>L-Area Northern Groundwater</td>
</tr>
<tr>
<td>LASG</td>
<td>L-Area Southern Groundwater</td>
</tr>
<tr>
<td>LLRWDF</td>
<td>Low-Level Radioactive Waste Disposal Facility</td>
</tr>
<tr>
<td>km</td>
<td>kilometer</td>
</tr>
<tr>
<td>km$^2$</td>
<td>square kilometer</td>
</tr>
<tr>
<td>LTR</td>
<td>Lower Three Runs</td>
</tr>
<tr>
<td>LUCs</td>
<td>Land Use Controls</td>
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<tr>
<td>MAPSL</td>
<td>M-Area Abandoned Process Sewer Line</td>
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<td>MABS</td>
<td>M-Area Settling Basin</td>
</tr>
<tr>
<td>MBP</td>
<td>Metals Burning Pit</td>
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<tr>
<td>MCB</td>
<td>Miscellaneous Chemical Basin</td>
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<tr>
<td>MCL</td>
<td>maximum contaminant level</td>
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<tr>
<td>Met Lab</td>
<td>Metallurgical Laboratory</td>
</tr>
<tr>
<td>mi</td>
<td>miles</td>
</tr>
<tr>
<td>mi$^2$</td>
<td>square miles</td>
</tr>
<tr>
<td>MIPS2</td>
<td>M-Area Interactive Process Sewer Lines to Manhole 1 (081-M)</td>
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<td>MNA</td>
<td>Monitored Natural Attenuation</td>
</tr>
<tr>
<td>MWMF</td>
<td>Mixed Waste Management Facility</td>
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</tbody>
</table>
LIST OF ABBREVIATIONS AND ACRONYMS (Continued/End)

MZ  Mixing Zone
MZCL Mixing Zone Concentration Limit
ORWBG Old Radioactive Waste Burial Ground
OU Operable Unit
PAGW P-Area Groundwater
PAOU P-Area Operable Unit
PB Pen Branch
PBRP P-Area Burning/Rubble Pit
PCB polychlorinated biphenyl
PCE perchloroethylene (tetrachloroethylene)
RAGW R-Area Groundwater
RAOU R-Area Operable Unit
RCRA Resource Conservation and Recovery Act
RG remedial goal
ROD Record of Decision
RRSB R-Area Reactor Seepage Basin
SCDHEC South Carolina Department of Health and Environmental Control
SLF Sanitary Landfill
SRFS Savannah River and Floodplain Swamp
SRNL Savannah River National Laboratory
SRS Savannah River Site
SSTA Solvent Storage Tank Area
SVE soil vapor extraction
SVEU soil vapor extraction unit
TCE trichloroethylene
USDOE U.S. Department of Energy
USEPA U.S. Environmental Protection Agency
UTR Upper Three Runs
VOC volatile organic compound
1.0 INTRODUCTION AND BACKGROUND

Environmental Compliance and Area Completion Projects (EC&ACP) is responsible for the remediation of operable units (OUs) and the decontamination and decommissioning of excess facilities at the Savannah River Site (SRS). This document describes the SRS groundwater protection, remediation, and monitoring strategy for groundwater and the vadose zone.

SRS groundwater management is guided by Federal and South Carolina regulations, primarily those implementing the Resource Conservation and Recovery Act (RCRA), the Safe Drinking Water Act, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). As a result of historical operations, soils, surface water, and groundwater have been contaminated by releases of hazardous substances. These areas of contamination are identified as OUs warranting investigation and possibly remediation. Groundwater contamination areas may be addressed as separate units or as part of larger units. A map of the SRS groundwater contamination areas is shown in Figure 1.

This groundwater strategy and implementation plan guides field activities at SRS and facilitates negotiations with the United States Environmental Protection Agency (USEPA) and the South Carolina Department of Health and Environmental Control (SCDHEC). Detailed groundwater activities and implementation are described in Appendix A, Implementation Plan.

2.0 OBJECTIVES

This groundwater strategy and implementation plan describes the remediation of groundwater and the associated source units. The objectives include:

- Mitigate potential human and ecological exposure to contaminated groundwater and surface water;
- Minimize contaminated groundwater from impacting surface water above regulatory standards;
These objectives will be achieved by:

- Focusing on source and vadose zone treatment to prevent further impact to groundwater and to reduce cleanup time (principally, volatile organic compounds [VOCs]);
- Developing new technologies and using existing technologies to effectively remediate groundwater and the vadose zone;
- Maintaining LUCs (i.e., institutional controls and engineering controls) to minimize human and ecological exposure to contaminated groundwater and surface water;
- Transitioning active groundwater remedies to enhanced attenuation remedies or monitored natural attenuation (MNA);
- Optimizing remediation and long-term monitoring;
- Streamlining remediation efforts by integrating actions required for multiple OUs; and
- Practicing a “green” approach to remediation.

### 3.0 REGULATION OF GROUNDWATER ACTIVITIES

EC&ACP groundwater activities are regulated by the SRS RCRA Permit Renewal and the SRS Federal Facility Agreement (FFA). The SRS RCRA Permit Renewal is issued and overseen by SCDHEC. The FFA is a tri-party agreement between the U.S. Department of Energy (USDOE), USEPA, and SCDHEC. All three parties are responsible for ensuring groundwater cleanup activities are conducted in accordance with the applicable regulations for the protection of human health and the environment. These three parties form the Core Team, which provides input, technical support, and decisions at various stages of the remediation processes. Groundwater activities associated with on-site landfills are
regulated under SCDHEC’s Solid Waste Management: Solid Waste Landfills and Structural Fills regulation and are beyond the scope of this plan.

3.1 RCRA Groundwater and Vadose Zone Activities

RCRA groundwater characterization, monitoring, reporting, corrective action, and post-closure care are conducted for contaminated plumes associated with RCRA hazardous waste management facilities (HWMFs). These activities are regulated by SCDHEC. Groundwater and vadose zone corrective action at RCRA facilities are conducted in accordance with applicable regulations under the jurisdiction of the SRS RCRA Permit Renewal. Corrective action activities are proposed in RCRA Permit Renewal Applications, which are revised as needed, and associated Corrective Action Plans. All activities conducted under the RCRA Permit Renewal require SCDHEC approval and must be conducted in accordance with permit conditions. Field treatability studies of innovative technologies and standard corrective actions can be implemented under temporary authorizations that have received SCDHEC approval. If the studies or actions will extend beyond 180 days, then a RCRA Permit Renewal Application revision must be submitted to SCDHEC prior to the end of the 180 days for the activity to continue.

3.2 FFA Groundwater and Vadose Zone Activities

Groundwater contamination areas not associated with closed RCRA HWMFs are addressed under CERCLA as specified in the FFA. Remedial decision-making for these areas follows the CERCLA regulatory process. The CERCLA process requires documentation that must be approved by USEPA and SCDHEC, including a work plan or sampling analysis plan, OUs characterization, and an assessment of risks to human health and the environment. A Feasibility Study or Corrective Measures Study/Feasibility Study is prepared to evaluate potential remedial alternatives, and the selected remedy is made available for public comment in a Proposed Plan or Statement of Basis/Proposed Plan. The selected remedy is documented and institutionalized in a Record of Decision (ROD). Some early groundwater actions may be implemented under the removal action administrative process, which streamlines the documentation process.
Groundwater units have been established to allow separate characterization and remediation of the source of contamination and contaminated groundwater. This approach allows remediation of the source areas to be achieved on a relatively expedited schedule. Associated contaminated groundwater generally requires extensive characterization and evaluation before the remedy can be selected and implementation of the remedy is often a lengthy process conducted in phases. This approach of segregating groundwater units also allows for multiple contaminated groundwater areas to be addressed holistically. Under CERCLA, innovative technologies can be field-tested as Treatability Studies, which are approved by the USEPA and SCDHEC.

4.0 ELEMENTS OF THE GROUNDWATER STRATEGY

The SRS groundwater strategy focuses on protection, remediation, and monitoring of contaminated groundwater. Strategic elements for each of these areas are presented in the following sections.

4.1 Groundwater Protection

In addition to USEPA and SCDHEC programs that are designed to protect groundwater (e.g., underground storage tank program, underground injection control program, wellhead protection program, and waste disposal program), prevention of future groundwater contamination and the disposition of contamination sources are the primary ways by which SRS groundwater is protected. Key activities include removing or immobilizing contaminant sources before contamination can reach groundwater, reducing natural and artificial recharge in contaminated areas, and eliminating the opportunity for contaminants to reach groundwater along unsealed well casings or through wells that are no longer needed. Considerable progress has been made at numerous SRS operable units in this respect through capping, in situ stabilization, and VOC treatment technologies.

Reducing natural and artificial recharge in contaminated areas protects groundwater by reducing the transport of contaminants through the vadose zone into the unconfined aquifer. Water run-on/runoff control measures have been implemented in and around SRS OUs.
Wells that no longer serve a useful purpose at SRS potentially provide a pathway for contaminant migration to the vadose zone, the unconfined aquifer, or deeper zones. These wells fall into three broad categories:

- Older wells that are noncompliant with the current SRS well specifications;
- Wells that no longer serve an investigative, assessment or regulatory purpose; and
- Wells with open screens across confining zones.

To aid in protecting the aquifer from mobile contamination, wells must be evaluated to ensure that they still serve a useful purpose. Wells that are not necessary or cannot be used will be abandoned in accordance with SCDHEC regulations and SRS procedures. Wells are prioritized for abandonment based on the threat they pose to groundwater resources. The factors examined in characterizing the threat include proximity to contamination, depth, well construction method, casing material, and installation age.

4.2 Groundwater Remediation

The goal of groundwater remediation is to take actions to restore contaminated groundwater to its intended beneficial use and to protect human health and the environment. Groundwater remediation is underway at SRS. The benefits are already apparent and are reflected by:

- Reduction of risk;
- Continued implementation of early action groundwater remediation to control plume expansion, reduce contaminant mass, and better characterize aquifer response to corrective/remedial actions;
- Establishment of alternate concentration limits when demonstrated to attain protective cleanup goals; and
- Evaluation and development of alternative corrective actions/remediation technologies.

SRS uses a graded approach to groundwater remediation (Figure 2). The selection of groundwater remediation technologies for a specific contamination area is based on the
size, contaminant type, contaminant concentration, and configuration of the plume. These attributes are the result of the nature and mass of the source of contamination and the subsurface characteristics in the area of the plume. A schematic diagram of a generic plume is shown in Figure 2. Many large plumes consist of several zones that are most efficiently addressed with separate complementary corrective actions/remedial technologies. The highest concentrations of contaminants are found in the source zone. The most robust, high mass removal technologies are best suited for remediation of the source zone. In the primary plume zone, active remedies, such as pump-and-treat, may be necessary to remove contaminants and exert hydraulic control of the plume. In the dilute fringe zone, contaminants are generally in low concentrations and can often be treated with passive technologies.

### 4.2.1 Active and Passive Technologies

Aggressive active groundwater remediation technologies remove or immobilize sources and lower contaminant concentrations in plumes. As remediation projects mature and the bulk of contaminants are removed, it is most efficient to transition from robust active systems to passive low-energy-consumption, low-carbon-emission technologies. The active systems are terminated and replaced with passive and enhanced-passive technologies. Ultimately, when final remedial goals have been met, the groundwater remediation systems can be permanently terminated. SRS has groundwater remediation projects in all phases of remediation.

#### 4.2.1.1 Active Remediation Systems

A range of active remediation systems are used at SRS. Pump and treat systems are used to exert hydraulic control over plumes. Thermal technologies have been employed in several areas to mobilize and remove dense non-aqueous phase liquid (DNAPL) VOCs in the vadose zone and groundwater. Dynamic Underground Stripping (DUS) utilized steam injection to enhance removal from large DNAPL source zones. Electrical Resistance Heating has been used in smaller DNAPL source zones. Air strippers remove source zone VOC contaminants. Active recirculation well systems remove VOC contamination from primary VOC plume areas. Soil vapor extraction (SVE) units remove VOCs from vadose
zone source areas. A base injection system is used to treat low pH groundwater contaminated with metals.

4.2.1.2 Enhanced-Passive Systems

Enhanced-passive remedial systems are used extensively at SRS. These are low-energy-consumption, low-carbon-emission systems that are not completely passive. These “green” technologies leverage natural systems and forces to protect, manage, and remediate groundwater.

Many existing SVE systems have been converted from active vacuum extraction powered by fossil fuels to enhanced-passive systems powered by natural non-fossil-fuel energy sources. BaroBall™ and MicroBlower™ systems are two types of enhanced-passive SVE currently in operation at SRS. BaroBalls™ rely on natural changes in barometric pressure to pump VOCs from the subsurface at individual SVE wells. SVE wells with MicroBlowers™ are designed to use solar power to generate a vacuum that exhausteds VOC vapors from individual wells. These are low-energy-consumption, zero-carbon-emission devices that remove VOC contaminants from the subsurface.

Barrier or treatment walls are used to provide a passive measure of hydraulic control and/or treatment of plumes without pumping. For example, at F Area seepage basins, groundwater barrier walls channel groundwater flow toward base injection zones in a funnel-and-gate configuration to support in situ remediation.

Phytoremediation is in use as an enhanced-passive system. Tritium-contaminated groundwater is collected and controlled as it discharges to a dam/pond system. Water from the pond is used to irrigate a pine forest. The trees take up the tritium-contaminated water through their roots and release very low concentrations of tritium vapor into the atmosphere where it is safely diluted. This semi-passive system makes use of natural processes of hydrology and evapotranspiration to reduce the volume of tritium-contaminated water entering site streams and ultimately the Savannah River.
Subsurface injection systems are considered enhanced-passive systems when single or infrequent episodes of injection are planned to modify geochemical conditions and enhance natural processes that result in remediation. Edible oil has been injected into the subsurface to encourage microbiological activity that consumes VOCs. Silver chloride is being injected into an aquifer in an attempt to stimulate geochemical reactions that will bind and immobilize iodine-129. Zero-Valent Iron was injected into an aquifer zone to create a permeable reactive barrier that degrades VOCs in groundwater through reductive dechlorination.

4.2.1.3 Passive Systems

MNA is a passive groundwater remedial action where the fringe and dilute areas of a plume degrade by natural biogeochemical or physical processes such as biodegradation, radioactive decay, and simple dispersion. MNA remedies must be accompanied by source controls and a technical justification that conditions are favorable for natural attenuation. Generally, the groundwater plume should not be expanding significantly, and regulatory standards cannot be exceeded at the groundwater discharge point. MNA remedy justifications are supported by groundwater modeling and a commitment to continued monitoring and reporting until remedial goals within the plume are achieved. When only the uppermost aquifer is impacted, SCDHEC may issue a Mixing Zone (MZ) permit that is essentially a permit for an MNA remedy. SRS has a mixture of RODs that required MNA as the final action for groundwater under CERCLA, and RODs that require SCDHEC MZ permits to implement the MNA remedy.

4.2.2 Transition and Shutdown Criteria

In determining whether remediation is complete, shutdown criteria are used, which are typically established in regulatory documents. For groundwater, maximum contaminant levels (MCLs) are the regulatory standards most often used. For vadose zone soils, soil remedial goals (RGs) are typically established based on protection of groundwater. Once a demonstration has been made to the regulators that these criteria have been achieved, the remediation is considered complete.
Experience has shown that soil RGs are often difficult to achieve. The RGs are typically back-calculated using simple fate and transport models and conservative input assumptions. The physical processes responsible for VOC-retention in fine-grained soils are often not considered. The following alternative closure criteria, which are not all-inclusive, should be considered to support a remedial strategy for closure that is not based strictly on a soil RG.

- Site characterization data;
- Remedial system design;
- Performance monitoring results; and
- Mass flux to and from groundwater and evaluation of rate-limited vapor transport.

Defining the transition points for conversion from active remediation systems to enhanced-passive or entirely passive remediation systems can be achieved by using lines of evidence described above. For groundwater systems, if LUCs are effective and surface water is not impacted, the transition point can be identified in a cost/benefit analysis. The active and passive remediation systems can be compared by considering the following:

- Cost;
- Contaminant concentration and removal rates;
- Time to reach MCLs and/or RGs;
- Carbon emission;
- Waste generation; and
- Natural resource protection.

For vadose zone remediation, controlling the flux to groundwater is an important criterion to consider. Any combination of these parameters can be used in a technical justification of a proposal to transition a project from an active to a passive remedy.
4.2.3  **Modeling in Support of Groundwater Remediation**

Groundwater modeling is used to support groundwater corrective action/remediation selection. Groundwater flow and transport modeling is used to predict how groundwater contamination will change with time. Future contaminant concentrations in groundwater and at stream discharge locations can be predicted. This is helpful in determining whether MNA is an appropriate alternative for a plume or whether more active technologies are needed. When active groundwater corrective action/remediation is called for, the effectiveness of various remedial groundwater strategies can be compared using predictive models. The mass of contaminants removed, future contaminant concentrations in groundwater, and the time to reach RGs can be predicted for remedial alternatives. This information provides a technical basis for the selection of the optimal corrective action/remedial selection for each groundwater plume, that is acceptable to the regulators.

SRS uses a suite of groundwater modeling codes that are peer reviewed, widely used in the environmental professional community, utilized by other USDOE sites, and accepted by both USEPA and SCDHEC. Major groundwater modeling efforts have focused on A/M Area, F Area, H Area, Burial Ground Complex, and several of the reactor areas where the most extensive subsurface contamination is known to exist.

4.3  **Groundwater Monitoring**

4.3.1  **Introduction**

Extensive groundwater monitoring is conducted at SRS OUs and operating facilities. Wells are monitored regularly to meet sampling requirements in FFA-related approved monitoring plans and the SRS RCRA Permit Renewal. In areas with groundwater contamination, the major contaminants are VOCs and tritium. Metals and other radionuclides are also present. SRS personnel plan and mobilize sampling events, collect and ship the samples, and provide data management. SCDHEC-certified off-site commercial laboratories and on-site laboratories perform the sample analyses.

Groundwater monitoring plans are typically developed to satisfy a specific regulatory requirement or to address technical data needs at a specific time in the regulatory process.
Often the focus of these plans is collecting the data needed to answer specific questions (e.g., is the groundwater contaminated?). Monitoring plans also evaluate and address future questions (e.g., are microbes present to facilitate remediation?). Changes in the groundwater conceptual site model or monitoring objectives (e.g., characterization verses corrective action/remedial performance monitoring) may require changes to the plan.

4.3.2 Objective-based Groundwater Monitoring

Surface water and groundwater monitoring are based on a set of clearly defined objectives from which monitoring data are collected to specifically fulfill those objectives. Typically, these objectives directly support project decision making. The design of the monitoring plan (e.g., the number of wells, frequency of sampling, laboratory analyses, reporting frequency) is tied to the data quality objectives and uncertainties in order to make project decisions. The decisions and the objectives to be met may vary depending on the type or stage of the project. The typical operable unit project comprising a source of contamination and associated groundwater contamination usually consists of the following stages:

- Pre-characterization problem identification;
- Characterization problem identification;
- Remedy selection support;
- Pre-design refinement;
- Short-term remedy evaluation;
- Long-term remedy evaluation; and
- Post-closure long-term monitoring.

For each of these stages, the type, amount, and frequency of data will vary depending on the nature and scale of the problem being monitored and the specific decisions that need to be made. Thus, the monitoring conducted is tailored to the objectives to be met at each stage.
The seven stages identified above can be divided into two main phases: pre-remedy characterization and post-remedy monitoring. In general, the objectives of these phases are fundamentally very different: identifying the nature and scope of the problem and selecting an appropriate remedy and determining the effectiveness of that remedy. While pre-remedy characterization focuses on identifying the nature and scope of the problem and selecting an appropriate remedy, post-remedy monitoring involves determining the effectiveness of that remedy. Pre-remedy characterization usually consists of a few samples from a large number of wells, over a large area, for a broad spectrum of potential contaminants. Post-remedy monitoring includes long-term monitoring of conditions, typically from a focused area, often with a key objective to demonstrate whether the groundwater conditions are deviating from what is expected when the remedy is working as predicted. It is also important to recognize that the monitoring can change significantly as the remedy matures or changes. For example, if an active bioremediation system can be shut down and MNA is acceptable, the process monitoring or degree of remedial effectiveness measured by various biogeochemical parameters may no longer be needed.

In optimizing groundwater monitoring to meet the identified objectives, focus areas will include reporting (content and frequency), possible reduction in analyte analyses, and well network optimization (number of wells and frequency of sampling). Reporting content should be limited to value-added information, focusing on the key constituents with respect to RGs. Using the example cited above, continued reporting of methane concentrations, which provides nutrient information related to the effectiveness of a bioremediation process, would not add value if that remedial system was discontinued. Furthermore, if this process information was reported semiannually, it may now be appropriate to reduce reporting frequency to annually or biennially. Sampling analyses should focus on contaminants that are risk drivers. In addition, changes to RCRA monitoring requirements have been made. Under South Carolina Hazardous Waste Management Regulations R.264.98, targeted Appendix IX analysis at point-of-compliance wells can now be conducted, and constituents inconsistent with the facility conceptual site model and long-term monitoring history can be dropped from the list (e.g., dioxins/furans) with regulatory approval. This objective-based approach should also be used to refine sampling well
networks and the frequency of sampling. Large plumes in aquifers with relatively slow groundwater velocities require a lower density of wells and less frequent sampling. Tables 1 and 2 provide typical decision logic for retaining, adding or removing a well and changes in sampling frequency.

Although numerous statistical approaches exist to optimize monitoring networks, the specific conceptual site model and associated heterogeneities that exist when developing a monitoring plan must be considered. In addition, input from the Core Team (i.e., USDOE, USEPA, and SCDHEC) and their technical support should always be considered from an FFA perspective. SCDHEC input should always be considered from an SRS RCRA Permit Renewal perspective. Monitoring plans should be reevaluated upon each change in stage for a project lifecycle when a change in remedial systems is affected and at least every five years for long-term monitoring systems.

5.0 SCHEDULE

SRS developed the current schedule (Figure 3) for groundwater remediation consistent with the approved FFA Appendix E: Fiscal Year 2020 Long-Term Projections and the SRS RCRA Permit Renewal. Based on groundwater models or best professional judgment, it will take decades before RGs are reached for many of the projects.
Figure 1. Groundwater Contamination Areas
Figure 2. SRS Graded Approach to Groundwater Remediation

**Source Zone**

**Characteristics:**
- High Concentrations
- Significantly perturbed geochemistry

**Need:** Aggressive technologies to limit long-term damage

**Examples**
- Destruction or Stabilization in place; Heat/Steam;
- Chemical Oxidation or Reduction; Immobilization

**Primary Groundwater / Vadose Zone Plume**

**Characteristics:**
- Moderate to high aqueous / vapor phase concentrations

**Need:** Baseline methods or moderately aggressive alternatives

**Examples**
- Pump (gas or water) and Treat;
- Recirculation Wells; Enhanced Bioremediation

**Dilute Plume / Fringe**

**Characteristics:**
- Low aqueous / vapor phase concentrations
- Large water volume

**Need:** Innovative technologies - Sustainable low energy concepts

**Examples**
- Passive Pumping (siphon, barometric, etc.);
- Bioremediation;
- Phytoremediation; Geochemical Stabilization
Figure 3. SRS Groundwater and Associated Source Strategy Schedule
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Table 1. Qualitative Monitoring Network Optimization Decision Logic

<table>
<thead>
<tr>
<th>Reasons for Retaining or Adding a Well in a Monitoring Network</th>
<th>Reasons for Removing a Well from a Monitoring Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well is needed to further characterize the site or to monitor changes in contaminant concentrations through time.</td>
<td>Well provides spatially redundant information with a neighboring well (e.g., same constituents, and/or short distance between wells).</td>
</tr>
<tr>
<td>Well is important for defining the lateral or vertical extent of contaminants.</td>
<td>Well has been dry for more than two years and there is no expectation that the water levels will recover in the foreseeable future.</td>
</tr>
<tr>
<td>Well is needed to monitor water quality at a compliance point or receptor exposure point (e.g., sentinel well for municipal wells).</td>
<td>Contaminant concentrations are consistently below laboratory detection limits or cleanup goals.</td>
</tr>
<tr>
<td>Well is important for defining background water quality.</td>
<td>Well is not functioning properly (e.g., cannot be effectively redeveloped, screen improperly placed).</td>
</tr>
</tbody>
</table>

Table 2. Qualitative Monitoring Frequency Decision Logic

<table>
<thead>
<tr>
<th>Reasons for Increasing Sampling Frequency</th>
<th>Reasons for Decreasing Sampling Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater velocity is high.</td>
<td>Groundwater velocity is low.</td>
</tr>
<tr>
<td>Change in concentration would significantly alter a decision or course of action.</td>
<td>Change in concentration would not significantly alter a decision or course of action.</td>
</tr>
<tr>
<td>Well is close to source area or operating remedy.</td>
<td>Well is far from source area or operating remedy.</td>
</tr>
<tr>
<td>Whether concentrations will change significantly over time cannot be predicted or there is no ready explanation for recent irregular or contradictory data.</td>
<td>Concentrations are not expected to change significantly over time or contaminant levels have been below cleanup objectives for some period of time.</td>
</tr>
</tbody>
</table>
APPENDIX A

IMPLEMENTATION PLAN
A.0 IMPLEMENTATION PLAN

The Savannah River Site (SRS) approach to groundwater corrective action/remediation is discussed in this implementation plan. The approach includes the following activities:

- Select the appropriate technologies;
- Apply those technologies efficiently;
- Transition from active to passive remedies, when appropriate; and
- Optimize monitoring.

A.1 Groundwater Remediation Implementation

The SRS groundwater management strategy is to mitigate the source of contamination in the environment to significantly reduce contamination transport through soil and groundwater. Contamination that has already migrated from the source must be assessed to determine what remedy, if any, is needed. A wide range of corrective action/remedial activities has been implemented at SRS operable units (OUs), which are summarized in Table A-1.

Source zone remediation has been successfully deployed and completed at some OUs. For example, Dynamic Underground Stripping (DUS) using steam injection heating was implemented successfully and was discontinued after reaching shutdown criteria at two source zone locations in the A/M-Area plume. Electrical Resistance Heating (ERH) was successful in reaching remedial goals (RGs) at two separate source zones (C-Area Groundwater [CAGW] and Chemicals, Metals, and Pesticides [CMP] Pits). Biosparging at the Sanitary Landfill (SLF) was discontinued after cleanup goals had been successfully reached. The F- and H-Area Water Treatment Units and the pump and treat system associated with them were shut down when F/H-Area groundwater remediation was transitioned to the enhanced-passive phase with the implementation of barrier walls and base injection.

Successful implementation of the groundwater management strategy will move the program from active remedies to enhanced-passive and passive technologies over time, as shown in Figure A-1. As the program matures and the bulk of the contaminant mass is
successfully removed from the source areas and primary plumes, the number of passive and enhanced-passive remedies is expected to become proportionally greater.

### A.2 Groundwater Monitoring Implementation

Groundwater monitoring is required by Resource Conservation and Recovery Act (RCRA) post-closure care permit renewal conditions at the following facilities:

- F-Area Hazardous Waste Management Facility (HWMF);
- H-Area HWMF;
- M-Area and Metallurgical Laboratory (Met Lab) HWMFs;
- Mixed Waste Management Facility (MWMF); and
- SLF.

Groundwater monitoring is required as part of a remedy under a Comprehensive, Environmental Response, Compensation, and Liability Act Record of Decision (ROD) for the following OUs:

- C-Area Burning/Rubble Pit (CBRP);
- C-Area Groundwater (CAGW)
- Chemicals, Metals, and Pesticides (CMP) Pits;
- D-Area Oil Seepage Basin (DOSB);
- K-Area Burning/Rubble Pit (KBRP);
- L-Area Southern Groundwater (LASG);
- P-Area Burning/Rubble Pit (PBRP);
- P-Area Operable Unit (PAOU)
- R-Area Operable Unit (RAOU)
- R-Reactor Seepage Basins (RRSBs); and
- TNX Operable Unit (T Area).

Groundwater monitoring is implemented at each OU and RCRA facility in accordance with the appropriate site-specific monitoring plan. Monitoring requirements (e.g., wells and surface water stations to be sampled, frequency of sampling, constituents to be analyzed, and the reporting frequency) are explicitly identified in the appropriate regulatory document. The monitoring requirements are optimized to meet specific data needs for specific units.
A.3 Reducing Long-Term Costs

An important objective of the groundwater management strategy is reducing long-term costs of groundwater corrective action/remediation and monitoring. The groundwater optimization initiative described in Section 4.3.2 and begun in 2012 has saved nearly $400K per year at four RCRA permitted facilities and seven Federal Facility Agreement groundwater units. Another means of reducing monitoring costs is to eliminate unnecessary wells to reduce long-term maintenance. Figure A-2 depicts the number of monitoring wells sampled at SRS as well as the number of wells installed and abandoned during the years 2000 through 2019. A goal of the strategy is not to increase the overall number of wells, if appropriate, which is accomplished by an ongoing assessment of OU monitoring well networks. Sampling at wells that do not provide data that support decision making is discontinued, and monitoring wells will be abandoned if they no longer provide data of value in the future. However, additional wells may be installed as necessary to track plume expansion, provide necessary data for planned remediation, or provide data for corrective action/remedial system assessment.

Cleanup by Integrator Operable Unit Watershed

The Environmental Compliance and Area Completion Project (EC&ACP) consists of 14 groundwater contamination areas. Groundwater in the contamination areas migrates downward and laterally. Groundwater eventually discharges into one of the five on-site streams or the Savannah River. These six receiving waterbodies define the watersheds, also referred to as integrator operable units (IOUs) at SRS, and are listed below:

- Upper Three Runs;
- Fourmile Branch (FMB);
- Pen Branch;
- Steel Creek;
- Lower Three Runs (LTR); and
- Savannah River and Floodplain Swamp (SRFS).

The following sections of this document identify the progress toward implementing the Groundwater Management Strategy and achieving the goals of the project in each IOU. A description of each IOU, the associated groundwater plumes, groundwater contamination areas, and groundwater and source control initiatives are provided.
A.3.1 Upper Three Runs IOU

A.3.1.1 Watershed Description

Upper Three Runs (UTR) originates northeast of the SRS boundary and follows a southwesterly direction for approximately 30.6 kilometers (km) (19 miles [mi]) within the SRS boundary. It discharges directly into the Savannah River approximately 1.45 km (0.9 mi) upstream of T Area. Within the SRS boundary, the UTRs watershed, or IOU, drains approximately 251 km² (97 mi²). The northern portion of the UTR IOU within the site boundary includes portions of A Area, M Area and Savannah River National Laboratory (SRNL). The southern portion of the UTRs watershed includes the majority of the B Area (Administrative Facilities), S Area (Vitrification Facility), and Z Area (Saltstone Facility), as well as portions of E Area (Waste Management Complex), F and H Areas (Separation Facilities), and R Area. The main tributaries within the SRS portion of the UTRs watershed include Tinker Creek and Tims Branch. Smaller tributaries include Crouch Branch, McQueen Branch, and Mill Creek.

A.3.1.2 Groundwater Contamination Areas

Projects occurring within the UTRs IOU are discussed below and listed in Table A-1.

A and M (A/M) Areas – A/M Areas contained the main SRS administrative functions and manufacturing areas. These areas are addressed together because of their proximity and commingled contaminants. When combined, the A/M Areas constitute one of the largest groundwater contamination areas in the country. The M-Area HWMF consists of the M-Area Settling Basin (MASB) (a seepage area, overflow ditch, and inlet process sewer line), Lost Lake (a shallow upland depression [Carolina Bay]), the Solvent Storage Tank Area (SSTA), the M-Area Abandoned Process Sewer Line (MAPSL) that connected the M-Area facilities with the MASB, the SRNL and associated process sewer lines, and the A-014 Outfall and discharge tributary. A/M Area also includes the M-Area Inactive Process Sewer Lines (MIPSL). The Met Lab HWMF consists of the Met Lab Basin (a seepage area, overflow ditch, and inlet process sewer line) and a Carolina Bay (shallow upland depression).
The A-014 Outfall and unnamed tributary of Tims Branch Creek received wastewater that contained volatile organic compounds (VOCs) from the M-Area facilities from 1952 to 1979. Similarly, the unlined MASB operated from 1958 until 1985, receiving wastewater that contained VOCs, solvents used for metal degreasing, other chemical constituents, and depleted uranium from the M-Area fuel fabrication processes. The MASB was closed with a RCRA cap in 1990. The MAPSL transported M-Area process wastewater to the basin. The principal contaminants in the areas are VOCs (primarily tetrachloroethylene [PCE] and trichloroethylene [TCE]) in the groundwater and the vadose zone.

The Met Lab Basin received wastewater that contained VOCs and metals from the Met Lab Facilities from 1956 to 1983. The Met Lab Basin was closed with a RCRA cap in 1992. The principal contaminants in the areas are VOCs (primarily PCE and TCE) in the groundwater.

**B Area** – B Area contains an administrative office complex. Additionally, the SRS SLF, which received solid waste containing RCRA contaminated A/M Area also includes the MIPSL solvent rags and wipes is located in B Area. The SLF was closed with a geosynthetic cap in 1997 and remediated under the RCRA Permit Renewal. Active groundwater cleanup using biosparging was completed in 2005. The biosparging system focused on the cleanup of TCE and chloroethene (Vinyl Chloride). Monitoring continues under the Alternate Concentration Limit (ACL)/Mixing Zone Concentration Limit (MZCL) remedy.

**A.3.1.3 Remediation**

The M-Area and Met Lab HWMFs have been divided into five sectors to help manage corrective actions; Central, Northern, Southern, and Western Sectors and A-Area Burning/Rubble Pits and Rubble Pit/Miscellaneous Chemical Basin/Metals Burning Pit (ABRP/MCB/MBP) OU.

**A/M Vadose Zone** – Dense non-aqueous phase liquid (DNAPL) in silts and clays provides a long-term source of groundwater contamination that is difficult to remediate. DUS uses steam heating to volatilize VOCs that are then captured with vapor extraction wells. DUS
was used at the SSTA and MASB. Two soil vapor extraction units (SVEUs) (i.e., 782-3M and A-014 Mobile #3) remain active as of 2020 to remove VOCs from the vadose zone. Hydraulic fracturing was utilized to open up the “tight” soils to allow remediation. This technique was applied in conjunction with a high-vacuum SVEU, A-014 Mobile #3. MicroBlowers™ and/or BaroBalls™ are removing contaminant mass from the vadose at SVE wells near the MAPSL, SSTA, Met Lab (Building 717-A), the SRNL, and MIPSL.

**A/M Groundwater** – The initial remediation strategy has been to hydraulically contain the high concentration portion of the plume in the Lost Lake Aquifer, while removing mass using recovery wells and air strippers. The M-1 Air Stripper has been fed by up to 13 recovery wells (i.e., RWM 1 through RWM 11, RWM 17B, and RWM 17D) in the Central Sector and has operated since 1985. The A-2 Air Stripper was fed by six recovery wells (i.e., RWM 12, RWM 13B, RWM 13C, RWM 14B, RWM 14C, and RWM 15B) in the Northern Sector and operated from 1996 through 2012, when it was placed in standby with the South Carolina Department of Health and Environmental Control’s (SCDHEC) approval. In the Southern Sector and the ABRP/MCB/MBP OU plume areas, recirculation well technology has been used to *in situ* air strip the VOCs. Twelve wells (i.e., SSR 1 through SSR 12) operated in Southern Sector from 1996 to 2011 and eleven wells (i.e., MIS 1 through MIS 11) in ABRP/MCB/MBP OU from 2002 to 2011. As of 2019 both these systems have been approved by SCDHEC for shutdown.

Field-scale demonstrations of innovative technologies have long been a part of the overall strategy for the A/M plume given its size and complexity. Temporary authorizations (TA) under RCRA to implement these technology demonstrations have been submitted and approved using chemical oxidation in Western Sector and humate amendments to enhance aerobic biodegradation in Southern Sector with another TA planned for oil injection to enhance anaerobic degradation near the MASB. In Western Sector in 2018, chemical oxidants (i.e., 40,000 gal of both potassium permanganate and sodium persulfate) were successfully injected into eight injection wells. In 2020, a second round of oxidant injections will occur at the same project area in Western Sector at four new injection wells.
In Southern Sector, the humate project has been ongoing since 2015, but has yet to successfully inject humate into the Lost Lake Aquifer.

**SLF Groundwater** – Groundwater monitoring at the SLF is conducted under an ACL/MZCL remedy to ensure no additional active cleanup is required.

### A.3.1.4 Accomplishments

Operation of active SVEUs have removed about 500,000 pounds of VOCs from the vadose zone to date. There are only two active SVEUs still operating. All other SVEUs have been fully transitioned to a combination of MicroBlowers™ and BaroBalls™. As concentrations continue to decline at the active SVEUs, evaluations of the systems are being conducted to determine how the system can be optimized. For example, 782-3M SVEU, which operates at the A-014 Outfall, has 3 of the original 13 vapor extraction wells in service. Nine wells are proposed to be abandoned due to very low to no contaminant levels and one was converted to photovoltaic-powered MicroBlowers™. The 782-6M SVEU was successfully shut down with SCDHEC approval in 2019. The SVE well network connected to the 782-6M SVEU was partially transitioned to photovoltaic-powered MicroBlowers™ in 2013. After shutdown in 2019, 16 wells are connected to MicroBlowers™ while the remaining wells have been abandoned or are proposed to be abandoned. United States Environmental Protection Agency (USEPA) and SCDHEC in 2020 approved the completion of the SVE effort at MIPSL allowing dismantlement and abandonment of those SVE wells.

The two Western Sector DUS projects at SSTA and MASB also removed about 500,000 pounds of VOCs from the vadose zone and groundwater.

**Groundwater** – Operation of the two pump and treat systems and the recirculation wells have removed about 500,000 pounds of VOCs from the groundwater. As of 2020, the M-1 recovery well network has been optimized to remove three wells (i.e., RWM 9, RWM 11, and RWM 17D) from operation due to low VOC concentrations, add two wells (i.e., RWM018 and RWM019) to capture high concentration portions of the groundwater plume, and is currently evaluating the shutdown of RWM 17B due to low VOC
concentrations. In 2020, the A-2 Air Stripper was permanently shut down with SCDHEC approval. In 2018, SCDHEC approved the dismantle and removal of all equipment requiring maintenance at the Southern Sector and ABRP/MCB/MBP OU recirculation wells. SCDHEC also approved the abandonment of all eleven recirculation wells at ABRP/MCB/MBP OU, which was completed in 2019.

Operation of the biosparging system at the SLF reduced concentrations of the identified contaminants (Vinyl Chloride and TCE) to their respective cleanup goals in 2005.

Characterization activities continue in the various sectors of the M-Area and Met Lab HWMFs to aid in developing corrective actions as noted in the corrective action plan schedules contained in the RCRA Permit Renewal Application.

A.3.2 Fourmile Branch IOU

A.3.2.1 Watershed Description

The FMB IOU, which is located entirely within the SRS boundary, originates near the center of SRS and follows a southwesterly direction for approximately 24 km (15 mi). In the lower reaches, FMB broadens and flows through a delta that has been formed by the deposition of sediments during reactor operations. The majority of the flow discharges into the Savannah River; a small portion of the creek flows west and enters Beaver Dam Creek. When the Savannah River floods, water from the FMB flows into the Savannah River Floodplain Swamp (SRFS). The watershed drains about 57 km² (22 mi²) and includes several SRS facilities: C Area (C-Reactor Complex), N Area (Central Shops), F, H, and E Areas (General Separations Areas [GSAs]), and the Solid Waste Disposal Facility. Castor Creek is the principal tributary of FMB.

The FMB headwaters include a small blackwater stream that has been relatively unimpacted by SRS operations. FMB receives effluents from F, H, and C Areas and contaminated groundwater discharges that have migrated from SRS facilities and OUs into the stream and its tributaries.
A.3.2.2 Groundwater Contamination Areas

Projects occurring within the FMB IOU are discussed below and listed in Table A-1.

E Area – E Area consists of several adjacent facilities that are current or former waste disposal facilities, primarily for hazardous and radioactive wastes and spent solvents generated from chemical and manufacturing processes. One facility, the Burial Ground Complex (BGC), occupies approximately 79 hectares (ha) (195 acres [ac]) and is composed of several contiguous facilities that served as disposal locations for radioactive and hazardous waste (e.g., RCRA-regulated metals, VOCs, tritium, and other radionuclides). The BGC is comprised of three primary units: Old Radioactive Waste Burial Ground (ORWBG), Low-Level Radioactive Waste Disposal Facility (LLRWDF), and MWMF, which has underlying contaminated groundwater. RCRA closure systems have been installed at both LLRWDF and MWMF. Effective corrective actions have been employed for the groundwater areas and are being managed under the RCRA Permit Renewal. ORWBG, the highest risk remaining surface unit, has been consolidated with four nearby OUs to form the General Separations Area Consolidation Unit (GSACU). Final remedial action at the GSACU, which includes installation of an engineered low permeability cap over the ORWBG, began in 2003 and was completed in 2008.

F Area – F Area is part of the general separations operations where plutonium was separated from irradiated assemblies for refinement into metal buttons. The principal contaminants are tritium within the groundwater, and strontium, uranium, iodine-129, heavy metals, and solvents in soils and sediments. The primary remedial goal is to achieve source and plume control to reduce the release of contaminants to FMB. Besides soil and geosynthetic capping, other remedies deployed to treat contaminants in F Area include an underground barrier wall system using Base Injection with a Funnel and Gate Barrier System, and injection of a silver chloride amendment to immobilize iodine-129.

H Area – H Area is part of the general separations operations where plutonium was separated from irradiated assemblies for refinement into metal buttons. H Area was also used to process tritium and uranium and to produce plutonium-238. The principal constituents of concern are tritium, strontium, and mercury. The primary remedial goal is
to achieve source and plume control again reducing the release of contaminants to FMB. Many of the H Area high-risk units have been completed or are in remediation including Warner’s Pond, HP-52 (basin), and H-Area Retention Basin.

**C-Area** – All SRS reactor areas were constructed with similar facilities and similar processes were used during their operations. The areas where the reactors are located also contain former disposal sites for hazardous substances such as burning/rubble pits and basins. Principal contaminants at the C Area are cesium-137, tritium, and spent organic chemicals. Monitoring wells indicate the presence of tritium and VOCs. A VOC groundwater plume extends from the CBRP to FMB. A VOC and Tritium plume emanating from the C-Area Reactor Building Complex and Seepage Basins extend to Castor Creek to the south and FMB.

**N Area** – N Area contains burning/rubble pits, equipment maintenance areas, and chemical and runoff basins that were used between 1951 and 1973 to dispose of various waste materials, including hazardous substances such as organic and inorganic chemicals and radioactively contaminated materials. In the Central Shops portion of N Area, groundwater was contaminated with hydrocarbons from leaking underground storage tanks.

**A.3.2.3 Remediation Projects**

**MWMF Groundwater Southwest Plume** – At the MWMF, phytoremediation is utilized by capturing tritium-contaminated water in a 10.2M liters (L) (2.7M gal) pond and irrigating the water on 24.7 ha (61 ac) of pine trees for transpiration, which has resulted in a 70% annual tritium reduction (from 1,500 to 2,000 curies to 450 curies) to FMB. The original 8.9 ha (22-ac) system was expanded and upgraded by adding an additional 15.8 ha (39 ac) of pine trees and doubling the capacity of the irrigation supply and distribution system.

**F- and H-Area HWMFs Groundwater** – A pump-and-treat system was operated at F- and H-Area HWMFs for several years; the system was replaced with a more passive funnel-and-gate treatment system at F Area and a barrier system at H Area. The barrier systems at F- and H-Area HWMFs have been very effective in managing tritium and metal
flux to FMB. SRS has achieved several RCRA corrective action goals and is actively working to achieve the Phase 2b RCRA corrective action goals for FMB.

The base injection system at F Area utilizes base to neutralize acid, which reduces the metal concentration in the groundwater. The system has been augmented with 34 additional wells between the barrier system and FMB to further reduce contaminant flux. A base injection system was constructed for the wetland area below the barrier at H Area; the system consists of 30 base delivery wells and a pumping and mixing system. SRS has developed an injectable capture media to immobilize in situ iodine-129 in groundwater and is creating a reactive treatment zone within one of the F Area gates.

**C-Area Groundwater** – The U.S. Department of Energy (USDOE), USEPA, and SCDHEC agreed in December 2016 to address a portion of the VOC plume that is discharging to surface water near Castor Creek using a non-time critical removal action administrative approach. A one-time injection of emulsified oil into the highest concentration portion of the VOC plume was completed in August 2019. Monitoring began in December 2019 to assess the performance of the removal action.

For the CBRP OU, MicroBlowers™ are used to remove VOCs from the vadose zone and monitored natural attenuation (MNA) is the selected remedy for groundwater. Both physical and anaerobic biological processes are attenuating VOCs in the plume.

### A.3.2.4 Accomplishments

The base injection system at F Area was started in 2005 and the H Area system was started in 2010. The systems in both areas are operated as needed to adjust pH levels. Since operations began, F Area has injected approximately 138M gal and H Area injected approximately 44.1M gal of base solution. The base injection systems will likely require periodic operation until the groundwater pH returns to natural levels.

Deactivation of the F- and H-Area groundwater treatment units are completed.

A subsurface reactive treatment zone using an injectable silver chloride amendment is being constructed as a means of controlling iodine-129. Bench-scale testing and a pilot
injection test indicated that the silver will be effective in managing the contaminant. Ultra-fine ground solid silver chloride was injected in 2011, 2015, and 2019 at F Area. Reductions in the concentration of iodine-129 have been observed. SRS is continuing to monitor the effects of injection.

The MWMF phytoremediation system has operated since 2000. Evapotranspiration has been determined to be 80-90% effective, with tritium concentrations in FMB being reduced by 70%.

ERH with SVE was used to address elevated levels of TCE in the vadose zone near the C-Reactor Building (105-C) Complex. This interim remedy was completed in September 2006. Subsequent soil sampling indicated that over 99% of the source contamination was removed. The residual TCE concentrations are being addressed through an emulsified oil treatment barrier prior to discharge to Castor Creek.

A.3.3 Pen Branch IOU

A.3.3.1 Watershed Description

The Pen Branch IOU originates near the center of SRS and flows in a southwesterly direction for approximately 17.6 km (11 mi), and then discharges into the SRFS rather than flowing directly into the Savannah River. The Pen Branch IOU is located entirely on SRS property. Pen Branch flows southwesterly from its headwaters, about 3.2 km (2 mi) east of K Area, to the Savannah River Swamp. After entering the swamp, Pen Branch flows parallel to the Savannah River for about 8.0 km (5 mi) before it enters and mixes with the water from Steel Creek, about 0.32 km (0.2 mi) from the mouth of Steel Creek at the Savannah River. The Pen Branch IOU drains about 54.4 km² (21 mi²) and includes K Area (K-Reactor Complex), portions of N Area (Central Shops), the CMP Pits OU and the L-Area Northern Groundwater (LANG) OU. Indian Grave Branch is the principal tributary of Pen Branch.
A.3.3.2 Groundwater Contamination Areas

Projects occurring within the Pen Branch IOU are discussed below and listed in Table A-1.

**K Area** – All SRS reactor areas were constructed with similar facilities, and similar processes were used during their operations. The areas where the reactors are located also contain former disposal sites for hazardous substances, such as burning/rubble pits and basins.

Principal contaminants in the reactor areas are cesium-137, strontium-90, tritium, and VOCs. Monitoring wells indicate the presence of tritium and VOCs in groundwater. Tritium is also present in Indian Grave Branch. USDOE, USEPA, and SCDHEC reached agreement to conduct annual monitoring and five-year reporting.

The CMP Pits are located about 1.6 km (1 mi) north of L-Reactor Complex. These pits were used to dispose of chemicals, metals, and pesticides. As a result of past disposal practices, surface soil, subsurface soil, and groundwater have been contaminated. Primary contaminants are VOCs, pesticides, and polychlorinated biphenyls (PCBs). In 1984, the pits were excavated, and highly contaminated soil was removed. Enhanced bioremediation was used to treat surface soils contaminated with pesticides and PCBs. An ERH system with SVE was used to remove VOCs in the vadose zone. The final remedy for CMP Pits groundwater is MNA.

A.3.3.3 Remediation

**CMP Pits** – The ERH system was a soil treatment technology used to remediate localized solvent contamination in non-porous subsurface soils where electrodes are inserted into the subsurface to heat the soil to transform liquid solvents into the vapor phase. The contaminants were subsequently removed using SVE. Full-scale ERH operations began at the CMP Pits in March 2008. Confirmation sampling was conducted from 2009 to 2010 and indicated that RGs in the vadose zone were achieved. The final action for the groundwater is MNA.
The KBRP – MNA with a groundwater mixing zone was implemented as the chosen remedy at the KBRP to monitor for VOCs in the groundwater associated with the unit.

A.3.3.4 Accomplishments

As stated in the Effectiveness Monitoring Report for the CMP Pits OU (SRNS-RP-2010-00896, Revision 0, June 2010), the SVE unit in combination with the ERH system removed approximately 2,300 pounds of VOCs (primarily PCE) from March 2008 through March 2009. The emission rates from the SVE unit were well below the permit limits contained in the Title V Air Permit. After the ERH was completed, the SVE system reached the point of diminishing returns, and therefore, the system was shut down on April 23, 2009, and decommissioned. The SVE unit removed over 3,600 pounds of contaminants during its entire operation. MNA monitoring continues for VOCs in groundwater.

Annual groundwater reporting for KBRP concludes that the mixing zone remedy combined with MNA is effective, and the PCE and TCE concentrations have remained below MCLs since 2019.

The USDOE, USEPA, and SCDHEC issued a No Action ROD for LANG in 2011.

A.3.4 Steel Creek IOU

A.3.4.1 Watershed Description

The headwaters of Steel Creek originate near P-Reactor, southwest of PAR Pond. Steel Creek flows southwesterly about 3.2 km (2 mi) before it enters L Lake. L Lake is a dammed lake 6.4 km (4 mi) long with an area of about 418 ha (1,034 ac). Flow from the outfall of L Lake dam travels about 4.8 km (3 mi) before entering the Savannah River Swamp and another 3.2 km (2 mi) before entering the Savannah River. Steel Creek has received thermal discharges and increased flow from reactor operations that produced an extensive delta where Steel Creek enters the SRFS. Meyers Branch, the main tributary of Steel Creek, flows approximately 9.6 km (6 mi) before entering Steel Creek. Meyers Branch has been and remains relatively undisturbed by SRS operations. The total area
drained by the Steel Creek and Meyers Branch system is about 90.6 km² (35 mi²) and includes portions of P and L Areas.

A.3.4.2 Groundwater Contamination Areas

Projects occurring within the Steel Creek IOU are discussed below and listed in Table A-1.

P and L Area – All SRS reactor areas were constructed with similar facilities and similar processes were used during their operations. The areas where the reactors are located also contain former disposal sites for hazardous substances, such as burning/rubble pits and basins. Principal contaminants in the reactor areas are cesium-137, strontium-90, tritium, spent organic chemicals, and low-level radioactive debris. L Area has ongoing missions, whereas P Area has been closed. The P-Area Reactor Building (105-P) Complex was remediated through in situ decommissioning, which was completed in 2011. Monitoring wells indicate the presence of tritium and VOCs in the groundwater.

A.3.4.3 Remediation

The PAOU Early Action ROD included remediation of two vadose zone areas impacted with solvents. Remediation included hydraulic fracturing with chemical oxidation and SVE to treat these sources to the P-Area Groundwater (PAGW) OU. The vadose zone actions were completed in 2012 with the achievement of remedial goals for TCE and PCE. A treatability study evaluating enhanced bioremediation was also completed at PAGW, which had limited impacts in the area tested. USDOE, USEPA, and SCDHEC agreed in May 2017 to address a portion of the VOC plume that is discharging to upper Steel Creek using a non-time critical removal action, which consisted of injecting zero-valent iron to create a permeable reactive barrier intersecting the VOC plume. The removal action targets TCE in the upper aquifer zone of the UTRs Aquifer and was completed in December 2019.

At LASG the surface units responsible for groundwater contamination have been remediated. Subsequently, an MNA remedy has been approved for groundwater.
A.3.4.4 Accomplishments

The MNA remedies in L Area continue to be effective as documented in monitoring reports and the Fifth Five-Year Remedy Review Report for SRS OUs with Groundwater Remedies (SRNS-RP-2019-00511, Revision 1, July 2020) conducted from 2019 to 2020. Sampling and reporting optimization have been implemented for LASG and PBRP. The MNA remedy at L-Area Burning Rubble Pit (LBRP) has met remedial goals (maximum contamination levels [MCLs]) and was complete in 2017.

Concentrations of all constituents remain below their respective MCLs at PBRP since 2017 except for 1,4-dioxane which was added to the list of monitored constituents based on a recommendation in the Fourth Five-Year Remedy Review Report for the Savannah River Site (SRS) (SRNS-RP-2012-00011, Rev.1.1, November 2013).

A.3.5 Lower Three Runs IOU

A.3.5.1 Watershed Description

The LTR IOU is located on the eastern portion of SRS and lies partially within the SRS boundary. The LTR stream is the principal surface water body within the IOU and is located entirely on SRS property, including the narrow corridor that extends from Patterson Mill to the confluence with the Savannah River. The watershed, which drains about 461 km² (178 mi²), includes R Area, a portion of P Area, ecological laboratories and various EC&ACP OUs. Industrial facilities located outside the eastern SRS boundary are also located within the LTR IOU. A mainstream impoundment, PAR Pond, was constructed along with several retaining ponds on the headwaters of LTR to receive reactor effluent.

A.3.5.2 Groundwater Contamination Areas

Projects occurring within the LTR IOU are discussed below and listed in Table A-1.

R-Area – All SRS reactor areas were constructed with similar facilities, and similar processes were used during their operations. The areas where the reactors are located also contain former disposal sites for hazardous substances, such as burning/rubble pits and basins. Principal contaminants in the reactor areas are cesium-137, strontium-90, tritium,
spent organic chemicals, and low-level radioactive debris. In R Area, monitoring wells indicate the presence of strontium-90, tritium, and VOCs in the groundwater. R Area has been closed, and the R-Area Reactor Building (105-R) Complex was remediated through in situ decommissioning, which was completed in 2011.

A.3.5.3 Remediations

A groundwater mixing zone was chosen as the final remedy at the R-Area Reactor Seepage Basins (RRSB) OU and MNA was selected as the final remedy for the R-Area Groundwater (RAGW) OU.

A.3.5.4 Accomplishments

The remedies in R Area continue to be effective as documented in monitoring reports and the Fifth Five-Year Remedy Review Report for SRS OUs with Groundwater Remedies (SRNS-RP-2015-00419, Revision 1, July 2016) conducted from 2015 to 2016. Sampling and reporting optimizations have been implemented for the RRSBs.

A.3.6 Savannah River and Floodplain Swamp IOU

A.3.6.1 Watershed Descriptions

The Savannah River watershed drains about 27,387 km² (10,574 mi²), including western South Carolina, eastern Georgia, and a small portion of southwestern North Carolina. Approximately 31% of the watershed area, referred to as the SRFS IOU, is located in the Coastal Plain and includes Augusta, GA, SRS, and Savannah, GA and continues to the Atlantic Ocean. The SRFS IOU includes the 100-year floodplain (including the Savannah River Swamp) and any continuous wetlands, including the Savannah River adjacent and downgradient of SRS. This area encompasses approximately 72 km (45 mi) from the northern boundary of SRS above UTRs southward to the U.S. Highway 301 Bridge. The five major SRS streams feed into the SRFS (UTRs, FMB, Pen Branch, Steel Creek, and LTR). SRFS IOU includes portions of A/M Areas, D Area, and TNX Area.


A.3.6.2  Groundwater Contamination Area

Projects occurring within the SRFS IOU are discussed below and listed in Table A-1.

D Area – D Area was used beginning in the mid-1950s, the primary missions to produce heavy water and power for the site. Materials disposed of included coal ash, oil, chemicals, and construction debris. The coal burning power plant was operated in D Area, until shut down in 2012. Sampling results indicate that soil and groundwater in the area are contaminated by metals, tritium, and VOCs. Aqueous Film Forming Foam (AFFF) has recently been identified as a long-lived contaminant associated with firefighting and has the potential to contaminate groundwater. Preliminary results indicate that these contaminants are present in D-Area groundwater.

T Area – T Area was operated from the mid-1950s through the mid-1980s to conduct pilot tests to support SRS operations. The principal contaminants are mercury, thorium, uranium, radium, and chlorinated solvents. Because of its location near the Savannah River, the T Area was the first EC&ACP Completion in 2006.

A.3.6.3  Remediation

T Area – T Area (TNX) has a small persistent TCE/PCE plume that was remediated using pump & treat (T-1 Air Stripper) from 1996 to 2007 and, eventually reached a point of diminishing effectiveness. A new remediation strategy, which uses Edible Oil to sequester and biologically destroy the VOCs, was subsequently implemented. Neat Edible Oil was injected to sequester the VOCs (vadose zone source), and Edible Oil emulsion (food source) was injected to promote microbial activity and reducing conditions in groundwater (reductive dichlorination of PCE and TCE). By implementing this new remediation in 2008, use of the air stripper was eliminated by 2013.

D Area – For D-Area Groundwater, historical field scale treatability studies included phytoremediation of VOCs using a drip irrigation delivery system, and sulfate-reducing biotreatment of the low pH metals plume. A treatability study was begun in 2020 to evaluate the efficiency of natural flushing of the aquifer with higher pH water from a deeper
aquifer in D Area. A removal action was also completed in 2020 to address the low pH shallow soils through the addition and mixing of limestone amendment.

For the DOSB, removal of debris and deep basin soils was conducted to remove the source of contamination. The selected remedy for the groundwater at the DOSB is MNA/groundwater mixing zone with institutional controls. Naturally-occurring mechanisms will continue to reduce remaining contaminant concentrations over time.

A.3.6.4 Accomplishments

The edible oil treatability study demonstrated the ability to decrease the contaminant mass and areal extent of the TCE plume in less time and at lower cost than the remedy selected in the TNX Area OU ROD, and still be protective of the groundwater. The effectiveness of edible oil warranted a change in the remedy for TNX groundwater. An Explanation of Significant Difference was issued on June 12, 2013, with the following modifications to the remedy selected in the ROD for the TNX Area OU groundwater component:

- Injection of additional edible oil treatment as needed using the existing well network if a sustained rebound lasting over one (1) year in excess of 75 µg/L of TCE, PCE, or carbon tetrachloride occurs in any well. If the rebound occurs, then additional edible oil will be determined appropriate by the USDOE, SCDHEC, and the USEPA.

- Permanent removal of the T-1 Air Stripper from service. The T-1 Air Stripper was closed in accordance with a state approved closure plan.

In 2015, edible oil was injected although the rebound conditions to trigger additional oil injections had not been exceeded. To prevent future rebound of TCE concentrations, additional edible oil was injected at ten monitoring wells. Emulsified Oil Substrate® was reinjected into the original treatment zone and both neat oil and Emulsified Oil Substrate® were injected outside of the original treatment zone to target monitoring wells with elevated TCE concentrations.

Results collected since the 2015 edible oil injections indicate that edible oil injection fluids were placed into the aquifer successfully, TCE concentrations are less than the MCL in all...
wells in the treatment area, and reductive conditions are present in the treatment area. TCE concentrations exceeding the MCL (5 µg/L) are located downgradient of the edible oil treatment area in the distal groundwater plume. The monitoring wells inside the edible oil treatment area are depleted of residual TCE contamination as increases in water elevation no longer cause increased TCE concentrations. The few wells continuing to exceed the MCL have TCE concentrations just greater than 5 µg/L.
Figure A-1. Groundwater Management Strategy – Active to Passive Remediation
Figure A-2. Number of Monitoring Wells Sampled, Installed, or Abandoned Annually at SRS (2000-2019)
### Table A-1. SRS Groundwater Corrective Action/Remediation Projects

<table>
<thead>
<tr>
<th>Area</th>
<th>IOU</th>
<th>Plume</th>
<th>Project</th>
<th>Remedial Activities</th>
</tr>
</thead>
</table>
| A/M Upper Three Runs                      | A/M   | A/M Groundwater and Vadose Zone; Miscellaneous Chemical Basin (MCB)/ Metals Burning Pit (MBP); and MIPSL |･ DUS (Completed)  
･ SVEUs  
･ Pump & Treat (Air Stripper)  
･ Recirculation Wells (Partial Shutdown)  
･ Fracture Enhanced SVEU  
･ Vadose Zone Oil Treatment (Completed)  
･ Chemical Oxidation  
･ Bioremediation  
･ MicroBlowers™  
･ BaroBalls™ |<br/>|                                |･ A/M Groundwater and Vadose Zone; Miscellaneous Chemical Basin (MCB)/ Metals Burning Pit (MBP); and MIPSL |･ DUS (Completed)  
･ SVEUs  
･ Pump & Treat (Air Stripper)  
･ Recirculation Wells (Partial Shutdown)  
･ Fracture Enhanced SVEU  
･ Vadose Zone Oil Treatment (Completed)  
･ Chemical Oxidation  
･ Bioremediation  
･ MicroBlowers™  
･ BaroBalls™ |
| ABRP                                      | ABRP  | A-Area Burning/Rubble Pits and Rubble Pit (ABRP)                       |･ A/ Area Burning/Rubble Pits and Rubble Pit (ABRP)                       |･ MicroBlowers™  
･ BaroBalls™  
･ SVE Recirculation Wells (Completed Interim Action) |
| B Upper Three Runs                        | SLF   | Sanitary Landfill Groundwater                                          |･ Sanitary Landfill Groundwater                                          |･ Biosparging (Completed)  
･ Alternate Concentration Limit (ACL) / Mixing Zone Concentration Limit (MZCL) |
| C Fourmile Branch                         | CAGW  | C-Area Groundwater - Interim                                           |･ C-Area Groundwater - Interim                                           |･ Electrical Resistance Heating (ERH)(Completed) |
|                                           | CBRP  | C-Area Burning/Rubble Pit                                              |･ C-Area Burning/Rubble Pit                                              |･ MicroBlowers™  
･ MNA |
| D Savannah River and Floodplain Swamp     | DAGW  | D-Area Groundwater                                                      |･ D-Area Groundwater                                                      |･ Characterization planned to start in FY2020 |
|                                           | DOSB  | D-Area Oil Seepage Basin                                               |･ D-Area Oil Seepage Basin                                               |･ MNA/Mixing Zone (MZ) |
| E Fourmile Branch                         | MWMF  | MWMF Groundwater Northeast                                             |･ MWMF Groundwater Northeast                                             |･ MNA  
･ MNA  
･ MNA  
･ MNA  
･ Phytoremediation |
<p>| GSA Eastern                               | GSA Eastern Groundwater / H-Area Tank Farm |･ GSA Eastern Groundwater / H-Area Tank Farm                             |･ GSA Eastern Groundwater / H-Area Tank Farm                             |･ Characterization in progress |
| GSA Western                               | GSA Western Groundwater / F-Area Tank Farm |･ GSA Western Groundwater / F-Area Tank Farm                             |･ GSA Western Groundwater / F-Area Tank Farm                             |･ Characterization in progress |</p>
<table>
<thead>
<tr>
<th>Area</th>
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<th>Plume</th>
<th>Project</th>
<th>Remedial Activities</th>
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<tr>
<td>F</td>
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<td>F-Area HWMF Groundwater</td>
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<td>• Barrier Wall with Base Injection</td>
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<td>• Silver Chloride Injection</td>
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<td>CMP Pits Groundwater</td>
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<td>• CMP Pits Vadose Zone</td>
<td>• ERH with SVE (Completed)</td>
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<td>• Silver Chloride Injection (if needed)</td>
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<td>P</td>
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<td>Creek</td>
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<td>• Characterization is in progress</td>
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<td>R-Reactor Seepage Basin</td>
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<td>Runs</td>
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<td>T</td>
<td>Savannah River and Floodplain Swamp</td>
<td>TNX</td>
<td>TNX Groundwater</td>
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