1.0 Test Plan Summary

The amount of petroleum contaminated soil (PCS) at the Savannah River Site (SRS) that has been identified, excavated, and is currently in storage has increased several fold during the last few years. Several factors have contributed to this problem:

- South Carolina Department of Health and Environmental Control (SCDHEC) lowered the sanitary landfill maximum concentration for total petroleum hydrocarbons (TPH) in the soil from 500 to 100 ppm.
- SCDHEC mandated removal and replacement of underground storage tanks at several sites.
- SCDHEC disallowed aeration to treat contaminated soil.
- Several large contaminated areas of soil associated with leaking underground storage tanks, leaking pipes, disposal areas, and spills were discovered.

Because of the factors listed above, SRS urgently needs to remediate large quantities of petroleum contaminated soil that is currently stockpiled. Accidental spills are likely to be a long-term source of new PCS. As long as petroleum-based products are used at the Site, we will generate contaminated soil that will require remediation.

The sOILS Facility is the location where PCS will be remediated. This facility is a concrete structure 400 feet long and 40 feet wide and divided into four cells 200 feet long and 20 feet wide. The bases slope to a leachate control system and any water collected is reapplied via sprinklers. The leachate collection system is designed to hold a catastrophic 25-year rainfall event. A base of clean soil will be applied to a depth of 6-9 inches to provide good soil drainage. Contaminated soil will be applied on the drainage bed 6-12 inches deep. The soil will be kept moist but not damp and aerated via roto-tilling once a week. The design uses existing site equipment, such as trucks and graders, to transport, apply, and distribute the soil. Monthly analyses will consist of inorganic nutrients, pH, and microbes. Weekly measurements for volatile organic compounds (VOCs) in the air and moisture will be taken from random parts of the system to ensure that volatilization and particulate emissions are below annual air emission limits. Once demonstrated to be below 100 ppm TPH and 10 ppm benzene, ethyl benzene, toluene, and xylenes (BTEX) treated soil will be removed to a sanitary landfill. The facility should be able to treat 900 yd^3 of contaminated soils every 6-12 weeks, depending on the concentration level of PCS and weather. Thus, 3000-8000 yd^3 of soil can be processed every year. The facility is permitted by SCDHEC via the Soil Correction Action Plan (sCAP) and an air permit waiver, based on the air emissions calculations found in the sCAP.

The facility has no precedence in South Carolina or Georgia and as such represents new technology for the area. However, since several other states have demonstrated similar facilities, the sOILS Facility represents low risk and should receive high public acceptance. The facility will also provide South Carolina with the opportunity to demonstrate and evaluate an innovative, environmentally sound, remediation technique onsite that can be used to handle fuel spill cleanup and the growing leaking underground storage tank (LUST) problem. The system demonstration and optimization is expected to last approximately two years, at which time, Central Services Works Engineering (CSWE) will continue to operate the facility as the PCS treatment center onsite.

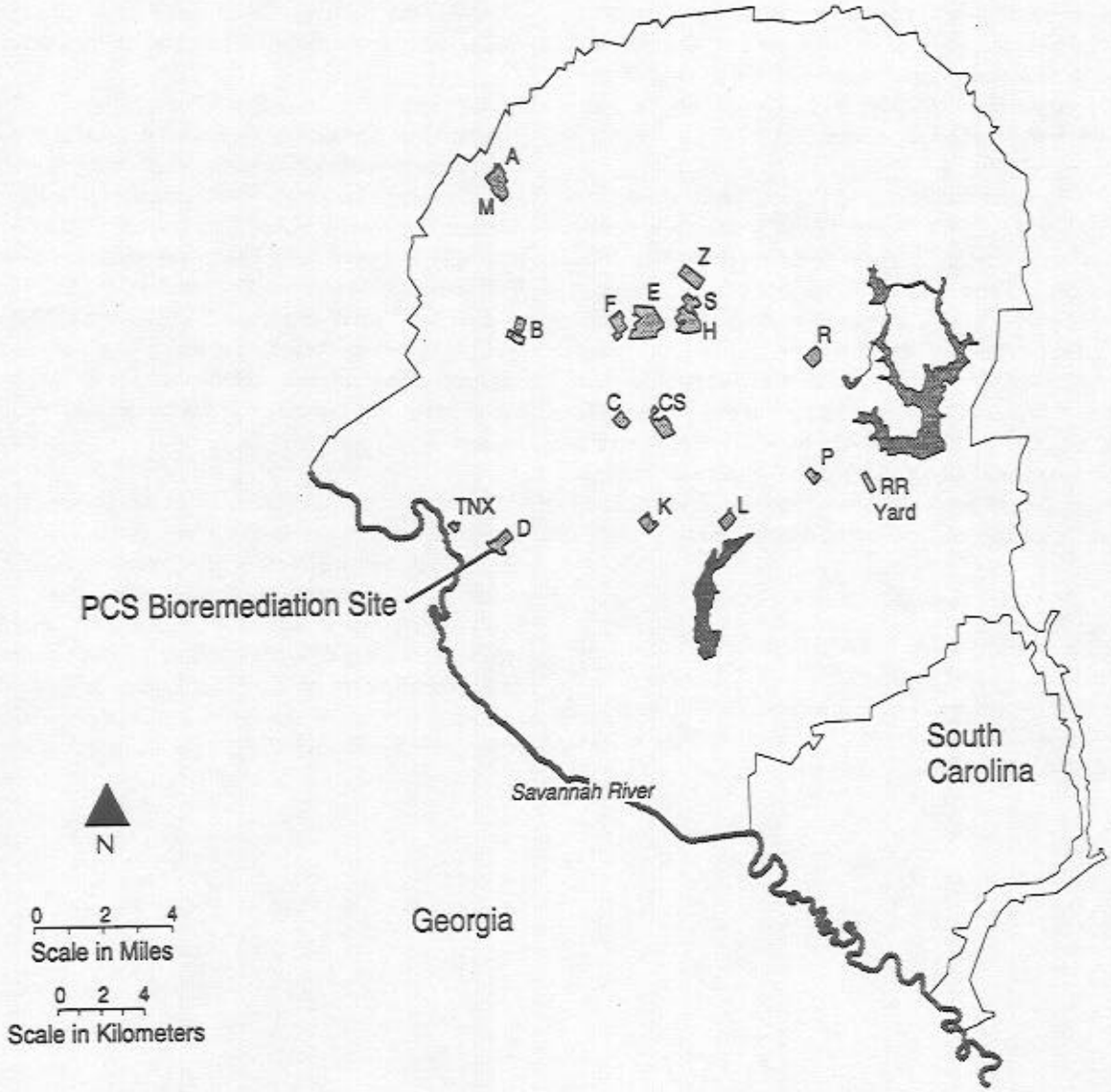


Figure 3.6.1. Site Map

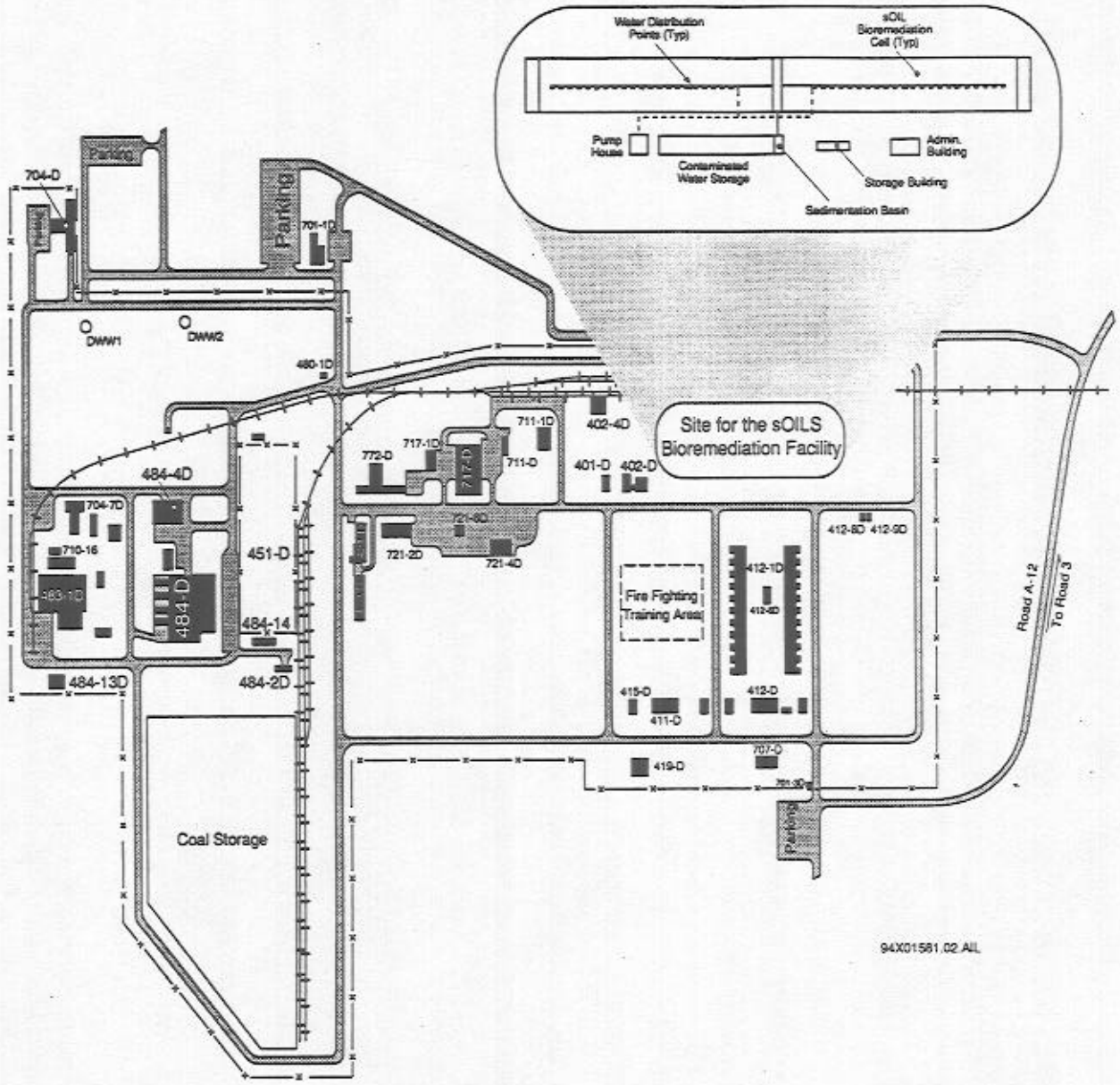


Figure 3.6.2. D Area and Vicinity

4.0 Test Plan

4.1 Criteria for Success

There are three primary criteria by which the overall success of this demonstration will be evaluated:

1. Evidence of biological destruction (biodegradation) of petroleum (TPH and BTEX) from the contaminated soils. Since a major advantage of bioremediation is destruction, it is important and significant to demonstrate that biodegradation is occurring. The evidence is to come from comparing soils analysis taken before and after the PCS is treated (nutrient addition, aeration, pH adjustment, and moisture control) to stimulate biodegradation.
2. Relatively simple and trouble-free operation. A critical assumption for successfully demonstrating the facility is that the system, as designed, will function with little or no down time and provide operating conditions that minimize fugitive air emissions and maximize biodegradation rates. Low risk can and has been demonstrated. The proposed facility has no precedence in South Carolina or Georgia and as such represents new technology for the area. However, since several other states have demonstrated similar facilities, it represents low risk and should receive high public acceptance. The simplistic design contributes direct benefits associated with the ease of management and operation. A minimal staff would be required to operate the facility again adding to the low-risk factor by limiting exposure to operations personnel.
3. Demonstration of ELISA or enzyme-linked immunosorbent assay (immunoassay) as an effective method for screening TPH and BTEX. Using these assays for interim screening required during the treatment process will significantly reduce cost and a secondary waste stream normally generated from other analytical methods (freon extraction) used for PCS assays. Minimizing the number of sets of analyses will also reduce field and analytical time, adding to the cost-effective and efficient operation of the facility.

4.2 Groundwater Protection Program

The sOILS Facility has concrete floors and a storm water drainage containment system. Contaminated rainwater will be collected into a leachate collection tank to be reapplied to cells for moisture adjustment. Because of the unlikely possibility of contamination of groundwater from the bioremediation facility, there are no plans to install monitoring wells around the facility.

4.3 Air Emissions

Stockpiled or containerized contaminated soil will be transported into the bioremediation site to be placed directly into cells, 9-12 inches deep, 20 feet wide, and 400 feet long. Fugitive dust will be emitted from unloading (placing into cells) and loading (removal of treated soil to the landfill) operations. Another emission source is from volatilization of organic constituents (i.e., TPH and BTEX) from contaminated soil during soil turnover or tilling operation. Fugitive dust and volatile organic emissions have been calculated using the U.S. Environmental Protection Agency (USEPA), recommended AP-42 formula (USEPA 1985), and have been determined to be 397.1 lb/mo TPM and 288.1 lb/mo VOC using the highest median value (i.e., 6.34 K ppm TPH) presented in Table 4.3.1. In order to remain in

Table 4.3.1. Petroleum Contaminated Soil (PCS) Analysis

Source	yd^3	TPH	Benzene	Toluene	Ethyl Benzene	Xylene
Spill	3,000	144-719,000	0.5-15	0.5-160	0.5-18	1-118
		(6.34000)	(11)	(11)	(11)	(22)
Spill	2,000	16,000-654,500	0.01-250	0.01-410	0.01-1400	0.02-41000
		(189)	(15)	(0.8)	(0.8)	(1)
UST	2,000	210-880	0.02-40	0.02-77	0.02-19	0.02-111
		(551)	(0.6)	(10)	(9)	(34)

Note: Values in parenthesis represent median (PPM).

compliance with state emissions standards and develop a baseline inventory, a weekly air emissions inventory will be taken for the first six months of operations. When the baseline is established, the air sampling frequency will be reduced to a monthly time interval to monitor long-term emissions trends. Standard surface emissions sampling protocol using isolation flux chamber procedures (Dupont 1987) will be used in field sampling activities. The emission calculations follow:

4.3.1 Calculations

1. Fugitive dust associated with unloading/loading contaminated soil and tilling soil once weekly during soil treatment.

   a. Unloading and loading operation:

$$E = K\,(0.0018)\,\frac{\left(\frac{s}{5}\right)\left(\frac{U}{5}\right)\left(\frac{H}{5}\right)}{\left(\frac{M}{2}\right)^2\left(\frac{Y}{6}\right)0.33}\quad lb/ton$$

   where:

   E = total suspended particulates, lb/ton

   K = particle size (use 0.73 for < 30 μm particulates)

   U = mean wind speed (use 6 mph)

   H = drop height (use 5 feet)

   M = moisture content (use 0.25%)

   Y = dumping device capacity (use 1 yd^3 capacity)

   s = soil silt content (use 18%)

$$E = 0.73\,(0.0018)\,\frac{\left(\frac{18}{5}\right)\left(\frac{6}{5}\right)\left(\frac{5}{5}\right)}{\left(\frac{0.25}{2}\right)^2\left(\frac{1}{6}\right)0.33}\quad 0.66\quad lb/ton$$

   b. Soil roto-tilling:

   $E = k\,(4.8)\,(s)^{0.6}$ lb/acre

   where:

   E= emission factor

   s= silt content (use 18%)

   k = 1

   $E= 1(4.8)\,(18)^{0.6}$

   = (27.19 lb/acre) (2.2957×10^{-5} acre/ft^2) (20 ft × 200 ft)

   = (2.5 lb/cell/tilling) (4 cells × 4 tilling/mo)

   = 40 lb/mo (0.055 lb/hr)

   total particulate matter (TPM):

   TPM = 277.22 + 40 =317.22 lb/mo (0.44 lb/hr)

2. Volatile organic emissions are estimated such that 25% of original constituent is emitted to the air. Employing this estimate to a contaminated soil having a TPH = 6340 ppm; benzene = 15 ppm, toluene = 11 ppm, ethyl benzene = 11 ppm, and xylene = 34 ppm (see Table 4.3.1). Assuming that 900 yd^3 of contaminated soil can be treated to acceptable levels every 4-12 weeks, the VO emission to the air is approximately 0.40 lb/mo as estimated below. This calculation assumed that VOC equals 25% of soil contaminants.

   a. VO emission = 0.25 (6340 ppm) (7.48×10^{-6} lb/ft^3/ppm) × 27 ft^3/yd^3 × 900 yd^3/mo = 288.1 lb/mo (0.40 lb/hr)

   b. Air toxics (benzene, toluene, ethyl benzene, and xylenes) emissions:

      1. Benzene = 0.25 (15 ppm) (7.48×10^{-6} lb ft^3/ppm)

         (27 ft^3/yd^3) × 900 yd^3/mo = 0.68 lb/mo (0.001 lb/hr)

      Similarly,

      2. Toluene = 0.50 lb/mo (0.001 lb/hr)

      3. Ethyl benzene = 0.50 lb/mo (0.001 lb/hr)

      4. Xylene = 1.54 lb/mo (0.002 lb/hr)

4.4 Air Dispersion Modeling

The operations of the sOILS Facility will result in airborne emissions of particulates, VOC/TPH, and the air toxics benzene, toluene, ethyl benzene and xylenes. The toxics are regulated emissions under SCDHEC, Air Pollution Regulation 62.5, Standard 8, Toxic Air Pollutants (1991). Both median and worst-case data for emissions of particulates and toxics were modeled using initial values from the Bureau of Air Quality Control Modeling Toxics Questionnaire (Appendix B).

Using the median estimates, the maximum 24-hour average concentrations of air toxics at the site boundary were found to be near zero (Stewart 1992). The characteristics of the source and the emission rates, in lb/hr, of each pollutant are shown in Tables 4.4.1 and 4.4.2, respectively.

Table 4.4.1. Source Characteristics Input to Industrial Source Complex Screening Technique Model

Release Height	1.0 ft
Exit Temperature	64°F (ambient)
Surface Area	16,000 ft^2

Source: SRT-ETS-920 419; Stewart

The format used for the air dispersion modeling of the sOILS Facility was developed by the USEPA (1987). The Industrial Source Complex Screening Technique is approved by SCDHEC for use in supporting air permit applications. The maximum concentration value for VOC/TPH were calculated using emission estimates of 45.4 lb/hr. The maximum site boundary concentrations of particulates and the worst-case emissions of VOC/TPH shown in Table 4.4.2 are considerably below applicable ambient standards set by the state of South Carolina.

Table 4.4.2. "Worst Case" Maximum Concentration in $\mu g/m^3$ at Site Boundary

Pollutant	Lb/hour	1-hour Average	24-hour Average	Standard
Particulates	0.550	7.29	2.92	260.00
VOC/TPH	45.400	601.83	240.73	none
Benzene	0.016	0.22	0.09	150.00
Toluene	0.026	0.34	0.14	2000.00
Ethyl Benzene	0.090	1.17	0.47	4350.00
Xylene(s)	2.600	34.47	13.79	4350.00

Source: SRT-ETS-920 419; Stewart

4.5 Facility Design and Construction

The facility design consists of a reinforced concrete floor 400 feet long and 40 feet wide. This base is divided into four cells 200 feet long and 20 feet wide. The bases slope to the center where a leachate control system collects any water in a reinforced concrete holding tank that can reapply any leachate or rainwater via a pumping system powered by a Burks model 5WT5, 1/2-horsepower self-priming centrifugal-type pump connected to a sprinkler system with distribution heads mounted on the center wall. The sprinkler heads are designed to provide water to each cell or to the entire unit as needed. The leachate collection system is designed to hold water from a catastrophic 25-year rainfall event. Each cell is equipped with a full-size, dark-brown, ultraviolet light-resistant tarp to act as a watershed and heat sink during cold weather operation. The tarps made of light weight, high-strength, tear resistant material and can be easily removed for roto-tilling or quickly installed by one person in the case of heavy rain. A base of clean soil will be applied to a depth of 6-9 inches to provide good soil drainage. The contaminated soil will be applied to the top surface of the drainage bed to a depth of 6-12 inches. The design loading requirements consider using existing site equipment (e.g., special trucks and graders) to transport, apply, and distribute the soil in the facility. Each cell is open on the end easy access by large vehicles. The facility will be able to treat approximately 900 yd^3 of contaminated soils every 6-12 weeks, depending on the concentration level of the PCS, ambient temperature, and weather conditions. Thus, 3000 - 8000 yd^3 of soil could be processed every year. Although relatively simplistic, the design provides good environmental control and operating conditions that minimize fugitive air emissions and maximize biodegradation rates. The as-built design drawings listed in Table 4.5.1 are available in the SRS document control center at Central Shops.

Table 4.5.1. Controlled Design Drawings of the sOILS Facility

Drawing Number	Description
C-CT-D-0001	Site Plan
C-CC-D-0089	Concrete Details
C-CC-D-0090	Concrete Details
P-PA-D-0031	Piping Plan and Details
E-E9-D-0112	Electrical

The construction activities began on March 12,1993, with perimeter ground penetrating radar (GPR) to assure no subsurface interferences existed. Two interferences were detected, located by hand excavation, and determined to be abandoned water lines. The lines were cut, capped, and abandoned in place. On March 23, 1993, clearing and grubbing followed and the top soil was removed and stockpiled. In April, heavy rains and material acquisition problems slowed progress, but construction revised work schedules and manpower to bring the project back on schedule. Excavation for the leachate collection system began on May 5, 1993. Several unforeseen site conditions (i.e., perched water, poor soil conditions, and large buried stumps) resulted in design modifications when the excavating the leachate tank. With excellent cooperation from Site Services and Design Engineering, the project remained on schedule and under budget.

Form work, rebar installation, and concrete placement for the bioremediation cells, leachate system, and connecting sump continued concurrently. Throughout the summer months (July, August, and September), extremely hot weather forced many schedule and shift changes. During this period of record breaking temperatures, concrete placements were made at night and workers were placed on four ten-hour workdays with shifts beginning at 6 a.m. This action resulted in much higher worker productivity, no lost time or recordable accidents, no heat exhaustion or heat stress related illness, and no concrete placement was lost due to excessive heat. The final concrete was placed in early October and by October 25, 1993, final piping, mechanical, and electrical components (sprinkler heads, water pump and electrical panel) were installed. With major construction complete, a final inspection and safety walkdown (SMI 51) was down on October 29, 1993. The sOILS Facility was found to be complete to plans and specifications. Six minor punch list items were noted. The punch list items were corrected and the system was approved for operation on November 16, 1993. A Construction Turnover Completion Package was submitted to SRTC on December 2, 1993, and final acceptance of Project S-4946 was on January 10, 1994. A turnover package from SRTC to CSWE was prepared and transmitted. The package contained original documentation, including as-built design drawings, safety inspection records, a test plan for operational guidance and facility history, and correspondence transferring ownership of the facility to CSWE.

4.6 Facility Operations

Operating the facility requires a three-step approach

1. Screening and loading the bioremediation cells with PCS.
2. Treating the material.
3. Removing and disposing of the remediated soil.

The process of preparing the PCS for placement in the sOILS Facility begins in the Central PCS Storage Facility operated by CSWE. The CSWE facility is located in D Area adjacent to the sOILS Facility. (The storage area is administratively controlled in accordance with WSRC 3Q Manual, Procedure ECM 6.23, "Waste Acceptance Criteria Central Petroleum Contaminated Soil Storage Facility". This procedure governs the control, sampling requirements, and assigned responsibilities for SRS personnel and subcontractors who generate, transport, or provide temporary storage for PCS at the Central Petroleum Contaminated Soil Storage Facility [CPCSSF]). Upon receipt of PCS at the CPCSSF, the material will by checked for appropriate documentation, accepted, and classified according to contaminant type (i.e., diesel fuel, gasoline, waste oil). As additional PCS is needed at the sOILS Facility, CSWE will transport commonly classified PCS to the facility and place it according to the direction of the sOILS Facility operator. A material tracking database and inventory system has been set up by CSWE to track PCS for its complete life cycle, from the time it arrives in the CPCSSF to its final disposition or disposal location. An example of the inventory database can be seen in Appendix C.

The treatment process will begin with an initial screening of the PCS for inorganic nutrients, pH, contaminant concentrations, moisture, and microbes. Adjustments to the pH, nutrients, and moisture will be made as needed to stimulate and optimize the biodegradation rate. The soil will be kept moist but not damp and aerated (to add oxygen) via roto-tilling once a week. Monthly analysis will continue for inorganic nutrients, contaminants, and microbes. Weekly measurements for air emissions, pH, and moisture will be taken by random samples to ensure that volatilization and particulate emissions are below annual air emission limits. The bioremediation process will continue until the soil has been demonstrated by gas chromatography (GC) analysis to be below 100 ppm for TPH and 10 ppm for BTEX.

CSWE personnel will remove the remediated soil. The final concentration of the soil will dictate the final disposition of the material or its disposal location. Soils with TPH and/or BTEX below detectable levels (< 1 ppm) may be used as erosion control material or road base material. Other soil (i.e., above detection but below clean-up criteria) will be removed to a sanitary landfill per SCDHEC mandate.

4.7 Sampling and Analysis

Initial sampling and analysis of the soil put into the facility will consist of three random samples per cell for inorganic nutrients (nitrogen/nitrates, sulfates, phosphorus/phosphate), pH, contaminants, TPH, BTEX, heavy metals, polycyclic aromatic hydrocarbons (PAH), moisture, and microbes (direct counts and viable counts and enrichments). Fertilizer may be applied if necessary depending on the results of the inorganic nutrient analysis. Monthly (weekly if necessary) random samples will be taken from each of the four cells to determine if cleanup criteria has been met and/or if additional nutrients are necessary.

4.7.1 Sampling Protocol

The primary goal of the sampling activity will be to obtain an unbiased statistical estimate of the mean TPH and/or BTEX concentration within the treatment cell(s). As discussed above, simple random samples will be taken for analysis for the parameters shown in Table 4.7.1.1 after the contaminated soil is applied to a cell. Random samples will be taken monthly to monitor the soil biodegradation rate. Sampling and analysis will be performed using EPA protocols (i.e., SW 846, Third Edition, 1986). Required holding times for soil samples can be seen in Table 4.7.1.2.

Tables of uniformly distributed random x, y, and depth coordinates will be used to establish sampling locations and depths. These tables will be generated using a computer software random number generator. The coordinates represent the distance in feet from the origin of each axis. Depth values represent the distance below the surface in inches. The range of values are based on the size of the cell and the extent of the distribution of contaminated material within the cell. Using the SRS coordinate grid system, the orientation of the x and y axis will be north/south and east/west respectively, with the northerly and easterly directions from the origins being positive. Each cell has been assigned an alpha-numeric designator, the northeast cell being "A", southeast "B", southwest "C", and northwest "D". The center wall that forms the cells is numbered 1 through 40 in an easterly and westerly direction from the point of origin. The end of each cell will be numbered 1 through 4 forming sample plots that are five square feet in size in each cell.

4.7.2 Analytical Procedures

The EPA 8000 series analytical procedures found in Table 4.7.1.2 will be used to analyze PCS samples. The use of these methods is now nearly universal in public and private sector laboratories. Each of these methods has an associated list of target compounds for which it was specifically developed and evaluated. These methods use gas chromatography (GC) and mass spectrometers (MS) or a combination of both GC/MS techniques to detect organic compounds. These instruments are well known for their excellent sensitivity and selectivity for specific target compounds.

Table 4.7.1.1 Frequency Parameters for Soil Samples

	Initial	Monthly	Weekly	Final
Organics				
TPH	Y	Y	as needed	Y
BTEX	Y	Y	as needed	Y
PAH	Y	as needed	as needed	as needed
Inorganics				
N	Y	Y	-	-
P	Y	Y	-	-
Moisture	Y	Y	Y	-
pH	Y	Y	Y	-
Metals	Y	-	-	-
Microbes	Y	Y	-	-

Table 4.7.1.2 Soil Sample Holding Times

Contaminant	Holding Time
Benzene, toluene, ethylbenzene, xylenes	Analyze as soon as possible (maximum 14 days)
Total petroleum hydrocarbon (low to medium bp fuels)	Analyze as soon as possible (maximum 14 days)
Total petroleum hydrocarbon (high bp fuels)	Extract within 14 days Analyze within 40 days
Polycyclic aromatic hydrocarbons (PAH) (including naphthalene)	Extract within 14 days Analyze within 40 days
Mercury	28 days[1]
Metals (except mercury)	6 months[1]

[1] Soil samples must be at least 200 g and usually required no preservation other than storing at 4°C until analyzed.

Detection of complex hydrocarbon mixtures is best achieved using a GC with a flame ionization detector (GC-FID). The GC-FID analysis provides a more adequate representation of the degree of hydrocarbon contamination. EPA Method 418.1 does not provide information on the type of hydrocarbon contamination and the low-boiling point components are easily lost. This method will only be used for screening purposes and final disposal will be governed by GC analysis (SCDHEC 1992).

The procedures outlined in Table 4.7.2.1 list different methodologies for the low-to-medium boiling point hydrocarbons (gasoline) and the high boiling point hydrocarbons (diesel motor fuels and light heating fuels). A purge and trap or head space is preferred for the more volatile contaminants whereas the high-boiling point contaminants are to be analyzed using a GC-FID. The gas chromatographic analysis is equivalent to the well known "California Method" for testing TPHs for the Underground Storage Tank Program. For highly contaminated samples, the waste dilution technique may be used but this must be documented with the analytical results. Any sample dilutions performed must also be documented with the analytical results (SCDHEC 1992)

As part of the criteria for success in this test plan, using immunoassay to screen for the absence of soil contamination is a high priority. We hope to demonstrate, with a high level of confidence, that immunoassays have unique properties that should be utilized for environmental testing. Field soil vapor analyzers have been used for many years to measure for indicator parameters. However, these instruments are not quantitative, and the values have been shown to correlate poorly with laboratory-derived results (Denchan et al. 1990; Preslo et al. 1990). Factors affecting variability in results are instrument response time, sensitivity, calibration procedures, and environmental conditions. Immunoassays offer both sensitivity and specificity in a quick and relatively inexpensive format. In addition, they can be performed using crude sample preparations and are easily adaptable to onsite testing (Hammock et al. 1990; Vanderlaan et al. 1990). Recently, preliminary studies by the SRTC Environmental Sciences Section have shown sensitivity and specificity levels by immunoassays to be within a 95% confidence interval for the detection of TPH and BTEX. Concentration ranges as low as 2.5 ppm for BTEX and 4 ppm for TPH have been consistently detected The results of this study can be seen in Table 4.7.2.2. Additional information on the laboratory techniques used and the results obtained in the analysis and evaluation of the various immunoassay test kits can be

Table 4.7.2.1 Dissolved Hydrocarbons and Corresponding Methods of Analysis

Analytical Group	Constituent	Analytical Method
Gasoline (all motor gasoline and gasohol)	1,2-dichloroethane	EPA Method 8010
	benzene	EPA Method 8020
	toluene	EPA Method 8020
	ethylbenzene	EPA Method 8020
	total xylenes	EPA Method 8020
	total volatile organic aromatics	EPA Method 8020 EPA Method 5030 GC-FID California
Middle distillates (kerosene, diesel fuel and light fuel oils)	naphthalene and other semivolatiles	EPA Method 8270 EPA Method 8020
	BTEX	Approved test kits[1] (screening only)
	n-propylbenzene	EPA Method 8020 EPA Method 3550 GC-FID California[1]
Other or unknown	priority pollutant metals	Toxicity Characteristic Leaching Procedure
	total petroleum hydrocarbons	EPA Method 9071 with silica gel cleanup EPA Method 418.1[2] Approved test kits[3] (screening only)

1 California Method: Leaking Underground Fuel Tanks Field Manual. Guidelines for Site Assessment, Cleanup and Underground Storage Tank Closure. State of California, May 1988.

2 Method 418.1 is no longer a recommended method by SCDHEC for final soil disposal determinations. However, this analytical method is acceptable for a preliminary screening process.

3 The following test kits can be used for screening and in-process analysis of BTEX and TPH. Final testing for disposal will be by approved EPA methods listed in Table 4.7.2: Reference: SW-846, 3rd edition, 1986. Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods.

Petro RIS™ * Test Kit. EPA approved for TPH, SW846; method 4030. Ensys Environmental Products, Inc., P. O. Box 14063; Research Triangle Park, NC 27709

DTECH™ Test Kit No. TK-1003-1, Extraction Pac TK-1003S-1 required. Screening for BTEX in soil and water. EM Science/SDI, 480 Democrat Ave., Gibbstown, NJ 08027

EnviroGard™ Test Kit; Petroleum Hydrocarbons in soil. Millipore, Bedford, MA 01730.

The Quantix™ Portable Workstation for BTEX and PAHs in soil and water; Quantix Systems, 2611 Branch Pike, Cinnaminson, NJ 08077.

Table 4.7.2.2 Sensitivity and Specificity of Immunoassay Test Kits

Test Kit/Specificity	Sensitivity ppm	Comments
DTech™/BTEX	Low <2.5	Not quantifiable without their detector; uses color card comparisons
Millipore™/TPH	Gasoline Low = <7/Hi = >485 Diesel Low = <4/Hi = >592	Quantifiable, but only by converting from home heating oil equivalents
Quantix™/BTEX	Low* = 3.5 Hi = 940 Low* = 0.7 Hi = 140	Quantifiable, but only with their quantimeter, which has two ranges for readings. Technician must assume whether to use Low or Hi range calcurve. The procedure is not user friendly.
Ensys™/TPH	Gasoline Low* = 10 Diesel Low* = 15	

*Vendor supplied specification may vary pending test results

found in SRTC laboratory notebooks number WSRC-NB-90-357, p. 126, and WSRC-NB-93-321, pp. 29-34 and 39-44.

4.7.3 Microbiological Procedures

Three microbiological analyses will be done on a monthly basis. The soil samples from the facility will be collected and processed on the same day the sampling was done. The first test will give total direct cell counts in the soil, using an acridine orange stain for bacterial nucleic acids. This test will provide a total bacterial cell count, expressed in cells per gram dry weight. The second analysis to be performed is viable counts that will give the total number of organisms that can be cultured on an oligitrophic media. This number is expressed in colony-forming units per gram dry weight. The third analysis is an enrichment for TPH. Bacteria will be grown on minimal salts media with trace metals and no available carbon source.

Acridine Orange Direct Counts

The acridine orange direct counts (AODC) will provide a direct estimate of the total number of bacteria in the environment, regardless of ability to grow on any media that might be used. Samples are preserved in phosphate buffered formalin. Samples (1 to 3 grams) are extracted three times with a non-ionic homogenizing detergent to remove bacteria from the sediment particles. Homogenates are cleared by low-speed centrifugation and the supernatants are pooled. Ten microliters of supernatant is spotted onto each well of a toxoplasmosis microscope slide, stained with 0.01% acridine orange, then rinsed with distilled water. The number of cells stained with acridine orange are counted by epifluorescence microscopy. The number of cells per sample is normalized by dividing by the dry weight of the sediment (ASTM 1987). Counts are reported as cells per gram (Sinclair and Ghiorse 1989).

Aerobic Heterotrophic Plate Count

This method will provide an estimate of the total number of viable aerobic and facultatively anaerobic bacteria in the groundwater. Low and high nutrient concentrations of a medium will be used to indicate differences in bacteria adapted to oligotrophic and eutrophic conditions. Samples (1 to 3 grams) are weighed directly into 15 ml conical centrifuge tubes containing 9 ml of pyrophosphate buffer. Subsequent serial dilutions are made in phosphate buffered saline. Exactly 0.1 ml of each appropriate dilution was inoculated onto a corresponding plate of appropriate medium. For this study, 1% peptone-trypticase-yeast extract-glucose (PTYG) is used (Balkwill 1989). Plates are incubated at room temperature for at least two weeks before to counting. Bacterial colonies are counted using low-power magnification. Counts are normalized to sediment dry weights and reported as colony-forming units (CFU) per gram.

Total Petroleum Hydrocarbon Enrichment

This method will provide an estimate of the total number of viable aerobic and facultatively anaerobic bacteria capable of living in an enriched TPH soil. Successful bioremediation of TPH can also be in terms of increased microbial activity, increased biomass, particularly biomass which contains TPH degrading machinery, and increased biomass capable of consuming TPH as evidence of stimulation by treatments. Minimal salts media (Fogel et al. 1986, AEM 51(4): pp. 720-724) will be used. The plates will be incubated in an enclosed environment with TPH vapors available to the bacteria as a source of carbon for metabolism. This count will also be in colony-forming units per gram dry weight. As petroleum will be the only carbon source available, this will be a count of TPH degraders only.

5.0 Safety, Quality Assurance, and Security

5.1 Safety

The chemical hazards and health risks associated with PCS are very low, based on the concentration levels of TPH and BTEX seen in the soil analyses taken from site samples. To reduce the possibility of exposure, work gloves (rubber gloves during sampling) and boots with shoe covers should be worn while working in the sOILS Facility. The majority of the work performed in the facility is done with enclosed cab heavy equipment, therefore workers will be protected from potential air emissions. A weekly air emissions inventory will be taken for the first six months of operations to establish a baseline and assure compliance with South Carolina emissions standards.

5.1.1 Savannah River Site

General safety rules for the Savannah River Site are documented in the Savannah River Site (SRS) Safety Manual (8Q) and in DOE Order 5483.1A.

5.1.2 Savannah River Technology Center

Savannah River Technology Center Safety Practices and Procedures Manual (8Q8) documents safety procedures for all activities for SRTC employees, SRTC visitors, and vendors/subcontractors.

5.1.3 Screening Process Hazards Review

As defined in Savannah River Site (SRS) Safety Manual (8Q) in Procedure 10-1, a screening process hazards review was performed onsite with cognizant functional personnel and completed August 20, 1992. The Screening Process Hazards Review Report and a review of the design output document did not identify any potential hazards. Thus, in accordance with Section 5.1.1.1 of procedure DE-DP-300, a Design Process Hazard Review is not required.

5.1.4 Other Safety Information

Other sources of safety information include: NIOSH Pocket Guide to Chemical Hazards, publication No. 90-117, Federal Motor Carrier Safety Regulations Pocketbook, and WSRC Safety Guidelines for Subcontractors.

5.2 Quality Assurance and Quality Control

All activities at SRS are governed by WSRC Quality Assurance Program as outlined in WSRC Management Policies, WSRC-1-01, MP 4.2. Specific quality assurance procedures are documented by organization as required. A task technical plan (QA record) has been produced to document the record keeping and procedural documentation required for each task in this test plan.

5.2.1 Westinghouse Savannah River Company

WSRC quality assurance is documented in WSRC Quality Assurance Manual (1Q).

5.2.2 Waste Management and Environmental Technology Department

Quality assurance implementation procedures for the WM&ET Department are documented in WM&ET Quality Assurance Implementation Procedures (1Q31).

5.2.3 Environmental Sciences Section

Quality assurance procedures for the section are found in ESS Quality Assurance Implementation Procedures (1Q31-1). Operating procedures for the section are documented in ESS Operating Procedures Manual (WSRC-L-14-1).

5.3 Security

WSRC security requirements and procedures are documented in the WSRC Security Manual (7Q). These procedures are as required by federal laws and applicable DOE orders (e.g., DOE Order 5631.1A).

6.0 Permits, Patents, and Authorizations

6.1 National Environmental Policy Act

In January of 1992, NEPA documentation was submitted to DOE/SR and Categorical Exclusion SR-CX-9202001 was issued by DOE/SR on January 26, 1992.

6.2 Air Permit from South Carolina Department of Health and Environmental Control

Based on the sCAP emissions calculations, SCDHEC issued an air permit exemption on January 15, 1992.

6.3 DOE/SRS Site Use and Site Clearance Permits

Site Use and Site Clearance documents were submitted for approval, because the proposed location was already a construction laydown and mobilization area, a Site Use permit would not be required. The Site Clearance Permit SC-3221 was approved on March 5, 1992.

6.4 Soils Corrective Action Plan

The final guidance document submitted on August 13, 1992, to SCDHEC was the Soils Corrective Action Plan (sCAP), which gained final SCDHEC approval on September 9, 1992.

6.5 Patents

The DOE Office of Patent Counsel prepared a preliminary patentability search report, File No. 93-1427/SRS-92-410/ DOE Case No.: S-77,153, for the prepared bed bioreactor. Design patent references listed in Table 4.7.2.1 have been issued.

Table 6.5.1 Related Patent References

Parent	Date	Inventor	Search Class
5,134,078	07/92	Sicksmeyer, et al.	432/262
5,128,262	07/92	Lindoerfer, et al.	435/262 XR
4,962,034	10/90	Kahan	435/262
4,871,673	10/89	Rehm, et al.	435.262
4,678,582	07/87	Lavigne	435/262 XR
4,584,102	04/89	Bogart, et al.	405/128 XR
4,447,541	05/84	Peterson	435/262

6.6 Notice of Authorization (Construction)

A Notice of Authorization to (FMS-FPC-93-0226) construct the facility was issued to BSRI Construction Management by SRTC on February 10, 1993.

7.0 References

Aadland, R. K., 1990, *Classification of Hydrostratigraphic Units at the Savannah River Site, South Carolina*, WSRC-RP-90-987, Westinghouse Savannah River Company, Aiken, SC 29808.

American Society of Testing and Materials, 1987, "Standard Test Method for Enumeration of Aquatic Bacteria by Epifluorescence Microscopy Counting Procedure", *ASTM D4455-85, Annual Book of ASTM Standards*, Vol 11.02, Water. American Society of Testing and Materials, Philadelphia, PA.

Balkwill, D. L., 1989, "Numbers, diversity, and morphological characteristics of aerobic, chemoheterotrophic bacteria in deep subsurface sediments from a site in South Carolina", *Geomicrobiology Journal* 7:33-52.

Bartha, R. and I. Bossert, 1984, "Treatment and Disposal of Petroleum Refinery Wastes", In: R. M. Atlas (ed.), *Petroleum Microbiology*, Macmillan Publishers, New York, NY.

Denahan, S. A., B. J. Denahan, W. G. Elliott, W. A. Tucker, and M. G. Winslow, 1990, In: *Petroleum Contaminated Soils*, Vol. 3, p. 93, (Kostecki, P. T., and Calabrese, E. J., Eds.), Chelsea, MI, Lewis Publishers.

Dupont, R. R., 1987, *Quantitation and Modeling Volatile Hazardous Constituent Emissions from a Hazardous Waste Land Treatment Facility*, USEPA, R. S. Kerr Environmental Research Laboratory, Ada, OK 74820.

ECOVA, 1989, *Solid Phase Bioremediation*, ECOVA Corporation, Redmond, WA.

Fogel, M. M., A. R. Taddeo, and S. Fogel, 1986, "Biodegradation of chlorinated ethenes by a methane-utilizing mixed culture", *Applied Environmental Microbiology*, 51:720-724.

Hammock, B. D., S. J. Gee, R. O. Harrison, F. Jung, M. H. Goodrow, Q. X. Li, A. D. Lucas, A. Szekacs, and K. M. S. Sundaram, 1990, In: *Immunochemical Methods for Environmental Analysis*, p. 112, (Van Emon, J. M. and Mumma, R. O., Eds.), Washington, DC, American Chemical Society.

Lombard, K. H., 1990, "Proposal for a Pilot Project Soils Facility; a Petroleum Contaminated Soil Bioremediation Facility", Invited presentation to the South Carolina Department of Health and Environmental Control, WSRC-91-115, Westinghouse Savannah River Company, Aiken, SC 29808.

Looney, B. B., C. A. Eddy, M. Ramdeen, J. Pickett, V. Rogers, M. T. Scott, and P. A. Shirley, 1989, *Geochemical and Physical Properties of Soils and Shallow Sediments at the Savannah River Plant*. WSRC-RP-90-1031, Westinghouse Savannah River Company, Aiken, SC 29808.

Molnaa, B. A. and R. B. Grubbs, 1989, "Bioremediation of Petroleum Contaminated Soils Using a Microbial Consortia as Inoculum", In: E. J. Calabrese and T. Kostecki (eds.), *Petroleum Contaminated Soils*, vol. 2, Lewis Publishers, Chelsea, MI.

O'Brien and Gere Engineering, Inc., 1987, *Groundwater Impact Assessment: Coal Pile Runoff Basins*, File 2832.019 (1.02). E. I. du Pont de Nemours and Company.

Preslo, L. M., W. M. Leis, and R. Pavlick, 1990, In: *Petroleum Contaminated Soils*, Vol. 2, p. 111. (Kostecki, P. T., and Calabrese, E. J., Eds.), Lewis Publishers, Chelsea, MI.

Raymond, R. D., 1994, *Draft Sampling Plan for the Investigation of Diesel Contamination at the Burma Road Landfill*, Bechtel Savannah River Inc., Aiken, SC 29808.

Ross, D., T. P. Marziarz, and A. L. Bourquin, 1988, "Bioremediation of Hazardous Waste Sites in the USA: Case histories", In: *Superfund '88, Proc. 9th National Conference*, Hazardous Materials Control Research Institute, Silver Spring, MD.

Sims, J. L., R. C. Sims, and J. E. Matthews, 1989, *Bioremediation of Contaminated Surface Soils*, USEPA. EPA/600/9-89/073.

Sims, R. C., 1986, "Loading Rates and Frequencies for Land Treatment Systems", In: R. C. Loehr and J. F. Malina, Jr. (eds.), *Land Treatment: A Hazardous Waste Management Alternative*, Water Resources Symposium No. 13, Center for Research in Water Resources, University of Texas at Austin, Austin, TX.

Sinclair, J. L. and W. C. Ghiorse, 1989, "Distribution of aerobic bacteria, protozoa, algae, and fungi in deep subsurface sediments", *Geomicrobiology Journal* 7:15-32.

Siple, G. E., 1967, "Geology and Groundwater of the Savannah River Plant and Vicinity, South Carolina", U.S.G.S. Water Supply Paper 1841.

South Carolina Department of Health and Environmental Control, 1992, "Petroleum Hydrocarbon Analytical Methodology for Ground Water and Soil Assessment", Laboratory Certification Section, P. O. Box 72, State Park, SC 29147.

St. John, W. D. and D. J. Sikes, 1988, "Complex Industrial Waste Sites", In: G. S. Omenn (ed.), *Environmental Biotechnology, Reducing Risks from Environmental Chemical through Biotechnology*, Plenum Press, New York, NY.

U. S. Army Corps of Engineers, 1952, "Foundation Grouting Operations Savannah River Plant", Charleston District Corps of Engineers.

U. S. Department of Health and Human Services, 1990, *NIOSH Pocket Guide to Chemical Hazards*, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

U. S. Department of Transportation (USDOT), 1989, *Federal Motor Carrier Safety Regulations Pocketbook*, J. J. Keller and Associates, Inc., Pub. Neenah, Washington 54957-0368.

U. S. Environmental Protection Agency (USEPA), 1985, *Compilation of Air Pollutant Emission Factors*, AP-42, 4th Edition, Office of Air Quality, Research Triangle Park, NC 27711.

U. S. Environmental Protection Agency (USEPA), 1986, *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods*, SW-846, 3rd Edition, Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

U. S. Environmental Protection Agency (USEPA), 1987, *Industrial Source Complex (ISC) User's Guide*, Second Edition (Revised), EPA-450/2-78-027R, Office of Air Quality, Research Triangle Park, NC 27711.

U. S. Environmental Protection Agency (USEPA), 1988, *A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants*, EPA-450/4-88-009, Office of Air Quality, Research Triangle Park, NC 27711.

Vanderlaan, M., L. H. Stanker, and B. E. Watkins, 1990, In: *Immunoassays for Trace Chemical Analysis*, p. 2, (Vanderlaan, M., Stanker, L. H., Watkins, B. E. and Roberts, D. W., Eds.) Washington, DC, American Chemical Society.

Watts, J. R. and J. C. Corey, 1982, "Land Application Studies of Industrial Waste Oils", *Environmental Pollution* (Series A). 28:165-175.

Westinghouse Savannah River Company, 1989b, *RCRA Facility Investigation Program Plan*, WSRC-RP-89-994, Aiken, SC 29808.

Westinghouse Savannah River Company, 1991, *RCRA Facility Investigation/Remedial Investigation Work Plan for the A-, C-, D-, F-, H-, K-, and P-Area Coal Pile Runoff Basins*. WSRC-RP-90-291, Rev. 1, Aiken, SC 29808.

Westinghouse Savannah River Company, 1989a, *Safety Analysis —200-F Area, Savannah River Site, F-Canyon Operations*, Chapter 3.0, "F-Canyon Site Characteristics", WSRC-89-60, Vol. 3, Aiken, SC 29808.

Westinghouse Savannah River Company, 1989d, Savannah River Site Area Maps. WSRC-RP-89-291, Aiken, SC 29808.

Westinghouse Savannah River Company, 1991a, Savannah River Site Environmental Report 1990. WSRC-IM-91-28, Aiken, SC 29808.

Westinghouse Savannah River Company, 1991, "The Environmental Health Protection Department, Environmental Monitoring Section", *The Savannah River Site's Groundwater Monitoring Program*, First Quarter 1991, ESH-EMS-910087, Aiken, SC 29808.

Westinghouse Savannah River Company, 1991b, Environmental Protection Department's Well Inventory, ESH-EMS-910091, Aiken, SC 29808.

Westinghouse Savannah River Company, 1989, "Waste Management Units - Savannah River Site, WSRC-RP-89-898, Aiken, SC 29808.

Westinghouse Savannah River Company, *Safety Guidelines for Subcontractors*, pocket handbook issued through SRS Safety Department.

2.0 Test Plan Objective

The objectives of this test plan are to show the value added by using bioremediation as an effective and environmentally sound method to remediate PCS by:

- demonstrating bioremediation as a permanent method for remediating soils contaminated with petroleum products
- establishing the best operating conditions for maximizing bioremediation and minimizing volatilization for SRS PCS during different seasons
- determining the minimum set of analyses and sampling frequency to allow efficient and cost-effective operation
- determining best use of existing site equipment and personnel to optimize facility operations and conserve SRS resources
- as an ancillary objective, demonstrating and optimizing new and innovative analytical techniques that will lower cost, decrease time, and decrease secondary waste streams for required PCS assays.

3.0 Site Background and Chronology

In 1982, Watts and Corey demonstrated at SRS that waste oils could be spread over the surface and tilled with fertilizer as a waste treatment technique. This study demonstrated that surface soils at SRS have the indigenous microbes necessary for petroleum hydrocarbon degradation and that their activity could be enhanced by simple inorganic fertilizers. More recent work by Hazen and Bledsoe (WSRC 1990) has further demonstrated that soil contaminated with diesel fuel from a leaking underground storage tank has hydrocarbonclastic microbes that can be enhanced by aeration and inorganic nutrient supplementation. Thus, the biological feasibility of the technology for SRS has been demonstrated.

The concept of using bioremediation to cleanup PCS was presented to the Westinghouse Savannah River Company (WSRC) Board of Directors in June 1990. SRS formed a committee of members with PCS problems, the site's regulatory personnel, and technical experts from Waste Management, Savannah River Technology Center (formerly the Savannah River Laboratory), the Environmental Protection Department (EPD) and Bechtel Savannah River, Inc. (BSRI) Construction Management Environmental Group. With WSRC Board approval, EPD, assisted by the committee, briefed SCDHEC on developing the technology for a bioremediation facility to treat PCS. On October 15, 1990, SCDHEC responded to SRS approving the technology for development in the State of South Carolina. After evaluating cost, effectiveness, and permitability of several remediation options, a prepared bed bioremediation facility was chosen as the most attractive. On December 6, 1990, the committee made a formal proposal to SCDHEC to construct a soils bioremediation facility at SRS. Between December 1990 and December 1991, SCDHEC and WSRC resolved fugitive air emissions and treatment level issues. The final guidance document submitted on August 13, 1992, to SCDHEC was the sCAP, which received SCDHEC approval on September 9, 1992.

Concurrent with preparing the sCAP, the Site permitting process began. In January 1992, National Environmental Policy Act (NEPA) documentation was submitted to DOE/SR and Categorical Exclusion SR-CX-9202001 was issued by DOE/SR on January 26, 1992. Site Use and Site Clearance documents were submitted for approval, but because of the proposed location was already a construction laydown and mobilization area, a Site Use permit would not be required. The Site Clearance permit was approved on March 5, 1992, for the D-Area location shown in Figure 3.6.2. In May 1992, based on the conceptual BSRI/CSWE proposed design (see Appendix A), the SRTC Laboratory Site Services Engineering Group began the facility design and preliminary process hazards review (PPHR). The final design was completed by BSRI-Design Engineering in August and funding was approved as Capital Project S-4946 by DOE/SR in November 1992. Based on the sCAP emissions calculations, SCDHEC issued an air permit exemption on January 15, 1993, completing the regulatory permitting process. A Notice of Authorization was issued to BSRI-Construction Management on February 10, 1993, and pre-construction activities began on February 18, 1993. Excavation and other major construction activities began in late March, with concrete placement starting in mid May and continuing through mid September. Final electrical and mechanical work was complete in early October and the system was accepted by SRTC on January 10, 1994.

The petroleum contaminated soil stored at SRS is estimated to be 7000 yd^3 with 1000 yd^3 of new material expected per year. The existing contaminated soil came from oil spill cleanups (4000 yd^3) and underground tank excavations (3000 yd^3) and is stockpiled and/or stored in containers. Contaminated soil that is stockpiled is covered with an impervious material (e.g., plastic sheeting) and bermed to prevent or minimize erosion. Samples taken from stockpiled and containerized materials show a total petroleum hydrocarbon (TPH) median range of 189 to 6340 ppm and benzene at 0.6 to 15 ppm. Analytical data for the different types of contaminated soil are summarized in Table 4.3.1. Several samples were subjected to the toxicity characteristic leaching procedure (TCLP) test and were determined to be below the TCLP limits and therefore not hazardous. SRS plans to test contaminated soils from waste oil spills using TCLP procedure to ascertain they are not hazardous. Process knowledge or Material Safety Data Sheets are also acceptable methods for determining the hazard class of the contaminant. The sOILS Facility will not generate, treat, or process hazardous waste.

While the technology has not been used at SRS or in South Carolina, the facility uses technology that has been proven in other states. This technology should represent a substantial cost savings over conventional remediation methods (e.g., incineration). Site-specific data for this approach came from a bioremediation feasibility study done at the N-Area (Central Shops) Bulk Fuels Storage Facility.

3.1 Technological Background

Biodegradation of petroleum hydrocarbons in soil (petroleum land farming) has been used by the oil industry for more than 30 years as an efficient way to destroy oil sludges (Bartha and Bossert 1984). Indigenous microorganisms in the soil can degrade large quantities of petroleum hydrocarbons if they have sufficient water, oxygen, and other limiting nutrients, usually phosphorus and nitrogen (P and N). By applying oil to the soil surface, adding fertilizer (P and N), water, and then tilling to aerate (oxygen), the soil microbes have been shown to completely degrade large quantities of oil. A demonstration of this technology using waste oil was done at SRS near Central Shops in 1980 (Watts and Corey 1982).

Until recently, the state-of-the-art approach to soil remediation was excavation and disposal at a secure landfill. Changes in liability concerns, costs, and regulatory constraints have decreased the popularity of excavation and disposal as a soil cleanup alternative. Landfill disposal of contaminated soil does not remove the future liability of its generator, who will be held jointly liable with the landfill operator for any future associated contamination. Thus, onsite permanent solutions must be sought whenever possible.

The basic treatment design is referred to by the U. S. Environmental Protection Agency as a "prepared bed" bioreactor (Sims et al. 1989), a proven technology in several states with several different concerns. Sims (1986) reported 50-100% reduction of fossil fuels in soil after only 22 days. St. John and Sikes (1988) reported that a prepared bed system, complete with fugitive air emissions control, at a Texas oil field was able to reduce volatile organic carbon by >99% after 94 days, with semivolatiles being reduced by more than 89%. In California, Ross et al. (1988) reported that four acres of soil 15 inches deep, contaminated with diesel and waste motor oils, was decreased from 2800 ppm TPH to less than 380 ppm in only four weeks. He also reported that at another site owned by a heavy equipment manufacturer, 7500 yd^3 was reduced to <100 ppm TPH after nine weeks and an additional 9000 yd^3 with 180 ppm TPH was reduced to <10 ppm after only five weeks. Another site in California had 600 yd^3 reduced from 1000 ppm TPH to <200 ppm in 35 days. Molnaa and Grubbs (1989) report other sites in California where similar results were obtained:

- 2000 yd^3 with 2800 ppm TPH was reduced to less than 38 ppm in 74 days
- a truck stop where 15,000 yd^3 was reduced from 3000 ppm TPH to less than 30 ppm TPH in 62 days
- a site contaminated with lubricating oils where 25,000 yd^3 was reduced from 4800 ppm down to 125 ppm in 58 days.

Clearly, the higher rain fall and higher ambient temperatures of the climatic region of South Carolina would suggest that rates would be even greater in this area than in many of the previous sites where this technology has proven successful.

3.2 Biodegradation Process

The microbial metabolism and fate of BTEX, TPH, polycyclic aromatic hydrocarbons (PAHs), and straight-chain and branched alkanes in the natural environment are areas of intense concern. Many of these compounds and their breakdown products display toxic and carcinogenic properties. Many microorganisms, including bacteria, fungi, yeasts, and algae, have the enzymatic capacity to metabolize petroleum hydrocarbons to complete destruction, and use the carbon substrate to generate new biomass. For example, bacteria under aerobic conditions oxygenate PAs to form dihydrodiol, which is used in cell production. Figure 3.2 is an example of the bacterial oxidation pathway of naphthalene to catechol. Naphthalene and other arenes are among the most water soluble and potentially toxic compounds of petroleum and it associated products. Indigenous microorganisms in the soil can degrade large quantities of petroleum hydrocarbons if they have water, oxygen, and other limiting nutrients, usually nitrogen and phosphorus. Knowing these facts, it is easy to understand why using bioremediation as a remedial action is the best method to treat PCS at SRS. Use of this technology has shown that TPH soil concentrations higher than 5000 ppm can be reduced to less than 10 ppm in six to eight weeks or less depending on the ambient temperature.

3.3 Technical Need

As sources of clean surface water steadily decline, reliance on groundwater will undoubtedly continue to increase far into the next century. Thus, with increasing urgency, ways have been sought to cleanup (i.e., remediate) petroleum contaminated soil. The sOILs Facility will provide SRS and the state of South Carolina with the opportunity to demonstrate and evaluate an innovative, environmentally sound, cost-effective remediation technique that can be used onsite to handle fuel spill clean-up and the growing leaking underground storage tank (LUST) problem.

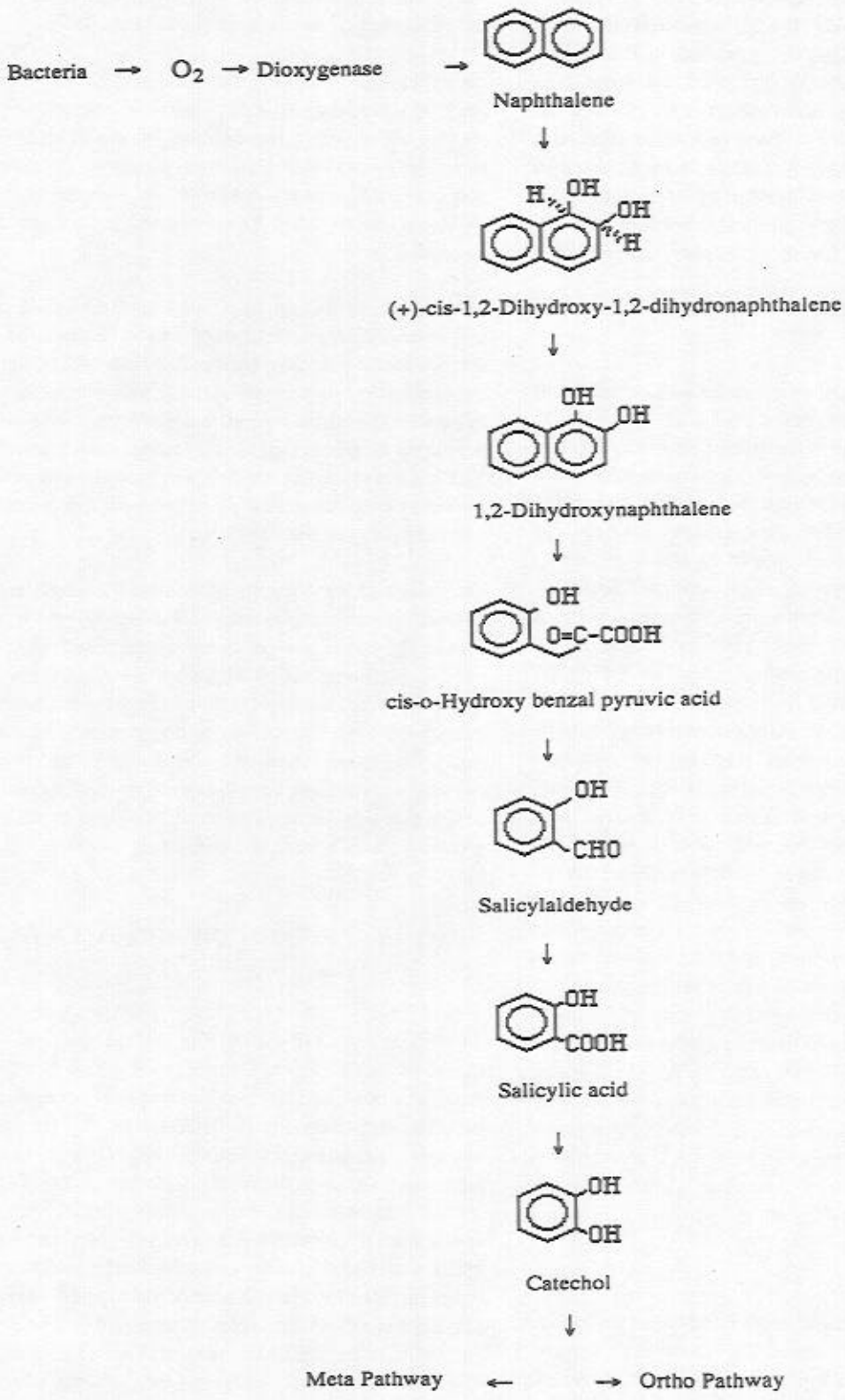


Figure 3.2 Bacterial Oxidation Pathway of Naphthalene to Catechol

The basic concepts of this technology are expected to be applicable to other sites in the DOE Complex having PCS. However, the particular process designs will be site-specific. The experience gained at the SRS demonstration will provide the basis for designs for other sites. Regulatory drivers for this activity are RCRA (40 CFR Parts 280, 280.20, 280.21 and 280 22. and Parts 280.70-280.74), the State Underground Petroleum Environmental Response Bank Act of 1988 (SUPERB), S.C. Code Ann. §§ 44-2-10 et seq., State Safe Drinking Water Act of 1976, S.C. Code Ann. § 44-55-10, et seq., Pollution Control Act of 1970 (PCA) and Federal Safe Drinking Water Act (40 CFR 141).

3.4 Alternatives

A variety of alternative technologies to land disposal of untreated petroleum contaminated soil exist today. They include in situ/ex situ bioremediation, soil stabilization and solidification, vapor extraction, bioventing, soil washing and/or chemical treatment, and incineration. Several of these technologies have disadvantages that far out weigh the advantage of being used in lieu of ex situ bioremediation. For example, soil stabilization and solidification, although relatively low cost, generate a volume increase of disposable material and can create possible limitations on future use of sites where this method is used as it does not destroy the contaminants it only immobilizes them. Vapor extraction and bioventing are viable methods but require extensive site characterization and they are very site-specific applications, as is in situ bioremediation. Soil washing (flushing) and chemical treatment can be used as a permanent treatment method but additional waste streams are generated, requiring further treatment and expense. High- and low-temperature incineration is an effective method to destroy PCS. The performance of these systems is measured by the destruction and removal efficiency (DRE). Meeting the mandates of a high-temperature DRE of 99.9% can be costly, by using large amounts of supplemental fuel to meet minimum operating parameters. Low-temperature incineration is more applicable to PCS remediation but with both applications, permit conditions, contaminant concentrations, soil volume, incinerator efficiency, and heating values of the soil all control what the final cost of operations will be, not withstanding the NIMBY (not in my backyard) factor.

3.5 Benefits

There are distinct advantages associated with the onsite PCS remediation. By excavating the contaminated material to an above-ground treatment cell, the engineer/scientist has better control over the critical factors that dictate the rate at which the degradation takes place. Nutrient concentration, moisture content, oxygen availability, and, in many cases, temperature can be controlled to maximize the efficiency of the process (Lombard 1990).

Sampling and analyzing the PCS and the excavated area become simplified. It is far easier to demonstrate that the area is clean when the contaminated material has been removed from the site. In order to optimize the sampling and analysis, many agencies and/or customers have required the material be excavated to ensure complete cleanup.

The simplistic design can be safely and easily managed and operated. A minimal staff would be required to operate the facility adding to the low risk factor by limiting exposure to operations personnel. This action supports the efforts of the organization to remain cost-effective while providing Site personnel with a safe working environment. The results of many studies by independent researchers indicate that bioremediation is the most cost-effective way to treat PCS (Lombard 1990).

The facility has no precedence in South Carolina or Georgia and as such represents new technology for the area. However, since several other states have demonstrated similar facilities, the sOILS Facility represents low risk and should receive high public acceptance. Through technology transfer, the facility will also provide South Carolina with the opportunity to demonstrate and evaluate an innovative, environmentally sound, remediation technique onsite that can be used to handle fuel spill cleanup and the growing leaking underground storage tank (LUST) problem.

3.6 Site Description and Area Maps

The Savannah River Site is a 320-square mile facility owned by the U.S. Department of Energy and operated under contract DE-AC09-89R180035 by the Westinghouse Savannah River Company. The Site is located near Aiken, South Carolina, and has been operated as a nuclear production facility for DOE since 1950. The production processes performed during the past 40 years have generated considerable waste and waste sites. This waste includes radiological, waste heavy metals, organic solvents, sanitary landfills, petroleum contaminated soil from spills and leaking underground storage tanks, and other types of mixed wastes. Many contaminated environments at SRS have been identified including both surface water and soils, subsurface sediment, and groundwater. Cleanup of these wastes and waste sites has become a top priority for DOE. Because of the large number of waste sites and

large volume of contaminants at many of these sites, a considerable amount of time and money will be required to complete the mandated cleanup. Thus, another priority stemming from this cleanup program is to develop and demonstrate new and innovative technologies that may decrease costs, time, and environmental impact and/or result in a cleaner end point.

The site for the sOILS Facility is near Building 402-D in D Area, approximately two miles from the Savannah River. The site and general vicinity are not located on a flood plain and every effort will be made to contain and control a catastrophic 25-year rainfall event. A site map, Figure 3.6.1, is attached for orientation.

A map of D Area and vicinity, Figure 3.6.2, shows the location of wells DWW1 and DWW2, which are now completed and developed. These wells are more than 1000 feet from the site and are not expected to be affected. Both DWW1 and DWW2 are screened from 620 to 680 feet below ground level and are therefore in the Cretaceous. Because this aquifer is confined and is below Ellenton, which has a reverse head (upward flow when penetrated), it would be physically impossible for a released material from the proposed facility to affect the quality of water in these wells. Figure 3.6.2 also shows the site location, local facilities, infrastructure, and transportation routes.

3.6.1 D-Area Hydrogeology

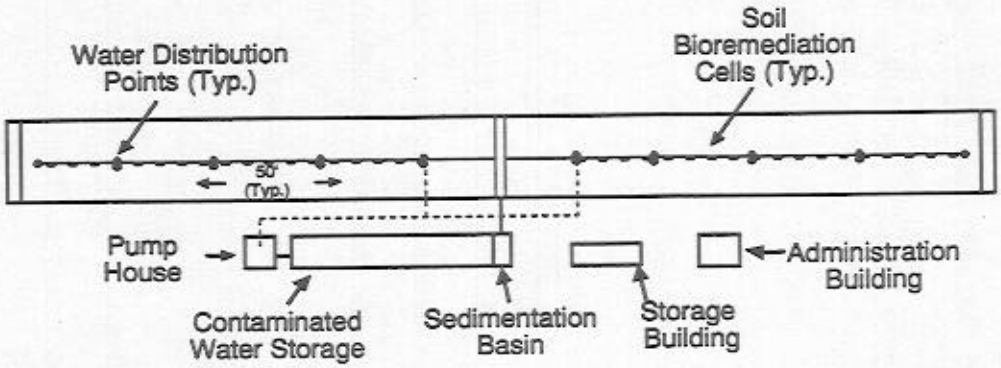
The sOILS Facility is located within 3000 feet of the D-Area Coal Pile Runoff Basin (CPRB). The D-Area CPRB is underlain by stream terrace deposits of the Savannah River (O'Brien and Gere 1987). These deposits consist predominantly of unconsolidated silt, sand, and clay with minor gravel. A clay zone lies just below the average water table depth; however, the confining characteristics, if any, are unknown. The average depth to the water table is approximately 10 feet with a range between 5 and 20 feet. Since monitoring began in 1982, water table levels have remained relatively constant compared to the other CPRBs. The water table at this time had a gradient of approximately 50 feet/mile to the southwest. Based on the water table contours, D Area lies on a groundwater divide. Flow in the vicinity of D Area is to the west and southeast, perpendicular to the trend of the divide.

In the immediate vicinity of the D-Area CPRB, the groundwater table mounding with historical groundwater flow to the west-southwest. No significant flow variations over time have occurred. Well responses to recharging and discharging aquifer conditions, shown in the DCB-series hydrographs, have been consistent among the wells with little variance over time. The subdued well responses and lack of significant impacts of the D-Area CPRB on these wells may reflect that the Savannah River exerts a principal controlling influence on the water table in D Area. The Savannah River is a major groundwater sink with the SRS region.

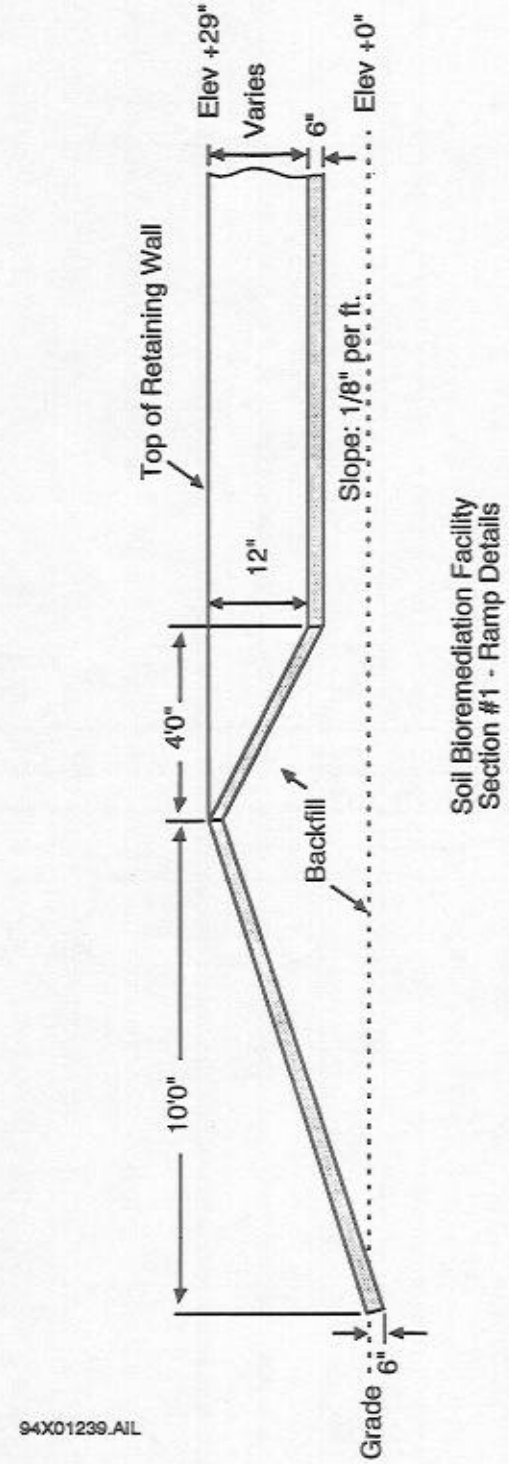
Any potential contaminants from the D-Area CPRB that intercept the water table are likely to initially migrate in a general southwest direction. Since D Area is on a groundwater divide, contaminant migration, after the initial southwest trend, would be expected to follow flow patterns noted for the D-Area vicinity. Contaminants, therefore, would likely be discharged along with groundwater to swamps west of the basin and southeast along Four Mile Branch and ultimately to the Savannah River.

Appendix A

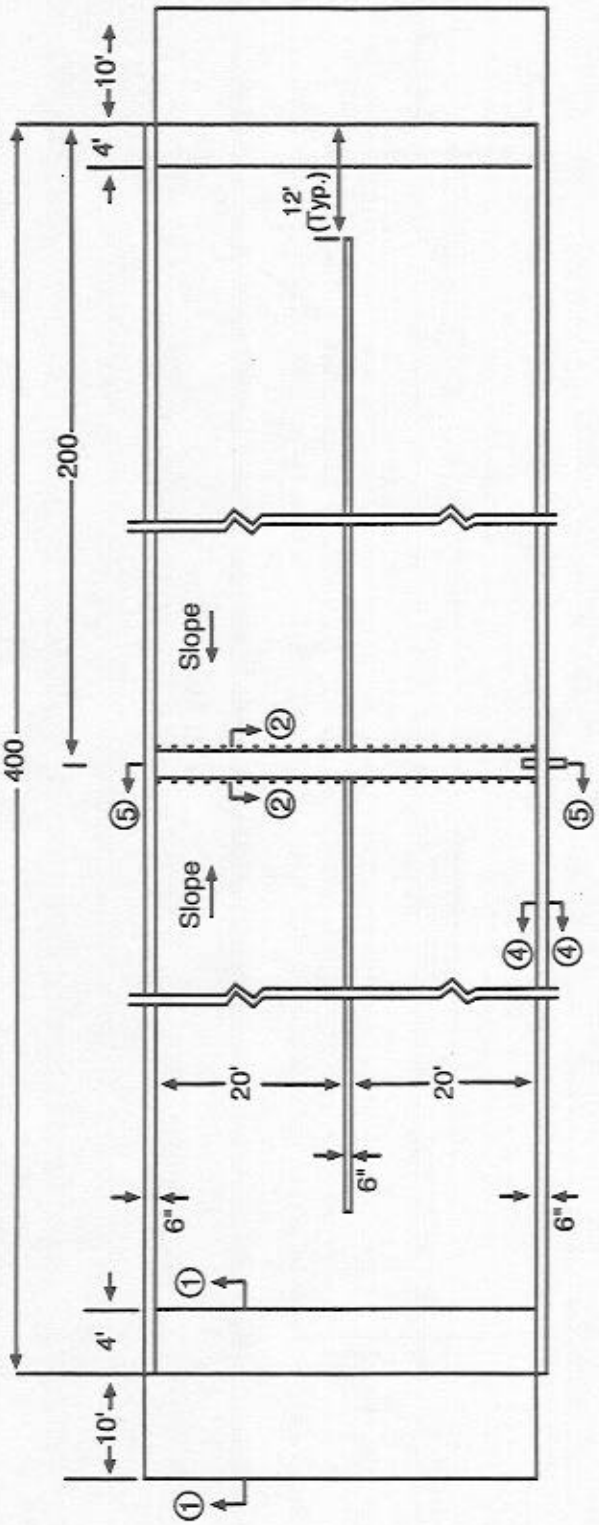
Conceptual Facility Design



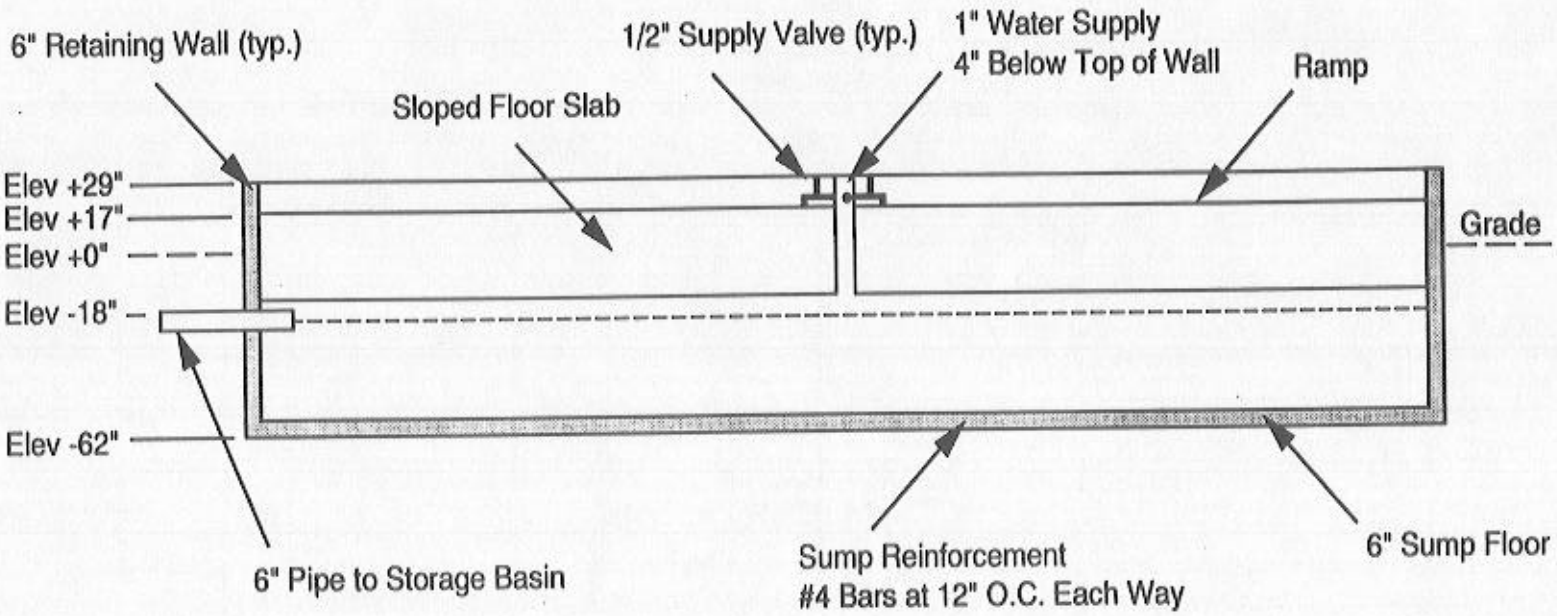
Soil Bioremediation Facility
Facility Plan



Soil Bioremediation Facility
Section #1 - Ramp Details



Soil Bioremediation Facility
Double Unit - Plan View



94X10239.AIL

Soil Bioremediation Facility
Section #5—Cross Section (Double)