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RESOURCE CONSERVATION AND RECOVERY ACT FACILITY INVESTIGATION ZONE K SOLID WASTE MANAGEMENT UNIT 166 TREATABILITY STUDY CNC CHARLESTON SC

3/1/1999

ENSAFE

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY CHARLESTON NAVAL COMPLEX CHARLESTON, SOUTH CAROLINA

ZONE K SWMU 166 TREATABILITY STUDY WORK PLAN

Revision: 0

CTO: 029

Prepared for:

Department of the Navy
Southern Division
Naval Facilities Engineering Command
North Charleston, South Carolina

Prepared by:

EnSafe Inc.
5724 Summer Trees Drive
Memphis, Tennessee 38134
(901) 372-7962

March, 1999

DEPARTMENT OF THE NAVY
SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
P.O. BOX 190010
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NORTH CHARLESTON, S.C. 29419-9010

5090/11
Code 18710
23 Mar 1999

Mr. John Litton, P.E.
Director, Division of Hazardous and Infectious Waste Management
Bureau of Land and Waste Management
South Carolina Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201

Subj: SUBMITTAL OF ZONE K SWMU 166 TREATABILITY STUDY WORKPLAN

Dear Mr. Litton:

The purpose of this letter is to submit the enclosed Zone K SWMU 166 Treatability Study Work Plan, Revision 0, for Naval Base Charleston. The work plan is submitted to fulfill the requirements of condition IV.E.2 of the RCRA Part B permit issued to the Navy by the South Carolina Department of Health and Environmental Control and the U.S. Environmental Protection Agency (USEPA).

The workplan has been revised since the Draft version based on comments made by the Department and the USEPA.

The Navy requests that the Department and the USEPA review and provide comment or approval whichever is appropriate. If you should have any questions please contact Billy Drawdy or myself at (843) 743-9985 and (843) 820-5543 respectively.

Sincerely,

David P. Dodds

DAVID P. DODDS
Remedial Project Manager
Environmental Department

Encl:
(1) Zone K SWMU 166 Treatability Study Work Plan, dated March 1999
Copy to:
SCDHEC (Paul Bergstrand, Johnny Tapia), USEPA (Dann Spariosu)
CSO Naval Base Charleston (Billy Drawdy), SOUTHNAVFACENGCOM (Tony Hunt)
SPORTENVDETCHASN (Bobby Dearhart)

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY CHARLESTON NAVAL COMPLEX CHARLESTON, SOUTH CAROLINA CTO-029

RESPONSE TO COMMENTS FOR

DRAFT ZONE K SWMU 166 TREATABILITY STUDY WORK PLAN

Prepared for:

Department of the Navy
Southern Division
Naval Facilities Engineering Command
Charleston, South Carolina

SOUTHDIV Contract Number:
N62467-89-D-0318

Prepared by:

EnSafe Inc.
5724 Summer Trees Drive
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March 1999
Revision: 0

SWMU 166 Treatability Study Work Plan
Comments/Response to Comments

The following is a summary of DHEC's verbal comments of the SWMU 166 TS WP and EnSafe's responses from the telephone conference between Paul Bergstrand and Johnnie Tapia (DHEC) and Ronnie Britto and Larry Bowers (EnSafe), 5 Jan 1999. It also includes the results of a follow-up telephone conversation between Ronnie Britto and Paul Bergstrand on 6 Jan 1999. In addition, the listed responses include input from David Dodds and Tony Hunt (SDIV), and they also respond to a subsequent round of DHEC comments (listed as replies from Paul Bergstrand and Johnny Tapia, 19 Jan 99).

DHEC Comment 1:
Figures 1.2 and 1.3 … these figures are not complete, fill material is shown, what fill material?, litho as presented appears homogeneous, legend does not match figure symbols, is this a Zone F cross section?, does this consider the most recent data available? Please correct to accurately portray site cross-section conditions.

EnSafe Response 1:
Figures 1.2 and 1.3 has been replaced by a figure taken from the Zone K RFI (Figure 2.5). This figure differentiates between the upper and lower units of the shallow aquifer and provides greater detail than the figure presented in the draft TS WP.

DHEC Comment 2:
Section 1.2 … SWMU 166 is referred to as the sewer system … this is no longer correct as the sewer system has been re-designated as SWMU 185, please correct in this section of the WP and elsewhere if necessary.

EnSafe Response 2:
Concur. Section 1.2 has been revised (Page 1-3).

DHEC Comment 3:
Section 1.1 … first sentence states that TS is based on Zone F RFI? We believe you meant Zone K, please correct.

EnSafe Response 3
Concur. The WP has been revised (Page 1-1).

DHEC Comment 4:
Figures 1.4 and 1.5 … we would like to see more (and most recent) potentiometric contours …

is the GW flow direction, as shown in the TS, constant and representative of current site conditions?

EnSafe Response 4
Figures 1.4 and 1.5 have been renumbered to Figures 1.3 and 1.4. Additional potentiometric maps were generated using data collected in January, 1999. This data has been contoured and is shown on figures 1.5 and 1.6.

There are currently no other sets of water level data collected from a sufficient quantity of wells within a close enough space of time to produce representative contours. However, additional water level data will be collected prior to beginning the AA sequencing study to further assess seasonal fluctuations in groundwater elevations. Water levels will also be monitored during system start-up to assess changes in potentiometric surface due to the extraction and injection wells. Details of the water level monitoring events will be provided in the O&M plan submitted as part of the design document.

DHEC Comment 5:
The WP lacks a statement regarding GW hydrodynamics of the TS w.r.t. extraction and re-injection wells, location of these wells, and the proposed monitoring wells ... please include a section in the WP that details the pump test (the process and its objectives).

EnSafe Response 5
EnSafe has added a new section (Section 4) regarding the pump test and subsequent GW modeling efforts. This additional section briefly outlines the pump test, objectives, information that will be available from it, and how it will be used in the treatability study design and implementation. Original Section 4 and those following it have been renumbered.

In addition, a goal of the modeling prior to performing the treatability study is to demonstrate that the Navy has considered and understands the effects of the TS on GW at the site during the test. Furthermore, the results of the GW model (Capture Zone) will be included in the pending design and specifications document.

DHEC Comment 6:
Injection well permits? Did you inquire into this with DHEC? Impact to TS effort, etc.?

EnSafe Response 6
A permit summary section has been added to Section 7 of the WP. Previous conversations with the permitting authorities did not indicate any potential difficulties in obtaining the required permits.

The WP revision follows:

Section 7.1 Permit Requirements

The permits required to perform this treatability study are summarized in Table 7.1.

Table 7.1
Treatability Study Permit Summary

Task	Permit Required	Agency/Contact
Well Installation	Well Construction Permit	SCDHEC / Paul Bergstrand
Aquifer Test	Sewer Use Agreement	North Charleston Sewer District / Kelly Singer
Above-ground Groundwater Amendment System	Construction Permit Application - Water and/or Wastewater Facilities, DHEC Form 1970 (01/1998)	SCDHEC / Marion Sadler
Groundwater Re-injection	Underground Injection Control Permit Application, DHEC Form 2502 (08/1997)	SCDHEC / Robert Devlin

DHEC Comment 7:

Section 1.4 ... Nature and Extent ... we would like to see a 3D presentation of data, would like to see MNA COC data included, would like to see all existing and current data portrayed, did not see biological data (as a benchmark).

EnSafe Response 7

Figure 4.2 has been revised so that the treatability study area and its proposed location is overlaid onto a plan view map showing the chlorinated VOCs plume and the potentiometric surface in the deeper portion of the aquifer. VOCs are limited to the deeper portion of the surficial aquifer in the area of this treatability study, so 3-dimensional mapping would not enhance the presentation of this data at this time. However, 3-dimensional mapping may be used in the CMS report where vertical migration of contamination appears to be occurring.

Currently, the feasibility of MNA as a remedial alternative at SWMU 166 is being evaluated based on two geochemical groundwater sampling events. A report is being prepared summarizing the findings of the MNA analysis. The treatability study could impact the geochemistry of the aquifer and the groundwater chemical concentrations. The exact nature of the treatability study's impact is difficult to predict. Therefore, an MNA sampling event will likely be required after the treatability study is completed and the aquifer is allowed to return to its pre-treatability study conditions. The data from this sampling event will be used to re-evaluate the feasibility of MNA at SWMU 166.

DHEC Comment 8:
Section 3.1 ... why 4 months for TS completion? Provide rationale.

EnSafe Response 8:
EnSafe added a brief statement (Page 3-1) about why biological systems generally show response in a 2 to 6 month time frame. Additionally, the 4 month time frame in the report is not rigid. If based on the progress (or the lack of it) of the study - based on analytical chemical sampling results - a short-term extension is required, it will be recommended.

DHEC Comment 9:
The WP lacks a permit section. We would like to see a section stating permit issues.

EnSafe Response 9:
The revised WP includes a specific section pertaining to permits. Reference EnSafe Response 6.

DHEC Comment 10:
The WP lacks an IDW section.

EnSafe Response 10
The WP revision follows:

Section 7.2 IDW Management
Soils and groundwater generated during drilling activities and other investigative derived waste (IDW) will be disposed of in accordance with the IDW Management Plan presented in the Comprehensive RFI Work Plan for the Charleston Naval Complex.

DHEC Comment 11:
Section 5.4 ... please clarify which piping system is for air and which is for water.

EnSafe Response 11:
Section 5.4 is now 6.4. EnSafe has revised the WP to clarify aforementioned issue.

DHEC Comment 12:
Section 6 ... its vague, please provide details as to when system is up, down, sampling frequency, etc.

EnSafe Response 12:
Section 6 is now Section 7. This section now states that the O & M manual (to be developed as part of the Plans and Specification document) will include the type of details as expressed by DHEC.

DHEC Comment 13:
Table 7.1 ... sampling frequency of four events seems short. Please explain your rationale. DHEC would like to see more than four rounds, say six or seven. Also, it seems that two monitoring wells is inadequate. Please explain your rationale.

EnSafe Response 13:
At this point, for a four month study, four events would provide the data and information required to plot out and estimate degradation rates. If, however, the study prolongs beyond four months to six months, then one more final sampling event would be recommended. However, before this extension would occur, EnSafe would make a recommendation with supporting rationale for the extension to the project team. In addition, the design document O&M plan will clarify the identity of wells that will be gauged for water levels before, during and after the TS. Wells, other than the two listed for sampling in the WP, may also be sampled at the request of the project team and/or if the results of the GW model indicate that nearby wells are in the zone of TS influence.

DHEC Comment 14:
Section 8 ... vii and viii ... shouldn't this type of data be evaluated via plots? Please explain significance of these parameters. In addition, viii does not appear to define an action or outcome, it appears to merely state a fact. Please explain.

EnSafe Response 14:
Section 8 is now Section 9.

Regarding vii, nutrient data will be evaluated and mapped as required. Nutrients are measured at the beginning and at intermediate points with the sole purpose of ensuring that they don't reduce to levels that limit or inhibit biological activity. If plotting them in the form of curves, bar charts or other graphical forms is useful, they will be utilized in the TS report.

Regarding viii, (measurement of heterotrophic plate counts), EnSafe concurs with DHEC's comment and the WP has been revised to define the outcome after stating the fact (Page 8-3).

DHEC Comment 15:
WP needs to state that report will meet TS requirements as spelled out in the Comprehensive CMS WP.

EnSafe Response 15:
The revised TS WP includes a statement that the TS Report will meet the applicable requirements as stated in the Comprehensive CMS WP. Its important to note that the "site-specific TS WP" provides "site-specific processes and objectives" and therefore it is more applicable than the general statements provided by the Comprehensive CMS WP. The general intent of the comprehensive WP has been satisfied in this site specific WP.

DHEC Comment 16:
Section 7... Table 7.1. Are the two monitoring wells proposed in the TS one and the same as the two observation wells shown in the permit request diagram provided to DHEC by EnSafe's Pete Bayley for the aquifer pump test?

EnSafe Response 16:
Section 7 is now Section 8. Table 7.1 is now Table 8.1.

The two aquifer pump test-slated observation wells are different from those proposed for the TS-proposed monitoring wells. These piezometric wells will remain in place during the treatability test. If the GW model determines that they are within the area of influence of the TS area, they would be considered for monitoring of important field parameters such as dissolved oxygen and oxidation-reduction potential. They could also be used to provide groundwater samples for chemical and microbial analysis if deemed necessary based on the initial progress of the TS.

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY CHARLESTON NAVAL COMPLEX CHARLESTON, SOUTH CAROLINA

ZONE K SWMU 166 TREATABILITY STUDY WORK PLAN

Revision: 0

CTO: 029

Prepared for:

Department of the Navy
Southern Division
Naval Facilities Engineering Command
North Charleston, South Carolina

Prepared by:

EnSafe Inc.
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March, 1999

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1.0 PROJECT DESCRIPTION

1.1 Introduction

This treatability study is based on information presented in Zone K RFI (EnSafe, December 1997), the AOC 607 and SWMU 166 CMS Work Plan (EnSafe, April 1998), and additional sampling performed as part of monitored natural attenuation (MNA) and CMS data gap sampling activities performed since production of the CMS work plan.

This work plan describes the theory, the general application methodology, objectives, and anticipated schedule for this treatability study. After work plan approval, a separate design document will be generated which will include detailed treatment system, groundwater well, and plumbing installation specifications.

Currently, the feasibility of monitored natural attenuation (MNA) at SWMU 166 is being evaluated based on two geochemical sampling events. A report is being prepared summarizing the findings of the MNA analysis. The treatability study could impact the geochemistry of the aquifer. Therefore, an MNA sampling event will be performed after the treatability study is performed to re-evaluate the feasibility of MNA at the site.

This work plan is broken into eight sections:

- Section 1 — Introduction
  Briefly summarizes results from the RCRA Facility Investigation Report including site history, geology and hydrogeology, and the distribution of the primary contaminants of concern.

- Section 2 — Remedial Technology Description
  Describes the theory, process flow, and application methodology of the study technology.

- Section 3 — Treatability Study Objectives

  Defines the primary and secondary objectives and goals of the treatability study.

- Section 4 — Recommendations for Conducting the Aquifer Pumping Test.

  Describes the purpose and procedure for conducting a constant rate pumping test in the AA-sequencing study area.

- Section 5 — Treatability System Set-up

  This section describes the main components of the treatability system. It also includes a description and figure of the study area.

- Section 6 — Treatability System Design Work Plan

  Outlines general system specifications. A detailed design document separate from this work plan will be generated prior to implementing this treatability study.

- Section 7 — Systems Operation and Maintenance

  A general overview of the operations and maintenance manual is described in this section. The content of the actual manual will be described in detail and produced during the development of the plans and specifications design document.

- Section 8 — Effectiveness Monitoring and Sampling

  Details the type and frequency of sampling to assess changes in study area groundwater.

- Section 9 — Treatability System Evaluation

  Parameters for evaluating the effectiveness of the treatability study will be described in this section.

- Section 10 — Schedule and Reporting
  Describes the content of the subsequent report and provides a schedule for key elements of the study.

- Section 11 — References
  Reference material is listed in this section.

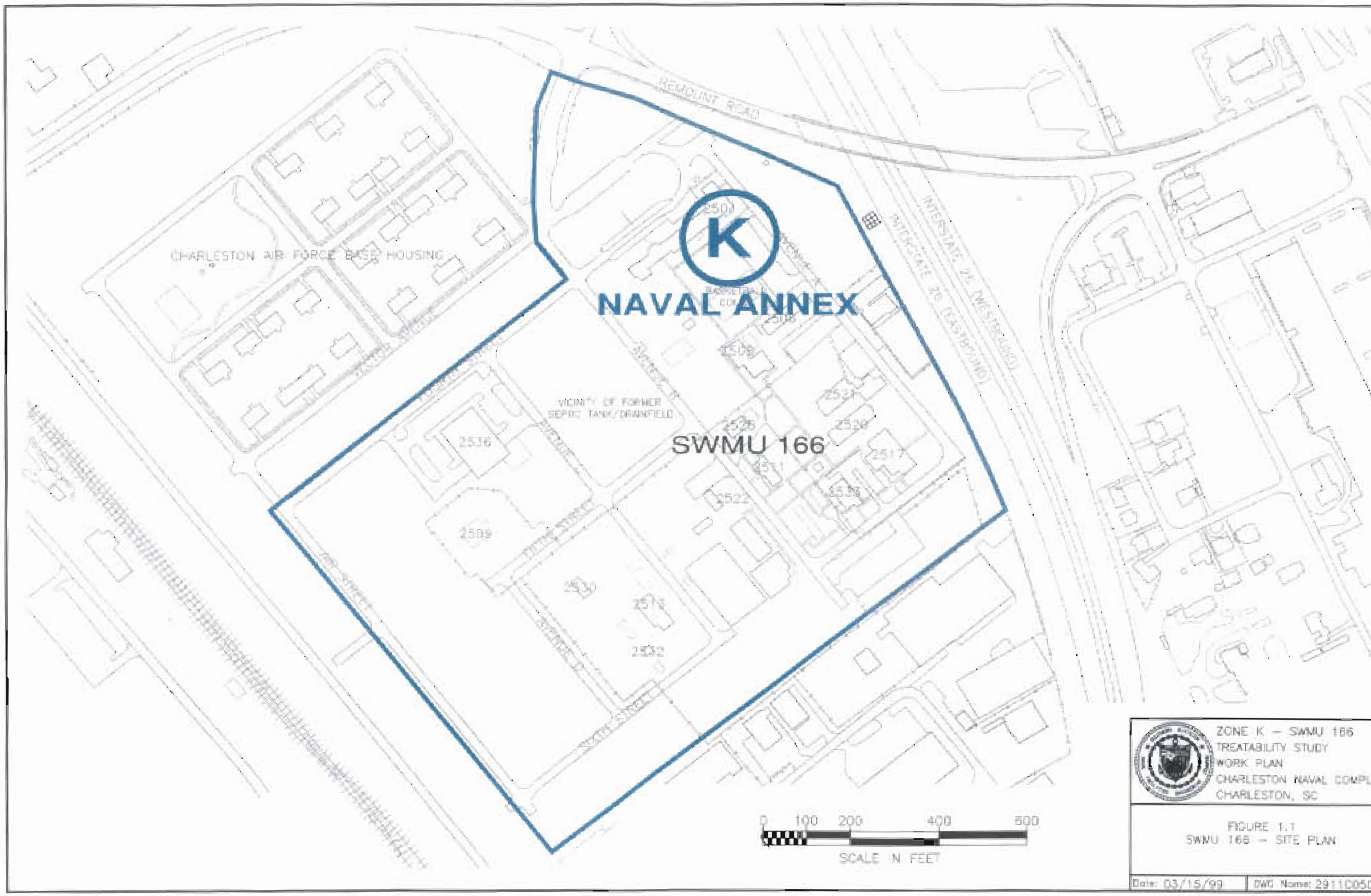
1.2 Site Description

The Naval Annex is currently used by the U.S. Marine Corps as a reserve training center. The training center is comprised of administrative and classroom type buildings, and a heavy vehicle storage and maintenance/small repair facility.

SWMU 166 is a solvent plume that was discovered during the investigation of the sanitary sewer line and septic system serving the annex. The latter unit has been designated as SWMU 185. Initially, the sewer system and the solvent plume were jointly referred to as SWMU 166. However, the sewer system was later designated as SWMU 185. The surface cover at the Naval Annex consists of grass, asphalt, concrete and buildings. Figure 1.1 shows the site area and distribution of buildings and roads.

During the SWMU 166 RFI, TCE was discovered in groundwater at the Naval Annex in an area currently occupied by a U.S. Marine Corps Reserve Training Center. The TCE plume has migrated east and is discharging offsite into the french drain and storm water sewer system associated with the adjacent Interstate-26.

High concentrations of TCE were also found in an area of surface soil independent of the sanitary sewer line and were identified as the probable source for VOCs in groundwater. This soil has since been removed by the Environmental Detachment.



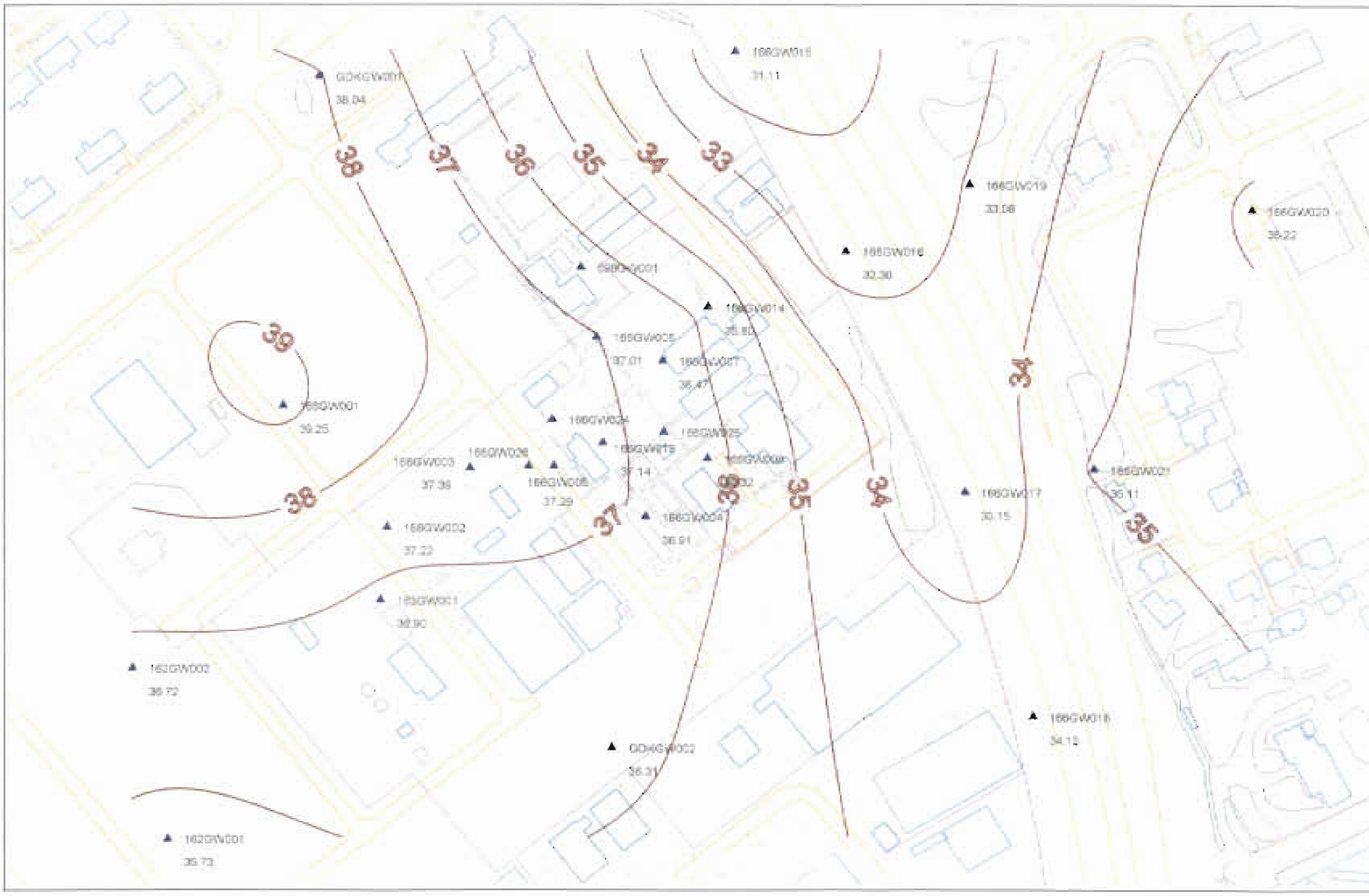
REMOUNT ROAD
CHARLESTON AIR FORCE BASE HOUSING
NAVAL ANNEX
K
INTERSTATE 26 (WESTBOUND)
INTERSTATE 26 (EASTBOUND)
VICINITY OF FORMER SEPTIC TANK/DRAINFIELD
SWMU 166
2536
2509
2530
2532
2522
2517
2520
2521
2526
2508
0 100 200 400 600
SCALE IN FEET
ZONE K — SWMU 166
TREATABILITY STUDY
WORK PLAN
CHARLESTON NAVAL COMPLE
CHARLESTON, SC
FIGURE 1.1
SWMU 166 — SITE PLAN
Date: 03/15/99
DWG Name: 2911C050

1.3 Site Geology and Hydrogeology of the TCE Investigation Area

Figure 1.2 provides geologic profiles of the area of the Naval Annex, Interstate-26, and between Interstate-26 and Gas Light Square Shopping Center. Three primary lithologies were encountered across the area of investigation and are identified on the profiles. The uppermost lithologic unit (Qs) is primarily a clean, well-sorted, fine-to medium-grained sand with traces of mica. Below this sand unit, another primarily sand unit (Qcs) was encountered; however, this unit contained some silt and clay along with phosphate nodules and shell hash. In places, clay was the primary texture. The upper sand unit was 20 to 25 feet thick. The lower clayey sand unit was approximately 10 feet thick. The Ashley Formation (Ta) underlies the Qcs throughout the entire study area. A bed of peat was encountered in the upper sand in the vicinity of the Gas Light Square Shopping Center.

Figures 1.3 through 1.6 are March 1998 and January 1999 potentiometric surface maps for the shallow and deep portions of the water table aquifer, respectively. The shallow potentiometric map encompasses a larger area than the deep potentiometric map due to the broader distribution of shallow wells. Both potentiometric maps identify the hydraulic gradient on both sides of the interstate to be toward the interstate. The area of the interstate is a potentiometric low due to the effect of the french drain system that is in place underneath the interstate.

Slug test and water level data from study area wells 16607D and 16610D indicate that horizontal hydraulic conductivity is about 4.0 ft/day and hydraulic gradients are about 0.01 ft/ft. Assuming an aquifer porosity of 0.25, groundwater flow velocities through the study area are about 0.16 ft/day, or about 50 ft/yr. However, data from a constant rate aquifer pumping test scheduled for January 1999 will be used to refine these estimates.



N

100 0 100 Feet

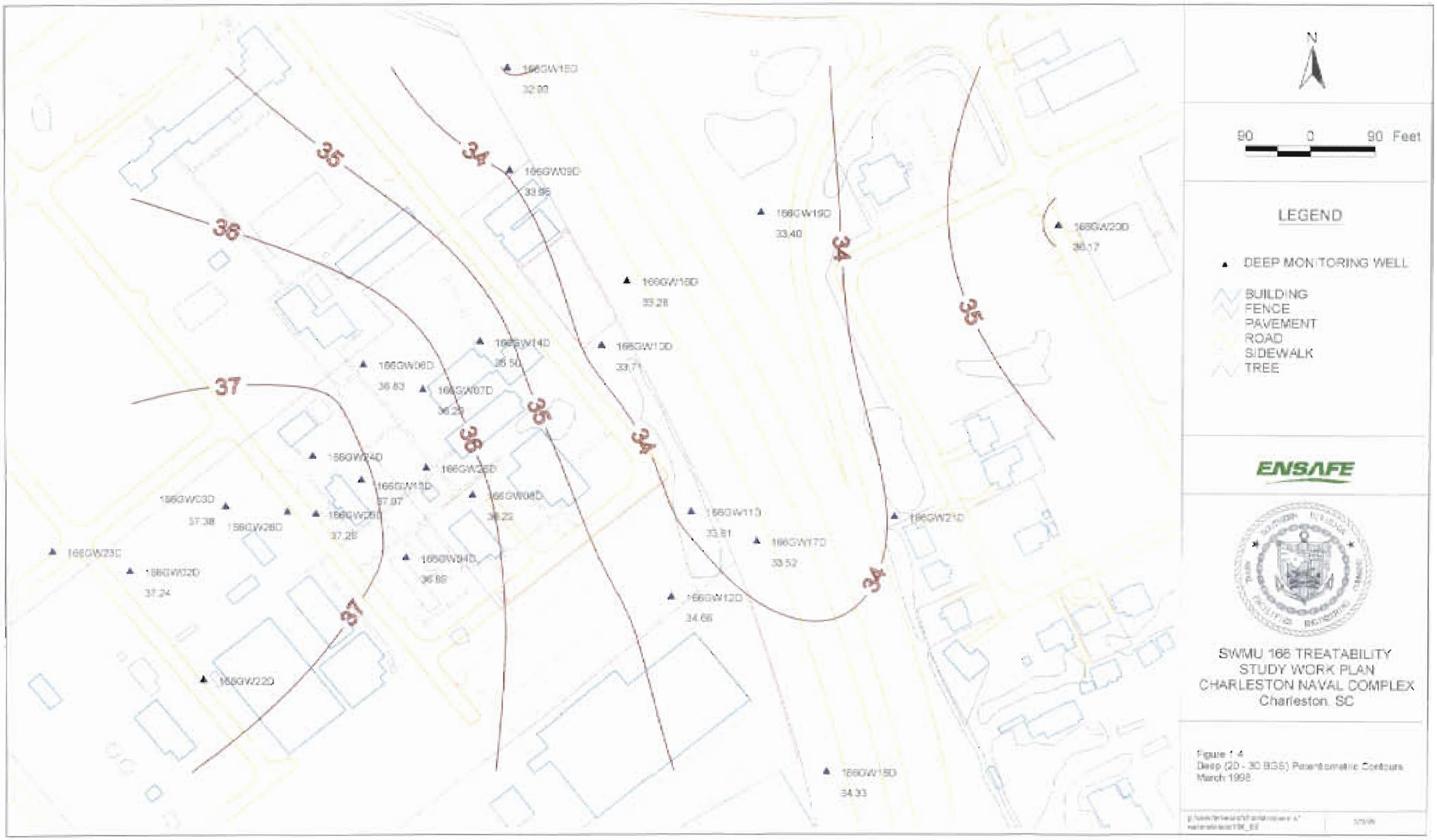
LEGEND

SHALLOW MONITORING WELL
BUILDING
FENCE
PAVEMENT
ROAD
SIDEWALK
TREE

ENSAFE

SWMU 166 TREATABILITY
STUDY WORK PLAN
CHARLESTON NAVAL COMPLEX
Charleston, SC

Figure 1.3
Shallow (5 - 15 BGS) Potentiometric Contours
March 1998



SWMU 166 TREATABILITY STUDY WORK PLAN
CHARLESTON NAVAL COMPLEX
Charleston, SC

Figure 1.4
Deep (20 - 30 BGS) Potentiometric Contours
March 1998

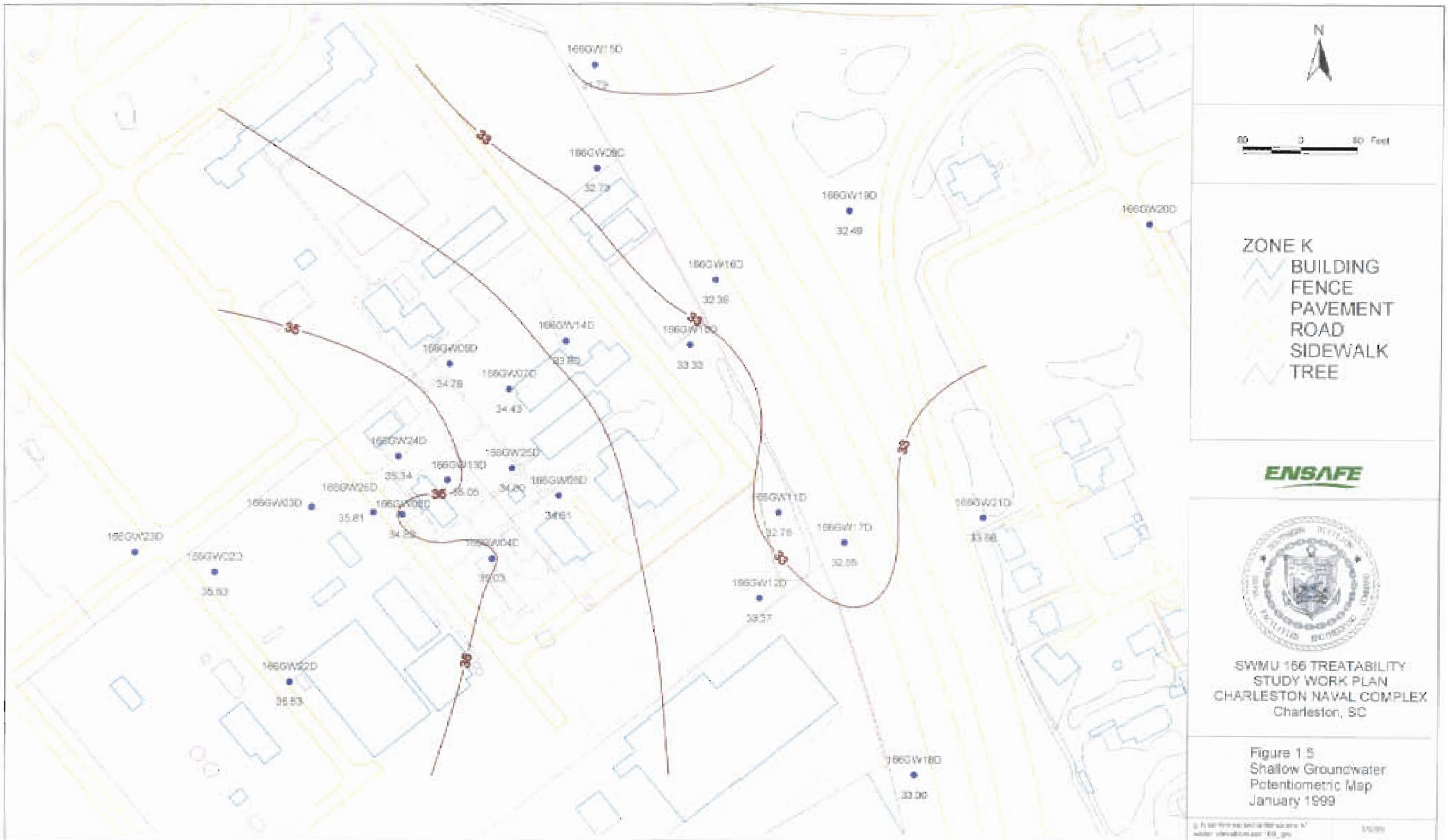
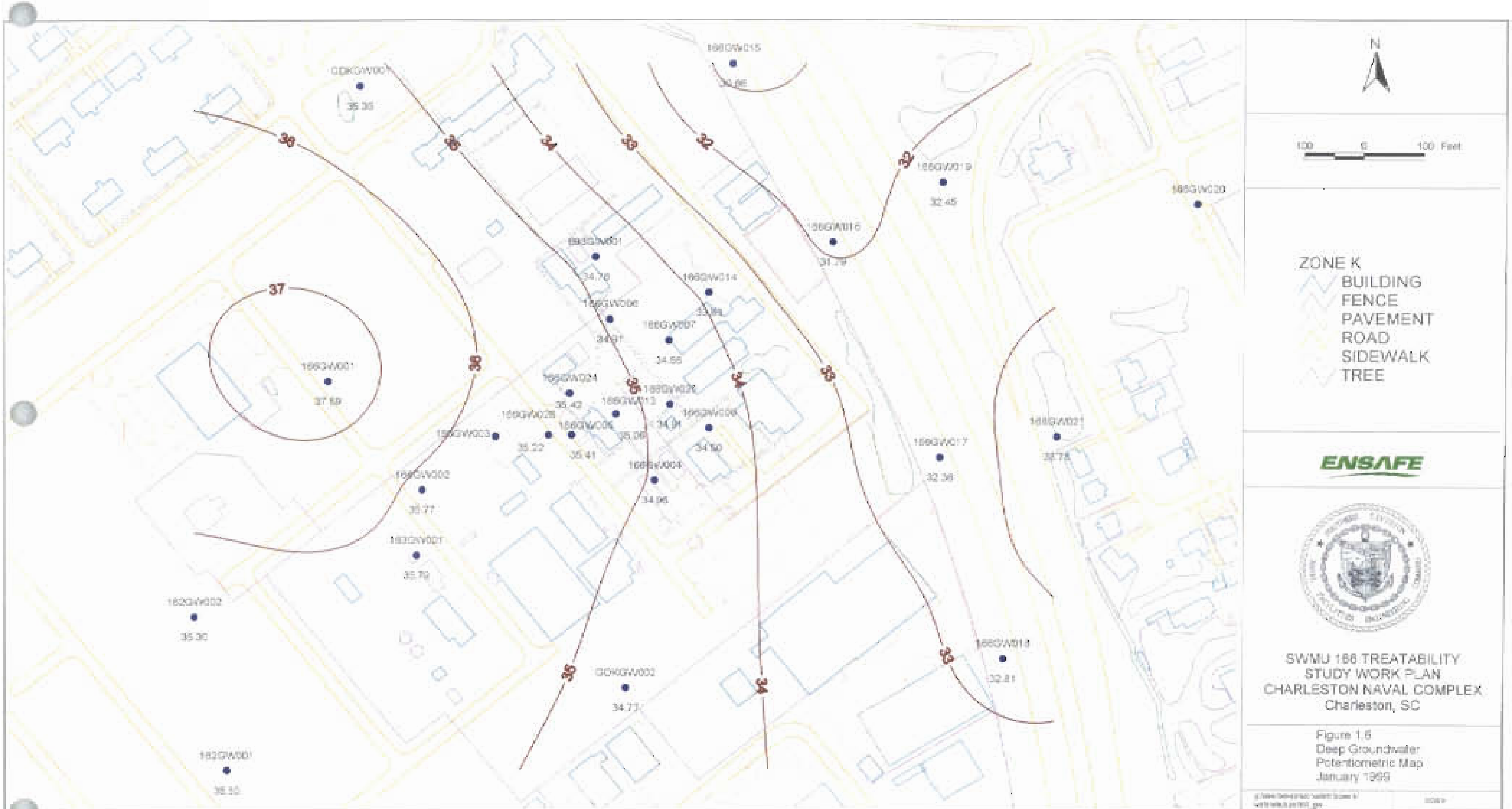


Figure 1.5
Shallow Groundwater
Potentiometric Map
January 1999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ENSAFE
SWMU 166 TREATABILITY
STUDY WORK PLAN
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Figure 1.6
Deep Groundwater
Potentiometric Map
January 1999

1.4 Nature and Extent of Contamination

Soil

VOC contaminated soils were removed by the Environmental Detachment as part of interim corrective measures at this site. No other soils will be addressed during this treatability study or the CMS.

Contamination in Groundwater

The RFI identified a chlorinated VOC plume in the shallow and deep portions of the surficial aquifer at this site (Figures 1.7 and 1.8). As shown on the plume maps, the chlorinated VOCs are concentrated in the deep zone of the surficial aquifer. The plume originates near the soil source area described above, migrates east toward Interstate-26, extends past to the property boundary where it appears to be discharging into the interstate subsurface drainage system which discharges to a storm sewer running northeast and away from the site.

Chlorinated VOCs were also found in groundwater east of the interstate. However, it is believed that those VOCs are linked to releases from a former dry cleaning facility located on the east side of the interstate.

Figure 1.7
Shallow Zone Total Chlorinated VOCs

Figure 1.8
Deep Zone Total Chlorinated VOCs

2.0 REMEDIAL TECHNOLOGY DESCRIPTION

2.1 Introduction

Anaerobic-aerobic sequential groundwater treatment also known as two-zone interception treatment is designed for enhanced in-situ bioremediation of chlorinated solvent contamination. The technology has been demonstrated as an Emerging Technology under the Superfund Innovative Technology Evaluation (SITE) Program by the U.S. Environmental Protection Agency (USEPA).

2.2 Theory

Most chlorinated solvents at contaminated groundwater sites are amenable to biodegradation. However, in contrast to petroleum hydrocarbons, chlorinated solvents are more sensitive to groundwater oxidation-reduction potentials (redox), availability of natural organic carbon or anthropogenic organic substrates (BTEX contamination or other man-made carbon sources), and natural groundwater electron acceptors such as dissolved oxygen, nitrate, sulfate, and carbon dioxide.

While petroleum hydrocarbons can serve as a primary organic substrate (food source that provides energy) or electron donor for microorganisms, chlorinated solvents - particularly the highly chlorinated solvents such as perchloroethylene (PCE) and trichloroethylene (TCE) - are not a direct food or energy source. PCE and TCE serve more as electron acceptors similar to the role played by oxygen, nitrate, sulfate, and carbon dioxide in BTEX or natural organic carbon degradation. In other words, anaerobic or reduced conditions (absence of dissolved oxygen) are more suitable to PCE and TCE degradation. Moreover, the more strongly reduced an aquifer is, the more readily PCE and TCE degrade.

The lesser chlorinated solvents such as 1,2-dichloroethylene (DCE) and vinyl chloride (VC) (which are the biodegradation breakdown products or daughter compounds of PCE and TCE) are more likely to serve as primary organic substrates or electron donors and are more amenable to biodegradation in the presence of oxygen.

2.3 Treatment Process

The anaerobic or aerobic state of the aquifer can be estimated from redox measurements. The lower the redox potential (measured in millivolts) of the aquifer the more anaerobic or strongly reducing the aquifer is. In general, redox potentials less than +50 millivolts represent anaerobic reducing conditions. If redox measurements in the vicinity of the PCE and TCE plume are greater than +50 millivolts, nutrients (nitrate and phosphate fertilizers) and substrate (organic carbon) can be added to increase biological respiration and drive the system into strongly anaerobic or reducing conditions. Generally, enough carbon is added to both create anaerobic conditions and be available as a food source during subsequent reductive degradation of highly chlorinated solvents such as PCE and TCE. Conversely, if redox measurements in the vicinity of DCE and VC are less than +50 millivolts, air sparging techniques can be used to increase oxygen availability and allow maximum biological consumption of substrates such as DCE and VC.

2.4 Methodology

By creating an anaerobic zone upgradient of an aerobic zone within a VOC contaminated groundwater plume, a sequential anaerobic-aerobic system is established that is capable of degrading PCE and TCE sequentially to innocuous gaseous end-products. Moreover, flow through these zones can be accelerated through the use of a low-flow extraction well placed downgradient of the aerobic zone and re-injection of pumped water upgradient of the anaerobic zone.

Anaerobic Zone

The creation of an anaerobic zone is achieved by pumping groundwater from downgradient extraction wells and amending the groundwater aboveground with carbon and other nutrients before reinjecting it into upgradient wells. The pumped groundwater is first sent to an aboveground chemical amendment system where carbon (sucrose) and nutrients (ammonium phosphate) are added. Amended groundwater is then reinjected into the aquifer. The amendments are designed to provide a ready food source which stimulates microbial respiration which in turn utilizes all available oxygen in the pumped groundwater. This recirculation process of extraction and re-injection continues until gradually an anaerobic zone is created in the vicinity of the re-injection wells. Highly chlorinated solvents such as PCE and TCE are amenable to reductive dechlorination (biological removal of the chlorine in these compounds) under anaerobic conditions. In other words, once the anaerobic zone is established, microorganisms will turn to sources other than oxygen, such as chlorinated VOCs, in order to complete respiration.

Aerobic Zone

Anaerobic reductive dechlorination results in the formation of lesser-chlorinated daughter products, namely 1,2, cis-DCE and VC. However these compounds breakdown more readily in an aerobic environment. Therefore, an aerobic zone is created in the vicinity of the downgradient extraction wells by injecting air into the aquifer via air sparging wells connected to an aboveground blower. The air sparging wells will be located about 100 feet downgradient of the re-injection wells. Air sparging is generally performed intermittently based on groundwater dissolved oxygen (DO) concentrations in area monitoring wells. If required, carbon and nutrients can also be added to the air sparging wells to enhance the aerobic degradation of 1,2, cis-DCE and VC. Aerobic degradation of VC results in the formation of innocuous gaseous end-products such as ethylene and ethane.

3.0 TREATABILITY STUDY OBJECTIVES

3.1 Primary Objectives

The main objective of performing this study is to determine the feasibility of using A-A sequencing to remediate the chlorinated VOC groundwater plume. Though this technology is based on fundamental microbial principles, it has been applied at only a few sites in the United States and is considered an innovative technology. Furthermore, this technology is easily enhanced or inhibited by inherent chemical, geological, and hydrogeological variabilities difficult to reproduce in a laboratory. Therefore, a field-scale treatability study is needed to assess its effectiveness at SWMU 166. Effectiveness will be assessed through periodic sampling and analysis of groundwater in the study area.

Generally, biologically augmented groundwater remediation systems take a few weeks to months to show response to treatment. The rate of remediation is dependent on site hydrogeology, type of contamination, and nutrient availability. If the proposed technology is viable, reductions in TCE and daughter breakdown compounds (1,2-DCE and VC) can be expected in a 2- to 6-month time frame. Therefore, the treatability study is expected to last about 4 months. Based on the progress of the study and chemical sampling results of TCE and its daughter breakdown compounds, the study could extend beyond four months until results are available to ascertain the feasibility of the technology. Study results will be used to compare this technology with other treatment alternatives in the CMS report and to provide cost and design data for full-scale implementation in the event this technology is selected as part of the final remedial alternative for this site.

3.2 Secondary Objectives

Secondary objectives of the treatability study include:

(a) the periodic measurement of field operating parameters and their evaluation. Field parameters (detailed in Section 7) include dissolved oxygen, pH, oxidation-reduction potential, heterotrophic plate counts, nutrients (nitrogen and phosphorus), and total organic carbon (TOC). Changes in values of these parameters (particularly dissolved oxygen) and the time period in which these changes occur will be noted. These measurements can be used to determine how effectively groundwater is being amended to obtain distinct anaerobic and aerobic zones that are required for chlorinated solvent degradation.

(b) the periodic measurement of groundwater extraction and re-injection rates and changes in groundwater levels in the area monitoring wells as a result of these operations. These measurements will help provide estimates of groundwater re-circulation patterns in the test area.

(c) the measurement of the amounts of carbon (and other nutrients) added to the extracted groundwater. Monitoring of the carbon amounts will aid in maintaining approximate stoichiometric mass balances of organic carbon in the aquifer.

(d) the monitoring of the blower and the times for which the blower is utilized for sparging air to create the downgradient aerobic zone. This information can be used to size blower requirements for full-scale remediation.

4.0 RECOMMENDATIONS FOR CONDUCTING THE AQUIFER PUMPING TEST

4.1 Introduction

The first step in the design process is to conduct an aquifer pumping test in the proposed AA_sequencing test area. The test will provide information needed to refine extraction, re-injection, and monitoring well placements and model the anticipated changes in head in the aquifer due to extraction/injection activities.

4.2 Well Installation

The dewatering test well will be installed in a boring drilled to a depth of about 25 feet to target the deeper zone of the aquifer just above the lower confining unit. The completed drill hole will have an outer diameter of 8 to 12 inches, and should be large enough to accommodate a 4-inch inside diameter (ID) well screen and standpipe. The well screen will consist of a 10-foot section of machine-slotted polyvinyl chloride (PVC) flush-joint casing, equipped with a solid cap at the bottom and a 7-foot (nominal) joint of solid PVC flush-joint casing above it, resulting in a stick-up of approximately 2-feet above the ground surface. The No. 20 slot screened section shall have a centralizer at the top and bottom. The annulus between the screen and the natural formation shall consist of Global™ No. 7 silica sand filter pack, or equivalent approved by the engineer. The sand pack shall extend 2 feet above the top of the screen, followed by a 1-foot layer of granular bentonite, followed by a 2-foot-thick seal of concrete at the ground surface.

After installation, the dewatering test well shall be thoroughly developed by the drill crew for at least 2 hours, using a combination of pumping, surging, and flushing with potable water. All residuals derived from drilling and developing the dewatering test well will be managed as hazardous waste. Development will be completed when the engineer has judged the well to be clean and hydraulically responsive. Short-term specific capacity and pumping rate information will be recorded to aid in design of the step test, using pumps provided by the drilling contractor.

Two nested piezometer pairs will be installed in boreholes 10 feet and 20 feet away from the dewatering test well and in line with the perimeter of the proposed dewatering system. Piezometer pairs will be screened from 7 to 10 feet and from 17 to 20 feet. The test borings will not be sampled, unless additional Shelby tube samples or driven (split spoon) samples are required for laboratory testing. The piezometers shall consist of 2-inch ID screen and flush-joint casing. The machine slot PVC screen shall have a No. 20 slot size and centralizers placed on the top and bottom of the screened section. Flush-joint PVC casing shall be installed above the screen and a solid cap placed at the bottom of the screen. The piezometers will be placed in holes no less than 6 inches in diameter. The annulus between the well screen and the formation shall be filled with Global™ No. 7 silica sand or approved equivalent to a level of 2 feet above the top of the screen, followed by a 1-foot layer of granular bentonite, followed by a grout seal to the ground surface.

After installation, piezometers shall be thoroughly developed by the drill crew for at least 1 hour each, using a combination of pumping, surging, and flushing with potable water. All residuals derived from drilling and developing the piezometers shall be managed as investigative derived waste.

4.3 Step Test

A step pumping test shall be performed in the dewatering test well to determine the following information.

- Safe yield for the constant rate test
- Specific capacity of the dewatering test well
- Well efficiency or "well loss" of the test well
- Responsiveness of the two piezometers to pumping at the dewatering test well

Using estimates of sustainable pumping rate acquired during the well development program, an appropriately size, electrically-powered pump will be used for the step pumping test. The expected short-term yield is 1 to 10 gallons per minute (gpm), but this could change depending on the water-bearing strata encountered. The pump shall be equipped with a discharge control valve capable of controlling the flow to accommodate the number of steps required. Typically, this will consist of three to five steps starting with the lowest flow rate and ending with the highest flow rate. Each flow rate is held constant for a period for 30 minutes and the water level is measured in the pumping well every 5 minutes. Water levels in the piezometers may be checked every 10 or 15 minutes.

At the end of each 30 minute step, the flow will be increased and the next step begun. The test will be completed when the maximum flow rate of the pump is reached or the water level in the dewatering test well falls below the level of the pump intake, whichever occurs first.

Since the same pump will probably be used for both the step test and the constant rate test, it will be appropriate to run the groundwater produced directory through a drum(s) of granular activated carbon (GAC), then discharge it into the sanitary sewer for disposal. A letter of authorization should be obtained from the local POTW before this test is begun and the drum(s) of GAC should be appropriately sized to accommodate the maximum flow rate anticipated. During the test, the actual flow rate should be determined using a calibrated 5-gallon bucket and stopwatch at the discharge of the GAC treatment unit, or a calibrated in-line water meter, or both.

4.4 Constant Rate Test

As soon as the step drawdown test is completed, the constant rate test can be set up by running the test pump and setting the discharge valve to the pumping rate that will be used for the constant rate test. Then the entire system will be shut down and allowed to reach hydraulic equilibrium at least overnight.

Pressure transducers shall then be placed in:

- The dewatering test well
- Both piezometers
- Selected monitor wells in close proximity to the test

The pressure transducers shall then be attached to data loggers and allowed to record tidal effects and antecedent water level trends for a period of at least 48 hours prior to the start of pumping.

Prior to the start of the constant rate test, the data loggers will all be reset to record the early data in a logarithmic sequence. When the test is begun, the pump will be turned on at its preset rate and the pumping rate checked periodically to make sure it is constant. Manual measurements will be recorded using electric water level indicators as a backup to the electronically recorded data.

While the constant rate test is in progress, water samples will be taken at 12-hour intervals from a sampling tap placed in the discharge line, before it reaches the drum of GAC. The samples will be tested for VOCs by United States Environmental Protection Agency (USEPA) Method 8260. Samples will also be collected at the discharge side of the GAC drum at 24-hour intervals and tested for VOCs in accordance with USEPA Method 8260.

Barring system difficulties or significant rainfall events, the constant rate test will run uninterrupted for a period of 48 to 72 hours. When the decision is made by the engineer or hydrogeologist to shut down the test, the data loggers will again be reset to start recording logarithmically when the pump is stopped to acquire the recovery data. The data loggers will continue to record water level data for at least 8-hours after the pump is turned off.

4.5 Engineering Design of the AA-Sequencing System

Results of the aquifer pumping tests will be analyzed to compute the distance-drawdown relationships necessary to establish parameters for design of the extraction and injection systems. As presently envisioned, the system will consist of 1 extraction well and 2 or 3 re-injection wells set 20 to 40 feet apart about 200 feet upgradient of the extraction well. Each well will be screened from about 20 to 30 feet bgs. Aquifer test results will be presented and used in the design document to estimate capture zones and re-injection mounding effects.

5.0 TREATABILITY SYSTEM SET-UP

5.1 System Elements

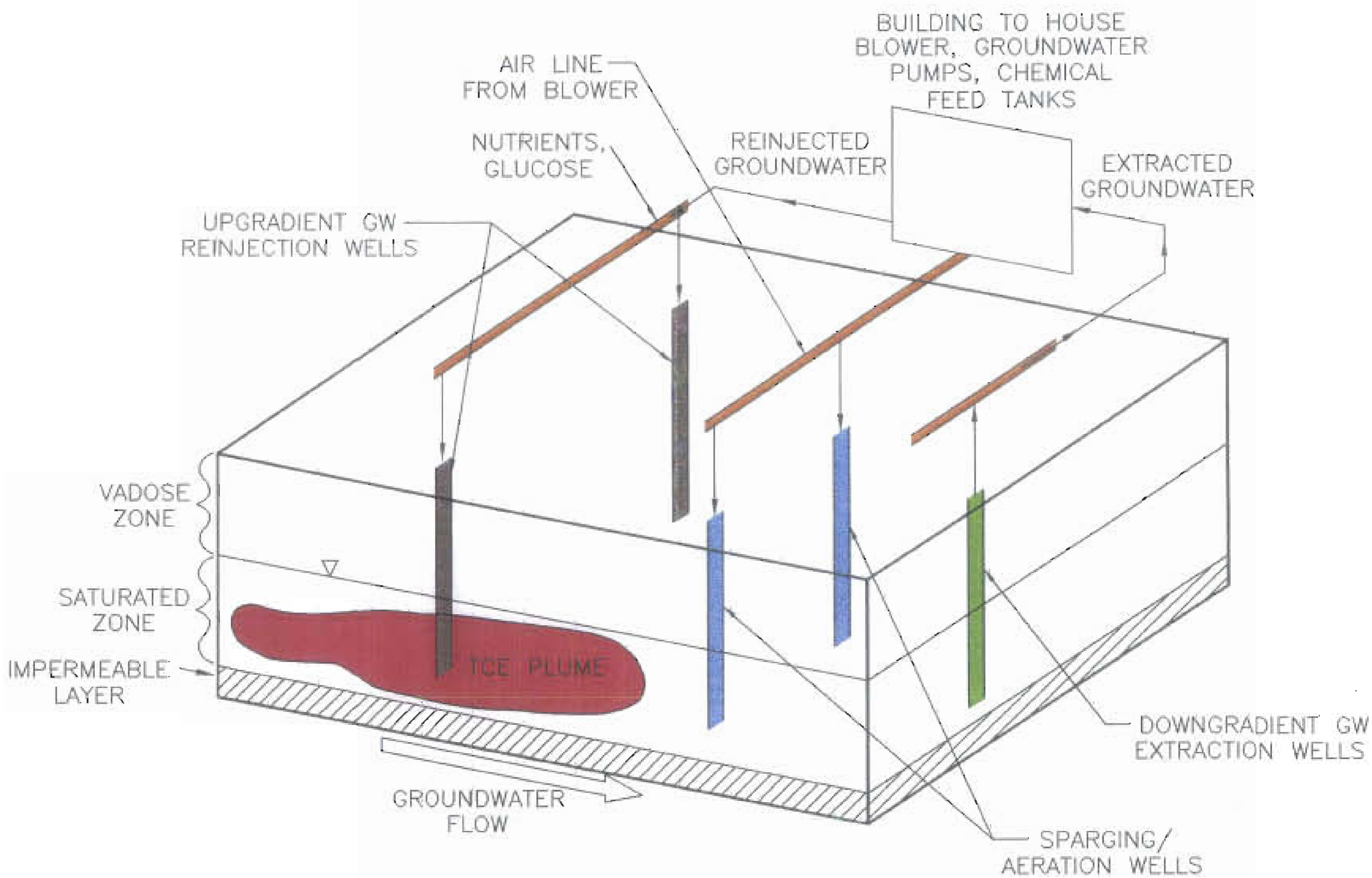
Figure 5.1 is a three-dimensional conceptual remedial technology schematic layout of a typical anaerobic-aerobic treatment system. The figure demonstrates the set-up of the treatability system. It includes the extraction wells, re-injection wells, the aboveground groundwater chemical amendment system, and the air sparging wells. The main features of the treatability system are described below.

Groundwater Extraction Well

The groundwater extraction well will be a 4-inch diameter stainless steel (SS) well screened in the deep saturated zone. It will be approximately 45 feet in depth with a 4-foot long SS screen at the bottom. The well will have a 5 gallon per minute (gpm) capacity submersible pump located at the depth of the screen and will be connected by a 1-inch black iron piping system to an aboveground chemical feed tank. A pressure transducer will be set in the bottom of the well to toggle the pump on and off to maintain an average drawdown in the well of 10 feet. Based on available hydrologic data, the drawdown should increase groundwater flow velocities in the study area to about 0.80 ft/day or about 300 ft/yr. However, data from a constant rate aquifer pumping test scheduled for January 1999 will be used to refine these estimates.

Groundwater Re-injection Wells

Water from the extraction well will be amended with nutrients and substrate in an above ground system. Amended water will then be re-injected into the aquifer via two, 45-foot deep, 2-inch diameter SS wells with a 4-foot long SS screen at the bottom in the saturated zone.



NOT TO SCALE

SWMU 166 AA SEQUENCING TREATABLITY STUDY WORK PLAN CHARLESTON NAVAL COMPLEX	FIGURE 5.1 CONCEPTUAL REMEDIAL TECHNOLOGY SCHEMATIC FOR ANAEROBIC-AEROBIC SEQUENTIAL GROUNDWATER TREATMENT SWMU 166
	DWG DATE: 03/05/99 DWG NAME: 2911G001

Groundwater Air Sparging Wells

Air will be injected via two, 45-foot deep, 2-inch diameter SS air sparging wells with 2-foot long screens at the bottom of the saturated zone. The wells will be located downgradient of the re-injection wells and upgradient of the extraction well.

Treatability Study Monitoring Wells

Two additional groundwater monitoring wells will be installed to monitor the progress of the treatability system. These wells will be approximately 45 feet in depth, 2-inch diameter SS wells and will have a 2-foot screen at the bottom in the saturated zone.

Groundwater Recirculation System

The groundwater recirculation system will be housed in a pre-fabricated 15-foot by 20-foot metal building. The recirculation system comprises a 200-gallon polyethylene tank with a 1-inch inlet at the top and a 1-inch outlet at the bottom. The inlet is connected to the groundwater extraction well and the outlet is connected to the re-injection wells by an aboveground piping network system. A pneumatic pump will be used to pump the extracted and amended groundwater from the polyethylene mixing tank into the re-injection wells. Two 1-gallon plastic drums will be used to prepare chemical feed solutions. The flow from the drums can be monitored through metering pumps.

Air Sparging System

A blower system will be installed in the building to supply air to the air sparging wells. The blower will be a 5-horsepower (hp), 15 pounds per square inch (psi) positive-displacement, sliding vane type system coupled to an electric motor with the capacity to supply up to 50 standard cubic feet per minute (scfm). It will be fitted with an air-pressure relief valve, a flow regulation control valve, temperature, pressure, and flow gages.

5.2 Study Area

RFI results show that chlorinated VOC contamination is concentrated primarily in the deeper zone of the surficial aquifer. The maximum total chlorinated VOC concentration in groundwater in the most recent round of sampling was 10,160 μg/L (9,700 μg/L TCE; 460 μg/L 1,2-DCE) in well 166GW26D. At that concentration, microbial degradation is only marginally feasible. However, downgradient and near the property line, total chlorinated VOCs begin to drop off to more feasible concentrations (2,400 μg/L TCE; 94 μg/L 1,2-DCE in well 166GW10D).

The absence of significant amounts of DCE and VC indicates that drops in TCE concentrations may be more attributable to diffusion and dilution rather than microbial degradation. This lack of microbial degradation of TCE may be due to a lack of required nutrients and substrate or an abundance of oxygen or other electron acceptors.

Because high concentrations near the source zone may inhibit microbial activity, and site conditions indicate that there is little microbial degradation currently occurring within the plume centerline, this treatability study will focus on the area near the property line where total chlorinated VOC concentration are expected to range from about 1,000 to 4,000 μg/L. Study area length in the direction of groundwater flow will be about 200 feet, and study area width will be about 100 feet. Figure 5.2 shows the approximate location of the proposed wells.

Figure 5.2
Proposed Treatability System Layout
March 1999

6.0 TREATABILITY SYSTEM DESIGN WORK PLAN

6.1 Plans and Specifications Design Document Outline

The plans and specifications design document will include the following sections:

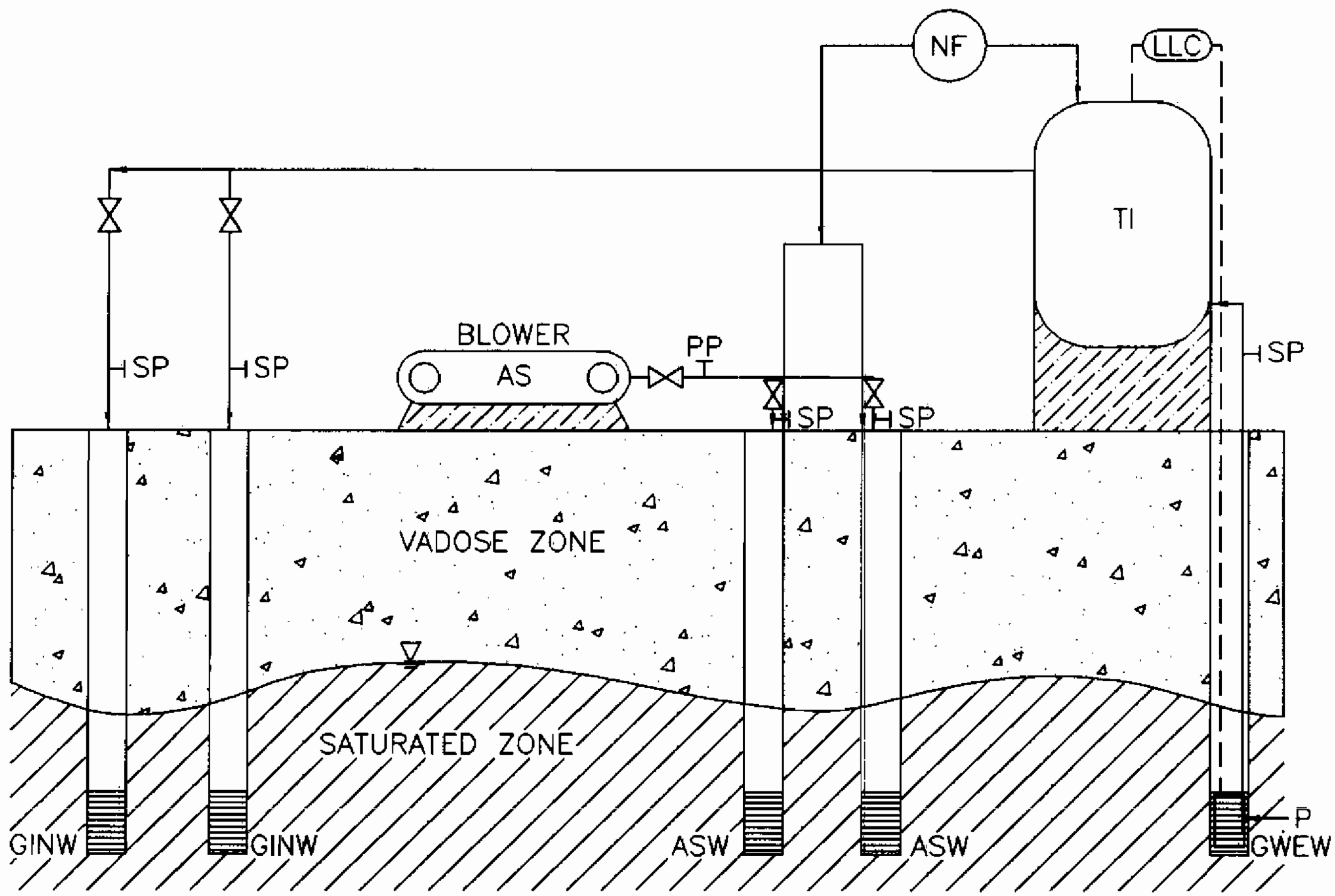
- Electrical
- Concrete
- Steel
- Piping
- Pumps
- Above-ground chemical amendment system
- Blowers
- Instrumentation information
- Drawings

    a. Process and Instrumentation Drawing (P&ID)
    b. P&ID Symbol Sheet
    c. Layout Drawing (Equipment)

A conceptual process flow diagram of the remedial system is shown in Figure 6.1. A detailed drawing will be provided in the design document.

6.2 Well Construction

Typical air sparging, extraction, injection, and monitoring wells for anaerobic-aerobic sequential treatment are illustrated in Figure 6.2. Well construction details including borehole diameter, filter pack, casing and screen specifications, and wellhead completion requirements will be detailed in the system design document.



LEGEND

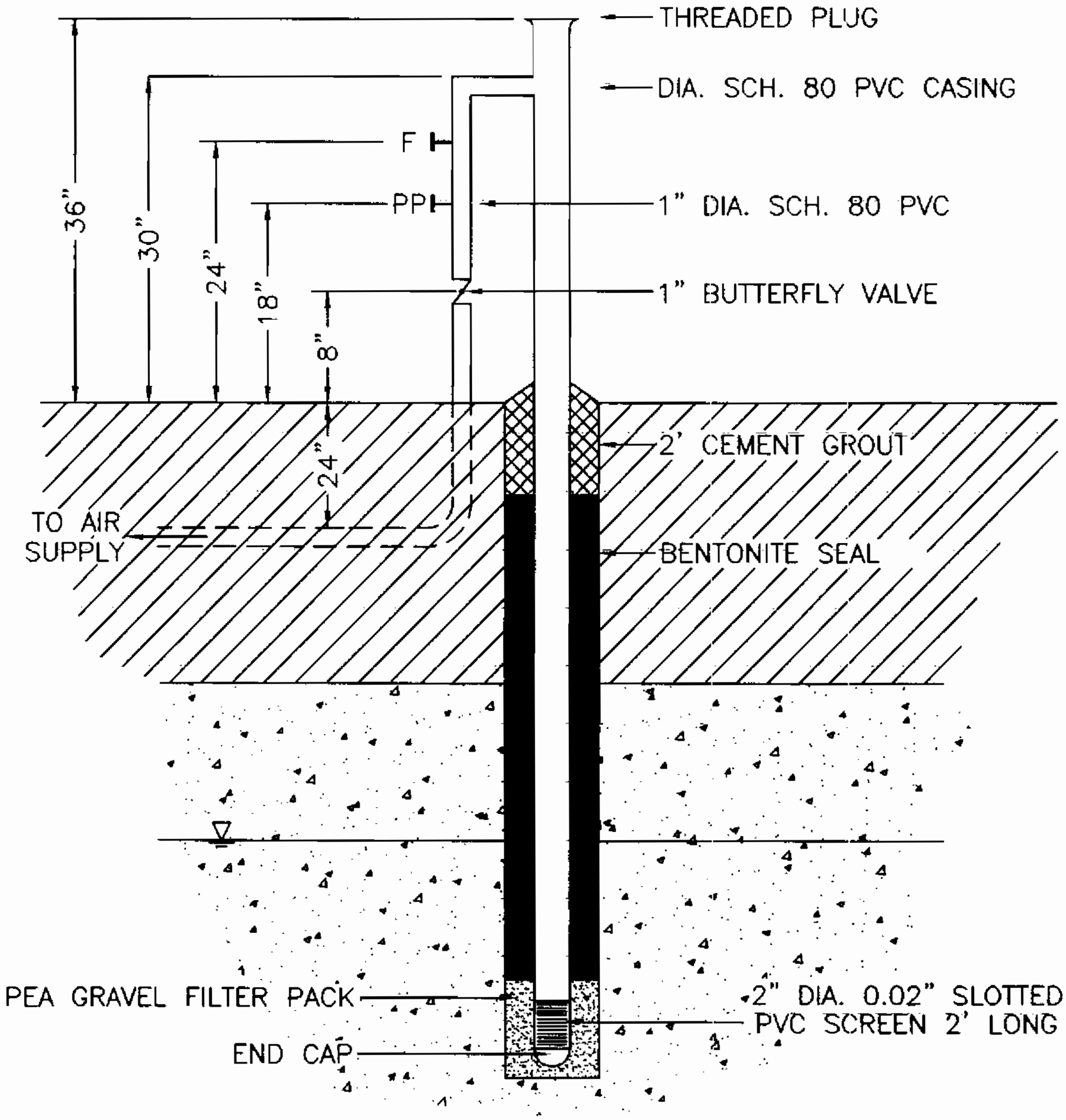
⋈	VALVE
PP	PRESSURE PORT
SP	SAMPLE PORT
TI	RECIRCULATION TANK
NF	NUTRIENT FEED SYSTEM
LLC	LIQUID LEVEL CONTROLLER
AS	AIR SPARGING SYSTEM
ASW	AIR SPARGING WELL
GWEW	GROUNDWATER EXTRACTION WELL
GINW	GROUNDWATER INJECTION WELL
P	PUMP

NOT TO SCALE

SWMU 166 AA
SEQUENCING TREATABLITY
STUDY WORK PLAN
CHARLESTON
NAVAL COMPLEX

FIGURE 6.1
CONCEPTUAL PROCESS FLOW DIAGRAM
FOR ANAEROBIC–AEROBIC SEQUENTIAL
GROUNDWATER TREATMENT
SWMU 166

DWG DATE: 03/05/99 | DWG NAME: 2911G002



F: FLOW METER
PP: PRESSURE PORT

NOT TO SCALE

SWMU 166 AA SEQUENCING TREATABLITY STUDY WORK PLAN CHARLESTON NAVAL COMPLEX	FIGURE 6.2 TYPICAL AIR SPARGING, EXTRACTION, INJECTION, AND MONITORING WELLS FOR ANAEROBIC–AEROBIC SEQUENTIAL TREATMENT SWMU 166
	DWG DATE: 03/05/99 DWG NAME: 2911G003

6.3 Blower System

A blower will be required to supply air to sparging wells in the aerobic treatment zone. It will be designed to supply air at a flow of 10 to 15 standard cubic feet per minute (scfm) per well and a maximum pressure of 15 pounds per square inch (psi). Detail specifications along with installation and design parameters will be provided in the design plan and specification document.

Mechanical Equipment for Blower

Mechanical equipment consists of the following:

- Blower system capable of producing 15 psig (less system and piping losses). Blower will be equipped with at least the following:
  - 460/3/60 TEFC motor
  - V-belt drive
  - OSHA-approved belt guard
  - Blower and motor stand
- Pressure relief valve operating at 15 psig.
- Inlet filter to remove 97 % to 98 % of particles measuring to 8 to 10 microns or larger, and sized to minimize performance losses and filter maintenance.
- Discharge silencer.
- System skid — the system skid will be constructed from structural carbon steel and coated with enamel paint.

- Pressure gage mounted on the blower discharge and air flow monitoring assembly consisting of an air flow indicator and pressure gage calibrated in scfm for air flow monitoring.

Air Temperature at Operating Conditions

- Inlet air temperature (68°F assumed)
- Air temperature rise through the blower (224° F)
- Discharge temperature (292° F)

6.4 Piping and Pump Systems

Black iron piping for the air sparging system will be installed to 10 feet from the outlet of the blower to account for heat from the injection air. The remainder of the supply and return piping to the well will be Schedule 80 PVC. Piping is to be set 12 to 18 inches below ground surface. Detailed piping specifications will be provided in the document.

The groundwater pump(s) shall be of the submersible type with an integrated motor and pumping unit (pneumatic and/or electric). The pump will include a liquid level controller. Pump construction, impeller, volute, seal shaft, bearing, motor, and cable will be specified in the design document.

6.5 Electric System

The selected electrical contractor will provide three phase, 46-volt, 60 Hz electric power for the operation of the air sparging system, as necessary. The electrical contractor will provide labor and materials for wiring conduit, switches, meters, and control as necessary. All electrical service, wiring, switches, controls, and connections will conform to the local and National Electric Code.

7.0 SYSTEMS OPERATION AND MAINTENANCE

EnSafe will provide personnel to monitor the operation and maintenance of the anaerobic-aerobic sequential treatment system test. Prior to treatability study commencement, an operations and maintenance (O&M) manual will be provided along with a schedule for monitoring and maintenance operations, sampling, and field forms for data recording. The O&M manual will further be described in the design and specifications document.

Monitoring should consist of general upkeep of the blowers, pumps, controllers, wells, piping, and other system equipment. Maintenance procedures and schedules for the blower and pump will also be presented in the O&M manual which will be provided prior to system startup.

7.1 Permit Requirements

The permits required to perform this treatability study are summarized in Table 7.1.

Table 7.1
Treatability Study Permit Summary

Task	Permit Required	Agency/Contact
Well Installation	Well Construction Permits	SCDHEC/ Paul Bergstrand
Aquifer Test	Sewer Use Agreement	North Charleston Sewer District / Kelly Singer
Above-ground Groundwater Amendment System	Construction Permit Application - Water and/or Wastewater Facilities, DHEC Form 1970 (01/1998)	SCDHEC / Marion Sadler
Groundwater Re-injection	Underground Injection Control Permit Application, DHEC Form 2502 (08/1997)	SCDHEC / Robert Devlin

7.2 IDW Management

Soils and groundwater generated during drilling activities and other investigative derived waste (IDW) will be disposed of in accordance with the IDW Management Plan presented in the Comprehensive RFI Work Plan for the Charleston Naval Complex.

8.0 EFFECTIVENESS MONITORING AND SAMPLING

Treatability system monitoring and sampling will be performed to measure or estimate the effectiveness of the treatment technology and develop scale-up factors for the design and cost of full-scale remediation. Monitoring will include field monitoring and analytical sampling.

8.1 Field Monitoring

Groundwater

Groundwater wells in the test area will be monitored on a weekly basis for significant field parameters. If required, some parameters such as dissolved oxygen (DO) may be measured more frequently for better control of the system. Wells to be monitored include the extraction well, re-injection wells, air sparging wells, treatability study monitoring wells, and the permanent monitoring wells located within the area of influence of the treatability system. The field parameters to be monitored include:

- Water Levels
- Dissolved Oxygen (DO)
- Carbon Dioxide
- pH
- Oxidation-reduction (Redox) Potential

Standard field meters and instruments will be used to make these measurements. The instruments will be calibrated in accordance with their manufacturer's instructions. Measurements will be recorded in field data monitoring sheets.

Blower

Blower operating parameters - air flow, pressure, and temperature - will be measured and recorded on field data sheets on a weekly basis. Adjustments to system flow will be made based on these measurements and system effectiveness.

Chemical Feed System

The metering pumps at the chemical feed tanks will be monitored weekly and readings recorded on field data sheets. The pumps will be adjusted if higher amounts of chemicals (carbon and/or nutrients) are required. Groundwater extraction and re-injection rates will also be measured or estimated, and readings recorded.

8.2 Analytical Sampling

Groundwater samples will be collected from area wells and analyzed for chemical and microbial data (Table 8.1). All sampling will be performed in accordance with the Quality Assurance Project Plan (QAPP) and the Sampling and Analysis Program (SAP) developed as part of the RFI for this site and as referred to in the Comprehensive CMS Work and Project Management Plans (EnSafe, 1997). Samples to be analyzed will be sent to the site-wide selected contracted laboratory. Analytical work on 10% of the samples submitted will be performed to CLP Level IV standards with the remainder at CLP Level III standards, all at standard turnaround times.

Table 8.1
Groundwater Sampling Protocol

Analyte	Analytical Method	Wells to be sampled	Sampling Frequency
Volatile Organic Compounds (VOCs)	SW 8260	Extraction well (1), re-injection wells (2), treatability study monitoring wells (2), and existing area monitoring wells (3)*	Before commencement of study; one month and two months after treatability system operation; at the end of the study**
Metals	Method 6010/7000	Groundwater extraction well (1), reinjection wells (2), and sparging wells (2)	After one month of treatability system operation

Table 8.1
Groundwater Sampling Protocol

Analyte	Analytical Method	Wells to be sampled	Sampling Frequency
Total Kjeldahl Nitrogen (TKN)	351.1 - 351.4	Groundwater extraction well (1), reinjection wells (2), and treatability study monitoring wells (2), and existing area monitoring wells (3)	Before commencement of study, one month and 3 months after system operation.
Ammonia-nitrogen	350.1		
Total Phosphorus	365.4		
Orthophosphate	365.2 - 365.3		
Nitrate-nitrogen	352.1		
Total Organic Carbon (TOC)	415.1		
Chloride	325.3		
Total Heterotrophic Counts	9215B		

Notes:

* The list of existing monitoring wells that will be sampled will be based on the final location of the extraction, reinjection, and sparging wells. The design plan will list existing wells to be sampled.

** Based on VOC sampling results, the study could be extended beyond four months. In this case, the number of sampling events would also increase from four to the desired number of events until the treatability study is completed.

9.0 TREATABILITY SYSTEM EVALUATION

Groundwater analytical results will be evaluated to estimate the effectiveness of the anaerobic-aerobic technology and its potential application to full-scale site remediation.

(i) Graphs of chlorinated VOC concentrations will be plotted against time to evaluate changes in TCE concentrations and its daughter products (1,2-DCE and VC). Graphs will provide a visual indication of the rate of degradation of TCE and the rate of formation and breakdown of 1,2-DCE and VC. Graphs also provide information on the rate of initial breakdown versus the rate of breakdown at the end of the treatability study and whether the degradation is linear or non-linear. Graphs will also provide an indication of the relative degradation at different locations in the test area, i.e. degradation in upgradient locations versus degradation in downgrading locations of the test area.

(ii) Changes in VOC concentrations over time will be used to estimate field degradation rates or kinetic rates of microbial degradation. These degradation rates will be useful in predicting time for remediation to cleanup levels. Depending on the nature of degradation, a first-order (non-linear) or zero-order (linear) model can be used to estimate degradation rates.

(iii) Historical site VOC concentrations in groundwater and the VOC concentrations measured during the treatability study can be used to estimate the amount or the fraction of the original contaminant that is remediated during the test. This mass balance calculation can be used to estimate the efficiency of removal and to predict the potential amount that can be remediated using this technology.

(iv) Chloride is generally considered to be a conservative breakdown product of TCE degradation. Increases in chloride concentration in the aquifer over time can be stoichiometrically related to the original TCE concentrations to provide an estimate of the fraction of the contaminant remediated during the treatability study.

(v) Groundwater monitoring parameters, namely DO, CO_2, and redox potential will be plotted over time to determine how the applied treatment technology effects these parameters. These parameters are closely influenced by and in turn influence chlorinated solvent degradation. Changes in these parameters over time will reflect the attainment and delineation of anaerobic and aerobic zones within the aquifer. Contours or isoconcentration maps of these parameters in the test area will also be plotted to delineate anaerobic and aerobic zones and study changes over time.

(vi) Measurement of carbon quantities fed into the reinjection wells, TOC measurements and reductions in these measurements in the wells will be used as an indirect indication of microbial activity.

(vii) Nutrient concentrations (nitrogen and phosphorus) and depletion or uptake during the treatability study will provide an indirect indication of microbial activity. Nutrients also are generally analyzed at the beginning and intermediate points with the sole purpose of ensuring that they don't reduce to levels that limit or inhibit biological activity. Nutrient data will be suitably mapped or plotted as required to depict their uptake.

(viii) Total heterotrophic plate counts indicate the number of microorganisms present in the aquifer and are expressed as colony forming units (CFUs) per milliliter (ml) of groundwater. These numbers generally range anywhere from 10^2 to 10^7 per ml, with the higher numbers indicating strong microbial activity and consequently better potential for biodegradation. Total groundwater heterotrophic counts from individual wells will be tabulated and the numbers compared to provide a relative indication of microbial activity. If required, total heterotrophic counts will be suitably plotted to depict microbial activity.

10.0 SCHEDULE AND REPORTING

10.1 Schedule

Following submission and approval of the treatability study work plan and a subsequent aquifer test, a design and specifications document will be completed and the system will be installed. The schedule for installing and constructing, implementing and completing the study is shown in Figure 10.1 The schedule is subject to minor variations depending on equipment availability, unexpected weather conditions, unforeseen site conditions and degradation progress during operations. It is expected that the treatability study results and report will be completed in September 1999.

10.2 Reporting

The treatability study results and evaluation will be summarized in a report after field studies are completed. The report will meet the applicable requirements as stated in the Comprehensive CMS WP and PMP, and it will include an engineering analysis of the feasibility of treating chlorinated solvents at SWMU 166 by sequential anaerobic-aerobic technology. The report will include a complete chronology of activities performed onsite and tabulation of the performance monitoring data. It will include estimates of the mass of chlorinated solvent treated, and an analysis of the length of time and cost required to meet the goals of full-scale treatment. The operating and design criteria required for full-scale treatment of the aquifer at SWMU 166 will be presented.

Table 10.1 Treatability Study Schedule

11.0 REFERENCES

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