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INTERIM MEASURE WORK PLAN SOLID WASTE MANAGEMENT UNIT 166 (SWMU 166)
ZONE K CNC CHARLESTON SC
1/16/2002
CH2M HILL

INTERIM MEASURE WORK PLAN

SWMU 166. Zone K

Charleston Naval Complex
North Charleston, South Carolina

SUBMITTED TO
U.S. Navy Southern Division
Naval Facilities Engineering Command

CH2M-Jones

January 2002

Contract N62467-99-C-0960

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CH2MHILL

January 16, 2002

Mr. David Scaturo
Division of Hazardous and Infectious Wastes
South Carolina Department of Health and
Environmental Control
Bureau of Land and Waste Management
2600 Bull Street
Columbia, SC 29201

Re: Interim Measure Work Plan (Revision 0) – SWMU 166, Zone K

Dear Mr. Scaturo:

Enclosed please find four copies of the Interim Measure Work Plan (Revision 0) for SWMU 166 in Zone K of the Charleston Naval Complex (CNC). This report has been prepared pursuant to agreements by the CNC BRAC Cleanup Team for completing the RCRA Corrective Action process.

The principal author of this document is Sam Naik. Please contact him at 770/604-9182, extension 255, if you have any questions or comments.

Sincerely,

CH2M HILL

Dean Williamson, P.E.

cc: ✓Rob Harrell/Navy, w/att
Gary Foster/CH2M HILL, w/att

INTERIM MEASURE WORK PLAN

SWMU 166, Zone K

Charleston Naval Complex
North Charleston, South Carolina

SUBMITTED TO
U.S. Navy Southern Division
Naval Facilities Engineering Command

PREPARED BY
CH2M-Jones

January 2002

Revision 0
Contract N62467-99-C-0960
158814.ZK.PR.07

Certification Page for Interim Measure Work Plan (Revision 0) – SWMU 166, Zone K

I, Dean Williamson, certify that this report has been prepared under my direct supervision. The data and information are, to the best of my knowledge, accurate and correct, and the report has been prepared in accordance with current standards of practice for engineering.

South Carolina

P.E. No. 21428

Dean Williamson, P.E.

1/3/2002

Date

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Acronyms and Abbreviations

ASR	aquifer storage and recovery
BCT	BRAC Cleanup Team
BEQ	benzo(a)pyrene equivalent
BRAC	Base Realignment and Closure Act
BRC	background reference concentration
BTEX	benzene, toluene, ethylbenzene, and xylene
CMS	corrective measures study
CNC	Charleston Naval Complex
COC	contaminant of concern
COPC	contaminant of potential concern
CSI	Corrective Study Investigation
CVOC	chlorinated volatile organic compound
DAF	dilution attenuation factor
DO	dissolved oxygen
ECD	electron capture detector
EnSafe	EnSafe Inc.
EPA	U.S. Environmental Protection Agency
ft bls	feet below land surface
IDW	investigation-derived waste
IM	interim measure
IMWP	interim measure work plan
MCL	maximum contaminant level
MIP	Membrane Interface Probe
MNA	Monitored Natural Attenuation
MSDS	Material Safety Data Sheet
msl	mean sea level
$\mu g/kg$	micrograms per kilogram
$\mu g/L$	micrograms per liter

Acronyms and Abbreviations

mg/kg	milligrams per kilogram
mg/L	milligrams per liter
NAVBASE	Naval Base
ORP	oxidation-reduction potential
PCE	tetrachloroethene
PF	Pneumatic Fracturing
PID	photoionization detector
PPE	personal protective equipment
psig	pounds per square inch per gauge
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
ROI	radius of influence
SCDHEC	South Carolina Department of Health and Environmental Control
SSL	soil screening level
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TCE	trichloroethene
TTA	target treatment area
TTI	targeted treatment intervals
UIC	underground injection control
VOC	volatile organic compound
ZVI	zero-valent iron

Section 1.0

1.0 Introduction

1.1 Purpose and Objectives of the Interim Measure Work Plan

This Interim Measure Work Plan (IMWP) has been prepared by CH2M-Jones to document the basis for an Interim Measure (IM) at Solid Waste Management Unit (SWMU) 166 and downgradient areas within Zone K (the former Naval Annex) of the CNC. The location of SWMU 166 within the CNC is presented in Figure 1-1.

The goal of this IM is to remediate the groundwater contamination source areas near SWMU 166, which are contaminated primarily with trichloroethene (TCE). Low levels of 1,2-Dichloroethene (1,2-DCE) were also found in some of the areas targeted for treatment as part of this IM, and one area in SWMU 163 showed detections of low levels of tetrachloroethene (PCE). The areas contaminated with TCE include SWMU 163, the former automobile service rack (ASR) area at SWMU 166, and the areas that are downgradient from SWMU 166 extending to the eastern boundary of the Naval Annex. For brevity, the term "SWMU 166" will be used in this document to refer to all areas being targeted for subsurface treatment by this IMWP, although several of these areas fall outside the original footprint of the SWMU 166 boundary indicated in the *Zone K RCRA Facility Investigation Report, Revision 0* (EnSafe Inc. [EnSafe], 1999a). Figure 1-2 shows an infrared aerial photograph of Zone K, including SWMU 166.

The IM will include a pilot study at one of the eight TTAs to optimize the effectiveness of zero-valent iron (ZVI) in reducing the elevated concentrations of TCE in groundwater at the SWMU 166 area in Zone K. The pilot study results will be used to determine optimum treatment parameters for the remaining seven TTAs.

This IMWP describes the general technical approach and procedures employed during the introduction of ZVI into the subsurface both during the pilot study and the subsequent full-scale remediation. Minor variations to the technical approach and procedures outlined in this IMWP may be warranted based on an evaluation of the pilot study results. These variations, if any, and the reasons for such variations will be documented in an IMWP addendum and submitted to South Carolina Department of Health and Environmental Control (SCDHEC) for review following the pilot study and prior to implementation of the full-scale remediation.

Remediation of the source areas is not necessarily intended to be the final remedy for the SWMU 166 area. However, abatement of the source areas is expected to be compatible with the final remedy selected for SWMU 166.

After completion of the pilot study at this site, the RCRA Corrective Measures Study (CMS) process will be followed to identify appropriate final remedial measures for SWMU 166, should additional corrective action be necessary.

1.2 Organization of the IMWP

This IMWP consists of the following sections, including this introductory section:

1.0 Introduction – Presents the purpose of the work plan and background information related to the proposed investigation.

2.0 Site Background and Previous Investigations – Provides the site background and a brief summary of previous investigations.

3.0 Technical Approach – Describes the rationale behind TTA delineation, the selected treatment technology, and the technical approach for completing the pilot study and subsequent full-scale remediation at SWMU 166.

4.0 Investigation-Derived Waste – Describes the procedures to be implemented for management of the investigation-derived waste (IDW).

5.0 Project Schedule – Provides a detailed outline of the schedule to be implemented during the pilot study.

6.0 References – Lists the references used in this document.

Appendix A – Includes Figure 2.5 of the *Zone K RCRA Facility Investigation Report, Revision 0* (EnSafe, 1999a), depicting the lithological cross section for SWMU 166.

Appendix B – Contains a material safety data sheet (MSDS) for the ZVI powder, which will be used in the pilot study and subsequent full-scale remediation.

All tables and figures appear at the end of their respective sections.

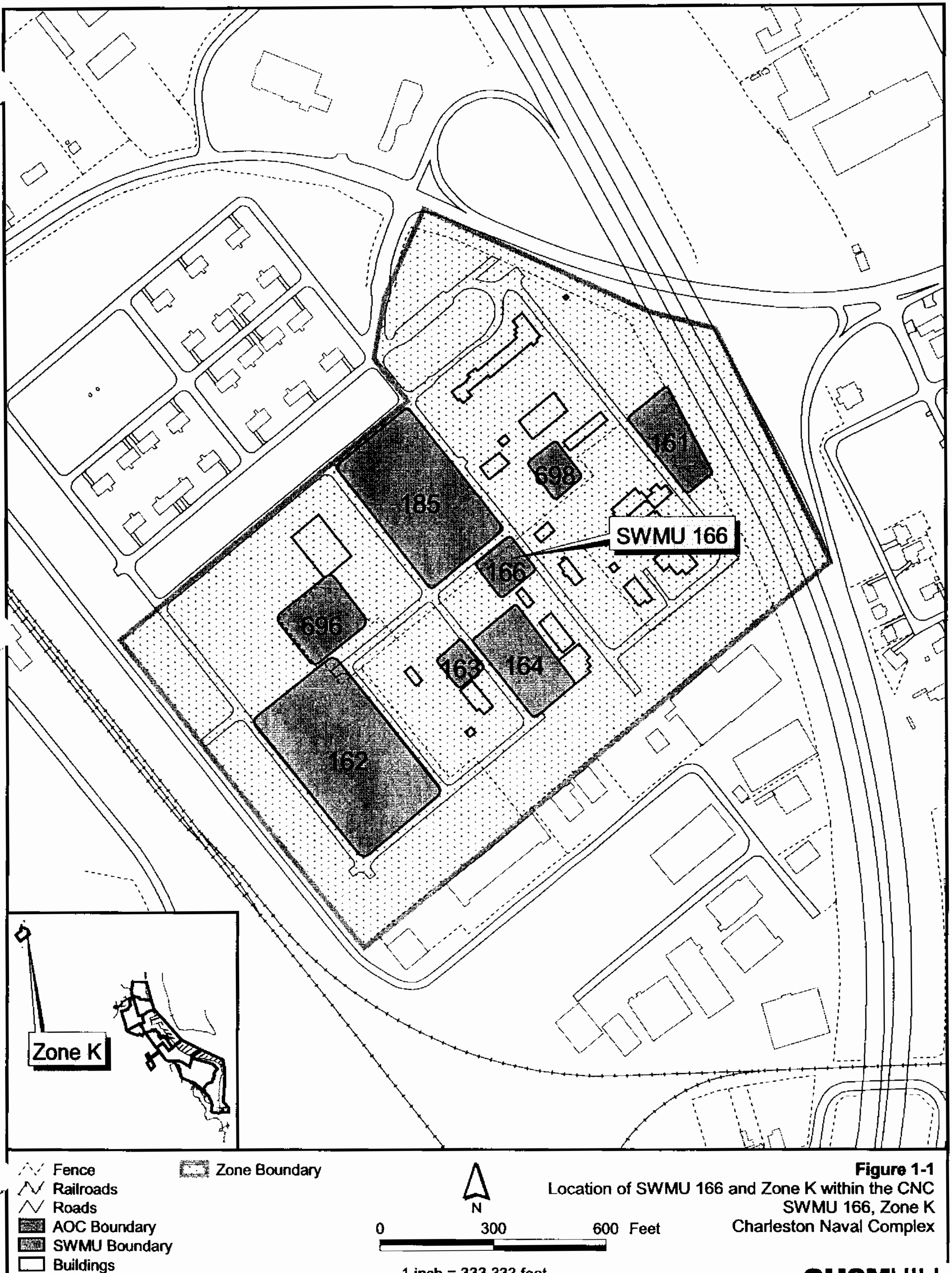

Figure 1-1
Location of SWMU 166 and Zone K within the CNC
SWMU 166, Zone K
Charleston Naval Complex

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NOTE: Aerial Photo Date is 1997
NOTE: Original figure created in color

Figure 1-2
Site Location Map
SWMU 166, Zone K
Charleston Naval Complex

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File Path: C:\18gis\Projects\Zone_K\Swmu_166\Aprs\swmu166.apr, Date: 06 Dec 2001 7:08, User: NMOUDRY, Figure 1-2 Site Location Map

Section 2.0

2.0 Site Background and Previous Investigations

This section provides a brief description of site background and previous investigations. Descriptions of site background and previous investigations are provided in greater detail in the *Zone K RFI Report, Revision 0* (EnSafe, 1999a) and the *RFI Report Addendum, SWMU 166, Zone K, Revision 0* (CH2M-Jones, 2002a).

2.1 Site Background

SWMU 166, located in Zone K at the CNC Naval Annex, includes areas west of Avenue B and south of Fifth Street to just east of Interstate 26. Prior to 1941, the Naval Annex area consisted of open spaces and forested areas. The Naval Annex is a flat-lying area, approximately 40 feet above mean sea level (msl). During World War II, the Naval Annex was owned by the Air Force and was the location of a weather forecasting facility. In 1954 the Naval Annex was turned over to the 792nd Squadron of the Tactical Air Command. From 1954 to 1981 the facility was used as an operating radar system. In 1981, the radar station was dismantled and the Naval Annex was acquired by Naval Station Charleston. Mobile Mine Assembly Group 11 assumed operations at that time. The U.S. Marine Corps currently uses most areas of the Naval Annex as a reserve training center, with administrative and classroom-type buildings and a heavy vehicle storage and maintenance/small repair facility.

SWMU 166 includes a former ASR area which is unpaved and located at the southwest corner of the intersection of Avenue B and Fifth Street immediately north of Building 22. The former ASR area was identified in the *Zone K RFI Report, Revision 0* (EnSafe, 1999a) as the suspected source area for chlorinated volatile organic compounds (CVOCs) in groundwater at SWMU 166. During a November 1996 groundwater screening sampling event performed for SWMU 185 at Zone K, one sample contained TCE at a concentration of 53 micrograms per liter (µg/L). This sample which was collected from the shallow aquifer at approximately 10 feet below land surface (ft bls) initiated additional RFI field activities to delineate the extent of chlorinated solvent contamination in the area.

2.2 Site Geology and Hydrogeology

A detailed description of site geology and hydrogeology are summarized in Section 2 of the *Zone K RFI Report, Revision 0* (EnSafe, 1999a). Three primary lithological units were identified during the RFI monitoring well installation activities. The uppermost lithologic unit, Quaternary Sand (Qs), is primarily clean, well-sorted, fine-to-medium grained sand and is 20 to 25 feet in thickness. Shallow wells installed at the Naval Annex are screened within the Qs unit. Below the Qs unit is another sand unit, the Quaternary clayey sand (Qcs), which is made up of fine-to-medium grained sand with silt, clay lenses, with trace phosphatic nodules and shell hash. The Qcs unit is approximately 10 feet in thickness. The deep wells installed at the Naval Annex are primarily screened within the Qcs unit. Lithostratigraphic cross sections and groundwater flow paths for SWMU 166 are presented on Figure 2.5 of the *Zone K RFI Report, Revision 0* (EnSafe, 1999a). This figure is presented in Appendix A.

The Ashley Formation (Ta) underlies Qcs throughout the region, as well as the Naval Annex, and is a tight, slightly calcareous, clayey silt with varying amounts of fine-grained sand which decreases rapidly with depth. The Ashley Formation is firm to stiff and low in plasticity. The elevation of the Ashley Formation ranges from 9.9 feet msl at 1660GW9D to 3.2 feet msl at 166GW05D. A structural contour map of the top of the Ashley Formation is provided as Figure 2-1.

Groundwater elevations at SWMU 166 vary seasonally, ranging from 5 to 7 ft bls. Shallow and deep groundwater at SWMU 166 flows east toward Interstate 26. The Interstate 26 corridor is believed to represent a potentiometric low due to groundwater discharge into a French drain beneath the highway. Figures 2-2 and 2-3 present a potentiometric surface map of the shallow and deep zones of the aquifer at Zone K, using groundwater elevation data collected in July 2000.

2.3 Previous Investigations

2.3.1 Initial and Supplemental RCRA Facility Investigations (RFI)

The initial RFI activities at Zone K were conducted by the Navy/EnSafe team between March 1997 and August 1998. These activities are described in detail in the *Zone K RFI Report, Revision 0* (EnSafe, 1999a) which presents the results of the soil, sanitary sewer system, and groundwater investigations, as well as conclusions concerning site geology, soil and groundwater contamination, and risk from site constituents. Supplemental RFI investigations conducted after August 1998 are described in more detail in the *RFI Report Addendum, Revision 0* (CH2M-Jones, 2002a).

The soil investigations described below are specific to the ASR area, whereas the groundwater investigations described below summarize investigative activities that include the rest of the SWMU 166 investigations. Soil investigations conducted at other AOCs/SWMUs within Zone K are described in other site-specific reports that were submitted separately.

2.3.1.1 RFI Soil Investigations

As part of the original RFI field investigations, surface and subsurface soil samples were collected from 16 soil sample locations in the ASR area and identified as ASRSB001 through ASRSB016. Surface and subsurface soil samples were analyzed for volatile organic compounds (VOCs) only. RFI soil boring locations at SWMU 166 are shown in Figure 2-4.

In surface soil samples (depth interval of 0 to 1 ft bls), TCE was detected in 14 of the 16 samples at concentrations ranging from 2 to 59,000 micrograms per kilogram (μg/kg). Only one sample showed a TCE concentration of 59,000 μg/kg at ASRSB007, which is above the U.S. Environmental Protection Agency (EPA) Region III residential risk-based concentration (RBC) of 58,000 μg/kg. No other VOCs were detected above the laboratory method detection limits in the 16 surface soil samples. The RFI identified TCE as a chemical of potential concern (COPC) in the surface soil at SWMU 166.

In subsurface soils (depth interval 3 to 5 ft bls), TCE was detected in two samples from boring locations ASRSB006 (at 65 μg/kg) and ASRSB007 (at 1,800 μg/kg) at concentrations above the soil screening level (SSL) of 30 μg/kg. The RFI adopted the SSLs from the *EPA Soil Screening Guidance: Technical Background Document* (1996), using a dilution attenuation factor (DAF)=10 for comparison with TCE concentrations detected in soil. Additionally, PCE and 1,1,2,2-tetrachloroethane were detected in the subsurface soil sample at boring location ASRSB007 at concentrations of 150 μg/kg and 5 μg/kg, respectively, above their corresponding SSLs. No other VOCs were detected above their corresponding SSLs in the 16 subsurface soil samples.

The risk assessment conducted during the initial RFI concluded that TCE was the sole chemical of concern (COC) in the surface soil and that there were no COCs in the subsurface soils.

TCE-impacted soils were removed as part of an IM conducted by the Navy DET during September-October 1998. During this IM, 905 tons of TCE-impacted soil were removed from the ASR area of SWMU 166, thereby removing a TCE source in the vadose zone soils at this area. Details of this IM effort are described in greater detail in the *RFI Report Addendum, Revision 0* (CH2M-Jones, 2002a). Additional RFI investigations conducted after the conclusion of the initial RFI efforts in August 1998 focused on further delineation of TCE contamination in groundwater in downgradient areas of Zone K.

2.3.1.2 RFI Groundwater Investigations

During the initial RFI, groundwater samples were collected from 72 direct push technology (DPT) borings. These samples were collected to characterize the lateral and vertical extent of TCE contamination in the shallow and deep aquifers at SWMU 166. Groundwater samples were collected from three depth intervals in the saturated zone: the shallow interval (approximately 8 to 11 ft bls), the intermediate interval (22 to 26 ft bls), and the deep interval (33 to 36 ft bls).

The RFI did not compare detected VOC concentrations from the DPT investigations against screening criteria, but the information was used to identify areas of elevated VOC concentrations and to direct the locations for installing permanent monitoring wells. As part of the initial RFI and supplemental CMS source area investigation activities, shallow and deep monitoring wells were installed at 26 locations and sampled between March 1997 and December 1999.

Additional investigations were conducted after the initial RFI activities, and various reports describe these investigations in greater detail. These details are beyond the scope of this IMWP and will not be presented here. These investigations are:

- Monitored Natural Attenuation (MNA) Study. Results from the MNA study are presented in the *Monitored Natural Attenuation Interim Report, Revision 0* (EnSafe, 1999b).
- Aerobic-Anaerobic Sequencing Treatability Study. Results from the Aerobic-Anaerobic Sequencing Treatability Study are described in detail in the *A-A Sequencing Treatability Study Report, Zone K (SWMU 166), Revision 0* (EnSafe, 2000).
- Offsite Groundwater Investigation Study. The study area for the Offsite Groundwater Investigation comprised of the Charleston Air Force Base housing area located adjacent to the northwestern Naval Annex boundary. Results and recommendations from this

study are presented in the *Zone K RFI Offsite Groundwater Sampling Technical Memorandum, Revision 1* (EnSafe, 2001).

Figure 2-5 shows the locations of all groundwater monitoring wells and DPT wells installed during the groundwater investigations at Zone K (excluding offsite investigation locations).

2.3.1.3 MIP Pilot Studies

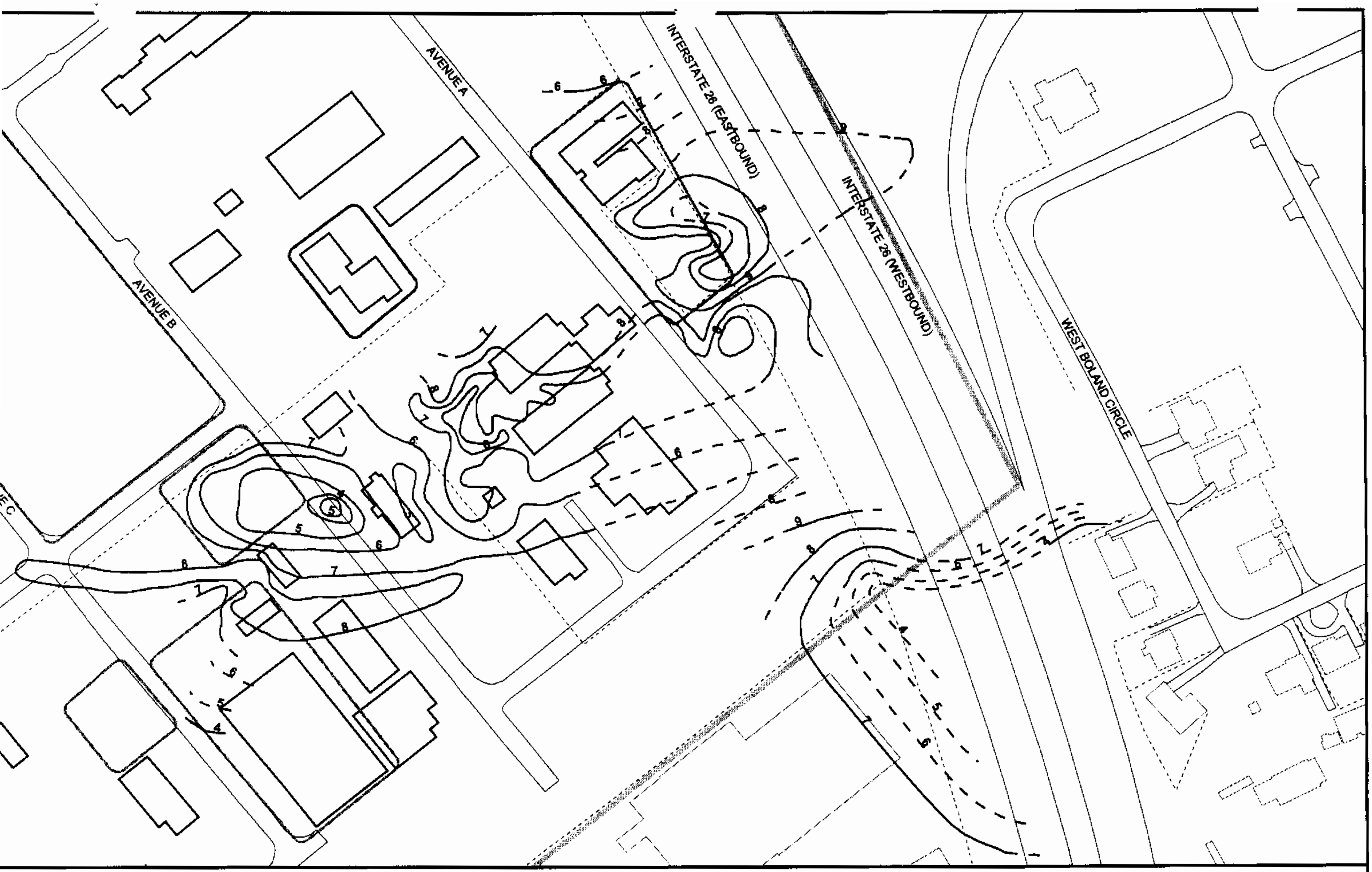
A CMS Membrane Interface Probe (MIP) Pilot Study was conducted by CH2M-Jones in two phases. Phase I of the MIP Pilot Study was completed during September 2000 and investigated the effectiveness of the MIP technology in detecting the subsurface presence of chlorinated VOCs. Phase II of the MIP Pilot Study was conducted to further characterize the magnitude and the lateral and vertical extents of subsurface TCE plumes delineated during previous investigations. Results of the Phase I Pilot Study were presented as part of the CMS Work Plan - MIP Pilot Study, Phase II (CH2M-Jones, 2001). Results of the Phase I Pilot Study have been presented as part of the MIP Phase II Pilot Study Report, (CH2M-Jones, 2002b).

As part of the MIP pilot studies, 119 MIP borings were introduced. The MIP utilized an electron capture detector (ECD) to detect halogens in the subsurface and a photoionization detector (PID) to detect VOCs. A soil conductivity probe that is part of the MIP was used to evaluate local subsurface geology during this investigation.

At 38 of the MIP locations, vertical profilers (VP) were introduced into the subsurface using DPT borings, and groundwater samples were collected at various depth intervals. The specific locations and depths selected for collecting these VP samples were directed by an evaluation of the ECD responses of the MIP borings. The VP borings were introduced at places where elevated ECD responses were detected and indicated elevated chlorinated solvent concentrations at these locations. Typically, the VP samples were located within 1 to 2 feet of those MIP borings where elevated ECD responses were reported. The VP groundwater samples were then analyzed for VOCs at an offsite laboratory using the EPA Method 8260B.

Figure 2-6 shows the locations of the Phase I and Phase II MIP borings and VP/DPT borings.

This IMWP incorporates the findings of previous RFI groundwater investigations conducted at Zone K, along with the Phase I and Phase II MIP Pilot studies delineating the approximate lateral and vertical extents of the TCE TTAs. The technical approach employed in this delineation is described in greater detail in the following section.



Inferred Contour Elevation (ft msl)
Known Contour Elevation (ft msl)
Fence
Railroads
Roads
AOC Boundary

SWMU Boundary
Buildings
Zone Boundary
ft msl = elevation in feet referenced to mean sea level

N

200 0 200 Feet

1 inch = 150 feet

Figure 2-1
Interpreted Top of Ashley Formation Elevation
SWMU 166, Zone K
Charleston Naval Complex

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File Path: C:\18gis\Projects\Zone_K\Swmu_166\Aprs\swmu166.apr, Date: 12 Dec 2001 7:35, User: NMOUDRY, Figure 2-1 Interpretated Top of Ashley Formation Elevation landscape

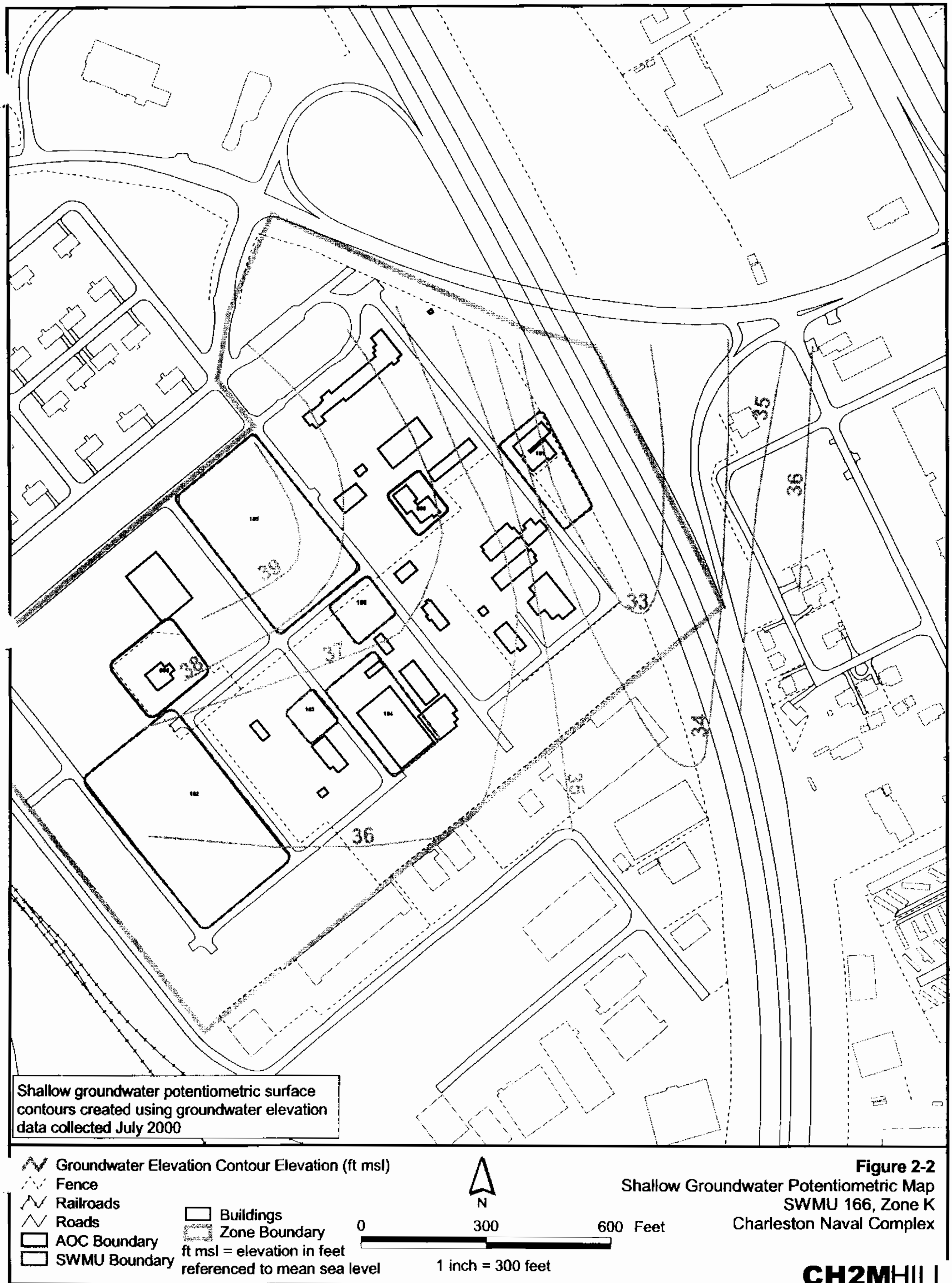
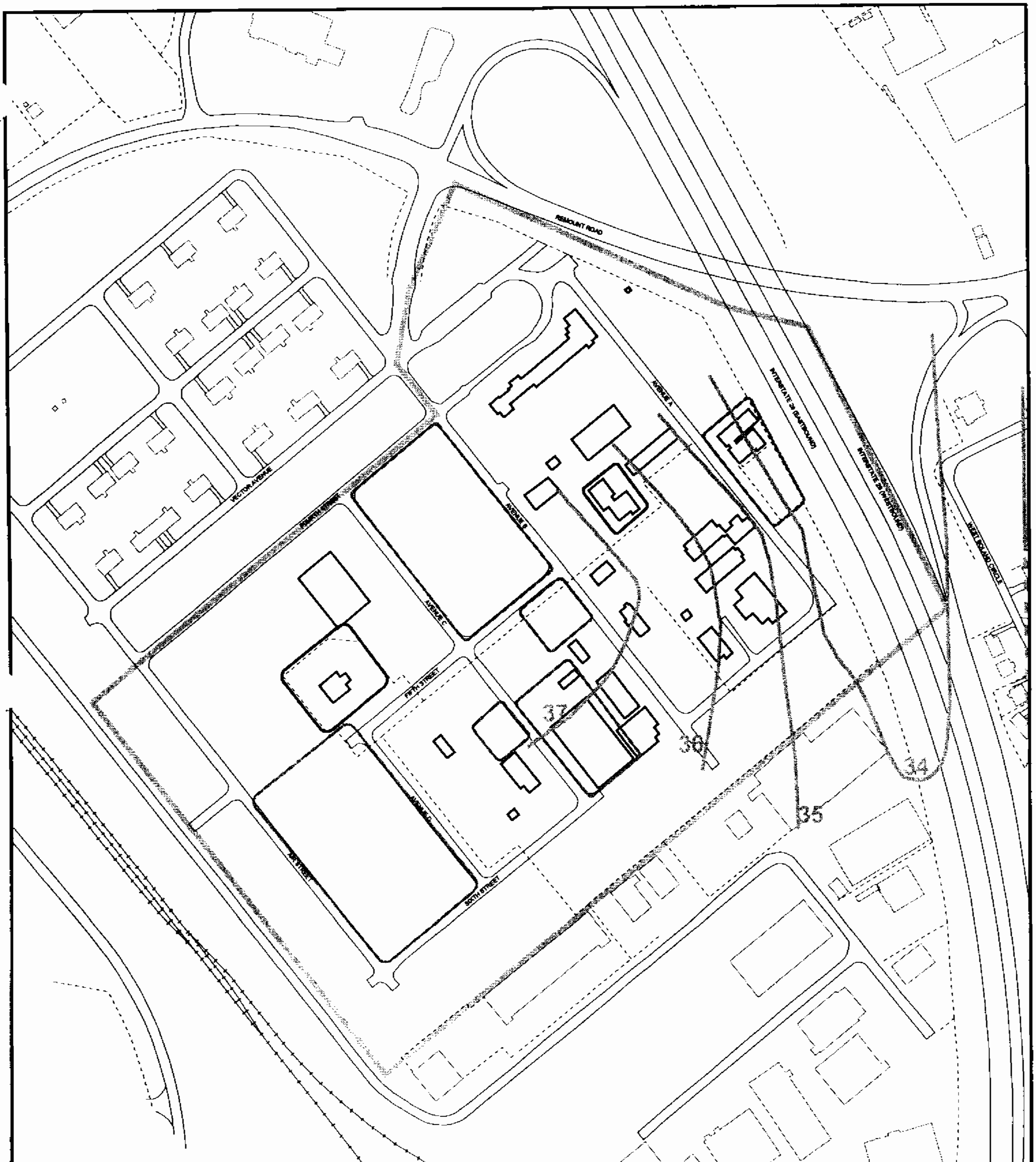


Figure 2-2
Shallow Groundwater Potentiometric Map
SWMU 166, Zone K
Charleston Naval Complex



Deep groundwater potentiometric surface contours created using groundwater elevation data collected July 2000

Groundwater Elevation Contour Elevation (ft msl)
Fence
Railroads
Roads
AOC Boundary
SWMU Boundary
Buildings
Zone Boundary
ft msl = elevation in feet referenced to mean sea level

N

0 300 600 Feet
1 inch = 300 feet

Figure 2-3
Deep Groundwater Potentiometric Map
SWMU 166, Zone K
Charleston Naval Complex

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File Path: C:\18gis\Projects\Zone_K\Swmu_166\Aprs\swmu166.apr, Date: 11 Jan 2002 7:55, User: NMOUDRY, Figure 2-2 Groundwater Potentiometric Map - Deep

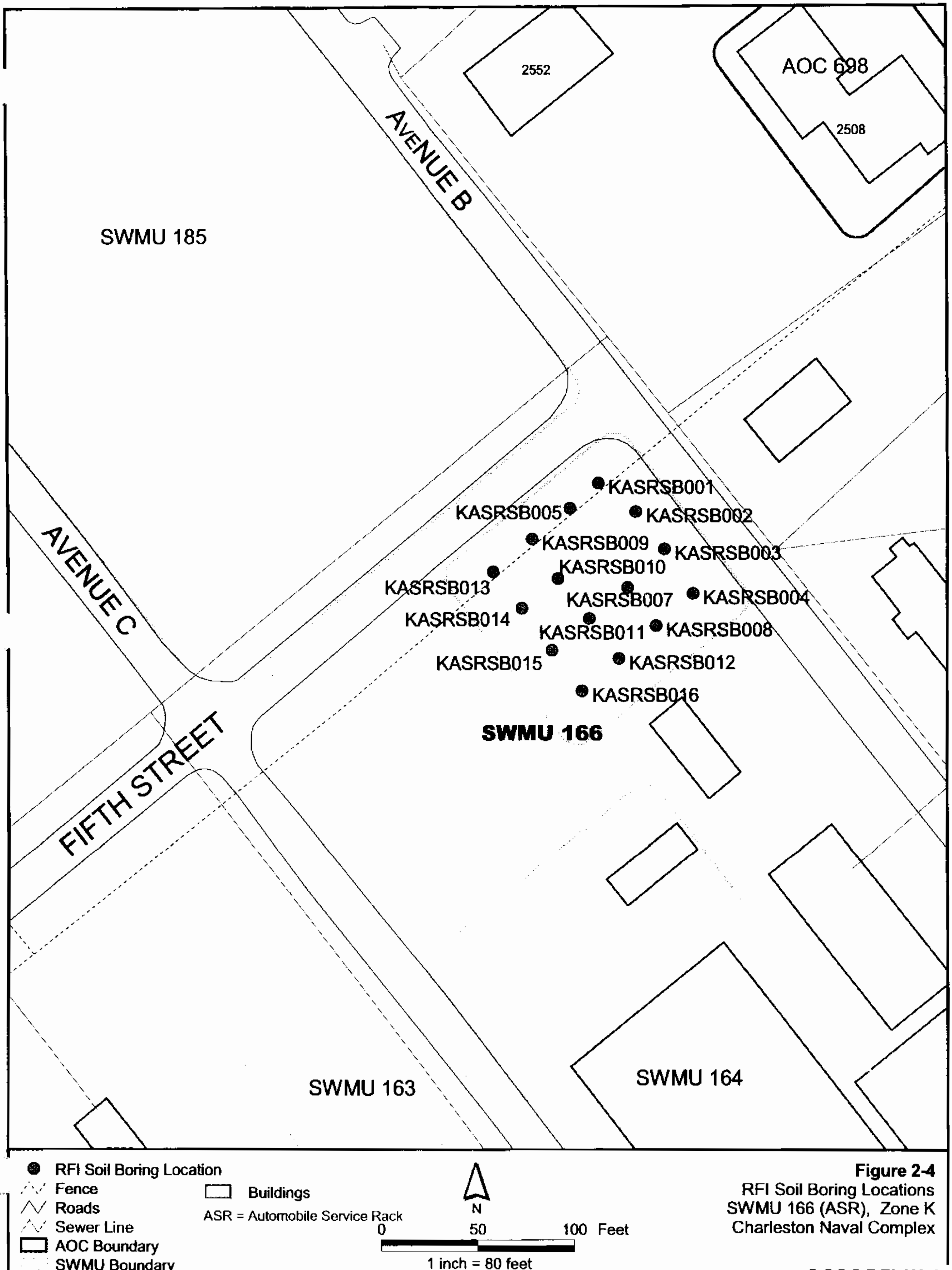

Figure 2-4
RFI Soil Boring Locations
SWMU 166 (ASR), Zone K
Charleston Naval Complex

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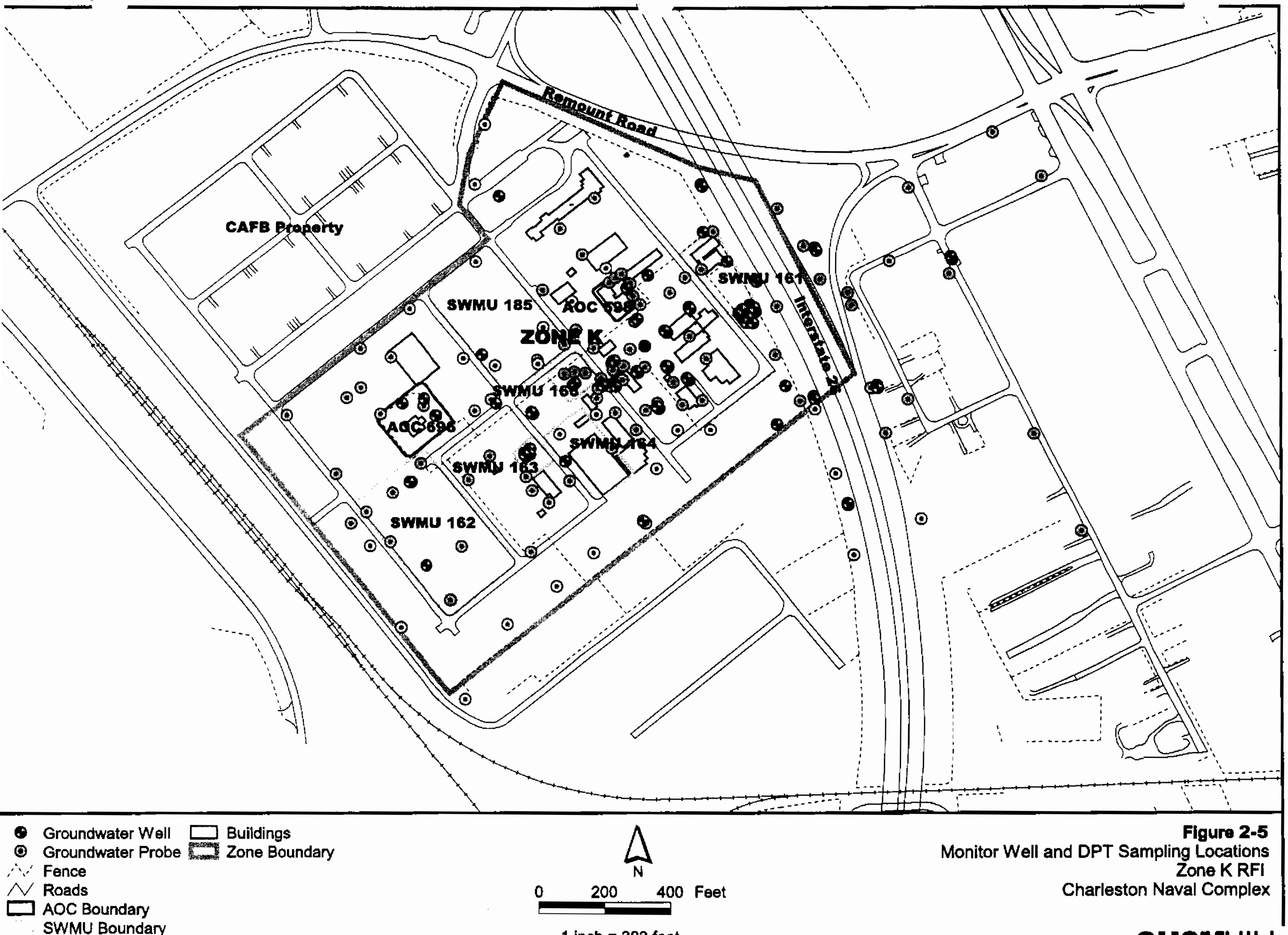

Figure 2-5
Monitor Well and DPT Sampling Locations
Zone K RFI
Charleston Naval Complex

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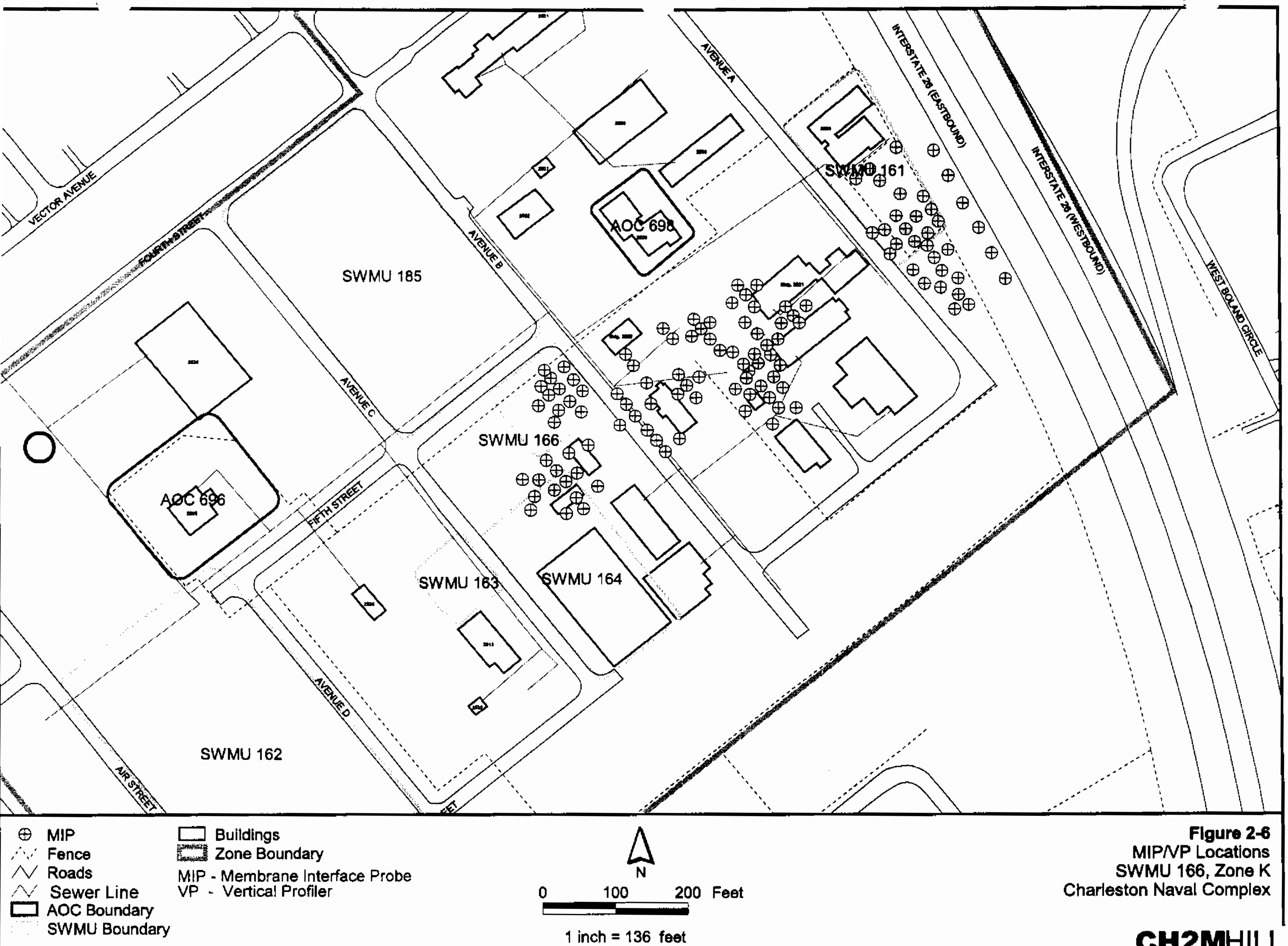

Figure 2-6
MIP/VP Locations
SWMU 166, Zone K
Charleston Naval Complex

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Section 3.0

3.0 Technical Approach

3.1 Target Treatment Area (TTA) Delineation

The TTAs represent the approximate lateral and vertical extent of a suspected TCE plume with elevated TCE concentrations. During the groundwater investigations conducted at Zone K as part of the initial RFI and supplemental investigations, concentrations of TCE were detected in groundwater up to a maximum of 51,800 µg/L. The maximum solubility of TCE in water is approximately 1,100 milligrams per liter (mg/L). Concentrations of TCE greater than 1 percent of this maximum solubility (i.e., greater than 11 mg/L or 11,000 µg/L) may indicate the presence of a dense non-aqueous phase liquid (DNAPL) source area near the monitored location. TCE concentrations detected during previous investigations at SWMU 166 exceed these DNAPL-like levels at several locations. As a conservative measure, a target TCE concentration which is approximately 10 percent of this DNAPL-like TCE concentration (i.e., approximately 1,000 µg/L) is being used by this IMWP to delineate the boundaries of the TTAs. It is anticipated that any low-level PCE or 1,2-DCE present in the TTAs will also be treated during this IM implementation.

Based on the distribution of TCE concentrations, the potential DNAPL source areas within the TTAs at SWMU 166 include the shallow zone of the aquifer at 11 to 17 ft bls at one location near the former ASR area, at the interface between the clayey sand unit and overlying sandy unit (at approximately 23 to 28 ft bls) in several areas, and a deeper zone at the top of the Ashley Formation (approximately 31 to 37 ft bls) in most TTAs. An area near SWMU 163 also indicated elevated concentrations of PCE in one shallow monitoring well at a depth of approximately 11 ft bls and is being included as part of a TTA.

The areas at SWMU 166 with elevated TCE concentrations have been grouped into eight TTAs numbered TTA1 through TTA8. TTA4 and TTA5 each include two small treatment areas, combined due to their close proximity. Figure 3-1 shows the general locations of the TTAs within Zone K. Figures 3-2 through Figure 3-8 show individual TTAs and sample locations with groundwater TCE concentrations above 1,000 µg/L at different depths below land surface. In these figures, the lateral and vertical extents of the TTAs were derived by including all sample locations that showed a TCE concentration greater than 1,000 µg/L. These TTAs were selected from a combined dataset containing the analytical results of groundwater samples collected from DPT borings, estimations from the MIP ECD response readings, VP borings, and groundwater monitoring wells. Certain portions of these TTAs identify MIP boring locations only as "ECD Response", with no TCE concentrations adjacent to them. These are locations where elevated ECD responses were detected during the MIP installations and are assumed to indicate total chlorinated solvent concentrations above 1,000 µg/L. The TTA boundaries also include those areas where the only data point is an elevated ECD response, indicating the possible presence of CVOCs greater than 1,000 µg/L. There is only one TTA (TTA 2) where treatment is indicated in the shallow zone (at a depth less than 20 ft bls) (see Figure 3-3). Also, TTA 8 targets the DPT boring location GDKGP011 where an isolated TCE source is suspected. The lateral extent of each TTA is assumed to be uniform within the depth intervals selected for treatment at each TTA.

Areas east of Interstate 26 that have shown detections of chlorinated compounds during previous investigations are not being included as part of the SWMU 166 remediation. These areas of contamination are believed to be due to an offsite source east of the CNC Naval Annex boundary and not related to past site activities of the Navy at the Naval Annex. Additionally, Interstate 26 represents a groundwater "sink", which hydraulically separates Zone K from areas east of the Interstate, as shown in Figure 2-2.

3.2 Target Treatment Goals

The maximum TCE concentration detected in the shallow and deep saturated zones at SWMU 166 during previous investigations was 51,800 µg/L in TTA 2. This IMWP proposes a target treatment goal of reducing the TCE concentration at each TTA to 5 percent of the average TCE concentration detected within the respective TTA. For example, from those concentrations depicted in Figure 3-3 (excluding ECD response locations), the average TCE concentration at TTA 2 is approximately 22,500 µg/L. Thus, a target treatment goal for TTA 2 would be a reduction in TCE concentrations to approximately 5 percent of 22,500 µg/L or approximately 1,125 µg/L.

Residual concentrations of chlorinated VOCs present after the IM implementation is complete will be considered as part of a CMS.

3.3 Treatment Technology Selection and Background

The treatment technology selected for remediation of CVOCs (primarily TCE) at SWMU 166 is in-situ chemical reduction of chlorinated VOCs through the use of highly reactive ZVI powder. The vendor selected to implement the IM using this treatment technology is ARS

Technologies, Inc. (ARS), out of New Brunswick, New Jersey. ARS employs a patented subsurface in-situ remediation process called the Ferox^{SM} process, which is described below. Information presented in the following sections has been provided by ARS (ARS, 2001).

3.3.1 Ferox^{SM} Technology Background

The Ferox^{SM} technology is a patented in-situ subsurface remediation process for the treatment of chlorinated solvents and dissolved metals. The Ferox^{SM} technology involves the subsurface injection and dispersion of specific quantities of highly reactive ZVI powder into saturated or unsaturated contamination zones. The ZVI incorporated in the Ferox^{SM} application is a 98+ percent pure, reduced iron powder imported from Japan. The powder's particle size, shape, and carbon content result in a highly reactive material. The small particle size of this ZVI powder, as compared to domestic-grade iron powder, provides more surface area per unit weight, resulting in this powder being more reactive in the subsurface.

The ZVI will be delivered into the subsurface through ARS's patented Liquid Atomized Injection (LAI) Technology. In conjunction with the LAI process, ARS can apply Pneumatic Fracturing (PF) at each injection point, if necessary, prior to introducing the ZVI into the subsurface. The use of LAI in conjunction with fracturing provides a unique method to apply the ZVI to the subsurface and directly access and target contaminants within the subsurface.

3.3.2 Reductive Dechlorination of CVOCs by ZVI using Ferox^{SM} Method

The reaction mechanism for the reduction of TCE begins with the corrosion of ZVI as it comes into contact with a water molecule. The products of corrosion are ferrous iron (Fe^{+2}), hydrogen gas (H^2), and a hydroxyl ion (OH^-). The hydrogen gas produced combines with the halogenated organic compound (e.g., TCE) on the surface of a catalyst (iron powder, naturally-occurring electron mediator, or unidentified constituents in the soil organic matter) whereby the contaminant is dehalogenated. In addition to the dehalogenated compound, proton (H^+) and chloride ion (Cl^-) are produced. The proton combines with the hydroxyl ion, formed during the corrosion reaction, to re-form as a water molecule. Accordingly, the end products of this reaction are ferrous iron, chloride ions, and dehalogenated compounds.

By using naturally occurring substances present in the soil as electron mediators, the target organic (i.e., TCE) does not have to be in direct contact with the iron powder in order to be treated. As a result of the dehalogenation reaction described above, changes to the groundwater geochemistry occur, including slight elevation of pH, a significant decrease of oxidation-reduction potential (ORP), an increase in chloride levels, and a decrease in dissolved oxygen (DO). The primary dehalogenation reaction process is represented by the following equation:

$$2Fe^{0} + 2\,H_2O \rightarrow 2Fe^{2+} + 2H_2 + 4\,OH^{-}$$

$$\underset{\text{(TCE)}}{C_2HCl_3} + 2H_2 \rightarrow \underset{\text{(ethene)}}{C_2H_4} + H^{+} + 3Cl^{-}$$

(ARS, 2001).

The end product of the reaction is ethene that is not persistent in the subsurface environment and quickly degrades further to methane, carbon dioxide, water, and chlorides.

3.3.3 Ferox[SM] Injection Method

A critical component of the proposed in-situ chemical reduction of the targeted CVOCs is ensuring that the ZVI is distributed within the subsurface zone in such a manner as to initiate and transfer the electrons required to reduce the TCE to the degradation products ethene, hydrogen and water. To accomplish this, ARS will incorporate a gas-based delivery approach for the emplacement of the ZVI into the subsurface. The emplacement method is as important as the chemical treatment since the heterogeneous geology at SWMU 166 presents significant limitations for other conventional hydraulic injection methods.

PF is a patented process in which a gas is injected into the subsurface at pressures that exceed the combined overburden pressure and cohesive soil strength of the geologic matrix, and at flow rates that exceed the effective permeability of the undisturbed soil. The result is the propagation of fractures outward from the injection well to distances of 20 to 25 feet. The use of PF will be critical to the in situ treatment process since it will allow for effective permeability enhancement of the clay lenses, sandy silts, and cohesive materials, resulting in a reduction of geologic heterogeneities present within the subsurface. This occurs prior to and while emplacing the reactive ZVI in the subsurface.

The ZVI slurry is fed directly into the gas stream aboveground and becomes atomized in the process gas. Relatively low pressures of 50 to 100 pounds per square inch gauge (psig) are needed to emplace the material within the subsurface. An integrated gas/Ferox[SM] atomization assembly consisting of pneumatic packers straddling a 360-degree injection nozzle creates discrete target intervals of 18 to 36 inches. ARS's current commercial equipment is capable of injecting up to 50 gallons of ZVI slurry per minute. Figure 3-9 shows the schematic of a typical injection well.

3.4 Remediation (Treatment) Approach

Remediation of SWMU 166 in Zone K will be implemented through a phased approach, with an initial focus on the performance of a pilot test at TTA4, followed by the subsequent full-scale remediation of the remaining TTAs. The performance of a pilot test at TTA4 will allow operational parameters to be developed and optimize injection rates for the remaining injections at the other seven TTAs. As part of the project scope, several individual tasks will be performed to effectively meet the goals outlined in this work plan. The following itemized list summarizes the sequence of field activities and related tasks.

1. Baseline Soil Sampling/Borehole Casing Installation (TTA4)
2. PF/Ferox^{SM} Injection (TTA4)
3. Post-Injection Soil Sampling
4. Post-Injection Groundwater Sampling (5, 30 and 60 days following injections)
5. Data Review/Design Addendum
6. Baseline Soil Sampling/Borehole Casing Installation (Remaining TTAs)
7. PF/Ferox^{SM} Injection (Remaining TTAs)
8. Post-Injection Soil Sampling (Remaining TTAs)
9. Post-Injection Groundwater Sampling (5, 30, and 60 days following injections) (Remaining TTAs)
10. Site Restoration
11. Reporting

3.4.1 Injection Operations

The injection process consists of a skid-mounted gas pressure module complete with an injection control manifold and a digital data logger used to monitor various operational parameters. Due to the large quantity of compressed gas needed for the Ferox^{SM} injections, a bulk nitrogen "tube" trailer will be mobilized to the site.

The compressed nitrogen is routed through the gas module's control manifold and is connected by a high-pressure hose to the downhole packer/nozzle assembly. Once all equipment is in place and all field personnel are instructed on safety aspects of the activities, the outer drive casing will be raised, exposing the injector nozzle to the formation. The packers will be inflated and the formation will be pneumatically fractured. Fracturing will consist of applying pressurized nitrogen for approximately 15 seconds within a 20-to-36-inch interval isolated by the use of a double pneumatic straddle packer assembly.

Ferox[SM] injections will be performed immediately following pneumatic fracturing at each injection interval within the borehole. The ZVI powder will be injected into the subsurface utilizing a nitrogen gas stream as the carrier fluid. The gas manifold system will provide accurate control over the injection pressures, which will enable ARS to achieve the optimal iron powder dispersion.

The iron slurry-nitrogen mixture will be injected through the pneumatic packer assembly and performed in approximately 20-to-36-inch intervals. The duration and number of injections in each borehole are directly dependent upon the quantity of iron desired within the specific zone. Each borehole will be addressed starting at the deepest interval and working upward. This will ensure that borehole stability is maintained. When the targeted dosage of iron is emplaced into the formation, the packers will be deflated, and the nozzle assembly will be raised to the next injection location. Where appropriate, the injection operations will be initiated at the periphery of the TTA and moved inward within the TTA.

3.4.2 Pneumatic Fracturing (PF) Monitoring Parameters

During each PF injection, the following monitoring parameters will be observed and collected:

- Downhole injection initiation and maintenance pressures
- Injection pressure influence at surrounding monitoring points (if available)
- Ground surface heave adjacent to and in the vicinity of the injection point
- Visual observations during injection will also be recorded

Detailed discussions of these operational parameters are provided below.

3.4.2.1 Injection Initiation and Maintenance Pressures

During each injection, a pressure transducer will be used to record data every 1/8 of a second. This data will be used to create a pressure-history curve from which the initiation pressure and the maintenance pressure can be determined. The initiation pressure represents the pressure at which the formation yields to the influx of injection fluids. The maintenance pressure represents the pressure required to maintain the injection flow into the formation. The graphical representation of this data plotted over time provides information on the in situ stresses of the formation corresponding to depth, as well as a confirmation that any fractures were created and propagated.

3.4.2.2 Pressure Influence at Adjacent Wells

During the injections, pressure gauges will be placed at wells near the injection points to monitor for pressure influence. Each pressure gauge is outfitted with a drag arm indicator that records the maximum pressure detected at the monitoring point during the injection.

3.4.2.3 Ground Surface Heave

Ground surface heave monitoring will be conducted during each injection using surveying transits in conjunction with heave rods. The heave rods will be placed at locations of varying radial distance from the fracture/injection well. During each injection event, the rods will be observed for the maximum amount of upward motion (surface heave) and the post-injection resting position (residual heave). Ground surface heave monitoring data provides additional information that can be used to assess the distances and orientation of injection fluid propagation. Due to the presence of an asphalt surface and building structures, heave is expected to be minimal.

3.4.3 Ferox^{SM} Injection Monitoring Parameters

During the injection process, ARS personnel will monitor the quantity of slurry injected, as well as the duration of injection. The quantity of slurry injected will be recorded after each injection and measured by either counting the number of "strokes" of the diaphragm pump or visually measuring the amount of liquid that is displaced from the slurry holding tank. Typically, a single batch of iron powder slurry is mixed and injected at a time, and therefore exact quantities are recorded during each injection event.

The injection pressure will also be observed to ensure proper operation of the system and dispersion of ZVI powder into the formation. ARS personnel will keep record of these and other operational parameters during the field activities.

3.4.4 Injection effects on nearby structures

Typically, structural modeling and analysis of all buildings in the vicinity of the field operations are conducted to ensure that subsurface injections have no effect on the integrity of the structures. The majority of the injections at SWMU 166 will occur in open areas or adjacent to "temporary" or "abandoned" storage buildings. The abandoned storage buildings are presently in poor condition and there is minimal risk of affecting the current condition. Prior to mobilization, a structural analysis model will be run utilizing the as-built drawings of the existing buildings near the TTAs, in order to simulate the effects of the PF on the structural integrity of the buildings.

During injections adjacent to the CNC Naval Annex buildings near TTA4 and TTA5 (Buildings 2520 and 2521), the structures will be monitored for movement. If differential movement of either building in TTA4 and TTA5 is greater than 0.5 inches, the injection event will be terminated.

3.4.5 Injection Well Installation

Prior to drilling, each TTA location will be surveyed for utilities by CH2M-Jones. These utilities will be marked on the surface for easy identification when positioning the drill rig and applying injections.

To successfully deliver the ZVI powder into the subsurface at SWMU 166, boreholes need to be drilled and stabilized in such a way that the injection equipment can be placed to the desired depths and safely withdrawn when injections are complete. Typically, open boreholes are used throughout the injection procedures. However, based upon the geologic makeup of the soils at SWMU 166, there is a possibility of borehole collapse. Therefore, a Geoprobe® (or similar push-brand) drill rig, capable of driving 4.5-inch OD casing, will be used to install temporary conduits for the injection equipment. This approach (as described below) has been successfully utilized by ARS at other sites where borehole collapse was a concern.

Using the hydraulic push and hammering capabilities of a Geoprobe® (or similar push-brand) drill rig, a 4.5-inch outer diameter, threaded HW (heavy-wall) casing will be advanced to the targeted depth. This casing will serve as a conduit for the ARS equipment. Once the packer/nozzle assembly is lowered inside the casing to the required depth, the outer drive casing will be raised approximately 3 to 6 feet (depending on the packer configuration) using a forklift, thereby exposing the packer and nozzle assembly to the formation. The packers are inflated against the formation using compressed nitrogen, providing a seal above and below the nozzle. Maintaining the casing above the packers prevents borehole collapse on top of the downhole equipment. The hydraulics on the hoist truck are sufficient to overcome any collapse which may occur around the nozzle assembly before or after injections. Once the injection is complete and the designed dosage of iron powder is emplaced into the subsurface formation, the nozzle is raised to the subsequent shallower injection interval, and the entire process is repeated.

3.5 Pilot Test Field Application (TTA4)

As part of the overall goal in treating all eight TTAs within the SWMU 166 site, an initial pilot test will be performed within TTA4. The performance of a pilot test will allow for the establishment of site-specific injection parameters prior to treating the remaining TTAs. Specific operational parameters to be observed and established will include radius of influence (ROI), ground surface heave, initiation and maintenance pressures, and injection flow rates. In addition, the TTA4 pilot test will also be used to derive the maximum achievable iron dosage which can be delivered into the site soils and allow the refinement of the required quantities of gas and ZVI for the larger TTAs. Selection of TTA4 as the pilot test location was based upon its location, size, and overall accessibility at the site.

3.5.1 Baseline Sample Collection

As part of the pilot test design approach, groundwater and soil samples will be collected from TTA4 to establish baseline geochemical parameters. Collection of these parameters will be required to successfully evaluate the performance of the Ferox^{SM} technology and facilitate the overall treatment application of TTA4. Table 3-1 provides a detailed list of the target parameters.

3.5.2 Subsurface Soil Sampling

Prior to installation of the injection wells, soil cores will be collected at TTA4 from each of the three injection well locations. A Geoprobe® will be utilized to collect continuous cores from the Targeted Treatment Intervals (TTI). The soil cores will be visually logged and screened in the field with a PID and magnetic susceptibility meter for soil vapors and baseline magnetic iron levels, respectively. One (1) sample registering the highest PID reading will be collected from each core and sent to a commercial laboratory for total iron and chloride analyses. The soil boring logs will provide useful information in determining the approximate extent of contamination and geologic makeup of the target intervals specific to the site.

3.5.3 Groundwater Sampling

Prior to the field injections, CH2M-Jones will collect groundwater samples from TTA4 to establish baseline parameters relating to specific groundwater geochemical properties. Where applicable, groundwater samples will be collected from existing monitoring wells situated within or around TTA4. If suitable groundwater monitor locations are not found near TTA4 for baseline groundwater sampling, new monitoring wells will be installed after submitting a well-installation request to SCDHEC and receiving SCDHEC approval for the well installation. Groundwater samples collected from TTA4 will be analyzed for target parameters consisting of pH, chloride, dissolved oxygen (DO), ORP, and dissolved iron. The groundwater sampling will be conducted in accordance with the EPA low-flow protocol in order to provide accurate field measurements.

3.5.4 TTA4 Site Specific Conditions

TTA4 is comprised of two isolated regions identified in **Figure 3-5A** as Region 1 and Region 2. The target zone's aerial coverage is estimated at approximately 1,000 ft^2. Previous site investigations conducted in Region 1 identified elevated concentrations of TCE (>1,000 μg/L) at various depths ranging from 23 to 33 ft bgs. Elevated concentrations of TCE in Region 2 were reported as being limited to 28 ft bgs, where a maximum TCE concentration of 3,800 μg/L was reported.

3.5.5 TTA4 Injection Well Layout

Utilizing a preliminary injection radial influence of approximately 20 feet, it is estimated that three (3) injection boreholes are needed to target the entire TTA4 area. Two (2) injection wells will be installed in Region 1 and one (1) injection well will be installed in Region 2 (Figure 3-5A). The location and number of injection points may change slightly depending on the presence of utilities, building locations, and accessibility issues.

3.5.6 Ferox^{SM} Injection Parameters

The Ferox^{SM} injections at TTA4 will target vertical intervals which have been identified as containing elevated concentrations of TCE exceeding 1,000 μg/L.

Injections in TTA4 (Region 1) will focus on a TTI of 15 feet. Injections will be initiated at a depth of 35 feet and terminate at 20 ft bgs, corresponding to a total of five (5) injections per borehole. The estimated quantity of ZVI required to treat TTA4 (Region 1) was based on the maximum reported TCE concentration (12,000 μg/L) and a desirable iron-to-TCE ratio of 2000:1 by weight. Based on these parameters, the minimum quantity of ZVI required for the entire TTI will be 5,900 pounds (or 2,950 pounds for each borehole) (**Table 3-2**).

Injections in TTA4 (Region 2) will focus on a TTI of 6 feet. It is estimated that one (1) injection borehole will be required to effectively distribute the ZVI within the TTI for Region 2. Injections will be initiated at a depth of 30 feet and terminate at 24 ft bgs, corresponding to a total of two (2) injections per borehole. The estimated minimum quantity of ZVI required to treat TTA4 (Region 2) was based on the maximum reported TCE concentration of 3,800 µg/L. Based on these parameters, the minimum quantity of ZVI per borehole will be 100 pounds (Table 3-2).

The actual injected mass of ZVI will depend greatly on site-specific limitations, such as the extensiveness of interconnected soil pores and the volume of the iron powder slurry that can be injected into the soils. ARS will attempt to meet and exceed the amount of iron specified in Table 3-2 to provide a higher level of treatment material in the subsurface that will result in enhanced treatment of the dissolved and residual CVOCs at the site over time.

3.5.7 Post-Injection Monitoring

The post-injection sampling at TTA4 will serve the following three purposes: 1) derive preliminary site-specific rate kinetics on the reduction of TCE within the targeted areas; 2) ensure the expected groundwater geochemical properties conducive to chemical reduction are occurring; and 3) estimate the in situ distribution of ZVI within the TTI. The post-injection monitoring will be accomplished through the collection and analysis of soil and groundwater samples from TTA4.

3.5.8 Post-Injection Soil Sampling

To evaluate the in situ dosage of ZVI at TTA4, post-injection soil sampling will be performed by ARS following the completion of the Ferox℠ application. To obtain this information, a Geoprobe® will be used to collect continuous soil cores from the TTI at 5-foot radial increments from the injection well. Soil cores will be screened using a magnetic susceptibility meter for total magnetic iron content and compared with the pre-injection soil core screening results, which were collected as part of the injection well installation. Soil samples will be collected from each core and sent to a laboratory for total iron and chloride analysis.

3.5.9 Post-Injection Groundwater Sampling

Post-injection verification groundwater sampling will be performed by CH2M-Jones at TTA4, following the completion of the Ferox℠ injections. The purpose of post-injection groundwater sampling will be to monitor the rate of reduction of CVOCs, as well as monitor changes in groundwater geochemical parameters. Groundwater will be analyzed for CVOCs, total and dissolved iron, chloride, pH, DO, and ORP. These values will be compared to baseline values as a means of providing data for optimizing the injection dosages at subsequent TTAs.

The post-injection groundwater sampling schedule is presented as part of the Ferox^{SM} injection schedule shown in **Figure 5-1**, and includes three groundwater sampling events over a 60-day period following the completion of the injection.

3.6 Pilot-Test Report and Design Addendum

A pilot-test report will be prepared to present the findings from the pilot test at TTA4 75 days after completion of the pilot-test injections. This will include analytical results of all sampling conducted as part of the pilot-test, and recommendations for a design addendum to incorporate modifications (if any) to the injection layouts, iron loading ratios (ZVI:TCE ratios), and injection parameters for the full-scale implementation.

3.7 Baseline Monitoring for Full-Scale IM Implementation

In order to establish pre-treatment (baseline) conditions at TTAs 1 through 8 (except for TTA 4 where the baseline monitoring will be performed prior to the pilot test), existing and newly-installed monitoring wells will be used to conduct sampling. Monitoring locations will be selected both within the TTAs and immediately downgradient of the TTAs to measure pre-treatment and post-treatment concentrations of CVOCs and MNA parameters. Table 3-1 shows the parameters that will be monitored during pre-and post-treatment monitoring. The locations of these monitoring points will be determined after the completion of the pilot test at TTA4 and the design addendum is prepared prior to full-scale IM implementation.

3.8 Full-Scale IM Implementation

Following the completion of the TTA4 Pilot Test and post-injection monitoring activities, a design addendum report will be prepared to finalize injection well locations and ZVI quantities for the remaining seven TTA dosage estimates. The remaining TTAs are identified in Figure 3-1 as TTA1, TTA2, TTA3, TTA5, TTA6, TTA7, and TTA8. The sections below discuss the site-specific application for each TTA, as well as preliminary minimum ZVI dosage estimates. The information provided below has been based on the existing data and a general design assumption that a 20-foot ROI and an iron-to-TCE contaminant ratio of 2,000:1 by weight could be achieved in situ at the site. Operational changes and adjustments generated from pilot test data will be addressed in the design addendum report.

The actual in situ injected ZVI mass will depend greatly on site-specific limitations such as the extensiveness of inter-connected soil pores and the volume of the iron powder slurry that can be injected into the soils. The actual ZVI dosages achieved in the field will attempt to meet and exceed the minimum amounts of ZVI specified in Table 3-2 to provide a higher level of treatment effect on the target dissolved and residual CVOCs at the site. The Ferox[SM] injections will target the intervals that have been identified to contain elevated concentrations of TCE exceeding 1,000 μg/L. The location and number of injection points may change depending on the presence of utilities, building structures, and accessibility.

3.8.1 TTA1

3.8.1.1 Site Specific Conditions

TTA1 consists of one region, identified in Figure 3-2A. The target zone's aerial coverage is estimated at approximately 3,413 ft^2. Previous site investigations conducted in TTA1 identified elevated concentrations of TCE (>1,000 μg/L) at various depths ranging from 27 to 34 ft bgs. A maximum TCE concentration of 35, μg/L was identified at the VP sampling location 166VP025 at 29 ft bgs.

One building is partially located in TTA1. This building, designated as Building 2522, is located along the northeast corner of the TTA.

3.8.1.2 Preliminary Injection Parameters

Four (4) injection boreholes will be required to treat TTA1 (as shown in Figure 3-2A). Injections in TTA1 will focus across a TTI of 9 feet. Injections will be initiated at a depth of 34 feet and terminate at 25 ft bgs, corresponding to a total of three (3) injections per borehole. The minimum estimated quantity of ZVI required to treat TTA1 was based on an average TCE concentration of 22,500 μg/L. Based on these parameters, the minimum quantity of ZVI required for the entire treatment area will be 27,900 pounds or 6,975 pounds per borehole (Table 3-2). Larger ZVI dosages may be required in localized regions of TTA1 containing significantly higher concentrations than the estimated average TCE concentration of 22,500 μg/L, and these will be field-determined.

3.8.2 TTA2

3.8.2.1 Site Specific Conditions

Based on drawings provided by CH2M-Jones, the target zone's aerial coverage is estimated at approximately 3,475 ft^2. Previous site investigations conducted at TTA2 identified elevated concentrations of TCE (>1,000 μg/L) at various depths ranging from 8 to 36 ft bgs. The extent of TCE contamination in TTA2 is subdivided into two specific regions, as shown in Figure 3-3A. TCE contamination within the northern half of TTA2 extends from a depth of 8 to 36 ft bgs. TCE contamination in the southern portion of TTA2 is limited to a depth of 12 to 18 ft bgs. A maximum TCE concentration of 51,800 μg/L was identified at the VP sampling location 166VP024 at 11 ft bgs.

3.8.2.2 Preliminary Injection Parameters

Four (4) injection boreholes will be required to treat TTA2 (as shown in Figure 3-3A). Injections within the northern half of TTA2 will focus on a TTI of 30 feet. Injections will be initiated at a depth of 37 feet and terminate at 7 ft bgs, corresponding to a total of 10 injections per borehole. Injections within the southern half of TTA2 will be applied across a 9-foot interval, corresponding to three (3) injections per borehole. Injections will be initiated at a starting depth of 18 feet and terminating at 9 ft bgs.

The minimum estimated quantity of ZVI required to treat the northern half of TTA2 was based on a maximum TCE concentration of 3,000 μg/L. Based on these parameters, the minimum quantity of ZVI required for the northern treatment area will be 5,700 pounds or 2,850 pounds per borehole (Table 3-2).

The minimum estimated quantity of ZVI required to treat the southern half of TTA2 was based on an average TCE concentration of 16,400 μg/L. Based on these parameters, the minimum quantity of ZVI for the southern treatment area will be 10,800 pounds or 5,400 pounds per borehole (Table 3-2). Larger ZVI dosages may be required in localized regions containing significantly higher concentrations than the estimated average TCE concentration of 16,400 μg/L.

3.8.3 TTA3

3.8.3.1 Site Specific Conditions

The target zone's aerial coverage is estimated at approximately 7,884 ft^2 (as shown in Figure 3-4). Previous site investigations conducted at TTA3 identified elevated concentrations of TCE (>1,000 μg/L) at various depths ranging from 28 to 34 ft bgs. A maximum TCE concentration of 29,200 μg/L was identified in 166VP019 at 30 ft bgs. Building 2511 is situated within TTA3.

3.8.3.2 Preliminary Injection Parameters

Ten (10) injection boreholes will be required to treat TTA3. Figure 3-4A shows the locations of the injection boreholes relative to Building 2511 and the access road located along the southwest extent of the TTA. In order to achieve the required radial coverage, injection boreholes will be installed adjacent to Building 2511, as identified in Figure 3-4A.

Injections in TTA3 will focus across a TTI of 9 feet. It is estimated that 10 injection boreholes will be required to effectively distribute the ZVI across the TTI, including areas below the building and access road. Injections will be initiated at a depth of 35 feet and terminate at 26 ft bgs, corresponding to a total of three (3) injections per borehole. The minimum estimated quantity of ZVI required to treat TTA3 was based on a averaged TCE concentration of 7,200 μg/L. Based on these parameters, the minimum quantity of ZVI for the entire treatment area will be 20,000 pounds or 2,000 pounds per borehole (Table 3-2). Larger ZVI dosages may be required in localized regions containing significantly higher concentrations than the estimated average TCE concentration of 7,200 μg/L.

3.8.4 TTA5

3.8.4.1 Site Specific Conditions

TTA5 is comprised of two isolated regions, identified in Figure 3-5A as Region 1 and Region 2 (see Figure 3-5A). The target zone's aerial coverage is estimated at approximately 6,853 ft^2. Previous site investigations conducted in Region 1 identified elevated concentrations of TCE (>1,000 μg/L) at various depths ranging from 28 to 35 ft bgs. Elevated concentrations of TCE (>1,000 μg/L) in Region 2 were reported as being limited to 33 to 35 ft bgs. The maximum TCE concentration in Region 1 and Region 2 were identified in VP sample locations 166VP013 and 166VP016, corresponding to a concentration of 15,900 μg/L and 3,260 μg/L, respectively.

3.8.4.2 Preliminary Injection Parameters

Eight (8) injection boreholes will be required to treat TTA5 (Figure 3-5A), corresponding to eight (8) injection wells in Region 1 and one (1) injection well in Region 2. Injections within the Region 1 will focus on a TTI of 9 feet. Injections will be initiated at a depth of 35 feet and terminate at 26 ft bgs, corresponding to three (3) injections per borehole location. Injections in Region 2 will focus on a TTI of 6 feet. Injections will be initiated at 36 feet and terminate at 30 ft bgs, corresponding to two (2) injections per borehole location.

The minimum estimated quantity of ZVI required to treat Region 1 was based on an average TCE concentration of 9,500 μg/L. Based on these parameters, the minimum target quantity of ZVI for Region 1 will be 23,000 pounds or 3,300 pounds per borehole (Table 3-2). Larger ZVI dosages will be applied in localized regions containing significantly higher concentrations than the estimated average of 9,500 μg/L.

The minimum quantity of ZVI required to treat Region 2 was based on a maximum TCE concentration of 4,000 μg/L. Based on these parameters, the minimum quantity of ZVI for Region 2 will be 300 pounds (Table 3-2).

3.8.5 TTA6

3.8.5.1 Site Specific Conditions

Based on drawings provided by CH2M-Jones, the target zone's aerial coverage is estimated at approximately 32,000 ft^2. Previous site investigations conducted at TTA6 identified elevated concentrations of TCE (>1,000 μg/L) at various depths ranging from 21 to 28 ft bgs. The vertical extent of contamination in TTA6 has been identified to vary significantly. TCE concentrations exceeding 1,000 μg/L in the northern half of TTA6 extend from a depth of 21 to 28 ft bgs, while in the southern half the contamination is limited to 28 ft bgs. Maximum TCE concentrations of 11,000 μg/L were identified in two (2) existing monitoring wells located in the southern portion of TTA6, designated as K166GWIN3 and K166GWTM4.

3.8.5.2 Preliminary Injection Parameters

A total of seven (7) injection boreholes will be required to treat the northern section of TTA6 (Figure 3-6A). Injections within the northern section will be focused across a TTI of 9 feet. Injections will be initiated at a depth of 31 feet and terminated at a depth of 22 ft bgs, corresponding to three (3) injections per borehole location.

A total of eight (8) injection boreholes will be required to treat the southern section of TTA6 (Figure 3-6A). Injections within the southern section will be focused across a TTI of 3 feet. Injections will be performed at one (1) interval, corresponding to 27 to 30 ft bgs.

The minimum quantity of ZVI required to treat the northern portion of TTA6 was based on a maximum TCE concentration of 4,740 μg/L. Based on these parameters, the minimum quantity of ZVI for the northern portion will be 12,800 pounds or 1,600 pounds per borehole (as indicated in Table 3-2).

The minimum quantity of ZVI required to treat the southern portion of TTA6 was based on a maximum TCE concentration of 11,000 μg/L. Based on these parameters, the minimum quantity of ZVI for the southern portion will be 7,600 pounds or approximately 1,100 pounds per borehole location (as indicated in Table 3-2).

3.8.6 TTA7

3.8.6.1 Site Specific Conditions

TTA7 consists of one region, identified in Figure 3-7A. Based on drawings provided by CH2M-Jones, the target zone's aerial coverage is estimated at approximately 488 ft^2. Previous site investigations conducted in TTA7 identified elevated concentrations of TCE (>1,000 μg/L) at a depth of 8 ft bgs.

3.8.6.2 Ferox^SM Injection Parameters

Based on the small size of TTA7, one (1) injection well will be installed. Injections will be performed over a 3-foot interval, corresponding to a depth of 7 feet to 10 feet. The minimum required ZVI dosage for this area will be 200 pounds (Table 3-2).

3.8.7 TTA8

3.8.7.1 Site Specific Conditions

TTA8 consists of one region, identified in Figure 3-8A. Based on drawings provided by CH2M-Jones, the target zone's aerial coverage is estimated at approximately 484 ft^2. Previous site investigations conducted in TTA8 identified elevated concentrations of TCE (>1,000 μg/L) at a depth of 33 ft bgs.

3.8.7.2 Preliminary Injection Parameters

Based on the small size of TTA8, one (1) injection well will be installed. Injections will be performed over a 3-foot interval, corresponding to a depth of 32 feet to 35 feet. The minimum required ZVI dosage for this area will be 200 pounds (Table 3-2).

3.9 Post-Treatment Monitoring for Full-Scale IM Implementation

In order to evaluate the effectiveness of the remediation from the Ferox^SM technology, periodic groundwater monitoring will be conducted after the full-scale IM implementation. Sampling for VOCs and MNA parameters will be conducted in select wells approximately every 3 months during the first year following conclusion of full-scale remediation. Table 3-1 shows the parameters that will be sampled during the post-treatment monitoring events. A quarterly report summarizing the findings of each sampling event will be provided 45 days after each sampling event.

3.10 Polishing Injections

The first sampling event for post-treatment monitoring will be conducted 75 days after the conclusion of full-scale injections. Should a dramatic elevation or rebound of TCE concentration in any of the TTAs be noticed after the injections, or if elevated TCE concentrations persist, additional injections will be conducted during a polishing phase. This evaluation will be made based on the findings of the first post-treatment sampling event. Should polishing phase injections be required, polishing injections will be performed using similar operating procedures described previously for the full-scale remediation injections. Post-injection sampling will be conducted 75 days after completion of the polishing phase or during the quarterly post-treatment monitoring of previously-selected wells. A polishing phase report will be submitted to document the polishing injection activities and to present the findings of the post-treatment monitoring.

3.11 Permitting

3.11.1 SCDHEC Well Installation Request

In accordance with R.61-79.265 Subpart F of the South Carolina Hazardous Waste Management Regulations and R.61-71 of the South Carolina Well Standards and Regulations, a request for the advancement of any additional monitoring wells or VP borings is required to be submitted to SCDHEC two weeks prior to the scheduled activity. The written request describes the purpose of the injection boreholes and VP boring activities and consists of construction details, if required, as well as a map depicting the proposed locations. In addition, because the injection boreholes and VP locations are considered temporary, the request will include a brief description of the method used for abandonment.

3.11.2 SCDHEC Underground Injection Control (UIC) Permit Application

An Underground Injection Control (UIC) Permit will be requested for approval prior to the installation of injection wells. Field work will be initiated after the UIC Permit is approved by SCDHEC.

3.12 Health and Safety Monitoring

CH2M-Jones places significant emphasis on the health and safety of our personnel, our subcontractors, and the local community. Once all personnel have arrived on site as part of the mobilization phase of the IMWP, a project briefing and health and safety orientation meeting will be held. All work completed as part of this IMWP will be performed in accordance with the CH2M-Jones Site-Specific Health and Safety Plan (CH2M-Jones, 2000).

A copy of the MSDS for the ZVI powder is included in Appendix B.

TABLE 3-1
Analytical Methods and Data Use
Interim Measure Work Plan, SWMU 166, Zone K, Charleston Naval Complex

Analysis	Method	Comments	Data Use	Field or Fixed-Base Laboratory
VOCs	SW-846 8260B	Determine extent of chlorinated VOC contamination.	Data will be used to evaluate potential remedial approach(es) to be field tested as part of pilot study	Fixed-base
Dissolved Oxygen*	DO Meter calibrated in the field according to the supplier's specifications		Concentrations < 0.5 mg/L generally indicate an anoxic pathway	Field
Nitrate	Ion Chromatography Method E300		Substrate for microbial respiration if oxygen is depleted	Fixed-Base
Soluble Manganese [MN (II)]	Colorimetric Hach Company Method 8149	Filter if turbidity interferes with analysis	May indicate an anoxic degradation process due to depletion of oxygen, nitrate, and manganese	Field
Ferrous Iron [FE(II)]	Colorimetric Hack Company Method 8146	Filter if turbidity interferes with analysis.	May indicate an iron-reducing environment	Field
Sulfate	IC Method E300		Substrate for anoxic microbial respiration	Fixed-Base
Hydrogen Sulfide	Color Disk methylene Blue Method	Hack Catalog Number 2238-01	The presence of H2S suggests a sulfate-reducing environment	Field
Methane	SW-846 method 3810 Modified		The presence of CH4 suggests biodegradation via methanogenesis	Fixed-Base

TABLE 3-1
Analytical Methods and Data Use
Interim Measure Work Plan, SWMU 166, Zone K, Charleston Naval Complex

Analysis	Method	Comments	Data Use	Field or Fixed-Base Laboratory
Oxidation Reduction Potential (ORP)	ASTM Method A2580B	Measurements made with electrodes and meter; protect sample from oxygen. Report results against the hydrogen electrode (Eh) by adding a correction factor specific to the electrode used	The ORP of groundwater reflects the relative oxidizing or reducing nature of the groundwater system. ORP is influenced by the nature of the biologically mediated degradation of contaminants, and may range from 800 mV (oxygenated) to less than –400 (strongly reducing)	Field
pH	Field probe with direct-reading meter calibrated in the field according to the supplier's specifications		Aerobic and anoxic processes are pH-sensitive; abiotic reduction of chromium is pH – sensitive	Field
Temperature	Field Probe with direct-reading mater			Field
Conductivity	E120.1/SW-846 Method 9050, direct meter reading		General water quality parameters used as a marker to verify that site samples are obtained from the groundwater system	Field
Hydrogen	Equilibration with gas; determined with reduction gas detector (Microseeps)		Determine terminal electron accepting process. Under biotic conditions, hydrogen may act as an electron donor	Fixed-Base

* Table entries that are highlighted in gray represent MNA parameters.

mg/L milligram per liter

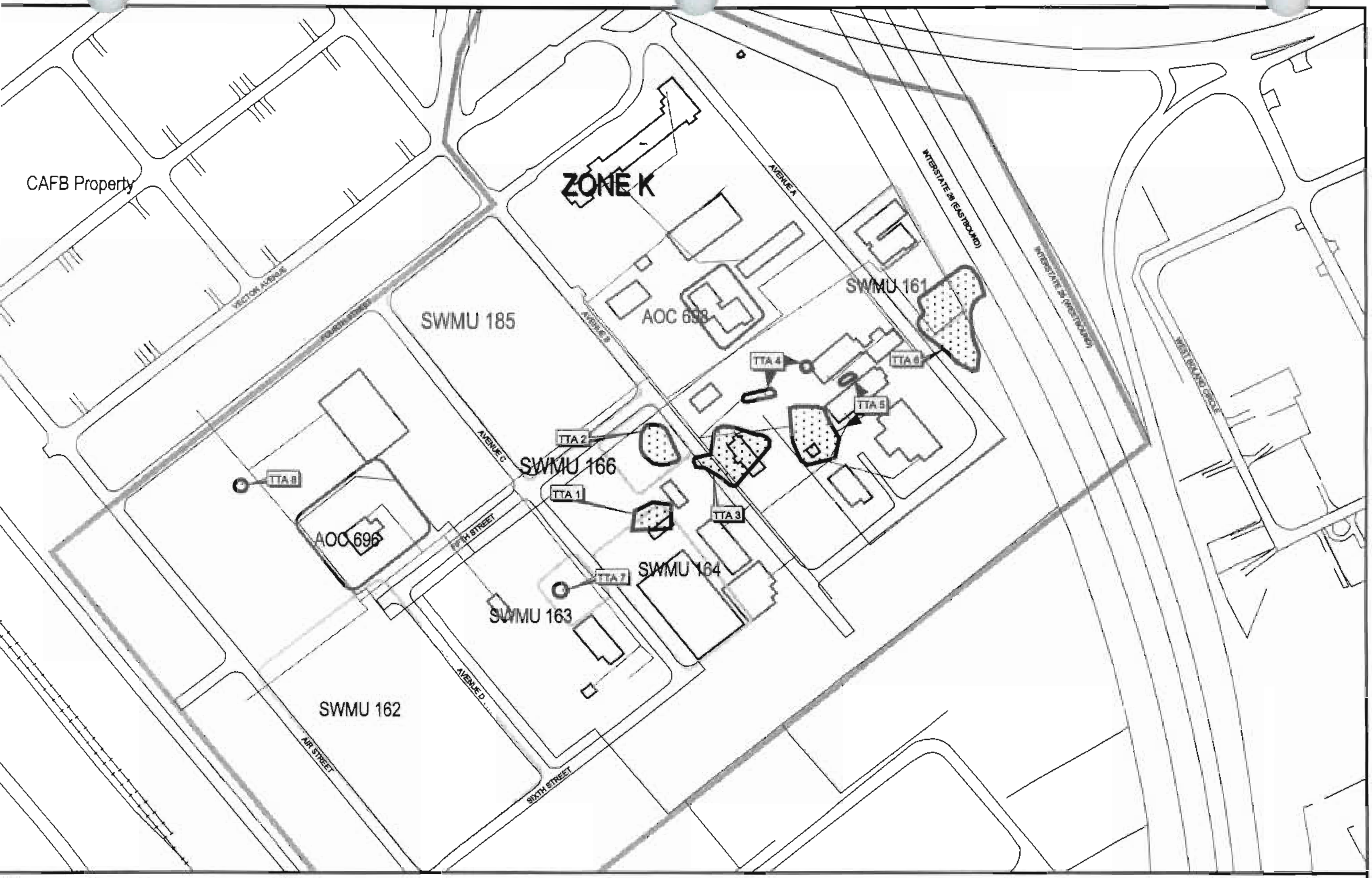
TABLE 3-2

FEROX[SM] INJECTION SUMMARY
SWMU 166, ZONE K

CHARLESTON NAVAL COMPLEX
CHARLESTON, SOUTH CAROLINA

Target Treatment Area (TTA)	Approx. Area of TTA (ft^2)	Ave. Conc. (mg/L)	Max. Conc. (mg/L)	Target Treatment Interval (TTI) (ft-bgs)	TTI Thickness (ft)	Minimum Iron Dosage/TTA (lbs/TTA)	Number of Injection Boreholes/TTA	Minimum Iron Dosage/TTI within each Borehole (lbs/TTI)	Number of Injection Intervals (assuming 36-inches)/TTI	Minimum Iron Dosage/Injection Interval (lbs/36-inch interval)
TTA 1	4,570	23	36	25-34	9	27,900	4	6,975	3	2,325
TTA 2 North	1,420	16	52	8-38	30	5,700	2	2,850	10	285
TTA 2 South	1,360	N/A	3	8-17	9	10,800	2	5,400	3	1,800
TTA 3	7,500	7	29	26-35	9	20,000	10	2,000	3	667
TTA 4 Region 1	840	N/A	12	20-35	15	5,900	2	2,950	5	590
TTA 4 Region 2	220	N/A	4	24-39	15	100	1	100	5	20
TTA 5 Region 1	6,850	10	16	25-34	9	23,000	7	3,286	3	1,095
TTA 5 Region 2	315	N/A	4	30-36	6	300	1	300	2	150
TTA 6 North	8,800	N/A	11	21-30	9	12,800	8	1,600	3	533
TTA 6 South	6,700	N/A	5	27-30	3	7,600	7	1,086	1	1,086
TTA 7	510	N/A	2	07-10	3	200	1	200	1	200
TTA 8	250	N/A	0.15	33-36	3	200	1	200	1	200
TOTALS	39,335					114,500	46			

Source of table: ARS Technologies, Inc.



Approx. Target Treatment Area (TTA)
Fence
Roads
Sewer Lines
AOC Boundary
SWMU Boundary
Buildings
Zone Boundary

N

0 100 200 Feet

1 inch = 239 feet

Figure 3-1
Approximate Target Treatment Areas
Zone K
Charleston Naval Complex

CH2MHILL

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NOTE: Original fig[...]d in color

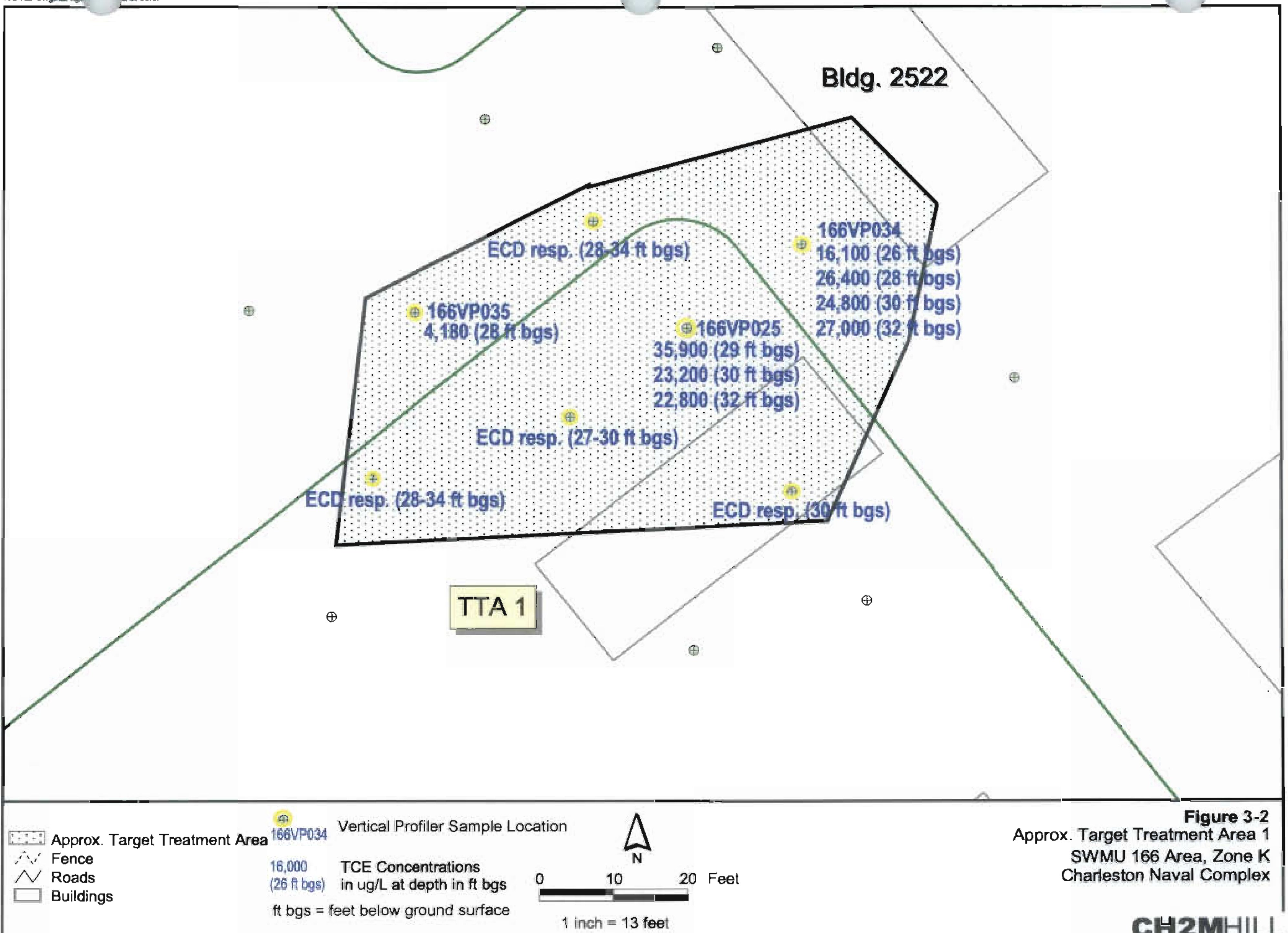

Figure 3-2
Approx. Target Treatment Area 1
SWMU 166 Area, Zone K
Charleston Naval Complex

CH2MHILL

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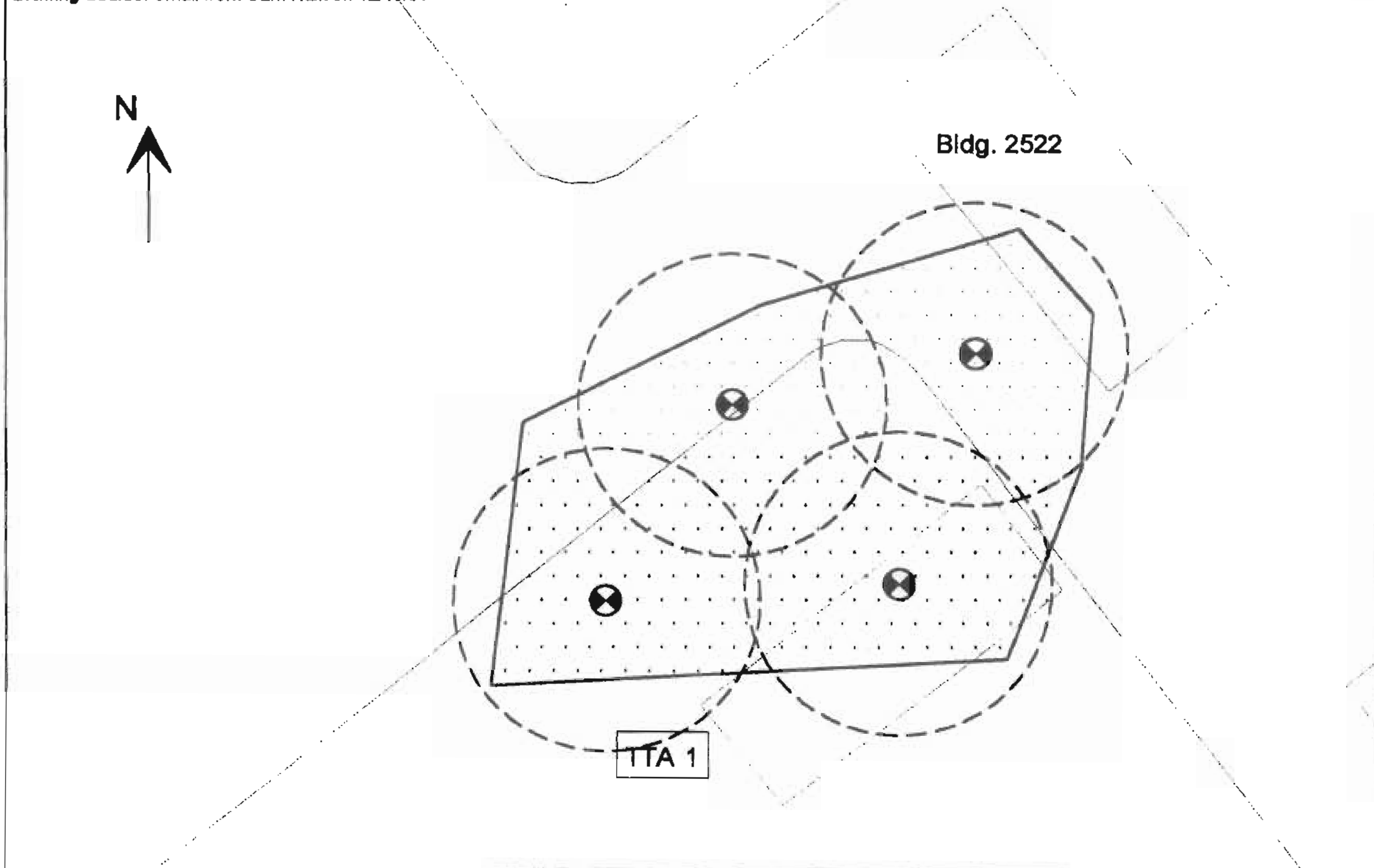
Drawing Source: email from Sam Naik on 12/19/01



Legend

Target Treatment Area

Radius of Influence (20 ft.)

Injection Borehole Location

0 20 40

Approx. Scale (feet)

Figure 3-2A

Approx. Target Treatment Area 1
SWMU 166 Area, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

NOTE: Original fig... d in color

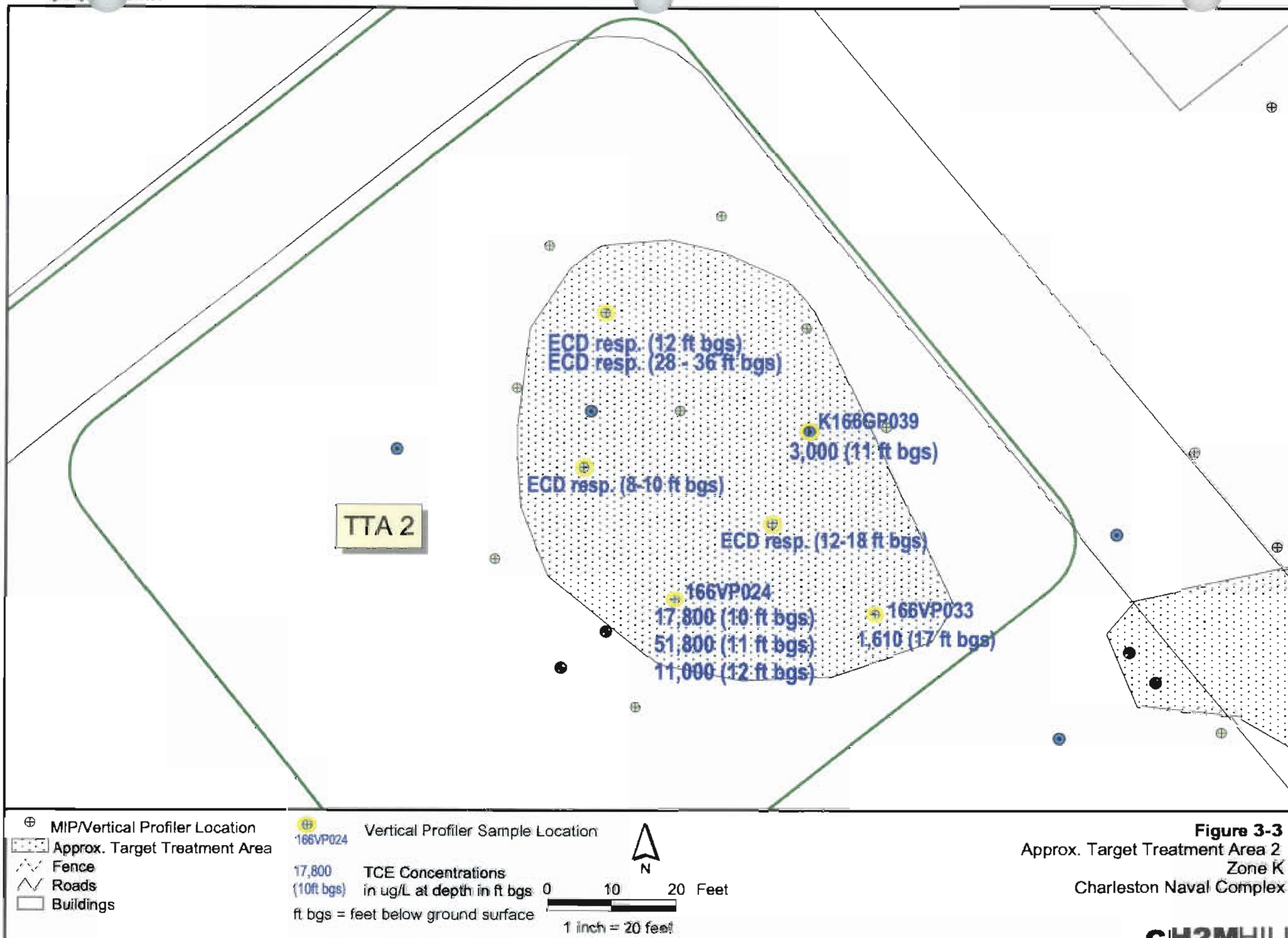


Figure 3-3
Approx. Target Treatment Area 2
Zone K
Charleston Naval Complex

CH2MHILL

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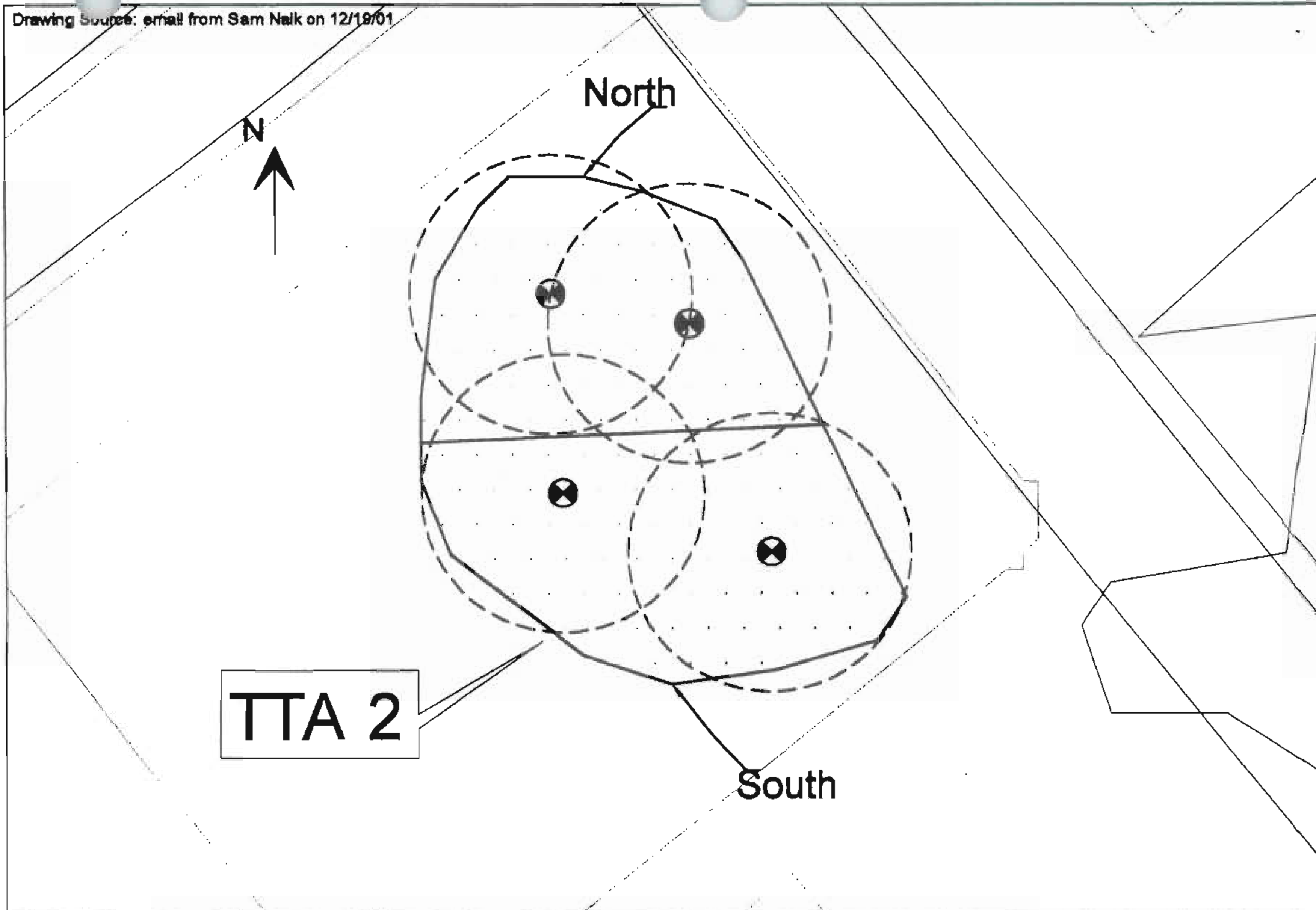

Legend

Target Treatment Area

Radius of Influence (20 ft.)

Injection Borehole Location

0 20 40
Approx. Scale (feet)

Figure 3-3A
Approx. Target Treatment Area 2
SWMU 166, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

NOTE: Original fig d in color

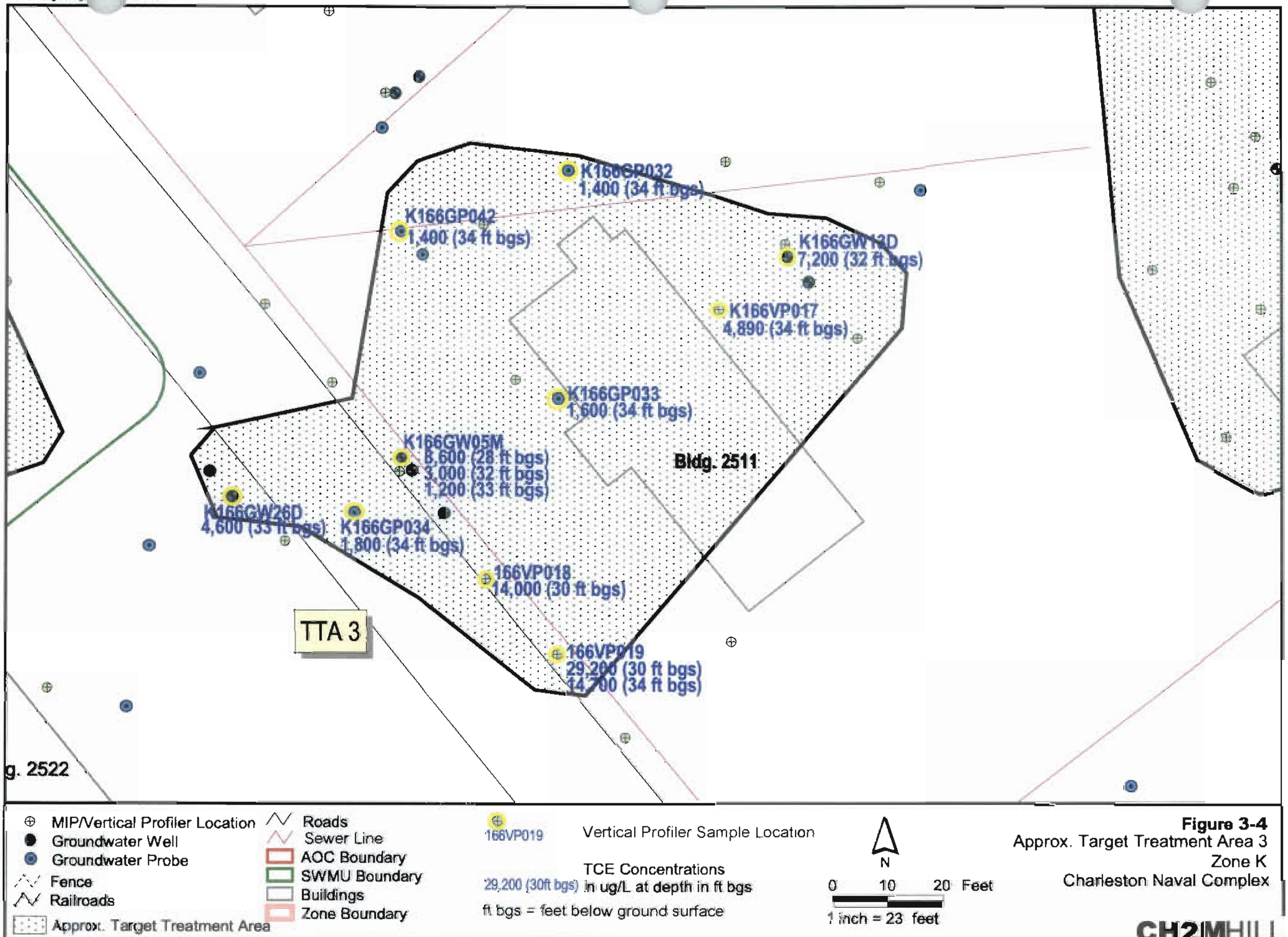

Figure 3-4
Approx. Target Treatment Area 3
Zone K
Charleston Naval Complex

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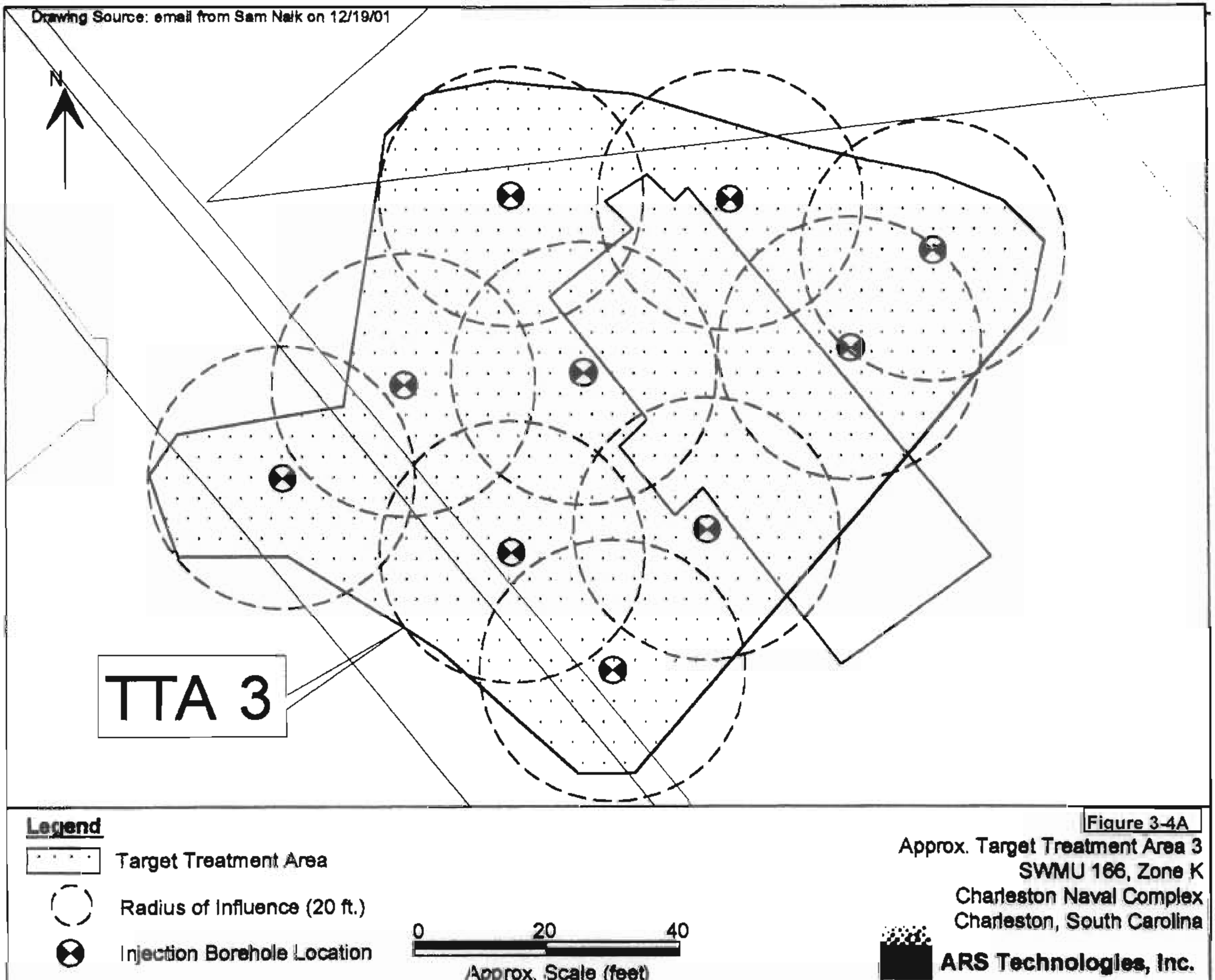


Legend

Target Treatment Area

Radius of Influence (20 ft.)

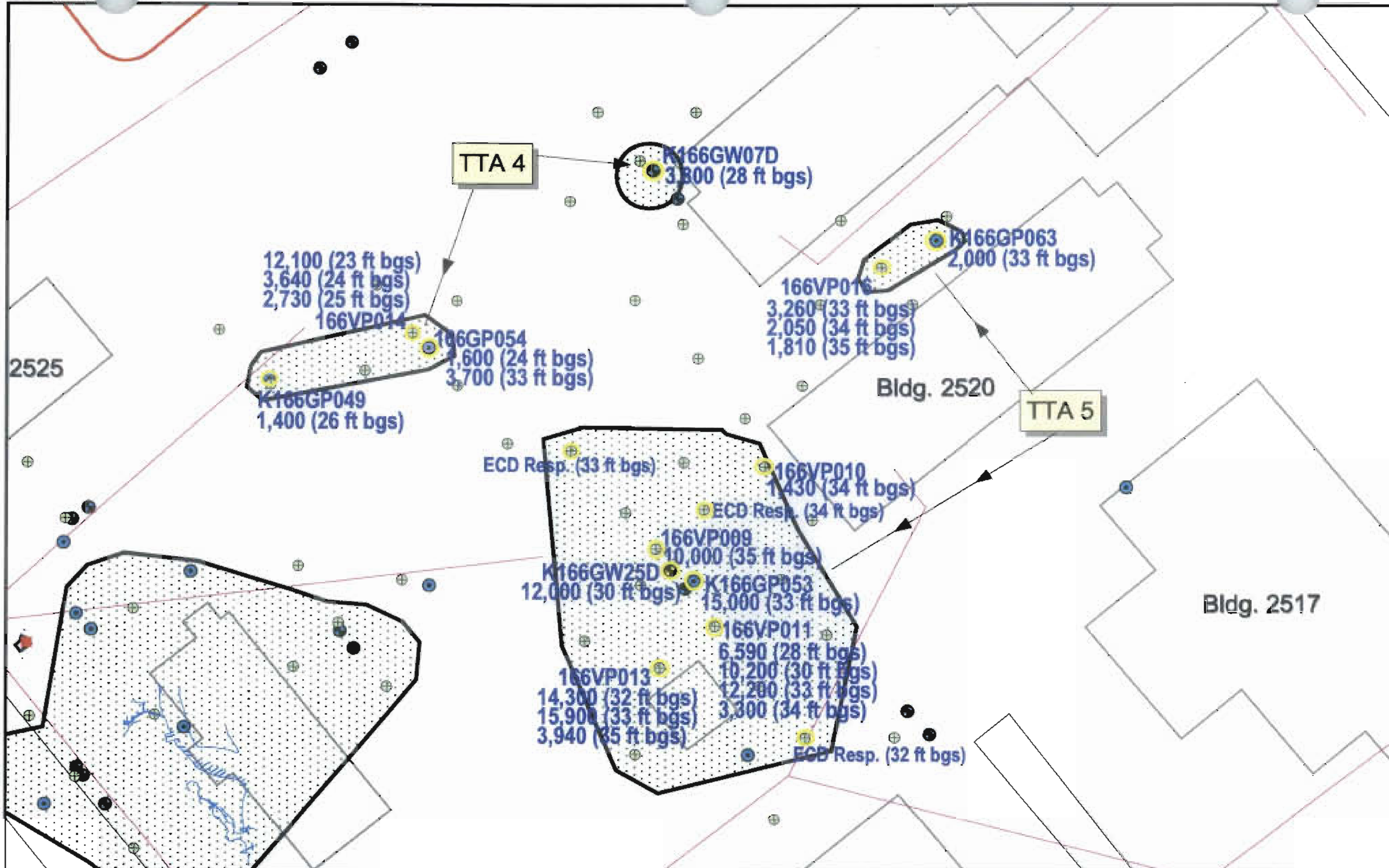
Injection Borehole Location

Figure 3-4A

Approx. Target Treatment Area 3
SWMU 166, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

NOTE: Original fig d in color



MIP
Groundwater Well
Groundwater Probe
Roads
Sewer Line
Approx. Target Treatment Area (TTA)

AOC Boundary
SWMU Boundary
Buildings
Zone Boundary

166VP013 Vertical Profiler Sample Location

14,300 (32 ft bgs) TCE Concentrations in ug/L at depth in ft bgs

ft bgs = feet below ground surface

N

0 20 40 Feet

1 inch = 37 feet

Figure 3-5
Approx. Target Treatment Areas 4 & 5
Zone K
Charleston Naval Complex

CH2MHILL

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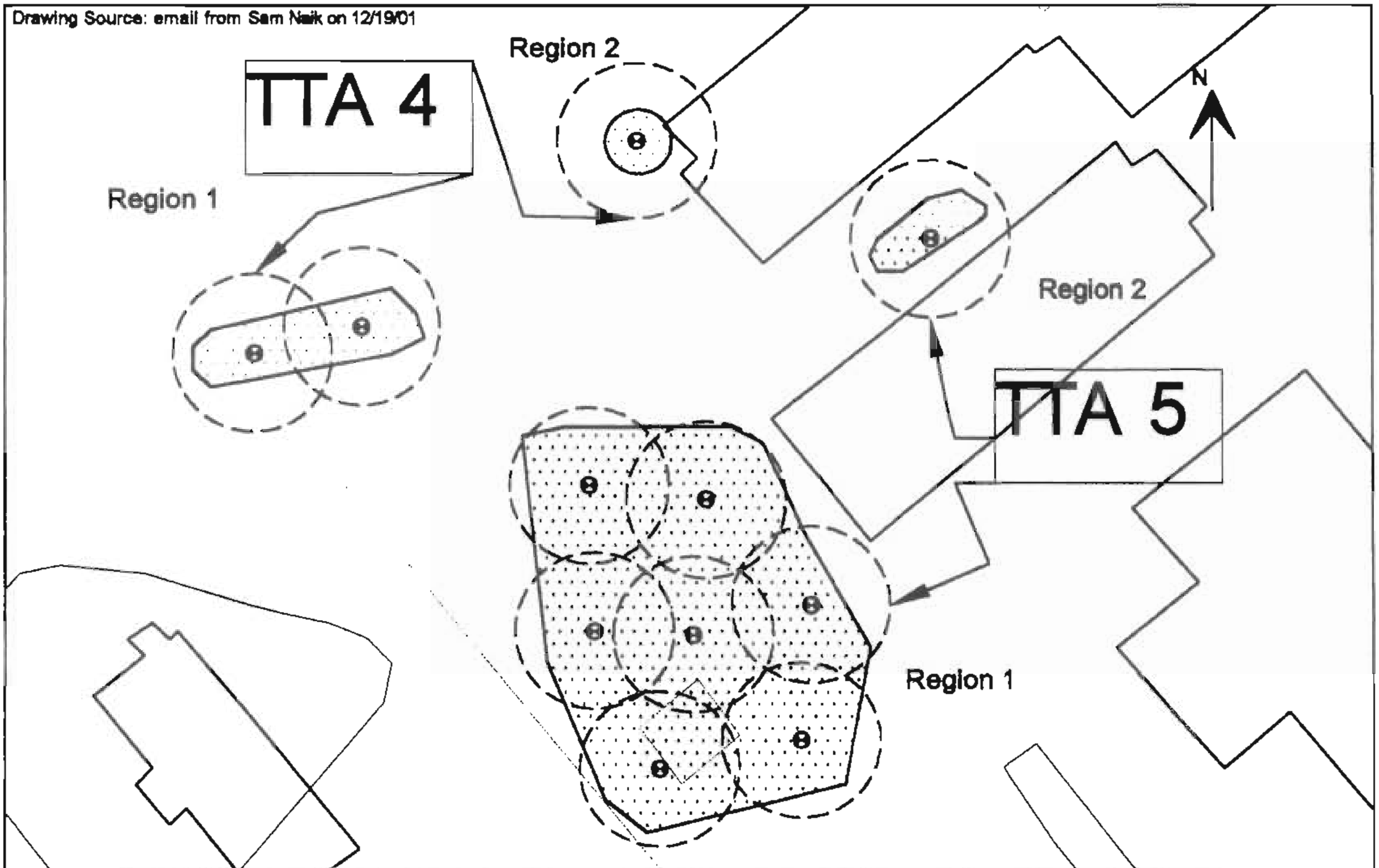


Legend

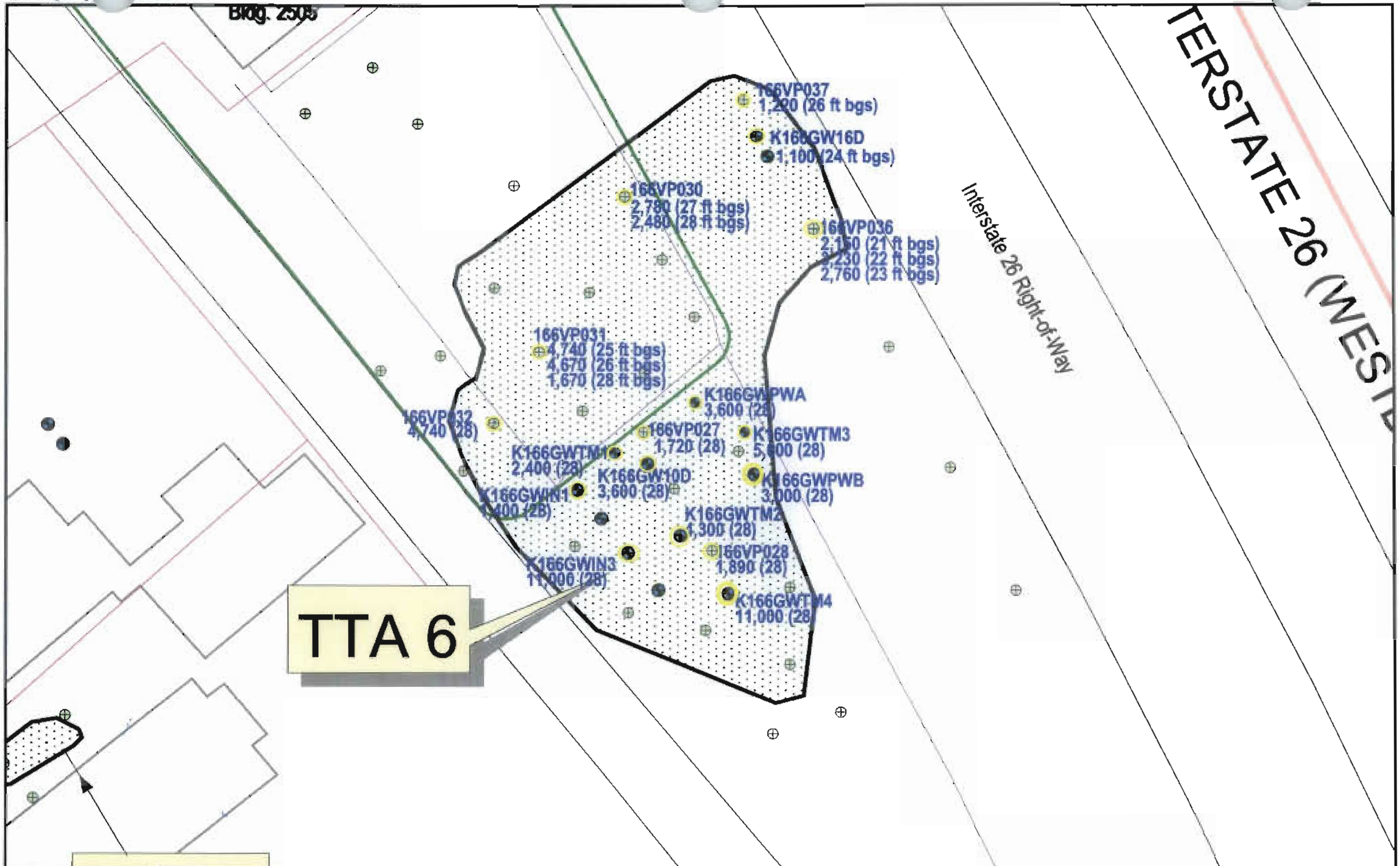
- Target Treatment Area
- Radius of Influence (20 ft.)
- Injection Borehole Location

0 40 80
Approx. Scale (feet)

Figure 3-5A
Approx. Target Treatment Area 4 & 5
SWMU 166, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

NOTE: Original fig... d in color



MIP
Groundwater Well
Groundwater Probe
Fence
Roads
Sewer Line
Approx. Target Treatment Area
AOC Boundary
SWMU Boundary
Buildings
Zone Boundary

K166GWTM4 — Groundwater Monitor Well Sample Location

11,000 (28) — TCE Concentrations in ug/L (with depth in ft bgs)

ft bgs = feet below ground surface

N

0 20 40 Feet

1 inch = 40 feet

Figure 3-6
Approx. Target Treatment Area 6
Zone K
Charleston Naval Complex

CH2MHILL

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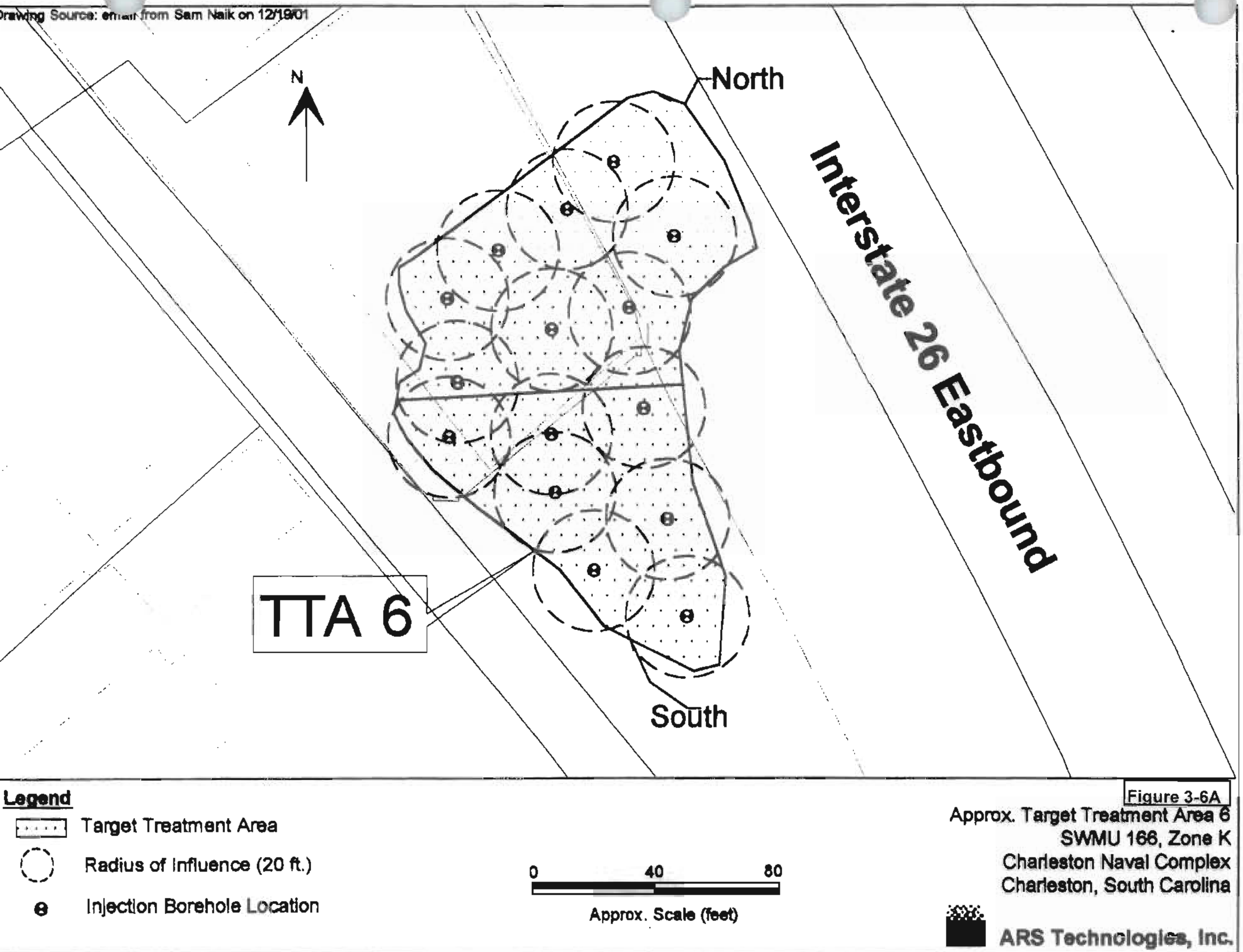
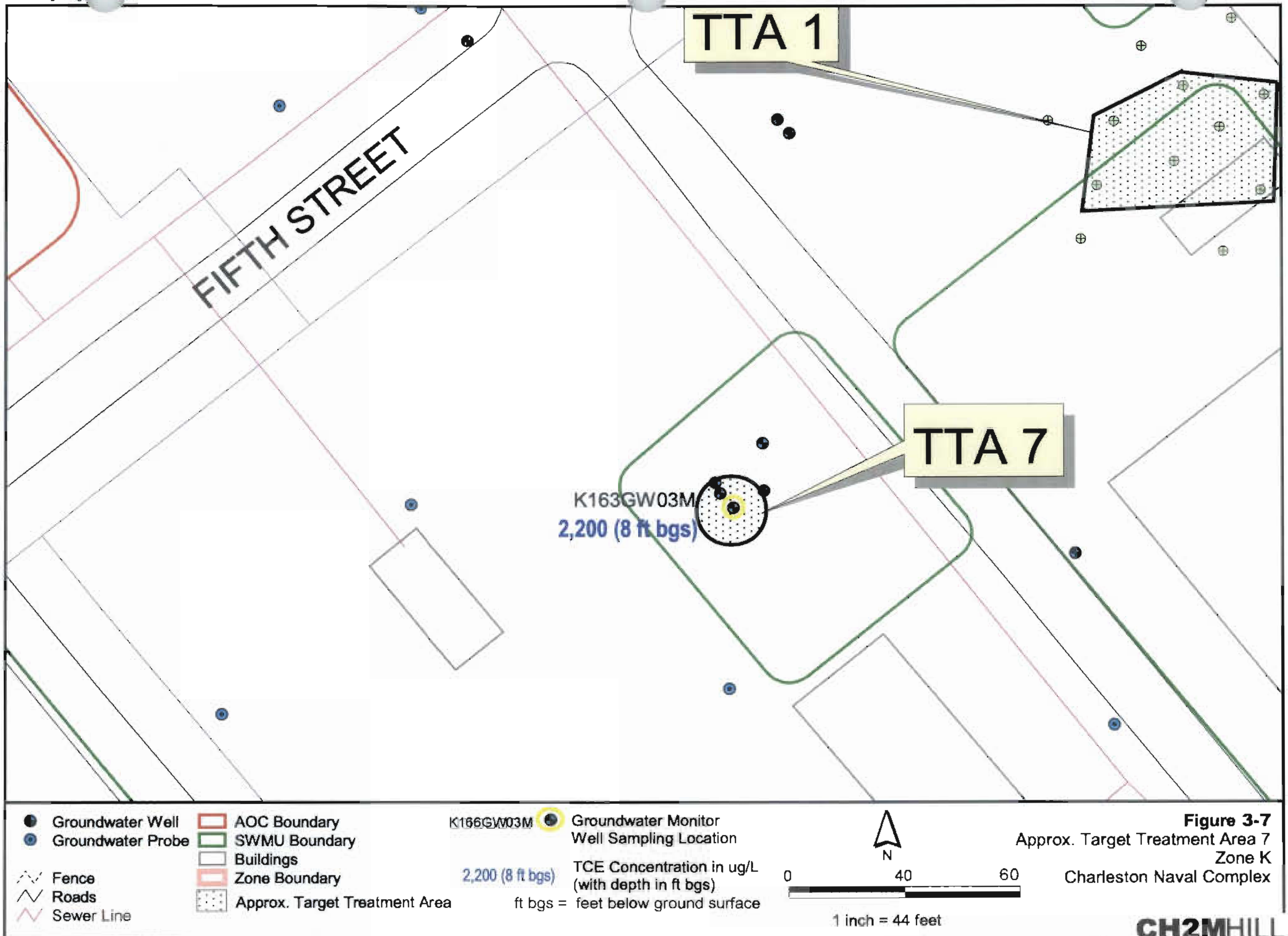


Figure 3-6A
Approx. Target Treatment Area 6
SWMU 166, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

NOTE: Original fig d in color



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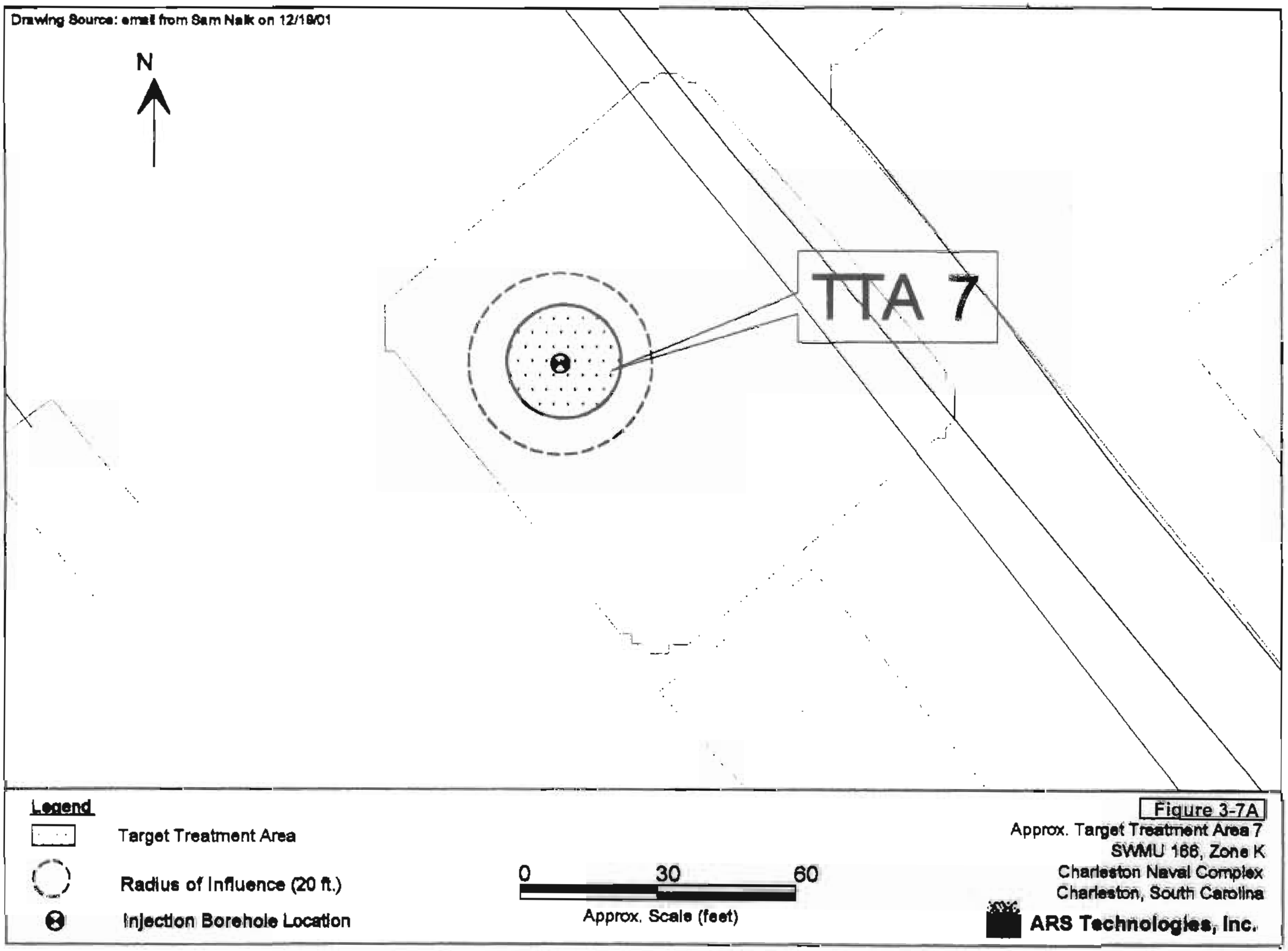
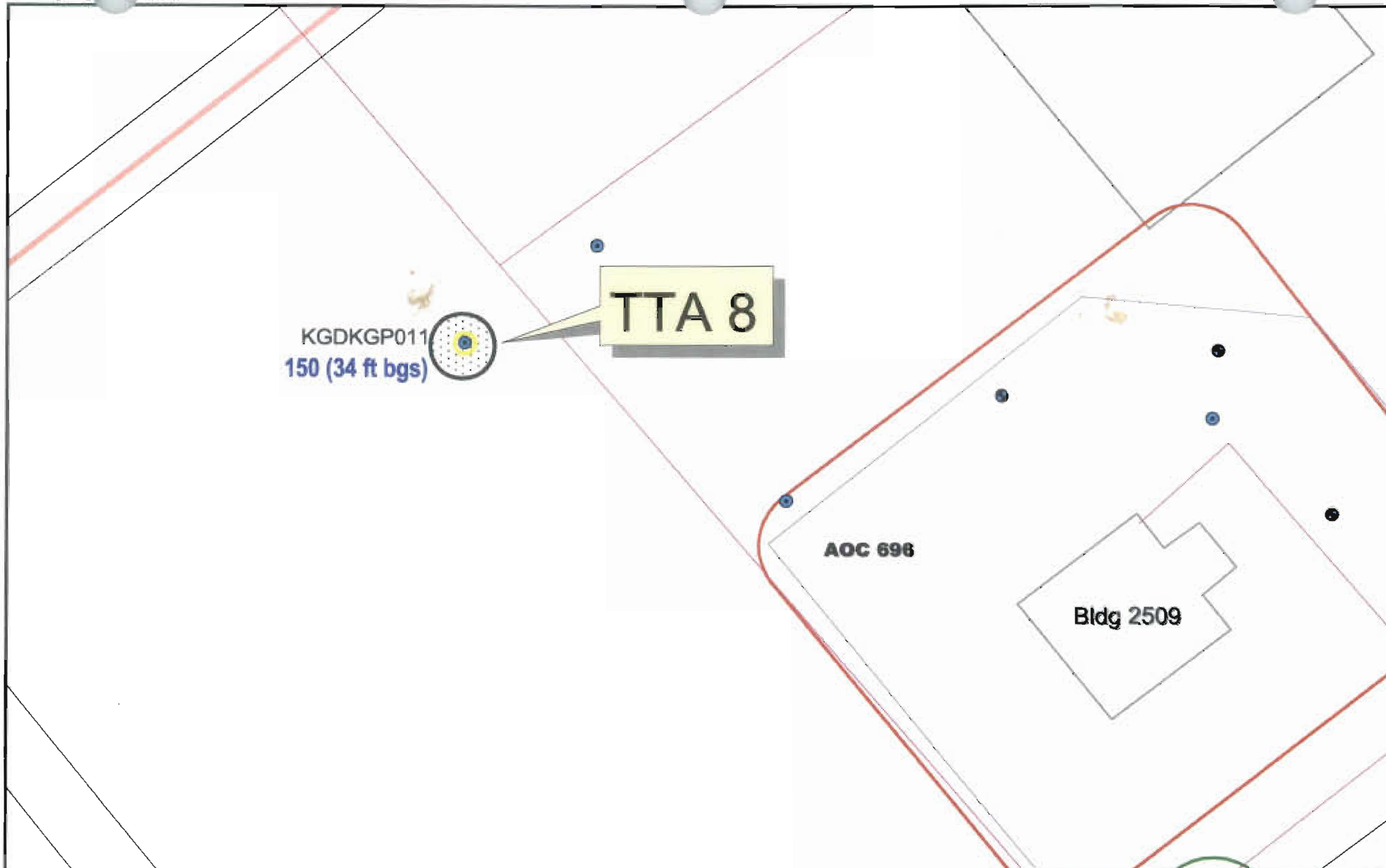


Figure 3-7A
Approx. Target Treatment Area 7
SWMU 166, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

NOTE: Original fig... d in color



Groundwater Well
Groundwater Probe
Fence
Roads
Sewer Line

AOC Boundary
SWMU Boundary
Buildings
Zone Boundary
Approx. Target Treatment Area

KGDKGP011 Groundwater DPT Sampling Location

150 (34 ft bgs) TCE Concentration in ug/L (with depth in ft bgs)

ft bgs = feet below ground surface

N

0 30 60 Feet

1 inch = 44 feet

Figure 3-8
Approx. Target Treatment Area 8
Zone K
Charleston Naval Complex

CH2MHILL

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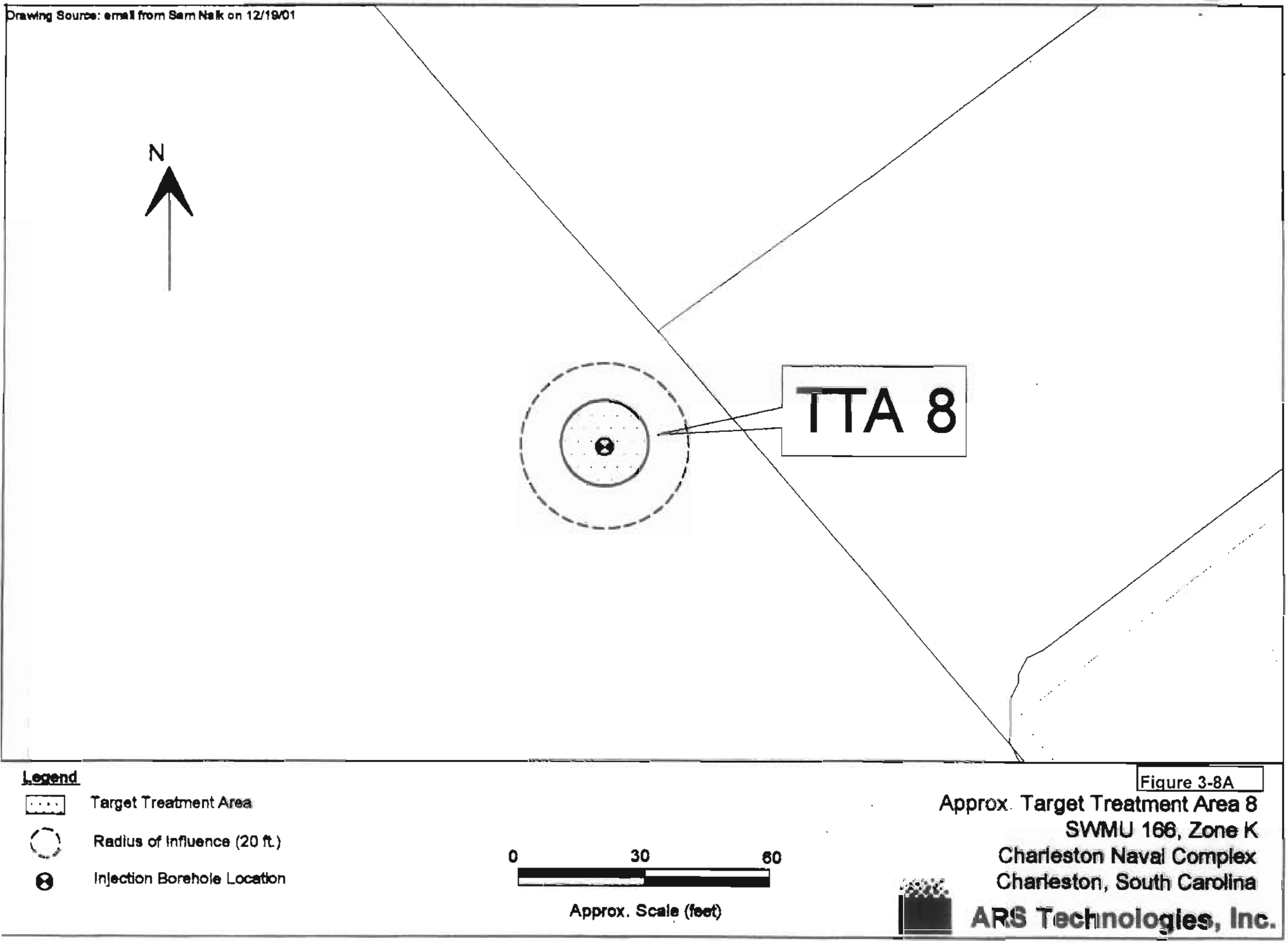

Figure 3-8A

Approx. Target Treatment Area 8
SWMU 166, Zone K
Charleston Naval Complex
Charleston, South Carolina

ARS Technologies, Inc.

Section 4.0

4.0 Investigation-Derived Waste

IDW that is generated during this effort will include purge water from the groundwater sampling activities, soil cuttings from injector installation, and personal protective equipment (PPE). IDW will be collected in labeled 55-gallon drums or portable tanks for proper handling. Contained IDW will remain on site temporarily until it is transported to the less-than-90-day storage facility located at Building 1824 in the CNC. Once the analytical results have been reviewed, the 55-gallon drums or portable tank containing the groundwater contents will be transported, as required, to a permitted and licensed facility for treatment or disposal.

Section 5.0

5.0 Project Schedule

Figure 5-1 shown on the following page, presents the project schedule.

FIG.
PROPOSED SCHEDULE FEROX INJECTION SWMU 196
CHARLESTON NAVEL COMPLEX, CHARLESTON, SC

ID	Task Name	Duration
1	Pre-Mobilization	0 days
2	Contract/Pre-Construction Submittals	5 days
3	HASP and Work Plan	10 days
4	UIC and Regulatory Review (CH2M-JONES)	40 edays
5	Pilot test Field Activities	0 days
6	Pilot Testing at TTA-4	4 edays
7	Post-injection Sampling & Analysis	60 edays
8	Design Addendum	45 edays
9	Full-Scale Field Injections	0 days
10	Material Procurement Prep and Mobilization to Site	4 days
11	Field Setup	2 days
12	Field Injections	24 days
13	Decon and Demobilization	2 days
14	Post Injection Sampling and Reporting	0 days
15	Interim Report of Initial Field Injections	30 edays
16	Verification Sampling and Analysis (CH2M-JONES)	75 edays
17	Polishing Injections (If Necessary)	0 days
18	Prep Mobilization to Site for Polishing	4 days
19	Field Setup	2 edays
20	Field Injections	7 edays
21	Decon and Demobilization	2 edays
22	Post Injection Sampling and Reporting	0 days
23	Addendum Report for Polishing Phase	20 edays
24	Verification Sampling and Analysis (CH2M-JONES)	90 edays

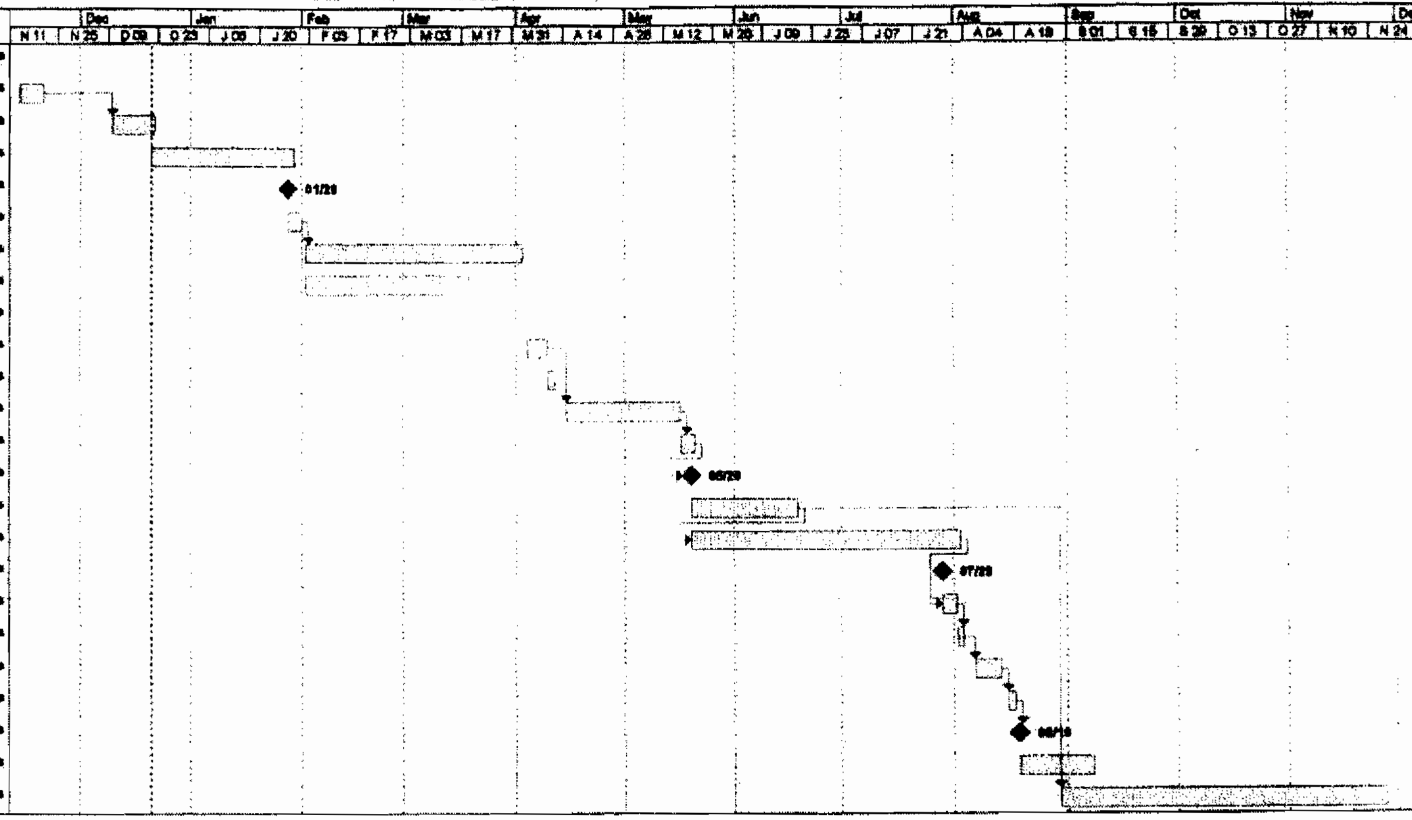

Figure 5-1 Proposed IM Implementation Schedule
Source : ARS Technologies, Inc.

Schedule Update for Draft Work Plan
Date: Fri 12/21/01

Task | Split | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Split | Rolled Up Milestone | Rolled Up Progress | External Tasks | Project Summary

Section 6.0

6.0 References

ARS Technologies, Inc., *Draft FeroxSM Field Implementation Work Plan, SWMU 166*. CNC. December 2001.

CH2M-Jones. *Membrane Interface Probe-Phase II Pilot Study Report, CMS Work Plan, SWMU 166, Zone K, Revision 1*. February 2001.

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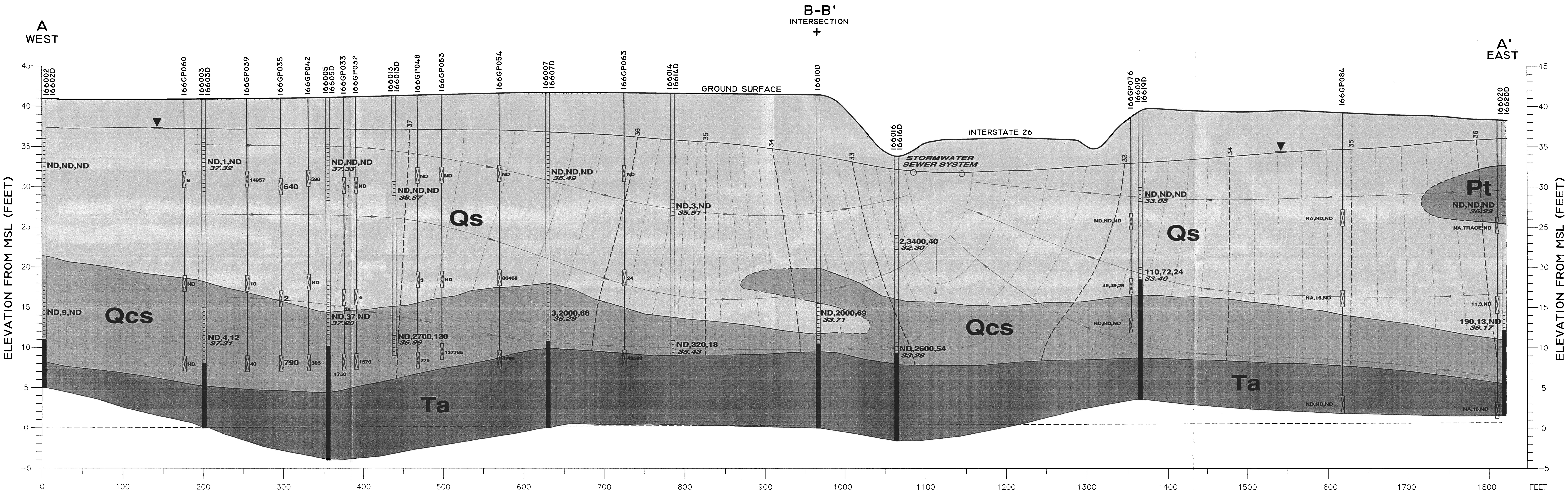
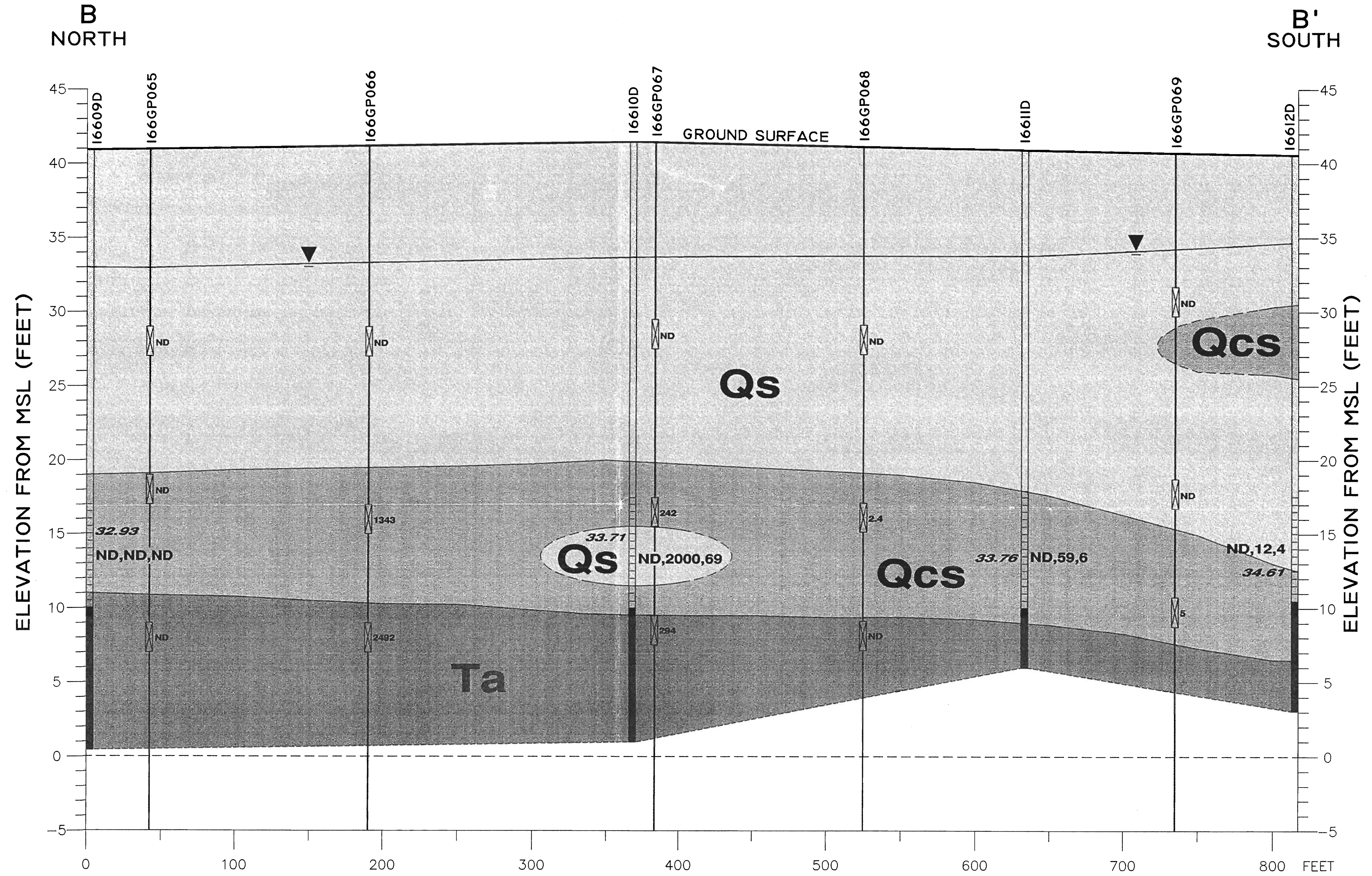
EnSafe Inc. *Zone K RCRA Facility Investigation Report, Revision 0*. CNC. June 11, 1999a.

EnSafe Inc. *Monitored Natural Attenuation Interim Report, Revision 0*. 1999b.

Appendix A



CROSS-SECTION A - A'



CROSS-SECTION B - B'

LEGEND:

- EQUIPOTENTIAL LINE (0.2 FOOT INTERVALS)
- FLOW LINE
- WATER TABLE SURFACE
- ND,2000,69 / 33.70 — SCREENED INTERVAL OF MONITORING WELL – INCLUDING FILTER PACK WITH PCE, TCE, AND DCE CONCENTRATIONS IN $\mu g/L$ AND WATER LEVEL ELEVATION (ON 03/06/98)
- BENTONITE
- DPT SAMPLE LOCATION WITH COMBINED TCE/DCE CONCENTRATIONS (ONE NUMBER) OR PCE, TCE, AND DCE CONCENTRATIONS (THREE NUMBERS)
- GEOLOGIC CONTACTS – DASHED WHERE INFERRED
- MEAN SEA LEVEL (MSL) DATUM
- VERTICAL SCALE: 1" = 5'-0"
- (VERTICAL EXAGGERATION: 1 : 10)
- HORIZONTAL SCALE: 1" = 50'-0"

FLOW NET SCHEMATIC:
EQUIPOTENTIAL LINES DO NOT REFLECT RELATIVELY SMALL DIFFERENCE IN HYDRAULIC CONDUCTIVITIES BETWEEN THE SAND FACIES (Qs) AND THE UNDERLYING CLAYEY SAND FACIES (Qcs)

LITHOSTRATIGRAPHIC UNITS

QUATERNARY AGE

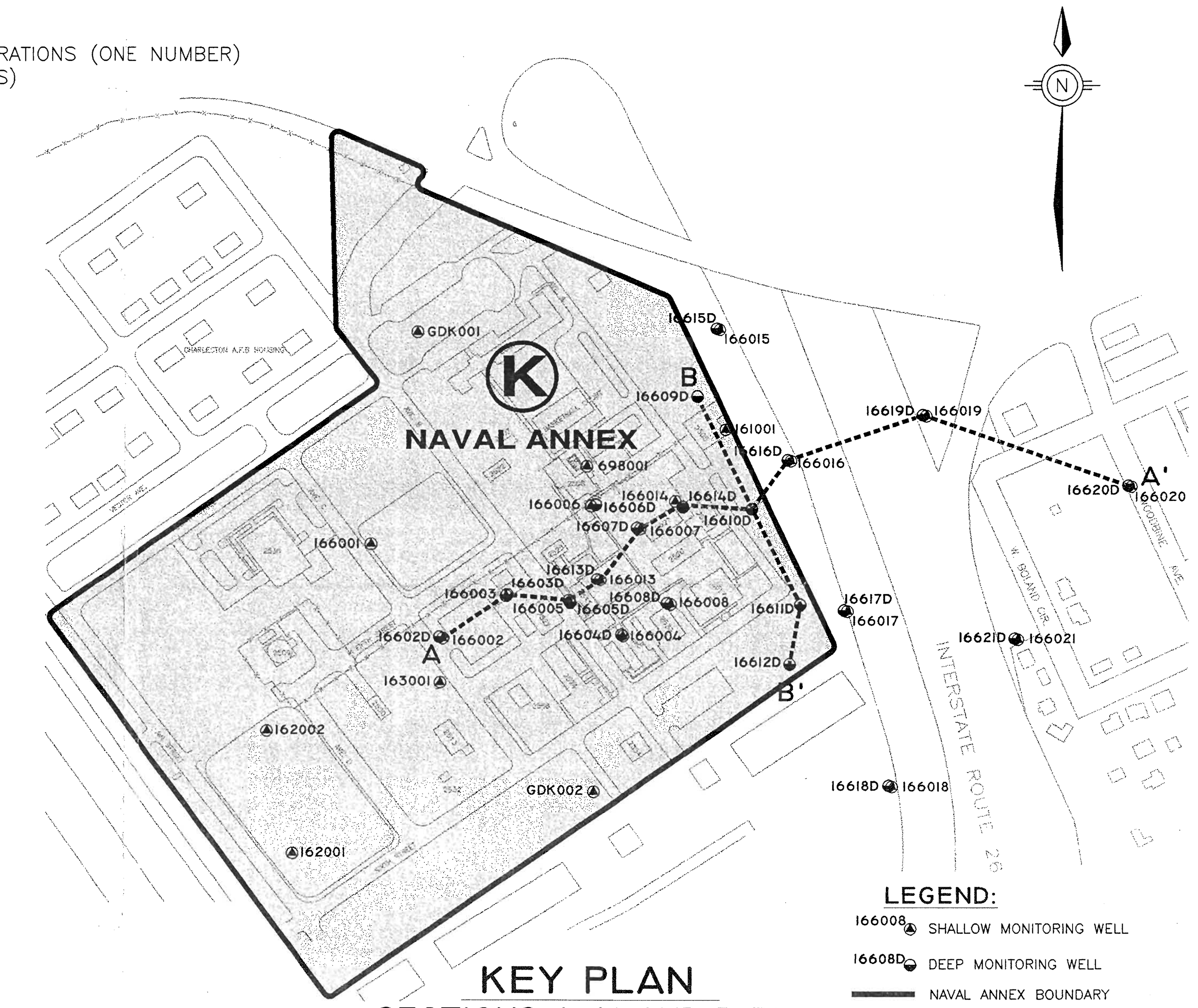
Qs — SAND: TYPICALLY GRAY,GREEN, ORANGE, OR BROWN; FINE TO MEDIUM SLIGHTLY SILTY; MICACEOUS.

Pt — PEAT: DARK BROWN; WOODY FRAGMENTS; DECOMPOSING GRASSES; SPONGY

Qcs — CLAYEY SAND TO CLAY: TYPICALLY GREEN TO GRAY–GREEN; FINE TO COARSE; CLAYEY; VARYING AMOUNTS OF SILT; PHOSPHATE NODULES AND SHELL CLAY GENERALLY FIRM TO STIFF AND PLASTIC

TERTIARY AGE

Ta — SILT: TYPICALLY OLIVE BROWN; CLAYEY, DENSE, CALCAREOUS, ASHLEY FORMATION



KEY PLAN
SECTIONS A-A' AND B-B'

REVISIONS		
Rev Number:	Rev Date:	Rev By:
Rev Number:	Rev Date:	Rev By:
Rev Number:	Rev Date:	Rev By:
Rev Number:	Rev Date:	Rev By:
Rev Number:	Rev Date:	Rev By:

ZONE K
RCRA FACILITY
INVESTIGATION REPORT
CHARLESTON NAVAL COMPLEX
CHARLESTON, SC

FIGURE 2.5
LITHOSTRATIGRAPHIC
CROSS-SECTIONS A-A' and B-B'

Dr by: W. FAULK	Tr by: –	
Ck by: T. KAFKA	Appr by: S. PARKER	Sheet 1
Date: 05/27/99	DWG Name: 2911C061	Of 1

Appendix B

Material Safety Data Sheet

MFE063

[1] Product Identification

Product name	E−200
Manufacturer's name	Dowa Iron Powder Co.Ltd
Manufacturer's address	7 Chikkosakaemachi Okayama City Japan
Emergency telephone number	086(262)2228
Telephone number for information	086(262)2228
Date prepared	Feb.1,2000
Signature of prepare	Koichi Maruoka

[2] Ingredients

Chemical name	Iron (Fe)	95wt%<
CAS No.	7439-89-6	

[3] Physical/Chemical Characteristic

Boiling point	2730℃
Melting point	1535℃
Vapor pressure	N.A.
Vapor density	N.A.
Particle size	75 μm
Specific gravity(H_2O=1)	7.8
Viscosity	N.A.
pH value	N.A.
Evaporation rate	N.A.
Solubility in water/other solvents	Negligible
Appearance/Odor	Dark gray powder/Odorless

[4] Fire and Explosion Hazard Data

Flash point	N.A.
Ignition temperature	N.A.
Explosion(Flammable) limits	Lower : N.A. Upper : N.A.
Thermal decomposition	N.A.
Extinguishing media	Dry sand , Powder or CO_2
Special fire fighting procedures	N.A.
Unusual fire and explosion hazards	U

[5] Reactivity Data

Stability	Stable
Hazardous polymerization	Will not occur
Incompatibility(Materials to avoid)	Nothing
Hazardous decomposition or byproducts	Nothing

[6] Health and Hazard Data

Route(s) of entry	
Inhalation	yes
Ingestion	yes
Skin	no
Others	eye
Sings and symptoms of exposure	U
Medical conditions generally aggravated by exposure	U
Toxicity	U

[7] First-Aid

Emergency and first-aid procedures

Eye contact	: Flush with water until remove foreign body.
Skin contact	: Wash with water
Ingestion	: In case of large quantity , let a person see a doctor.

[8] Protection Information

Respiratory protection	Preferable to put on single mask.
Eye protection	Preferable to put on goggles.
Protective gloves	Preferable to clothe gloves.
Other protective clothing or equipment	Eyewash equipment etc. as required by your company.
Ventilation	Good general ventilation should be sufficient for most conditions
Work/Hygienic practices	Wash with water after handling.

[9] Precautions for Safe Handling and Use

Steps to be taken in case material is released or spilled	
	Sweep up and remove.
Waste disposal method	Dispose of the materials in accordance with local regulations as incombustible substance
Precautions to be taken in handling and storing	
	Store in dry and cool place.
Other precautions	U