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CORRECTIVE MEASURES STUDY WORK PLAN RATIONALE FOR NO FURTHER ACTION SOLID WASTE MANAGEMENT UNIT 185 (SWMU 185) ZONE K CNC CHARLESTON SC

2/1/2001

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CORRECTIVE MEASURES STUDY WORK PLAN

Rationale for No Further Action

Solid Waste Management Unit 185, Zone K

Charleston Naval Complex
North Charleston, South Carolina

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

PREPARED BY
CH2M-Jones

February 2001

Revision 0
Contract N62467-99-C-0960

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Certification Page for Corrective Measures Study Work Plan – SWMU 185, Zone K

Rationale for No Further Action

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

Temporary Permit No. T2000342

Dean Williamson

Dean Williamson, P.E.

2/7/2001

Date

SOUTH CAROLINA CERTIFICATE OF AUTHORIZATION

CH2M HILL, INC.

No. C00201

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Acronyms and Abbreviations

AOC	area of concern
BCT	BRAC Cleanup Team
BRAC	Base Realignment and Closure Act
CA	corrective action
CMS	corrective measures study
CNC	Charleston Naval Complex
COC	chemical of concern
COPC	chemical of potential concern
DPT	direct push technology
EnSafe	Ensafe Inc.
MCL	maximum contaminant level
NAVBASE	Naval Base
NFA	no further action
NFI	no further investigation
OWS	oil-water separator
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
SCDHEC	South Carolina Department of Health and Environmental Control
SWMU	solid waste management unit
UST	underground storage tank

Introduction

1.0 Introduction

In 1993, Naval Base (NAVBASE) Charleston was added to the list of bases scheduled for closure as part of the Defense Base Realignment and Closure Act (BRAC), which regulates closure and transition of property to the community. The Charleston Naval Complex (CNC) was formed as a result of the dis-establishment of the Charleston Naval Shipyard and NAVBASE on April 1, 1996.

Corrective Action (CA) activities are being conducted under the Resource Conservation and Recovery Act (RCRA) with the South Carolina Department of Health and Environmental Control (SCDHEC) as the lead agency for CA activities at the CNC. All RCRA CA activities are performed in accordance with the Final Permit (Permit No. SC0 170 022 560).

In April 2000, CH2M-Jones was awarded a contract to provide environmental investigation and remediation services at the CNC. This submittal has been prepared by CH2M-Jones to document the basis for a No Further Action (NFA) decision for Solid Waste Management Unit (SWMU) 185 in Zone K of the Naval Annex. Figure 1-1 illustrates the location of Zone K within the CNC.

1.1 Background

SWMU 185 is a former sanitary sewer and septic tank system that served the Naval Annex, with the exclusion of the Air Force housing area. Figure 1-2 shows an aerial photograph of the SWMU 185 area. The sanitary sewer system (formerly SWMU 166 in the RCRA Facility Assessment [RFA]) includes approximately 5,300 linear feet of gravity sewer lines. Wastewater entering the system consists of domestic wastewater only. A single trunk line exits the property at the southwest boundary for treatment in the North Charleston Sewer District Privately Owned Treatment Works. No known industrial discharges currently enter the sanitary sewer system. There are no known reports or observations indicating any contaminants discharged to the system.

The RFA also described a former septic tank and drain field system located between Fourth and Fifth Streets and Avenues B and C. The leach (tile) field contained 26 lines. It is not known how long the septic tank system operated or what was discharged through the system. The site became a SWMU because of possible contaminants entering the sanitary sewer system and impacting the surrounding environment, or entering and impacting the former septic tank and/or drain field.

1.2 Purpose of the CMS Work Plan – Rationale for NFA

This report provides information about SWMU 185 that documents the conclusions from the RCRA Facility Investigation (RFI) and supports the RFI recommendation of NFA for SWMU 185 (EnSafe Inc. [EnSafe] 1999a). A copy of the table which contains this information (Table 11.1, *Zone K Site Conclusions and Preliminary Recommendations*) is provided in Appendix A.

Prior to changing the status of any site to NFA in the CNC RCRA CA permit, the BRAC Cleanup Team (BCT) agreed that the following issues should be considered:

- Status of the RFI
- Presence of metals (inorganics) in groundwater
- Potential linkage to SWMU 37, Investigated Sanitary Sewers at the CNC
- Potential linkage to Area of Concern (AOC) 699, Investigated Storm Sewers at the CNC
- Potential linkage of AOC 504, Investigated Railroad Lines at the CNC
- Potential linkage to surface water bodies (Zone J)
- Potential contamination associated with oil-water separators (OWSs)
- Relevance or need for land use controls at the site

Information regarding these issues is provided in this Corrective Measures Study (CMS) Work Plan to expedite evaluation of closure of the site.

Provided that the information presented in this work plan is adequate to address these site closeout items, it is expected that the BCT will concur that NFA is appropriate for the site. At that time, a Statement of Basis will be prepared that will be available for public comment in accordance with SCDHEC policy. This will allow for public participation in the final remedy selection.

1.3 Report Organization

This CMS Work Plan, Rationale for NFA, consists of the following sections, including this introductory section:

1.0 Introduction — Presents the purpose of the report and background information relating to the CMS Work Plan , Rationale for NFA.

2.0 Summary of RFI Conclusions for SWMU 185 — Summarizes the conclusions from the RFI investigations and risk evaluations for SWMU 185.

3.0 Summary of Closeout Issues—Discusses the various site closeout issues that the BCT agreed to evaluate prior to site closeout.

4.0 Recommendations—Provides recommendations for proceeding with site closure.

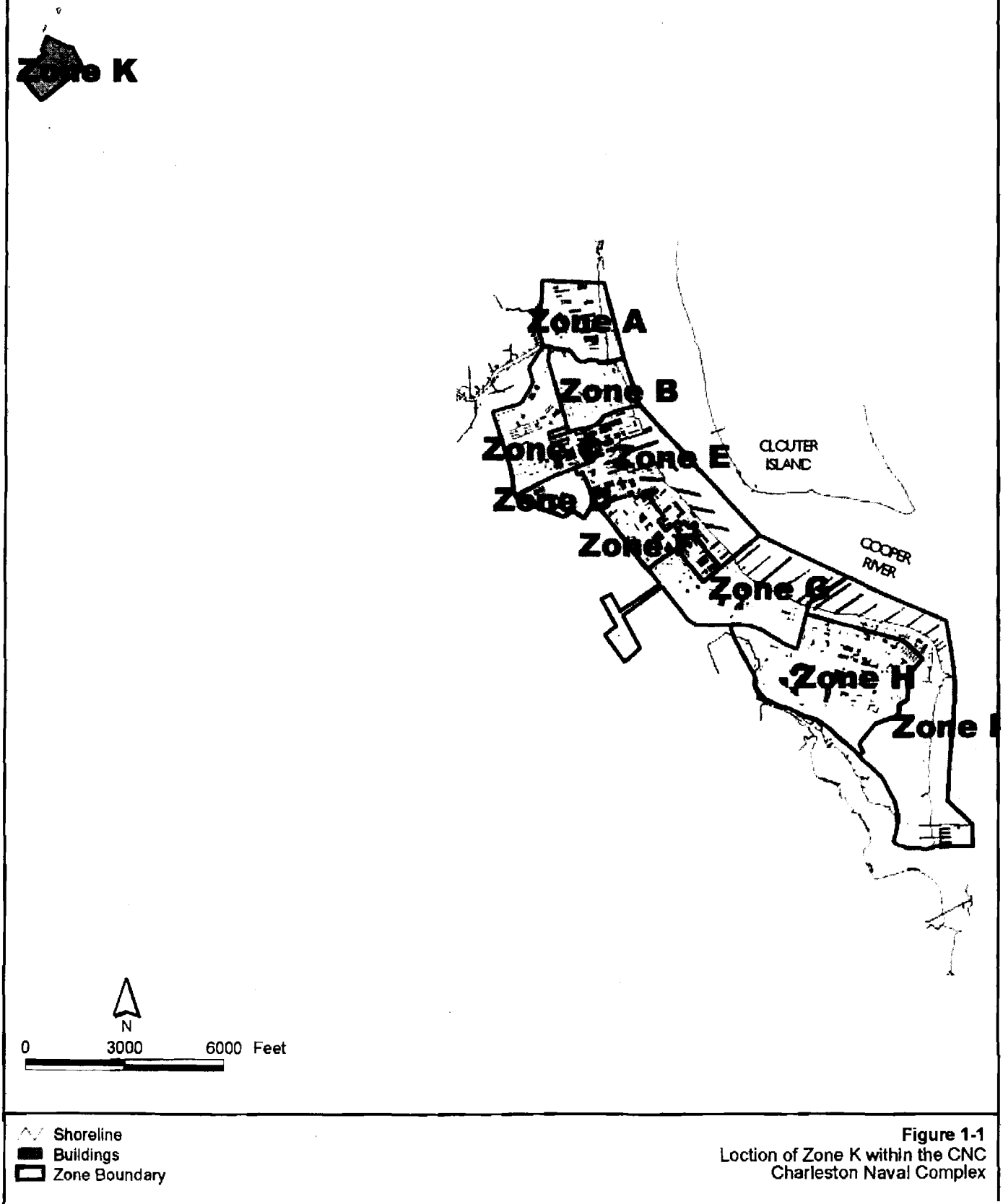
5.0 References — Lists the references used in this document.

Appendix A contains Tables 11.1 and 11.9 of the *Zone K RFI Report*.

Appendix B contains excerpts from the *Zone K RFI Report*, including page 10.5.22.

Appendix C contains Table 4.3 from the Project Team Notebook, which presents the RFI Completion Process for Zones E, F, G, H, I, and K.

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



Shoreline
Buildings
Zone Boundary

Figure 1-1
Loction of Zone K within the CNC
Charleston Naval Complex

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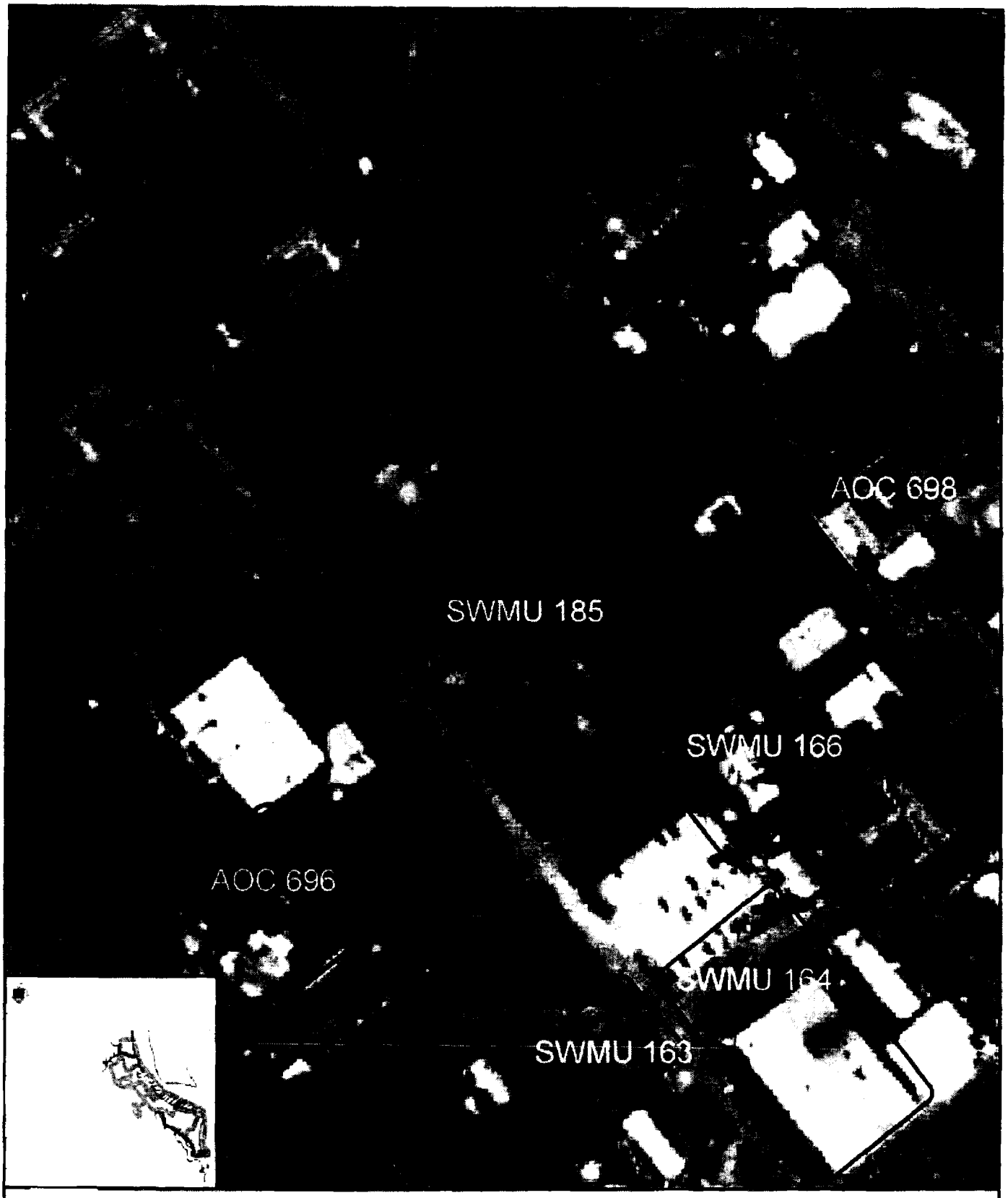

AOC Boundary
SWMU Boundary
Zone Boundary

N

0 100 200 Feet

Figure 1-2
Aerial View of SWMU 185
Zone K
Charleston Naval Complex

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Summary of R&D Technology for SWMU 185

2.0 Summary of RFI Conclusions for SWMU 185

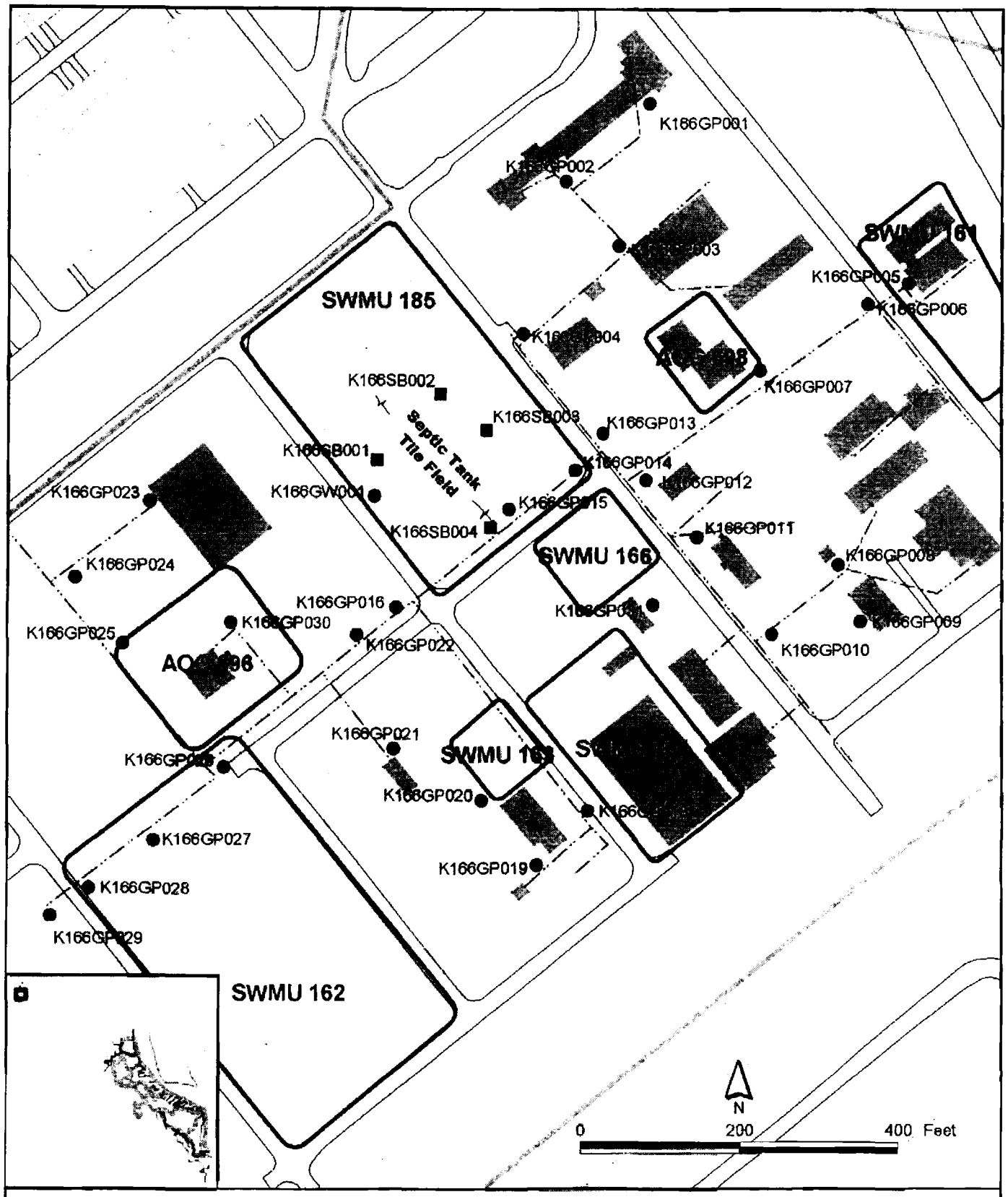
As part of the Zone K RFI, soil and groundwater investigations were conducted in the area of the former septic tank/drain field and along the sewer lines. Figure 2-1 presents the site and test locations of samples collected within this area.

During the RFI, soil borings were made for collection and analysis of four surface soil and four subsurface soil samples in the vicinity of the septic tank/drain field. Thirty groundwater samples were collected along the sewer lines using direct push technology (DPT) methods. A monitor well was also installed to allow collection and analysis of groundwater samples near the septic tank/drain field. Appendix B presents excerpts from the RFI report for this site. No soil or groundwater chemicals of potential concern (COPCs) were identified in the human health risk assessment for SWMU 185. According to the risk summary in paragraph 10.5.4.4 of the *Zone K RFI Report*: "A conservative screening process was used to evaluate data generated from the soil and groundwater samples collected at this site. No COPCs were identified for either soil or groundwater at SWMU 185" (EnSafe, 1999a). These conclusions apply to the septic tank/drain field and the sewer lines.

Appendix B contains page 10.5.22 where this excerpt is found.

The RFI further concluded that NFA is appropriate at SWMU 185, according to the recommendations provided in Table 11.1 (see Appendix A). There are no ecological risk drivers for SWMU 185 as stated in RFI report Table 11.9, *AOCs/SWMUs Associated with Zone K Subzones* (see Appendix A).

During a scoping meeting to plan the completion of the RFI for Zone K held with representatives of SCDHEC in September 2000, it was concluded that No Further Investigation (NFI) was required at this site. Thus, as the investigation was completed with no detection of COPCs or COCs, NFA is appropriate for this site.



- Groundwater Probe Samples
- Groundwater Samples
- Soil Boring Samples
- Railroads
- Roads - Lines
- Sewer Line
- AOC Boundary
- SWMU Boundary
- Buildings
- Zone Boundary

Figure 2-1
SWMU 185
Site and Test Locations
Charleston Naval Complex

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APPENDIX

Summary of Information Related to Site Closeout Issues

3.0 Summary of Information Related to Site Closeout Issues

3.1 RFI Status

The *Zone K RFI Report* (EnSafe, 1999a) addressed SWMUs/AOCs within the Naval Annex, including SWMU 185. Because the investigation was considered to be complete for this site, the subsequent *Zone K RFI Report Work Plan Addendum* (EnSafe, 1999b) did not address SWMU 185. Reports, comments, and responses following the Zone K RFI Report also confirm that additional soil or groundwater samples are not required. The RFI Work Plan Addendum written by EnSafe (1999b) does not recommend any further sampling for SWMU 185, and the CH2M-Jones Work Plan Addendum (2000a) recommends no additional samples be collected.

In accordance with the RFI completion process as summarized in Figure 4-3 of the Project Team Notebook (CH2M-Jones, 2000b) (see Appendix C), upon completion of the Zone K RFI Report, if a determination of NFI is made then a site may proceed to either NFA status or to a CMS. As there were no COCs detected at this site, NFA is appropriate.

3.2 Presence of Inorganics in Groundwater

For the purpose of site closeout documentation, the inorganics in groundwater issue refers to the occasional or intermittent detection of several metals (primarily arsenic, thallium, and antimony) in groundwater at concentrations above the applicable maximum contaminant level (MCL), preceded or followed by detections of these same metals below the MCL or below the practicable quantitation limit.

Groundwater samples collected in the vicinity of SWMU 185 (K166GW001) were evaluated as part of the Zone K RFI for groundwater quality. The RFI reported that none of the inorganic samples from this well exceeded their respective MCLs. Table 3-1 presents a summary of analytical results for arsenic, thallium, and antimony for groundwater samples collected from monitor well K166GW001. All of the results for these metals were below the detection limit.

3.3 Potential Linkage to SWMU 37, Investigated Sanitary Sewers at the CNC

Because of the location of this site at the Naval Annex, there is no potential linkage to SWMU 37, which is located at the Charleston Naval Shipyard.

3.4 Potential Linkage to AOC 699, Investigated Storm Sewers at the CNC

Because of the location of this site at the Naval Annex, no linkage to AOC 699, the storm sewer at the Charleston Naval Shipyard, is possible. In addition, because there were no COCs identified in groundwater or soil, COC migration is not a concern at this site.

3.5 Potential Linkage to AOC 504, Investigated Railroad Lines at the CNC

No railroad lines are present at the Naval Annex, so further evaluation of a potential linkage between AOC 504 and the subject site is not necessary.

3.6 Potential Migration Pathways to Surface Water Bodies at the CNC

The nearest named surface water body to SWMU 185 is Filbin Creek, which is located more than 3,000 feet to the southeast.

Two potential migration pathways from the site to surface water are overland flow via stormwater runoff, and subsurface flow via groundwater. Due to the fact that source area contamination was not identified at SWMU 185, and that the nearest water-receiving body is 3,000 feet to the southeast, surface water runoff from SWMU 185 would not be an ecological concern at Filbin Creek. In addition, there were no COPCs in surface soil at SWMU 185; therefore, further evaluation of a potential pathway for contaminant migration via stormwater runoff is not warranted.

No groundwater COCs were identified at SWMU 185. Therefore, further evaluation of potential migration of contaminated groundwater to a surface water body is not warranted.

3.7 Potential Contamination in Oil-Water Separators (OWSs)

The issue of potential contamination of OWSs refers to the possible presence of an OWS that has not yet been investigated at a SWMU or AOC as part of the RCRA or underground storage tank (UST) process.

Neither the RFA nor the RFI refers to the presence or possible presence of an OWS at SWMU 185. In addition, there is no visual evidence of an OWS at this site. Therefore, further evaluation of this issue at SWMU 185 is not warranted.

3.8 Land Use Control Management Plan

The human health risk assessment in the RFI screening did not detect any COPCs in groundwater or soil at SWMU 185. This conservative evaluation considered potential future residential use, which is considered unrestricted use. The *Charleston Naval Annex Reuse Plan* (Wilbur Smith Associates, 1997) indicated that light industrial distribution/mixed uses are planned for this site. Thus, land use controls are not necessary at SWMU 185.

TABLE 3-1
Summary Analytical Results for Selected Metals in Groundwater – Monitor Well 166GW001
CMS Work Plan, Rationale for No Further Action, SWMU 185, Zone K, Charleston Naval Complex

Sample Date	Arsenic		Thallium		Antimony	
	Result (µg/L)	Qualifier	Result (µg/L)	Qualifier	Result (µg/L)	Qualifier
01/03/1997	1.7	U	6	U	2.4	U
04/18/1997	3	U	5.2	U	2.2	U
07/23/1997	2.8	UJ	3.9	U	2.3	U
10/22/1997	1.8	UJ	6.7	U	2.8	U

Notes:

U The compound was not detected.
UJ The compound was not detected and the detection limit is an estimated value.

section 4

Recommendations

4.0 Recommendations

SWMU 185 includes a septic tank and drain field that have not been used for decades, as well as a sewer system that currently services the few active buildings at the Naval Annex. The site became a SWMU because of possible contaminants entering the sanitary sewer system and impacting the surrounding environment (i.e., the former septic tank and/or drain field). However, there have been no reports or observations indicating any contaminant was discharged to the existing or former systems.

No soil or groundwater COPCs were identified at SWMU 185. According to the risk summary in paragraph 10.5.4.4 of the *Zone K RFI Report*: "A conservative screening process was used to evaluate data generated from the soil and groundwater samples collected at this site. No COPCs were identified for either soil or groundwater at SWMU 185" (EnSafe, 1999a).

The RFI further concludes that NFA is appropriate at SWMU 185 according to the recommendations provided in Table 11.1 (see Appendix A). Further investigation or corrective action is not necessary at SWMU 185.

Once the BCT concurs that NFA is appropriate for the site, a Statement of Basis will be prepared that will be made available for public comment in accordance with SCDHEC policy. This will allow for public participation in the final remedy selection .

References

5.0 References

Wilbur Smith Associates. *Charleston Naval Annex Reuse Plan.* Charleston, S.C. February, 1997.

EnSafe Inc. *Zone K RFI Report, NAVBASE Charleston.* Revision 0. June, 11, 1999a.

EnSafe Inc. *Zone K RFI Report Work Plan Addendum, NAVBASE Charleston.* November, 16, 1999b.

CH2M-Jones. *Zone K RFI Report Work Plan Addendum- Zone K Naval Station Annex, NAVBASE, Charleston.* September, 2000a.

CH2M-Jones. *RCRA Corrective Action Project Team Notebook and Project Instructions for the Charleston Naval Complex Environmental Restoration.* September, 2000b.

APPENDIX A

Cost Model Report Tables 1.1.1 and 1.1.2

considered. No further action recommendations are not acceptable for sites where a potential risk exists under a residential scenario even though an industrial reuse of the property is expected since institutional controls for the site will be required. Final recommendations and the rationale for the risk management decisions will be documented in an addendum to this report.

A summary of the preliminary recommendations for all the sites investigated in Zone K is included in Table 11.1.

Table 11.1
Zone K Site Conclusions and Preliminary Recommendations

Site Designation	Conclusion/Recommendations
SWMU 161	No Further Action
SWMU 162	Recommended for inclusion in the CMS
SWMU 163	Recommended for inclusion in the CMS
SWMU 164	Recommended for inclusion in the CMS
SWMU 185	No Further Action
AOC 693/694	Recommended for inclusion in the CMS
AOC 695	RFI Investigatory Designation will be assigned in the Zone J RFI
AOC 696	Additional sampling recommended prior to assigning investigatory designation
AOC 698	Recommended for inclusion in the CMS
SWMU 166	Recommended for inclusion in the CMS

The following sections summarize the recommendations for each site, level of risk/hazard posed by each of the sites recommended for corrective measures, the media affected, and the chemicals driving that risk.

Table 11.9
AOCs/SWMUs Associated with Zone K Subzones

AOC/SWMU	Description	Ecological Risk Drivers: Chronic Exposure	Ecological Risk Drivers: Subchronic Exposure[1]
	Subzone K-1		
AOC 695	Electric locomotive shop	Arsenic Chromium Nickel[2]	
	Subzone K-2		
AOC 693	Fuse and primer house	Arsenic Copper Lead Mercury	Barium Cadmium Selenium Zinc
AOC 694	Former ammunition depot		
	Subzone K-4		
SWMU 161	Vehicle maintenance shop	None	Mercury
SWMU 162	Sludge drying field	Mercury 4,4'-DDE 4,4'-DDT	Arsenic Cadmium Zinc
SWMU 163	Concrete pit area	None	Arsenic Cadmium Lead Zinc 4,4'-DDE 4,4'-DDT
SWMU 164	Blasting operations	Arsenic	Cadmium Lead Zinc
SWMU 185	Sewer system	None	None
AOC 696	Transformer area near Building 2509	4,4'-DDT	Arsenic Cadmium Zinc 4,4'-DDE Aroclor 1260

APPENDIX

Excerpts from the June KCRH Report

Page 10 3 of 2

10.5 SWMU 185, Sewer System and Former Septic Tank System, Naval Annex

SWMU 185, originally identified in the work plan as SWMU 166, consists of the sanitary sewer, and septic tank system, serving the Naval Annex excluding the Air Force housing area. The sanitary sewer system is comprised of approximately 5,300 linear feet of gravity sewer lines. Most lines are constructed of vitrified clay, although some are constructed of ductile iron, cast iron, PVC, or polypropylene. All wastewater generated at the Naval Annex is collected by a single trunk line which exits the property at the southwest boundary. A March 5, 1957, Naval Annex schematic identifies the former septic tank and drainfield system located between Fourth and Fifth Streets and Avenues B and C. The associated leach or tile field contained 26 lines and was located in this same area. It is unknown how long the septic system operated. Figure 10.5.1 illustrates the layout of the Naval Annex sewer system and the location of the former septic tank and associated drainfield.

The composition of effluent from the sanitary sewer system is unknown. However, a review of historical activities conducted at Naval Annex indicates possible materials such as metals, petroleum products, and waste paint/solvents were in use at Naval Annex and may have been disposed of through the sanitary sewer. No known industrial discharges currently enter the sanitary sewer system.

Materials of concern identified in the *Final Zone K RFI Work Plan (E/A&H, September 1996)* for SWMU 166 included metals, petroleum products, solvents, paints, and biodegradation gases. Potential receptors include current and future site users involved in invasive activities.

To fulfill CSI objectives, soil and groundwater were sampled in accordance with the Final Work Plan and as described in Section 3 of this report to confirm whether any contamination resulted from onsite activities at SWMU 166. Figure 10.5.1 also presents the sample locations proposed

Figure 10.5.1 SWMU 185 Sample Locations

in the approved work plan. The only deviation to the workplan was the number of groundwater screening samples collected. This deviation is described in Section 10.5.2.

During the investigation of the sewer system a groundwater screening sample detected the VOC trichloroethene (TCE). To facilitate investigation of this detection, the NAVBASE project team reassigned SWMU 166 to the TCE plume investigation associated with the automobile service shop. The investigation of the sewer system was reassigned as SWMU 185.

10.5.1 Soil Sampling and Analysis

The work plan proposed collection of four soil samples from the upper interval (0 to 1 foot bgs) and four lower interval (3 to 5 feet bgs) for the former septic tank and drainfield area at SWMU 185 (Figure 10.5.1). Each of these samples were collected.

Soil samples collected from the four proposed locations were submitted for analysis at DQO Level III for VOCs, SVOCs, metals, cyanide, pesticides, and PCBs. Two duplicates were collected and submitted for Appendix IX analyses at DQO Level IV. Table 10.5.1 summarizes soil sampling for the sewer system and septic tank investigation at SWMU 185.

Table 10.5.1
Soil Sampling Summary
SWMU 185 - Naval Annex

Interval	Samples Proposed	Samples Collected	Analyses Proposed	Analyses Performed	Deviations
Upper (0' to 1')	4	4	VOCs, SVOCs, pesticides, PCBs, cyanide, and metals.	VOCs, SVOCs, pesticides, PCBs, cyanide, and metals.	None
Lower (3' to 5')	4	4	VOCs, SVOCs, pesticides, PCBs, cyanide, and metals.	VOCs, SVOCs, pesticides, PCBs, cyanide, and metals.	None
		Duplicate - 2		Appendix IX	

Notes:
Appendix IX = Analyses collected for primary samples plus hex-chrome, dioxins, herbicides, and OP pesticides at DQO Level IV.

10.5.1.1 Nature and Extent of Soil Contamination

Organic compound analytical results for soil samples collected in the vicinity of the former septic tank and associated drainfield are summarized in Table 10.5.2. Inorganic analytical results for samples collected in the vicinity of the former septic tank and associated drainfield are summarized in Table 10.5.3. Appendix E contains a complete analytical data report for all samples collected in the SWMU 185 investigation.

Volatile Organic Compounds in Soil

No VOCs were detected in the surface soil samples from SWMU 185 in the vicinity of the former septic tank and associated drainfield.

Acetone was the only VOC detected in subsurface soil in the vicinity of the septic tank and associated drainfield. The single detection of 3 μg/kg (duplicate sample collected at 166SB00202) was far below acetone's SSL of 8,000 μg/kg.

Table 10.5.2
Organics Detected in Soil
SWMU 185 - Naval Annex

Analyte	Sampling Interval	Frequency of Detection	Range of Detection	Mean of Detection	RBC (upper) SSL (lower)	Number of Samples Exceeding RBCs/SSLs
VOCs (8 samples collected: 4 upper interval, 4 lower interval, 2 duplicate samples for Appendix IX analyses) (μg/kg)						
Acetone	Upper	0/4	ND	NA	780,000	NA
	Lower	1/4	3	3	8,000	0
Pesticides/PCBs (8 samples collected: 4 upper interval, 4 lower interval, 2 duplicate samples for Appendix IX analyses) (μg/kg)						
4,4'-DDD	Upper	2/4	4.15 - 59.1	31.6	2,700	0
	Lower	1/4	269	269	700	0
4,4'-DDE	Upper	2/4	31.2 - 195	113	1,900	0
	Lower	1/4	62.2	62.2	500	0
4,4'-DDT	Upper	2/4	20.7 - 201	111	1,900	0
	Lower	1/4	276	276	1,000	0
Endrin Ketone	Upper	1/4	9.49	9.49	2,300[a]	0
	Lower	0/4	ND	ND	400	0
alpha-Chlordane	Upper	2/4	3.61 - 5.05	4.33	490[b]	0
	Lower	1/4	8.78	8.78	2,000	0
gamma-Chlordane	Upper	0/3	ND	ND	490[b]	0
	Lower	1/4	5.84	5.84	2,000	0

Table 10.5.2
Organics Detected in Soil
SWMU 185 - Naval Annex

Analyte	Sampling Interval	Frequency of Detection	Range of Detection	Mean of Detection	RBC (upper) SSL (lower)	Number of Samples Exceeding RBCs/SSLs
Dioxin (2 lower interval duplicate samples for dioxin) (µg/kg)						
TCDD TEQ	Upper	0/0	ND	NA	0.0043	NA
	Lower	2/2	3E-05 - 0.00188	0.00096	NL	NA

Notes:

a	=	The RBC for endrin was used as a surrogate for endrin ketone.
b	=	The RBC for Chlordane was used as a surrogate for alpha- and gamma-Chlordane
NA	=	Not applicable
ND	=	Not detected
NL	=	Not listed

Table 10.5.3
Inorganics Detected in Soil
SWMU 185 – Naval Annex

Analyte	Sampling Interval	Frequency of Detection	Range of Detection	Mean of Detection	Reference Conc.	RBC (upper) SSL (lower)	Number of Samples Exceeding RBC and Reference (upper) or SSL and Reference (lower)
Metals (8 samples collected: 4 upper interval, 4 lower interval, 2 duplicates for Appendix IX analysis) (mg/kg)							
Aluminum (Al)	Upper	4/4	652 - 7,320	4,946	11,200	7,800	0
	Lower	4/4	4,250 - 7,310	5,518	10,500	560,000	0
Arsenic (As)	Upper	3/4	1.3 - 1.9	1.6	3.00	0.43	0
	Lower	3/4	0.66 - 1	0.82	1.98	15	0
Barium (Ba)	Upper	4/4	7.3 - 15	11.8	26	550	0
	Lower	4/4	2.8 - 10.4	5.0	6.83	820	0
Cadmium (Cd)	Upper	3/4	0.06 - 0.08	0.07	0.13	3.9	0
	Lower	0/4	ND	ND	**	4	0
Calcium (Ca)	Upper	4/4	447 - 2,050	1,261	NA	NL	NA
	Lower	4/4	370 - 1,020	575	NA	NL	NA
Chromium (Cr)	Upper	4/4	0.29 - 5.9	3.9	8.4	39	0
	Lower	4/4	3.6 - 5.5	4.2	8.76	19	0
Cobalt (Co)	Upper	0/4	ND	ND	0.34	470	0
	Lower	1/4	0.28	0.28	0.62	990	0
Copper (Cu)	Upper	4/4	0.41 - 3	1.7	3.86	310	0
	Lower	2/4	0.54 - 5.8	3.2	0.34	5,600	0
Iron (Fe)	Upper	4/4	337 - 4,160	2,514	NA	2,300	3
	Lower	4/4	465 - 2,480	1,082	NA	NL	NA
Lead (Pb)	Upper	4/4	4.3 - 15.2	10.1	39.6	400[a]	0
	Lower	4/4	2.7 - 59.1	17.1	6.43	400	0
Magnesium (Mg)	Upper	4/4	125 - 376	216	NA	NL	NA
	Lower	4/4	51.3 - 266	112	NA	NL	NA
Manganese (Mn)	Upper	4/4	3.8 - 12.5	8.48	26.4	180	0
	Lower	4/4	2.2 - 8.9	4.1	5.93	550	0
Nickel (Ni)	Upper	3/4	1.3 - 2	1.6	1.7	160	0
	Lower	4/4	1.0 - 2.2	1.8	2.64	65	0
Potassium (K)	Upper	3/4	106 -154	123	NA	NL	NA
	Lower	3/4	33.5 -129	74	NA	NL	NA
Silver (Ag)	Upper	0/4	ND	ND	0.44	39	0
	Lower	1/4	1.3	1.3	0.42	17	0
Sodium (Na)	Upper	4/4	10.1 -31.9	21.4	NA	NL	NA
	Lower	4/4	5.1 -16.7	10.6	NA	NL	NA
Thallium (Tl)	Upper	0/4	ND	ND	NA	NL	NA
	Lower	1/4	0.69	0.69	NA	0.4	1
Vanadium (V)	Upper	4/4	1.5 - 9.3	7.08	15.8	55	0
	Lower	4/4	3.5 - 8.3	6.0	12.2	NL	NA

Table 10.5.3
Inorganics Detected in Soil
SWMU 185 - Naval Annex

Analyte	Sampling Interval	Frequency of Detection	Range of Detection	Mean of Detection	Reference Conc.	RBC (upper) SSL (lower)	Number of Samples Exceeding RBC and Reference (upper) or SSL and Reference (lower)
Zinc (Zn)	Upper	4/4	5.4 - 23.8	14.4	14.8	2,300	0
	Lower	2/4	2.8 - 9.9	6.4	NA	42,000	0

Notes:
NA = Not applicable
ND = Not detected
NL = Not listed
a = An RBC for lead is not available. The USEPA residential soil cleanup level was used for comparison (OSWER Directive 9355.4-12).
** = Number of nondetects prevented determination of background concentration.

Semivolatile Organic Compounds in Soil

No SVOCs were detected in the surface or subsurface soil from SWMU 185.

Pesticides/PCBs in Soil

Five pesticides were detected in surface soil samples at SWMU 185. No detections exceeded their respective RBCs.

Five pesticides were detected in subsurface soil. All detections were far below their respective SSLs.

Other Organic Compounds in Soil

Dioxins were detected in both subsurface duplicate samples collected at SWMU 185. No SSL is available for dioxin TEQs.

Inorganics in Soil

Sixteen metals were detected in surface soil samples at SWMU 185. With the exception of the essential nutrient iron, no detections exceeded their respective RBC and background reference concentrations.

In the subsurface soil samples barium, copper, lead, manganese, and silver were detected at concentrations which exceeded their respective background reference concentrations. However, none exceeded their respective SSLs. Thallium was detected in one sample (166SB00202) at a concentration of 0.69 μg/kg which slightly exceeded its SSL of 0.4 μg/kg. No subsurface background reference concentration was established for thallium in Zone K.

10.5.2 Groundwater Sampling and Analysis

The work plan proposed the installation of one shallow monitoring well and the collection of 31 groundwater screening samples (Figure 10.5.1). Thirty groundwater screening samples were collected. Sample 166GP017 was not collected because it was located near monitoring well 163001. Analytical results for well 163001 are confirmed in Tables 10.3.5 and 10.3.6. As shown in Table 10.5.4 the groundwater sample from the proposed monitoring well (166001) was analyzed for VOCs, SVOCs, metals, pesticides, and PCBs at DQO Level III. The groundwater screening samples were analyzed for VOCs and metals at DQO Level II.

Table 10.5.4
Groundwater Sampling Summary
SWMU 185 - Naval Annex

Event	Samples Collected	Analyses Performed	Remarks
November 1996 (Groundwater Screening Samples)	30	VOCs and metals	None
January 1997 (Monitoring well 166001 - first round)	1	VOCs, SVOCs, Pesticides/PCBs and metals	None
April 1997 (Monitoring well 166001 - second round)	1	VOCs, SVOCs, Pesticides/PCBs and metals	None

Table 10.5.4
Groundwater Sampling Summary
SWMU 185 - Naval Annex

Event	Samples Collected	Analyses Performed	Remarks
July 1997 (Monitoring well 166001 - third round)	1	VOCs, SVOCs, Pesticides/PCBs and metals	None
October 1997 (Monitoring well 166001 - fourth round)	1	VOCs, SVOCs, Pesticides/PCBs and metals	None

10.5.2.1 Groundwater Screening Results

Table 10.5.5 summarizes the VOC analytical results for the 30 shallow (8 to 11 feet bgs) groundwater screening samples collected across the sewer system. Table 10.5.6 summarizes the inorganic analytical results for the same area. The analytical data report for the screening samples are contained in Appendix E.

Table 10.5.5
VOCs Detected in Shallow Groundwater Screening Samples
SWMU 185 - Naval Annex

	Compound Detected (µg/L)	
Sample Location	TCE	Carbon Disulfide
Groundwater Screening - November 1996 (shallow groundwater screening samples were collected at locations 166GP001 through 166GP031)		
166GP005	ND	4
166GP006	ND	6
166GP011	53	ND

Notes:
Shallow (8-11 feet bgs)
ND = Compound not detected.
Appendix E contains the analytical data reports for sample analysis.

Table 10.5.6
Inorganics Detected in Shallow Groundwater Screening Samples
SWMU 185 - Naval Annex

Analyte	Frequency of Detection	Range of Detection	Mean of Detection	Tap Water RBC/MCL	Reference Concentration	Number of Samples Exceeding RBC/MCL
Inorganics (μg/L)						
Aluminum (Al)	29/30	25,730 - 545,000	134,537	3,700/50	NA	29/29
Antimony (Sb)	4/30	2.1 - 5.4	3.35	1.5/6	NA	4/0
Arsenic (As)	25/30	2.8 - 32.5	8.13	0..043/50	NA	25/0
Barium (Ba)	29/30	75.8 - 1,330	325	260/2,000	31.4	12/0
Beryllium (Be)	29/30	0.52 - 8.7	1.65	0.016/4	NA	29/1
Cadmium (Cd)	6/30	0.23 - 1.12	0.47	1.8/5	NA	0/0
Calcium (Ca)	29/30	2,100 - 66,600	15,982	NL/NL	NA	NA/NA
Chromium (Cr)	29/30	32.7 - 497	144	18/100	NA	29/14
Cobalt (Co)	29/30	3.9 - 43.1	16.7	220/NL	NA	0/NA
Copper (Cu)	29/30	11.75 - 194	43.1	150/1,000	NA	1/0
Iron (Fe)	29/30	8,340 - 70,700	26,899	NL/NL	NA	NA/NA
Lead (Pb)	29/30	11 - 208	59.7	15/15	NA	25/25
Magnesium (Mg)	29/30	1,495 - 13,600	5,286	NL/NL	NA	NA/NA
Manganese (Mn)	29/30	63.9 - 529	218	84/50	15.5	28/29
Mercury (Hg)	12/30	0.18 - 2.6	0.56	1.1/2	NA	1/1
Nickel (Ni)	29/30	9.3 - 128	42.3	73/100	NA	4/2
Potassium (K)	29/30	1,655 - 12,400	5,862	NL/NL	NA	NA/NA
Selenium (Se)	4/30	5.4 - 22	10.7	18/50	NA	1/0
Silver (Ag)	2/30	1.1 - 1.2	1.15	18/100	NA	0/0
Sodium (Na)	29/30	1,430 - 6,630	2,918	NL/NL	NA	NA/NA
Vanadium (V)	29/30	21.3 - 182	75.1	26/NL	NA	27/NA
Zinc (Zn)	23/30	37.3 - 1,420.5	272	1,100/5,000	NA	1/0

Notes:
NA = Not Applicable
NL = Not Listed
μg/L = micrograms per liter

Volatile Organic Compounds in Groundwater

Two VOCs were detected in shallow groundwater screening samples at SWMU 185. Carbon disulfide was detected in samples from 166GP005 and 166GP006 at 4 μg/L and 6 μg/L respectively. The tap water RBC for carbon disulfide is 104 μg/L. TCE was detected in 166GP011 at 53 μg/L which exceeds the RBC of 1.6 μg/L and MCL of 5 μg/L. This TCE detection initiated an investigation which is addressed in Section 10.10 of this RFI as SWMU 166. No other VOCs were detected in any other groundwater screening samples at SWMU 185 or in samples from monitoring well 163001.

Inorganics in Groundwater

Twenty-two metals were detected in shallow groundwater screening samples collected at SWMU 185. Fourteen of these exceeded tap water RBCs. Seven of the 14 also exceeded respective MCLs. Because these samples were collected using DPT methods, without an engineered filter pack and proper well development, the samples contained significant suspended sediment. Which is most likely the cause of the uncharacteristically high metals content in these samples. The sample from well 163001 exhibited no inorganic detections which exceeded the RBC, MCL or background reference concentrations.

10.5.2.2 Nature and Extent of Groundwater Contamination

Table 10.5.7 summarizes the organic analytical results for groundwater samples collected from monitoring well 166001 for all sampling rounds. Table 10.5.8 summarizes the inorganic analytical results for the groundwater samples collected from well 166001 for all sampling rounds. Appendix E contains a complete analytical data report for all samples collected at SWMU 185.

Volatile Organic Compounds in Groundwater

No VOCs were detected in the groundwater samples collected from the monitoring well installed in the area of the former septic tank and associated drainfield at SWMU 185.

Table 10.5.7
Organics Detected in Shallow Groundwater
SWMU 185 - Naval Annex

Analyte	Sampling Event	Frequency of Detection	Range of Detection (µg/L)	RBC (µg/L)	Number of Samples Exceeding both RC and RBC
Semivolatile Organic Compounds (1 shallow groundwater sample collected during each event)					
bis(2-Ethylhexyl)phthalate	Jan. 97	0/1	ND	4.8	NA
	April 97	0/1	ND		NA
	July 97	0/1	ND		NA
	Oct. 97	1/1	2		0

Notes:
NA = Not applicable
ND = Not detected

Table 10.5.8
Inorganics Detected in Shallow Groundwater
SWMU 185 - Naval Annex

Analyte	Sampling Event	Frequency of Detection	Range of Detections (µg/L)	Reference Concentration (µg/L)	RBC (µg/L)	MCL	Number of Samples Exceeding both RC and RBC
Inorganics (1 shallow groundwater sample collected during each event)							
Aluminum (Al)	Jan. 97	1/1	2,810	**	37,000	200 5	0
	Apr. 97	0/1	ND				NA
	July 97	1/1	1,100				0
	Oct. 97	1/1	370				0
Barium (Ba)	Jan. 97	1/1	20.3	31.4	2,600	2,000	0
	Apr. 97	1/1	12				0
	July 97	1/1	6.6				0
	Oct. 97	1/1	7.5				0
Calcium (Ca)	Jan. 97	1/1	12,300	NA	NL		NA
	Apr. 97	1/1	9,230				NA
	July 97	1/1	8,510				NA
	Oct. 97	1/1	9,080				NA
Chromium (Cr)	Jan. 97	1/1	1.9	**	180	100	0
	Apr. 97	0/1	ND				NA
	July 97	0/1	ND				NA
	Oct. 97	0/1	ND				NA
Copper (Cu)	Jan. 97	1/1	5.2	**	130,000	1,000	0
	Apr. 97	0/1	ND				NA
	July 97	0/1	ND				NA
	Oct. 97	0/1	ND				NA
Iron (Fe)	Jan. 97	1/1	671	NA	NL	300	NA
	Apr. 97	0/1	ND				NA
	July 97	1/1	269				NA
	Oct. 97	1/1	124				NA

Table 10.5.8
Inorganics Detected in Shallow Groundwater
SWMU 185 – Naval Annex

Analyte	Sampling Event	Frequency of Detection	Range of Detections (μg/L)	Reference Concentration (μg/L)	RBC (μg/L)	MCL	Number of Samples Exceeding both RC and RBC
Magnesium (Mg)	Jan. 97	1/1	702	NA	NL		NA
	Apr. 97	1/1	438				NA
	July 97	1/1	752				NA
	Oct. 97	1/1	976				NA
Manganese (Mn)	Jan. 97	1/1	17.3	15.5	840	50 S	0
	Apr. 97	0/1	ND				NA
	July 97	0/1	ND				NA
	Oct. 97	1/1	21.8				0
Nickel (Ni)	Jan. 97	1/1	1.9	**	730	100	0
	Apr. 97	0/1	ND				NA
	July 97	0/1	ND				NA
	Oct. 97	0/1	ND				NA
Potassium (K)	Jan. 97	1/1	827	NA	NL		NA
	Apr. 97	0/1	ND				NA
	July 97	1/1	946				NA
	Oct. 97	1/1	1,250				NA
Sodium (Na)	Jan. 97	1/1	3,410	NA	NL		NA
	Apr. 97	0/1	ND				NA
	July 97	1/1	4,490				NA
	Oct. 97	0/1	ND				NA
Vanadium (V)	Jan. 97	0/1	ND	**	260		NA
	Apr. 97	0/1	ND				NA
	July 97	1/1	1.2				0
	Oct. 97	0/1	ND				NA

Notes:
** = Number of nondetects prevented determination of UTL.
ND = Not Detected
NA = Not Applicable
NL = Not Listed

Semivolatile Organic Compounds in Groundwater

Only one SVOC was detected in groundwater samples collected from the monitoring well installed at SWMU 185. Bis(2-Ethylhexyl)phthalate was detected in only the fourth sampling event at a concentration of 2 μg/L, which is lower than its RBC.

Pesticides or PCBs in Groundwater

No pesticides or PCBs were detected in groundwater samples collected from the monitoring well at SWMU 185.

Inorganics in Groundwater

Twelve metals were detected in groundwater samples collected from the monitoring well at SWMU 185 during the four sampling events. None exceeded their respective background reference concentration and RBC.

10.5.3 Fate and Transport

Environmental media sampled as part of the SWMU 185 investigation include surface and subsurface soil, and shallow groundwater. Potential constituent migration pathways investigated for SWMU 185 include soil-to-groundwater, groundwater-to-surface water, and emission of volatiles from surface soil to air.

10.5.3.1 Soil-to-Groundwater Cross-Media Transport

Table 10.5.9 compares maximum detected organic constituent concentrations in surface and subsurface soil samples to risk-based soil screening levels considered protective of groundwater. For inorganics, maximum concentrations in soil are compared to the greater of (a) risk-based soil screening levels, or (b) background reference concentrations. To provide a conservative screen, generic soil screening levels are used; leachate entering the aquifer is assumed to be diluted by a ratio of 10:1, with no attenuation of constituents in soil (DAF=10).

No organic constituents were detected in SWMU 185 surface soil or subsurface soil at concentrations exceeding groundwater protection SSLs. No inorganic constituents were detected above applicable SSLs in surface soil. One inorganic analyte, thallium, was detected in subsurface

Table 10.5.9
Chemicals Detected in Surface and Subsurface Soil, and Shallow Groundwater
Comparison to Soil-to-Groundwater SSLs, Tap Water RBCs, Soil-to-Air SSLs, and Reference Concentrations
SWMU 185 - Naval Annex

	Max. Concentration		Max. Concentration		Screening Concentration							
Analyte	Surface Soil	Subsurface Soil	Shallow GW	Deep GW	Soil-to-GW SSL	Tap Water RBC	Soil-to-Air SSL	Soil Units	Water Units	Leaching Potential	Groundwater Migration Concern	Volatilization Potential
Volatile Organic Compounds												
Acetone	ND	3	ND	NA	8000	3700	100000000	UG/KG	UG/L	NO	NO	NO
Semivolatile Organic Compounds												
bis(2-Ethylhexyl)phthalate (BEHP)	ND	ND	2	NA	1800000	4.8	3.1E+07	UG/KG	UG/L	NO	NO	NO
Pesticides/PCB Compounds												
alpha-Chlordane	5.05	8.78	ND	NA	5000	0.19	20000	UG/KG	UG/L	NO	NO	NO
gamma-Chlordane	ND	5.84	ND	NA	5000	0.19	20000	UG/KG	UG/L	NO	NO	NO
4,4'-DDD	59.1	269	ND	NA	8000	0.28	NA	UG/KG	UG/L	NO	NO	NA
4,4'-DDE	195	62.2	ND	NA	27000	0.2	NA	UG/KG	UG/L	NO	NO	NA
4,4'-DDT	201	276	ND	NA	16000	0.2	1.0E+09	UG/KG	UG/L	NO	NO	NO
Endrin ketone	9.5	ND	ND	NA	340	11	NA	UG/KG	UG/L	NO	NO	NA
Dioxin Compounds												
Dioxin (TCDD TEQs)	ND	1.88	NA	NA	1600 c	0.45	NA	NG/KG	PG/L	NO	NO	NA
Inorganics												
Aluminum	7320	7310	2810	NA	560000 c	37000	NA	MG/KG	UG/L	NO	NO	NA
Arsenic	1.9	1	ND	NA	15	0.045	750	MG/KG	UG/L	NO	NO	NO
Barium	15	10.4	20.3	NA	820	2600	690000	MG/KG	UG/L	NO	NO	NO
Cadmium	0.08	ND	ND	NA	4	18	1800	MG/KG	UG/L	NO	NO	NO
Chromium (total)	5.9	5.5	1.9	NA	19	180	270	MG/KG	UG/L	NO	NO	NO
Cobalt	ND	0.28	ND	NA	990 c	2200	NA	MG/KG	UG/L	NO	NO	NA

Table 10.5.9
Chemicals Detected in Surface and Subsurface Soil, and Shallow Groundwater
Comparison to Soil-to-Groundwater SSLs, Tap Water RBCs, Soil-to-Air SSLs, and Reference Concentrations
SWMU 185 – Naval Annex

	Max. Concentration		Max. Concentration		Screening Concentration							
Analyte	Surface Soil	Subsurface Soil	Shallow GW	Deep GW	Soil-to-GW SSL	Tap Water RBC	Soil-to-Air SSL	Soil Units	Water Units	Leaching Potential	Groundwater Migration Concern	Volatilization Potential
Copper	3	5.8	5.2	NA	5600 c	1500	NA	MG/KG	UG/L	NO	NO	NA
Lead	15.2	59.1	ND	NA	400	15	400	MG/KG	UG/L	NO	NO	NO
Manganese	12.5	8.9	21.8	NA	480c	730	NA	MG/KG	UG/L	NO	NO	NA
Nickel	2	2.2	1.9	NA	65	730	13000	MG/KG	UG/L	NO	NO	NO
Silver	ND	1.3	ND	NA	17	180	NA	MG/KG	UG/L	NO	NO	NA
Thallium	ND	0.69	ND	NA	0.36	2.6	NA	MG/KG	UG/L	YES	NO	NA
Vanadium	9.3	8.3	1.2	NA	3000	260	NA	MG/KG	UG/L	NO	NO	NA
Zinc	23.8	9.9	ND	NA	6200	11000	NA	MG/KG	UG/L	NO	NO	NA

Notes:

Soil to GW — Generic SSLs based on DAF = 10, adapted from 1996 EPA Soil Screening Guidance (first preference) or calculated using values from Table 6.4
Tap Water RBC — From EPA Region III Risk-Based Concentration Table, October 1997
Soil to Air — From 1996 EPA Soil Screening Guidance (first preference) or EPA Region III Risk-Based Concentration Table, June 1996
For inorganics, Soil to GW SSLs and Tap Water RBCs are greater than corresponding background reference values in every case.
c — Calculated soil to groundwater SSL value (See Table 6.4; some values revised as per October 1997 RBC Table)
NA — Not available/Not applicable
ND — Not detected
SSL — Soil screening level
RBC — Risk-based concentration
MG/KG — Milligrams per kilogram
NG/KG — Nanograms per kilogram
PG/L — Picograms per liter
UG/KG — Micrograms per kilogram
UG/L — Micrograms per liter

soil slightly above its SSL. This constituent was present in only one of the four subsurface samples. The limited horizontal and vertical occurrence of thallium suggests a very limited subsurface source which may or may not be naturally occurring. The site history does not indicate thallium to be an expected constituent of concern. Therefore, the most likely possibility is that this represents a limited natural occurrence of thallium. Furthermore, thallium was non-detect in shallow groundwater, thus invalidating this pathway of transport.

10.5.3.2 Groundwater Transport

Table 10.5.9 also compares maximum detected organic constituent concentrations in shallow groundwater samples to risk-based concentrations for drinking water. For inorganics, maximum concentrations in groundwater are compared to the greater of (a) risk-based drinking water concentrations, or (b) background reference concentrations for groundwater. To provide a conservative screen, no attenuation or dilution of constituents in groundwater is assumed before comparison to the relevant standards. Additionally, results from all four sampling events have been used in the screening process.

No organic or inorganic species were detected in groundwater above applicable screening levels. Consequently, this exposure pathway is not considered to be valid.

10.5.3.3 Soil-to-Air Cross-Media Transport

Table 10.5.9 lists the VOCs detected in surface soil samples collected at SWMU 185, along with corresponding soil-to-air volatilization screening levels. No volatiles were detected in site soil that exceeded applicable screening levels, and the migration pathway therefore is invalid.

10.5.3.4 Fate and Transport Summary

Constituents present above leachability-based SSLs were limited to one inorganic species, and were further limited in distribution to only one sample location. The low concentration, the

limited distribution, and the site history all suggest that this is an isolated natural occurrence and should not be construed a site contamination. Furthermore, the absence of thallium in shallow groundwater invalidates the migration pathway. There were no constituents present above screening levels for groundwater migration or the soil-to-air volatilization pathway, thus invalidating those pathways of exposure for SWMU 185.

10.5.4 Human Health Risk Assessment

10.5.4.1 Site Background and Investigative Approach

SWMU 185 (former SWMU 166) consists of the sanitary sewer and septic tank system serving the Naval Annex, excluding the housing area. The ground surface at SWMU 185 consists primarily of buildings, paved roads, and some open grassy areas. The eastern boundary of SWMU 185 runs alongside Interstate 26, which also forms the eastern boundary of Zone K at NAVBASE Charleston.

Section 10.5.1 provides the details of the soil sampling effort performed for the SWMU 185 RFI. A total of four soil samples were collected from each of the upper and lower intervals as part of the RFI activities. All four samples were analyzed for VOCs, SVOCs, pesticides/PCBs, cyanide and metals.

Section 10.5.2 provides the details of the groundwater sampling effort for the SWMU 185 RFI. The one shallow monitoring well, 166001, was sampled during four sampling events. Samples from all four sample events were analyzed for VOCs, SVOCs, metals, and pesticides/PCBs. Samples from the screening effort were not considered in the risk assessment.

10.5.4.2 COPC Identification

Soil

Based on the screening comparisons described in Section 7 of this RFI and presented in Table 10.5.10, no soil COPCs were identified for this site. Wilcoxon rank sum test analyses did not result in the inclusion of any inorganic parameters that had been screened out on the basis of upper tolerance limit only.

Groundwater

As shown in Table 10.5.11, no groundwater COPCs were identified for this site. Wilcoxon rank sum test analyses did not result in the inclusion of any inorganic parameters that had been screened out on the basis of background reference concentration comparisons only.

10.5.4.3 Risk Uncertainty

Characterization of Exposure Setting and Identification of Exposure Pathways

Screening comparisons were based on residential use of the site which would not be expected, based on current site uses and the nature of surrounding buildings. If this area were to be used as a residential site, the surface soil conditions would likely change – the soils could be covered with landscaping soil and/or a house. Consequently, exposure to surface soil conditions as represented by samples collected during the RFI would not be likely under a true future residential scenario. These factors indicate that screening comparisons used in this HHRA would are generally conservative.

Groundwater is not currently used at SWMU 185 for potable or industrial purposes. A basewide system provides drinking and process water to buildings throughout Zone K. This system is expected to remain in operation under the current base reuse plan. As a result, groundwater is not anticipated to be used for these purposes under future site use scenarios. Therefore, the potable

Table 10.5.10
Chemicals Present in Site Samples
SWMU 185 - Surface Soil
Naval Base Charleston, Zone K
Charleston, South Carolina

Parameter		Frequency of Detection		Range of Detection		Average Detected Concentration	Range of SQL		Screening Concentration Residential RBC	Reference	Units	Number Exceeding RBC	Reference
Pesticides													
4,4'-DDD		2	4	4.15	59.1	31.6	3.66	3.68	2700	NA	UG/KG		
4,4'-DDE		2	4	31.2	195	113	3.66	3.68	1900	NA	UG/KG		
4,4'-DDT		2	4	20.7	201	111	3.66	3.68	1900	NA	UG/KG		
alpha-Chlordane		2	4	3.61	5.05	4.33	1.89	1.89	490	NA	UG/KG		
Endrin ketone		1	4	9.49	9.49	9.49	3.66	3.73	2300	NA	UG/KG		
Inorganics													
Aluminum (Al)		4	4	652	7320	4946	NA	NA	7800	11200	MG/KG		
Arsenic (As)		3	4	1.3	1.9	1.6	0.41	0.41	0.43	3	MG/KG	3	
Barium (Ba)		4	4	7.3	15	11.8	NA	NA	550	25.6	MG/KG		
Cadmium (Cd)		3	4	0.06	0.08	0.070	0.04	0.04	3.9	0.13	MG/KG		
Calcium (Ca)	N	4	4	447	2050	1261	NA	NA	NL	NA	MG/KG		
Chromium (Cr)		4	4	0.29	5.9	3.97	NA	NA	39	8.4	MG/KG		
Copper (Cu)		4	4	0.41	3	1.72	NA	NA	310	3.86	MG/KG		
Iron (Fe)	N	4	4	337	4160	2514	NA	NA	2300	NA	MG/KG		
Lead (Pb)		4	4	4.3	15.2	10.1	NA	NA	400	39.6	MG/KG		
Magnesium (Mg)	N	4	4	125	376	216	NA	NA	NL	NA	MG/KG		
Manganese (Mn)		4	4	3.8	12.5	8.48	NA	NA	180	26.4	MG/KG		
Nickel (Ni)		3	4	1.3	2	1.63	0.13	0.13	160	1.7	MG/KG		1
Potassium (K)	N	3	4	106	154	123	15.3	15.3	NL	NA	MG/KG		
Sodium (Na)	N	4	4	10.1	31.9	21.4	NA	NA	NA	NA	MG/KG		
Vanadium (V)		4	4	1.5	9.3	7.08	NA	NA	55	15.8	MG/KG		
Zinc (Zn)		4	4	5.4	23.8	14.4	NA	NA	2300	14.8	MG/KG		2

Notes:

* - Indicates chemical was identified as a COPC
SQL - Sample quantitation limit
RBC - Risk-based concentration
UG/KG - micrograms per kilogram
MG/KG - milligrams per kilogram
NA - Not applicable or not available
NL - Not listed
N - Essential nutrient

Table 10.5.11
Chemicals Present in Site Samples
SWMU 185 - Groundwater (Shallow and Deep)
Naval Base Charleston, Zone K
Charleston, South Carolina

Parameter		Frequency of Detection		Range of Detection		Average Detected Concentration	Range of SQL		Screening Concentration Tap Water RBC	Reference	Units	Number Exceeding RBC	Reference
Inorganics													
Aluminum (Al)		3	4	370	2810	1427	225	225	3700	NA	UG/L		
Barium (Ba)		4	4	6.6	20.3	11.6	NA	NA	260	31.4	UG/L		
Calcium (Ca)	N	4	4	8510	12300	9780	NA	NA	NL	NA	UG/L		
Chromium (Cr)		1	4	1.9	1.9	1.9	0.67	5.1	18	NA	UG/L		
Copper (Cu)		1	4	5.2	5.2	5.2	0.89	6.8	1500	NA	UG/L		
Iron (Fe)	N	3	4	124	671	355	166	166	NL	NA	UG/L		
Magnesium (Mg)	N	4	4	438	976	717	NA	NA	NL	NA	UG/L		
Manganese (Mn)		2	4	17.3	21.8	19.6	4.7	8.3	84	15.5	UG/L		2
Nickel (Ni)		1	4	1.9	1.9	1.9	0.67	6	73	NA	UG/L		
Potassium (K)	N	3	4	827	1250	1008	643	643	NL	NA	UG/L		
Sodium (Na)	N	2	4	3410	4490	3950	1420	2490	NL	NA	UG/L		
Vanadium (V)		1	4	1.2	1.2	1.2	0.56	3	26	NA	UG/L		
Semivolatile Organic													
bis(2-Ethylhexyl)phthalate (BEHP)		1	4	2	2	2	10	10	4.8	NA	UG/L		

Notes:

* - Indicates chemical was identified as a COPC
SQL - Sample quantitation limit
RBC - Risk-based concentration
UG/L - micrograms per liter
NA - Not applicable or not available
N - Essential nutrient

use scenario on which the groundwater screening is based is highly conservative, and associated pathways are not expected to be completed in the future.

Of the organic CPSSs identified for soil none was reported at a concentration within approximately 10% of the RBC. Arsenic was the only inorganic analyte reported in soil whose concentration exceeded its corresponding RBC, but was eliminated from further consideration because all detections were below its background concentration.

The organic CPSS identified for groundwater, bis(2-Ethylhexyl)phthalate, was not detected at a concentration which was within approximately 10% of its RBC. No inorganic parameters were eliminated from the formal assessment based solely upon comparison to background reference concentrations.

10.5.4.4 Risk Summary

A conservative screening process was used to evaluate data generated from soil and groundwater samples collected at this site. No COPCs were identified for either soil or groundwater at SWMU 185.

10.5.5 Corrective Measures Considerations

Based on the analytical results and the human health risk assessment for SWMU 185, no COCs requiring further evaluation through the CMS process were identified for future residential use.

Attachment
DR Evaluation Forms for Zones
E, F, G, H, I and K

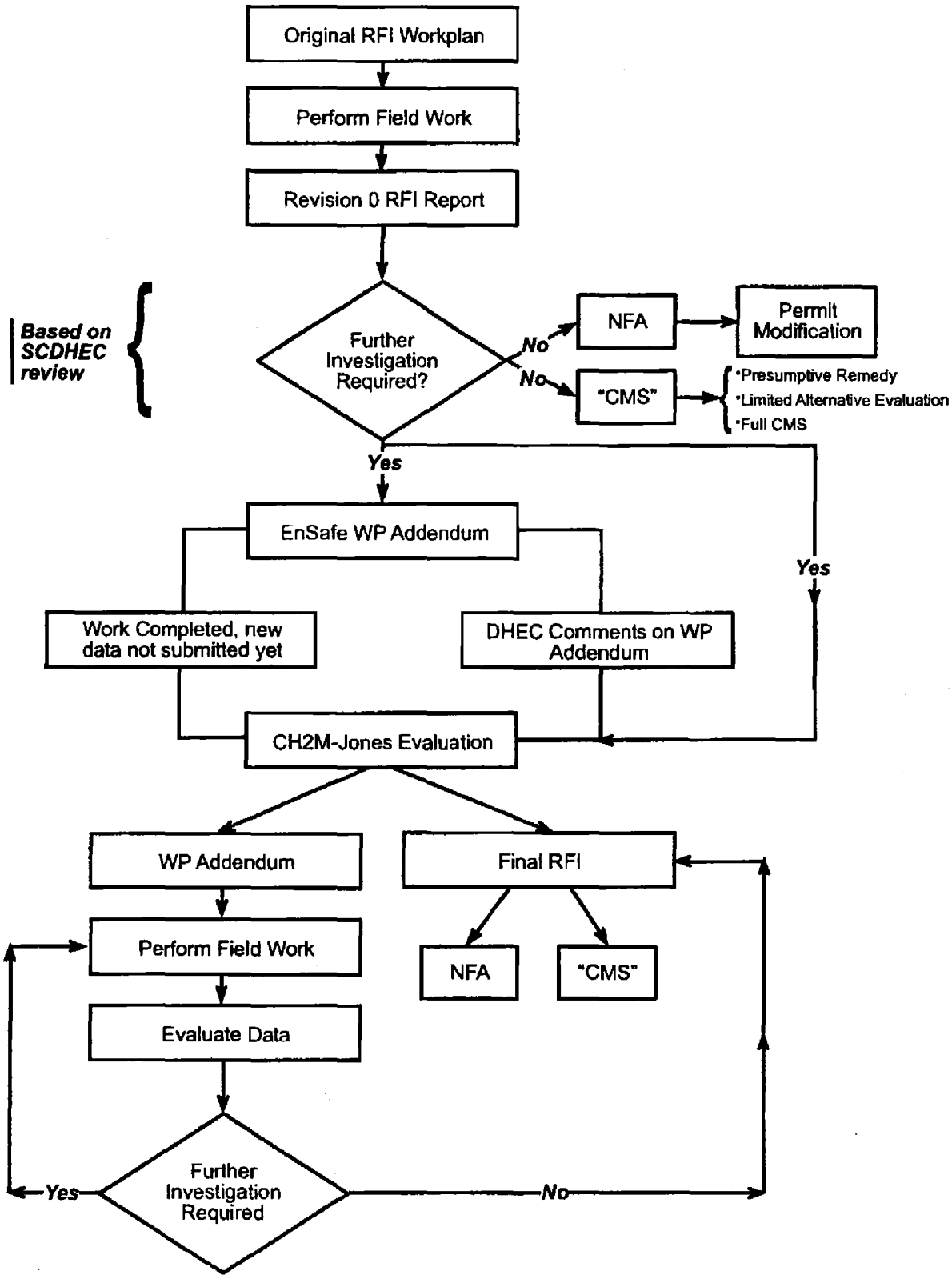

Figure 4-3
RFI Completion Process for Zones E, F, G, H, I, and K

CH2M HILL
3011 S.W. Williston Road
Gainesville, FL
32608-3928
Mailing address:
P.O. Box 147009
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Tel 352.335.7991
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CH2MHILL

May 10, 2002

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

Re: RFI Report Addendum (Revision 0) – SWMUs 170/171, Zone E

Dear Mr. Scaturo:

Enclosed please find four copies of the RFI Report Addendum (Revision 0) for SWMUs 170/171 in Zone E 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

RFI REPORT ADDENDUM

SWMUs 170/171, Zone E

Charleston Naval Complex
North Charleston, South Carolina

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

PREPARED BY
CH2M-Jones

May 2002

Revision 0
Contract N62467-99-C-0960
158814.ZE.PR.23

Certification Page for RFI Report Addendum (Revision 0) – SWMUs 170/171, Zone E

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.

5/2/2002

Date

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Appendix

A Excerpts from the *Zone E RFI Report, Revision 0* (EnSafe, 1997)
B Responses to SCDHEC Comments on the *Zone E RFI Report, Revision 0* on SWMU 170 and SWMU 171

Acronyms and Abbreviations

AOC	Area of concern
AST	Aboveground storage tank
BCT	BRAC Cleanup Team
BRAC	Base Realignment and Closure Act
BRC	Background reference concentration
CA	Corrective action
CFR	*Code of Federal Regulations*
CMS	Corrective measures study
CNC	Charleston Naval Complex
COC	Chemical of concern
COPC	Chemical of potential concern
CSI	Confirmatory sampling investigation
DAF	Dilution attenuation factor
DD	Dry dock
EnSafe	EnSafe, Inc.
EPA	U.S. Environmental Protection Agency
HHRA	Human health risk assessment
IM	Interim measure
LUC	Land use control
mg/kg	Milligram per kilogram
NAVBASE	Naval Base
NFA	No further action
NFI	No further investigation
OWS	Oil/water separator
PCB	Polychlorinated biphenyl
RBC	Risk-based concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation

Acronyms and Abbreviations, Continued

SCDHEC	South Carolina Department of Health and Environmental Control
SSL	Soil screening level
SWMU	Solid waste management unit
UST	Underground storage tank
VOC	Volatile organic compound

1.0 Introduction

In 1993, Naval Base (NAVBASE) Charleston was added to the list of bases scheduled for closure as part of the Defense Base Realignment and Closure Act (BRAC), which regulates closure and transition of property to the community. The Charleston Naval Complex (CNC) was formed as a result of the dis-establishment of the Charleston Naval Shipyard and NAVBASE on April 1, 1996.

Corrective Action (CA) activities are being conducted under the Resource Conservation and Recovery Act (RCRA) with the South Carolina Department of Health and Environmental Control (SCDHEC) as the lead agency for CA activities at the CNC. All RCRA CA activities are performed in accordance with the Final Permit (Permit No. SC0 170 022 560).

In April 2000, CH2M-Jones was awarded a contract to provide environmental investigation and remediation services at the CNC. This submittal has been prepared by CH2M-Jones to complete the RCRA Facility Investigation (RFI) for Solid Waste Management Units (SWMUs) 170 and 171 in Zone E of CNC. The location of this combined site in Zone E is shown in Figure 1-1. Figure 1-2 shows an aerial photograph of the site.

Based on a review of site data and conditions, SWMUs 170 and 171 are recommended for No Further Action (NFA).

1.1 Background

SWMUs 170/171 consist of storage areas immediately west of drydock (DD) 1 and DD 2, respectively. Missile launching tubes removed from decommissioned ballistic missile submarines were stored in these areas for removal of polychlorinated biphenyl (PCB)-containing components. These missile tube dismantling areas had no secondary containment. It is estimated that missile tube dismantling began around the late 1980s, with operations ceasing no later than 1996 when CNC military operations were discontinued. The site is paved with concrete and asphalt. The sites were recommended in the CNC RCRA Facility Assessment (RFA) report for a Confirmatory Sampling Investigation (CSI).

The chemicals of concern (COCs) at SWMUs 170/171 indicated in the *Final Zone E RFI Work Plan* (EnSafe Inc. [EnSafe]/Allen & Hoshall, 1995a) are PCBs. This area of Zone E is zoned M-2 (for industrial land use).

The RFI was initially conducted by the Navy/EnSafe team. RFI activities were documented in the *Zone E RFI Report, Revision 0* (EnSafe, 1997), which was submitted during 1997.

Regulatory review was conducted on this document and draft responses to the comments from SCDHEC were prepared by the Navy/EnSafe team.

1.2 Purpose of the RFI Report Addendum

The purpose of this RFI Report Addendum is to document the results of previous RFI activities conducted by EnSafe at SWMUs 170/171. This RFI Report Addendum also discusses various close-out issues and the findings of previous investigations, the existing site conditions, and surrounding area land use.

1.3 Report Organization

This RFI Report Addendum consists of the following sections, including this introductory section:

1.0 Introduction – Presents the purpose of the report and background information relating to the RFI Report Addendum.

2.0 Summary of RFI Conclusions for SWMU 170/171 – Summarizes the conclusions from the RFI and risk evaluations for SWMU 170/171, as presented in the *Zone E RFI Report, Revision 0.*

3.0 Interim Measures and UST/AST Removals – Provides information regarding any interim measures (IMs) or tank removal activities performed at the site.

4.0 Summary of Additional Investigations – Summarizes information, if any, collected after completion of the *Zone E RFI Report, Revision 0.*

5.0 COPC/COC Refinement – Provides further evaluation of chemicals of potential concern (COPC) based on RFI and additional data to assess them as COCs.

6.0 Summary of Information Related to Site Closeout Issues – Discusses the various site closeout issues that the BRAC Cleanup Team (BCT) agreed to evaluate prior to site closeout.

7.0 Recommendations – Provides recommendations for NFA at SWMUs 170/171.

8.0 References – Lists the references used in this document.

Appendix A – Contains excerpts from the *Zone E RFI Report, Revision 0,* including summary of the detections of chemicals and a groundwater flow map for the site vicinity (Figure A-1).

Appendix B – Contains responses to SCDHEC comments for SWMU 170/171 from the *Zone E RFI Report, Revision 0.*

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

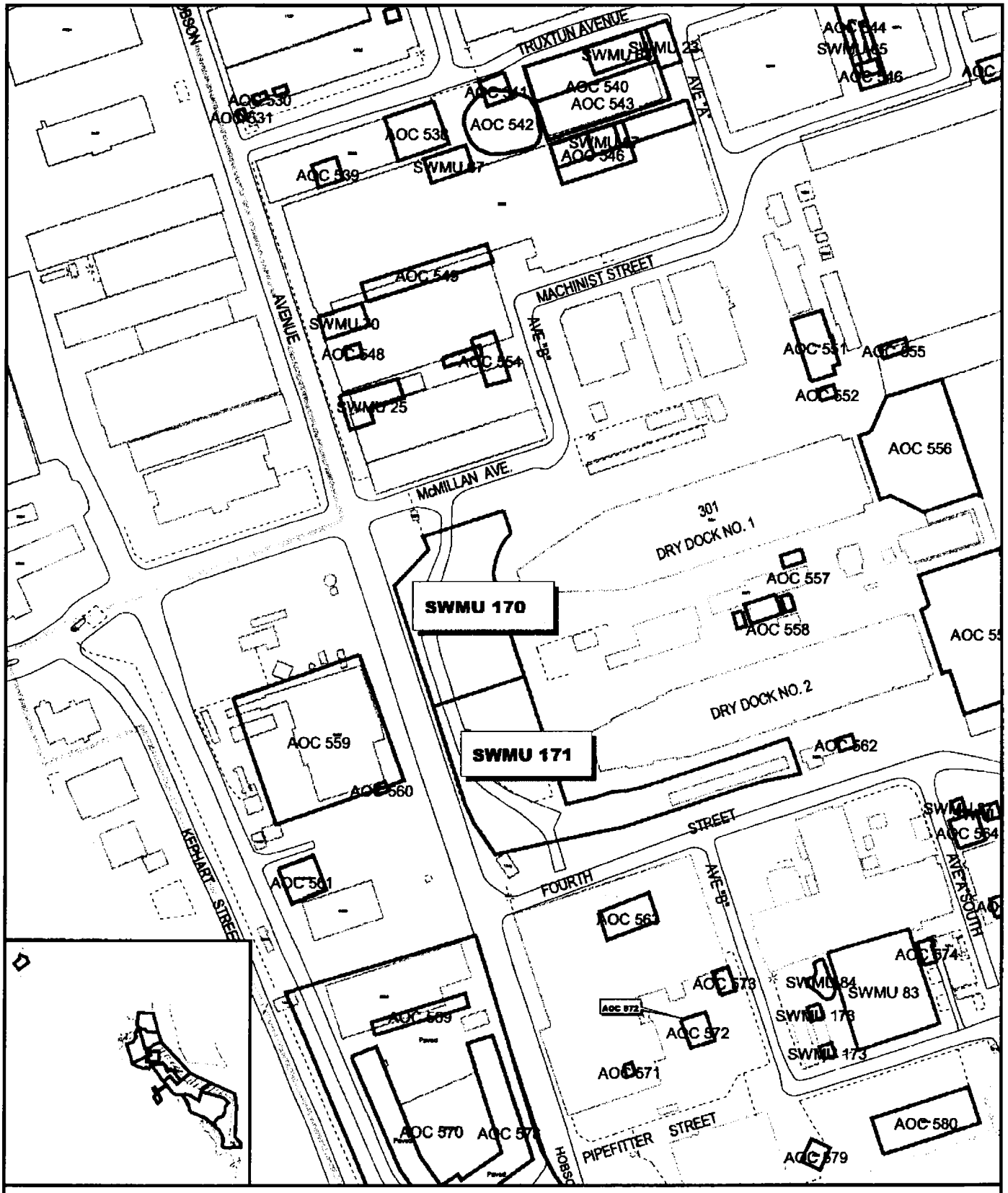

Figure 1-1
Location of SWMU 170 and SWMU 171 in Zone E
Charleston Naval Complex

CH2MHILL

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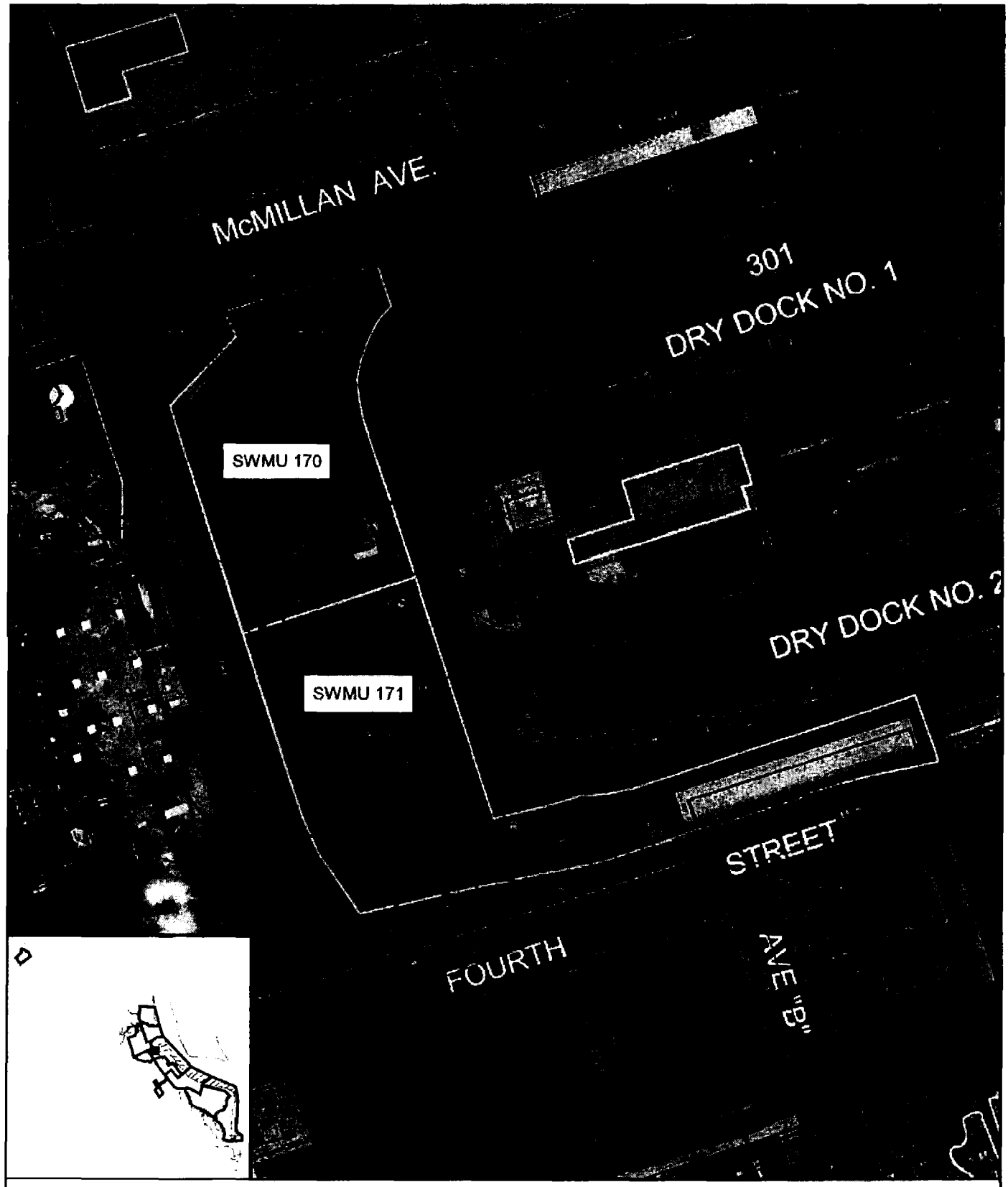
NOTE: Aerial Photo Date is 1997



Railroads
AOC Boundary
SWMU Boundary
Buildings
Zone Boundary

N

0 90 180 Feet

1 inch = 117.25 feet

Figure 1-2
Site Location of SWMU 170 and SWMU 171
Zone E
Charleston Naval Complex

File Path: C:\18gis\CNC\cnc-egis.apr, Date: 26 Feb 2002 10:59, User: MKARAFA, EGIS: Charleston Naval Complex - Figure 1-2 Site Location of SWMU 170 and SWMU 171

2.0 Summary of RFI Conclusions for SWMU 170/171

This section summarizes the results and conclusions from the soil and sediment investigations conducted at SWMUs 170/171, which were reported in the *Zone E RFI Report, Revision 0* (EnSafe, 1997). Figure 2-1 shows the soil and sediment sampling locations. No groundwater investigation was conducted at this site, however a pair of shallow and deep grid wells (EGDGW016 and EGDGW16D) were installed at the site.

As part of the Zone E RFI, soil, sediment, and asphalt-core sampling was conducted at SWMUs 170/171 during 1995 and 1996. The RFI report presented the results of these investigations and conclusions concerning contamination and risk, as summarized in the following sections. A further evaluation of COCs at this combined site is provided in Section 5.0.

2.1 Soil Sampling and Analysis

During the soil sampling event, 35 surface samples and 27 co-located subsurface soil samples were collected from SWMUs 170 and 171. These boring locations were identified as E170SB001 through E170SB015, and E171SB001 through E171SB025. All samples were collected from beneath the pavement, since there are no unpaved areas at these sites. The samples were analyzed for PCBs. In addition, nine samples were analyzed for volatile organic compounds (VOCs), based on elevated vapor readings or petroleum odors noted during the sampling. Figure 2-1 shows the RFI soil boring locations. A summary of detected concentrations in site soil samples is presented in Appendix A.

2.1.1 Surface Soil

During the initial RFI, surface soil detections of organic compounds were evaluated against the U.S. Environmental Protection Agency (EPA) Region III industrial risk-based concentrations (RBCs). Surface soil detections of inorganic compounds were evaluated against the EPA Region III industrial RBCs and the Zone E background reference concentrations (BRCs).

The detected concentrations of organic and inorganic analytes that exceeded their respective screening criteria were as follows:

- **VOCs:** No VOCs exceeded the screening criteria in surface soils.
- **PCBs:** No PCBs exceeded the screening criteria in surface soils.

2.1.2 Subsurface Soil

During the RFI, subsurface soil detections of organic compounds were compared with generic soil screening levels (SSLs) (using a dilution attenuation factor [DAF]=10). Subsurface soil detections of inorganic compounds were compared with generic SSLs (using a DAF=10) and the Zone E BRCs.

Detected concentrations of organic and inorganic compounds from subsurface soil samples are as follows:

- **VOCs:** No VOCs exceeded the screening criteria in subsurface soils.
- **PCBs:** No PCBs exceeded the screening criteria in subsurface soils.

2.2 Sediment Sampling and Analysis

The RFI Work Plan for Area of Concern (AOC) 572 proposed the collection of six sediment samples from catch basins. Accordingly, sediment samples E170M0001 through E170M0004, E171M0001, and E171M0002 were collected and analyzed for PCBs. Figure 2-1 shows the sediment sampling locations. During the RFI, detections in sediment samples were compared with the industrial RBCs for soils. The maximum detected PCB concentration was an Aroclor-1260 detection of 0.2 milligrams per kilograms (mg/kg) in the sediment sample. No PCBs exceeded the screening criteria in the sediment samples.

2.3 Asphalt Core Sampling and Analysis

The *Final Zone E RFI Work Plan* (EnSafe/Allen & Hoshall, 1995a) proposed collecting 40 asphalt-core samples at this site. Thirty-two asphalt core samples were collected and analyzed for PCBs. Eight of the proposed locations did not have asphalt pavement and were not sampled. Figure 10.17.3 from the *Zone E RFI Report, Revision 0* (EnSafe, 1997), a copy of which is included in Appendix A, shows the locations of the asphalt-core samples. The RFI report concluded that one PCB congener, Aroclor-1260, was detected in seven of the 32 samples with concentrations ranging from 0.0037 mg/kg to 0.48 mg/kg.

2.4 RFI Human Health Risk Assessment (HHRA)

The *Zone E RFI Report Revision 0* (EnSafe, 1997) used a fixed-point risk evaluation (FRE) approach at this site. The FRE considered site resident and site worker scenarios during the

FRE. The detailed risk assessment for the SWMU 170/171 sites are presented in Section 10.17.8 of the RFI report.

2.4.1 Soils

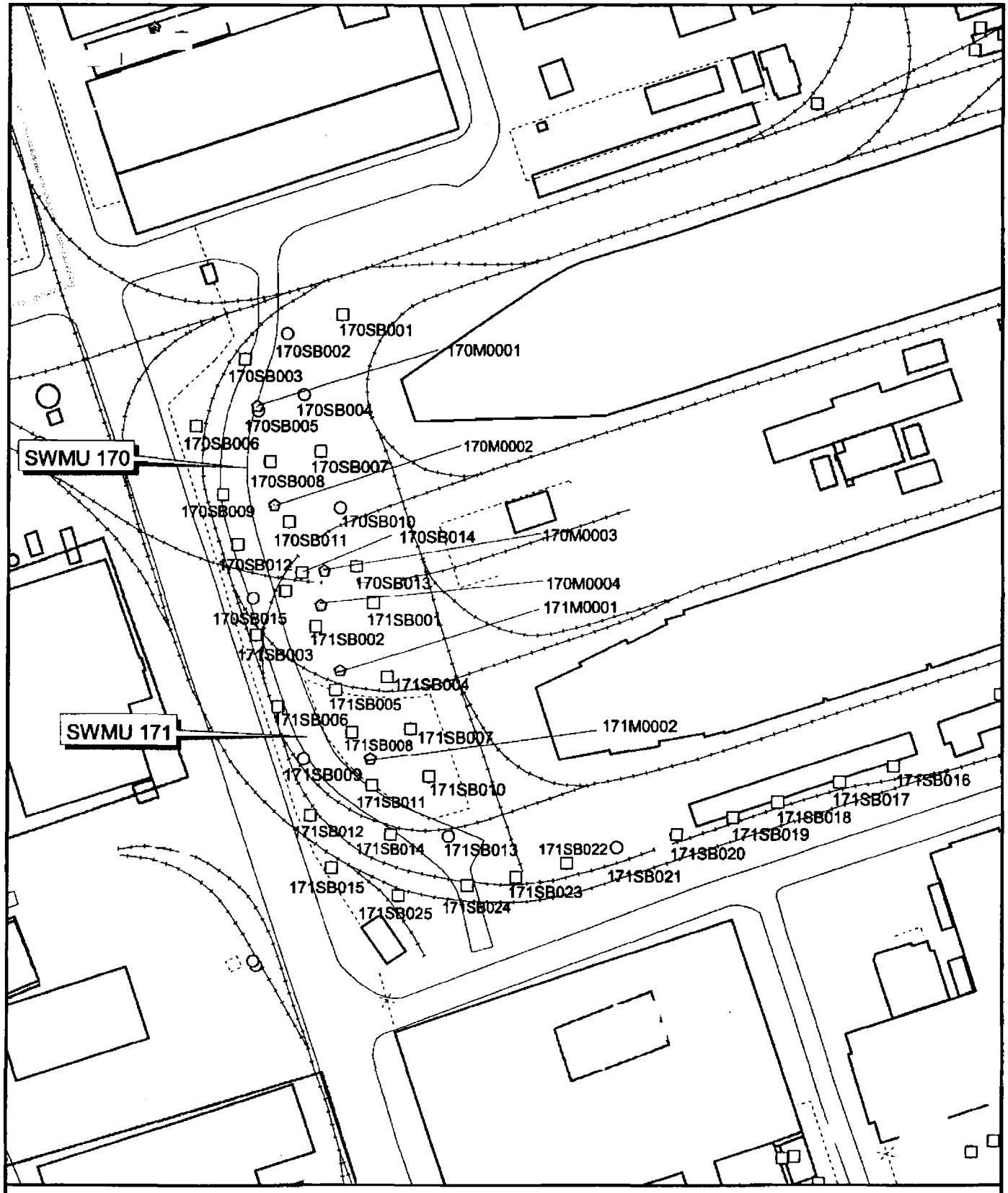
For the unrestricted (residential) future land use scenario, only Aroclor-1260 was identified as a COC for surface soil at SWMU 170/171. For the commercial/industrial re-use scenario, no COCs were identified in soils.

No COCs were identified for sediments or for asphalt.

2.5 RFI Conclusions and Recommendations

Aroclor-1260 in surface soil was the only COC identified based on exceedances of the unrestricted (residential) land use RBC of 0.083 mg/kg (which was in effect during the RFI), at two surface soil locations (171SB0012 and 171SB0013). The RFI report concluded that these samples were collected from beneath the pavement, and that the risk associated with Aroclor-1260 for these two sample locations was within EPA's acceptable risk ranges of 1E-06 and 1E-04. Therefore, the *Zone E RFI Report, Revision 0* recommended NFA for soil at SWMUs 170/171. No specific recommendations were made in the RFI report for a Corrective Measures Study (CMS) for any medium at this site.

NOTE: Original figure created in color



Soil Boring
Sediment
Surface Soil Sample Only
Fence
Railroads
Shoreline

AOC Boundary
SWMU Boundary
Buildings
Zone Boundary

N

0 90 180 Feet

1 inch = 117.25 feet

Figure 2-1
RFI Sampling Locations
SWMU 170 and SWMU 171
Charleston Naval Complex

File Path: C:\18gis\CNC\cnc-egis.apr, Date: 26 Feb 2002 13:36, User: MKARAFA, EGIS: Charleston Naval Complex - Figure 2-1 RFI Sampling Locations

Section 3.0

3.0 Summary of Interim Measures and UST/AST Removals at SWMUs 170/171

3.1 UST/AST Removals

There is no indication of an underground storage tank (UST) or aboveground storage tank (AST) being present at SWMUs 170/171.

3.2 Interim Measures

There were no IMs conducted at this site.

4.0 Summary of Additional Investigations

No additional investigations have been conducted at SWMUs 170/171 since the RFI field work, which was conducted by EnSafe during the period of 1995 - 1997.

5.0 COPC/COC Refinement

The *Zone E RFI Report, Revision 0* (EnSafe, 1997) identified only Aroclor-1260 as a surface soil COC for SWMUs 170/171. The nature of occurrence and the relevance of these chemicals at these sites are further discussed below.

5.1 Surface Soil

5.1.1 Aroclor-1260

Aroclor-1260 was identified during the RFI as a surface soil COC based on exceedances of the residential RBC of 0.083 mg/kg (in effect during the RFI), at two surface soil locations 171SB0012 (beneath a gravel area) and 171SB0013 (beneath asphalt pavement). Both detections were at 0.48 mg/kg, which is slightly above the current residential RBC of 0.32 mg/kg. However, all of the other PCB results are below the current residential RBC, and the average site soil PCB concentration is below the current residential RBC. The PCB concentrations are also below the EPA target cleanup goal of 1 mg/kg for unrestricted land use in high occupancy areas, which is based on 40 *Code of Federal Regulations* (CFR) 761.125, *PCB Remediation Waste* (EPA, 2001). Based on these considerations, PCBs are not considered a COC at the site.

5.2 Sediment

Sediment samples were analyzed for PCBs during the RFI. The maximum PCB concentration was an Aroclor-1260 detection of 0.20 mg/kg in the sediment sample E171M0002. This sample was collected from a catch basin. This sample does not represent sediment from a surface water body, and the detections can be compared with soil screening criteria. The maximum detected concentration is below the target cleanup goal of 1 mg/kg for unrestricted land use in high occupancy areas. Therefore, Aroclor-1260 is not a COC in sediments.

5.3 COC Summary

No COCs for any media were identified at this site for unrestricted (residential) future land use.

6.0 Summary of Information Related to Site Closeout Issues

6.1 RFI Status

The *Zone E RFI Report, Revision 0* (EnSafe, 1997) addressed SWMUs/AOCs within Zone E of the CNC, including SWMUs 170/171.

In accordance with the RFI completion process, if a determination of No Further Investigation (NFI) is made upon completion of the RFI, then a site may proceed to either NFA status or to a CMS. The RFI report for SWMUs 170/171 identified Aroclor-1260 as a COC for surface soils. Based on the discussion presented in Section 5.1 above, Aroclor-1260 in surface soil is not considered a COC at SWMUs 170/171.

The remaining subsections address the issues that the BCT agreed to evaluate prior to site closeout.

6.2 Presence of Inorganics in Groundwater

Groundwater was not targeted for investigation at SWMUs 170/171.

6.3 Potential Linkage to SWMU 37, Investigated Sanitary Sewers at the CNC

There is no data indicating a connection between the investigated sanitary sewers and site opreations or constituents at SWMUs 170/171. Therefore, further evaluation of this issue is not warranted.

6.4 Potential Linkage to AOC 699, Investigated Storm Sewers at the CNC

There is no data suggesting an impact to the storm water sewer system near the site from site constituents. Further evaluation of this linkage is not warranted.

6.5 Potential Linkage to AOC 504, Investigated Railroad Lines at the CNC

Railroad lines run near SWMUs 170/171 between (dry docks) DD 1 and DD2. No linkage between site constituents and the railroad lines has been established, therefore no further evaluation of this issue is warranted.

6.6 Potential Migration Pathways to Surface Water Bodies at the CNC

The nearest surface water body to SWMUs 170/171 is the Cooper River, which lies approximately 700 feet east of the site. The only potential migration pathway from the site to surface water is via overland flow via stormwater runoff. The site is covered with pavement, which eliminates contact of surface soil with stormwater. Similarly, runoff directed to the storm sewer system, which discharges to the Cooper River, does not contact the soil. No further evaluation of a potential pathway for contaminant migration via stormwater runoff is warranted.

6.7 Potential Contamination in Oil/Water Separators (OWSs)

There are no OWSs associated with SWMUs 170/171. In addition, there is no reference to an OWS at the site in the *Oil Water Separator Data* report, Department of the Navy, September 2000. Therefore, further evaluation of this issue is not warranted.

6.8 Land Use Controls (LUCs)

The Navy has agreed that all of Zone E will have at least some LUCs and restrictions. At a minimum, these LUCs are likely to include restrictions against residential land use. Site-specific LUCs are also expected to be required at specific sites within Zone E depending on the results of the site-specific investigations. At SWMUs 170/171, no COCs were detected for the unrestricted land use criteria, therefore LUCs are not required at this site.

7.0 Recommendations

SWMUs 170/171 consist of former storage areas immediately west of DD 1 and DD 2, respectively. Missile-launching tubes removed from decommissioned ballistic missile submarines were stored in these areas for removal of PCB-containing components, beginning in the late 1980s and ending no later than 1996. The site was recommended in the RFA report for a CSI to assess whether PCBs had been released to site soils.

The *Zone E RFI Report, Revision 0* indicated that PCBs were detected in only 13 out of 35 soil samples collected at the site. Aroclor-1260 in surface soils was identified as a COC for the SWMUs 170/171 site, based on the exceedance in two soil samples of the residential RBC in effect at the time of the original RFI report. The average site PCB concentrations are below the current residential RBC. Therefore, PCBs are not considered COCs at the site. No other COCs were identified for any medium at this site for the unrestricted future land use scenario. Therefore, this site is recommended for NFA.

8.0 References

EnSafe Inc./Allen & Hoshall. *Final Zone E RFI Work Plan, Revision 1, NAVBASE Charleston.* June 1995a.

EnSafe Inc./Allen & Hoshall. *Final RCRA Facility Assessment, NAVBASE Charleston.* July 1995b.

EnSafe Inc. *Zone E RFI Report, Revision 0, NAVBASE Charleston.* 1997.

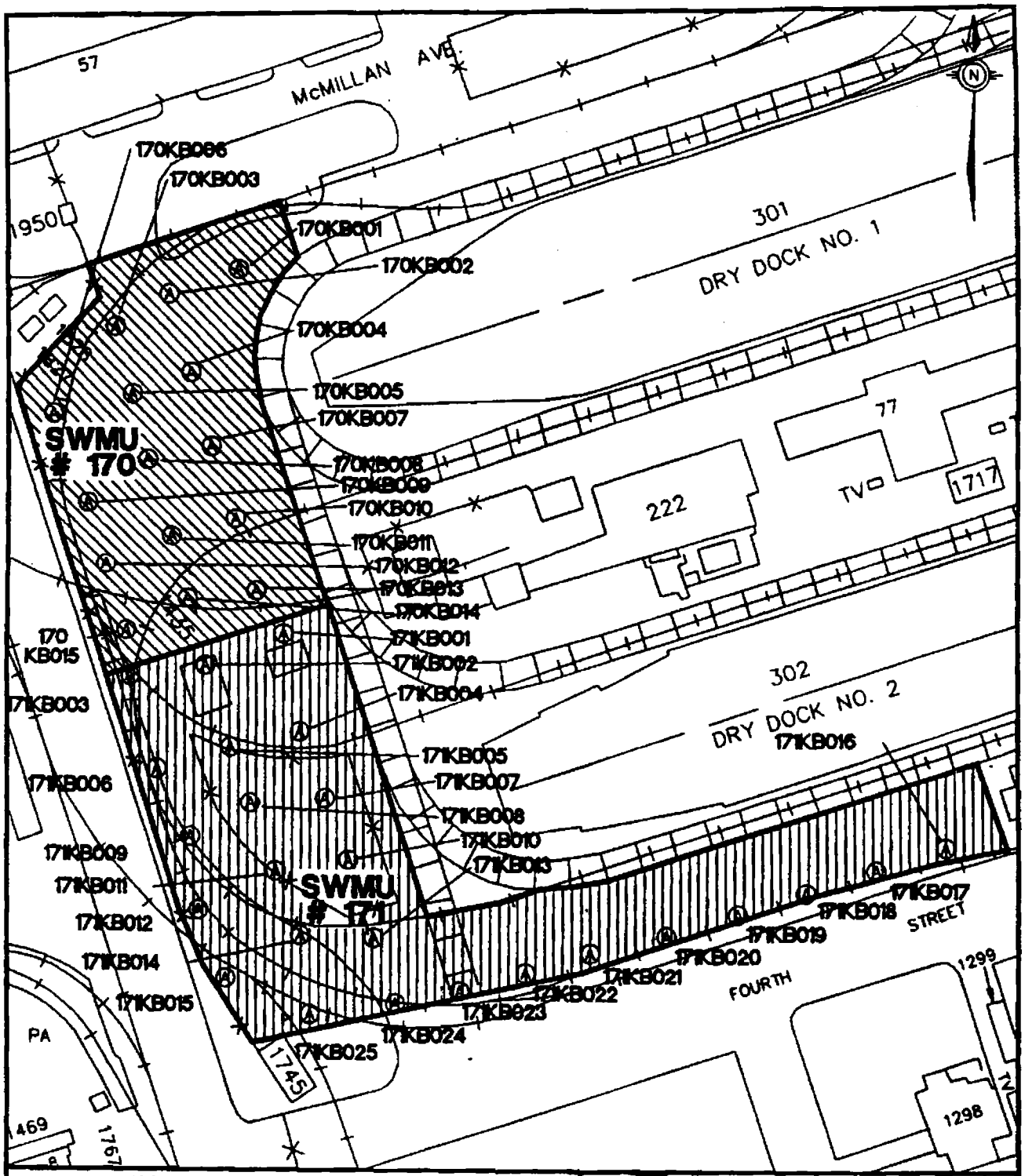
South Carolina Department of Health and Environmental Control, Final RCRA Part B Permit No. SC0 170 022 560.

U.S. Environmental Protection Agency. *Code of Federal Regulations, 40 CFR 761.125 PCB Remediation Waste.* 2001.

Table 10.17.A
Chemicals Present in Site Samples
SWMU 170, SWMU 171 - Surface Soil
NAVBASE - Charleston, Zone E
Charleston, South Carolina

Parameter	Frequency of Detection		Range of Detection		Average Detected Concentration	Range of SQL		Screening Concentration Residential RBC	Industrial RBC	Reference	Units	Number Exceeding Res.	Ind.	Ref.
Pesticides/PCBs														
Aroclor-1260 *	13	35	11	480	144.4	73	90	83	740	NA	UG/KG	8		
gamma-Chlordane	1	2	1.5	1.5	1.5	1.8	1.8	490	4400	NA	UG/KG			
4,4'-DDT	1	2	25	25	25	3.4	3.4	1900	17000	NA	UG/KG			
4,4'-DDE	1	2	14	14	14	3.4	3.4	1900	17000	NA	UG/KG			
TCDD Equivalents														
Dioxin Equiv.	4	4	0.0279	0.8262	0.2674	NA	NA	1000	1000	NA	NG/KG			
Volatile Organics														
Acetone	4	4	73	4400	1248	NA	NA	780000	20000000	NA	UG/KG			

* - Identified as a residential COPC
SQL - Sample Quantitation Limit
UG/KG - micrograms per kilogram
NG/KG - nanograms per kilogram
NA - Not Applicable



LEGEND

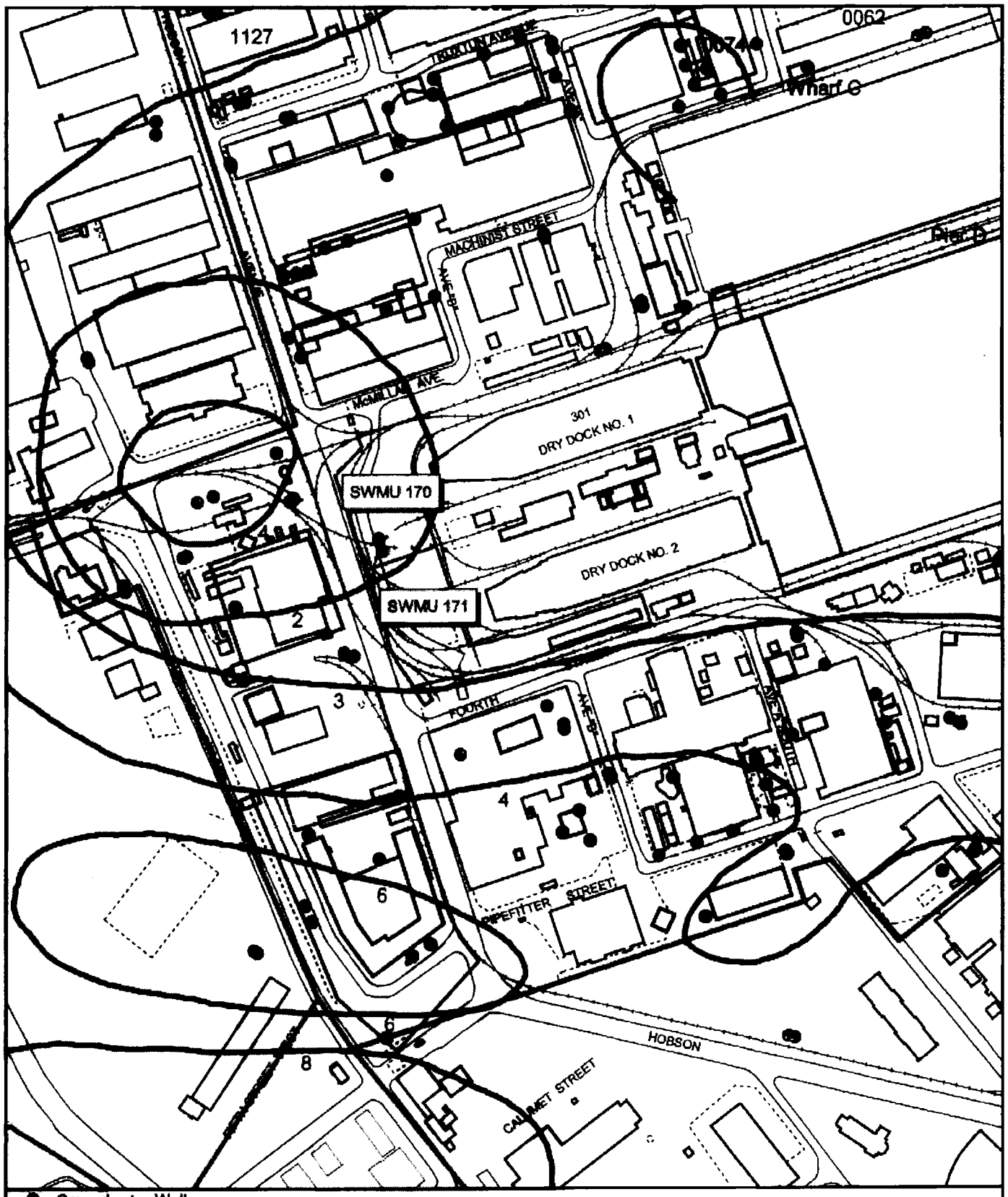
- ● - SOIL BORINGS
- Ⓒ - CORE SAMPLES
- ◒ - DEEP MONITORING WELLS
- ◭ - SHALLOW MONITORING WELLS
- ▲ - SEDIMENT SAMPLES
- Ⓣ - THICKNESS SAMPLES
- Ⓦ - WIPE SAMPLES
- Ⓢ - SURFACE WATER SAMPLES

GRAPHIC SCALE 100 0 100 200

ZONE E
RFI REPORT
NAVAL BASE CHARLESTON
CHARLESTON, S.C.

FIGURE 10.17.3
ASPHALT SAMPLE LOCATIONS
SWMU #170, DD #1 AREA
SWMU #171, DD #2 AREA
PCB REMOVAL OPERATIONS

DWG DATE: 09/02/97 | DWG NAME: 10-17-3



Groundwater Well

Shallow Groundwater Contours ft bls

Fence

Railroads

Roads - Lines

AOC Boundary

SWMU Boundary

Buildings

Zone Boundary

N

0 100 200 Feet

1 inch = 93 feet

Figure A-1
Shallow Groundwater Contour Map
SWMU 170 and SWMU 171, Zone E
Charleston Naval Complex

File Path: C:\18gis\CNC\cno-egis.apr, Date: 22 Mar 2002 9:40, User: MKARAFA, EGIS

Comments Prepared by Charles B. Watson

SWMU 170/171

SCDHEC Comment 10:

Aroclor-1260 was detected above the residential RBC in borings 171SB0012 and 171SB0013. The vertical and horizontal extent of contamination should be determined.

Navy/EnSafe Response 10:

The area around boring 171SB013 has been delineated vertically and horizontally. Additional upper and lower-interval samples will be collected along the western edge of 171SB012 to complete delineation of Aroclor-1260 at this location.

CH2M-Jones Response 10:

The Aroclor-1260 detections of 0.48 milligrams per kilogram (mg/kg) in surface soil samples from both locations E171SB012 and E171SB013 are below the target cleanup goal of 1 mg/kg for unrestricted land use established by the EPA. No additional delineation for PCBs in soils is required.

CH2M HILL
3011 SW Williston Road
Gainesville, FL
32608-3928
P.O. Box 147009
Gainesville, FL
32614-7009
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Fax 352.335.2959

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National Engineers Week 2000

August 3, 2000

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

Subject: Charleston Naval Complex - Charleston, South Carolina
Corrective Measures Study Work Plan - Membrane Interface Probe Pilot Study
Phase 1 – SWMU 166

Dear Mr. Litton:

Enclosed please find 5 copies of the above referenced document for your review. If you have any questions, comments or need additional information, please do not hesitate to call me.

Sincerely,

CH2M HILL

Bryan B. McDonald, P.G.
Geologist
South Carolina P.G. No. 359

GNV\MIProbe_cvrltr.doc
c: Mr. Mihir Mehta, SCDHEC
Mr. Dann Spariosu, USEPA
Mr. Tony Hunt, SouthDiv
Mr. Dean Williamson, CH2M HILL
Mr. Casey Hudson, CH2M HILL

DEPARTMENT OF THE NAVY
SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
P.O. BOX 190010
2155 EAGLE DRIVE
NORTH CHARLESTON, S.C. 29419-9010

5090/11
Code 18B1
28 July, 2000

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 MEMBRANE INTERFACE PROBE PILOT STUDY, PHASE I, CORRECTIVE MEASURES STUDY WORK PLAN

Dear Mr. Litton,

The purpose of this letter is to submit the Membrane Interface Probe (MIP) Pilot Study, Phase I, Corrective Measures Study (CMS) Work Plan for Naval Base Charleston. . The Workplan 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 U.S. Environmental Protection Agency.

The document is distributed under separate cover letter by CH2M Hill. Appropriate certification is provided under that correspondence. We request that the Department and the EPA review this document and provide comments or approval whichever is appropriate. If you should have any questions, please contact Matthew Humphrey or Matthew A. Hunt at (843) 743-9985 and (843) 820-5525 respectively.

Sincerely,

Matthew A. Hunt

Matthew A.Hunt, P.E.
Environmental Engineer
BRAC Division

Copy to:
SCDHEC (4),
USEPA (Dann Spariosu)
CSO Naval Base Charleston (Matt Humphrey)
CH2M-Hill (Dean Williamson)

CH2M HILL
225 E. Robinson Street
Suite 505
Orlando, FL
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Tel 407.423.0030
Fax 407.839.5901

CH2MHILL

July 21, 2000

158814.ZK.PR.00

Tony Hunt
Base Environmental Coordinator
Charleston Naval Shipyard
Southern Division
Naval Facilities Engineering Command (Code 1877)
1255 Eagle Drive
North Charleston, SC 29406

Subject: Corrective Measures Study Work Plan
Membrane Interface Probe
Pilot Study – Phase I

Dear Tony:

Enclosed is one copy of the Corrective Measures Study Work Plan that outlines the technical approach for evaluating the membrane interface probe technology at SWMU 166. The CH2M-Jones team looks forward to implementing the pilot study and presenting its results and evaluation on the technology effectiveness. If you have any questions, comments or need additional information please do not hesitate to call.

Sincerely,

CH2M HILL

Casey E Hudson (SV)

Casey E. Hudson, P.E.
Project Engineer
(407) 423-0030 ext. 251

Dean Williamson

Dean Williamson, P.E.
Project Manager
(352) 335-5877 ext. 280

cc: Tom Beisel, P.G./CH2M HILL, ATL

CORRECTIVE MEASURES STUDY WORK PLAN

Membrane Interface Probe (MIP) Pilot Study Phase I

Solid Waste Management Unit (SWMU) 166
Charleston Naval Complex Annex
Charleston, South Carolina

SUBMITTED TO

U.S. Navy Southern Division
Naval Facilities
Engineering Command

PREPARED BY

CH2M-JONES

July 2000

Revision 0

Contract N62467-99-C-0960

158814.ZK.PR.00

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- 1.3 Organization of Pilot Study Work Plan 1-3

2.0 Technical Approach **2-1**
- 2.1 MIP/Vertical Profiler Borong Locations 2-1
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Appendix

MIP Output Interpretation
Standard Logging Procedures
Permeable Membrane Sensor for the Detection of Volatile Compounds in Soil

Acronyms and Abbreviations

CH2M-Jones, LLC	CH2M-Jones, Limited Liability Company
CMS	corrective measures study
CNC	Charleston Navy Complex
CSAP	Comprehensive Sampling and Analysis Plan
1,2-DCE	1,2-dichloroethene
DNAPL	dense non-aqueous phase liquid
DMP	Data Management Plan
DPT	Direct Push Technology
FID	flame ionization detector
ft bls	feet below land surface
GC/MS	gas chromatograph/mass spectrometer
IDW	investigative derived waste
mg/L	milligrams per liter
MIP	Membrane Interface Probe
µV	micro-volts
QAP	Quality Assurance Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SCDHEC	South Carolina Department of Health and Environmental Control
SWMU	solid waste management unit
TCE	trichloroethene
VOC	volatile organic compound

1.0 Introduction

1.1 Purpose of Pilot Study

This corrective measures study (CMS) work plan presents a technical approach for evaluating the viability of using the membrane interface probe (MIP) instrument to characterize the magnitude and extent of chlorinated solvents in groundwater at solid waste management unit (SWMU) 166, Charleston Naval Complex (CNC) Annex. The MIP is an innovative site characterization technology developed during the last 5 years by GeoProbe Systems, Inc., a leading developer and provider of direct push technologies (DPT) and hardware.

The MIP is a direct push device that is compatible with existing GeoProbe direct push probes and rods. It provides real-time, semi-quantitative data about the concentration of volatile organic chemicals in groundwater. Real-time data are generated via a variety of detectors (such as flame ionization, photo-ionization, or electron capture detectors) that are mounted in or on the direct push rig that drives the MIP. Additional information on the design, construction, and operation of the MIP is provided in the Appendix.

The MIP is as safe, or safer, to use than other currently available direct push sampling devices in common use for site characterization and does not result in detrimental impacts to groundwater systems. Also, because the MIP generates real-time data, it may be less likely to cause inadvertent downward mobilization of chlorinated solvent dense non-aqueous phase liquids (DNAPLs), which can occur during use of conventional direct push equipment. With conventional direct push equipment, if a pooled, mobile DNAPL phase is encountered, the DPT unit may be advanced downward through the pooled DNAPL, possibly allowing downward DNAPL migration. With the MIP, if a pooled DNAPL source is encountered, the real-time data provided enables the operator to make a decision to abort further downward advancement of the unit.

The pilot study will focus on identifying suspected locations of trichloroethene (TCE) DNAPL and elevated concentrations of TCE and 1,2-dichloroethene (1,2-DCE) in the groundwater source areas at SWMU 166. If the results of the pilot study are favorable

and demonstrate MIP as an effective means for source area characterization, it will be used to further vertically and horizontally profile the elevated concentration of chlorinated solvents present in the groundwater at SWMU 166 (CMS Work Plan - Phase II). The source area delineation information obtained from these activities will be used to lay out the array of electrodes required for six-phase electrical heating.

1.2 Site Background and Setting

The CNC Annex is north/northwest of CNC and is bound to the north by Airport Road, to the east by Interstate-26, to the south by Air Park Road, and to the west by the Charleston Air Force Base (Figure 1-1). The Naval Annex is a flat-lying area, approximately 40 feet above mean sea level. Previous investigations at SWMU 166 have identified concentrations of TCE at or greater than 1 percent of the maximum solubility in water at several locations at SWMU 166; the maximum solubility of TCE in water is approximately 1,100 milligrams per liter (mg/L). Concentrations of this nature are often a likely indicator of the presence of a DNAPL source area near the monitored location. The potential DNAPL source areas are expected to include the area at the top of the Ashley formation (approximately 31 to 37 feet below land surface [ft bls]) and at the interface between the clayey sand unit and overlying sandy unit (approximately 23 to 28 ft bls), and also may occur at other depths.

Aerial photographs of the Naval Annex indicate that the property consisted of open vegetation and forested areas prior to 1941 and was not fully developed until 1960. During World War II, the Naval Annex was owned by the Air Force and was the location of a weather forecasting facility. According to historical documents provided by the Air Force, the Annex was turned over to the 792nd Squadron of the Tactical Air Command in 1954. From 1954 to 1981, the Naval Annex was an operating radar station. In 1981 the radar station was dismantled and the Annex was acquired by the Naval Station Charleston. The U.S. Marine Corps currently uses the Naval Annex as a reserve training center, which houses administrative and classroom type buildings and a heavy vehicle storage and maintenance/small repair facility.

The identified chlorinated solvent plume is located in SWMU 166. When the sanitary sewer line and septic system serving the annex were first investigated, the SWMU that encompassed them was referred to as SWMU 166. However, SWMU 185 was later designated for the sewer system.

TCE was identified in groundwater at the Naval Annex in an area currently occupied by a U.S. Marine Corps Reserve Training Center during the SWMU 166 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI).

1.3 Organization of Pilot Study Work Plan

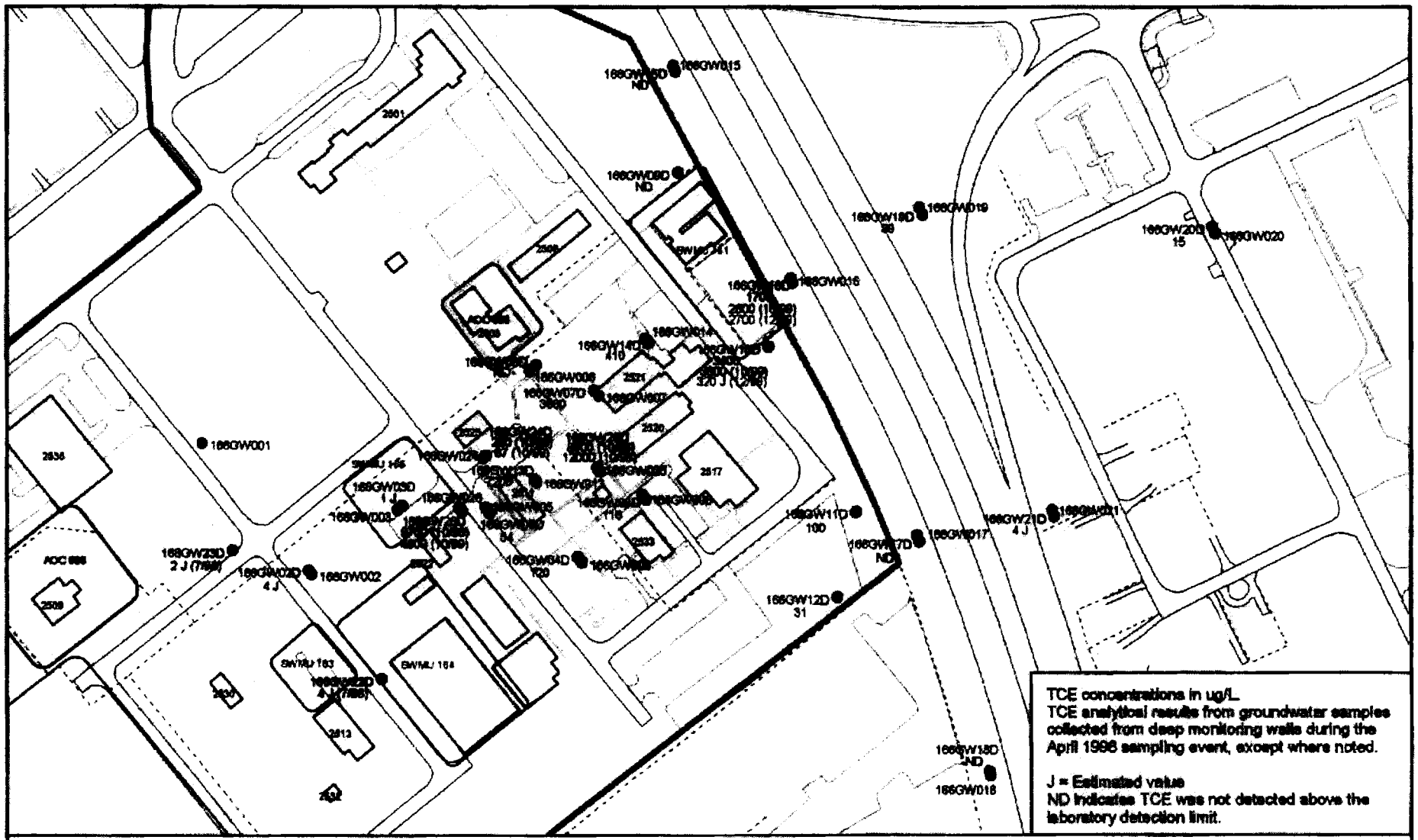
This pilot study work plan consists of the following four sections, including this introductory section:

1.0 Introduction — Presents the purpose of the report and background information regarding the demonstration.

2.0 Technical Approach — Provides a brief description of the technical approach for completing the pilot study.

3.0 Investigative-Derived Waste — Describes the procedures to be implemented for management of investigative-derived waste.

4.0 References — Lists the references used in this document.



- Deep Groundwater Well
- Shallow Groundwater Well
- Fence
- Railroads
- Roads
- Pavement
- Sidewalk
- Surrounding Area
- AOC Boundary
- SWMU Boundary
- Buildings
- Zone Boundary

N

0 200 400 Feet

Figure 1-1
Charleston Naval Complex Annex Location Map
Corrective Measures Study Work Plan
MIP Feasibility Demonstration - Phase 1
Charleston Naval Complex Annex (Zone K)

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2.0 Technical Approach

This section outlines the technical approach of the pilot study for the MIP technology at SWMU 166. The demonstration will be completed in a single day and will consist of up to five MIP/vertical profiler locations. The underground utilities in the area surrounding the proposed MIP and vertical profiler points will be identified and properly labeled prior to the initiation of the pilot study.

The overall strategy for demonstrating the feasibility of this technology will be to first advance the MIP through the TCE plume in the target area. MIP readings will be recorded as described later in this work plan. After removal of the MIP from the boring, a groundwater profiler will be advanced in a boring within 12 to 18 inches of the MIP location. Discrete groundwater samples will be collected and analyzed via an onsite gas chromatograph/mass spectrometer (GC/MS). The data from the MIP and the profiler will be compared to assess the degree of data correlation.

2.1 MIP/Vertical Profiler Locations

The initial MIP/vertical profiler location will be advanced adjacent to the deep groundwater monitoring well 166GW25D. This well was selected as a starting point because previous analysis of groundwater samples from this well were found to contain highly elevated TCE concentrations. Up to four additional MIP and vertical profiler points will be positioned in a 20-foot grid pattern surrounding the initial MIP/vertical profiler location in the northwest, northeast, and southwest directions. Each MIP and vertical profiler point will be separated by approximately 12 to 18 inches. The proposed locations are shown in Figure 2-1. The MIP and vertical profiler points will be identified as 166MP001 through 166MP005 and 166VP006 through 166VP010, respectively.

2.2 MIP Operations

CH2M-Jones will subcontract with Columbia Technologies to advance the MIP and vertical profiler points in the proposed locations. CH2M-Jones will provide a field

hydrogeologist or engineer who will be responsible for all field operations. Each MIP point will be advanced in the groundwater formation, beginning at the top of the saturated zone to the top of the Ashley formation at approximately 31 to 37 ft bls. The MIP will be advanced and readings from the detection device obtained at each linear foot in the groundwater formation. The MIP will pause at each depth interval for a sufficient period of time (approximately 1 minute) to allow volatile organic compound (VOC) molecules to move by diffusion across the membrane and be transported to the detector at land surface.

Since the membrane is heated and thin, the movement of VOCs across the membrane is rapid. After diffusing across the membrane, the VOCs partition into the carrier gas which sweeps the back side of the membrane. It takes less than 1 minute for the carrier gas stream to travel through approximately 100 feet of inert tubing and reach the detectors used by the system.

Due to the elevated concentrations present in the proposed demonstration area, the MIP will use a flame ionization detector (FID). FID detectors are less likely to be significantly impaired if extremely high concentrations of VOCs are encountered, as compared to an electron capture detector or photoionization detector. To evaluate the concentration of chlorinated solvents in the groundwater formation, a graph will be generated of the MIP-FID response in micro-volts (μV) versus depth in feet. The parameters recorded during the MIP advancement and used to interpret the chlorinated solvent concentrations in groundwater include conductivity, speed, and temperature. MIP operating information and procedures are provided in the Appendix.

2.3 Confirmatory Sampling of Groundwater

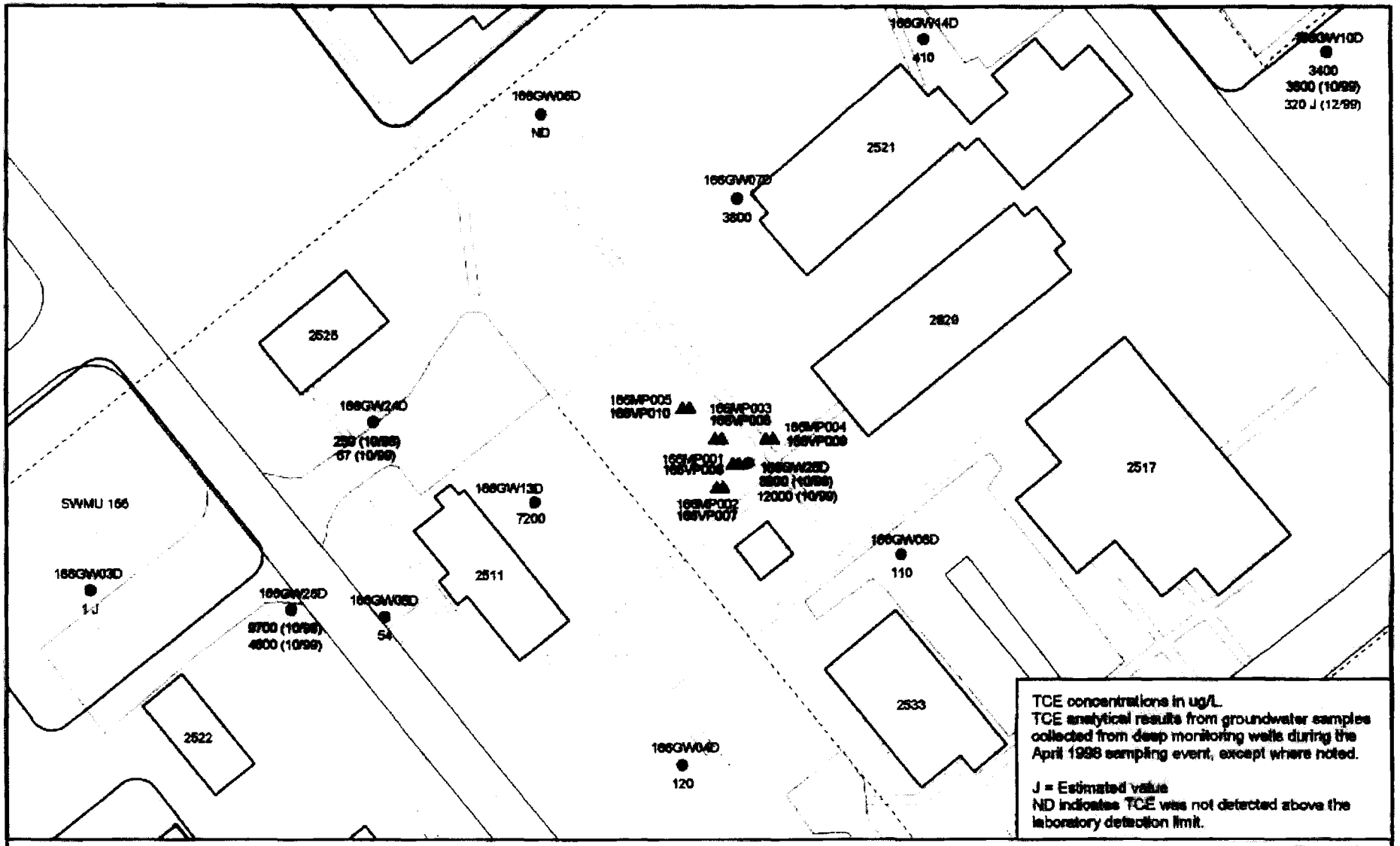
To evaluate the results from the MIP-FID detector, one vertical profiler point will be advanced approximately 12 to 18 inches from each MIP point. The vertical profiler equipment will be standard GeoProbe DPT devices, equipped with a 6-inch-long well screen for discrete groundwater sample collection. Three groundwater samples will be collected from approximately 10, 20, and 30 ft bls and analyzed for VOCs using an onsite GC/MS. However, the proposed sample collection intervals may be changed in the field on the basis of the MIP results. The onsite GC/MS unit will be provided by

Columbia Technologies. The groundwater results analyzed via the GC/MS will be compared to the results obtained from the MIP-FID detector. In addition, because an FID detects gases that may be present due to natural biological activity, a groundwater sample collected from the vertical profiler at approximately 10 ft bls in each boring will be analyzed for methane, ethane, and ethene with a gas chromatography and FID.

The groundwater analysis will follow the procedures found in the approved Comprehensive Sampling and Analysis Plan (CSAP) portion of the RFI Work Plan (Ensafe, Inc./Allen & Hoshall 1994) The CSAP outlines all monitoring procedures to be performed during the investigation in order to characterize the environmental setting, source, and releases of hazardous constituents. In addition, the CSAP includes the Quality Assurance Plan (QAP) and Data Management Plan (DMP) to verify that all information and data are valid and properly documented.

The completed MIP and vertical profiler points will be filled to the ground surface with bentonite pellets or slurry.

The results of the MIP pilot study will be summarized in a brief letter report, which will be submitted to the Navy and the South Carolina Department of Health and Environmental Control (SCDHEC) approximately 3 to 4 weeks after completion of the MIP demonstration. The letter report will document the field activities completed during the pilot study and will evaluate the effectiveness of the MIP technology.



TCE concentrations in ug/L.
TCE analytical results from groundwater samples collected from deep monitoring wells during the April 1998 sampling event, except where noted.

J = Estimated value
ND indicates TCE was not detected above the laboratory detection limit.

- Proposed MIP Location
- Proposed Vertical Profiler Location
- Deep Groundwater Well
- Fence
- Railroads
- Roads
- Pavement
- Sidewalk
- Surrounding Area
- AOC Boundary
- SWMU Boundary
- Buildings
- Zone Boundary

N

0 40 80 Feet

Figure 2-1
SWMU 166 MIP/Vertical Profiler Locations
Corrective Measures Study Work Plan
MIP Feasibility Demonstration - Phase 1
Charleston Naval Complex Annex (Zone K)

CH2MHILL

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3.0 Investigative-Derived Waste

Investigative-derived waste (IDW) consisting of purge water will be collected in a labeled 55-gallon drum and left onsite. Once the analytical results have been reviewed, the 55-gallon drum with the groundwater contents will be hauled by the U.S. Naval Detachment for offsite treatment. If arrangements cannot be made with the Detachment, CH2M-Jones will haul the drum to a permitted and licensed facility for treatment of the solvent-impacted groundwater.

4.0 References

EnSafe, Inc./Allen & Hoshall. *Final Comprehensive Corrective Action Management Plan.* August 30, 1994.

Appendix

MIP Output Interpretation

http://zebraenv.com/seusa/pdf-bin/Interpretation.PDF

MIP Output Interpretation

This is a brief introduction to MIP data interpretation. The MIP is a developing technology. It's true potential is not yet fully realized primarily due to limited experience of MIP operators in the field. Below I attempted to describe the very basics of MIP log interpretation, based on my field experience with ZEBRA's first unit, as well as work done in 1996 using Geoprobe System's prototype unit.

Alex Nadolishny, 03/06/2000

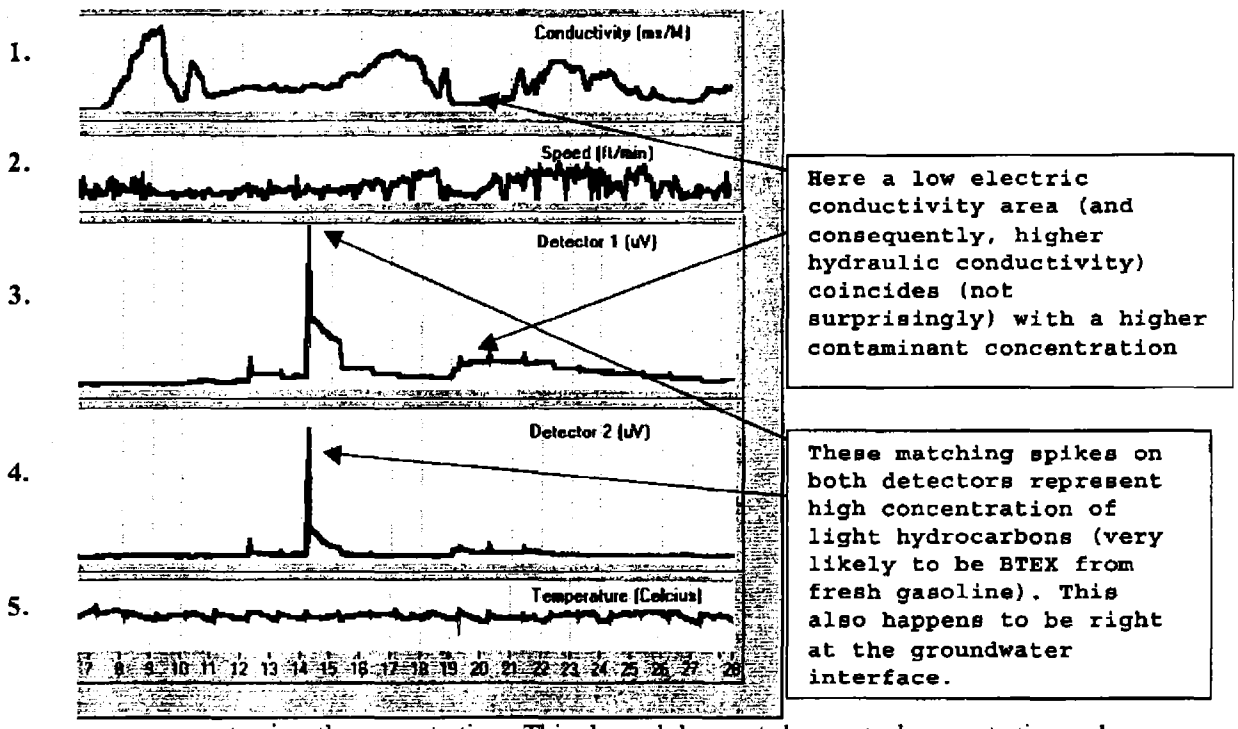
Channel comments:

The sample log below was recorded on a gasoline-contaminated site and represents the typical look of MIP system output. The probe was advanced in the proper manner (drive 1 foot + wait 1 minute).

1. **Conductivity:** Units of measure are millisiemens per Meter (ms/M); three distinct high conductivity units were detected here: 7-10'BG, 15-19'BG and 21-26'BG, representing silts and silty clays (remember, actual values are representative within a given geologic formation: silt in Florida may have different electric conductivity than silt in Massachusetts).

2. **Speed:** [- of probe penetration]. Gives a rough idea of how tight the formation is. There is not a reliable way to convert this into blow counts. Variations occur mostly, because actual speed depends a lot on operator's style (and his mood).

3. **Detector 1:** Normally the PID, although the detectors can be swapped; units are in micro Volts (uV) – This graphing represents voltage output from the electrometer, correlating with



contaminant's concentration. This channel does not show actual concentration, only detector output; you need to know the response factor and dilution factor to figure that

out. The easiest way to do it is to grab a representative sample and establish a correlation for a given site and given contaminant). Note that the detector output line consists of a number of spikes that represent advancement of the probe and related changes of contaminant transfer across the membrane. Additionally, light (and more volatile) compounds (such as benzene in the case of a gasoline plume) within the contaminant mixture go across the membrane faster than heavier compounds, creating a leading spike. The scale uses exponential format (also called 'scientific notation') to represent output values. 5E+6 means 5 x 10^6 (five times ten to the power of six), so it is 5,000,000 (micro volts). The scale is set to auto-scale by default, modifying the graph to fit the scale as detector response values go up.

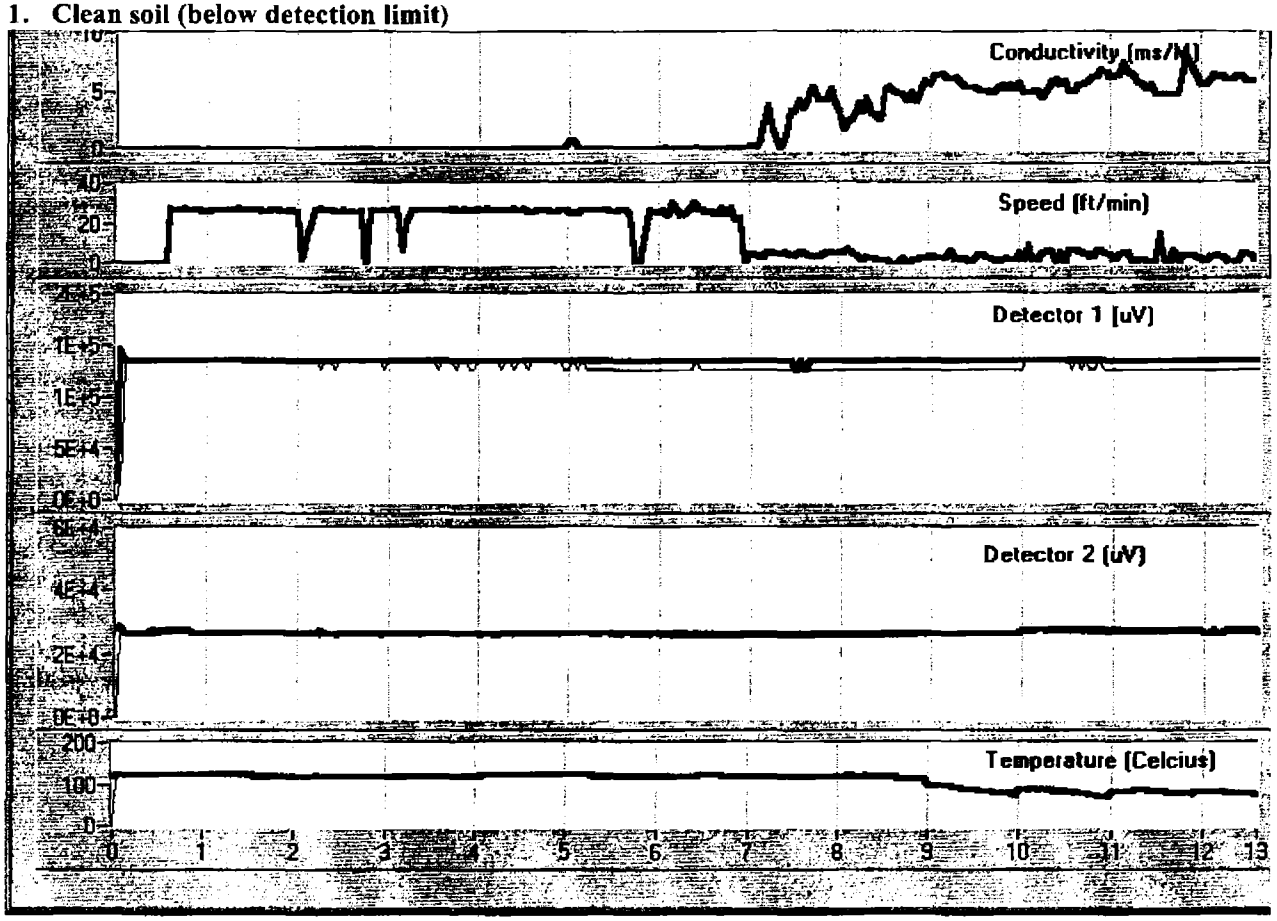
4. **Detector 2:** Normally the FID (on a BTEX site) or ECD (if dealing with halogenated compounds); same units as Detector 1 channel. Remember that FID can detect light hydrocarbons, such as methane or butane, which are out of reach for the PID. You can have a really high response on Detector 2 channel with nothing on Detector 1. In such case the chances are that you've run into an area with anaerobic degradation processes present, or you have detected a gas leak from a nearby natural gas line. The ECD detector generally is very stable except when entering the water table. Increased water vapor concentration causes the ECD's baseline to drop sharply at the groundwater interface. Additionally, the ECD's baseline has a tendency to slope down as the probe is advanced deeper (noticeable when going below 50-60' BG), as the amount of water going across the membrane increases with increasing pressure. The same is true for the PID detector, to a smaller extent.

5. **Temp:** Shows the output of a thermocouple built into the MIP probe's heating plate. It is useful for monitoring system performance and for troubleshooting. Each time the probe is advanced to the next depth increment, the temperature graph goes down; as soon as the probe stopped, the temperature starts to go back up until it reaches the target value of 120 C, at which point the heating plate controller disconnects power from the heating element to prevent overheating. At that temperature (120 C), the optimal rate of contaminant transfer across the membrane is achieved (as per Geoprobe). Under certain conditions (particularly coarse sands), the temperature channel can be used to pinpoint the top of an aquifer -- the temperature goes down with the probe advancement, but never comes back as high as it did above the water table.

Log Interpretation

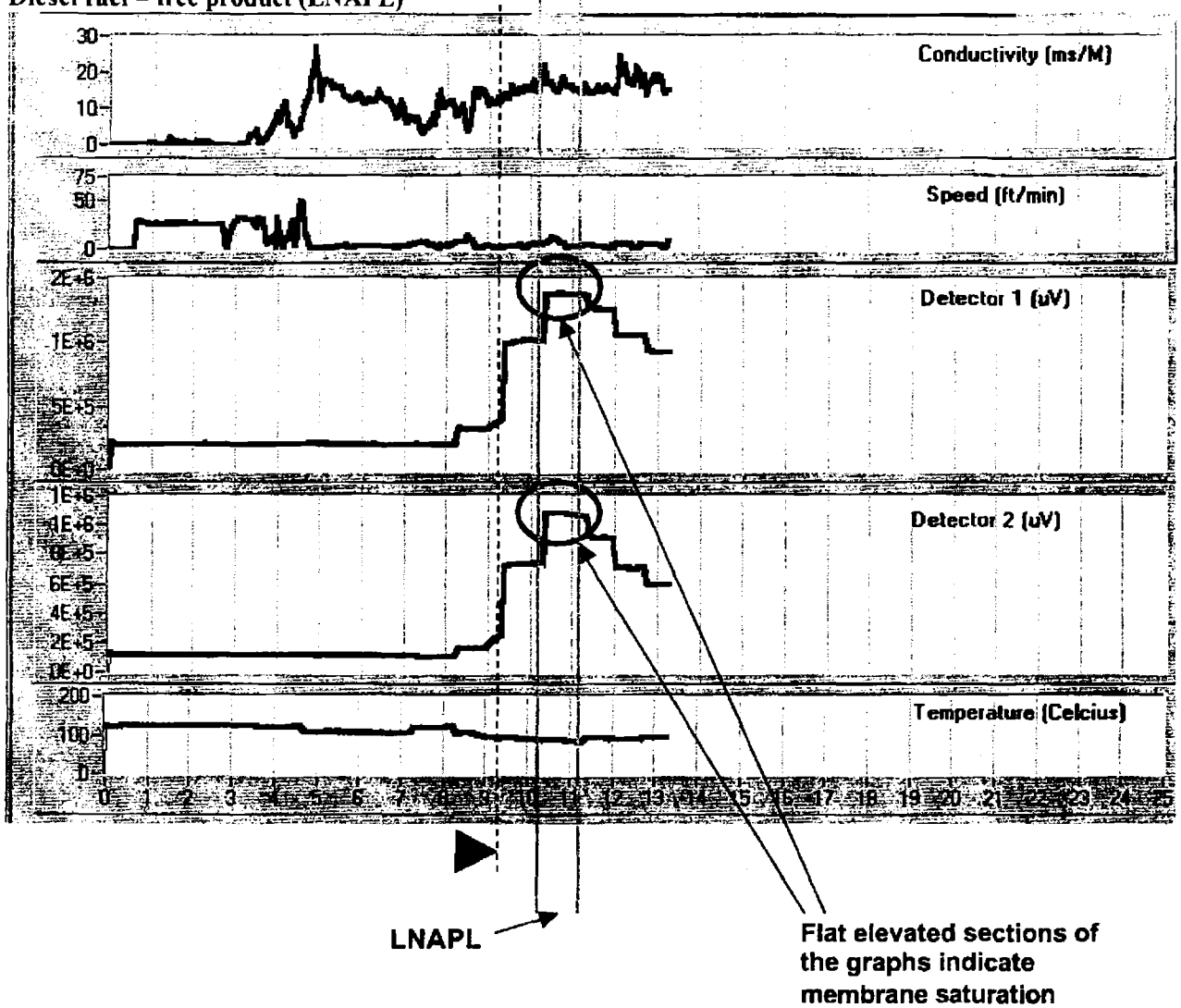
The interpretation of the logs below is based on confirmatory sampling and/or existing site data.

1. Clean soil (below detection limit)



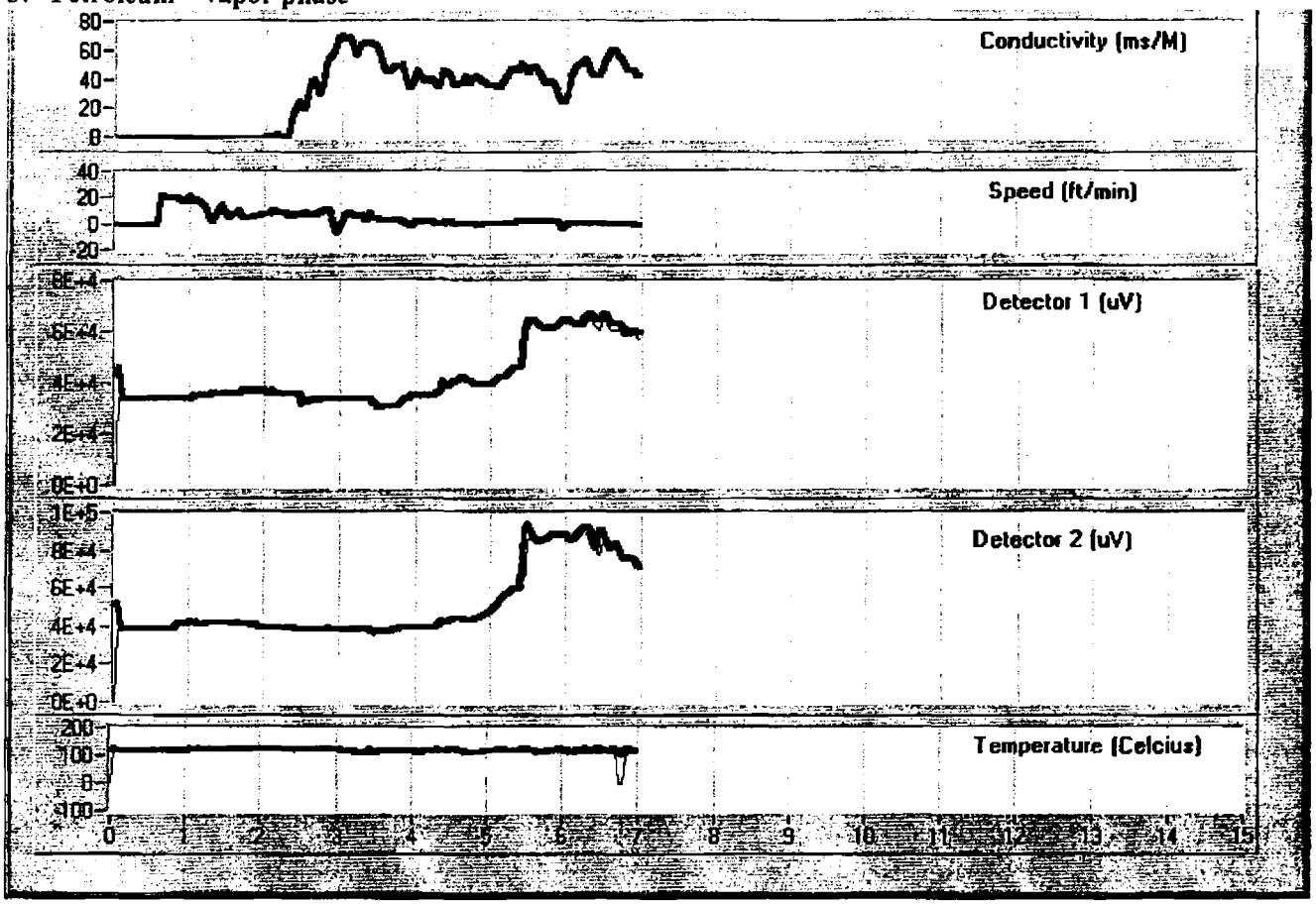
Clean soils (clean as far as MIP is concerned) typically produce flat output logs, featuring no significant spikes or elevated areas. Remember that although the MIP's detection limits are ~400 ppb for BTEX and ~200 ppb for Halogenated Hydrocarbons, even lower concentrations typically produce very uneven graph with lots of signal noise.

2. **Diesel fuel – free product (LNAPL)**



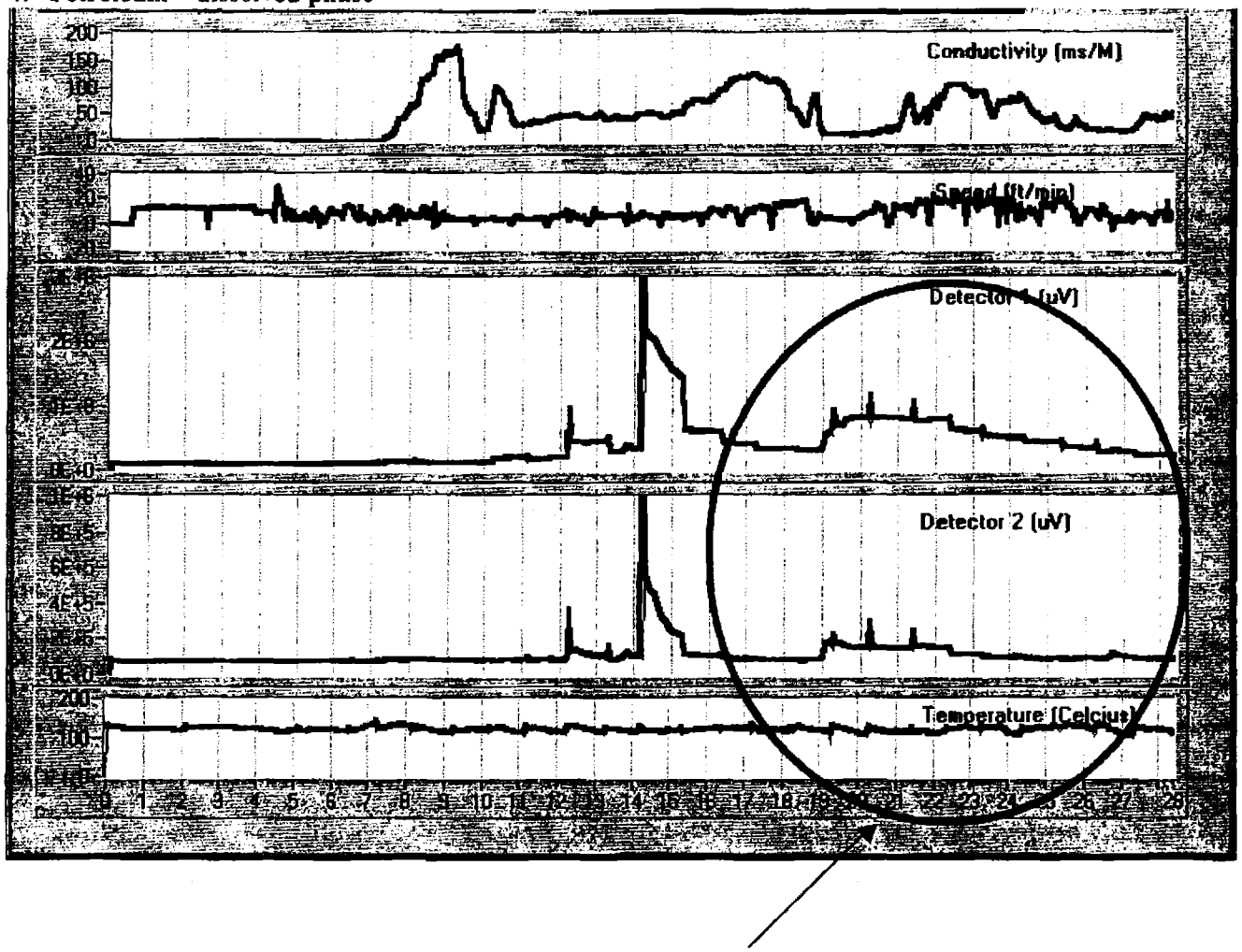
The contamination here was diesel fuel, approximately 10-year old spill. A flat line in the free product zone indicates membrane saturation (or detector saturation, in case of light hydrocarbons) – a condition associated with the presence of free-phase contamination.

3. **Petroleum – vapor phase**



This log was recorded in weathered shale, adjacent to pump islands at a gas station. The probe hit refusal at 7' BGS. The terminal depth here was high above the static water table. The detector response was caused by gasoline vapors present in the subsurface, above the free-phase gasoline at a lower depth.

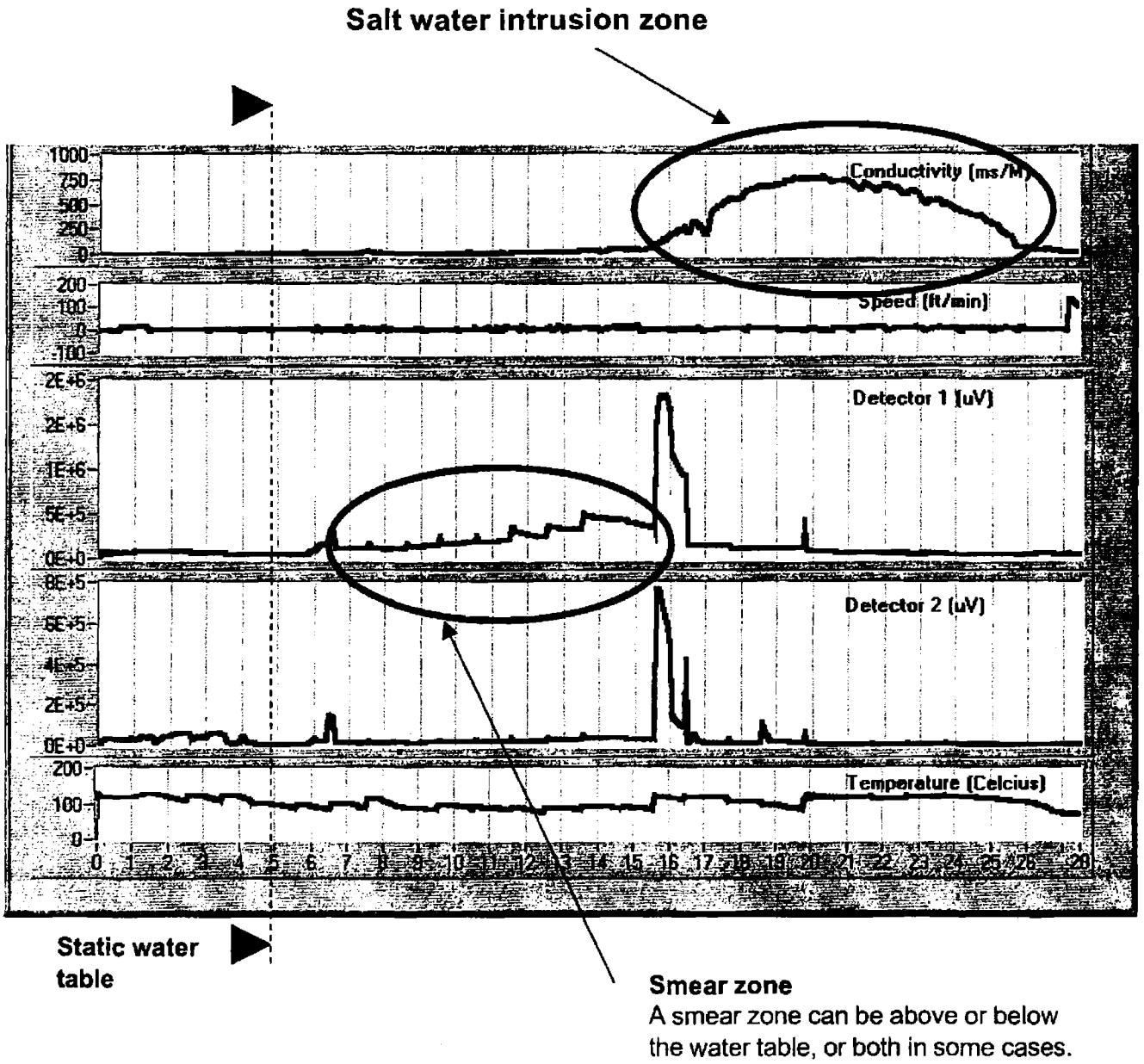
4. Petroleum – dissolved phase



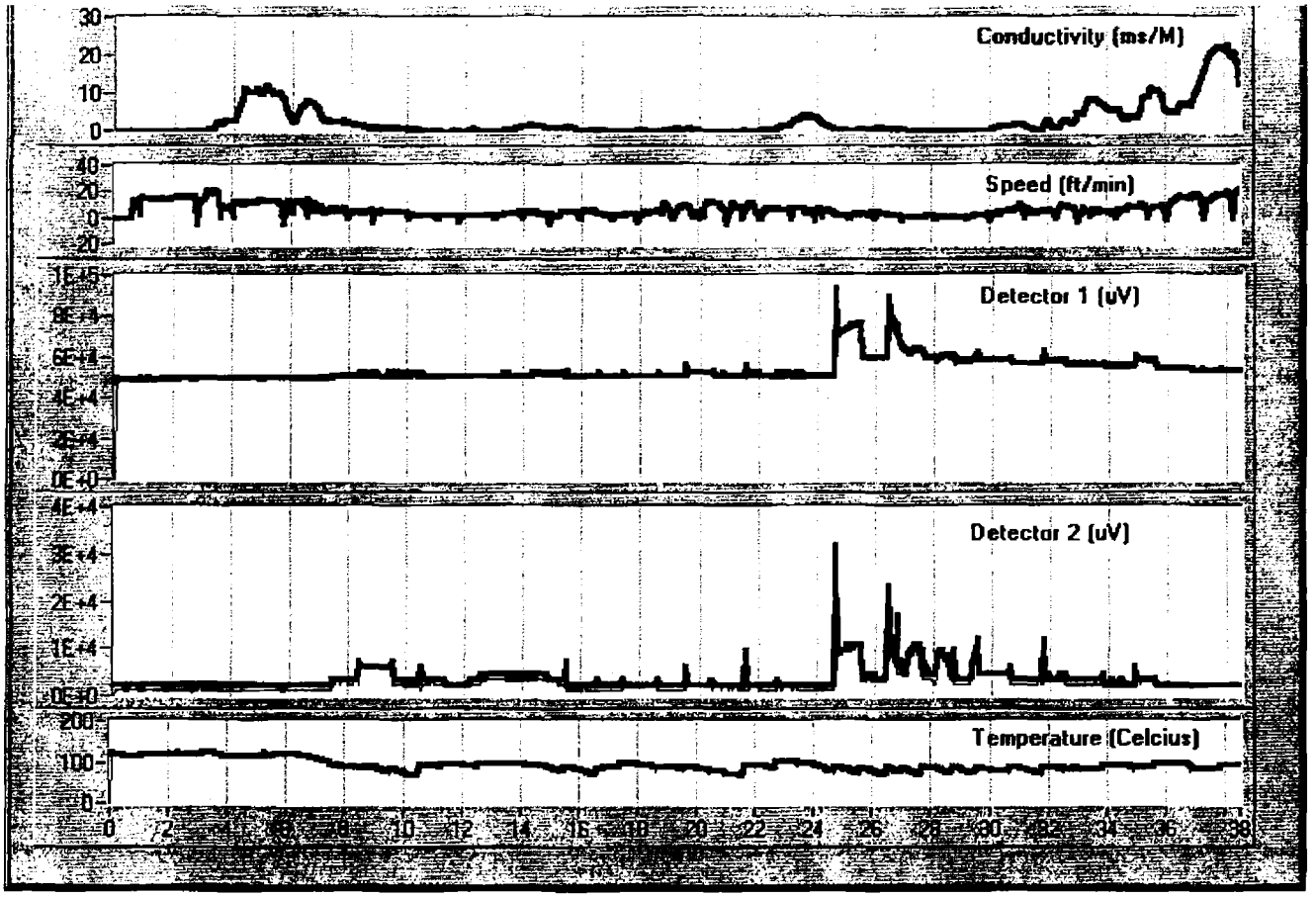
Dissolved contamination zone

Dissolved petroleum hydrocarbons can be reliably detected by the MIP system at concentrations of 400 ppb and above.

5. **Petroleum – smear zone + Salt water intrusion**

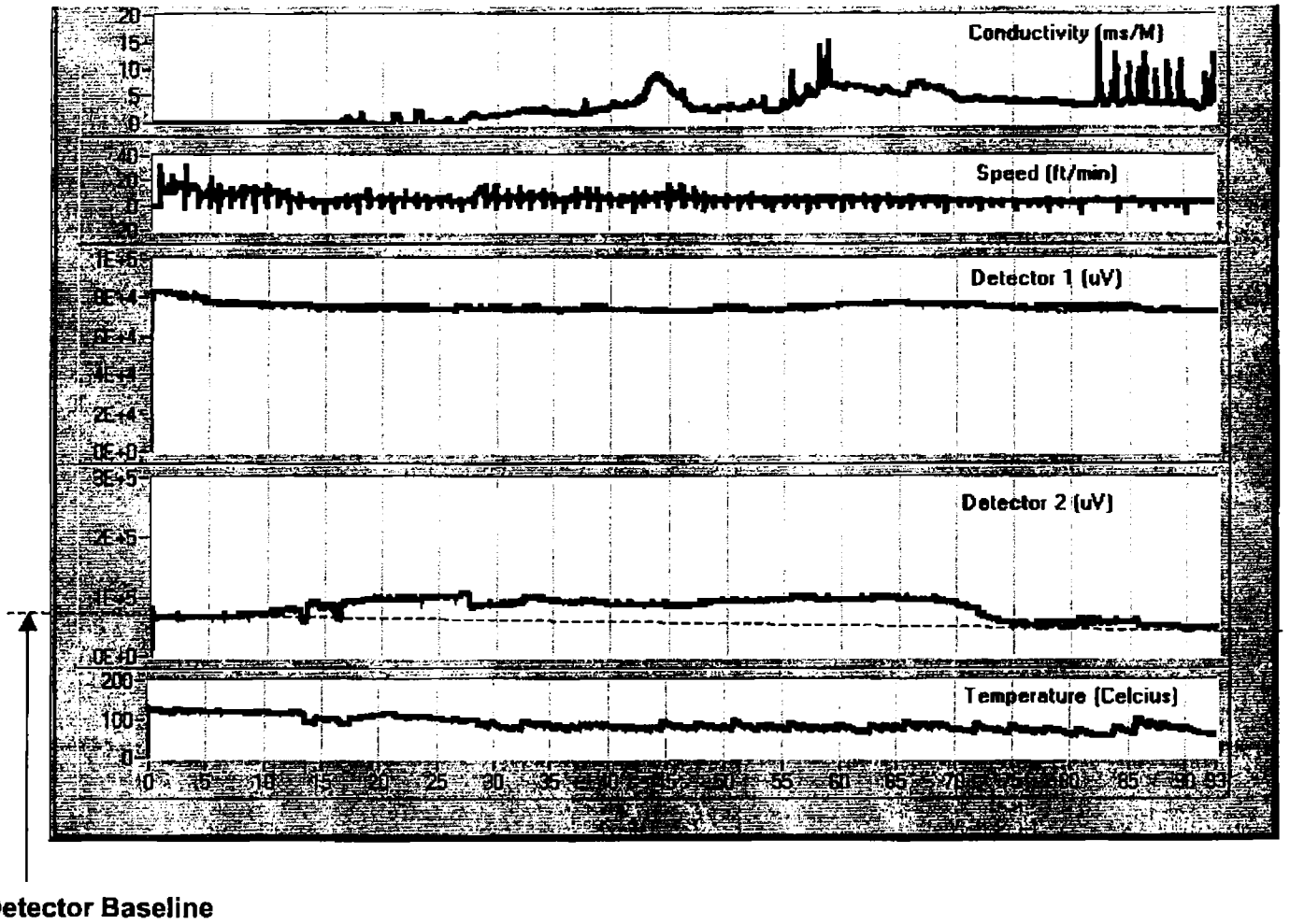


6. **Heavy petroleum, weathered**



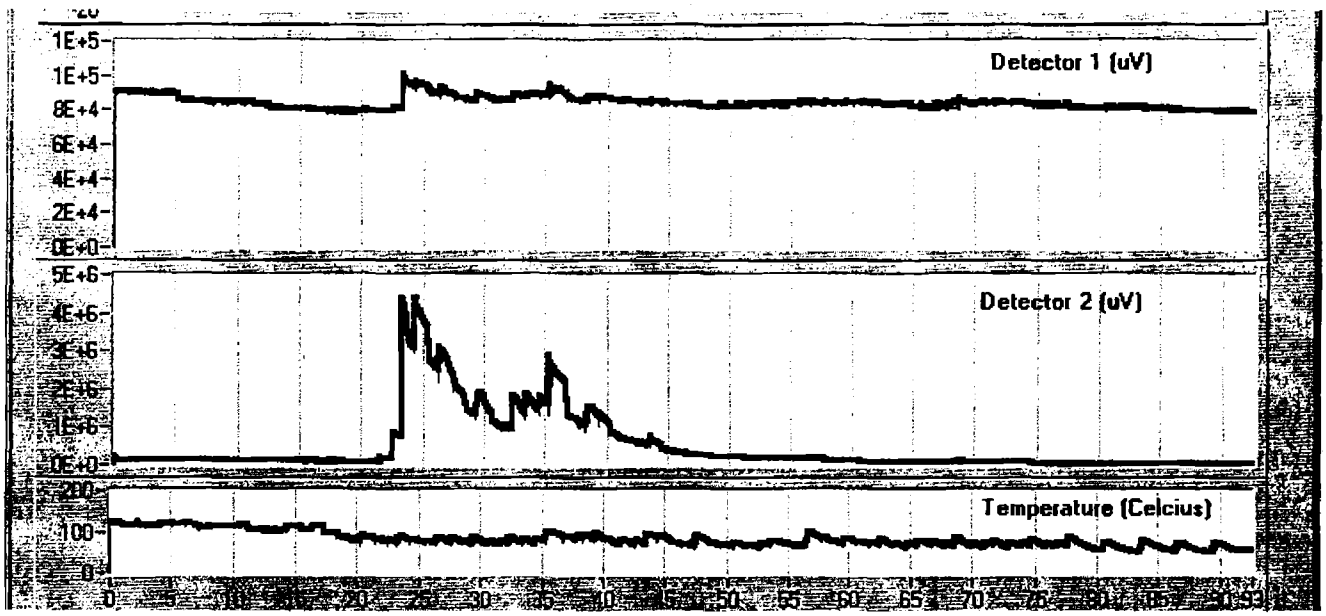
Detector 1 is the PID and Detector 2 is the FID. This log has been recorded on a site with a very deep water table. The contamination present is primarily Semi-VOCs in low concentrations. Note that the FID provides a better response. What the FID is actually picking up is not the semi-volatile compounds themselves, but rather by-products of their disintegration: light hydrocarbons, e.g. ethane, methane, etc.

7. **Halogenated solvents – dissolved (low concentration)**



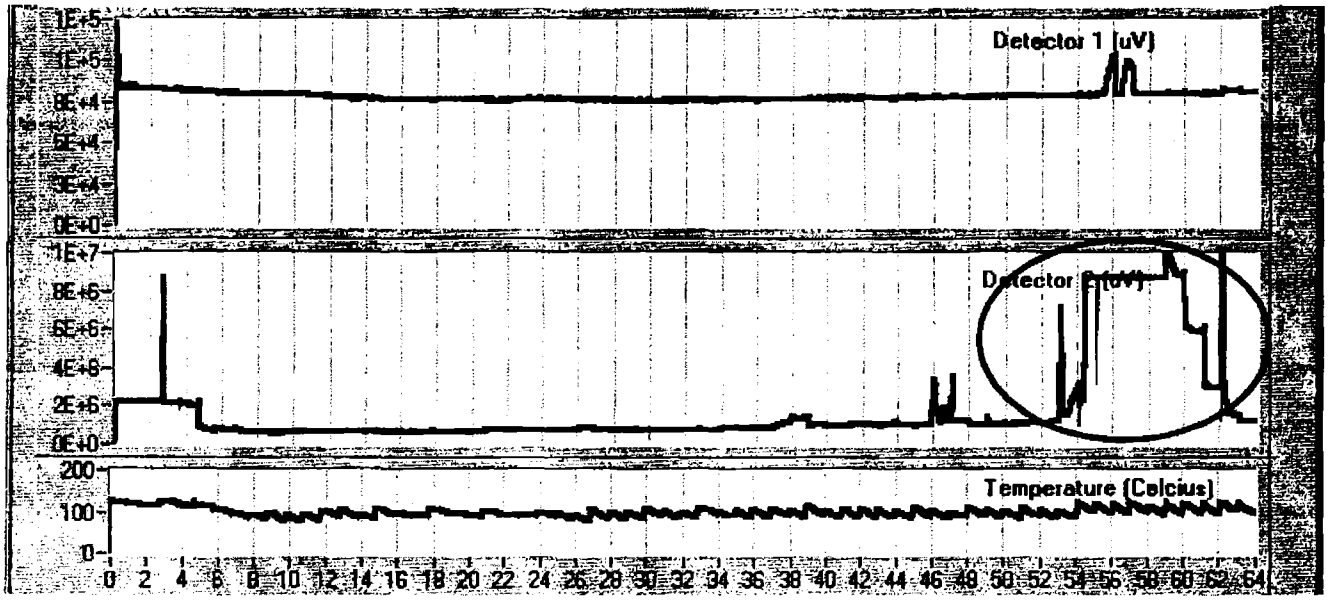
In this case, Detector 1 is the PID and Detector 2 is the ECD. Low (less than 300 ppb total) concentrations of chlorinated hydrocarbons are represented by a raised section of the Detector 2 graph.

8. **Halogenated solvents – dissolved (high concentration)**



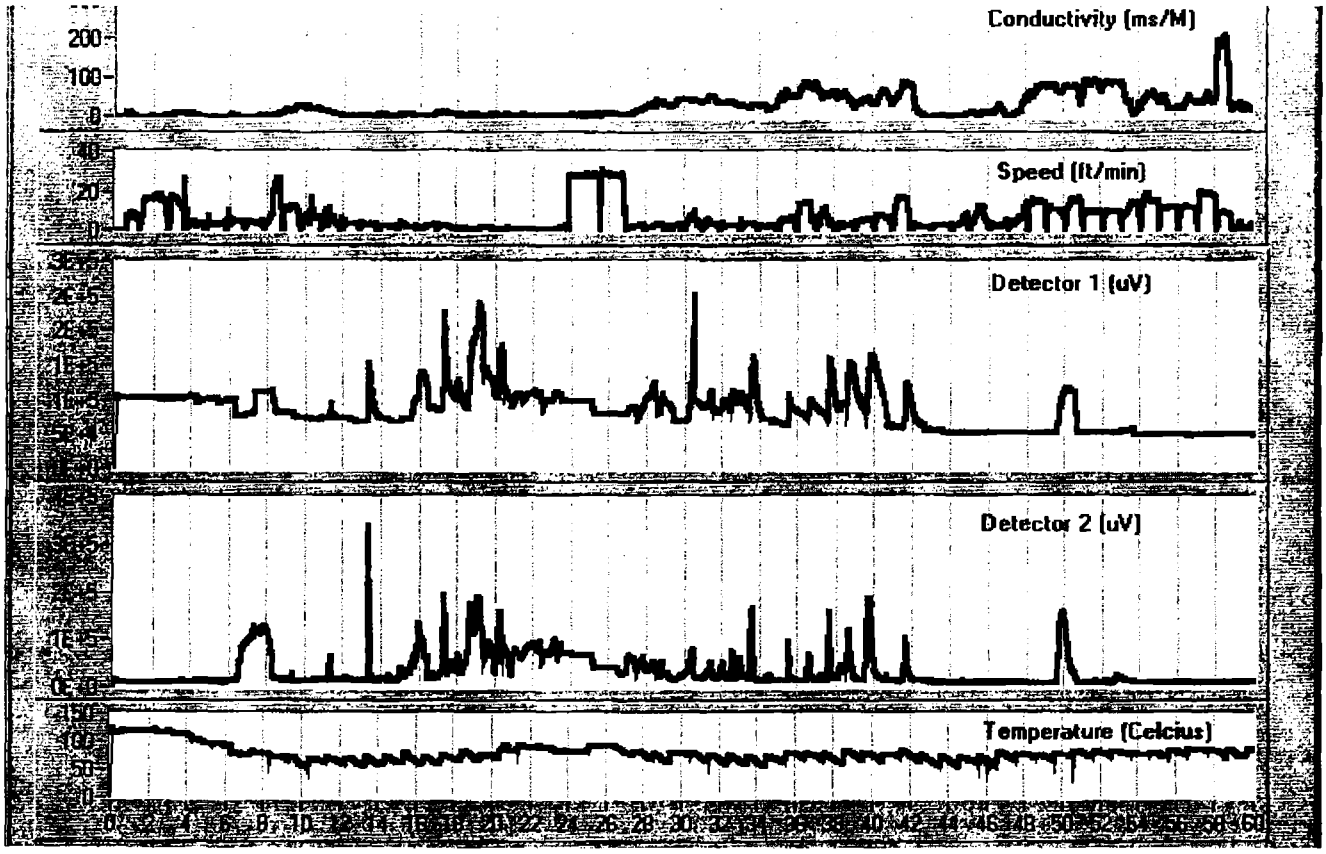
This log was recorded with the same detector arrangement as the log above and Chlorinated VOCs concentrations in 20-40 ppm range. Note very low response on the PID channel as Photo Ionization Detectors are far less sensitive to Halogenated compounds than Electron Capture Detectors.

9. **Halogenated solvents - free phase product (DNAPL)**



At this location a free-phase Freons (in the DNAPL form) was collected at the 56-58' interval during subsequent confirmatory sampling. Note that the PID (Detector 1) has an extremely weak response to Freons.

10. MTBE [byproducts]

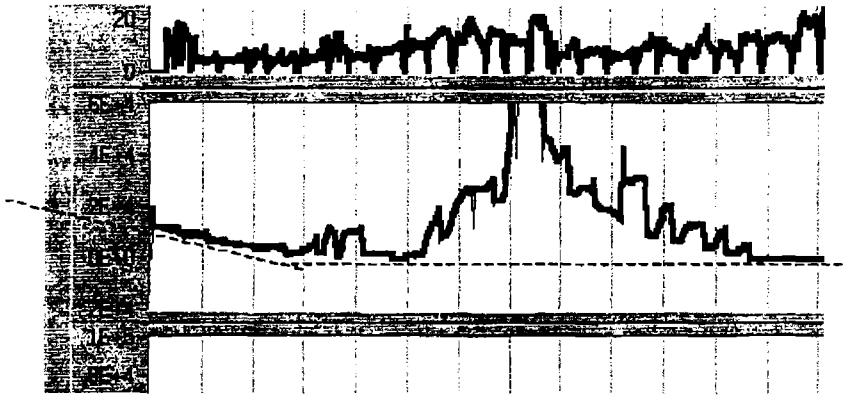


This log represents the MIP system response on an old MTBE site. Although MTBE by itself is very difficult to detect using MIP system, the MIP picks up by-products of MTBE disintegration. Previous sampling data at this site show maximum concentrations of MTBE in the range of 500 ppb and total BTEX below detection limit.

Anomalies

Here are some additional comments on several types of abnormalities frequently found in the MIP logs:

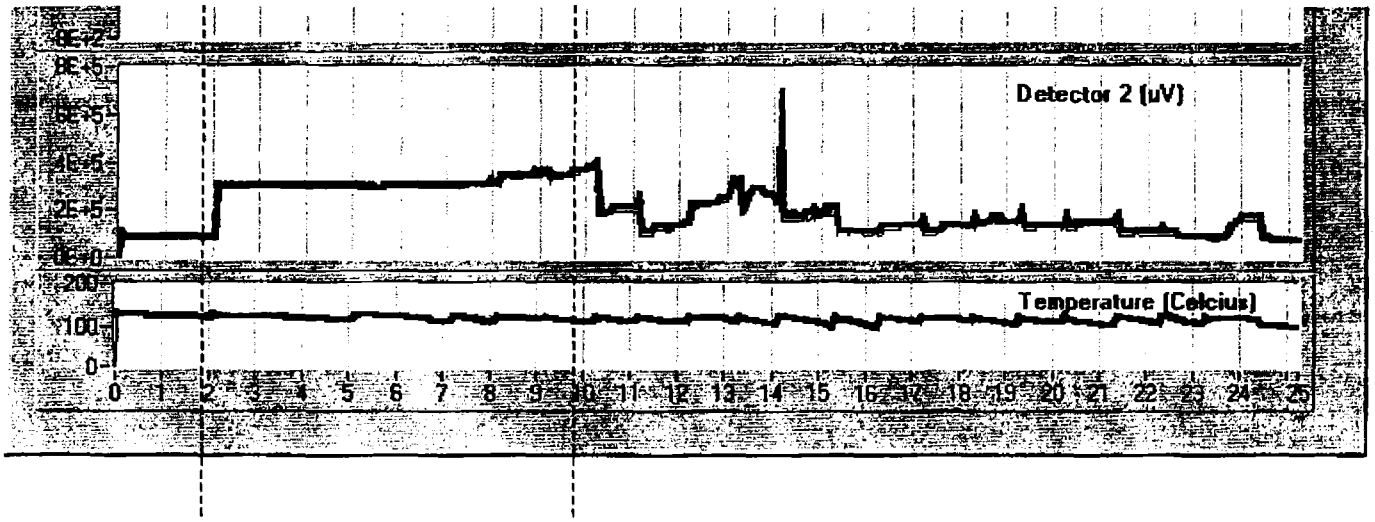
1.Sloping PID and ECD baseline:



PID and ECD output is affected by water vapor concentration in the carrier gas, which has a definite quenching effect. For that reason PID and ECD baseline ('zero' line) in dry soil is higher then in the soil with a high moisture contents.
Other possible causes may include elevated concentrations of VOCs in ambient air on the surface (caused by vehicle exhaust, etc.) or insufficient probe or wiper plate cleaning after a previous logging location.

2. Elevated sections of a baseline (PID, ECD or FID):

The MIP system has two controls where signal Range/Attenuation can be changed: one on the GC detector controller and the other one built into the data acquisition software.
The first one (Range) is incremented as a power to which the factor 2 is raised, e.g. Range 3 makes the multiplication factor 8 (2^3). The other one (Attenuation) is expressed as a multiplication factor, e.g. 8. If for any reason those two settings don't match, a detector output gets multiplied or divided by whatever difference in Range/Attenuation resulted from the error.
In the example below, at 2' BG the Range setting on FID detector was changed without a corresponding

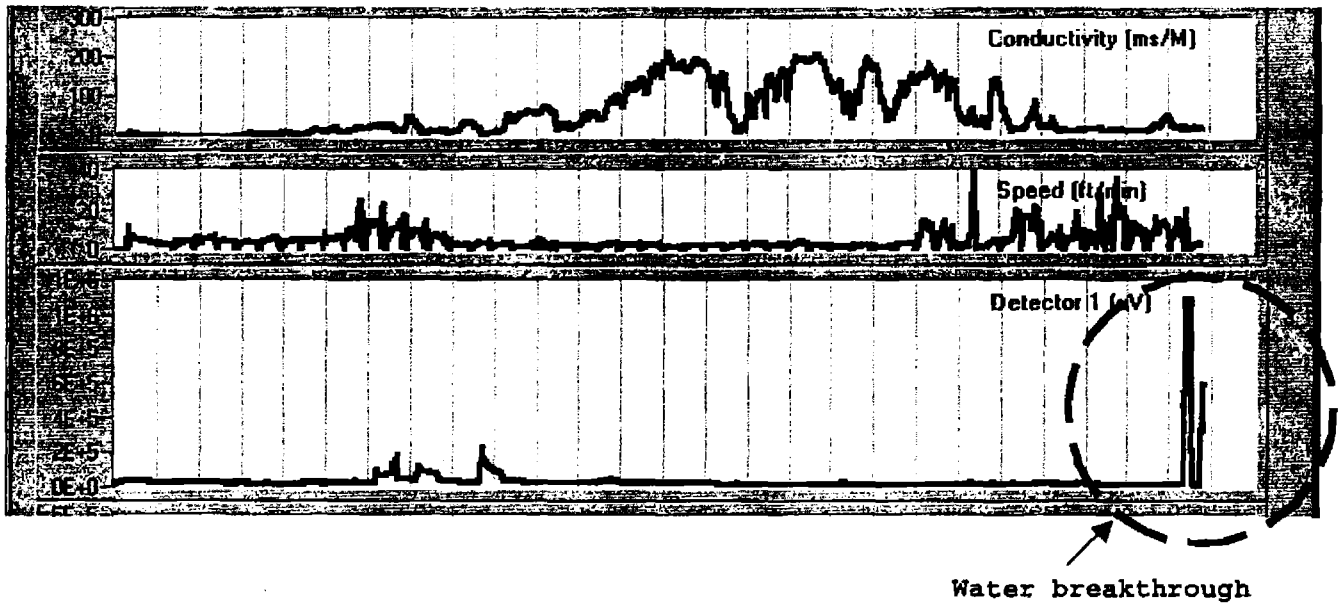


change of Attenuation setting on the software. Later, at 10.2' BG, the error was corrected. NOTE: certain soil contamination patterns, such as "smear zones", can produce similar logs. The only sure way to distinguish between the two is to check the '.inf' file for the location, which contains, among other information, a record of changes made to the Attenuation setting.

3."False hit" – a sharp spike with immediate drop below baseline.

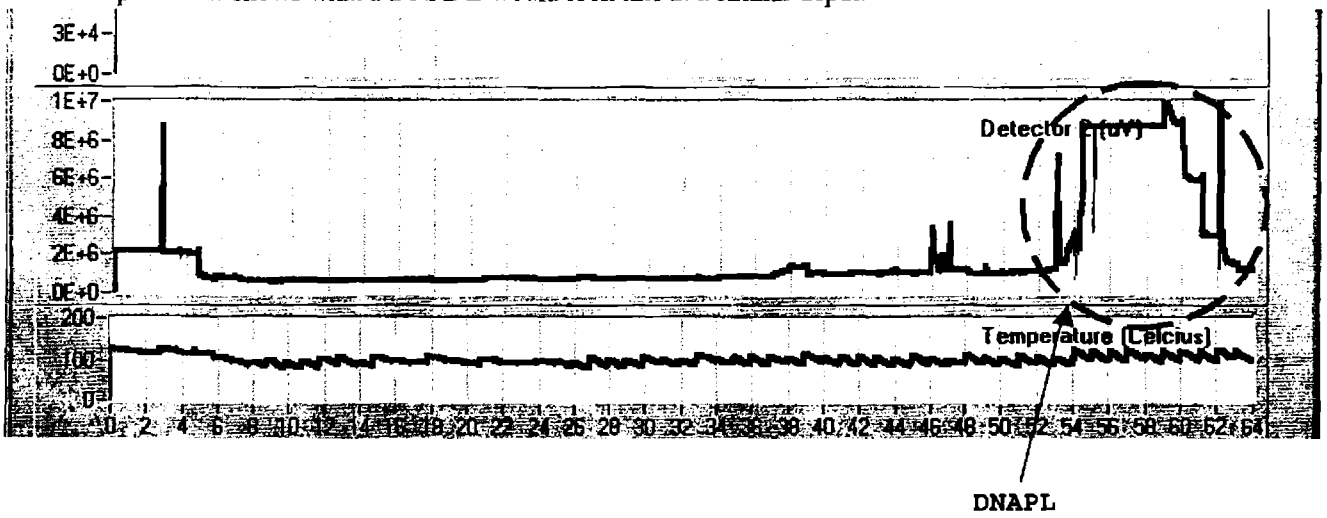
A rare problem caused by a breakthrough of liquid water across the membrane, either due to mechanical failure of the membrane, or water being forced across the membrane due to a very high pore pressure, without any physical damage to the membrane.

The mechanical failure typically occurs while pulling the rods from the ground (due to the probe configuration) and usually does not get recorded in the log. The second can happen while logging in clays at depth exceeding 50' BG.
In both cases, in order to distinguish between equipment malfunction and a true hit, it is important to remember that a true hit of contaminants will have at least some carryover effect. If you are looking for PCE and at 80' BG you get a sharp spike that immediately goes back to zero – it CAN NOT BE PCE.
The only exceptions are: FID response to methane above the water table, and PID response to a vapor phase gasoline in highly porous soils. In both instances, the spikes occur at shallow depth and typically are being repeated several times.
Below are some examples illustrating this topic:



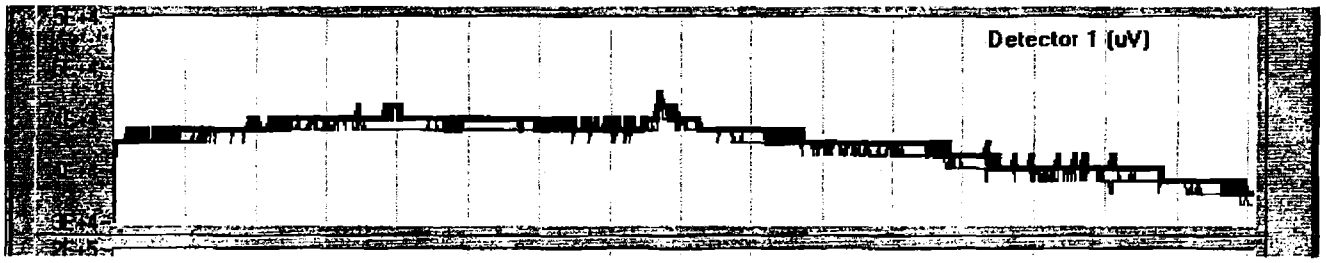
This is an example of a water breakthrough due to a very high pore pressure.

The example below shows what a DNAPL would look like at a similar depth:



4. Double-lines

The MIP Data Acquisition Module is reading data within a very small pre-set time interval, and records the highest and the lowest reading within that time interval. That produces two sets of data for each depth increment (.05 foot). The data acquisition software plots both lines simultaneously. The vertical scale on the software is set by default to auto-scale, so when the detector response magnitude is small (for example, when dealing with very low concentrations of contaminants), it is common to see "double-lines" on detector output, as in the example below:



Standard Logging Procedures

http://zebraenv.com/seusa/pdf-bin/Logging%20Sop.pdf

Standard Logging Procedures

Please refer to the "Start-up Procedures" for proper system start-up.

1. **Open a new file to store data from the current location.**
   Suggested file formats: "[mmdd]_[serial#]"
   "[Client-defined id]"
   "[Site name]_[serial#]"

2. **If using ECD detector – open the carrier gas valve at the flow splitter.**

3. **Drill through pavement using a rotary drill steel and clear all subsurface obstructions by creating a pilot hole to the depth of at least 2' BG.**
   Use a high-speed core drill if reinforced concrete over 6" thick is present.
   Otherwise, use 2" blind probe to clear possible obstructions.
   On sites where construction debris was used to backfill, pre-probe the logging location as deep as possible. Pre-probe to a depth without risking or compromising data accuracy. (DO NOT extend the pilot hole into contaminated soil).

4. **Place the wiper plate underneath the probe unit's foot directly over the pilot hole.**

5. **Lower the foot onto the wiper plate.**
   Apply as much weight of the carrier vehicle as possible without loosing stability. Having a large static force on top of the probe rods greatly reduces wear of the probe and rod threads.

6. **OPTIONAL: fasten the Anchoring Frame to the ground surface either by driving augers into the soil or by placing concrete anchors into the floor.**

7. **Put the slotted drive cap on the probe drive head.**

8. **Insert the probe into the wiper plate opening and push it with the unit so the membrane is level with the ground surface.**

9. **Connect the stringpot string to the piston weight.**

10. **Check the system parameters (pressure readings, detector baselines and heater cycling) and press Trigger - "ON".**
    From this moment on, the log is being recorded.

11. **Advance the MIP probe into the soil.**
    Refer to "MIP Output Interpretation" for tips on interpreting MIP logs and listing of common anomalies found in the MIP logs.

LOGGING TIPS

WIRE AND TRUNK LINE INTEGRITY

Attention must be paid at all times to prevent damage to wires, transducer string and the trunk line. The trunk line contains Teflon gas tubes, which can get crushed if the trunk line is being stepped on or gets kinked or jammed between parts of the Geoprobe machine. Slotted drive caps and pull caps used with the MIP system develop sharp edges with the wear and can cut into the trunk line protective cover. The wiring and the gas tubes are critical components for the MIP. Any significant damage to a critical component will render the system inoperable and will lead to significant down time.

TIME INTERVALS:

- Start logging with **1 min** time intervals between advancing the probe in 1 foot increments
- when the log shows indications of a free-phase contamination (LNAPL or DNAPL), it is recommended to increase the time interval up to **3 min** in order to prevent contamination carryover and detect the end of a NAPL
  Refer to "MIP Output Interpretation" for tips on interpreting MIP logs
- When logging heavy hydrocarbons LNAPL (e.g. jet fuel) or chlorinated solvent DNAPL, increase the time interval to **5 min** until the detector readings drop, and then return to the **3 min** interval

DEPTH INCREMENTS:

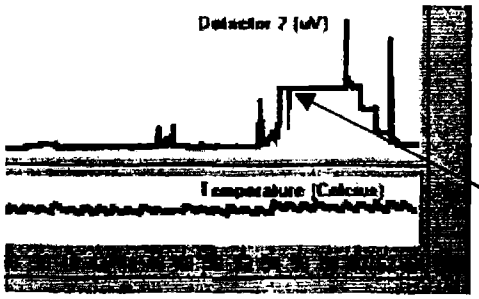
- Default is **1 foot** increment
- If it is known that contamination is not present until a certain depth, the probe may be advanced straight to the interval of concern **without stopping;** the log recorded in this manner will still provide accurate depth and soil conductivity data and will detect high concentrations of contaminants on the way down. Once the probe down into contaminated zone, the rate of advancement can be slowed and returned to a normal **1 foot/1 minute** routine
- When delineating free product plumes, it is recommended to reduce the depth increment to **6 inches** once NAPL is reached in order to increase vertical resolution

DETECTOR ATTENUATION:

Detector attenuation must be adjusted simultaneously as Detector **Range** and **Attenuation** setting on the data acquisition software. PID and ECD **Range** controls located on the GC control panel, FID control is on the standalone Detector Amplifier. It is

important to remember that for PID and ECD Range setting is expressed as a power to the base 2: **range 3** is in fact **2^3 = 8.**
So if you change detector's range to 3, then you have to change attenuation setting to 8

- Sites with unknown concentrations of contaminants – start with all detectors in **Range 1 (Attenuation 0)** then adjust it as soon as detector signal flat lines:



Flat line indicates detector saturation at given attenuation level

- Sites where wide range of contaminant concentrations are present – start in **Range 2 (Attenuation 4)** then adjust as necessary – or, in case of BTEX sites, set **PID in Range 3 (Attenuation 8)** and **FID in Range 1 (Attenuation 0)**

- When mapping NAPL plumes – set detectors in **Range 3 (Attenuation 8).** Flat line (detector saturation) at Range 3 indicates free-phase contaminant at most sites for most common contaminants

- On chlorinated sites set **PID Range to 1 (Attenuation 0)** regardless of anticipated contaminant levels

CARRIER GAS PRESSURE

The carrier gas pressure should be in the range of **6 to 12 psi.**

- When logging low concentrations of contaminants at shallow depth, set carrier gas pressure to **6 to 8 psi** - this can improve detection limit

- When logging high concentrations of contaminants and/or logging at depths exceeding **40' BG**, set carrier gas pressure to **10 to 12 psi** – this will help to prevent contaminant carryover by faster purging and will help to prevent a breakthrough of liquid water through the membrane at high pressures often encountered at such depths

- Carrier gas pressure **will** fluctuate as the probe advances into the soil; typically, the pressure drops slightly (~ 1psi) during first 10-15 feet of logging, due to the probe cooling, and then increase (sometimes beyond the set point) as the depth increases, due to the decrease (and reversal) of pressure differential between the inside and outside of the membrane. These fluctuations, however, should stay within 1-2 psi range, and should reverse as the probe travels back to the surface. Any drastic change of the pressure reading is an indication of a malfunction. **Refer to the "Troubleshooting Guide" for problem diagnostic and repair instructions.**

  NOTE: any significant (over 1psi) change of carrier gas pressure will cause change of the gas trip time. The trip time should always be measured and recorded after any changes in gas flow.
  Refer to the "Start-up Procedures" for information on Butane Test/Gas trip time measurement.

PROBE TEMPERATURE

Probe temperature should stay within the range of **50 – 125 C.** It is normal for the temperature to stay in the range of **50-70 C** in coarse wet sand/gravel, **60-80 C** in wet silt, **70-100 C** in clays, and **100-110 C** in dry sand. Any drastic temperature change, constant low or very high temperature, or "double-line" on the Temperature channel is an indication of a malfunction. Although some contaminants may be detected with the heater off, the MIP probe should never be driven with non-operational heater, as proper seal around the heater cannot be ensured when the probe is cold. **Refer to the "Troubleshooting Guide" for problem diagnostic and repair instructions.**

12. **When the terminal depth of logging is reached, allow for the gas from the membrane to reach detectors (basically, pause for a time period that equals or exceeds the Trip Time).**

13. **Turn the Trigger – "OFF"**

14. **Press F5 on the computer keyboard to stop logging and save data.**

15. **If using ECD – close the carrier gas valve at the flow splitter.**

16. **Disconnect the stringpot string from the piston weight.**

17. **Start pulling the probe rod string.**
    It is recommended to use Geoprobe's Rod Grip Pull System to speed up rod retrieval. Slotted pull cap can also be used for pulling on units not equipped with the Rod Grip system.

18. DECON

- Probe Rod Wiper removes the bulk of contamination from the rods as they are being pulled
- Probe rods should be washed in Alconox or LIQUINOX solution and rinsed in tap water before they are placed back on the probe rod rack
- Special attention should be paid to cleaning rods' threads. Dirty threads will cause significantly faster wear
- The MIP probe itself should be washed in an Alconox or LIQUINOX solution and then rinsed in tap water
- If high levels of contaminants were encountered at the particular logging location, it is recommended to rinse the membrane with methanol
- The rod wiper plate must be decontaminated before moving to a new location

19. Post-logging check:

- Carrier gas pressure
- Temperature cycling
- Detector baseline

If everything is within specs – the system is ready for the next location.
Otherwise - refer to the "Troubleshooting Guide" for problem diagnostic and repair instructions.

Permeable Membrane Sensor for the Detection of Volatile Compounds in Soil

A Permeable Membrane Sensor For The Detection of Volatile Compounds in Soil

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Geoprobe Systems
601 N. Broadway • Salina, Kansas 67401

INTRODUCTION

The large volume of site investigation work being performed since 1980 has spurred numerous attempts to improve field methods of data collection. As part of this effort, Geoprobe Systems has developed two soil logging tools which can be driven into soil to determine either lithology or contaminant concentration. These two tools are the soil conductivity logging tool and the membrane interface probe. Both of these methods can be combined into the same probe giving the site investigator a powerful means of collecting subsurface information. The soil conductivity log of this probing tool is used to interpret lithology while the membrane interface probe is used to determine the position and approximate concentration of volatile organic compounds (VOCs).

This paper will describe the principle of operation of the combined soil conductivity (SC) and membrane interface probe (MIP). Data is presented in this paper from actual field use of the MIP/SC logging system on fuel hydrocarbon and chlorinated solvent contamination and comparisons are made to soil core analyses.

SYSTEM DESCRIPTION

The basic parts of the MIP/SC probe are shown on Figure 1. The probe is 1.5 inches (3.8 cm) in diameter and approximately 12 inches (30 cm) in length. The probe is driven into the ground at a rate of one foot per minute using the Geoprobe GH-40 hammer which can develop forces up to 50,000 pounds per blow and operates at a rate of 30 blows per second. Normal operating depth for this tool is 60 feet. (18m).

The soil conductivity portion of the tool utilizes a dipole measurement arrangement (Figure 2). An alternating electrical current is passed from the center, isolated pin of the SC probe to the probe body. The voltage response of the soil to the imposed current is measured across the same two points. This probe is reasonably accurate for measurement of soil conductivities in the range of 5 to 400 mS/m. In general, at a given location, lower conductivities will indicate sands while higher conductivities are indicative of silts and clays.

Figure 3 shows a schematic of the MIP portion of the probe. This probe has been developed and patented by Geoprobe Systems and tested in numerous settings of VOC contamination.

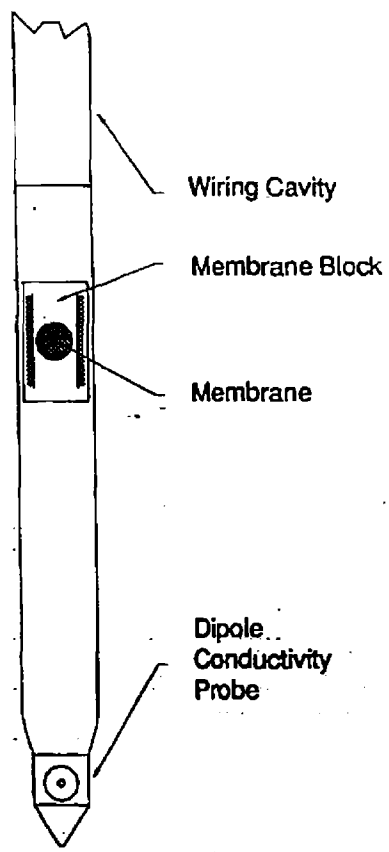

Figure 1
Basic Parts of the MIP / SC Probe

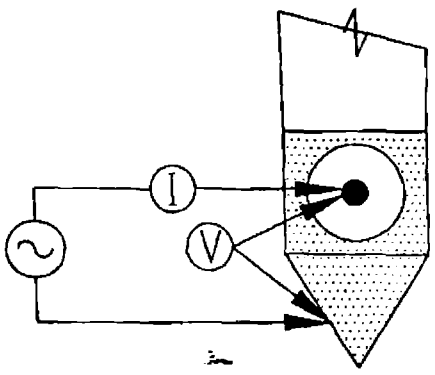

Figure2
Dipole Soil Conductivity Probe Schematic

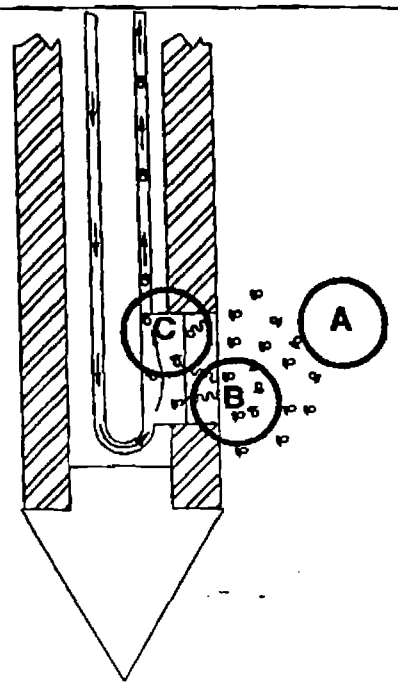

Figure 3
MIP Probe Schematic

The operating principle of the MIP is illustrated in Figure 3. Volatile organic compounds (VOCs) in the subsurface (Region A of Figure 3) come into contact with the heated surface of the MIP polymer membrane (B).

Upon contact, the VOCs will partition (adsorb) into the polymer membrane. The membrane is actually a composite of metal and polymer.

VOCs in Region A in the gaseous, dissolved, solid, or free product phases can partition into the membrane. Bulk fluids, either gases or liquids, do not travel across the membrane. This allows the MIP tool to be used in both saturated and unsaturated soils.

Once they are sorbed into the membrane, VOC molecules will move by diffusion across the membrane to regions where their concentration are lowest. Because the membrane is heated (80 to 125 deg. C operating temperature) and the membrane is thin, this movement across the membrane is very rapid.

After diffusing across the membrane, the VOC's partition into the carrier gas which sweeps the back side of the membrane (C). It takes about 35 seconds for the carrier gas stream to travel through about 100 feet of inert tubing and reach the detectors used in the system.

A number of detectors have been used to measure VOC concentration in the MIP permeate gas stream. The data shown in this paper was made using an FID detector. Data is therefore designated "MIP-FID". However, sevral different detectors could be used. Geoprobe Systems has used PID and XSD type detectors with good success. The detectors must be low dead volume gas chromatography detectors and must be heated to avoid condensation of water vapor which crosses the membrane.

REPRESENTATIVE MIP/SC LOGS.

The MIP/SC tool is driven into the ground at a rate of one foot (30 cm) per minute. Normally, driving the tool one foot will only require 15 to 30 seconds of time. However the tool is not moved again until the one minute increment from the start of driving is complete. Driving at this rate allows the tool to maintain its operating temperature.

A typical log of both soil conductivity and MIP response data is shown in Figure 4. The soil conductivity data is shown at the top of the graph with the soil conductivity scale being the right hand axis. The MIP log is shown at the bottom of the graph and its scale shown on the left hand axis. Data output for the MIP is the output voltage of the detector connected to the MIP gas stream. In this case the detector is an HP-5890 FID

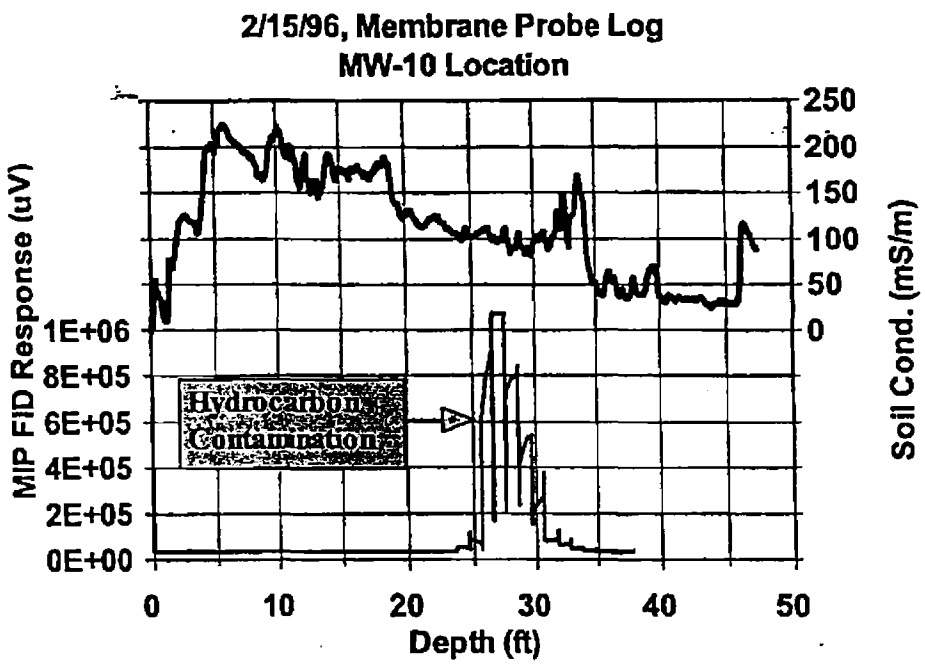

Figure 4
Soil Conductivity and MIP Response with Depth

detector and the detector response is given in micro-volts (uV). The MIP is not quantitative; however, this detector response can be used at a particular site to estimate soil concentrations.

The MIP log in Figure 4 shows hydrocarbon contamination occurring in a the 25 to 31 foot interval. The soil conductivity log shows a corresponding dip in conductivity in this interval that subsequent soil coring showed to be a sandy silt. There is a clay barrier at approximately 38 feet which forms the lower boundary for the hydrocarbon contaminant.

A comparison of MIP data to soil core analyses at this same location is shown in Figure 5. Soil Cores were recovered at this location using Geoprobe closed piston samplers. The comparison of soil core analyses to MIP response in this figure is typical for gasoline range organics. Geoprobe Systems in the U.S. has found that for gasoline range organics we attain an MIP response of 4,000 to 10,000 uV of MIP-FID response per

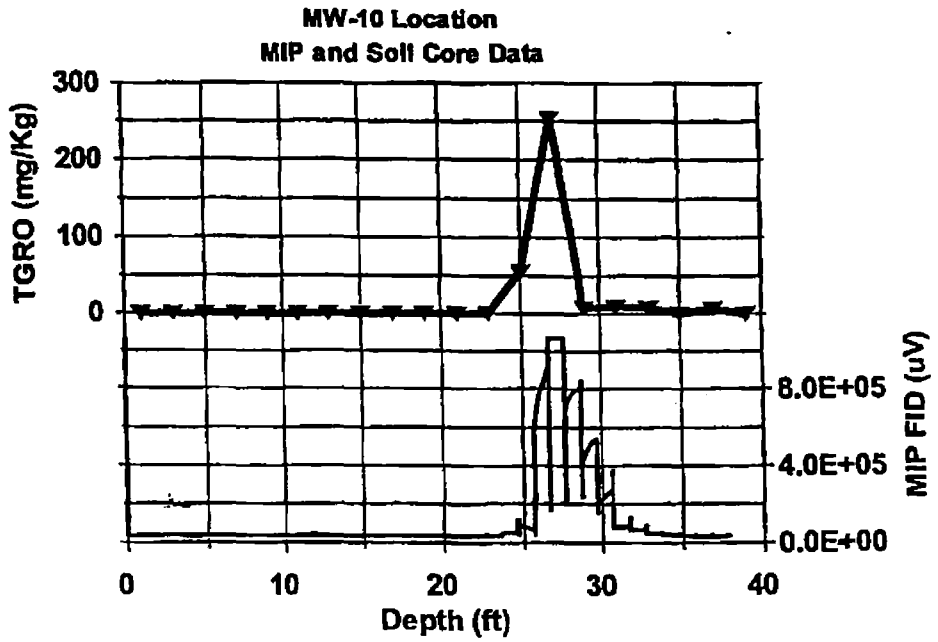

Figure 5
Comparison of MIP Response to Soil Core TGRO Measurement

mg/Kg in soil (ppm). Studies by Michel Rogge and Pascal Carlier of Geoprobe Environmental Technologies, s.a., n.v., Waterloo, Belgium, have found a typical response of 50,000 uV per ppm in clay soils, and 10,000 uV/ppm in sandy soils.

CROSS SECTIONS

All of the data obtained with the MIP/SC system is stored in columnar form in standard ASCII format files. These files can be imported into common spreadsheet programs for graphing of data. For example, figures 4 and 5 of this paper were made using the depth, soil conductivity, and MIP response columns of the data in a Quattro Pro spreadsheet.

Another use of the data is to import several logs in sequence into a 3-D graphing program and constructing a cross section of either soil conductivity or MIP response. Geoprobe Systems has constructed numerous cross sections using Surfer® for Windows, version 6 (Golden Software, Golden, CO).

Figure 6 shows a soil conductivity cross section made using 11 MIP/SC logs along a 500 foot (154 m) alignment. Clays in this figure are represented by dark color, while sands are light. Of particular interest in this section is a clay zone at 25 feet which decreases in thickness from left to right across the page. Note also that the sand at the base of the section generally increases in thickness and elevation as we move to the right across the figure.

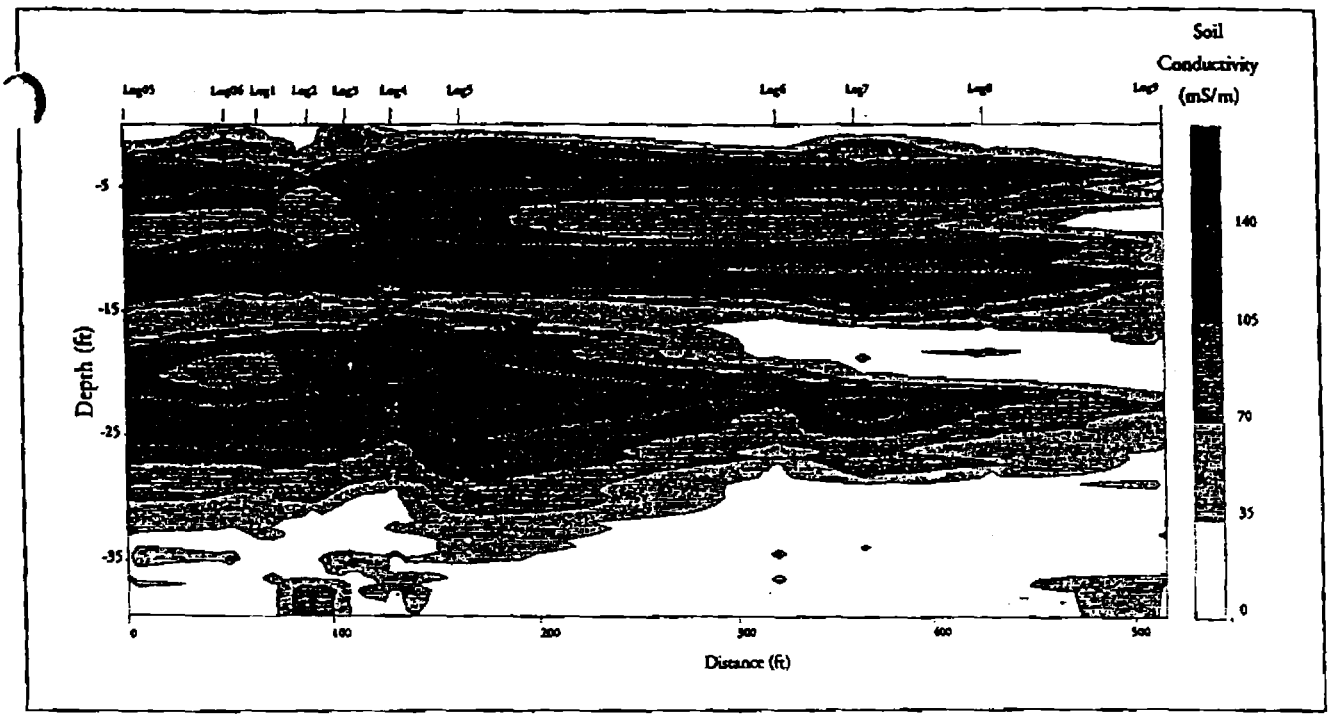

Figure 6
Soil Conductivity Cross Section

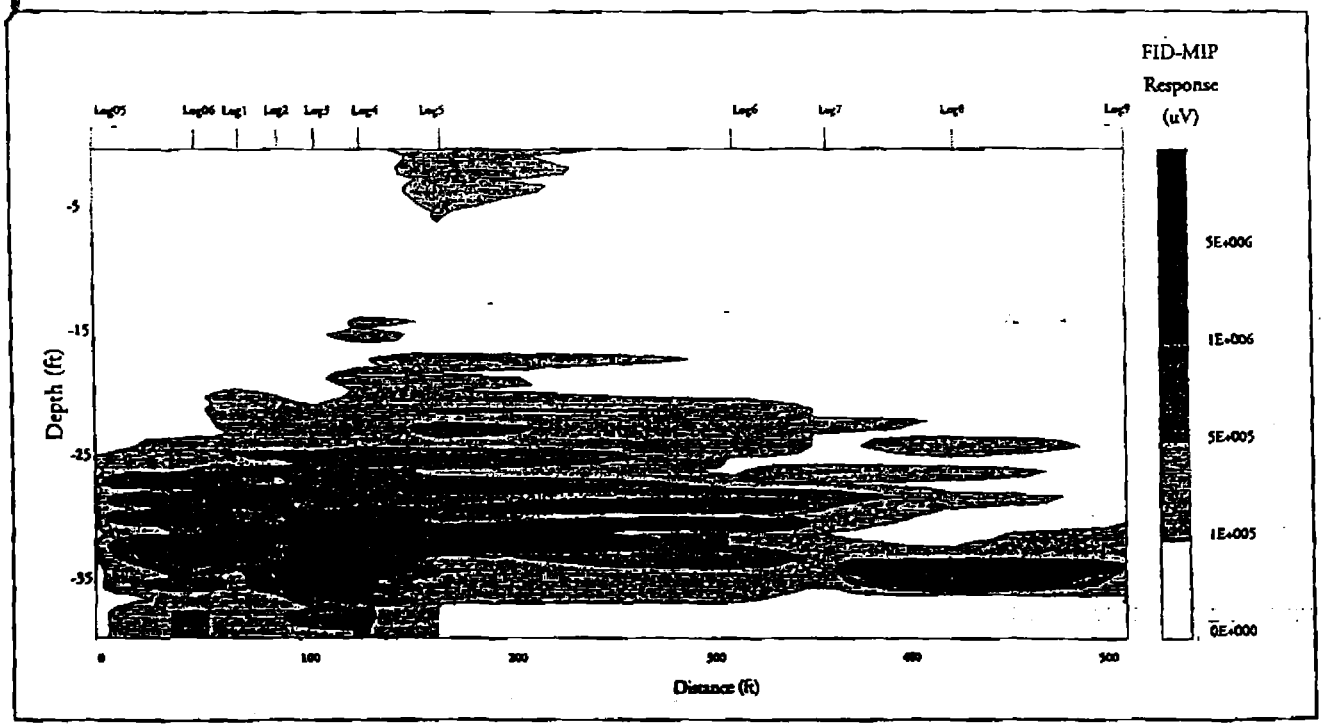

Figure 7
MIP Cross Section

Figure 7 shows a cross section through the same log locations using MIP response data. The contaminants at this site are fuel hydrocarbons. The water table at this location is at approximately 25 ft. bgs. Flow in the subsurface is generally in a direction pointed into the figure. In this case, MIP response increases with intensity of color. Note that the highest concentrations of hydrocarbon contamination are found well below the water table in the sand zone of the section at a depth of approximatel 35 feet. Two distinct areas of contamination are found, one on the left side of the figure, and one on the right.

MIP AND CHLORINATED SOLVENTS:

The MIP has been used in determining the distribution of chlorinated solvents in source areas. The detection limit for most chlorinated species using conventional PID and FID detectors is approximately 5 ppm, limiting the use of this logging tool to the important task of delineation of DNAPL source areas.

Data from a DNAPL investigation in Europe is shown in Figures 8, 9, and 10 which follow. This data was collected by Geoprobe Environmental Technologies, s.a., n.v. of Waterloo, Belgium. The chlorinated solvent species being measured include PCE, TCE, and their degradation products. Concentrations in groundwater samples collected at the site after MIP logging ranged as high as 70 ppm of total chlorinated species.

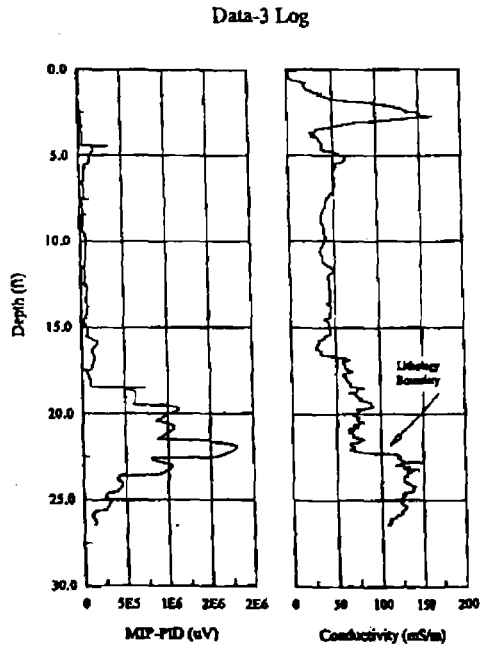

Figure 8
MIP Log: Soil Conductivity and PID Response
DNAPL Site - Europe

Figure 8 shows a typical MIP log at the site. The water table at this location is known to be shallow, occurring at approximately 6 to 8 ft. below ground surface. An obvious lithologic boundary is noted on the log at a depth of approximately 22 ft. At this point soil conductivity changes from a value of approximately 75 mS/m or less to a value of approximately 125 mS/m, indicating a change to a finer grained, lower permeability formation.

The MIP-PID log shows significant contamination beginning at approximately 16 ft. and peaking at a maximum value at the point of change in lithology at 23 ft. Signal below this point must be interpreted as a combination of degrading signal (bleed) from the massive amount of contaminants that have entered the MIP system, and some new contaminants being introduced from the formation.
Cross sections of both soil conductivity and MIP-PID data from 4 logs run across the site are shown in Figures 9 and 10. The soil conductivity cross section shows a consistent pattern of layered lithology across the site, including a persistent lithologic boundary at 23 ft.

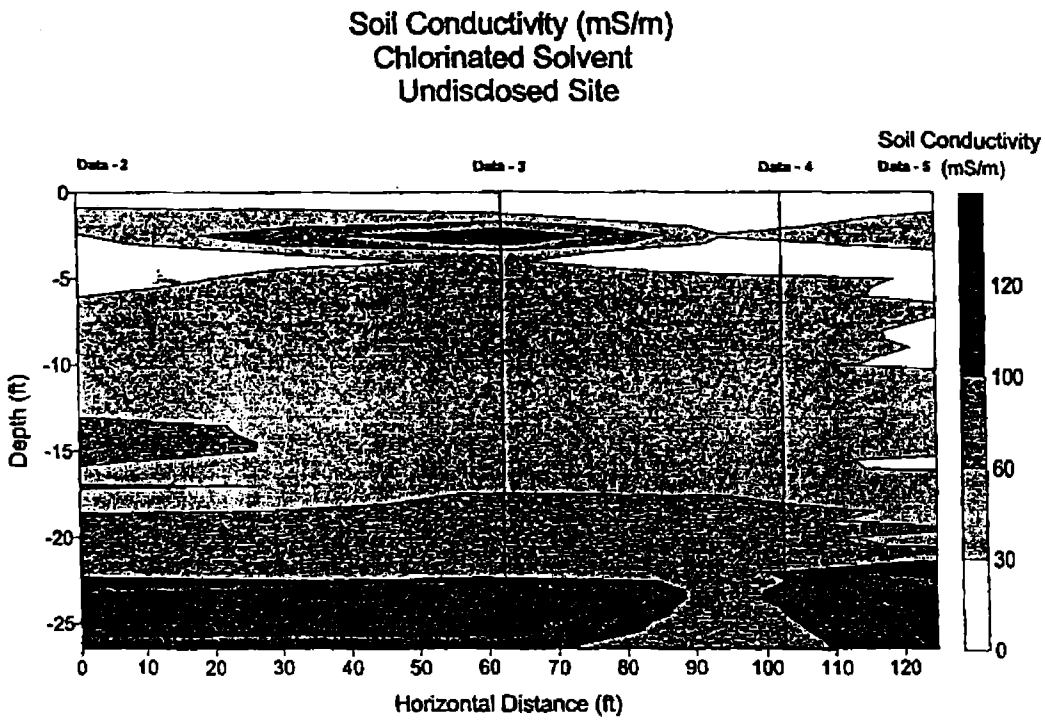

Figure 9
Soil Conductivity Cross Section
DNAPL Site - Europe

The MIP-PID cross section shows the movement of the DNAPL plume from a point of entry near the log Data-4 point and moving downgradient towards the Data-2 location. Note that the highest concentrations of the DNAPL are found above the lithologic boundary indicated by the soil conductivity log.

MIP-PID Response
Chlorinated Solvent
Undisclosed Site

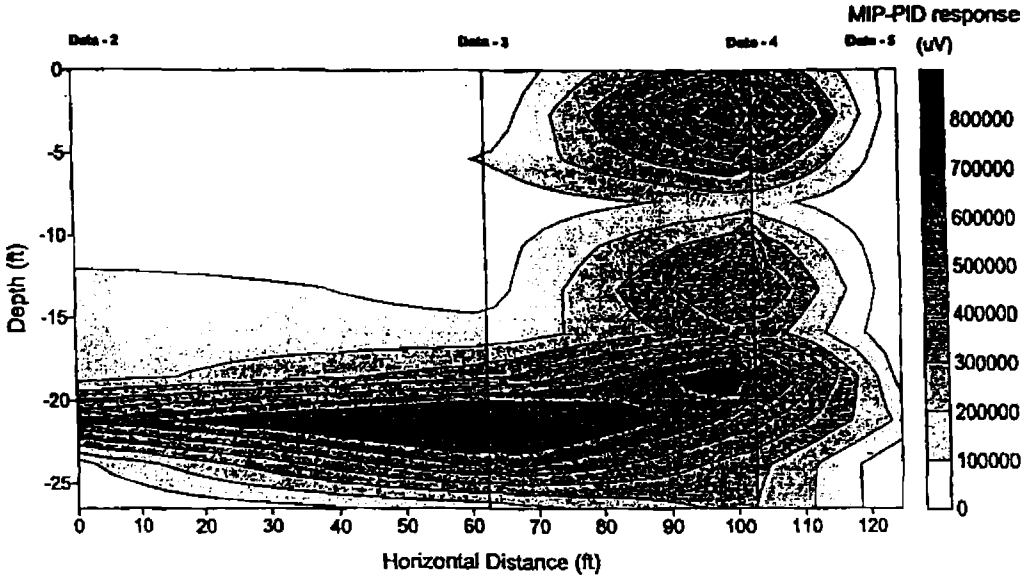

Figure 10
MIP-PID Cross Section
DNAPL Site - Europe

CONCLUSIONS

The membrane interface probe combined with soil conductivity is a new logging tool that yields a wealth of information about subsurface lithology and VOC contaminant distribution. From the examples given in this paper it is evident that these logging tools allow us to form images of the subsurface which were unobtainable using conventional sampling and analysis methods.

REFERENCES

Kejr, Inc., 1995, "A Percussion Probing Tool for the Direct Sensing of Soil Conductivity", Geoprobe Systems Technical Paper No. 94-100.

Christy, T.M., May 1996, "Driveable Permeable Membrane Sensor For the Detection of Volatile Compounds in Soil," presented at the 1996 National Outdoor Action Conference, Las Vegas, Nevada.

BIOGRAPHICAL SKETCH

Thomas M. Christy, P.E.

Mr. Christy earned his B.S. in Civil Engineering from the University of Missouri-Rolla in 1980. Upon graduation he worked as a consultant performing numerous site characterization studies for industrial clients. In 1987 Mr. Christy co-founded Geoprobe Systems, a manufacturer of percussion soil probing machines, sampling tools, and logging tools.

This paper was presented at the National Ground Water Association's Outdoor Action Conference in Las Vegas, Nevada, in May 1996.