N62578.AR.001635
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Work Plan Addendum

Remedial Investigation of Installation Restoration Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area)

Naval Construction Battalion Center North Kingstown, Rhode Island

Contract No. N62472-92-d-1296
Delivery Order No. 0097

Prepared for

Department of the Navy
Northern Division
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop No. 82
Lester, Pennsylvania 19113-2090

Prepared by

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November 2000
FINAL
29600.97.3101

00716

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James A. Shultz, CPG
CTO Manager

28 November 2000
Date

Robert Pace
Program Manager

11/27/00
Date

November 2000
FINAL
29600.97.3101

QUALITY REVIEW STATEMENT

Contract No. N62472-92-D-1296 EA Project No.: 29600.97.3101
Contract Task Order No. 0097
Activity: Naval Construction Battalion Center, North Kingstown, Rhode Island

Description of Report/Deliverable:

Final Work Plan Addendum, Remedial Investigation of IR Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area), Naval Construction Battalion Center, North Kingstown, Rhode Island

EA CTO Manager: James A. Shultz, C.P.G.

In compliance with EA's Quality Procedures for review of deliverables outlined in the Quality Management Plan, this final deliverable has been reviewed for quality by the undersigned Senior Technical Reviewer(s). The information presented in this report/deliverable has been prepared in accordance with the approved Implementation Plan for the Contract Task Order (CTO) and reflects a proper presentation of the data and/or the conclusions drawn and/or the analyses or design completed during the conduct of the work. This statement is based upon the standards identified in the CTO and/or the standard of care existing at the time of preparation.

Senior Technical Reviewer

Alexander Easterday 28 NOV 2000

Alexander C. Easterday, P.G. (Date)
Geologist

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LIST OF ACRONYMS

AST	Aboveground Storage Tank
ATV	Acoustic Televiewer
BCT	BRAC Cleanup Team
BG	Below Grade
BRAC	Base Realignment and Closure Act
CIL	Cost Impact Letter
CTO	Contract Task Order
CVOC	Chlorinated Volatile Organic Compounds
DO	Dissolved Oxygen
EA	EA Engineering, Science and Technology, Inc.
EBS	Environmental Baseline Survey
ECD	Electron Capture Detector
EPA	Environmental Protection Agency
ERA	Ecological Risk Assessment
FFTA	Fire Fighting Training Area
GPS	Global Positioning System
HAZWOPER	Hazardous Waste Operator
HHRA	Human Health Risk Assessment
HSA	Hollow Stem Augers
ID	Inner Diameter
IDW	Investigative Derived Waste
IR	Installation Restoration
IRP	Installation Restoration Program
LEL	Lower Explosive Limit
Mg/Kg	Milligrams per kilogram
μg/L	Microgram per liter
MIP	Membrane Interface Probe
MSL	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NACFAC	Naval Facility
NCBC	Naval Construction Battalion Center

ND	Not Detected
Ng/Kg	Nanaograms per kilogram
NOAA	National Oceanic and Atmospheric Administration
NORDIV	Northern Division
OD	Outer Diameter
OSHA	Occupational Safety and Health Administration
PAH	polycyclic aromatic hydrocarbons
PCB	Polychlorinated Biphenyls
PID	Photoionization Detector
ppb	Parts per billion
PPE	Personal Protective Equipment
ppm	Parts per million
PVC	Polyvinyl Chloride
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act, as amended
RI	Remedial Investigation
RIDEM	Rhode Island Department of Environmental Management
RIEDC	Rhode Island Economic Development Corporation
RIPA	Rhode Island Port Authority
SASE	Study Area Screening Evaluation
SHERP	Safety Health and Emergency Response
SSHO	Site Safety and Health Officer
SVOC	Semi-volatile Organic Compounds
TAL	Target Analyte List
TBD	To Be Determined
TCE	Trichloroethylene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Potential
TOC	Total Organic Carbon
ToNK	Town of North Kingstown, RI
TPH	Total Petroleum Hydrocarbons
USF&W	U.S. Fish & Wildlife
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VOA	Volatile Organic Analyses
VOC	Volatile Organic Compounds

1. INTRODUCTION

Under Contract No. N62472-92-D-1296 to EA Engineering, Science, and Technology, Northern Division of the Naval Facilities Engineering Command issued a Scope Change Memorandum dated 2 June 2000 for Contract Task Order No. 0097. This Work Plan Addendum has been prepared to conduct additional characterization and evaluation work at Installation Restoration (IR) Program Site 16 (Site) originally prepared and negotiated since the Implementation Plan and Cost Impact Letter 01. The work will include those site characterization efforts necessary to supplement the previously scoped ecological and human health risk assessment for Site 16. The locations of contamination as detected by the Membrane Interface Probe (MIP) screening during the execution of the Final Work Plan (March 2000) suggest that chlorinated volatile organic compounds are moving on to the site and that another source, unrelated to the known or suspected former Site 16 operations, appears to be contributing to ground-water contamination.

This Work Plan Addendum has been prepared to present the additional investigative plan and field procedures for the Remedial Investigation for IR Program Site 16 (Site 16) (*Remedial investigation of Site 16 [Former Creosote Dip Tank and Fire Fighting Training Area*]) at the Naval Construction Battalion Center (NCBC), North Kingstown, Rhode Island. The Quality Assurance Project Plan (QAPP) Addendum is provided as Appendix A and describes modifications to the laboratory testing program outlined in the Final Work Plan (March 2000). The related Site Safety, Health, and Emergency Response Plan (SHERP) Addendum is included as Appendix B, and all field work will be performed in accordance with the SHERP (Work Plan, March 2000, and this Addendum).

1.1 SITE LOCATION

1.1.1 NCBC Davisville

Refer to Section 1.1.1 of the Final Remedial Investigation Work Plan for Site 16, dated March 2000 (the "Work Plan").

1.1.2 Site 16 (Environmental Baseline Survey Review Item 28)

Site 16 (formerly designated Environmental Baseline Survey Review Item 28 and then Study Area 16) is located in the eastern portion of Zone 3 at NCBC Davisville as shown on Figures 1 and 2. The site boundary shown on Figure 2 was selected for convenience to be related to readily findable roads. In addition to the site, this Work Plan Addendum initially included adjacent areas outside of the bounds of Site 16 approximately 300 ft to the east, south and west, as depicted on Figure 2 (referred to as the "offsite" area). The offsite area has been extended south to Elm and Fir Streets (Figure 2) and west to Nerone Street to cover the extent of the area investigated by MIP screening. The area referred to as "onsite" is located north of Davisville Road, east of Westcott Road, and west of Allens Harbor Road as shown on Figure 2.

1.2 OBJECTIVES AND SCOPE OF THE WORK PLAN ADDENDUM

The objectives of the continued investigation of Site 16 under this Work Plan Addendum are to provide:

- Additional site remedial investigation efforts necessary to accomplish an ecological and human health risk assessment

  The ecological risk assessment and human health risk assessment will be conducted in accordance with the Work Plan (March 2000)

- Assessment of potential offsite source areas impacting the Site, and their relationships to the Site

- Continued assessment of potential onsite source areas

- Continued assessment of the nature and extent of ground-water contamination from the Site

- Continued assessment of the nature and extent of soil contamination from the Site.

To accomplish these objectives, the following work will be performed under this work plan addendum:

- Surface geophysical survey using seismic refraction profiling

- Subsurface screening using a MIP at 31 locations located to the east, south, and west of Site 16 (offsite area)

- Following the seismic refraction profiling and the MIP screening, the data will be assessed with regard to the location of the monitoring wells needed

- Install, develop, and test 27 new monitoring wells (21 screened in the deep zone and 6 completed in the upper 25 ft of competent bedrock)

- During drilling, collect, log, and field screen soil samples of each new monitoring well completed in the "deep" zone

- Borehole geophysical logging of monitoring wells completed in competent bedrock

- Sample and analyze ground water from the 27 new monitoring wells

- Perform data validation of the analytical results from the ground-water samples

- Addition of the new data to a report documenting the field investigation results, conclusions, and recommendations.

1.3 PROJECT ORGANIZATION

The updated Project Organization chart is shown on Figure 3.

1.4 WORK PLAN ORGANIZATION

This Work Plan Addendum is organized as follows:

- Chapter 1 presents the objectives of the investigation, the purpose and scope of the sampling plan, and project organization.
- Chapter 2 presents the description and history of the site.
- Chapter 3 presents the field program and rationale.
- Chapter 4 presents the field procedures that will be used to implement the field program.
- Attachment 1 provides the onsite Seismic Refraction Investigation Site 16, Former NCBC Facility Davisville, Rhode Island from Geophysics GPR International Inc., February 2000.
- Attachment 2 provides the Standard Operating Procedures for Seismic Refraction Surveys from Geophysical Applications, Inc., August 1999.
- Attachment 3 provides the Standard Operating Procedures for borehole geophysical logging from Geophysical Applications, Inc., November 2000.
- Appendix A presents the QAPP Addendum.
- Appendix B presents the SHERP Addendum.

2. BACKGROUND INFORMATION

2.1 SITE DESCRIPTION AND HISTORY

As shown on Figure 2, Site 16 is primarily vegetated with the exception of a paved area in the central portion of the site. An unnamed asphalt-paved road circles the outer perimeter of the wooded area of Site 16. The site was formerly used by the Navy for the purpose of training construction equipment operators. It has been previously understood that two primary uses occurred at this site which are briefly described below:

- **Creosote Dip Tank Area**—Creosote dipping of wood pilings occurred during the late 1960s in the western portion of the site. The wood pilings were dipped into tanks containing creosote and staged in the area to dry before being loaded onto ships. An up-ended creosote dip tank was located in the western portion of the site adjacent to the paved road. The location where the tank was found is the "original" Creosote Dip Tank Area; however, subsequent work expanded the investigation area, once it was reported that past creosote dipping operations were likely conducted over a larger area than originally noted.

- **Former Fire Fighting Training Area**—A former fire fighting area was reportedly located in an asphalt-paved area to the east of the former creosote dip tank area. Reportedly, structures were constructed, doused with flammable materials, set on fire, and extinguished as part of fire fighting training exercises during the late 1960s.

2.1.1 Potential Upgradient Source Areas

Based on findings from field work conducted onsite (seismic profiling, advancement and evaluation of MIP screening, soil samples collected from soil borings, and installation of monitoring wells), early data indicated the possibility of an upgradient source to the southwest of Site 16, i.e., in the vicinity of Building 41. The paragraphs below present a summary of previous work conducted at Building 41 and associated Environmental Baseline Survey Review Item 81 (located just north of this building), as it was presented in the Final Phase II Environmental Baseline Survey Report, Naval Construction Battalion Center, Davisville, Rhode Island (EA 1998). However, during October-November 2000, additional information has been obtained regarding the historical use of Building 41 through the review of floor plans (drawings) of the building on file with the Rhode Island Economic Development Corporation (RIEDC), and additional interviews and reconnaissance of the inside of Building 41. This recent information will be compiled and a summary submitted as a separate document.

Building 41 (Environmental Baseline Survey Review Item 29, EA 1998) was built in 1942 and used as a preservation and packing shop, and a construction equipment (electrical generators, bulldozers, and ship parts) and automotive parts storage building. The building has not been used for preservation operations since (at least) 1974. Building 41 has been used for the storage of hazardous substances and petroleum products. Preservation and degreasing operations in

Building 41 included the use of pentachlorophenol, creosote, copper napthanate, acids (nitric, phosphoric), trichloroethylene (TCE), and carbon tetrachloride (EA 1998).

USTs and ASTs related to Building 41 were addressed in accordance with Rhode Island Department of Environmental Management (RIDEM) Underground Storage Tank Closure procedures. Stained asphalt floors in Building 41 were not considered to be of concern, based upon the limited extent of staining, the absorptive ability of asphalt, and the lack of a direct pathway (e.g., spill runoff from the concrete to a foundation wall or soil). A review of building plans did not identify floor drains inside Building 41. The floor staining was considered to be consistent with the previous use of the building as an equipment preservation and packing shop, and parts storage. There were no reported releases nor had there been any regulatory action at the site (EA 1998).

Recommendations for no further action were made following review of available information and site visits conducted by the Base Closure Team (BCT) (i.e., the Navy, its contractors, RIDEM, and the U.S. Environmental Protection Agency), the Town of North Kingstown, and Rhode Island Economic Development Corporation (RIEDC) in September and October 1995.

Environmental Baseline Survey Review Item 81 addressed a suspected septic system associated with Building 41. Three manholes for a suspected septic tank leaching chamber are located on the northern side of the building. Inspection from the surface revealed a gravel-based underground corridor possibly connecting the manholes. Interviews with Base personnel and a historical document research revealed no information pertaining to the underground corridor and manholes. The structure was classified as a suspected septic system because of its location in close proximity to the bathroom facilities in Building 41. Sludge was removed and the septic tanks were cleaned and backfilled in April 1998 (EA 1998).

2.2 PHYSICAL CHARACTERISTICS

Refer to Section 2.2 of the Work Plan (March 2000) for the description of the local and regional physical characteristics of Site 16.

2.3 CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY AREA SCREENING EVALUATION

The Study Area Screening Evaluation conducted for Site 16 summarizes the findings of four Navy investigations conducted at IR Program Site 16 (EA 1999). The locations from which samples were collected during various phases of the work are shown on Figure 4 of the Work Plan (March 2000). Table 2-1 of the Work Plan (March 2000) provides a summary of samples collected previously from Site 16. The conclusions and recommendations of the Study Area Screening Evaluation are summarized in the Work Plan (March 2000).

2.4 GEOPHYSICS RESULTS

An onsite seismic refraction surface geophysical investigation was performed by Geophysics GPR International Inc. on 13-18 December 1999. An offsite seismic refraction investigation was

performed by Geophysical Applications, Inc. on 7-25 September 2000. The purpose of seismic refraction studies at Site 16 were to provide the interpreted configuration of the top of bedrock beneath and adjacent to the site. The results of both investigations are compiled on Figure 4. This interpreted surface of bedrock was refined using elevations of top of bedrock encountered at each of the 7 deep monitoring wells located onsite. A copy of the Geophysics GPR International Inc. report is provided as Attachment 1. The offsite seismic report by Geophysical Applications, Inc. will be submitted separately.

2.5 MEMBRANE INTERFACE PROBE RESULTS

The onsite MIP screening was performed by Zebra Environmental Corp. in April 2000 as described in the Work Plan (March 2000). The offsite MIP screening was performed by Zebra Environmental Corp. in October 2000. The purpose of the MIP field activity was to cost effectively screen the subsurface of Site 16 (onsite and offsite areas) from ground surface down to bedrock (or refusal) for the presence and relative concentration of VOC to increase understanding of the Site and to aid in the selection of locations for monitoring wells. During 6-26 April 2000, MIP logging was completed at 28 locations (each designated as "MIP16-__," Figure 5). During 10-25 October 2000, MIP logging was completed at 31 offsite locations (designated as "MIP16-W/S/E __," Figure 5).

2.5.1 Onsite Membrane Interface Probe

The locations of VOC responses (at depth along upgradient and in cross gradient [east] portions of the Site perimeter) as detected by the MIP screening during the execution of the existing Work Plan suggest that CVOC are moving on the site and that another source, unrelated to the known or suspected former Site 16 operations, appears to be contributing to VOC in ground water. A summary of the onsite electron capture detector (ECD) and photoionization detector (PID) responses are illustrated on Figures 6A and 6B, respectively. Table 2-1 provides a summary of the MIP response intervals recorded for the onsite locations. Elevated responses were recorded beneath the eastern portion of the Site and beneath the central portion of the Site in the vicinity of the alleged former FFTA. This Work Plan Addendum addresses the additional investigation to be performed in adjacent offsite areas to address those findings.

Based upon the preliminary review of the MIP findings, 16 locations/depth intervals (more than presented in the Final Site 16 Work Plan, dated March 2000) were selected for probe-collected ground-water samples for laboratory analysis of VOC, semivolatile organic compounds (SVOC), polycyclic aromatic hydrocarbons (PAH), and salinity. The locations were selected to generally provide quantification for the various types and relative strengths of PID and ECD responses by the MIP.

Results of the MIP screening performed in April 2000 were summarized in *Interim Submittal Data and Preliminary Findings of the Membrane Interface Probe (MIP) Screening at IR Program Site 16 (Former Creosote Dip Tank and Fire Fighting Area)*, dated May 2000. Figure 7 provides a preliminary summary of VOC results from probe-collected ground-water samples and Figure 8 provides a preliminary summary of SVOC/polycyclic aromatic hydrocarbon results from probe-collected ground-water samples.

2.5.2 Offsite Membrane Interface Probe

A summary of the offsite ECD and PID responses is illustrated on Figures 6A and 6B respectively. Table 2-2 provides a summary of the MIP response intervals recorded for the 31 offsite locations. In general, the main MIP ECD responses were recorded in the area extending east of Building 41 toward Nerone Street, northeast of Building 41 to Davisville Road and the southeast portion of Site 16, and southeast of Building 41 to approximately Low Street (Figure 6A). There were no significant responses on the PID at the offsite area MIP locations.

Based on the MIP responses observed in the field during completion of an initial 21 MIP locations, the remainder of MIP locations were selected to assess the north side of Building 41 (MIP16-S13 and –S14) (MIP16-14 is also located approximately 30-50 ft southeast of Environmental Baseline Survey No.81), the area east of wells MW16-05S/D and onsite MIP16-27 (MIP16-E04 and -05), and the extent of CVOC east and southeast of Building 41 (MIP16-S17, and –S18 through –S22). The presence of a denser soil (perhaps till) at depth precluded achieving the planned MIP probing depth west of the central portion of Building 41 and east of the central portion of the paved area just east of Building 41.

2.6 MONITORING WELLS AND SOIL BORINGS

Based upon the preliminary review of the onsite MIP findings which showed the presence of CVOC beneath more than the western portion of the Site (area of reported historical site activity), it was recommended that 6 of the 7 monitoring well pair locations be revised from what was shown in the Final Site 16 Work Plan (March 2000). The onsite monitoring well locations are shown on Figure 9.

Seven pairs of monitoring wells were installed at Site 16 from 12 May - 23 June 2000. After monitoring well installation, eight soil borings were advanced from 23-27 June 2000 (Figure 9) to collect surface and subsurface soil samples as described in the March 2000 Work Plan. Monitoring wells were developed from 28 June - 5 July 2000. Monitoring well MW16-04S could not be developed due to a blockage. On 18 August 2000, the blockage was cleared by flushing clean water down the well. Monitoring wells MW16-01S and MW16-05S could not be developed due to lack of water available within these wells. The screened interval for each of the onsite wells was selected based upon the depth of the apparent water table observed during drilling. Unfortunately, the water table was deeper than it appeared to be during drilling of MW16-01S and MW16-05S. These two wells are scheduled for replacement during installation of the new monitoring wells as part of this Work Plan Addendum. Monitoring wells MW16-04S, MW16-01S, and MW16-05S will be developed with the new monitoring wells installed as part of this Work Plan Addendum. Slug testing of six of the onsite monitoring wells was completed on 19 July 2000 prior to temporary stoppage of the onsite fieldwork until the 'offsite area' monitoring wells have also been installed. The following onsite monitoring wells will be slug tested along with the new monitoring wells: MW16-01S, MW16-04S, MW16-05S, MW16-03S, MW16-06S/D, and MW16-07S/D.

In accordance with the Work Plan (March 2000), a soil sample was collected at each onsite

monitoring well location from within the screened interval. Additionally, soil samples were collected from the surface (approximately 0-2 ft below ground surface) and subsurface (approximately 2 ft above the apparent water table) intervals at eight (8) soil boring locations (Figure 9). Results have been received from the analytical laboratory and are in the process of data validation. Soil sample analytical results will be made available to the BCT after receipt of the data validation reports.

Based upon the preliminary review of the offsite MIP findings, 21 deep wells and 6 rock wells are recommended for installation at offsite locations as depicted in Figure 10. The rationale for each of these monitoring well locations is presented in Table 2-3.

3. FIELD SAMPLING PLAN AND DATA USE IN RISK ASSESSMENTS

3.1 INTRODUCTION

Section 3.2 states the field program and rationale. The field procedures are presented in Chapter 4. Section 3.3 presents the data use, background, and approach for the human health risk assessment. Section 3.4 presents the data use, background, and approach for the ecological risk assessment.

3.2 FIELD PROGRAM

The field program for this Work Plan Addendum is comprised of the 5 key elements presented below. A summary of the sampling and analytical program is provided in Table 3-1.

1. **Seismic Refraction profiling**. In general, 7,410 linear feet of seismic refraction profiling has been performed to develop an understanding of the upper surface of competent bedrock in locations to the east, south and west of Site 16 and to provide data to aid in the refinement of the locations for new monitoring wells. Figure 4 has been revised to include both the onsite and offsite interpreted surface of bedrock, plus refinement based on the elevation of competent bedrock encountered at each of the 7 deep monitoring wells located onsite.

   A copy of the field procedures for seismic refraction is provided as Attachment 2. These procedures were previously submitted and approved for the nearby investigation of the former PR-58 Nike Site and NCBC Site 03. The profiling lines are included on Figure 4. This figure was e-mailed to the BCT for review on 31 August 2000, and also, discussed during the 14 September 2000 BCT Meeting. There was no disagreement with the planned locations.

2. **MIP Screening/Ground-Water Sampling**. This subtask includes the completion of 31 MIP screening locations located in the offsite area. The locations for the MIP screening were selected after receipt and review of the seismic refraction results, and are included on Figure 5. The resultant MIP data was used to assess the extent of VOC concentrations (MIP responses) and to compare those results with the findings from previous onsite investigations (see Section 2.3) and seismic refraction profiling described in Number 1. MIP screening expedites the process and reduces the cost of site investigation by providing real-time screening-level information about the vertical and horizontal distribution of VOC, as well as some geological interpretive information.

   The MIP screening process is described in section 4.3 of the Work Plan (March 2000).

3. **Drilling/Installation of Monitoring Wells**. This subtask includes the installation of 27 planned monitoring wells, as 21 deep wells, and 6 bedrock wells as shown on Figure 10. This work will provide additional geological information and the monitoring wells will provide locations from which to measure the depth to ground water and to collect ground-water samples for chemical analysis. Additionally, 2 shallow monitoring wells will be

installed and developed on site to replace MW16-05S and MW16-01S, which are dry. The existing dry wells (MW16-05S and MW16-01S) will be abandoned as described in Section 4.13 of Chapter 4.

The planned location of the offsite monitoring wells is based upon the seismic refraction survey and MIP screening results. The locations and screened intervals have been proposed based upon review of the initial field data and provided to the BCT by e-mail on 7 November 2000 and discussed during the 9 November BCT meeting for concurrence. Table 2-3 provides rationale for monitoring well locations, which are depicted on Figure 10. The 10-ft screened interval of the shallow wells will be across the apparent ground-water table. The 10-ft screened interval of the deep wells will be immediately above the upper surface of the competent bedrock, and the open borehole of the bedrock wells will be in the upper 25 ft of competent bedrock. The shallow and deep wells will be installed in accordance with the field procedures presented in Chapter 4 of the Work Plan (March 2000). Bedrock wells will be installed in accordance with the procedures added in this Work Plan Addendum (Sections 4.4 and 4.5). After completion of well development and slug testing (shallow and deep wells; including six onsite wells) or borehole geophysical logging (bedrock wells), a dedicated bladder pump will be installed in each onsite and offsite monitoring well for use during ground-water sampling.

Monitoring Well Abandonment

Monitoring wells MW16-01S and MW16-05S will be abandoned in place as described in Section 4.13 of Chapter 4.

4. **Geophysical Borehole Logging**. Geophysical logging of the open rock portions of the monitoring wells completed in the approximately upper 25 ft of competent bedrock will be performed by a subcontractor after completion of the drilling activity. These wells will be logged to aid in the assessment of bedrock fractures and areas of ground-water flow. The planned geophysical methods are caliper, single-point resistance, fluid temperature, heat-pulse flow meter, and acoustic televiewer logging. The logging procedures are provided in Attachment 3 of this Work Plan Addendum.

5. **Sampling and Analysis**. This Work Plan Addendum includes the addition of dioxin (Method 8290) to the original analytical program (Work Plan, March 2000) for the eight (8) soil boring locations, sixteen (16) soil samples [eight (8) surface, eight (8) subsurface]. Refer to the Work Plan for an explanation of soil sampling procedures during drilling. The results of these samples are currently undergoing validation. The results will be made available to the BCT upon receipt of the data validation reports.

   Deep monitoring wells will be advanced as described in Section 4.4 of the Work Plan (March 2000) with the following exception: continuous soil samples will be collected for soil logging and field screening with PID only, except as noted below. Based upon the results of the seismic refraction geophysical survey and MIP screening in the "offsite areas," and in order to characterize the soil in potential source area around Building 41, soil

samples will be collected from the screened intervals of 5 of the planned "deep" wells to be installed at locations near the former solvent recovery still (MIP16-08) and mid to high MIP responses (MIP16-S01, -S03, -S05, and -S17). Additionally, a soil sample will be collected from a soil boring from each of the 2 MIP response intervals at MIP16-S21, i.e., 20-22 ft bg and 32-34 ft bg. These samples will be analyzed for Target Compound List (TCL) VOC, SVOC, PAH, and pesticides/PCB, Target Analyte List (TAL) inorganics, total organic carbon (TOC), pH, and grain size, as described in Chapter 4, Section 4.4.1 of the Work Plan (March 2000) and included on Table 3-1 of this Work Plan Addendum.

Ground-water samples will be collected from the 27 new monitoring wells to aid in assessment of the deep and bedrock ground-water zones. The samples will be analyzed for Target Compound List VOC, SVOC, PAH, pesticides/PCB, TAL inorganics, and salinity (Table 3-1). The new monitoring wells will be sampled simultaneously with the 14 monitoring wells located onsite, i.e., MW16-01S/D through MW16-07S/D.

Ground-water samples will be collected using the low-flow sampling technique in accordance with the field procedures presented in Section 4.7.2, Chapter 4 of the Work Plan (March 2000).

3.3 HUMAN HEALTH RISK ASSESSMENT

The purpose of the Human Health Risk Assessment is to determine if, under expected exposure conditions, chemicals found in soil and ground water at Site 16 are at concentrations that may cause unacceptable risk to humans using the area. This protocol is described in the Work Plan (March 2000).

3.4 ECOLOGICAL RISK ASSESSMENT

The purpose of the Ecological Risk Assessment is to determine if, under expected exposure conditions, chemicals detected in soil, sediment, and ground-water samples collected from Site 16 are at concentrations that may cause unacceptable risk to organisms using the area. This protocol is described in the Work Plan, March 2000.

4. FIELD PROCEDURES

Procedures for seismic refraction profiling, MIP screening; drilling and monitoring well installation, development, and testing; soil, stormwater, sediment, seep and ground-water sampling; investigative-derived waste management; and decontamination of reused field equipment are presented in this chapter.

The seismic refraction profiling, MIP screening, and drilling activity will be performed as previously stated in the Work Plan (March 2000) using the following guidelines:

- Obtain NCBC Davisville and RIEDC approval for profiling and boring locations.
- Obtain all NCBC Davisville (401-294-6108), RIEDC (401-277-3134) and Dig Safe (800-225-4977) clearances for profiling and boring locations.
- Mitigate potential contamination of the aquifer by the drilling equipment.

All field work described herein will be performed in accordance with the QAPP (Appendix A of the Work Plan, March 2000), QAPP Addendum (Appendix A) and the SHERP (Appendix B of the Work Plan, March 2000), and the SHERP Addendum (Appendix B).

4.1 SUBSURFACE UTILITY CLEARANCE

NCBC Davisville, RIEDC, and Dig Safe clearance will be obtained prior to conducting any drilling or probing activities. Location and marking of all underground utilities in the vicinity of each site will be done prior to any drilling. This clearance will be coordinated by the EA Project Manager. The drilling subcontractor will obtain required drilling permits necessary for completion of the field work.

4.2 SEISMIC REFRACTION PROFILING

The seismic refraction profiling in the offsite areas has been performed by Geophysical Applications, Inc. A copy of the *Standard Operating Procedures for Seismic Refraction Surveys*, supplied by Geophysical Applications, Inc., dated August 1999, has been provided in Attachment 2.

A copy of the field procedures for seismic refraction is provided as Attachment 2. These procedures were previously submitted and approved for the nearby investigation of the former PR-58 Nike Site and NCBC Site 03. The profiling lines are shown on Figure 11. The offsite seismic refraction field work was performed from 7-25 September 2000.

Previous subsurface investigations at other NCBC Davisville sites have shown that the configuration of the upper surface of competent bedrock appears to have influenced the migration of chlorinated volatile organic compounds plumes. In general, seismic refraction interpretive data has been used to develop an understanding of the upper surface of competent bedrock in the adjacent offsite areas east, south, and west of Site 16 and to provide data to aid in the refinement of the locations for MIP screening and monitoring wells (Figures 4, 5, and 10).

4.3 MEMBRANE INTERFACE PROBE SCREENING

The MIP screening of 28 locations at Site 16 (onsite) and 31 locations offsite has been performed using the methods described in Attachment 3 of the Work Plan (March 2000). The results of onsite MIP screening are available in the *Interim Submittal Data and Preliminary Findings of the MIP Screening at IR Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area)*, May 2000.

An additional 31 MIP screening/profiling locations are required to further characterize VOC migration and aided in determining additional monitoring well locations associated with the site. The locations for this MIP screening were selected after receipt and review of the seismic refraction profiling results and submitted to the BCT for concurrence. The procedures for these additional MIP locations are in the Work Plan (March 2000) (Attachment 3). Onsite and offsite MIP locations are shown on Figure 5.

4.3.1 Membrane Interface Probe Backfilling

MIP locations were backfilled in accordance with the Work Plan (March 2000).

4.4 DRILLING AND SUBSURFACE SOIL SAMPLING

Borings will be advanced for the installation of 2 replacement "shallow" ("S") (soil/water table interface), 21 "deep" ("D") zone (10-ft interval just above competent bedrock; anticipated to be gravelly sand and/or weathered bedrock), and 6 "bedrock" ("R") monitoring wells, as stated in Section 3.2.

Drilling for shallow and deep wells will be performed as described in Section 4.4 of the Work Plan (March 2000) with the following modifications:

Shallow wells will be advanced as described in the Work Plan (March 2000), Chapter 4, Section 4.4.

Deep monitoring wells will be advanced as described in Section 4.4 of the Work Plan (March 2000) with the following exception: continuous soil samples will be collected for soil logging and field screening with PID only, except as noted below. Based upon the results of the seismic refraction geophysical survey and MIP screening in the "offsite areas," and in order to characterize the soil in potential source area around Building 41, soil samples will be collected from the screened intervals of 5 of the planned "deep" wells to be installed at locations near the former solvent recovery still

(MIP16-08) and mid to high MIP responses (MIP16-S01, -S03, -S05, and -S17). Additionally, a soil sample will be collected from a soil boring from each of the 2 MIP response intervals at MIP16-S21, i.e. 20-22 ft below ground surface and 32-34 ft below ground surface. These samples will be analyzed for Target Compound List VOCs, SVOCs, polycyclic aromatic hydrocarbons, and pesticides/PCB, Target Analyte List inorganics, total organic carbon, pH, and grain size, as described in Chapter 4, Section 4.4.1 of the Work Plan (March 2000) and included in Table 3-1 of this Work Plan Addendum.

Drilling for bedrock wells will proceed as follows.

Based upon the depth to bedrock encountered in the adjacent "D" companion well, advance 6.25 in. inner diameter HSA, to the top of competent bedrock. Then drill a 3-ft deep socket into rock. There will be no sampling of the overburden soil. Place and grout 4-in. inner diameter steel casing centered and to the bottom of the hole as the HSA is removed. Grout must set for a minimum of 24 hours before continuing with rotary drilling (3.875-in. diameter) of 25 ft of bedrock below the 4-in. inner diameter steel casing. An average total depth of 90 ft below grade is estimated for each well. No polyvinyl chloride (PVC) well will be constructed in the 4-in ID steel casing; these will be completed as open hole monitoring wells. The monitoring well will be completed approximately 2-3 ft above ground with a locking cap on the 4-in. inner diameter steel protective casing (some locations may need curb box completions) and centered in a 2-ft × 2-ft cement pad at ground surface.

Additional drilling, soil sampling, and monitoring well construction procedure details are described in the following sections.

4.4.1 Soil Boring and Sampling

Drill cuttings will be containerized and handled in accordance with the investigative-derived waste procedures, Section 4.12 of the Work Plan (March 2000). The area above the borehole will be monitored with a PID equipped with an 11.7 electron volt probe. The PID will be calibrated each work day before work begins and as required in the field as per Section 4.7.2.2. The procedures for the calibration of the PID are included in Attachment F of the SHERP (see Appendix B of the Work Plan, March 2000).

Drilling and sampling equipment including drill pipe, sampling tools, and drill casing will be freed of potentially contaminating materials by steam cleaning prior to use at each boring as stated in Section 4.11. The drill rig will be steam cleaned prior to use at NCBC Davisville Site 16 and as required by the EA Geologist or Geotechnical Engineer. The rig will be free of leaks which could potentially contaminate the borings. No petroleum-based grease will be used on drill pipe joints.

For each of the "deep" ("D") zone monitoring wells, soil samples will be collected continuously from ground surface to the top of bedrock or refusal. Soil samples will be collected for PID screening and soil logging purposes only. Soil sampling will not be preformed during the drilling of the adjacent shallow or bedrock well of a well pair or cluster.

Soil samples analyzed for dioxin were collected in June 2000 as described in Section 4.4.1.1 of the Work Plan (March 2000). These samples were collected from the eight (8) soil boring locations from two (2) distinct sample intervals. One sample per location was collected from the surface (0-2 ft bgs) and the second was collected from two ft above the apparent water table.

4.4.2 Water Source

One water source sample will be collected as part of the continuing field investigation described in this Work Plan Addendum. The source water sample will be collected in the manner described in Section 4.4.2 of the Work Plan, March 2000, and analyzed for the same parameters as the subsurface soil samples to be collected from the screened interval of selected monitoring well locations.

4.4.3 Borehole Logging

The drilling activities will be observed by an EA Geologist or Geotechnical Engineer. The Geologist or Geotechnical Engineer will log the subsurface conditions encountered in the boring and record the information on a soil boring log and rock core log as outlined in the Work Plan (March 2000).

4.4.3.1 Soil Borehole Logging Requirements

Refer to Section 4.4.3.1 of the Work Plan (March 2000).

4.4.3.2 Bedrock Borehole Logging Requirements

For "deep" monitoring wells, refer to Section 4.4.3.2 of the Work Plan (March 2000).

For monitoring wells completed in the approximately upper 25 ft of competent bedrock, there will be no coring (i.e., no core to log). Rather, the open rock portions of such monitoring wells will be logged geophysically using the following tools: caliper, single-point resistance, fluid temperature, heat-pulse flow meter, and acoustic televiewer. The resulting geophysical logs will be used to aid in the selection of the depth interval for the intake of the dedicated bladder sampling pump to be installed in each well. The following are considerations that will be used in that depth selection process: presence of interpreted fractures or fracture zones from the caliper and acoustic televiewer logs, and intervals located between the main ground-water inflow zones as interpreted from heat pulse flow meter, fluid temperature, and/or caliper logs.

4.4.3.3 Handling and Storage of Rock Core

For "deep" monitoring wells, refer to Section 4.4.3.3 of the Work Plan (March 2000).

4.4.4 Borehole Backfilling

Refer to Section 4.4.4 of the Work Plan (March 2000).

4.5 MONITORING WELLS

This section presents procedures for monitoring well installation, well material specifications, well development, and permeability testing.

4.5.1 Installation

4.5.1.1 Screened Interval

The screened intervals for the shallow, deep, and rock wells to be installed will be selected and added to this Work Plan Addendum after receipt and review of the seismic refraction and MIP results and BCT concurrence. The monitoring wells will be used as locations from which to collect ground-water samples and to measure depth to ground-water. Well construction materials are specified in Section 4.5.2 of the Work Plan (March 2000) and this Work Plan Addendum.

4.5.1.2 Construction

Refer to Section 4.5.1.2 of the Work Plan (March 2000) for the shallow and deep monitoring well construction.

For bedrock wells, it is planned to leave the borehole in bedrock open, i.e., a PVC monitoring well will not be constructed. Where the bedrock is of poor quality and the borehole is collapsing, a PVC well screen will be installed with the screen set adjacent to the most water conducting interval, based upon the field results. Well construction materials are specified in Section 4.5.2.

4.5.1.3 Protection and Completion of Wells

Refer to Section 4.5.1.3 of the Work Plan (March 2000).

4.5.2 Well Construction Materials

For wells constructed of PVC, refer to Section 4.5.2 of the Work Plan (March 2000).

4.5.3 Well Numbering and Labeling

Monitoring wells will be numbered sequentially for each well or well cluster location. The following suffixes will also be included: 'S' for wells completed in the shallow overburden zone, 'D' for wells completed in the deep overburden/weathered rock zone, and a 'R' for wells completed in the bedrock zone. A permanent monitoring well designation will be stenciled on each well with oil-based paint.

4.6 MONITORING WELL DEVELOPMENT AND BLADDER PUMP INSTALLATION

Monitoring Well Development

The monitoring wells will be developed no sooner than 48 hours after grouting is completed. Development protocol is described in Section 4.6 of the Work Plan (March 2000).

Bladder Pump Installation

For monitoring wells constructed with PVC screens, the intake of a bladder pump be installed a minimum of 2-3 ft above the bottom of the well to minimize sediment mobilization, except for shallow wells which breach the water table. For PVC monitoring wells with screens that breach the water table, the intake of a bladder pump will be positioned slightly below the mid-point of the water column, but at least 1.5 ft above the bottom of the well to mitigate drawing in of silt that may collect there.

For monitoring wells completed as open holes (no PVC) in the approximately upper 25 ft of competent bedrock, the borehole geophysical logs will be used to aid in the selection of the depth interval for the intake of the dedicated bladder sampling pump to be installed in each such well. The following are considerations that will be used in that depth selection process: presence of interpreted fractures or fracture zones from the caliper and acoustic televiewer logs, and intervals located between the main ground-water inflow zones as interpreted from heat pulse flow meter, fluid temperature, and/or caliper logs.

4.6.1 Well Development Records

A Well Development Form will be prepared and completed for each monitoring well installed. The form will be prepared by the EA representative present during the well development operations. Information provided on the Well Development Form is described in Section 4.6.1 of the Work Plan (March 2000).

4.7 AQUEOUS SAMPLE COLLECTION

4.7.1 Stormwater, Seep, and Sediment Sampling Procedures

Although these samples are part of the field activity presented in the Work Plan (March 2000), they will be collected during the Work Plan Addendum field activity. Therefore, refer to Section 4.7.1 of the Work Plan (March 2000) for the sampling procedures.

4.7.2 Ground-Water Sampling

Ground-water monitoring well sampling procedures include water level measurements, well purging, field measurements, and sample collection at each well will be performed in accordance with the Work Plan (March 2000). The equipment and protocol for collecting ground-water samples is described in Section 4.7.2 of the Work Plan (March 2000). Ground-water samples will be collected from both onsite and offsite monitoring wells during the Work Plan Addendum

field activity.

4.7.2.1 Purging and Sampling Equipment

Refer to Section 4.7.2.1, Chapter 4, of the Work Plan, March 2000.

4.7.2.2 Field Analytical Equipment

Instruments will be calibrated before sampling each day, and on an as-needed basis in accordance with the manufacturer's instructions. Additionally, PID instrument calibration will be checked before afternoon work and at the end of the work day to make sure that the readings are within an acceptable range (±10%). PIDs will be checked by attaching a tedlar bag containing calibration gas to the end of the probe and observing response. If the PID reading is 10 percent or more out of calibration, it will be recalibrated. All calibration and instrument checking readings will be recorded in the field notebook.

4.7.2.3 Ground-Water Sampling

Refer to Section 4.7.2.3 of the Work Plan, except as follows:

- Dedicated, in-place Teflon-lined polyethylene tubing with attached bladder pump will already have been installed so that the pump intake is at the approximate middle of the screened interval of the well or within 5 ft of the well bottom, if this zone is screened, except for shallow wells which breach the water table. For PVC monitoring wells with screens that breach the water table, the intake of a bladder pump will be positioned slightly below the mid-point of the water column, but at least 1.5 ft above the bottom of the well to mitigate drawing in of silt that may collect there.

4.8 *IN SITU* HYDRAULIC CONDUCTIVITY TESTING/LOGGING

4.8.1 Slug Testing

An *In Situ* permeability test (slug test) will be performed on each of the newly installed PVC wells after development and return of the water level to static conditions. The following existing Site wells will also be slug tested: MW16-01S, MW16-03S, MW16-04S, MW16-05S, MW16-06S/D, and MW16-07S/D. The permeability tests for PVC wells is described in Section 4.8.1 of the Work Plan (March 2000).

4.8.2 Bedrock Borehole Geophysical Logging

For bedrock wells, geophysical logging of the open rock portions of bedrock will be performed by a subcontractor after completion of the drilling activity. Each open boring in bedrock will be logged to aid in the assessment of bedrock fractures and areas of ground-water flow, and to aid in selection of the depth interval for the intake of the dedicated bladder-type sampling pump. The five planned geophysical logging methods are acoustic televiewer, caliper, single-point resistance, fluid temperature, and heat-pulse flowmeter.

4.9 PROFESSIONAL LAND SURVEYING

A licensed land surveyor will survey the new monitoring well locations in accordance to Section 4.9 of the Work Plan (March 2000). The MIP screening/profiling and seismic refraction profile line locations have been documented to within ±3 ft. by Global Positioning System, using a Trimble PRO-XRS.

4.10 SAMPLE DESIGNATION, LABELING, HANDLING, CUSTODY, SHIPPING, AND DOCUMENTATION

Refer to Section 4.10 of the Work Plan (March 2000).

4.11 DECONTAMINATION PROCEDURES

The primary objective of the decontamination process is to prevent the accidental introduction of potential contaminants to non-contaminated areas and/or samples. Refer to Section 4.11 of the Work Plan (March 2000) for the methods associated with decontamination of field equipment. The SHERP (Work Plan, March 2000, Appendix B) addresses personnel decontamination.

4.12 INVESTIGATIVE-DERIVED WASTE MANAGEMENT

The procedures for handling, collection, and storage of investigative-derived wastes and other decontamination-related wastes will be containerized in accordance with Section 4.12 of the Work Plan (March 2000).

4.13 MONITORING WELL ABANDONMENT

Monitoring wells MW16-01S and MW16-05S will be abandoned and replaced due to lack of groundwater available within the wells. RIDEM regulations for monitoring well abandonm nt state that wells with an impermeable annular seal can be abandoned in place by installing neat cement grout or a bentonite-cement grout mix into the well and overdrilling the top 4 ft. Both of these monitoring wells were constructed with an impermeable bentonite seal above the top of the screened interval and the annular space had been backfilled with bentonite cement grout.

The following summarizes the process was followed for each well abandoned:

- The location scheduled for abandonment will be confirmed.
- The depth to ground-water surface (if applicable) and total depth of the well will be measured from the top of the PVC well casing.. The measurements will be recorded in the field notebook.
- The protective well casing and concrete pad will be removed by using a sledge hammer and a cable from the drill rig.
- A bentonite cement grout slurry will be pressure pumped into the monitoring well from

the bottom to the top using a tremie pipe that is manually lifted as the grout is installed.

- When possible, the entire length of the PVC well casing will be pulled (removed) from the ground using a cable from the drill rig.

- When the entire well casing can not be removed from the ground, the PVC casing will be cut-off just below ground level and the well will be overdrilled to a minimum depth of 4 ft using solid stem augers with an 8-in. outside diameter. The auger will be removed from the hole and the remaining portion of the boring will be backfilled with a bentonite cement grout slurry.

- The top 1 ft of the abandoned well boring will be backfilled with materials similar to those surrounding the former well (i.e., native soil, concrete, asphalt patch).

- Materials recovered from the abandonment activities (i.e., steel protective casing, PVC, concrete) will be loaded onto trucks and removed from the site.

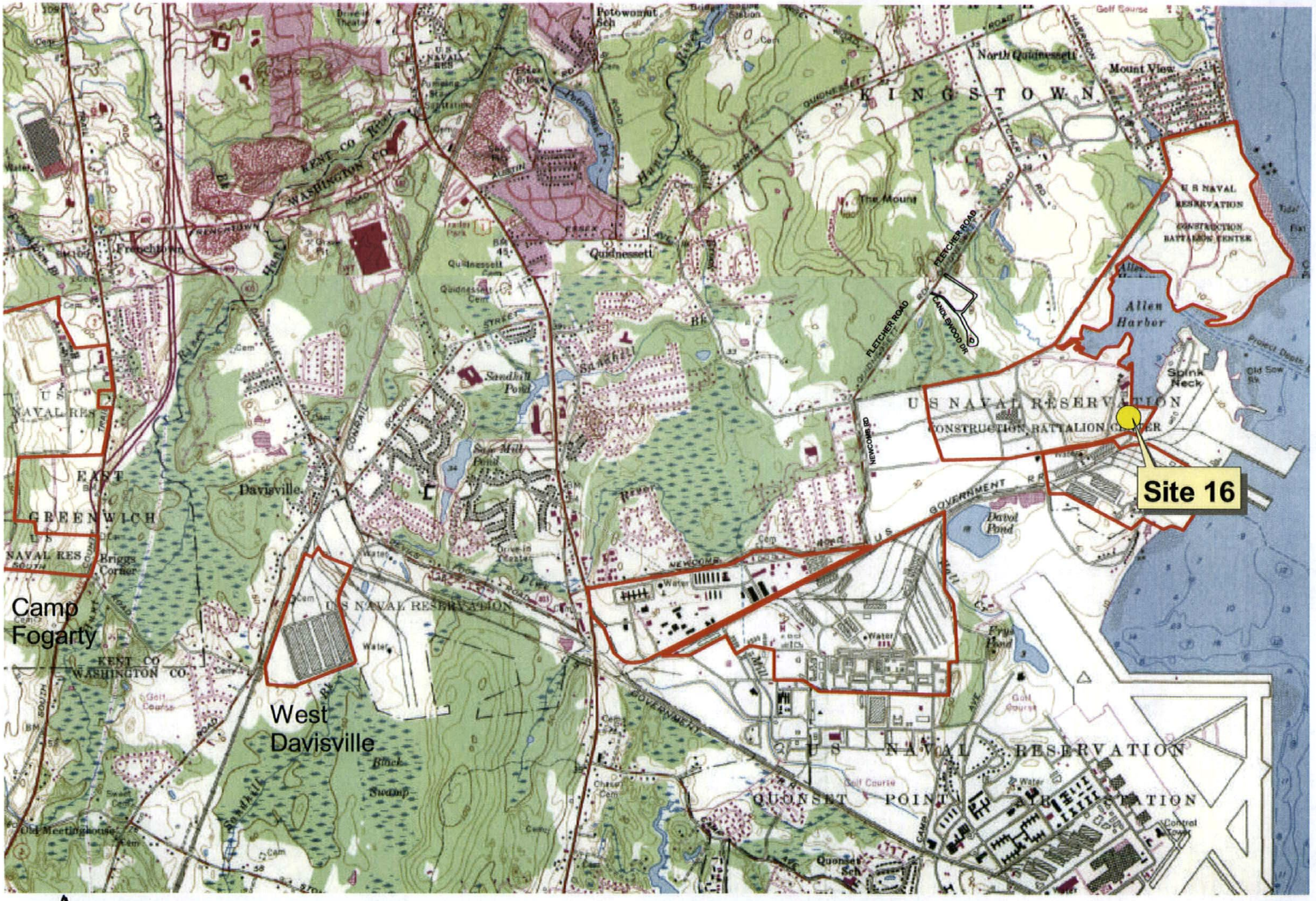
REFERENCES

EA Engineering, Science, and Technology. 1998. Final Phase II Environmental Baseline Survey Report, Naval Construction Battalion Center, Davisville, Rhode Island. February.

EA. 1999. Final Study Area 16 (Creosote Dip Tank and Fire Fighting Training Area) Comprehensive Report/Study Area Screening Evaluation, Naval Construction Battalion Center, Davisville, Rhode Island. December.

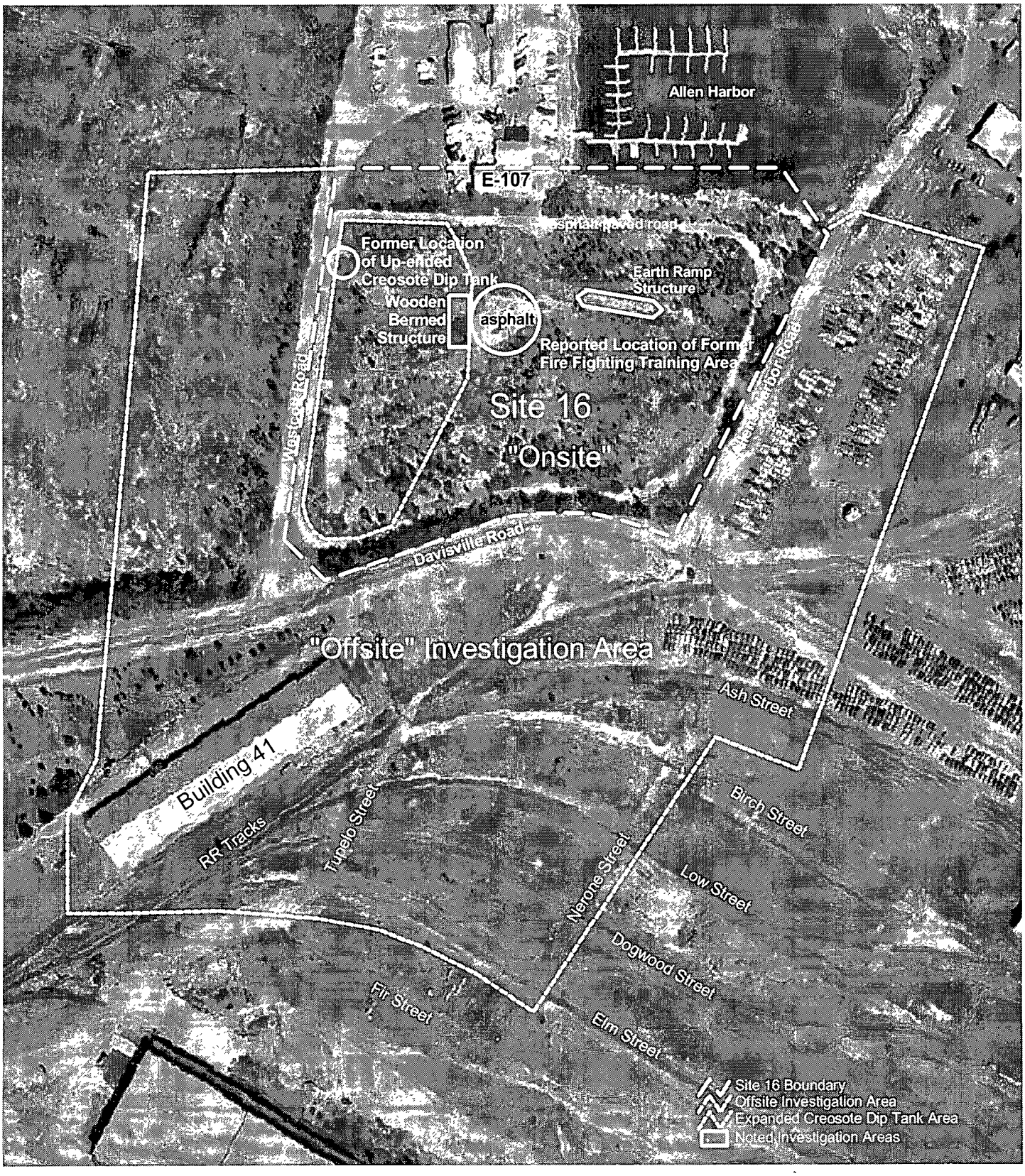
EA Technology. 2000. Work Plan, Final Remedial Investigation of IR Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area), Naval Construction Battalion Center, Davisville, Rhode Island. March.

EA. 2000. Interim Submittal Data and Preliminary Findings of the Membrane Interface Probe (MIP) Screening at IR Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area), Naval Construction Battalion Center, Davisville, Rhode Island. May.



Approximate Scale 1" = 3000 ft.

FIGURE 1
SITE LOCUS MAP - NCBC DAVISVILLE, RI



300 0 300 600 900 Feet

N

Figure 2
Site Map, Site 16
NCBC Davisville

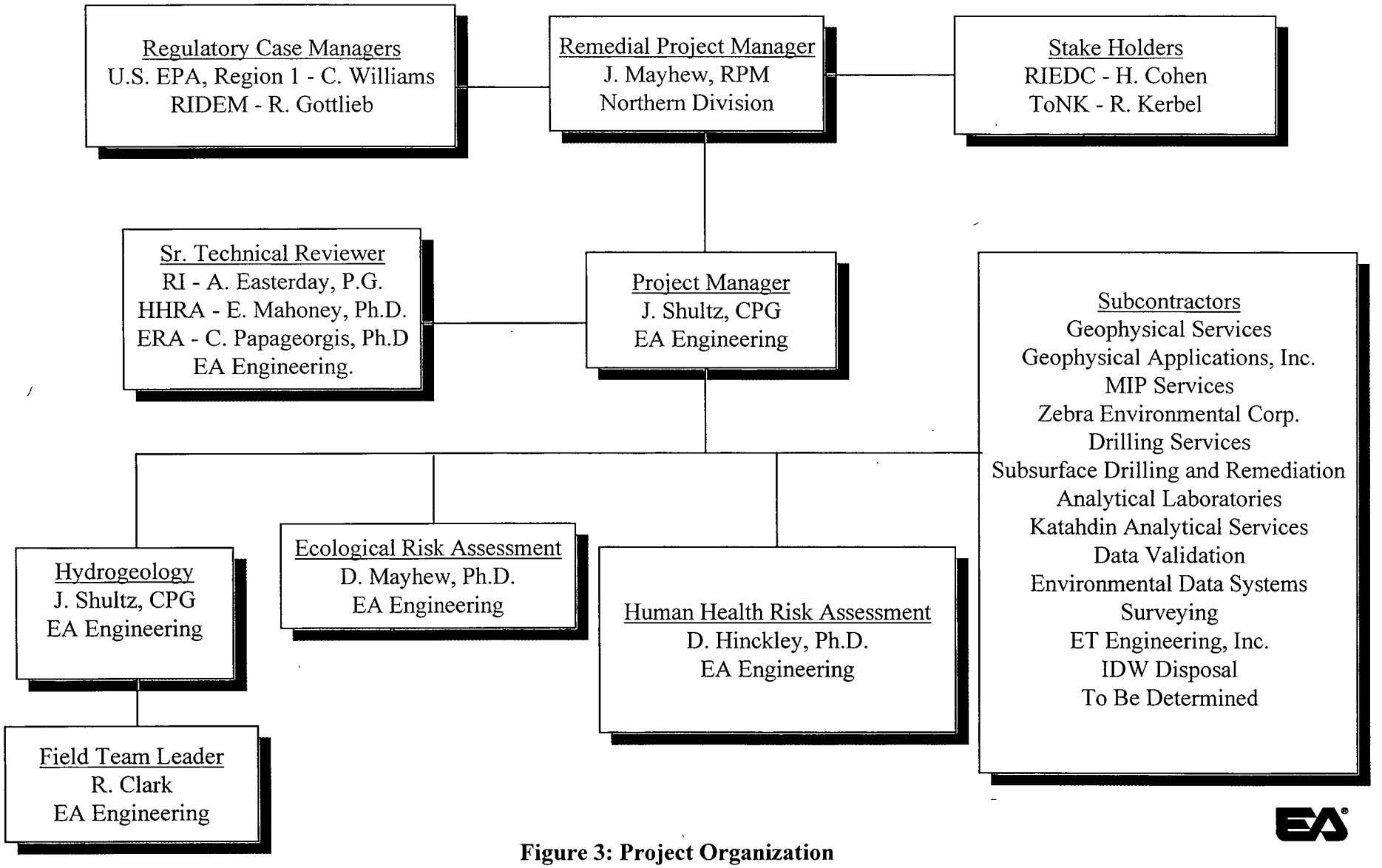
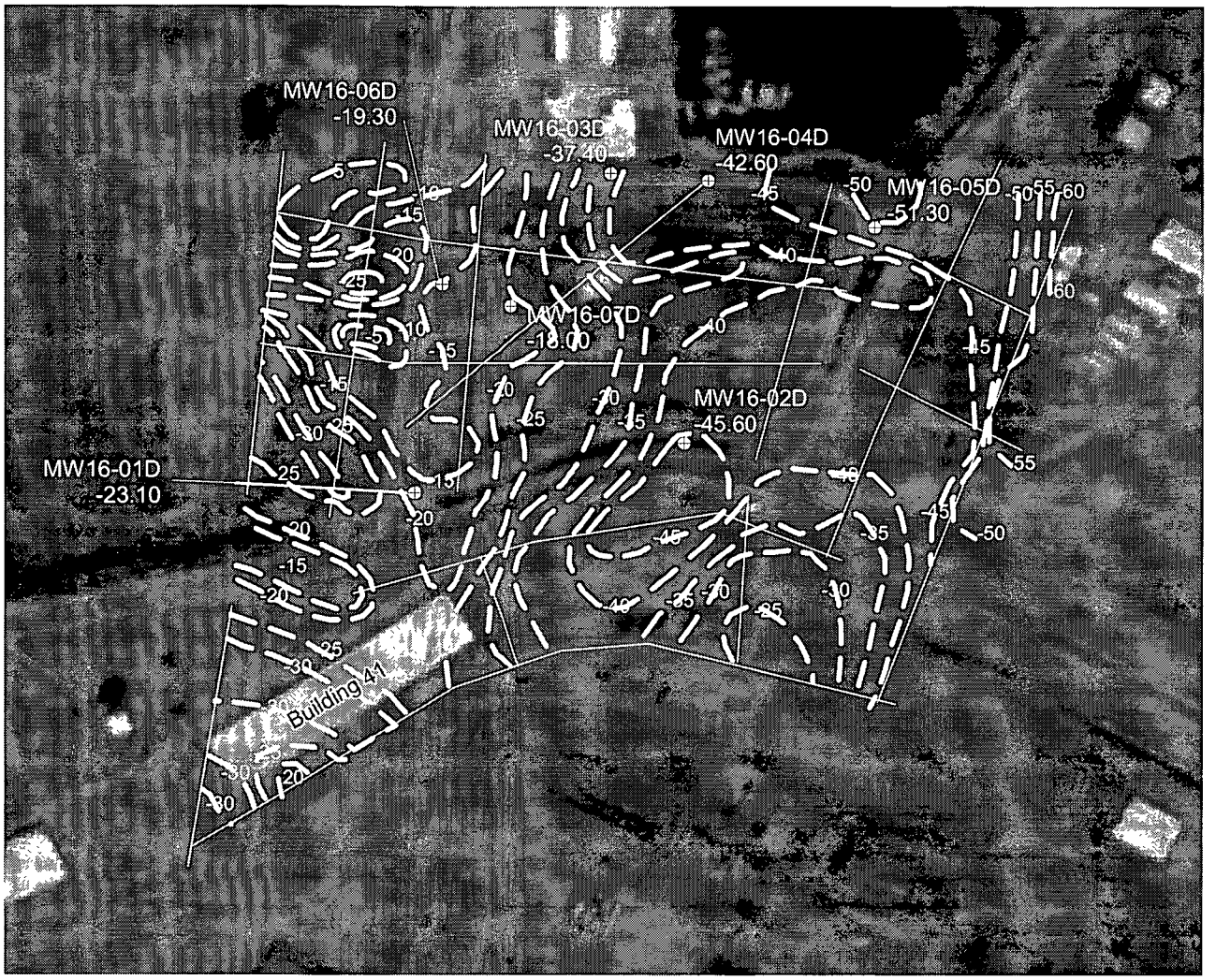


Figure 3: Project Organization

Site 16 Remedial Investigation, NCBC Davisville,R.I

Site 16, NCBC Davisville
Interpreted Surface of Bedrock



500 0 500 1000 1500 Feet

⊕ **Location of Deep (D) Monitoring Well**

MW16-01D Monitoring well designation
-23.10 with top of rock elevation

--40-- Interpreted Top of rock elevation contour line at 5' intervals (Ft/MSL)

___ Seismic Refraction Line

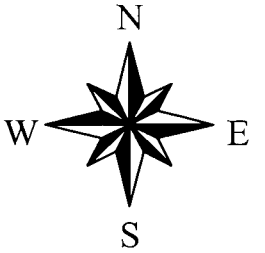


Figure 4

Location of MIP Screening Site 16, NCBC Davisville

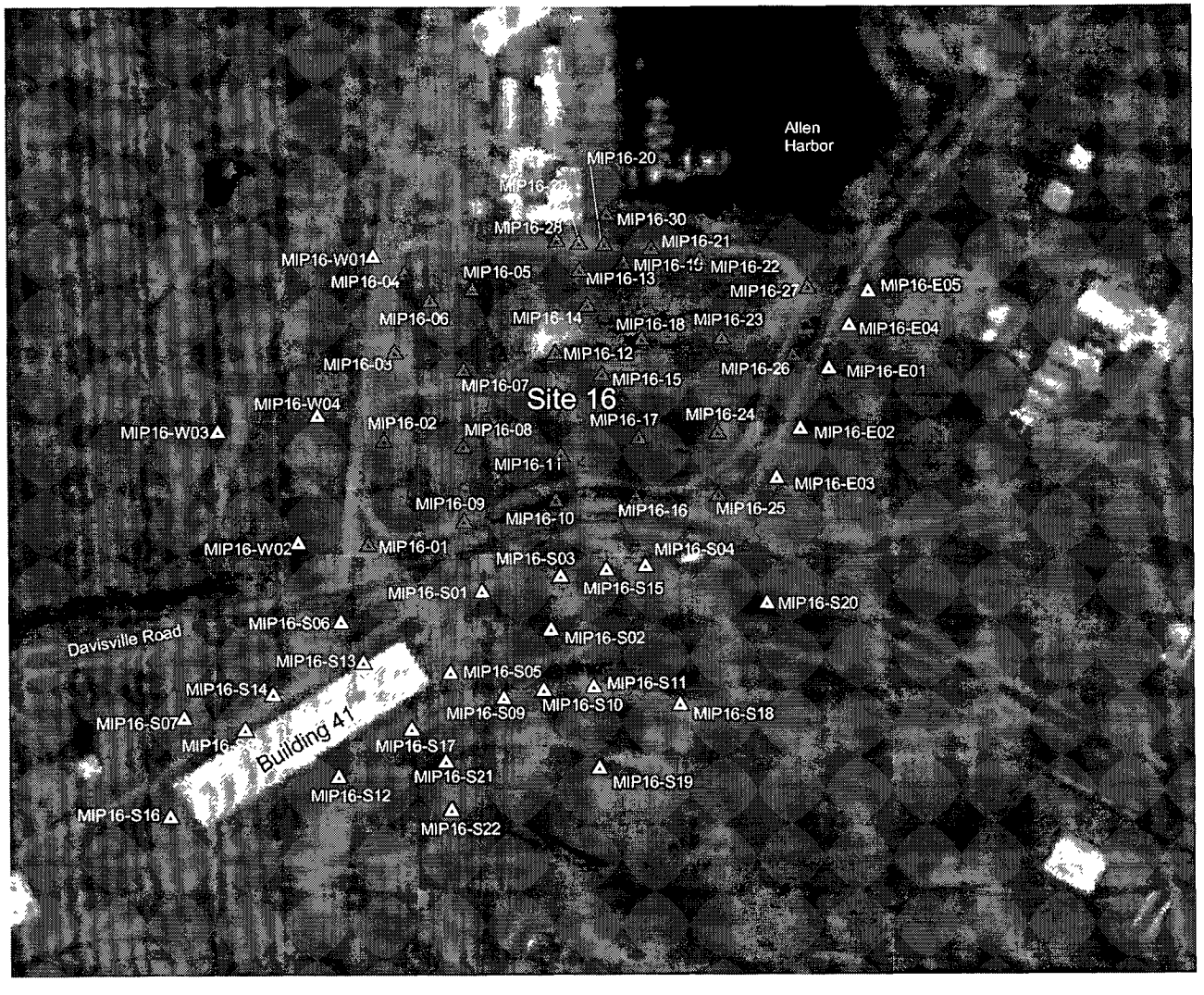
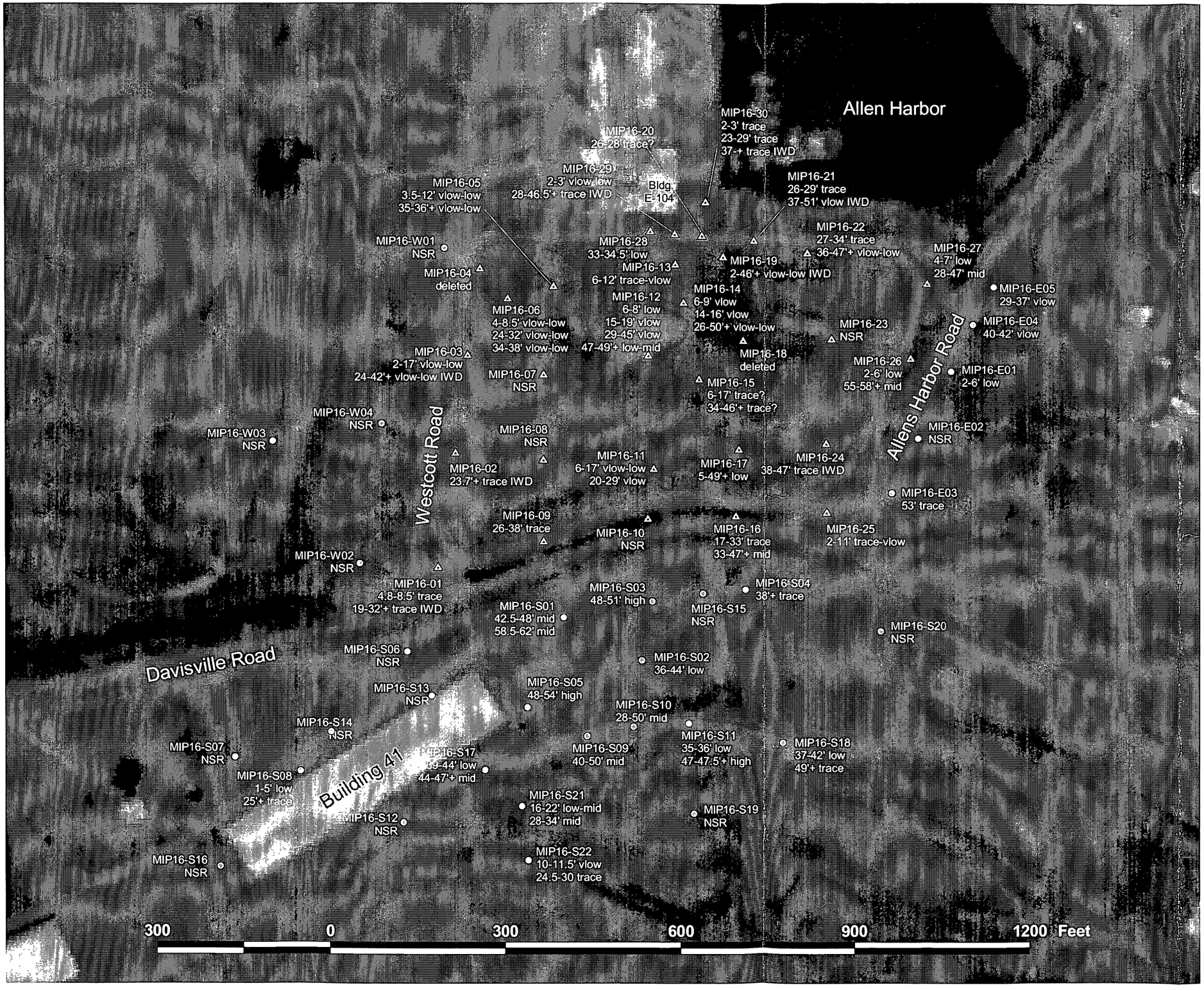


Figure 5

Summary of MIP ECD Responses

Site 16
NCBC Davisville



△ **Onsite MIP Location**
○ **Offsite MIP Location**

E-05 - location designation
29-37' - depth of ECD reponse in feet below grade
vlow - relative ECD reponse e.g. very low
NSR - no significant response
IWD - increasing with depth
ECD - Electron Capture Detector

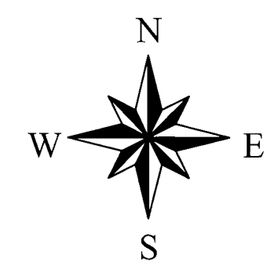
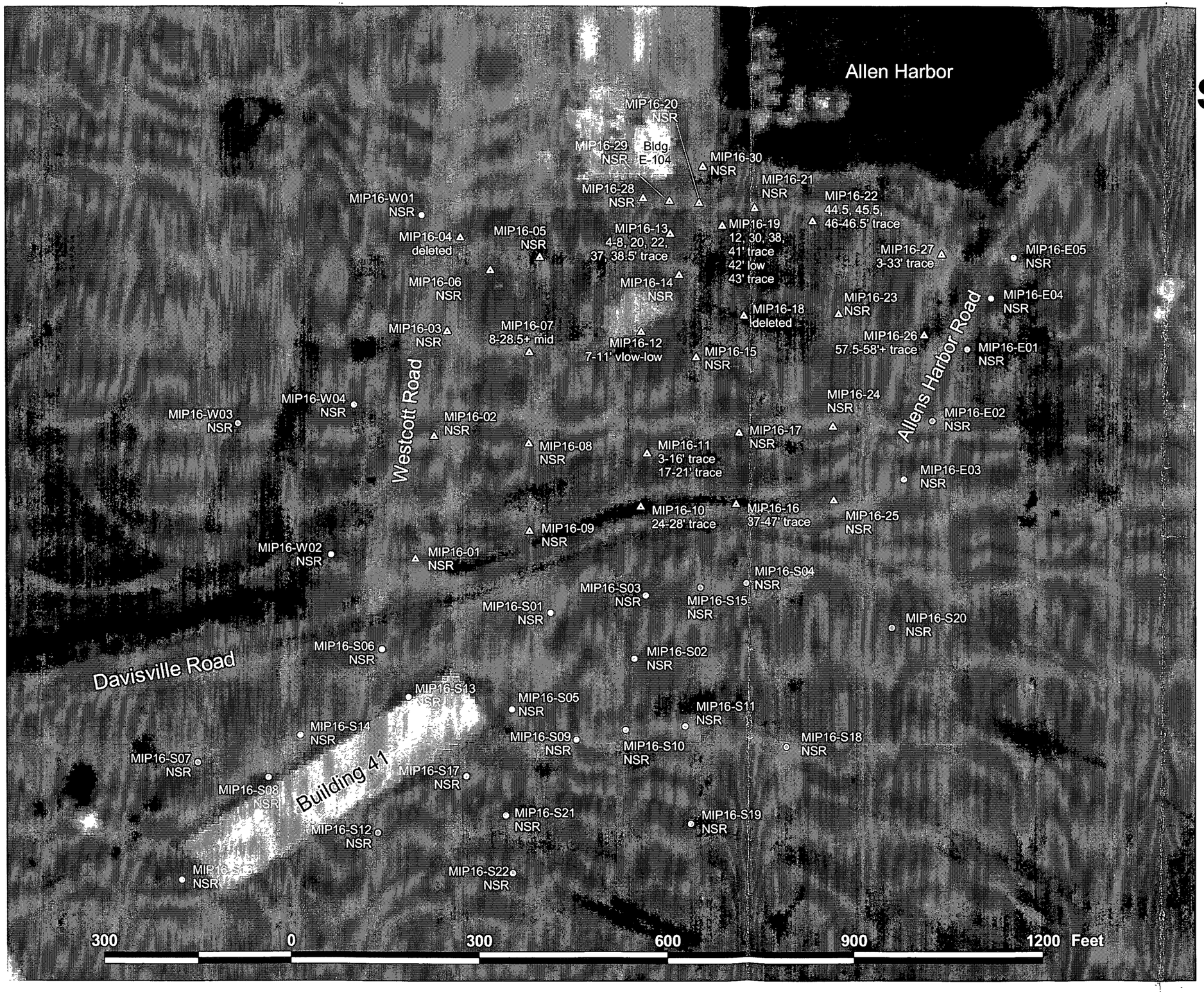


Figure 6A

Summary of MIP PID Responses

Site 16
NCBC Davisville



△ **Onsite MIP Location**
◎ **Offsite MIP Location**

MIP16-12 - location designation
7-11' - depth of PID response in feet below grade
vlow-low - relative PID response e.g. very low to low
NSR - no significant response
PID - Photoionization Detector

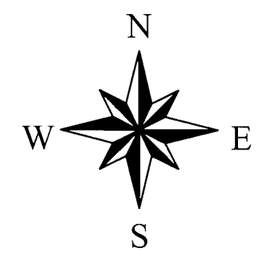
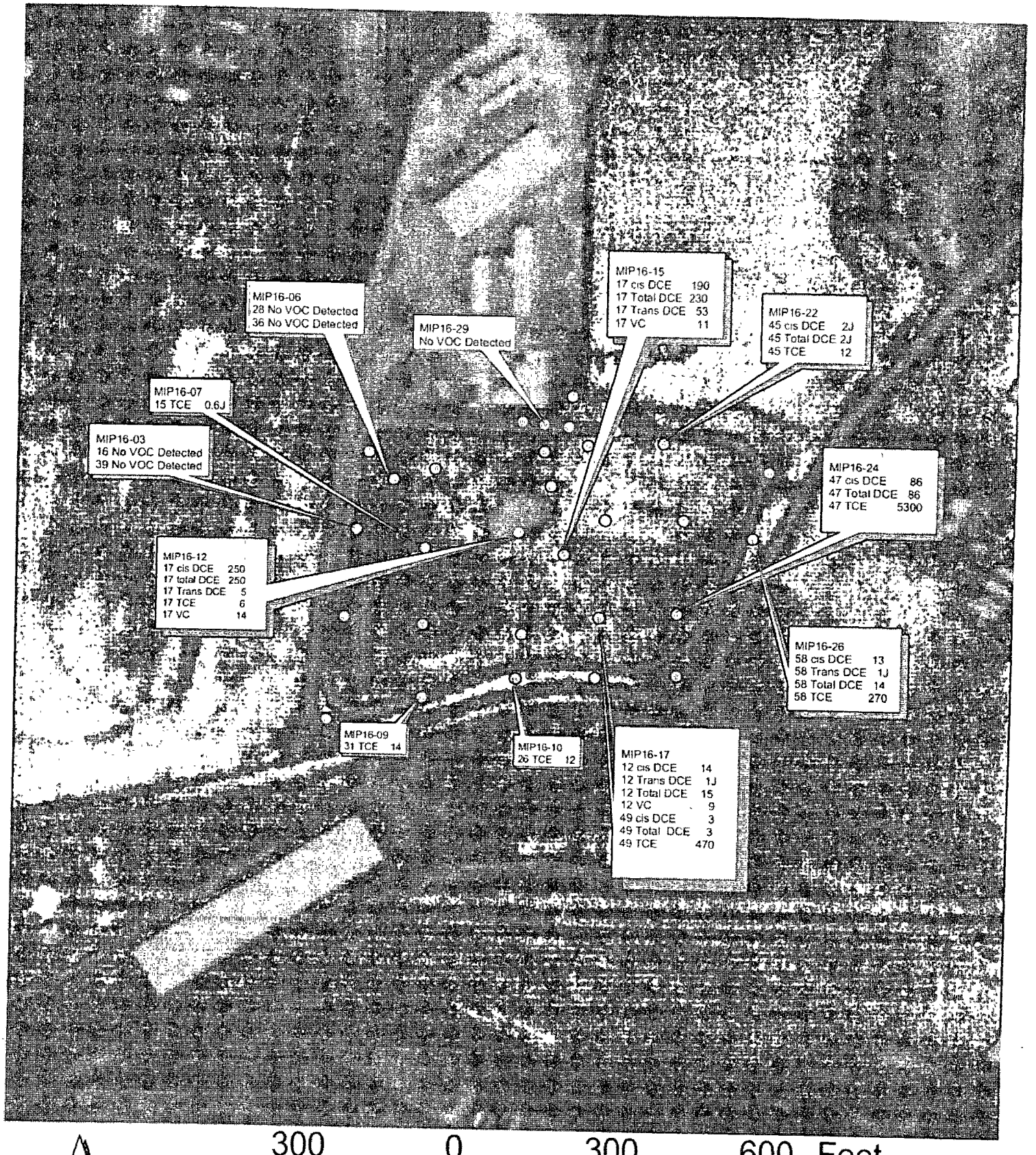


Figure 6B

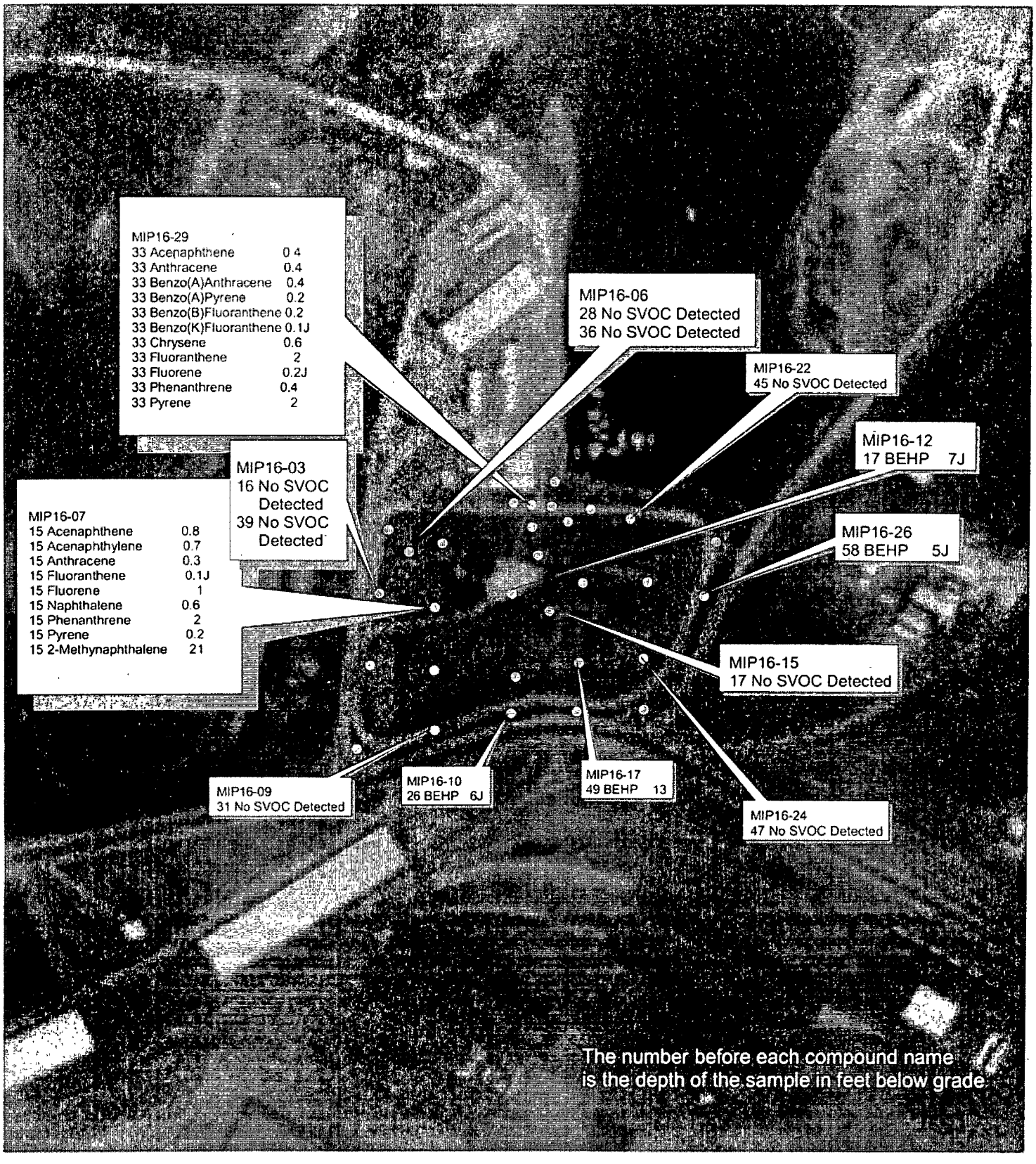


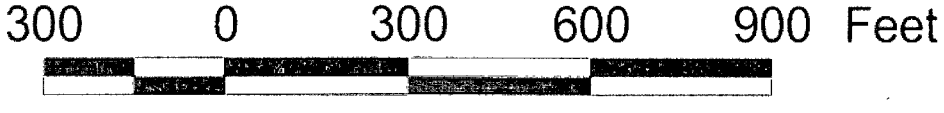
300 0 300 600 Feet

N

Preliminary Summary of VOC Results (ug/L)
From Probe-Collected GW Samples
Site 16

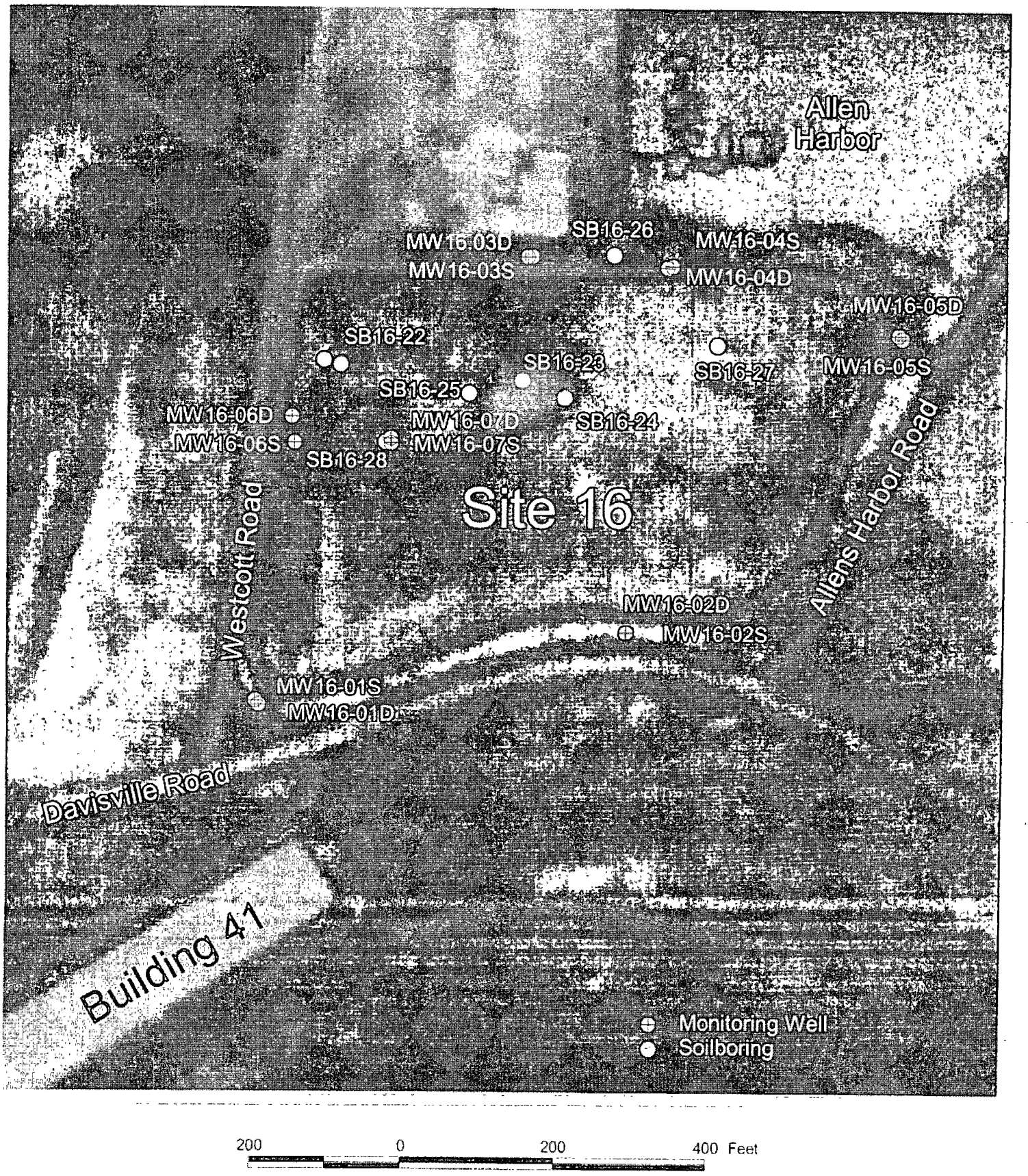
Figure 7





Preliminary Summary of SVOC/PAH Results (ug/L)
From Probe-Collected GW Samples
Site 16

Figure 8

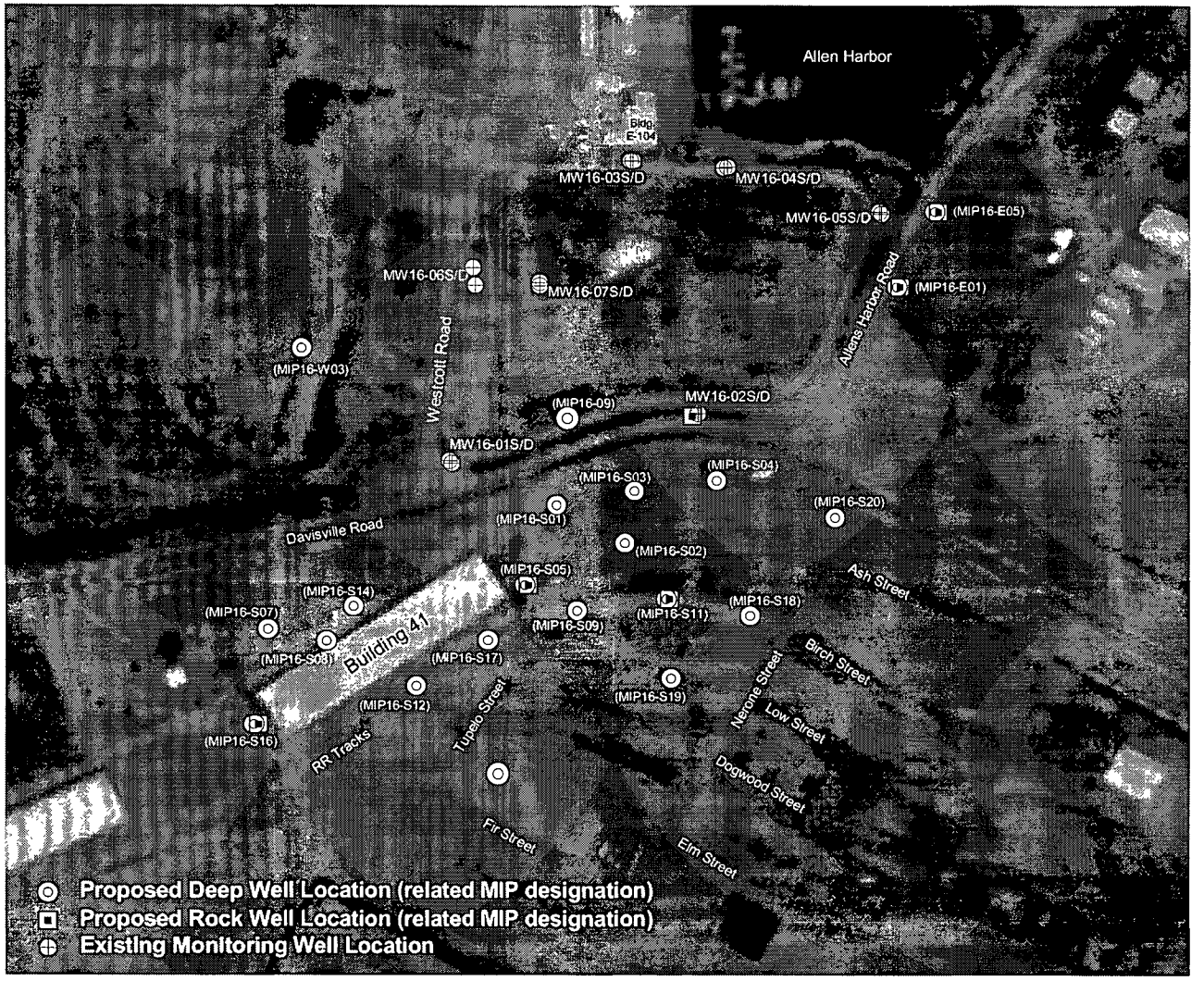


200 0 200 400 Feet

Location of Onsite Monitoring Wells and Soil Borings
Site 16

Figure 9

Location of Proposed Offsite Monitoring Wells
Site 16, NCBC Davisville



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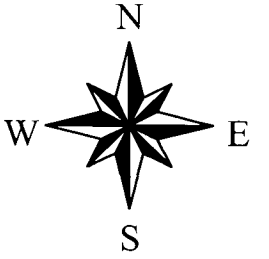
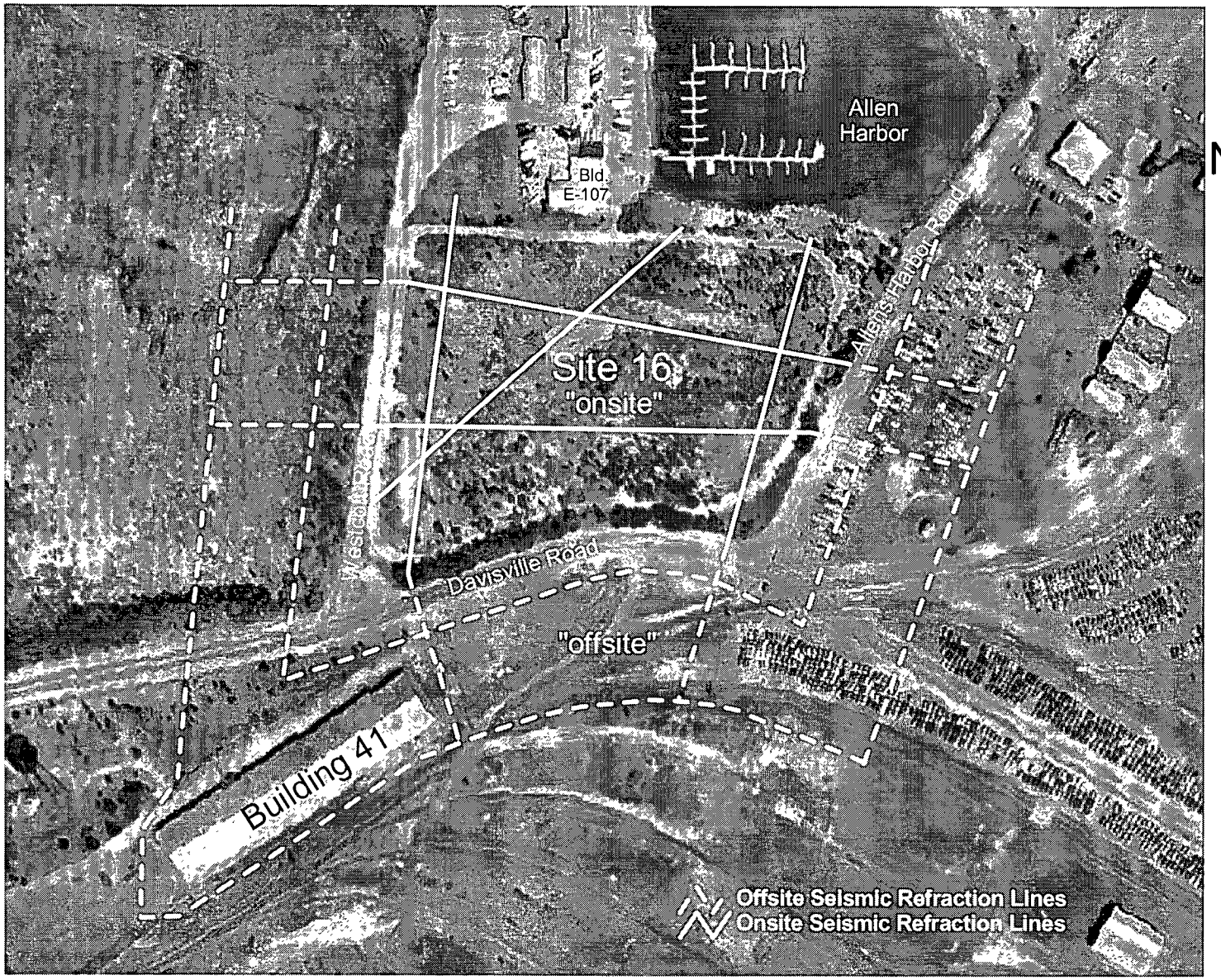


Figure 10



Site 16
NCBC Davisville
Seismic Refraction Lines

___ Seismic lines completed April 2000

- - - - Offsite seismic lines completed September 2000

500 0 500 1000 1500 Feet

N
W E
S

Figure 11

TABLE 2-1
SUMMARY OF MIP RESPONSE INTERVALS
SITE 16, Onsite Areas, NCBC DAVISVILLE

MIP Designation	MIP Depth Plan/Actual (ft bg)	Water Table (ft bg)	MIP Detector Response Depth Intervals							Probe-Collected Ground-Water Sampling (ft bg) Recommendations
			Electron Capture Detector (ECD) (ft bg)			Photoionization Detector (PID) (ft bg)			Conductivity (ft bg)	
			shallow	mid	deep	shallow	mid	deep		
01	45/32	18.5	4.8-8.5 (trace)	19-32$^+$ (trace with increase near refusal)					11.5-12 (25$^+$ ms/M), 14.5-15 (25$^+$ ms/M), 18-32 (12-15 ms/M)	Install MW Pair
02	42/23.7	16	23.7 (trace with increase near refusal)						1-1.5 (50$^+$ ms/M), 13-13.5 (50$^+$ ms/M), 21-23.7 (12 ms/M)	
03	40/42.3	12	2-17 (v. low - low)	24-42$^+$ (v low - low, steady increase)					36.5 (50 ms/M), 18-42 (8 ms/M)	16' & 42 and Install MW Pair
04	33/1-5		Location deleted; shallow probe refusal							
05	37/35.9	3.5-9	3.5-12 (v low-low)		35-36+ (v low-low)				1.5-19 (14 ms/M), 4.5 (39 ms/M)	
06	37/40.4	4-8	4-8.5 (v low-low)	24-32 (v low-low)	34-38 (v low-low)				3.5-5.5 (50$^+$ ms/M), 18 (50$^+$ ms/M), 40 (30 ms/M)	28' & 36'
07	42 & 32 / 28.5	6	NSR			8-28.5+ (mid; highest PID response at Site 16)			no data	15' and Install MW Pair
08	43/34.1	3-8	NSR						no data	
09	52/42.2	2-3		26-38 trace					3-16 (up to 20-25 ms/M spikes)	31'
10	57/32.7		NSR				24-28 (trace)		2.5-5 (up to 18 ms/M), 10.5 (60$^+$ ms/M), 13-19 (up to 60+ ms/M spikes)	26'
11	50/41.9	2-10	6-17 (v low-low)	20-29 (v low)		3-16 (trace)	17-21 (trace)		no data	
12	48/49	3-10	6-8 v low	15-19 v low	29-45 (v low), 47-49+ (low-mid)	7-11 (v low-low)			6-7 (900$^+$ ms/M), 13-21 (up to 800 ms/M)	17' & 49'
13	45/38.7	4	6-12 (trace-low)			4-8 (trace)	20 & 22 (trace)	37 & 38.5 (trace)	4-8 (up to 50 ms/M spikes)	
14b	60 & 44-46 / 50	2-10	6-9 & 14-16 (v low)	26-50$^+$ (v low-low)					4-17 (various spikes at 75$^+$ ms/M)	
15	56/46	1-8	6-17 (trace?)		34-46$^+$ (trace?)				no data	17'

TABLE 2-1
SUMMARY OF MIP RESPONSE INTERVALS
SITE 16, Onsite Ar as, NCBC DAVISVILLE

MIP Designation	MIP Depth Plan/Actual (ft bg)	Wat r Table (ft bg)	MIP Detector Respons Depth Intervals							Probe-Collected Ground-Water Sampling (ft bg) Recommendations
			Electron Capture Detector (ECD) (ft bg)			Photoionization Detector (PID) (ft bg)			Conductivity (ft bg)	
			shallow	mid	deep	shallow	mid	deep		
16	65/47.2	2-6	17-33 (trace)		33-47+ (mid; centered around 38-43')			37-47^{+} (trace)	1-3 (up to 40 ms/M), 8 (28 ms/M); silt layer 12-25'	Install MW Pair
17	62/48.6	2-7	5-49+ (low)						no data	12' & 49'
18	55/-		Location deleted; not accessible (too wet)							
19a	65 & 31 / 46	0-2	2-46+ (v low-low, increasing trend), spikes at 17.5, 23-25,30-31,and 38-39			12 (trace)	30 (trace)	38,41(trace), 42(low), 43 (trace)	3-12 (spikes up to 50^{+} ms/M), 12-46 (8 ms/M)	
20a	43/28	2-4		26-28+ (trace?)					2.5-9.5 (spikes up to 50^{+} ms/M), 9.5-28 (4 ms/M)	
21a	75/51.4	2-8		26-29 (trace)	37-51 (v low, increasing trend)				1.5-19 (spikes up to 50^{+} ms/M), 19-51 (4 ms/M)	Install MW Pair
22d	70/47	2-4		27-34 (trace), 36-47+ (v low-low)				44.5, 45.5, 46-46.5 (trace)	5-21(12-80^{+} ms/M), 12(80^{+} ms/M spike), 21-47 (12 ms/M)	45.5
23b	55/47	2-7	NSR							
24a	60/47	2-8			38-47+ (trace, increasing)				10-47 (6-18 ms/M) esp.11 33'	47'
25	60/40.8	2-4	2-11(trace-v low)						12-41 (6-18 ms/M) esp.12 16'	
26	55/58	2-7	2-6 (low)		55-58+ (mid)			57.5-58+ (trace)	1.5 + 6 (40^{+} ms/M), 8-36 (5 ms/M), 33-57 (5-20 ms/M)	58'
27	60/47	5-8	4-7 (low)	28-47+ (mid)		3-33 (trace)			10-47^{+} (5-12 ms/M)	Install MW Pair
28b	42/35.8	2-4		33-34.5 (low)					2-36^{+} (5 ms/M)	Install MW Pair
29a	43/46.5	2-4	2-3 (v low-low)	28-46.5^{+} (trace) (increasing trend)					5-5.5 (13,000 ms/M)	46'
30a	44/38	3	2-3 (trace)	23-29 (trace)	37+ (trace, increasing)				3-11 (10-24 ms/M) Max at 6.5'	

NSR = No Significant Response

TABLE 2-2
SUMMARY OF MIP RESPONSE INTERVALS
SITE 16 OffSite Areas, NCBC DAVISVILLE

MIP Designation	Est Depth to Rock & MIP Refusal (ft bg)	Water Table* (ft bg)	MIP Detector Response Depth Intervals Electron Capture Detector (ECD) (ft bg) shallow	deep
West of Westcott Road				
MIP16-W-01	NA / 33		NSR	
MIP16-W-02	58 / 49	10 - 14	NSR	
MIP16-W-03	47 / 47		NSR	
MIP16-W-04	34 /35	8 - 10	NSR	
East of Allens Harbor Road				
MIP16-E-01	50 / 50		2 - 6' low	
MIP16-E-02	51 / 46		NSR	
MIP16-E-03	52 / 53			53 - trace?
MIP16-E-04	59 / 48.5	5 - 8		40 - 42 v. low
MIP16-E-05	56 / 41.5	5 - 8		29 - 37 v. low
South of Davisville Road				
MIP16-S-01	66 / 62	16 - 20		42.5 - 48 mid 58.5 - 62+ mid
MIP16-S-02	NA / 48	8 - 12		36 - 44 low
MIP16-S-03	52 / 53	14 - 16		48 - 51 high
MIP16-S-04	69 / 38	9 - 12		38+ trace ?
MIP16-S-05	62 / 54	10 - 16		48 - 54+ high
MIP16-S-06	47 / 28		NSR	
MIP16-S-07	70 / 52	17	NSR	
MIP16-S-08	NA / 43	14 - 16	1 - 5 low	25+ trace ?
MIP16-S-09	48 / 56	10 - 14		40 - 54 mid
MIP16-S-10	60 / 52	8 - 11		28 - 50 mid
MIP16-S-11	53 / 47.5	7 - 11		35 - 36 low, 47 - 47.5+ high
MIP16-S-12	62 / 38		NSR	
MIP16-S-13	NA / 38	15 - 17	NSR	
MIP16-S-14	NA / 44	13 - 15	NSR	
MIP16-S-15	70 / 48	13 - 16	NSR	
MIP16-S-16	67 / 48	12 - 16	NSR	
MIP16-S-17	52 / 47	11 - 13		39 - 44 low, 44 - 47+ mid
MIP16-S-18	46 / 49	8 - 10		37 - 42 low, 49+ trace ?
MIP16-S-19	NA / 45	9 - 12	NSR	
MIP16-S-20	46 / 24	6 - 8	NSR	
MIP16-S-21	NA / 42	11		16 - 22 low-mid, 28 - 34 mid
MIP16-S-22	NA / 41	8 - 12	10 - 11.5 v. low	24.5 - 30 trace ?

TABLE 2-2
SUMMARY OF MIP RESPONSE INTERVALS
SITE 16 OffSite Areas, NCBC DAVISVILLE

MIP Designation	Est Depth to Rock & MIP Refusal (ft bg)	Water Table* (ft bg)	MIP Detector Response Depth Intervals	
			Electron Capture Detector (ECD) (ft bg)	
			shallow	deep

NSR = No Significant Response

NA = Not Available, I.e. not along a seismic refraction geophysical line from which an interpreted depth could be obtained.

No significant response was recorded by the photoionization detector (PID)

* Water table interpreted from temperature log

TABLE 2-3 RECOMMENDED[a] LOCATIONS FOR ADDITIONAL MONITORING WELLS SITE 16 AND OFFSITE AREAS, NCBC DAVISVILLE

MW Location (MIP Designation)	Type of MW	Reason
W-03	Deep	Within the old borrow pit area, west of central portion of Site 16 and upgradient of portion of Site 16.
15-25 ft southwest of S-16	Deep and Rock	Upgradient of Building 41 and Site 16.
S-07	Deep	North plume extent and/or upgradient. No significant MIP response, but MIP about 18 ft less than anticipated depth.
S-08	Deep	Adjacent to Building 41 former solvent recovery still area. Slight MIP response, but MIP did not achieve anticipated depth.
S-14	Deep	Near EBS Review Item #81. MIP did not achieve anticipated depth.
S-05	Deep and Rock	East end of Building 41. High MIP response.
S-17	Deep	South side of Building 41. Low-mid MIP response, but MIP did not achieve anticipated depth.
S-12	Deep	South side of Building 41. No significant MIP response, but MIP about 25 ft less than anticipated depth.
South of S-22, on Elm St.	Deep	Southern plume extent. Very low to trace MIP response. No geophysical data from which to interpret depth to bedrock.
S-09	Deep	Plume characterization. Mid MIP response. MIP achieved greater than the anticipated depth.
S-11	Deep and Rock	Plume characterization. Low to high MIP response, but MIP did not achieve anticipated depth.
S-19	Deep	Southern plume extent. No significant MIP response No geophysical data from which to interpret depth to bedrock.
S-18	Deep	Southeastern plume extent. Low to trace MIP response. MIP achieved anticipated depth.
S-01	Deep	Plume characterization. Two mid MIP responses. MIP achieved anticipated depth.
MIP16-09	Deep	Northern plume extent onsite north of S-01.
S-02	Deep	Plume characterization. Low MIP response, but MIP did not achieve anticipated depth.
S-03	Deep	Plume characterization. Low MIP response, but MIP did not achieve anticipated depth.
S-04	Deep	Plume characterization. Trace MIP response, but MIP about 30 ft less than anticipated depth.
S-20	Deep	Southeastern plume extent. No significant MIP response, but MIP about 20 ft less than anticipated depth.
100 ft east of E-01	Deep and Rock	Eastern plume extent. Low MIP response. MIP achieved anticipated depth.
100 ft northeast of E-05	Deep and Rock	Northeastern plume extent. Very low MIP response, but MIP about 15 ft less than anticipated depth.
MW16-02	Rock	Onsite plume characterization in shallow bedrock. High MIP response at depth, but only 30-55 HNu units for soil sample headspace during drilling of the deep well.

(a) Based on previous site data and the results of the seismic refraction survey and MIP findings.

TABLE 3-1 SUMMARY OF ADDITIONAL SAMPLING AND ANALYTICAL PROGRAM, SITE 16, NCBC DAVISVILLE

Sample Media	EPA Method (SW8460)	No. Field Samples	Number of QC Samples				Total Number of Samples
			Duplicate	Rinsate	MS/MSD	Trip Blank	
Ground-Water (new monitoring wells)	TCL VOC (detection limit, <1 µg/L) 8260	27	3		2/2	25	59
	TCL SVOC (8270)	27	3		2/2		34
	TCL PAH (8270 SIM)	27	3		2/2		34
	TCL Pest/PCB (8082)	27	3		2/2		34
	TAL Inorganics (6010/7000)	27	3		2/2		34
	Salinity (SM 2520B)	27	3				30
Subsurface soil from screened interval of 5 monitoring wells (located adjacent to MIP16-S01, MIP16-S03, MIP16-S05, MIP16-S08, MIP16-S17; Plus 2 intervals from soil boring adjacent to MIP16-S21 at 20-22 ft bgs and 32-34 ft bgs)	TCL VOC (8260)	7	1	1	1/1	6	17
	TCL SVOC (8270)	7	1	1	1/1		11
	TCL PAH (8270 SIM)	7	1	1	1/1		11
	TCL Pest/PCB (8082)	7	1	1	1/1		11
	TAL Inorganics (6010/7000)	7	1	1	1/1		11
	TOC (9060)	7	1	1			9
	pH	7					7
	Grainsize	7					7
Surface and Subsurface Soil Pairs (8)	Dioxin (8290)	16	2	2	1/1		22

NOTE: EPA = U.S. Environmental Protection Agency.
MS/MSD = Matrix spike/matrix spike duplicate.
TCL = Target Compound List.
VOC = Volatile organic compound.
SVOC = Semivolatile organic compound.
PAH = Polycyclic aromatic hydrocarbons.
TAL = Target Analyte List
Also see Table 3-1 in the Work Plan (March 2000).

Attachment 1

Onsite Seismic Refraction Report
Site 16, Former NCBC Facility
NCBC Davisville, Rhode Island

Geophysics GPR International Inc.
February 2000

GEOPHYSICS GPR INTERNATIONAL INC.

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SEISMIC REFRACTION INVESTIGATION

SITE 16, FORMER NCBC FACILITY

DAVISVILLE, RHODE ISLAND

Presented to:

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 Middlesex Turnpike Third Floor
Bedford, Massachusetts 01730

Presented by:

GEOPHYSICS GPR INTERNATIONAL, INC.
13 Highland Circle, Suite E
Needham Heights, Massachusetts 02494

February 4, 2000

GPR No. B99283
EA Ref. No. 29600 94

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FIGURES

Figure 1. Site Location Map
Figure 2. Refraction Line Positions Map

APPENDIX

Seismic Profiles
Tabulation of Results: Layer Thicknesses, Depths, Elevations, and Seismic Velocities
Seismic Refraction Method

1.0 INTRODUCTION

Geophysics GPR International, Inc., under a directive of EA Engineering, Science and Technology, Inc. (EA), performed a geophysical investigation at Site 16 of the former NCBC Davisville facility, North Kingstown, Rhode Island. This task was set out in our proposal SB99712, dated December 1, 1999.

The seismic refraction survey was conducted December 13 – 18, 1999, within the specified area. The primary objective of this geophysical survey was to determine depths and seismic velocities of bedrock and other subsurface features, to aid in the geologic characterization of the site.

2.0 SITE AND AREA CONDITIONS

Site 16 is located in the northerly portion of North Kingstown; the site is bounded on the south by Davisville Road, on the east by Allen Harbor (Spink Neck) Road, on the west by Westcott Road, and on the north by Allen Harbor. With the exception of two asphalt paved areas and a circumferential roadway, the investigated area is largely overgrown and required extensive brush clearing prior to the survey. Past modifications of the site terrain include bulldozed areas, built up earth ramp structures, and large boulders used to stabilize the embankment at the edge of Allen Harbor. The water table across the investigated area ranges from about five to ten or eleven feet below ground surface (BGS), decreasing in depth toward Allen Harbor.

3.0 SITE GEOLOGY

Overburden at this site consists of fine-grained glacial deposits including sand, silts, and clay overlying bedrock. This information was taken from soil cross sections and boring logs provided by EA.

4.0 METHODS OF INVESTIGATION

4.1 Seismic Refraction Survey

A 24-channel digital seismograph was used and set up in the seismic refraction mode using 20-foot geophone spacings. The refraction traverses were performed with five to seven energy points (shots) along each spread for our quality control of field data collection: forward and reverse offset (far) shots, end shots, a center shot, and quarter shots. A minimum two geophone overlap was laid out for contiguous spreads. In most instances line overlaps were more extensive, providing greater data redundancy.

The offset (far) shots allow detailed calculation of the profile and velocity of the bedrock, while the shots within the spread provide information on the lateral variation in the velocity of the overburden, which is required to determine the depth to bedrock (see Appendix). Due to site

constraints, it was impossible to shoot many of the normal far shots.

5.0 DATA ACQUISITION

5.1 Equipment

An ABEM Terraloc Mark 6 seismograph was used for this investigation. Amplification of the signals from the geophones is accomplished using integrated floating point technology, which allows maximum trace size throughout the record. Each seismogram is recorded digitally on the seismograph hard drive and transferred to floppy disks. When higher ambient noise levels were encountered, the noise was overcome by stacking and filtering of the seismic records. This proved to be particularly important at this site due to heavy nearby truck and auto traffic. An 8-gauge Betsy Seisgun was employed as the energy source.

5.2 Survey Procedures

Traverses were flagged and cleared according to the specified configuration prior to the commencement of the survey. Minor adjustments were made to accommodate site constraints such as earth ramp structures, etc. Specific traverse lengths were reached by varying line overlaps.

Differential surface elevation levelling was performed by GPR at the conclusion of each segment of refraction data acquisition using a transit level, measuring tape, and stadia rod to determine line positions and to make corrections to the seismic data.

Approximately 3,480 linear feet of seismic refraction profiling was accomplished along the specified traverses. The seismic surveys were performed at the specified locations and modified in the field, as required, to conform to the specified objectives. Information provided by relevant boring logs and cross sections was integrated into the final geophysical interpretation.

5.3 Interpretation and Accuracy

Qualitative, preliminary interpretation of selected lines was performed on-site as a quality control measure. Detailed processing and interpretation was accomplished in the office and included cross correlation. The results were also correlated with relevant cross section and soil boring information at the time of the interpretation.

Interpretation of the seismic refraction data was accomplished using the Hawkins method, and double-checked by the crossover distance method. The Hawkins Method allows computation of depths at every geophone. This method provides information on thickness of various sediment layers, depth to bedrock, and rock quality. It is based on closure times from the inner

shots, and calculates true rock velocities using the apparent velocities computed from the outer shots. The critical distance method calculates bedrock depths at shot points only. The concurrent use of both interpretive methods provides an important means of checking the validity of the interpretation.

Generally, the seismic refraction method allows determination of bedrock depths with a precision of 10% or better for depths greater than 30 feet, and ±3 feet for depths less than 30 feet. Bedrock velocities can be determined with a precision of ±3% - 5%. Due to site constraints it was impossible to complete far shots on many lines. Due to this limitation depths and velocities of bedrock at the ends of the lines without far shots were determined by extrapolation. These depths are represented on the profiles by dashed lines, and velocities are shown in parenthesis. Bedrock depths with a precision of 20 – 25% can be expected in these areas. Calibration with boring data will increase the precision to within normal limits.

6.0 RESULTS

6.1 Discussion of Results

The results of the seismic refraction surveys are presented as profile cross-sections, and tabulations of depths, elevations, thicknesses and seismic velocities of subsurface layers (see Appendix). Overburden seismic velocities at this site are generally indicative of relatively dry, fine grained material (1500 ft/s) overlying water saturated material (5000 ft/s). The velocities of the bedrock are in distinct contrast to the overlying deposits.

The typical velocities for relatively sound unweathered metamorphic rock in southern New England range from 12,000 to 15,500 ft/s, and for well weathered and/or fractured rock from 8,000 to 10,500 ft/s (below the water saturated zone).

Bedrock seismic velocities do provide information concerning the degree to which bedrock is weathered, fractured and, for metamorphic rocks, foliated. In general, higher velocities indicate hard, massive bedrock, while lower velocities are often associated with rock that is less solid and more weathered and fractured.

Within a foliated rock unit, such as schist and gneiss, seismic velocities may be higher when seismic lines are oriented parallel to the strike of the foliation, and lower when seismic lines are oriented obliquely or perpendicular to the strike. This is called anisotropy and can account for different velocities within the same interval where cross lines meet. This phenomenon is clearly seen at the intersection of seismic lines SL-2 and SL-4 where an anomalous zone was observed.

6.2 Seismic Lines

The following discussion summarizes characteristics of the five seismic profiles.

Seismic Line-1

Seismic Line-1, south to north 640 feet in length, starts near the intersection of Davisville and Westcott Roads, and runs approximately parallel to Westcott Road.

The bedrock surface, from south to north, starts at a depth of about 50 feet BGS, and with some variation, is inclined more or less upward over its entire length, terminating at a depth of about 27 feet. The bedrock depths show a good correlation with cross lines SL-2, 3, and 4.

This profile shows moderate bedrock velocities (13,500-15,500 ft/s) indicative of sound, unweathered bedrock. The degree of precision for the major portion of this line set is moderate to high, and fair to moderate near Davisville Road, where an off end shot was not possible.

Seismic Line-2

Seismic Line-2, northeast to southwest and 800 feet in length starts near the edge of Allen Harbor, traverses the site obliquely, and terminates at the edge of Westcott Road.

The bedrock surface, from northeast to southwest, starts at a depth of about 79 feet BGS, and slopes generally upward to a depth of 35 feet at chainage 5+00, then slopes downward to about 46 feet at 6+80, maintaining this approximate depth over the rest of the line. The bedrock depths show good correlation with borings PGU-Z3-09.

This profile shows moderate bedrock velocities (12,000 – 15,000 ft/s) indicative of sound, unweathered bedrock. A notable feature is a low bedrock velocity zone (8,000 ft/s) located from chainage 2+00 to 2+60. This zone corresponds to a similar low velocity zone on Seismic Line 4. This may indicate the presence of a fracture or shear zone. The degree of precision for this line set is moderate to high, except at the northeasterly end of the line where no farshot could be made.

Seismic Line-3

Seismic Line-3, west to east and 760 feet in length begins near the center of Westcott Road and terminates near the westerly edge of Spink Neck Road.

The bedrock surface, from west to east, starts at a depth of about 44 feet BGS, and is inclined generally downward with minor variations to a depth of about 61 feet BGS at the end of the traverse at 7+60.

This profile shows moderate and relatively consistent bedrock velocities (13,200 – 13,700 ft/s) indicative of sound, unweathered bedrock. The degree of precision for this line set is moderate to high, except at the easterly end of the line where no farshot could be made.

Seismic Line-4

Seismic Line-4, west to east and 760 feet in length starts near the center of the unnamed perimeter road next to Westcott Road, and terminates near the westerly edge of Spink Neck Road.

The bedrock surface, from west to east, starts at a depth of about 34 feet BGS, is inclined downward to about 58 feet at chainage 3+00, then slopes upward to 49 feet BGS at 4+75, and continues with about 5 feet of variation (51 – 55 feet BGS) for the remainder of the traverse.

This profile shows moderate bedrock velocities (12,500 to 15,300 ft/s) indicative of relatively sound, unweathered bedrock, with the exception of a low velocity zone (10,500 ft/s) from chainage 2+00 to 3+20. This low velocity zone corresponds to a similar zone noted on Seismic Line-2, which intersects Line-4 in this location. This velocity may indicate the presence of a fracture or shear zone in the bedrock. The degree of precision for this line set is moderate to high, except at the easterly end where no farshot could be made.

Seismic Line-5

Seismic Line-5, south to north and 520 feet in length begins near the intersection of Spink Neck Road and Davisville Road, and terminate north of the perimeter road, near Allen Harbor.

The bedrock surface, from south to north, starts at a depth of about 62 feet BGS, is more or less horizontal over the entire length of the traverse, varying between 62 and 54 feet.

This profile shows moderate bedrock velocities (13,300 ft/s) indicative of moderately sound bedrock. The degree of precision for this line set is moderate to high, except at the northerly end, where no far shot was possible.

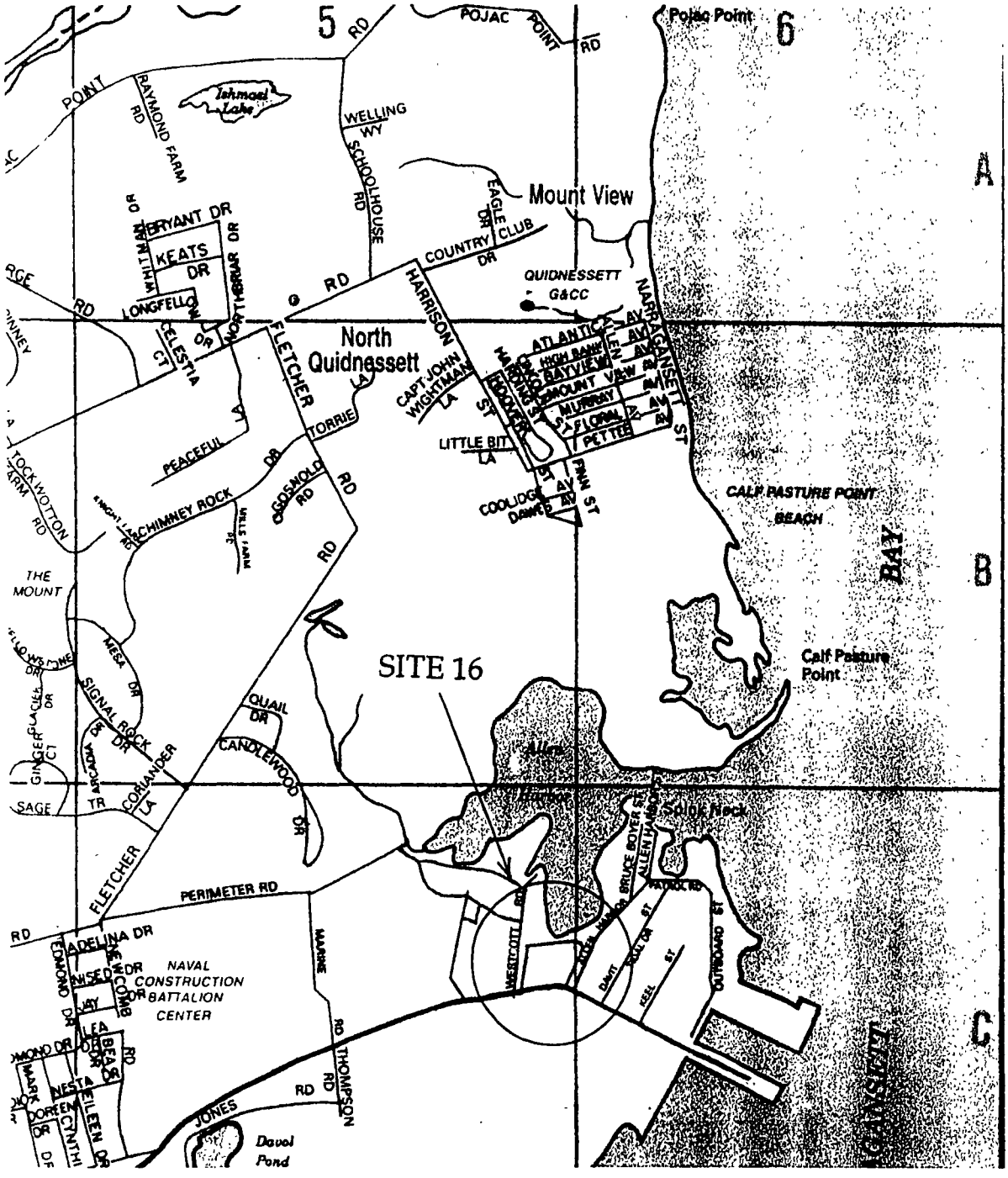
7.0 CONCLUSIONS

- The objectives for the seismic investigation were to define depths to the bedrock surface and other detectable interfaces, and to determine bedrock seismic velocities. The seismic method consistently detected bedrock, bedrock velocities, and the top of the water saturated overburden within the investigated area.

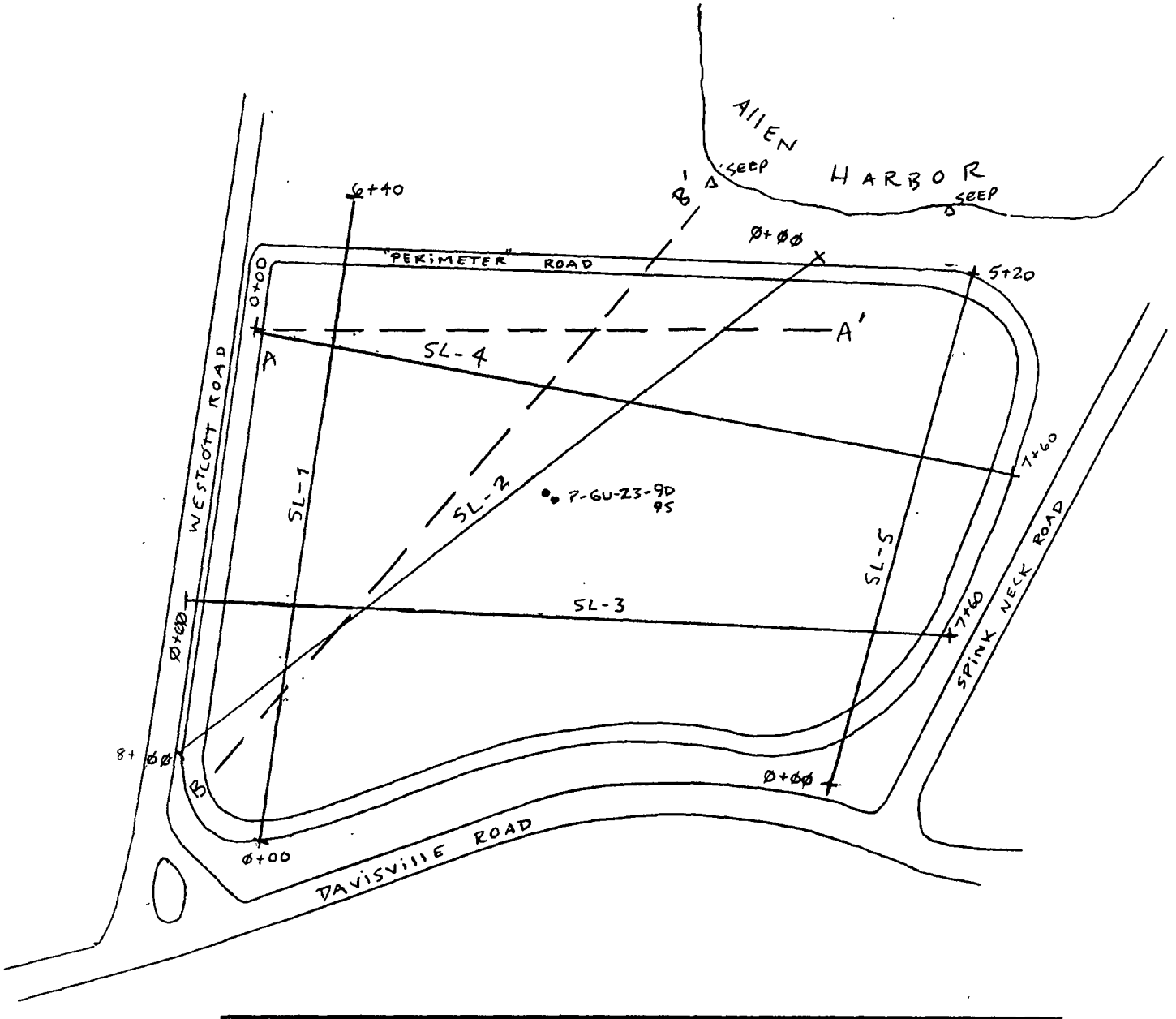
- The interpreted bedrock depths range from 27 feet to as much as 77 feet BGS. Bedrock

seismic velocities suggest relatively sound, unweathered rock over most of the site.

- A depression in the bedrock surface occurs near the intersection of seismic lines 2 and 4; the depression deepens to the northeast, toward Allen Harbor. A low bedrock velocity zone (8000 – 10, 500 ft/s) occurs approximately at the intersection of seismic lines 2 and 4, suggesting a possible fracture or shear zone in the bedrock. The correlation of this zone with the depression in the bedrock mentioned above suggests a site for further investigation.



PROJ. #	TITLE		
B99283	SITE LOCUS MAP		
DRAWN BY M. Kick	CLIENT EA Engineering, Science, and Technology		
CHECKED BY	PROJECT SITE 16, FORMER NCBC FACILITY DAVISVILLE, RHODE ISLAND		
APPROVED BY	DRAWING DATE 01/07/00	SCALE 1" = 1.8 MILES	Figure No. 1

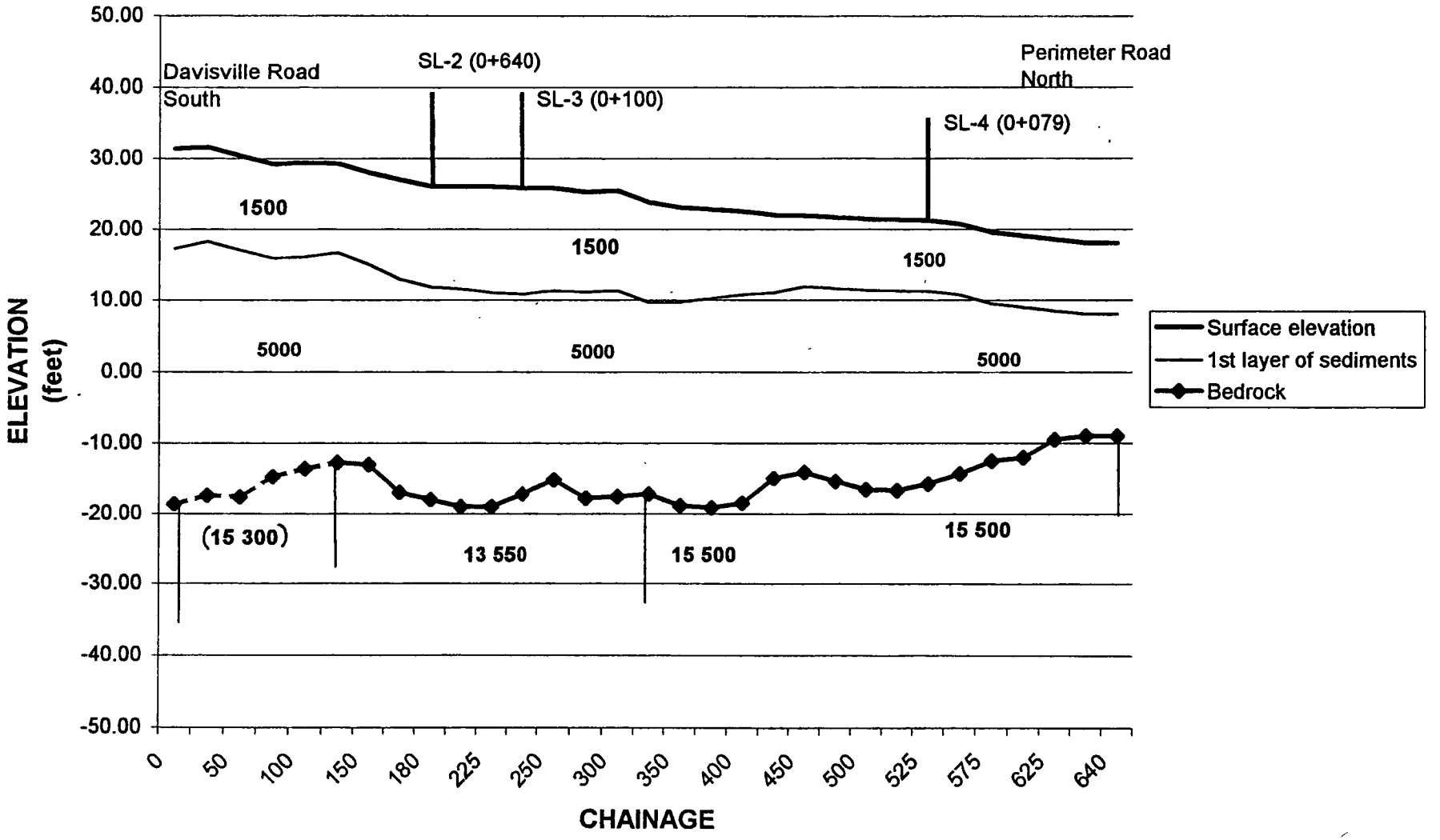


PROJ. #	TITLE		
B99283	SEISMIC LINE LOCATION MAP		
DRAWN BY M. Kick	CLIENT EA Engineering, Science, and Technology		
CHECKED BY	PROJECT SITE 16, FORMER NCBC FACILITY DAVISVILLE, RHODE ISLAND		
APPROVED BY	DRAWING DATE 01/07/00	SCALE 1" = 150'	Figure No. 2

APPENDIX

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

SEISMIC LINE SL-1-99



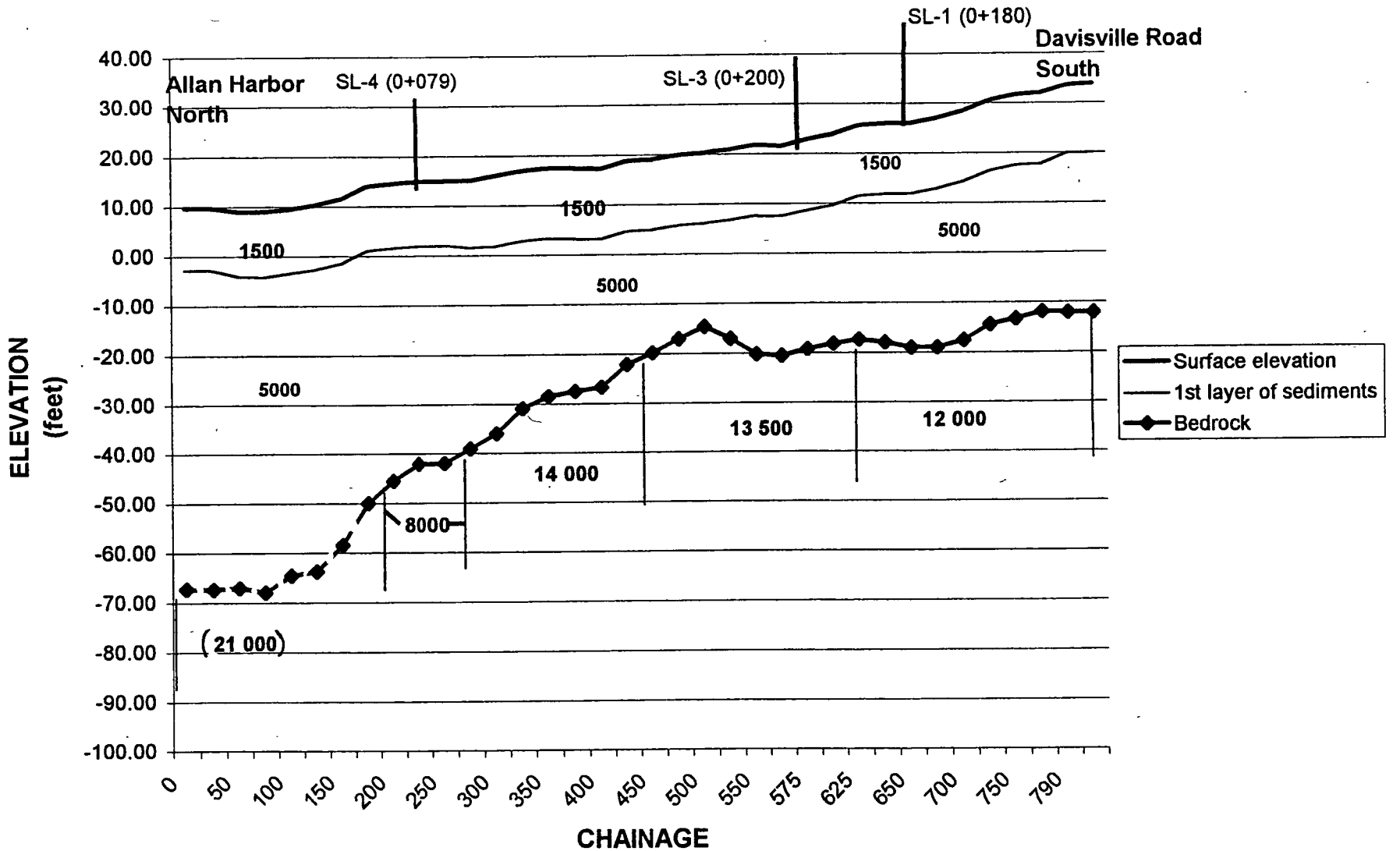
GEOPHYSICS GPR INTERNATIONAL INC.
B-99283

1/13/00

SL-1-99 BEDROCK PROFILE

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

SEISMIC LINE SL-2-99



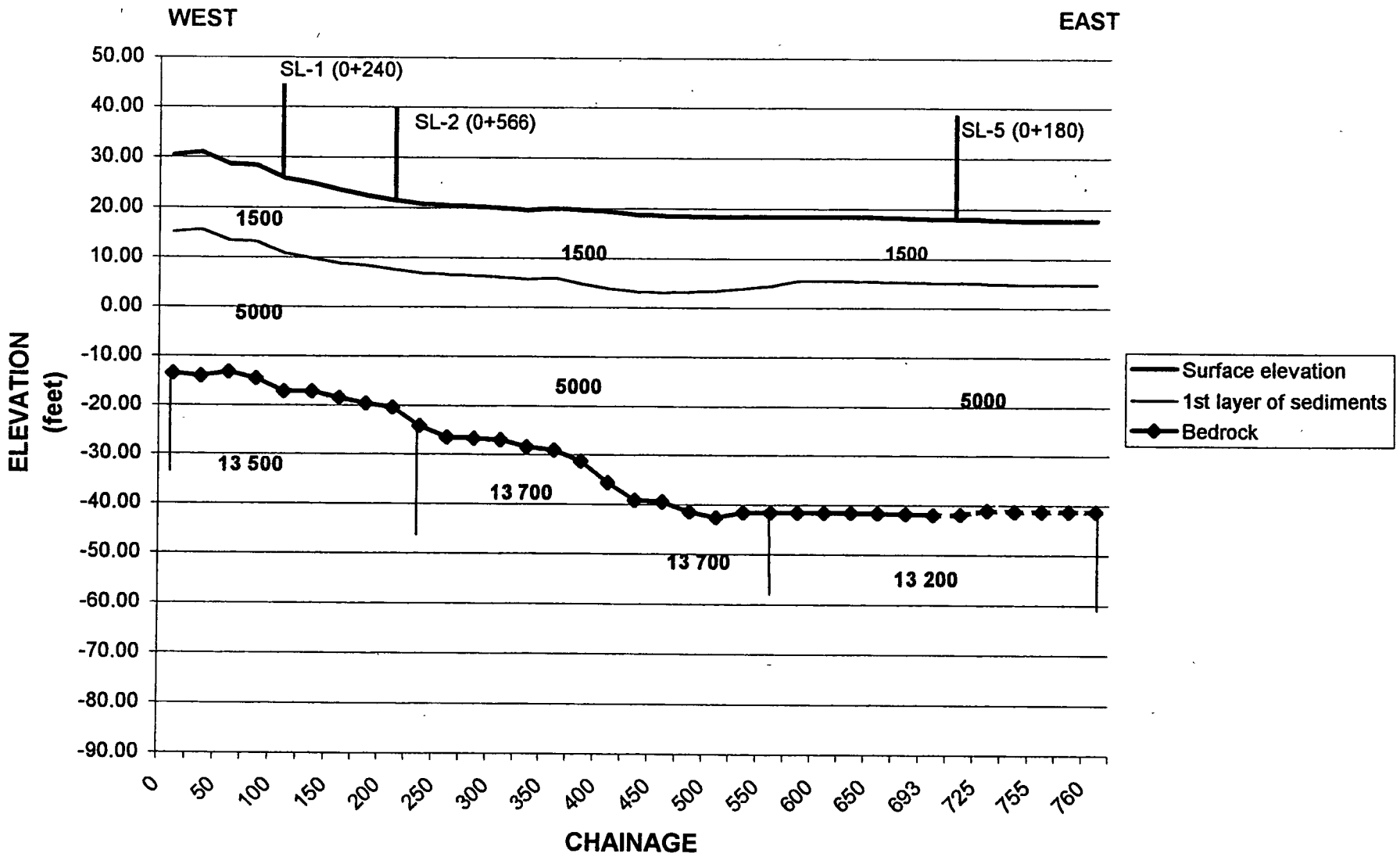
GEOPHYSICS GPR INTERNATIONAL INC.
B-99283

1/13/00

SL-2-99 BEDROCK PROFILE

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

SEISMIC LINE SL-3-99



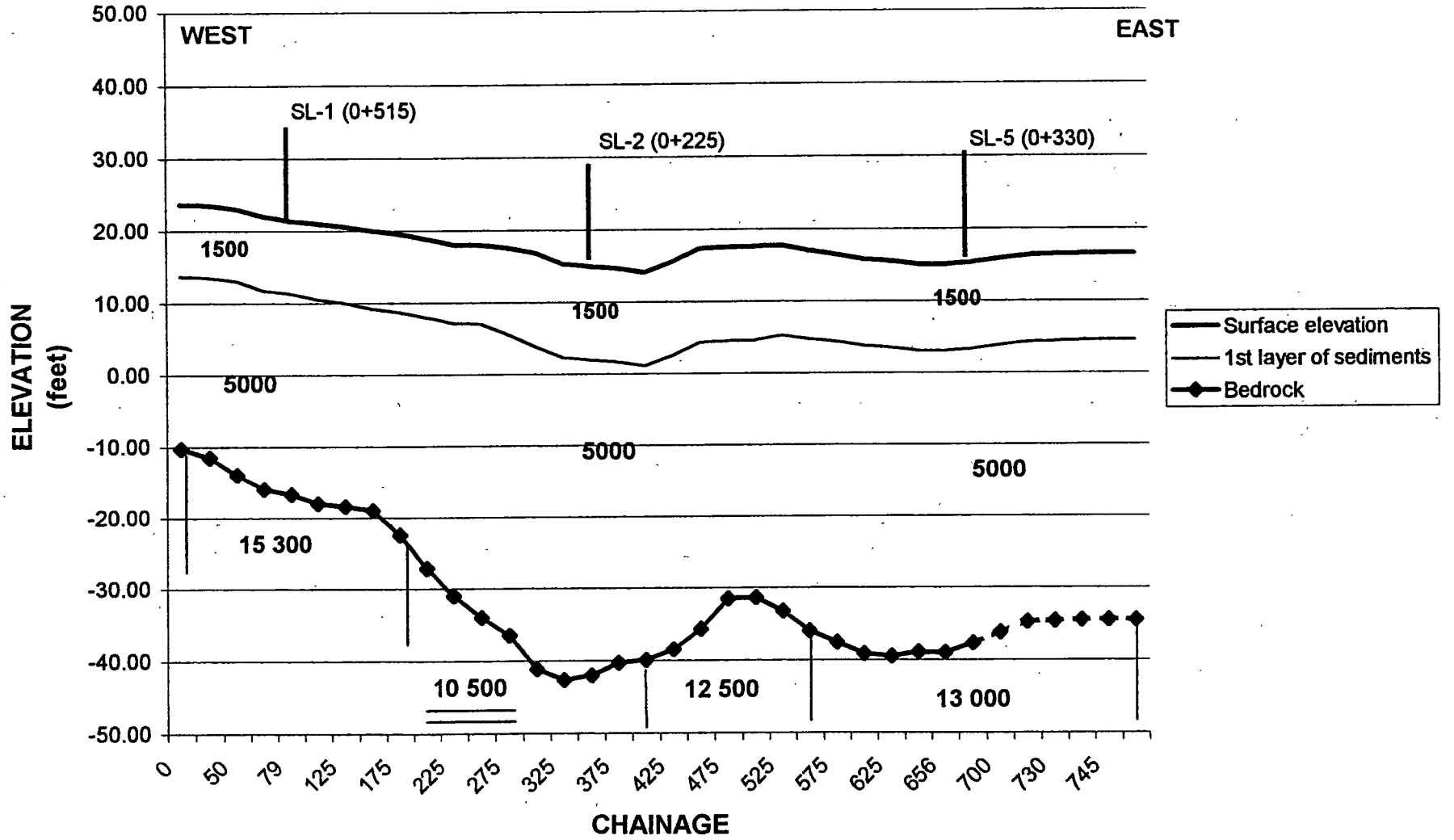
GEOPHYSICS GPR INTERNATIONAL INC.
B-99283

1/13/00

SL-3-99 BEDROCK PROFILE

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

SEISMIC LINE SL-4-99



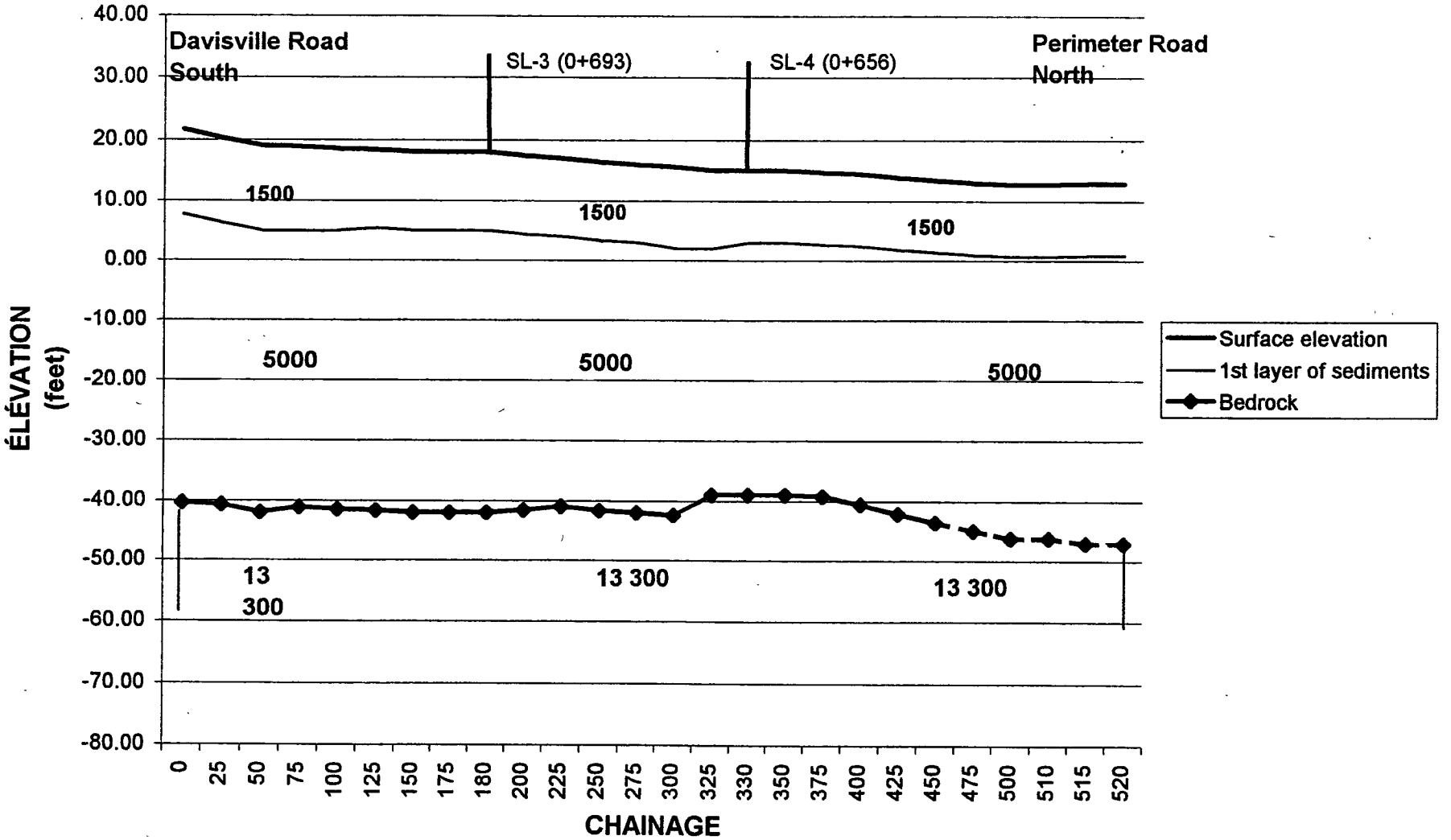
GEOPHYSICS GPR INTERNATIONAL INC.
B-99283

1/26/00

SL-4-99 BEDROCK PROFILE

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

SEISMIC LINE SL-5-99



GEOPHYSICS GPR INTERNATIONAL INC.
B-99283

1/13/00

SL-5-99 BEDROCK PROFILE

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

SITE 16, FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION RESULTS

SEISMIC LINE SL-1- 99

CHAINAGE	ELEVATION (feet)	Thickness of the 1st layer (feet)	Thickness of the 2nd layer (feet)	Bedrock depth (feet)	Seismic velocity of the 1st layer V1 (feet/sec)	Seismic velocity of the 2nd layer V2 (feet/sec)	Seismic velocity of bedrock Vr (feet/sec)
0+000	31.35	14.2	35.9	50.0	1500	5000	15300
0+025	31.58	13.4	35.6	49.0	1500	5000	15300
0+050	30.38	13.4	34.6	48.0	1500	5000	15300
0+075	29.23	13.4	30.6	44.0	1500	5000	15300
0+100	29.42	13.4	29.6	43.0	1500	5000	15300
0+125	29.25	12.6	29.4	42.0	1500	5000	15300
0+150	28.00	13.0	28.0	41.0	1500	5000	13500
0+175	27.00	14.1	29.9	44.0	1500	5000	13500
0+180	26.00	14.2	29.8	44.0	1500	5000	13500
0+200	26.00	14.5	30.5	45.0	1500	5000	13500
0+225	26.00	15.0	30.0	45.0	1500	5000	13500
0+240	25.81	15.0	28.0	43.0	1500	5000	13500
0+250	25.80	14.5	26.5	41.0	1500	5000	13500
0+275	25.20	14.2	28.9	43.0	1500	5000	13500
0+300	25.42	14.2	28.9	43.0	1500	5000	13500
0+325	23.80	14.2	26.9	41.0	1500	5000	13500
0+350	23.10	13.4	28.6	42.0	1500	5000	15500
0+375	22.80	12.6	29.4	42.0	1500	5000	15500
0+400	22.50	11.8	29.2	41.0	1500	5000	15500
0+425	22.00	11.0	26.0	37.0	1500	5000	15500
0+450	21.88	10.0	26.0	36.0	1500	5000	15500
0+475	21.60	10.0	27.0	37.0	1500	5000	15500
0+500	21.40	10.0	28.0	38.0	1500	5000	15500
0+515	21.30	10.0	28.0	38.0	1500	5000	15500
0+525	21.20	10.0	27.0	37.0	1500	5000	15500
0+550	20.70	10.0	25.0	35.0	1500	5000	15500
0+575	19.50	10.0	22.0	32.0	1500	5000	15500
0+600	19.00	10.0	21.0	31.0	1500	5000	15500
0+625	18.50	10.0	18.0	28.0	1500	5000	15500
0+640	18.04	10.0	17.0	27.0	1500	5000	15500

SITE 16, FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION RESULTS

SEISMIC LINE SL- 2 - 99

CHAINAGE	ELEVATION (feet)	Thickness of the 1st layer (feet)	Thickness of the 2nd layer (feet)	Bedrock depth (feet)	Seismic velocity of the 1st layer V1 (feet/sec)	Seismic velocity of the 2nd layer V2 (feet/sec)	Seismic velocity of bedrock Vr (feet/sec)
0+000	9.75	12.6	64.4	77.0	1500	5000	21000
0+025	9.70	12.6	64.4	77.0	1500	5000	21000
0+050	8.95	13.0	63.0	76.0	1500	5000	21000
0+075	9.00	13.3	63.7	77.0	1500	5000	21000
0+100	9.50	13.0	61.0	74.0	1500	5000	21000
0+125	10.24	13.0	61.0	74.0	1500	5000	21000
0+150	11.50	13.0	57.0	70.0	1500	5000	21000
0+175	14.00	13.0	51.0	64.0	1500	5000	21000
0+200	14.50	13.0	47.0	60.0	1500	5000	8000
0+225	14.91	13.0	44.0	57.0	1500	5000	8000
0+250	15.00	13.0	44.0	57.0	1500	5000	8000
0+275	15.00	13.5	40.5	54.0	1500	5000	14000
0+300	16.00	14.2	37.8	52.0	1500	5000	14000
0+325	17.00	14.2	33.8	48.0	1500	5000	14000
0+350	17.49	14.2	31.8	46.0	1500	5000	14000
0+375	17.44	14.2	30.8	45.0	1500	5000	14000
0+400	17.30	14.2	29.8	44.0	1500	5000	14000
0+425	18.80	14.2	26.8	41.0	1500	5000	14000
0+450	19.11	14.2	24.8	39.0	1500	5000	15500
0+475	19.90	14.2	22.8	37.0	1500	5000	15500
0+500	20.30	14.2	20.8	35.0	1500	5000	15500
0+525	20.90	14.2	23.8	38.0	1500	5000	15500
0+550	21.80	14.2	27.8	42.0	1500	5000	15500
0+556	21.50	14.0	28.0	42.0	1500	5000	15500
0+575	22.77	14.2	27.8	42.0	1500	5000	15500
0+600	23.80	14.2	27.8	42.0	1500	5000	15500
0+625	25.58	14.2	28.8	43.0	1500	5000	12000
0+640	26.00	14.2	29.8	44.0	1500	5000	12000
0+650	26.00	14.2	30.8	45.0	1500	5000	12000
0+675	27.00	14.2	31.8	46.0	1500	5000	12000
0+700	28.38	14.2	31.8	46.0	1500	5000	12000
0+725	30.50	14.2	30.8	45.0	1500	5000	12000
0+750	31.61	14.2	30.8	45.0	1500	5000	12000
0+775	32.00	14.2	29.8	44.0	1500	5000	12000
0+800	33.85	14.0	32.0	46.0	1500	5000	12000

SITE 16, FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION RESULTS

SEISMIC LINE SL- 3 - 99

CHAINAGE	ELEVATION (feet)	Thickness of the 1st layer (feet)	Thickness of the 2nd layer (feet)	Bedrock depth (feet)	Seismic velocity of the 1st layer V1 (feet/sec)	Seismic velocity of the 2nd layer V2 (feet/sec)	Seismic velocity of bedrock Vr (feet/sec)
0+000	30.44	15.4	28.6	44.0	1500	6000	13500
0+025	30.95	15.4	29.6	45.0	1500	6000	13500
0+050	28.69	15.3	26.7	42.0	1500	6000	13500
0+075	28.40	15.3	27.7	43.0	1500	6000	13500
0+100	25.81	15.0	28.0	43.0	1500	6000	13500
0+125	24.78	15.0	27.0	42.0	1500	6000	13500
0+150	23.50	14.7	27.3	42.0	1500	6000	13500
0+175	22.40	14.0	28.0	42.0	1500	6000	13500
0+200	21.50	14.0	28.0	42.0	1500	6000	13500
0+225	20.83	14.0	31.0	45.0	1500	5600	13700
0+250	20.50	14.0	33.0	47.0	1500	5600	13700
0+275	20.30	14.0	33.0	47.0	1500	5600	13700
0+300	20.00	14.0	33.0	47.0	1500	5600	13700
0+325	19.58	14.0	34.0	48.0	1500	5600	13700
0+350	19.94	14.0	35.0	49.0	1500	5600	13700
0+375	19.70	15.0	36.0	51.0	1500	5600	13700
0+400	19.40	15.6	39.4	55.0	1500	5600	13700
0+425	18.80	15.6	42.4	58.0	1500	5600	13700
0+450	18.57	15.6	42.4	58.0	1500	5600	13700
0+475	18.50	15.3	44.7	60.0	1500	5600	13700
0+500	18.40	15.0	46.0	61.0	1500	5600	13700
0+525	18.43	14.5	45.5	60.0	1500	5600	13700
0+550	18.40	14.0	46.0	60.0	1500	5600	13200
0+575	18.40	13.0	47.0	60.0	1500	5600	13200
0+600	18.40	13.0	47.0	60.0	1500	5600	13200
0+625	18.39	13.0	47.0	60.0	1500	5600	13200
0+650	18.34	13.0	47.0	60.0	1500	5500	13200
0+675	18.20	13.0	47.0	60.0	1500	5500	13200
0+693	18.00	13.0	47.0	60.0	1500	5500	13200
0+700	18.10	13.0	47.0	60.0	1500	5500	13200
0+725	17.90	13.0	46.0	59.0	1500	5500	13200
0+750	17.70	13.0	46.0	59.0	1500	5500	13200
0+755	17.70	13.0	46.0	59.0	1500	5500	13200
0+760	17.73	13.0	46.0	59.0	1500	5000	13200

SITE 16, FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION RESULTS

SEISMIC LINE SL- 4 - 99

CHAINAGE	ELEVATION (feet)	Thickness of the 1st layer (feet)	Thickness of the 2nd layer (feet)	Bedrock depth (feet)	Seismic velocity of the 1st layer V1 (feet/sec)	Seismic velocity of the 2nd layer V2 (feet/sec)	Seismic velocity of bedrock Vr (feet/sec)
0+000	23.68	10	24.0	34.0	1500	6000	14000
0+025	23.47	10	25.0	35.0	1500	6000	14000
0+050	23.00	10	27.0	37.0	1500	6000	14000
0+075	22.00	10.3	27.7	38.0	1500	6000	14000
0+079	21.30	10.0	28.0	38.0	1500	6000	14000
0+100	21.00	10.5	28.5	39.0	1500	6000	14000
0+125	20.53	10.5	28.5	39.0	1500	6000	14000
0+150	20.00	10.8	28.2	39.0	1500	6000	14000
0+175	19.50	10.8	31.2	42.0	1500	6000	14000
0+200	18.80	10.8	35.2	46.0	1500	6000	10500
0+225	18.00	10.8	38.2	49.0	1500	5500	10500
0+250	17.93	10.9	41.1	52.0	1500	5500	10500
0+275	17.50	12.0	42.0	54.0	1500	5500	10500
0+300	16.80	13.0	45.0	58.0	1500	5500	10500
0+325	15.30	13.0	45.0	58.0	1500	5500	10500
0+350	14.91	13.0	44.0	57.0	1500	5500	10500
0+375	14.65	13.0	42.0	55.0	1500	5500	10500
0+400	14.06	13.0	41.0	54.0	1500	5500	12500
0+425	15.50	13.0	41.0	54.0	1500	5000	12500
0+450	17.32	13.0	40.0	53.0	1500	5000	12500
0+475	17.50	13.0	36.0	49.0	1500	5000	12500
0+500	17.60	13.0	36.0	49.0	1500	5000	12500
0+525	17.76	12.5	38.5	51.0	1500	5000	13000
0+550	17.00	12.3	40.7	53.0	1500	5000	13000
0+575	16.40	12.0	42.0	54.0	1500	5000	13000
0+600	15.80	12.0	43.0	55.0	1500	5000	13000
0+625	15.50	12.0	43.0	55.0	1500	5000	13000
0+650	15.04	12.0	42.0	54.0	1500	5000	13000
0+656	15.00	12.0	42.0	54.0	1500	5000	13000
0+675	15.30	12.0	41.0	53.0	1500	5000	13000
0+700	15.80	12.0	40.0	52.0	1500	5000	13000
0+725	16.20	12.0	39.0	51.0	1500	5000	13000
0+730	16.40	12.0	39.0	51.0	1500	5000	13000
0+740	16.49	12.0	39.0	51.0	1500	5000	13000
0+750	16.49	12.0	39.0	51.0	1500	5000	13000

SITE 16, FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION RESULTS

SEISMIC LINE SL- 5 - 99

CHAINAGE	ELEVATION (feet)	Thickness of the 1st layer (feet)	Thickness of the 2nd layer (feet)	Bedrock depth (feet)	Seismic velocity of the 1st layer V1 (feet/sec)	Seismic velocity of the 2nd layer V2 (feet/sec)	Seismic velocity of bedrock Vr (feet/sec)
0+000	21.67	14.0	48.0	62.0	1500	5000	13300
0+025	20.26	14.0	47.0	61.0	1500	5000	13300
0+050	19.00	14.0	47.0	61.0	1500	5000	13300
0+075	18.86	14.0	46.0	60.0	1500	5000	13300
0+100	18.50	13.5	46.5	60.0	1500	5000	13300
0+125	18.36	13.0	47.0	60.0	1500	5000	13300
0+150	18.00	13.0	47.0	60.0	1500	5000	13300
0+175	18.00	13.0	47.0	60.0	1500	5000	13300
0+180	18.00	13.0	47.0	60.0	1500	5000	13300
0+200	17.40	13.0	46.0	59.0	1500	5000	13300
0+225	17.02	13.0	45.0	58.0	1500	5000	13300
0+250	16.39	13.0	45.0	58.0	1500	5000	13300
0+275	16.00	13.0	45.0	58.0	1500	5000	13300
0+300	15.60	13.5	44.5	58.0	1500	5000	13300
0+325	15.00	13.0	41.0	54.0	1500	5000	13300
0+330	15.00	12.0	42.0	54.0	1500	5000	13300
0+350	15.00	12.0	42.0	54.0	1500	5000	13300
0+375	14.70	12.0	42.0	54.0	1500	5000	13300
0+400	14.40	12.0	43.0	55.0	1500	5000	13300
0+425	13.80	12.0	44.0	56.0	1500	5000	13300
0+450	13.40	12.0	45.0	57.0	1500	5000	13300
0+475	13.00	12.0	46.0	58.0	1500	5000	13300
0+500	12.75	12.0	47.0	59.0	1500	5000	13300
0+510	12.75	12.0	47.0	59.0	1500	5000	13300
0+520	12.89	12.0	48.0	60.0	1500	5000	13300

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

Elevations

chainage	surface	1st layer	2nd layer	bedrock
0	31.35	17.2	-4.5	-18.65
25	31.58	18.22	-4.06	-17.42
50	30.38	17.02	-4.26	-17.62
75	29.23	15.87	-1.41	-14.77
100	29.42	16.06	-0.22	-13.58
125	29.25	16.85	-0.15	-12.75
150	28.00	15	0	-13.00
175	27.00	12.86	-2.86	-17.00
180	26.00	11.8	-3.8	-16.00
200	26.00	11.5	-4.5	-19.00
225	26.00	11	-4	-19.00
240	25.81	10.81	-2.19	-17.19
250	25.80	11.3	-0.7	-15.20
275	25.20	11.05	-3.65	-17.80
300	25.42	11.27	-3.43	-17.58
325	23.80	9.65	-3.05	-17.20
350	23.10	9.74	-5.54	-18.90
375	22.80	10.22	-6.62	-19.20
400	22.50	10.71	-6.71	-18.50
425	22.00	11	-4	-15.00
450	21.88	11.88	-4.12	-14.12
475	21.60	11.6	-5.4	-15.40
500	21.40	11.4	-6.6	-16.60
515	21.30	11.3	-6.7	-16.70
525	21.20	11.2	-5.8	-15.80
550	20.70	10.7	-4.3	-14.30
575	19.50	9.5	-2.5	-12.50
600	19.00	9	-2	-12.00
625	18.50	8.5	0.5	-9.50
630	18.04	8.04	1.04	-8.96
640	18.00	8.04	1	-8.96

Elevations are based on an elevation of 20.21 feet given for Boring No. P-GU-Z3-9D (top of riser).

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

Elevations

chainage	surface	1st layer	2nd layer	bedrock
0	9.75	-2.85	-54.65	-67.25
25	9.70	-2.9	-54.7	-67.30
50	8.95	-4.05	-54.05	-67.05
75	9.00	-4.3	-54.7	-68.00
100	9.50	-3.5	-51.5	-64.50
125	10.24	-2.76	-50.76	-63.76
150	11.50	-1.5	-45.5	-58.50
175	14.00	1	-37	-50.00
200	14.50	1.5	-32.5	-45.50
225	14.91	1.91	-29.09	-42.09
250	15.00	2	-29	-42.00
275	15.00	1.5	-25.5	-39.00
300	16.00	1.8	-21.8	-36.00
325	17.00	2.8	-16.8	-31.00
350	17.49	3.29	-14.31	-28.51
375	17.44	3.24	-13.36	-27.56
400	17.30	3.1	-12.5	-26.70
425	18.80	4.6	-8	-22.20
450	19.11	4.91	-5.69	-19.89
475	19.90	5.7	-2.9	-17.10
500	20.30	6.1	-0.5	-14.70
525	20.90	6.7	-2.9	-17.10
550	21.80	7.6	-6	-20.20
556	21.50	7.5	-6.5	-20.50
575	22.77	8.57	-5.03	-19.23
600	23.80	9.6	-4	-18.20
625	25.58	11.36	-3.22	-17.42
640	26.00	11.8	-3.8	-18.00
650	26.00	11.8	-4.8	-19.00
675	27.00	12.8	-4.8	-19.00
700	28.38	14.18	-3.42	-17.62
725	30.50	16.3	-0.3	-14.50
750	31.61	17.41	0.81	-13.39
775	32.00	17.8	2.2	-12.00
790	33.50	19.85	1.85	-12.15
800	33.85	19.85	1.84	-12.15

Elevations are based on an elevation of 20.21 feet given for Boring No. P-GU-Z3-9D (top of riser).

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

Elevations

chainage	surface	1st layer	2nd layer	bedrock
0	30.44	15.04	1.84	-13.56
25	30.95	15.55	1.35	-14.05
50	28.69	13.39	1.99	-13.31
75	28.40	13.1	0.7	-14.60
100	25.81	10.81	-2.19	-17.19
125	24.78	9.78	-2.22	-17.22
150	23.50	8.8	-3.8	-18.50
175	22.40	8.4	-5.6	-19.60
200	21.50	7.5	-6.5	-20.50
225	20.83	6.83	-10.17	-24.17
250	20.50	6.5	-12.5	-26.50
275	20.30	6.3	-12.7	-26.70
300	20.00	6	-13	-27.00
325	19.58	5.58	-14.42	-28.42
350	19.94	5.94	-15.06	-29.06
375	19.70	4.7	-16.3	-31.30
400	19.40	3.8	-20	-35.60
425	18.80	3.2	-23.6	-39.20
450	18.57	2.97	-23.83	-39.43
475	18.50	3.2	-26.2	-41.50
500	18.40	3.4	-27.6	-42.60
525	18.43	3.93	-27.07	-41.57
550	18.40	4.4	-27.6	-41.60
575	18.40	5.4	-28.6	-41.60
600	18.40	5.4	-28.6	-41.60
625	18.39	5.39	-28.61	-41.61
650	18.34	5.34	-28.66	-41.66
675	18.20	5.2	-28.8	-41.80
693	18.00	5	-29	-42.00
700	18.10	5.1	-28.9	-41.90
725	17.90	4.9	-28.1	-41.10
750	17.70	4.7	-28.3	-41.30
755	17.70	4.7	-28.3	-41.30
758	17.70	4.73	-28.27	-41.27
760	17.73	4.73	-28.27	-41.27

Elevations are based on an elevation of 20.21 feet given for Boring No. P-GU-Z3-9D (top of riser).

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

Elevations

chainage	surface	1st layer	2nd layer	bedrock
0	23.68	13.68	-0.32	-10.32
25	23.47	13.47	-1.53	-11.53
50	23.00	13	-4	-14.00
75	22.00	11.7	-5.7	-16.00
79	21.30	11.3	-6.7	-16.70
100	21.00	10.6	-7.5	-18.00
125	20.53	10.03	-7.97	-18.47
150	20.00	9.2	-8.2	-19.00
175	19.50	8.7	-11.7	-22.50
200	18.80	8	-16.4	-27.20
225	18.00	7.2	-20.2	-31.00
250	17.93	7.03	-23.17	-34.07
275	17.50	5.5	-24.5	-36.50
300	16.80	3.8	-28.2	-41.20
325	15.30	2.3	-29.7	-42.70
350	14.91	1.91	-29.09	-42.09
375	14.65	1.65	-27.35	-40.35
400	14.06	1.06	-26.94	-39.94
425	15.50	2.5	-25.5	-38.50
450	17.32	4.32	-22.68	-35.68
475	17.50	4.5	-18.5	-31.50
500	17.60	4.6	-18.4	-31.40
525	17.76	5.26	-20.74	-33.24
550	17.00	4.7	-23.7	-38.00
575	16.40	4.4	-25.6	-37.60
600	15.80	3.8	-27.2	-39.20
625	15.50	3.5	-27.5	-39.50
650	15.04	3.04	-26.96	-38.96
656	15.00	3	-27	-39.00
675	15.30	3.3	-25.7	-37.70
700	15.80	3.8	-24.2	-36.20
725	16.20	4.2	-22.8	-34.80
730	16.40	4.4	-22.6	-34.60
740	16.49	4.49	-22.51	-34.51
745	16.49	4.49	-22.51	-34.51
750	16.49	4.49	-22.51	-34.51

Elevations are based on an elevation of 20.21 feet given for Boring No. P-GU-Z3-9D (top of riser).

FORMER NCBC DAVISVILLE FACILITY
SEISMIC REFRACTION SURVEY 1999

Elevations

chainage	surface	1st layer	2nd layer	bedrock
0	21.67	7.67	-26.33	-40.33
25	20.26	6.26	-26.74	-40.74
50	19.00	5	-28	-42.00
75	18.86	4.86	-27.14	-41.14
100	18.50	5	-28	-41.50
125	18.36	5.36	-28.64	-41.64
150	18.00	5	-29	-42.00
175	18.00	5	-29	-42.00
180	18.00	5	-29	-42.00
200	17.40	4.4	-28.6	-41.60
225	17.02	4.02	-27.98	-40.98
250	16.39	3.39	-28.61	-41.61
275	16.00	3	-29	-42.00
300	15.60	2.1	-28.9	-42.40
325	15.00	2	-26	-39.00
330	15.00	3	-27	-39.00
350	15.00	3	-27	-39.00
375	14.70	2.7	-27.3	-39.30
400	14.40	2.4	-28.6	-40.60
425	13.80	1.8	-30.2	-42.20
450	13.40	1.4	-31.6	-43.60
475	13.00	1	-33	-45.00
500	12.75	0.75	-34.25	-46.25
510	12.75	0.75	-34.25	-46.25
515	12.89	0.89	-35.11	-47.11
520	12.89	0.89	-35.11	-47.11

Elevations are based on an elevation of 20.21 feet given for Boring No. P-GU-Z3-9D (top of riser).

THE SEISMIC REFRACTION METHOD

The seismic refraction method is used to infer subsurface conditions on the basis of contrasting seismic wave velocities. The primary goal of the seismic survey is to rapidly and efficiently obtain subsurface information, thereby reducing direct investment costs, such as drilling. Geological information typically obtained from a well-planned and executed seismic refraction survey will include: depth and configuration of the bedrock surface, nature and competency of bedrock (degree of fracturing, alteration, weathering), whether it is faulted or sheared, nature of overburden, and depth to the water table. Modern portable equipment makes the method accessible to remote and rough regions. A review of the seismic refraction theory, field methods and interpretational procedures can be found in Dobrin (1976) and Telford et al (1990).

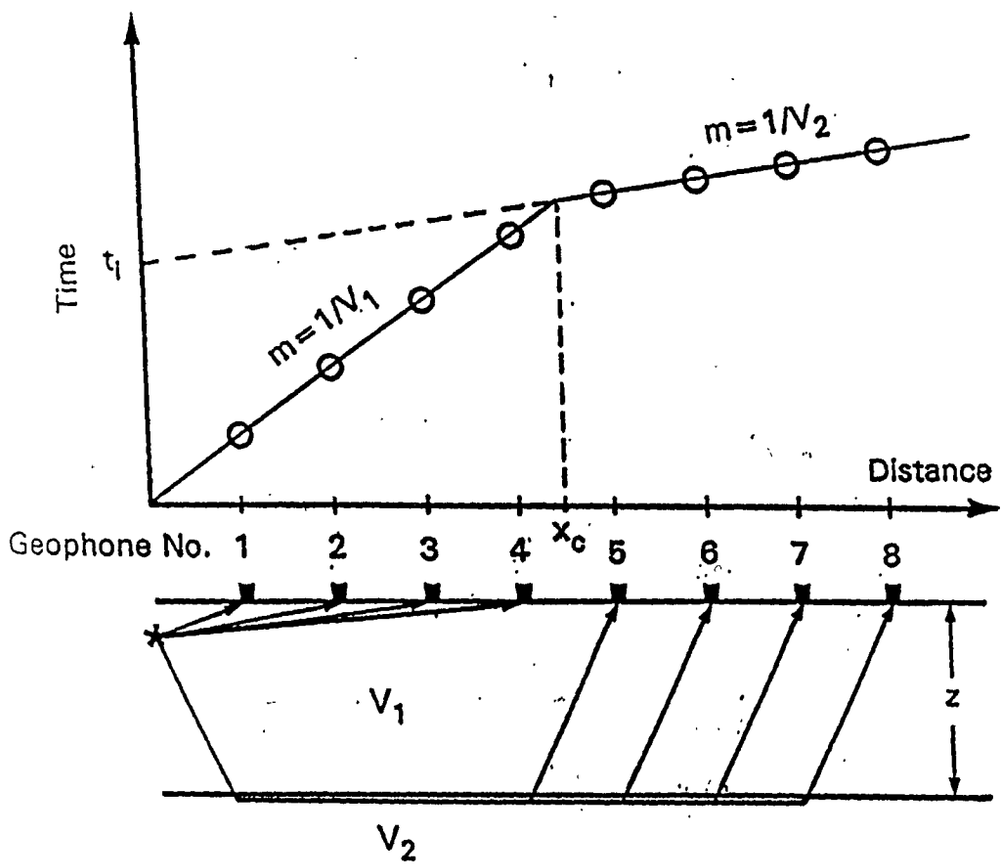
INSTRUMENTATION

The instrumentation involved in a seismic refraction survey consists of an acoustic seismic energy source to generate seismic waves, a line of geophones to detect the seismic energy, and a seismograph which is essentially a highly accurate stopwatch. By measuring the arrival times of the first seismic waves at various distances from the energy source (shotpoint), depths to interfaces and seismic velocities can be determined Seismographs are usually 12 or 24-channel, in that they can simultaneously record the energy arrivals at 12 or 24 geophones. The record of these vibrations is a seismogram Digital seismographs (for example, ABEM Terraloc, EG&G SMARTSEIS S24) acquire data with a built-in computer, whereas analog seismographs (e.g. ABEM Trio) output the data to photographic paper as it is acquired. The energy source must be coupled to the seismograph so that the instant of detonation or impact can be recorded. Timing marks, at 1 or 2 milliseconds intervals, are provided to permit very accurate estimates of arrival times.

FUNDAMENTAL PRINCIPLES

The seismic refraction method relies on measuring the transit time of the seismic wave that takes the shortest time to travel from the shotpoint to each geophone. The fastest seismic waves are the compressional (P) or acoustic waves, where displaced particles oscillate in the direction of wave propagation. The energy that follows this first arrival, such as reflected waves or transverse (S) waves, is not considered under routine seismic refraction interpretation.

Figure 1 shows a simple geological structure, where a layer with a velocity of V_1 overlies a second layer with a higher velocity, V_2. At one end of the spread, an energy source is triggered and the vibrations at each geophone are recorded. Seismic waves will travel via the direct path from the source to each of the geophones. Waves may also be refracted at some critical angle along the interface and travel at the higher velocity V_2.



V_1 = Velocity of Upper Layer
V_2 = Velocity of Lower Layer
m = Slope of Line Segment
x_c = Crossover Distance
t_i = Intercept Time

$$z=\frac{x_c}{2}\sqrt{\frac{V_2-V_1}{V_2+V_1}} \quad \text{or} \quad z=\frac{t_i}{2}\frac{V_2V_1}{\sqrt{V_2^2-V_1^2}}$$

Principles of Seismic Refraction

Fig. 3

Energy is continually transmitted back to the surface as it travels along the interface. A time-distance graph may be constructed, plotting the first arrival transit times as a function of position along the seismic line. The first arrival at the closest geophones is the direct wave. However, at the critical or crossover distance (Xc) the refracted wave which travels along the higher velocity layer overtakes the direct arrival. The inverse slope of a straight line segment of the time-distance curve is equal to the velocity in that layer. The crossover distance is directly proportional to the depth of the interface.

INTERPRETATION

The simplest methods of interpretation are illustrated in figure 1. Having determined the velocity of compressional waves through each layer, the calculation of depths can be done according to crossover distance or the intercept time formulas. The case of a horizontal interface, illustrated in figure 1, becomes slightly more complicated if the planar interface is dipping. The general case of an irregular interface can be handled by more complex interpretational calculations, including various delay-time methods, the reciprocal and generalized reciprocal methods, and ray tracing. One method may be better suited than another to a particular geological environment.

LIMITATIONS

Two important limitations of the seismic refraction method must be kept in mind. First, layers of insufficient thickness and velocity contrast will not produce first arrivals at the surface. This is the **hidden layer** problem. For example, a thin layer of glacial till or weathered bedrock overlying unweathered bedrock might be such a hidden layer. The presence of a hidden layer will lead to calculated depths that are too shallow. Secondly, the seismic refraction method requires that the velocities of all layers increase with depth. A low velocity layer at depth is termed a **blind zone**. Such layers will not yield first arrivals because critical refractions cannot occur. Computed depths will be greater than actual depths in this case. Fortunately, such velocity reversals are seldom encountered in shallow surveys. The generalized reciprocal method can be used to infer the absence or presence of blind zones and hidden layers. However, correlation with boreholes and uphole surveys may be necessary to accurately gauge the effects of such layers.

DESCRIPTIVE CLASSIFICATION OF BEDROCK SEISMIC VELOCITIES WITH RQD VALUES

The following table represents a descriptive classification of bedrock seismic velocities that can be correlated with RQD (Rock Quality Designation) values. The following table is extracted from a study by Coon and Merritt (ASTM STP 477).

This table may proved helpful for the developmental phase of this project, in terms of planning, security, and cost. The seismic refraction method measures the velocity of the bedrock to a depth of approximately 45 feet.

TABLE

ENGINEERING CLASSIFICATION FOR IN SITU ROCK (1)				
RQD (%)	VELOCITY INDEX	SEISMIC VELOCITY (ft/s) (2)	DESCRIPTION	SEISMIC DESCRIPTION
0 - 25	0.00 - 0.20	8000	Very poor	Low velocity
25 - 50	0.20 - 0.40	8000 - 11400	Poor	Low velocity
50 - 75	0.40 - 0.60	11400 - 14000	Fair	Intermediate
75 - 90	0.60 - 0.80	14000 - 16000	Good	Sound rock
90 - 100	0.80 - 1.00	16000 - 22000	Excellent	Sound rock

(1) Taken and adapted from: Coon,R.F. and Merritt,A.H.,**Predicting in-situ Modulus of Deformation using Rock Quality Indexes,** Determination of the in-situ modulus of deformation of rock, ASTM STP 477, American Society for testing and materials 1970, pp. 154-173.

(2) Taking into account a velocity of 18 000 ft/sec for the compressional wave measured in the laboratory (V_L)for a limestone rock.

The classification of Coon and Merritt is based upon the velocity index property of in situ rock, which is a measure of the discontinuities in the rock mass. According to Coon and Merritt, the velocity index is defined as the square of the ratio of seismic field velocity to laboratory compressional wave velocities, measured on a core sample, representative of a sound rock. The field seismic velocities are normalized by the laboratory results in order to minimize the influence of lithology. Hence as the number of joints decreases, the ratio of the velocities will approach one. This ratio is then squared to make the velocity index equivalent to the ratio of dynamic moduli.

Attachment 2

Standard Operating Procedures for Seismic Refraction Surveys

Geophysical Applications, Inc.
August 1999

Standard Operating Procedures for Seismic Refraction Surveys

Geophysical Applications, Inc.
August 1999

Purpose

This document provides guidelines for planning and conducting seismic refraction surveys. Seismic refraction surveys are often utilized during environmental or geotechnical investigations to measure depths to ground water, glacial till, or bedrock. Refraction depth calculations are based on the assumption that seismic velocity values increase with deeper geologic strata. Only features that exhibit contrasting seismic velocity values are identifiable with this method (e.g. saturated overburden versus bedrock, or fractured bedrock versus unfractured bedrock).

Pre-Survey Planning

Data requirements will be reviewed with the client to determine the survey objectives. Possible objectives include measuring depths to geologic strata, or locating bedrock fractures to be sampled with monitoring wells.

Background information should be requested from the client that may assist design of an effective survey. Such information may include:

- visible bedrock outcrops near the survey area
- previous seismic survey results or boring logs from the site vicinity
- available descriptions of regional geology.

The degree of accuracy required in the survey deliverables shall be discussed with the client. In general, higher-resolution surveys may require closer geophone spacings, more shot points, or more detailed ground surface elevation control than reconnaissance surveys.

If the approximate thickness and seismic velocity values of expected geologic strata are available, then forward travel-time models shall be prepared to confirm that enough seismic arrival times will be obtained to measure depths to each expected layer. In general, if fewer than two seismic arrivals are expected from a critical layer, then the geophysicist shall consider modifying geophone spacings or shot positions such that more arrival times will be detected.

Equipment Preparation

An equipment checklist (example attached) will be prepared before loading equipment into the field vehicle. Project-specific requirements (such as type of seismic energy source, or materials needed for equipment decontamination) will be indicated on the equipment checklist.

Instrumentation will be functionally-checked before mobilization. The field geophysicist will initial and date the checklist when all equipment is loaded, and a copy of the completed checklist will be placed in the project files.

Site Preparation

Proposed refraction traverses will be positioned by taped or paced distance measurements, and transit or compass bearings referenced to roads, buildings, or other noteworthy features. Brushcutting, if needed, shall be performed before laying out seismic cables to avoid cutting the cables with sharp tools.

If explosive energy sources are to be used, Dig-Safe or similar utility notification and a blasting permit shall be obtained by the subcontracted blaster as required by State law.

Data Acquisition

A field book shall be maintained during each survey to record geophone and shot positions, ground surface elevations, distance measurements between seismic spreads and noteworthy features, or other field observations. Each field book shall be labelled with the client's name, site name, job number, and dates of work.

Seismic cables shall be placed along the intended alignment, as straight as permitted by site conditions. Bends in the traverse shall be noted in the field book, preferably by noting compass bearings and lengths of each line segment. Twenty-four channel geophone arrays with 10 or 20-foot geophone spacings are generally used. Distances along each spread shall preferably increase from west to east, or south to north, and any exceptions shall be noted. Traverse orientations shall be recorded in the field book and on a plan map (if available).

Geophones shall be placed at each takeout along the seismic cables. Spiked geophones will be used in soft ground, and tripod-based geophones will be used on hard surfaces. If spike-based geophones are used, loose soil or forest litter shall be removed from the geophone positions with a shovel or by scraping with a boot heel to facilitate coupling with firm soil. If tripod-based geophones are used, then a small sandbag or similar weight shall firmly couple the geophone to the ground surface.

Geophones that must be located more than one foot from their intended positions due to site conditions will be noted in the field book.

Six shot points are typically located along each traverse, and all shotpoints shall be marked with flagging or stakes. Shot points will be located at each end of the geophone array, and usually between the 8th and 9th geophones and between the 16th and 17th geophones. Additional shots shall be offset outside the array endpoints, if permitted by site conditions. Offset shots will be located sufficiently far from the array end points to produce refracted bedrock arrivals at all geophones, if permitted by site conditions. All shot stations shall be identified in the field notebook.

If explosive energy sources are used, then shotholes will be driven at least two feet deep with a steel bullpoint and a sledge hammer. If a Betsy firing rod is used as an energy source, then shotholes will be driven at least one foot deep. Actual shot hole depths, and the energy source used, shall be noted in the field book.

The ABEM Terraloc Mark 6 seismograph shall be set up using a twelve-volt battery as a power source. Seismic cables and shot lines shall be connected to the seismograph, paying careful attention to correctly identify geophone channels 1 through 12 and 13 through 24. The seismograph shall be set up to sample the seismic waveforms at 0.25-millisecond intervals or less. Seismic recording duration shall be at least 25% longer than the latest expected arrival times. If necessary, record duration will be modified during the field program (for example, if bedrock depth increases and later arrival times are observed). In general, a low-cut filter (typically 10 to 30 hertz) should be used to minimize ambient vibration or wind interference. A 60-hertz notch filter shall be used only if interference from nearby electrical cables is detected.

The field geophysicist will use the ABEM's software menus to assign distance stations to each geophone and shot point. Distances shall be in feet. Each recorded seismogram will be identified by the shot station and a three to six-digit record number. The record number, shot station, type and amount of energy source, and shot depth shall be recorded in the field book.

The field geophysicist will evaluate each seismogram to determine whether arrival times can be measured at each geophone. Records will be re-shot, or stacked with successive shots, if needed to obtain more distinct first arrivals. Each seismogram will be stored on the seismograph's hard drive, and transferred to floppy diskette at the conclusion of each geophone spread.

Observed distances between an end shot and the first refracted arrivals from the bedrock surface shall determine the minimum offset shot distance (i.e., for shots outside the

geophone array endpoints). If the survey objective entails bedrock depth profiling, at least one seismogram from each geophone array shall be checked using the seismograph's software to confirm the velocity of seismic arrivals judged to represent bedrock. If the measured velocity value is lower than values that typically represent bedrock (e.g. less than 10,000 feet per second) then longer offset shots or longer geophone spacings will be used to assure that adequate depth penetration is achieved.

Elevation differences between geophones shall be noted using a hand-held level, or by visual estimation. Elevation differences between shot points will be measured using an electronic theodolite and a surveyor's elevation rod. All elevation observations shall be noted in the field book.

Adjacent geophone spreads shall be overlapped by at least one geophone position to permit modeling via delay-time or generalized reciprocal method (GRM) techniques.

Data Analysis

First arrival times will be measured using the seismograph or a separate software package. Arrival times will be recorded on floppy diskette, and formatted for input into SIPT2, ViewSeis, or SeisOpt2D modeling software. If arrival times are picked by a person other than the project's senior geophysicist, then the senior geophysicist shall spot-check the arrival time picks before modeling.

The software package to be used for data analysis will depend upon the survey objectives. In general, depth modeling using SIPT2 delay-time software will be performed to produce cross sections showing seismically-detected strata. GRM or other modeling may also be employed for projects where an intended objective is to identify discrete low-velocity zones that might represent fractured bedrock. ViewSeis GRM and SeisOpt2D software can import a SIPT2 data file, preserving layer assignments and shot parameters (location, depth, etc.).

Arrival times and shot parameters shall be entered into the interpretive software, and each arrival time shall be assigned to a layer (except for SeisOpt2D). Layer numbers increase from top to bottom of a geologic cross section (i.e., unsaturated overburden is layer no. 1, saturated overburden is layer no. 2, and bedrock is layer no. 3). Layer assignments and calculated layer depths shall be checked by the senior geophysicist, and compared to existing boring logs or geologic cross sections. The geophysicist shall endeavor to obtain calculated layer depths that agree to within $\pm$ 5% or better with nearby borings or intersecting seismic traverses. If such agreement cannot be obtained, then the geophysicist shall endeavor to determine the cause of the discrepancy.

Calculated layer depths and velocity values shall be transferred to presentation graphics software to prepare final cross sections. These cross sections shall show the seismically-inferred strata, calculated compressional seismic velocity values, and nearby borings, outcrops, or other relevant features. Cross sections will be plotted using horizontal and vertical scales of one inch equals fifty feet, unless alternative depth scales are required to present especially shallow or deep strata.

Attachment 3

Standard Operating Procedures for Geophysical Logging Surveys

Geophysical Applications, Inc.
August 1999

Standard Operating Procedures for Borehole Geophysical Surveys

Geophysical Applications, Inc.
November 2000

Purpose

This document provides guidelines for planning and conducting borehole geophysical logging surveys. These surveys are typically performed to help characterize overburden or bedrock stratigraphy or lithology, and also to identify and characterize water-bearing bedrock fractures.

Pre-Survey Planning

Data requirements will be reviewed with the client to determine the survey objectives. Possible objectives include measuring depths to geologic strata, or locating bedrock fractures with to help place monitoring well screens.

Background information should be requested from the client that may assist design of effective surveys. Such information may include:

- borehole diameter, depth, and type of well construction
- previous geologic or geophysical logging results from the site vicinity
- available descriptions of regional geology.

The survey goals shall be reviewed with the client, and the logging suite shall be revised to address, to the extent possible, the client's objectives.

Equipment Preparation

An equipment checklist will be prepared before loading equipment into the field vehicle. Project-specific requirements (such as downhole pumps or materials needed for equipment decontamination) will be indicated on the equipment checklist.

Instrumentation will be functionally checked and cleaned before mobilization. The field geophysicist will initial and date the checklist when all equipment is loaded, and a copy of the completed checklist will be placed in the project files.

Site Preparation

The logging equipment shall be mobilized to the jobsite, and unpacked. Generators or equipment boxes removed from the field vehicle shall be placed in visible locations where they are unlikely to be run over by vehicles or tripped over by pedestrians.

Data Acquisition

General

A field book shall be maintained describing the wells or boreholes logged, the logging probes used, datafile names, preset starting depths for each logging probe, or other field observations. Each field book shall be labeled with the client's name, site name, job number, and dates of work.

Borehole logging instrumentation shall be assembled consistent with the manufacturer(s) instructions. A tripod or pulley shall be positioned over the borehole to be logged, to guide the logging probe into the borehole. A thin coating of silicone grease shall be applied to each o-ring that protects electrical connections between the cablehead and a logging probe. Excess grease shall be wiped off the cablehead and probe exterior after assembly.

Chemical-resistant gloves (or other protective clothing, as required by the site health and safety plan) shall be worn when handling possibly-contaminated wirelines and logging probes.

Geophysical Logging

If geophysical logging is to be performed, the desired logging probe shall be attached to the cablehead. The logging software shall be initiated, and the correct probe driver selected.

The logging probe shall be positioned so that either the probe top or cablehead top is equal to the ground surface or casing top. The probe's preset depth shall be calculated and entered into the data-acquisition software. The preset depth typically consists of the probe length provided by the manufacturer, minus the casing stickup height, plus the cablehead length (if the cablehead top is at the casing top).

A log datafile shall be opened, and data recording initiated after any necessary instrument-setting adjustments (most logs can be recorded with default probe-driver settings). The acoustic televiewer recording window shall be adjusted so as to ignore reflections that occur inside the televiewer probe (typical minimum recording time of 82 microseconds).

Logging shall be performed at a speed suitable for the data being recorded. Fluid temperature and fluid resistivity logs shall be obtained in an undisturbed water column (to the extent possible) at a slow downward logging speed (typically less than 5 feet per minute). Caliper logs may be recorded at 10 to 15 feet per minute, while logging upwards. Polyprobe or natural gamma logs may be recorded at speeds up to 15 feet per minute, while logging either upward or downward. Acoustic or optical televiewer probes shall be lowered at speeds less than 15 feet per minute. Acoustic or optical televiewer

data shall generally be recorded only while logging upward at speeds permitted by the data acquisition software (typically less than 3 feet per minute, depending upon the data-acquisition parameters).

Acoustic and optical televiewer probes shall be utilized only after less-expensive logging probes (typically including at least a caliper log) have been lowered and raised through the borehole.

Heat-pulse flowmeter logging is performed at discrete intervals. The flowmeter's centralizers shall be selected so as to center the flowmeter probe within the borehole. The flowmeter's diverter petals shall be selected so as to provide as positive a seal as is possible between the borehole wall and the flowmeter probe. Flowmeter measurement depths shall be selected above or below suspected bedrock fractures, typically based on visual inspection of preliminary caliper, fluid temperature, and fluid resistivity logs. Flowmeter measurements shall be repeated at each depth interval until the measured flow values agree within $\pm$ 0.1 gallons per minute (gpm).

If both ambient and pumping flowmeter data are recorded, the ambient measurements shall be obtained during the downward run, and the pumping measurements shall be obtained during the upward run.

The logging wireline shall be de-contaminated with an Alconox wash and tap water rinse while raising the logging probe upward out of the borehole. The probe and any accessories (centralizers, pumps, etc.) shall be de-contaminated in a similar manner.

All geophysical-log data-files shall be stored on the field computer, and copied on-site onto another media (floppy disk, Zip disk, etc.) to assure redundant data storage.

Data Analysis

Geophysical log data shall be plotted using WellCAD or equivalent software. Each log shall be annotated with the client's name, project location, and well or borehole designation.

Log plot scales shall be selected so as to present as much detail as possible. Wrap-around of one or two times the log-display panel shall be acceptable. If more than one or two wrap-arounds are needed to display both large and small inflections on the same log, then that log shall be presented using two or more scales (on the same or different pages).

The logs shall be edited for spurious data values (e.g. electric logs above the water table or within steel casing), and annotated (or discussed in an accompanying report text).

Any site-specific limitations of the geophysical log data shall be noted on the log, or in the accompanying report text.

Appendix A

Quality Assurance Project Plan Addendum

Quality Assurance Project Plan Addendum

Remedial Investigation of Installation Restoration Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area)

Naval Construction Battalion Center North Kingstown, Rhode Island

Contract No. N62472-92-D-1296
Delivery Order No. 0097

Prepared for

Department of the Navy
Northern Division
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop No. 82
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November 2000
FINAL
EA Project No. 29600.97.3101

Quality Assurance Project Plan Addendum

Remedial Investigation of Installation Restoration Program Site 16 (Former Creosote Dip Tank and Fire Fighting Training Area)

Naval Construction Battalion Center North Kingstown, Rhode Island

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INTRODUCTION

This Quality Assurance Project Plan (QAPP) Addendum was written for the U.S. Navy, Northern Division, Naval Facilities Engineering Command to describe the additional field and laboratory testing program that will be utilized for the collection and reporting of analytical data in support of the Navy's remedial investigation (RI) of Site 16. This investigation, at the Naval Construction Battalion Center (NCBC), North Kingstown, Rhode Island, is being performed under the Base Realignment and Closure Act Contract No. N62472-92-D-1296, Contract Task Order 0097. The work will include those site characterization efforts necessary to supplement the previously scoped ecological and human health risk assessment for the Site 16. The locations of contamination as detected by the Membrane Interface Probe (MIP) screening during the execution of the Final Work Plan (March 2000) suggest that chlorinated volatile organic compounds are moving on to the site and that another source, unrelated to the known or suspected former Site 16 operations, appears to be contributing to ground-water contamination. Therefore, the majority of the work presented in this Addendum is related to investigation of adjacent offsite areas.

Site 16, formerly designated Environmental Baseline Survey Review Item 28 and then Study Area 16, is located in the eastern portion of Zone 3 at NCBC Davisville in the Town of North Kingstown, Rhode Island (Figure 1). The Site is generally defined as the area surrounded by Davisville Road to the south, Westcott Road to the west, Allen Harbor Road to the east, and Allen Harbor to the north (Figure 2). The offsite investigation area includes the approximately 300 ft adjacent and east, south, and west of the Site (Figure 2). A description and history of the site is summarized in Chapter 2 of the Work Plan.

The Work Plan Addendum (of which the QAPP Addendum is Appendix A) describes the additional field and laboratory activities that will be used. The QAPP Addendum has been prepared for use by EA to ensure that data collected are scientifically valid and legally defensible, and to establish the field and analytical protocols and documentation requirements that will ensure the data collected meet the quality objectives of the RI.

The following provides a brief summary of the additional work to be performed for the Navy under the Work Plan Addendum.

- Surface geophysical survey using seismic refraction profiling.
- Subsurface screening using MIP at 30 locations located to the east, south, and west of Site 16.
- Following the seismic refraction profiling and the MIP screening, the data will be assessed with regard to the location of the monitoring wells needed.
- Install, develop, and test 25 new monitoring wells

- During drilling, collect, log, and field screen soil samples of each new monitoring well.
- Borehole geophysical logging of monitoring wells completed in competent bedrock
- Sample and analyze ground water from the 25 new monitoring wells associated with Site 16.
- Perform data validation of the analytical results from the ground-water samples.

Prepare a report documenting the field investigation results, conclusions, and recommendations.

3. DISTRIBUTION LIST

The following is the list of organization and agency representatives to whom the Work Plan Addendum, including this QAPP Addendum, will be distributed. The QAPP is a dynamic document and should be revised or updated to reflect changes in organization and procedures needed to meet the Quality Objectives identified in the Work Plan. Whenever revisions are made or addenda added to the QAPP, those listed below will receive the revisions/addenda. This distribution system does not preclude making and using copies of the QAPP. However, those listed below are responsible for distributing the Work Plan and QAPP, and any additional material to update any copies within their organizations.

- EA Engineering, Science, and Technology
  James Shultz, EA Project Manager
- Northern Division
  John Mayhew, Remedial Project Manager
- U.S. Environmental Protection Agency, Region I (EPA)
  Christine Williams
- Rhode Island Department of Environmental Management (RIDEM)
  Richard Gottlieb
- U.S. Fish & Wildlife Service
  TBD
- National Oceanic and Atmospheric Administration
  Ken Finkelstein
- Town of North Kingstown
  Susan Licardi
- Rhode Island Economic Development Corporation
  Howard Cohen
- Gannett Fleming, Inc.
  Rayomand Bhuymgara

4. PROJECT ORGANIZATION

4.1 PROJECT ORGANIZATION CHART

The updated project organization is shown on Figure 3.

4.2 COMMUNICATIONS PATHWAYS

All official communication shall be through the EA Project Manager and the Navy Remedial Project Manager. All other communication shall be considered shadow communication and shall be non-binding and not official.

4.3 PROJECT ROLES AND RESPONSIBILITIES

The individuals directly involved with the Site 16 remedial investigation project and their specific responsibilities are outlined below.

John Mayhew, Navy Remedial Project Manager—Overall coordination of the project and decision-maker. Coordinates all activities within Northern Division for this site. Coordinate resolve issues with regulatory case managers. Navy member of the Base Closure Team (BCT).

Christine Williams, EPA Region 1, Remedial Project Manager—EPA Region 1 decision maker and oversight of Navy investigation and remediation. Coordinates all activities within EPA for this site. EPA member of the BCT.

Richard Gottlieb, RIDEM, Remedial Project Manager—RIDEM decision maker and oversight of Navy investigation and remediation. Coordinates all activities within RIDEM for this site. RIDEM member of the BCT.

James Shultz, EA Project Manager—Overall coordination and preparation of remedial investigation. Includes coordination and scheduling of laboratory analysis, data review, and validation, and overall coordination of field work. Delivers remedial investigation report to the Navy and regulatory case managers.

Ken Finkelstein (National Oceanic and Atmospheric Administration) and U.S. Fish and Wildlife Service (TBD)—Reviews the remedial investigation in relation to specific trustee responsibilities.

Howard Cohen (Rhode Island Economic Development Corporation) and Susan Licardi (Town of North Kingstown)—Reviews the remedial investigation in consideration of future use of the site.

4.4 SPECIAL TRAINING REQUIREMENTS/CERTIFICATION

No special training requirements or certifications are required for this project except for the 40-hour hazardous waste operations class and annual refresher.

5. PROJECT PLANNING AND PROJECT DEFINITION

5.1 PROJECT PLANNING MEETINGS

Project planning meetings will begin upon submittal of the draft work plan and QAPP. Project meetings will be as requested by either the EA Project Manager or Navy Remedial Project Manager.

5.2 PROBLEM DEFINITION, SITE HISTORY, AND BACKGROUND

Refer to the Work Plan (March 2000), Appendix A, Section 5.2.

The work will include those site characterization efforts necessary to supplement the previously scoped ecological and human health risk assessment for Site 16. The locations of contamination as detected by the MIP screening during the execution of the Final Work Plan (March 2000) suggest that chlorinated volatile organic compounds are moving onto the site and that another source, unrelated to the known or suspected former Site 16 operations, appears to be contributing to ground-water contamination. Therefore, the majority of the work presented in this Addendum is related to investigation of adjacent offsite areas.

6. PROJECT DESCRIPTION AND SCHEDULE

6.1 PROJECT OVERVIEW

Refer to Final Work Plan, March 2000, Appendix A, Section 6.1.

6.2 PROJECT SCHEDULE

Assuming concurrence of the BCT with the Work Plan Addendum, the following schedule is planned:

- Began Offsite Seismic Refraction Fieldwork — 7 September 2000
- Completed Offsite Seismic Refraction Fieldwork — 25 September 2000
- Began Offsite MIP Fieldwork — 10 October 2000
- Completed Offsite MIP Fieldwork — 26 October 2000
- Begin Monitoring Well Drilling — 4 December 2000
- Complete Field Work — 20 March 2001
- Laboratory Results due to EA — 17 April 2001
- Data Validation Completed — 15 May 2001
- Draft Remedial Investigation Report Submittal — 25 September 2001
- Final Remedial Investigation Report Submittal — 29 January 2002

7. PROJECT QUALITY OBJECTIVES AND MEASUREMENT PERFORMANCE CRITERIA

Project quality objectives are outlined in Chapter 7, Section 7.1, Appendix A of the Work Plan (March 2000). Measurement performance criteria are provided in Section 7.2, Chapter 7, Appendix A of the Work Plan (March 2000).

The objectives of the continued investigation of Site 16 under this Work Plan Addendum are to provide:

- Additional Site remedial investigation efforts necessary to accomplish an ecological and human health risk assessment

  The ecological risk assessment and human health risk assessment will be conducted in accordance with the Work Plan (March 2000)

- Assessment of potential offsite source areas and their relationships to the Site

- Continued assessment of potential onsite source areas

- Continued assessment of the nature and extent of ground-water contamination from the Site

- Continued assessment of the nature and extent of soil contamination from the Site.

Both accuracy and precision are calculated for each analytical batch, and the associated sample results are interpreted by considering these specific measurements. Accuracy is to be expressed as percent recovery and calculated using the equation in Table 7-1, Appendix A, Work Plan (March 2000). Project-specific precision and accuracy criteria are included in Table 7-2.

8. SAMPLING PROCESS DESIGN

8.1 SAMPLING DESIGN RATIONALE

For this additional work, the sampling design and rationale and planned sampling locations are provided in Chapter 3 of the Work Plan Addendum. A summary of the sampling and the analytical program for Site 16 is provided in Table 8-1 of Appendix A of the Work Plan (March 2000). Additional sampling is summarized in Table 8-1 of this QAPP Addendum.

9. SAMPLING PROCEDURES AND REQUIREMENTS

Sampling, decontamination, equipment calibration, and maintenance procedures for the additional work are provided in Chapter 4 of the Work Plan Addendum. Additional sample container, volume, preservation, and holding time requirements are provided in Tables 9-1 and 9-2 of this Work Plan Addendum.

10. SAMPLE HANDLING, TRACKING, AND CUSTODY REQUIREMENTS

Sample labeling, handling, tracking, and custody requirements for this additional work are provided in Section 4.10 of the Work Plan (March 2000), along with the field notes and documentation requirements.

11. FIELD ANALYTICAL METHODS REQUIREMENTS

The field analyses planned for this additional work include the use of a water quality unit (for pH, Eh, dissolved oxygen, temperature, conductivity, and salinity) and turbidity meter for measurements during well purging and sampling activities as stated in Chapter 4 of the Work Plan Addendum.

12. FIXED LABORATORY ANALYTICAL METHOD REQUIREMENTS

Refer to Chapter 12, Appendix A of the Work Plan (March 2000). Additional project reporting limits for dioxin samples are provided in Tables 12-1 and 12-2 of this Work Plan Addendum.

13. QUALITY CONTROL REQUIREMENTS

Refer to Chapter 13, Appendix A of the Work Plan (March 2000).

14. DATA ACQUISITION REQUIREMENTS

Refer to Chapter 14, Appendix A of the Work Plan (March 2000).

15. DOCUMENTATION, RECORDS, AND DATA MANAGEMENT

Refer to Chapter 15, Appendix A of the Work Plan (March 2000).

16. ASSESSMENTS AND RESPONSE ACTIONS

Refer to Chapter 16, Appendix A of the Work Plan (March 2000).

17. QUALITY ASSURANCE MANAGEMENT REPORTS

Refer to Chapter 17, Appendix A of the Work Plan (March 2000).

18. VERIFICATION AND VALIDATION REQUIREMENTS

The EA Project Manager and Navy Remedial Project Manager will be responsible for overall validation and final approval of the data in accordance with project purpose and use of the data. This investigation includes risk assessment and, therefore, it is assumed that Tier III validation will be required for 10 percent of the soil sample results and low-flow method collected ground-water sample results. The remainder of the analytical data for the soil samples and low-flow method collected ground-water samples will receive Tier II validation. The screening level MIP results will receive Tier I validation, as possible.

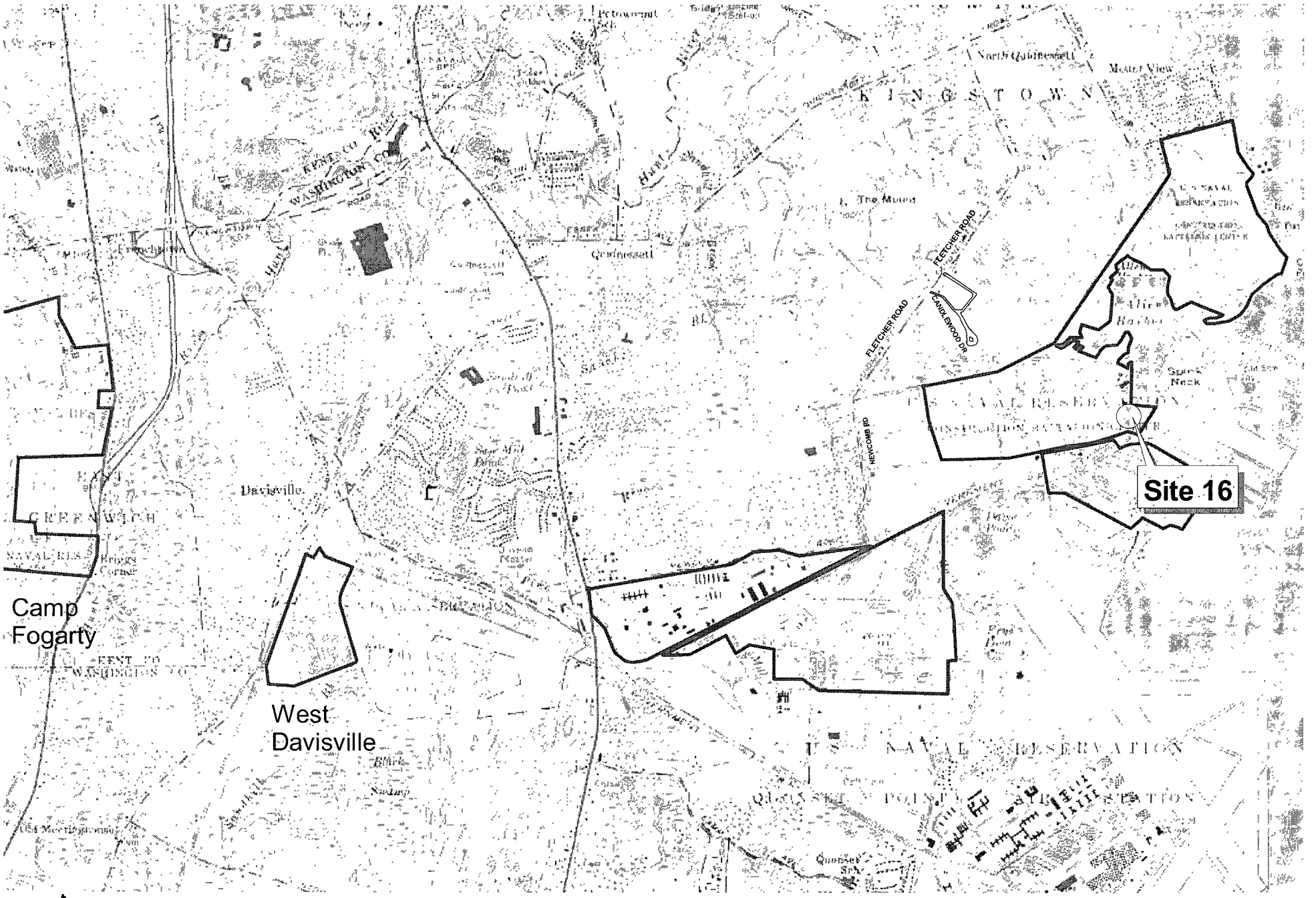
19. VERIFICATION AND VALIDATION PROCEDURES

The analytical data for the soil samples and the low-flow method collected ground-water samples will be validated in accordance with the EPA Data Validation Guidelines (July 1996, revised December 1996).

The EA Project Manager (or his designee) will perform the final review and approval of the data prior to it being considered valid. They will look at field duplicates, matrix spike/matrix spike duplicates, laboratory blanks, and laboratory duplicates to ensure they are acceptable. The EA Project Manager will also compare the sample descriptions with the field sheets for consistency and will ensure that any anomalies in the data are appropriately documented.

20. DATA USABILITY/RECONCILIATION WITH PROJECT QUALITY GOALS

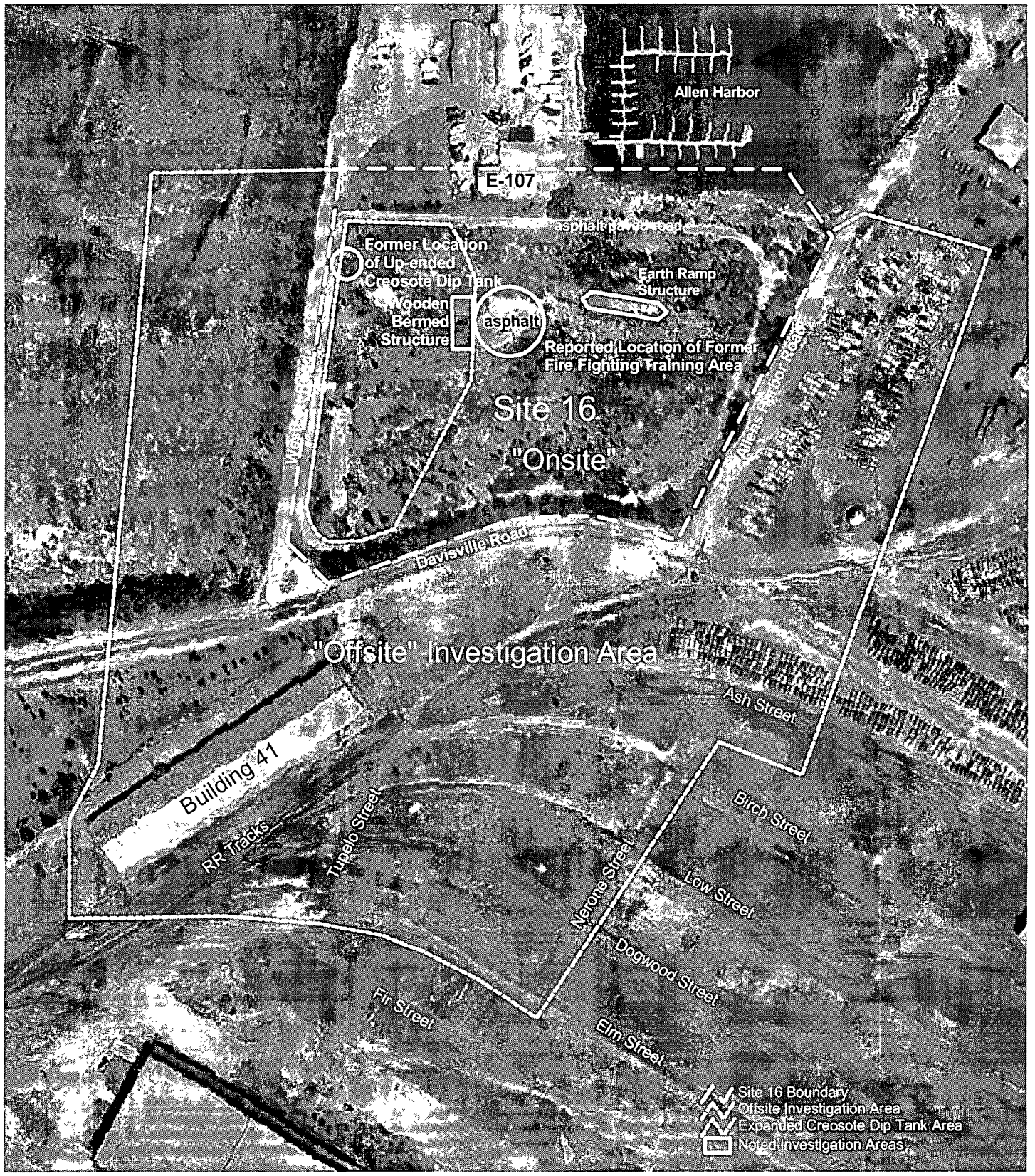
Refer to Chapter 20, Appendix A of the Work Plan (March 2000).



N

Approximate Scale 1" = 3000 ft.

FIGURE 1
SITE LOCUS MAP - NCBC DAVISVILLE, RI



300 0 300 600 900 Feet

N

Figure 2
Site Map, Site 16
NCBC Davisville

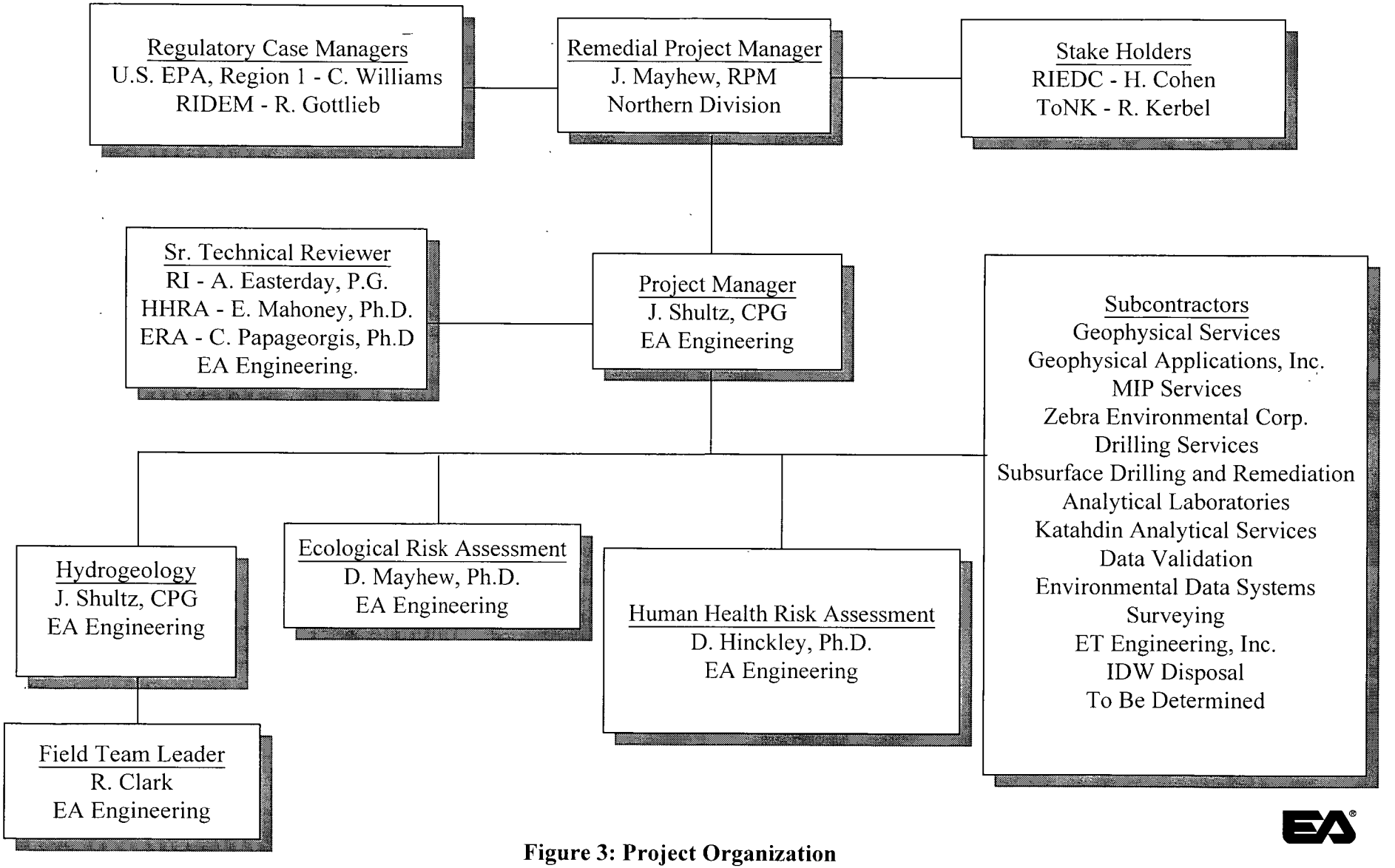


Figure 3: Project Organization

Site 16 Remedial Investigation, NCBC Davisville,R.I

TABLE 7-2 QUALITY CONTROL CRITERIA FOR PRECISION AND ACCURACY FOR MATRIX SPIKES, MATRIX SPIKE DUPLICATES, SURROGATES, AND LABORATORY CONTROL SAMPLES FOR SITE 16, NCBC DAVISVILLE

QC Parameter	Spiking Compounds	Accuracy (%R)		Precision[b]	
		Water	Sediment/Soil	Water	Sediment/Soil
SW6010B Metals by Inductively Coupled Plasma Atomic Emission Spectroscopy (Water, Sediment, Soil)					
Matrix Spike	Aluminum	75-125	75-125	≤20	≤20
	Antimony	75-125	75-125	≤20	≤20
	Arsenic	75-125	75-125	≤20	≤20
	Barium	75-125	75-125	≤20	≤20
	Beryllium	75-125	75-125	≤20	≤20
	Cadmium	75-125	75-125	≤20	≤20
	Calcium	75-125	75-125	≤20	≤20
	Chromium	75-125	75-125	≤20	≤20
	Cobalt	75-125	75-125	≤20	≤20
	Copper	75-125	75-125	≤20	≤20
	Iron	75-125	75-125	≤20	≤20
	Lead	75-125	75-125	≤20	≤20
	Magnesium	75-125	75-125	≤20	≤20
	Manganese	75-125	75-125	≤20	≤20
	Nickel	75-125	75-125	≤20	≤20
	Potassium	75-125	75-125	≤20	≤20
	Silver	75-125	75-125	≤20	≤20
	Sodium	75-125	75-125	≤20	≤20
	Selenium	75-125	75-125	≤20	≤20
	Vanadium	75-125	75-125	≤20	≤20
	Thallium	75-125	75-125	≤20	≤20
	Zinc	75-125	75-125	≤20	≤20
LCS	Aluminum	80-120	(c)	≤20	(c)
	Antimony	80-120	(c)	≤20	(c)
	Arsenic	80-120	(c)	≤20	(c)
	Barium	80-120	(c)	≤20	(c)
	Beryllium	80-120	(c)	≤20	(c)
	Cadmium	80-120	(c)	≤20	(c)
	Calcium	80-120	(c)	≤20	(c)
	Chromium	80-120	(c)	≤20	(c)
	Cobalt	80-120	(c)	≤20	(c)
	Copper	80-120	(c)	≤20	(c)
	Iron	80-120	(c)	≤20	(c)
	Lead	80-120	(c)	≤20	(c)
	Magnesium	80-120	(c)	≤20	(c)
	Manganese	80-120	(c)	≤20	(c)
	Nickel	80-120	(c)	≤20	(c)
	Potassium	80-120	(c)	≤20	(c)
	Silver	80-120	(c)	≤20	(c)

(a) Laboratory Control Sample (LCS) limits are based on historical performance data and are updated annually.
(b) Precision for matrix spikes is listed for relative percent difference (%RPD); for the LCS, the value is the precision calculated as the moving range for successive LCS recoveries.
(c) LCS is commercially prepared reference standard. Quality control limits differ with each lot.

NOTE: Dashes (---) indicate not applicable.

QC Parameter	Spiking Compounds	Accuracy (%R)		Precision[b]	
		Water	Sediment/Soil	Water	Sediment/Soil
LCS (Continued)	Sodium	80-120	(c)	≤20	(c)
	Selenium	80-120	(c)	≤20	(c)
	Vanadium	80-120	(c)	≤20	(c)
	Thallium	80-120	(c)	≤20	(c)
	Zinc	80-120	(c)	≤20	(c)
	Vanadium	80-120	(c)	≤20	(c)
	Mercury	75-125	75-125	≤20	≤20
	Mercury	80-120	(c)	≤20	(c)
SW7470A, SW7471A Mercury by Cold Vapor Atomic Absorption (Water, Sediment, Soil)					
Matrix Spike	1,2-Dichloroethane-d4	65-135	----	---	---
LCS[b]	4-Bromofluorobenzene(BFB)	69-125	---	---	---
SW5030B/8260B Volatile Organic Compounds by GC/MS (Water)					
Surrogate Spike	Toluene-d8	82-120	---	---	---
	Dibromofluoromethane	75-129	---	---	---
	Benzene	60-140	---	≤40	---
	Toluene	60-140	---	≤40	---
	Chlorobenzene	60-140	---	≤40	---
LCS/MS/MSD	1,1-Dichloroethene	60-140	---	≤40	---
	Trichloroethene	60-140	---	≤40	---
	Chlorobenzene	60-140	---	≤40	---
	1,2-Dichloroethane-d4	---	66-149	---	---
	4-Bromofluorobenzene (BFB)	---	64-152	---	---
SW5035/8260B Volatile Organic Compounds by GC/MS (Sediment/Soil)					
Surrogate Spike	Toluene-d8	---	68-147	---	---
	Dibromofluoromethane	---	66-149	---	---
	Benzene	---	60-140	---	≤40
	Toluene	---	60-140	---	≤40
	Chlorobenzene	---	60-140	---	≤40
LCS/MS/MSD	1,1-Dichloroethene	---	60-140	---	≤40
	Trichloroethene	---	60-140	---	≤40
	Chlorobenzene	---	60-140	---	≤40
	Nitrobenzene d5	36-117	14-107	---	---
	2-Fluorobiphenyl	47-114	32-109	---	---
SW3520C/3540C/8270C Semivolatile Organics by GC/MS (Water, Sediment, Soil)					
Surrogate Spike	Terphenyl-d14	35-126	26-116	---	---
	2-Fluorophenol	20-95	15-106	---	---
	Phenol-d5	10-115	30-105	---	---
	2,4,6-Tribromophenol	20-137	16-115	---	---
	Phenol	70-130	60-140	≤30	≤40
	2-Chlorophenol	70-130	60-140	≤30	≤40
	1,4-Dichlorobenzene	70-130	60-140	≤30	≤40
LCS/MS/MSD	N-Nitroso-di-n-propylamine	70-130	60-140	≤30	≤40
	1,2,4-Trichlorobenzene	70-130	60-140	≤30	≤40
	4-Chloro-3-methylphenol	70-130	60-140	≤30	≤40
	Acenaphthene	70-130	60-140	≤30	≤40
	4-Nitrophenol	70-130	60-140	≤30	≤40
	2,4-Dinitrotoluene	70-130	60-140	≤30	≤40
	Pentachlorophenol	70-130	60-140	≤30	≤40
	Pyrene	70-130	60-140	≤30	≤40

QC Parameter	Spiking Compounds	Accuracy (%R)		Precision[b]	
		Water	Sediment/Soil	Water	Sediment/Soil
LCS/MS/MSD (Continued)	2,4-Dinitrotoluene	70-130	60-140	≤30	≤40
	Decachlorobiphenyl	26-122	29-141	---	---
	Tetrachloro-m-xylene	47-100	50-110	---	---
SW8082 PCBs by GC (Water, Sediment, Soil)					
Surrogate Spike	Arochlor 1016	72-130	62-142	≤30	≤50
	Arochlor 1260	77-126	85-131	≤30	≤50
	Tetrachloro-m-xylene	47-100	50-110	---	---
LCS/MS/MSD	Decachlorobiphenyl	39-128	47-141	---	---
	Tetrachloro-m-xylene	45-94	52-126	---	---
SW8081 Pesticides by GC (Water, Sediment, Soil)					
Surrogate Spike	Alpha-BHC	50-113	55-116	≤30	≤50
	Gamma-BHC(Lindane)	55-114	61-119	≤30	≤50
	Beta-BHC	62-116	70-125	≤30	≤50
LCS/MS/MSD	Delta-BHC	54-124	71-140	≤30	≤50
	Heptachlor	28-121	61-113	≤30	≤50
	Aldrin	52-111	48-121	≤30	≤50
	Heptachlor Epoxide	68-117	75-118	≤30	≤50
	Gamma-Chlordane	69-116	77-119	≤30	≤50
	Alpha-Chlordane	71-117	78-121	≤30	≤50
	4,4'-DDE	59-120	69-124	≤30	≤50
	Endosulfan I	63-118	71-119	≤30	≤50
	Dieldrin	71-115	75-122	≤30	≤50
	Endrin	68-122	67-137	≤30	≤50
	4,4'-DDD	59-123	68-134	≤30	≤50
	Endosulfan II	73-119	77-128	≤30	≤50
	4,4'-DDT	70-119	77-127	≤30	≤50
	Endrin Aldehyde	69-119	50-107	≤30	≤50
	Methoxychlor	67-127	77-133	≤30	≤50
	Endosulfan Sulfate	67-135	84-144	≤30	≤50
	Endrin Ketone	75-129	89-142	≤30	≤50
	Methoxychlor	67-127	77-133	≤30	≤50
	Sulfide	---	85-105	---	---
	Metals	---	80-120	---	≤20
AVS/SEM (Sediment, Soil)					
	Metals	---	75-125	---	≤20
LCS/MS	Sulfide	---	85-105	---	---
LCS		25-145	25-145	≤35	≤35
MS		25-145	25-145	≤35	≤35
SW8290 PCDDs and PCDFs by HRGC/HRMS					
MS/MSD	Nitrobenzene-d5	30-150	30-150		
LCS/LCSD	2-Fluorobiphenyl	30-150	30-150		
SW8270C PAHs by SIM (Water, Sediment, Soil)					
Surrogate Spike	Terphenyl-d14	30-150	30-15		
	Acenaphthene	60-140	60-140	≤50	≤50
	Pyrene	60-140	60-140	≤50	≤50
LCS					

TABLE 8-1 SUMMARY OF ADDITIONAL SAMPLING AND ANALYTICAL PROGRAM, SITE 16, NCBC DAVISVILLE, RHODE ISLAND

Sample Media	EPA Method (SW8460)	No. of Field Samples	Number of Quality Control Samples				Total No. of Samples
			Duplicate	Rinsate	MS/MSD	Trip Blank	
Ground-Water (monitoring wells)	TCL VOC (detection limit, <1 µg/L) 8260	27	3		2/2	25	59
	TCL SVOC (8270)	27	3		2/2		34
	TCL PAH (8270 SIM)	27	3		2/2		34
	TCL Pesticides/PCB (8082)	27	3		2/2		34
	TAL Inorganics (6010/7000)	27	3		2/2		34
	Salinity (SM 2520B)	27	3				30
Subsurface soil from screened interval of 5 monitoring wells (located adjacent to MIP16-S01, MIP16-S03, MIP16-S05, MIP16-S08, MIP16-S17; Plus 2 intervals from soil boring adjacent to MIP16-S21 at 20-22 ft bgs and 32-34 ft bgs)	TCL VOC (8260)	7	1	1	1/1	6	17
	TCL SVOC (8270)	7	1	1	1/1		11
	TCL PAH (8270 SIM)	7	1	1	1/1		11
	TCL Pest/PCB (8082)	7	1	1	1/1		11
	TAL Inorganics (6010/7000)	7	1	1	1/1		11
	TOC (9060)	7	1	1			9
	pH	7					7
	Grainsize	7					7
Surface and Subsurface Soil Pairs (8)	Dioxin (8290)	16	2	2	1/1		22

NOTE: EPA = U.S. Environmental Protection Agency.
MS/MSD = Matrix spike/matrix spike duplicate.
TCL = Target Compound List.
VOC = Volatile organic compound.
SVOC = Semivolatile organic compound.
PAH = Polycyclic aromatic hydrocarbons.
TAL = Target Analyte List
Also see Table 8-1 in the Work Plan (March 2000).

TABLE 9-1 REQUIRED CONTAINERS, PRESERVATION TECHNIQUE, AND HOLDING TIMES FOR AQUEOUS SAMPLES AND BLANKS[a]

Parameter	Volume Required (mL)	Container[b]	Preservative	Recommended Holding Time
Polychlorinated dibenzo-p-dioxins and dibenzo-furans				
Dioxin	2,000	Glass	None	30 days
NOTE: See Table 9-1 in the Work Plan (EA 1999) for metals, organic, and inorganic holding times and bottle requirements.				

TABLE 12-1 PROJECT REPORTING LIMITS FOR AQUEOUS SAMPLES

Parameter	Units	Project Reporting Limit[a]
Polychlorinated dibenzo-p-dioxins and dibenzo-furans (Method 8290/1613)		
1,2,3,4,6,7,8,9-OCDD	pg/L	100
2,3,7,8-TCDF	pg/L	10
2,3,7,8-TCDD	pg/L	10
2,3,4,7,8-PECDF	pg/L	50
2,3,4,6,7,8-HXCDF	pg/L	50
1,2,3,7,8-PECDF	pg/L	50
1,2,3,7,8-PECDD	pg/L	50
1,2,3,7,8,9-HXCDF	pg/L	50
1,2,3,7,8,9-HXCDD	pg/L	50
1,2,3,6,7,8-HXCDF	pg/L	50
1,2,3,6,7,8-HXCDD	pg/L	50
1,2,3,4,7,8-HXCDF	pg/L	50
1,2,3,4,7,8-HXCDD	pg/L	50
1,2,3,4,7,8,9-HPCDF	pg/L	50
1,2,3,4,6,7,8-HPCDF	pg/L	50
1,2,3,4,6,7,8-HPCDD	pg/L	50
1,2,3,4,6,7,8,9-OCDF	pg/L	100
NOTE: See Table 12-1 in the Work Plan (March 2000) for a full parameter list.		

TABLE 12-2 REPORTING LIMITS FOR SOIL/SEDIMENT SAMPLES

Parameter	Units	Project Reporting Limit[a]
Polychlorinated dibenzo-p-dioxins and dibenzo-furans (Method 8290/1613)		
1,2,3,4,6,7,8,9-OCDD	ng/kg	10
2,3,7,8-TCDF	ng/kg	1
2,3,7,8-TCDD	ng/kg	1
2,3,4,7,8-PECDF	ng/kg	5
2,3,4,6,7,8-HXCDF	ng/kg	5
1,2,3,7,8-PECDF	ng/kg	5
1,2,3,7,8-PECDD	ng/kg	5
1,2,3,7,8,9-HXCDF	ng/kg	5
1,2,3,7,8,9-HXCDD	ng/kg	5
1,2,3,6,7,8-HXCDF	ng/kg	5
1,2,3,6,7,8-HXCDD	ng/kg	5
1,2,3,4,7,8-HXCDF	ng/kg	5
1,2,3,4,7,8-HXCDD	ng/kg	5
1,2,3,4,7,8,9-HPCDF	ng/kg	5
1,2,3,4,6,7,8-HPCDF	ng/kg	5
1,2,3,4,6,7,8-HPCDD	ng/kg	5
1,2,3,4,6,7,8,9-OCDF	ng/kg	10
NOTE: See Table 12-1 in the Work Plan (March 2000) for a full parameter list.		

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Date: 11/16/00 **Time:**

To: Robin Clark

From: Andrea Colby

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Comments: Robin, Here is the cover page for the Triangle SOP. The P&A limits I put in table 7-2 are OK w/ Triangle but you might want to include the information I faxed the other day also.
Please call with any questions.
— Andrea

From: Katahdin Analytical Services, Inc.
340 County Road No. 5
P.O. Box 720
Westbrook, ME 04098
Tel: (207) 874-2400 Fax: (207) 775-4029

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PCDDs AND PCDFs BY HRGC/HRMS - METHOD 8290			
TLI SOP No. DHR182	Version: 6	Effective Date:	March 25, 1998
Author:	Wojciech Krol	Date Written:	February 9, 1998
Authorization:	Management	Date Authorized:	2/16/98

I. SCOPE AND APPLICATION: This method provides procedures for the analysis f polychlorinated dibenzo-p-dioxins (tetra- through octachlorinated homologues; PCDDs), and polychlorinated dibenzofurans (tetra- through octachlorinated homologues; PCDFs) from extracts of samples prepared according to SW 846 Method 8290.

II. SAFETY CONSIDERATIONS: The 2,3,7,8-TCDD isomer has been found to be acenegenic, carcinogenic, and teratogenic in laboratory animal studies. Other PCDDs and PCDFs containing chlorine atoms in the 2,3,7,8 positions are known to have toxicities comparable to that of 2,3,7,8-TCDD. Extreme care must be exercised in all handling of extracts and standards in the application of this SOP. For additional safety information, see the TLI Safety and Health Manual and the appropriate MSDSs.

III. EQUIPMENT: The High-Resolution Gas Chromatograph/High-Resolution Mass Spectrometer/Data System (GC/MS/DS) equipment utilized for this analysis includes the following:

A. Gas Chromatographs: Hewlett Packard 5890 or 5890 Series II (equipped for temperature programming and capillary columns)

B. High Resolution Mass Spectrometers: VG 70 Series, VG 70-SE Series, VG Autospec.

C. Data Systems: VG Analytical PDP11 with 11-250 software or VAX Alpha with Opus 3.2 software.

D. GC Injection Port - The GC injection port is designed for capillary columns. Typically, 2 µL injection volumes are used unless otherwise noted.

E. Gas Chromatograph/Mass Spectrometer(GC/MS) Interface - The GC/MS interface components can withstand 350°C. The interface has been designed so that the separation of 2,3,7,8-TCDD from the other TCDD isomers achieved in the gas chromatographic column is not appreciably degraded. The GC column is fitted directly into the mass spectrometer ion source without being

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FAX TRANSMISSION

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To: Robin Clark

From: Andrea Colby

FAX No: 781 | 275-7253

Number of Pages (Including This Cover): 4

Comments: Dioxin QC information from Triangle Labs

From: **Katahdin Analytical Services, Inc.**
340 County Road No. 5
P.O. Box 720
Westbrook, ME 04098
Tel: (207) 874-2400 Fax: (207) 775-4029

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VIII. QUALITY CONTROL REQUIREMENTS

A. GC column performance must be demonstrated initially and verified prior to analyzing any sample in a 12-hour period. The GC column performance check solution must be analyzed under the same chromatographic and mass spectrometric conditions used for other samples and standards.

B. Routine calibrations must be performed at the beginning of a 12-hour period after successful mass resolution and GC resolution performance checks and at the end of a 12-hour period following the analysis of samples.

C. The target detection limits will be the following:

1. TDLs for waters (sample size - 1L):

≤ 10 ppq	TCDD & TCDF
≤ 50 ppq	Penta - HeptaCDD & CDF
≤ 100 ppq	OCDD & OCDF

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PCDDs AND PCDFs BY HRGC/HRMS - METHOD 8290		
TLI SOP No DHR182	Version: 6	Date Written: February 9, 1998

2. TDLs for solids (sample size - 10g):

≤ 1 ppt	TCDD & TCDF
≤ 5 ppt	Penta - HeptaCDD & CDF
≤ 10 ppt	OCDD & OCDF

3. For air (e.g., PUF, M-0023A) or Wipes (sample size - 1):

≤ 50 pg	TCDD & TCDF
≤ 250 pg	Penta - HeptaCDD & CDF
≤ 500 pg	OCDD & OCDF

D. Method Blank

1. Percent recoveries of all labeled standards should be between 40 - 135%. Method blank with standard recoveries below 40% (but ≥ 25%) is acceptable as long as signal to noise for affected standards is ≥ 10:1.
2. Target detection limits must be met for each analyte. (VIII. C.)
3. No reportable analytes should be present in the Method Blank. Up to 3 analytes may be present at levels below 1/2 Target Detection Limit (TDL) as long as the compounds were not reported in the previous analysis.
4. For Method Blanks associated with high level samples, the analyte level in the blank must be < 5% of the quantity present in the samples.

E. LCS/ LCSD and MS/ MSD

1. Percent recoveries of all labeled standards should be between 40 - 135%. LCS/ LCSD or MS/ MSD with labeled standard recoveries below 40% (but ≥ 25%) are acceptable as long as signal to noise for affected standards is ≥ 10:1.
2. Percent recoveries of all analytes should be between 70 - 130%. For up to two analytes, recoveries may be as high as 145% or as low as 60%, as long as the associated relative percent differences (%RPDs) meet criteria.
3. Relative percent difference between LCS and LCSD or MS and MSD should be ≤ 20% for all analytes. For up to two analytes, %RPDs may be higher (up to 35%), as long as the associated percent recoveries meet criteria.

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PCDDs AND PCDFs BY HRGC/HRMS - METHOD 8290		
TLI SOP No DHR182	Version: 6	Date Written: February 9, 1998

F. Samples

1. Percent recoveries of all labeled standards should be between 40 - 135%. Samples with standard recoveries below 40% (but ≥ 25%) are acceptable as long as signal to noise for affected standards is ≥ 10:1. In the case of OCDD internal standards, the OCDF analyte must be below TDL also.

2. Specific detection limits must not exceed the target detection limits unless prohibited by a limited sample size or the need for dilution.

3. If the method blank contains reportable analytes but those analytes are not detected in the sample, the sample data may be reported.

4. Samples which fail acceptance criteria listed above (VIII. F. 1. and 2.) or associated with failing method blank or LCS/ LCSD (VIII. D. 1. - 4.; VIII. E. 1. - 3.) must be reextracted and reanalyzed. Exceptions may be made for sample matrices which require extreme additional cleanup procedures.

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Appendix B

Site Safety, Health, and Emergency Response Plan Addendum

SITE SAFETY, HEALTH, AND EMERGENCY RESPONSE PLAN ADDENDUM

REMEDIAL INVESTIGATION OF IR PROGRAM SITE 16 (FORMER CREOSOTE DIP TANK AND FIRE FIGHTING TRAINING AREA)

NAVAL CONSTRUCTION BATTALION CENTER NORTH KINGSTOWN, RHODE ISLAND

CONTRACT NUMBER N62472-92-D-1296
DELIVERY ORDER NO. 0097

Prepared for:

Department of the Navy
Northern Division
Naval Facilities Engineering Command
10 Industrial Highway, Mail Stop No. 82
Lester, Pennsylvania 19113-2090

Prepared by:

EA Engineering, Science, and Technology, Inc.
175 Middlesex Turnpike, Wyman Building
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FINAL
November 2000
29600.97.3101

SITE SAFETY, HEALTH, AND EMERGENCY RESPONSE PLAN ADDENDUM

REMEDIAL INVESTIGATION OF IR PROGRAM SITE 16 (FORMER CREOSOTE DIP TANK AREA AND FIRE FIGHTING TRAINING AREA)

NAVAL CONSTRUCTION BATTALION CENTER NORTH KINGSTOWN, RHODE ISLAND

CONTRACT NUMBER N62472-92-D-1296 CONTRACT TASK ORDER NO. 0097

Barry R. Weissman CSP CHMM for Kris Hoiem — 28 November 2000

Kris H. Hoiem, Certified Industrial Hygienist — Date

Program Safety and Health Officer

James A. Shultz CPG — 28 November 2000

Date

CTO Manager

FINAL

November 2000

29600.97.3101

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ATTACHMENT B

Potential Hazardous Substances

1. SITE INFORMATION

Site: Naval Construction Battalion Center (NCBC), North Kingston, Rhode Island (Figure 1).

Location: Site 16 – Former Creosote Dip Tank Area and
Fire Fighting Training Area (including areas east, south, and west of Site 16, as depicted in Figure 2).

Work Plan Field Activities:

- Seismic refraction profiling
- Membrane interface probe screening
- Advancement of soil borings
- Installation, development, and testing of monitoring wells
- Borehole geophysical logging of monitoring wells completed in competent bedrock
- Collect ground-water samples from monitoring wells
- Collect soil samples from borings
- Collect seep and sediment samples from shoreline of Allen Harbor (part of the original SHERP, March 2000, but to be performed during this Addendum field activity)

2. PERSONNEL

2.1 KEY PERSONNEL

Project Manager:	Jim Shultz, CPG (781) 275-8846
Program Safety and Health Officer:	Kris Hoiem, CIH (410) 771-4950
Site/Task Manager*:	Robin Clark (781) 275-8846
Site Safety and Health Officer:	Kevin Baum
Field Personnel:	Robin Clark, Stella Kiras, Jim Shultz, Sam Whitin, Kevin Baum, James Gatherer, Tom Biolsi, Mike Chase, Stephanie D'jimas, Sue Chase, Dan Bishuk, Kim Shutty, Robert Wasserman, Stephen Cackowski, Jennifer Martin, John Clark
* Certification of 8-Hour Supervisor's Training for Hazardous Waste Operations is required for the Site Manager.	

2.2 RESPONSIBILITIES

Refer to Appendix B, Final Work Plan (March 2000).

2.3 VISITORS

Refer to Appendix B, Final Work Plan (March 2000).

3. PURPOSE AND WORK SCOPE

The objectives of the characterization within Site 16 are in accordance with the Final Work Plan (March 2000).

4. SITE DESCRIPTION

Refer to Appendix B, Final Work Plan (March 2000).

4.1 AREA TO BE INVESTIGATED

Site 16, formerly designated Environmental Baseline Survey Review Item 28, is located in the eastern portion of Zone 3 at NCBC Davisville (Figure 1). A site map is presented on Figure 2.

5. HAZARD ANALYSIS

Refer to Section 5 of Appendix B, Final Work Plan (March 2000).

5.1 Hazard Communication

Refer to Section 5.1 of Appendix B, Final Work Plan (March 2000)

5.2 Chemical Hazards

Refer to Section 5.2 of Appendix B, Final Work Plan (March 2000)

Based upon past Site use as a Fire Fighting Training Area, and laboratory results of soil samples collected during June 2000 from eight shallow soil borings (SB16-21 through SB16-28) shown on Figure 9 of this Work Plan Addendum, potential hazardous substances known to be present onsite include soil impacted with dioxin. An updated tabulated list of reported maximum

concentrations of previously detected analytes at NCBC Davisville Site 16 is presented in Table 5-1.

Dioxin has been added to Attachment B. The updated worker exposure limits including Permissible Exposure Limits/Threshold Limit Values (PELs/TLVs) and the Immediately Dangerous to Life or Health (IDLH) values for these hazardous substances are also included. The expected exposure (e.g., inhalation, dermal contact, and ingestion) to this additional hazardous substance is summarized below:

- Soil Sampling —Soil sampling will take place outside. Chemical hazards may include the exposure to dioxin when drilling onsite. Possible routes of exposure include inhalation, ingestion, skin and/or eye contact, and skin absorption.

The Agency for Toxic Substances and Disease Registry (ATSDR) states that a level of 1 ppb dioxin in residential soil indicates a potential need for public health action. Levels of dioxin detected in soil samples from the Site are less than one half that concentration.

During all phases of the fieldwork, strict adherence to the monitoring procedures, in Section 9, will be conducted to help protect against inhalation of vapors from potential or known chemicals of concern. The proper PPE will protect against other types of exposure to the chemical hazards. Additional precautions will be followed for drilling in onsite areas. See section 8 of this Work Plan Addendum.

6. EMPLOYEE TRAINING ASSIGNMENTS

Dates of employee training are documented in Table 6-1. Any person who does not meet these training requirements is prohibited from engaging in site operations. Once the Contract Task Order Manager has signed the Safety, Health, and Emergency Response Plan, no other personnel may be added to the project fieldwork without prior written approval by the Contract Task Order Manager or Site Safety and Health Officer, who must review the proposed employee's training and medical status. The following training must be completed prior to the start of work operations.

6.1 ALL SITE WORKERS

Refer to Section 6.1 of Appendix B, Final Work Plan (March 2000).

6.2 SITE MANAGER

Refer to Section 6.2 of Appendix B, Final Work Plan (March 2000).

6.3 FIRST AID/CPR

Refer to Section 6.3 of Appendix B, Final Work Plan (March 2000).

6.4 PRE-ENTRY BRIEFING

Refer to Section 6.4 of Appendix B, Final Work Plan (March 2000).

6.5 SUBCONTRACTOR TRAINING

Refer to Section 6.5 of Appendix B, Final Work Plan (March 2000).

7. MEDICAL SURVEILLANCE

Hazardous waste site workers must have satisfactorily completed a comprehensive medical examination by a licensed physician within 12 months prior to the start of site operations. Non-hazardous waste site workers will be medically examined to meet Occupational Safety and Health Administration requirements specific to their job. The date of medical examination of each site worker will be recorded on Table 6-1. Subcontractors will provide this information in writing to the EA Project Manager for their workers onsite prior to startup of field activities. Medical surveillance protocols shall comply with 29 CFR 1910.120.

8. PERSONAL PROTECTIVE EQUIPMENT

Refer also to Section 8 of Appendix B, Final Work Plan (March 2000).

Based on evaluation of the potential safety and health hazards (Section 5), the required initial levels of personal protective equipment (PPE) are presented in Table 8-1 for each work task. This table has been updated to include upgrade for dioxin exposure. Additional upgrade PPE levels are listed below:

- **Upgrade PPE Level D, Modified**—When onsite in unpaved, non-vegetated areas, the following upgrade components are required when working in an area where dust exposure is possible: disposable boot covers, tyvek coveralls, and full face or 1/2 face air purifying respirator with a HEPA Filter.

Only the SSHO can authorize an upgrade or downgrade in the PPE level worn onsite, using only those criteria presented in Section 9. All changes in PPE levels must be documented on Attachment E, along with the rationale for the PPE changes. When respirators are required, site workers must have been successfully fit-tested within 6 months prior to the start of work operations.

Subcontractors are required to supply their workers with the appropriate PPE.

The SSHO will review appropriate procedures for donning and doffing PPE prior to the start of work tasks. All PPE must be inspected by site workers prior to use and regularly during use. If any site worker experiences a failure or alteration of PPE that affects the level of protection offered, that person will immediately leave. Re-entry will not be permitted until the equipment has been repaired or replaced.

9. ENVIRONMENTAL MONITORING

Refer to Section 9 of Appendix B, Final Work Plan (March 2000).

10. SITE CONTROL

Refer to Section 10 of Appendix B, Final Work Plan (March 2000).

11. DECONTAMINATION PROCEDURES

Refer to Section 11 of Appendix B, Final Work Plan (March 2000).

12. EMERGENCY RESPONSE PLAN

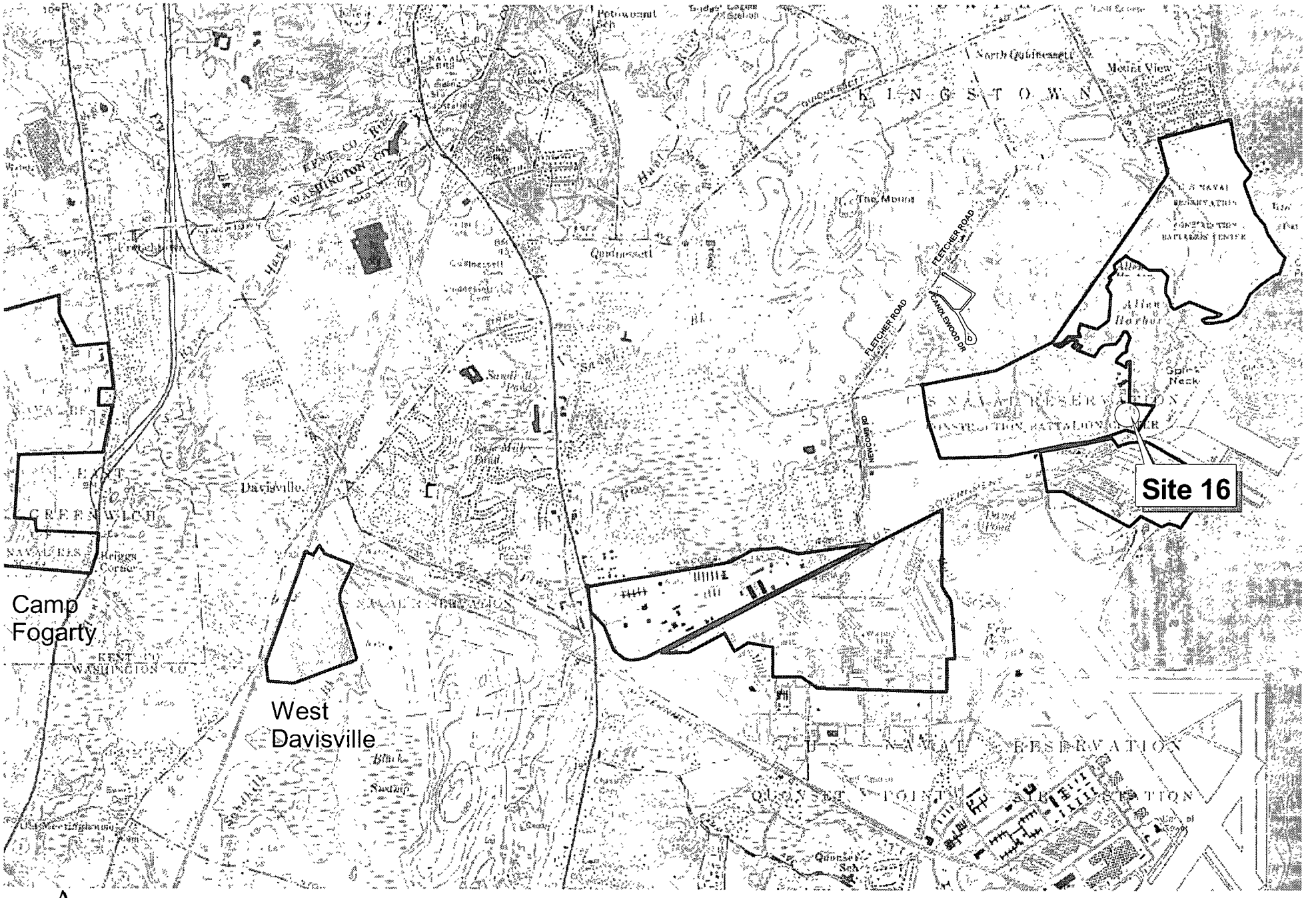
Refer to Section 12 of Appendix B, Final Work Plan (March 2000).

13. CONFINED SPACE ENTRY PROCEDURES

Refer to Section 13 of Appendix B, Final Work Plan (March 2000).

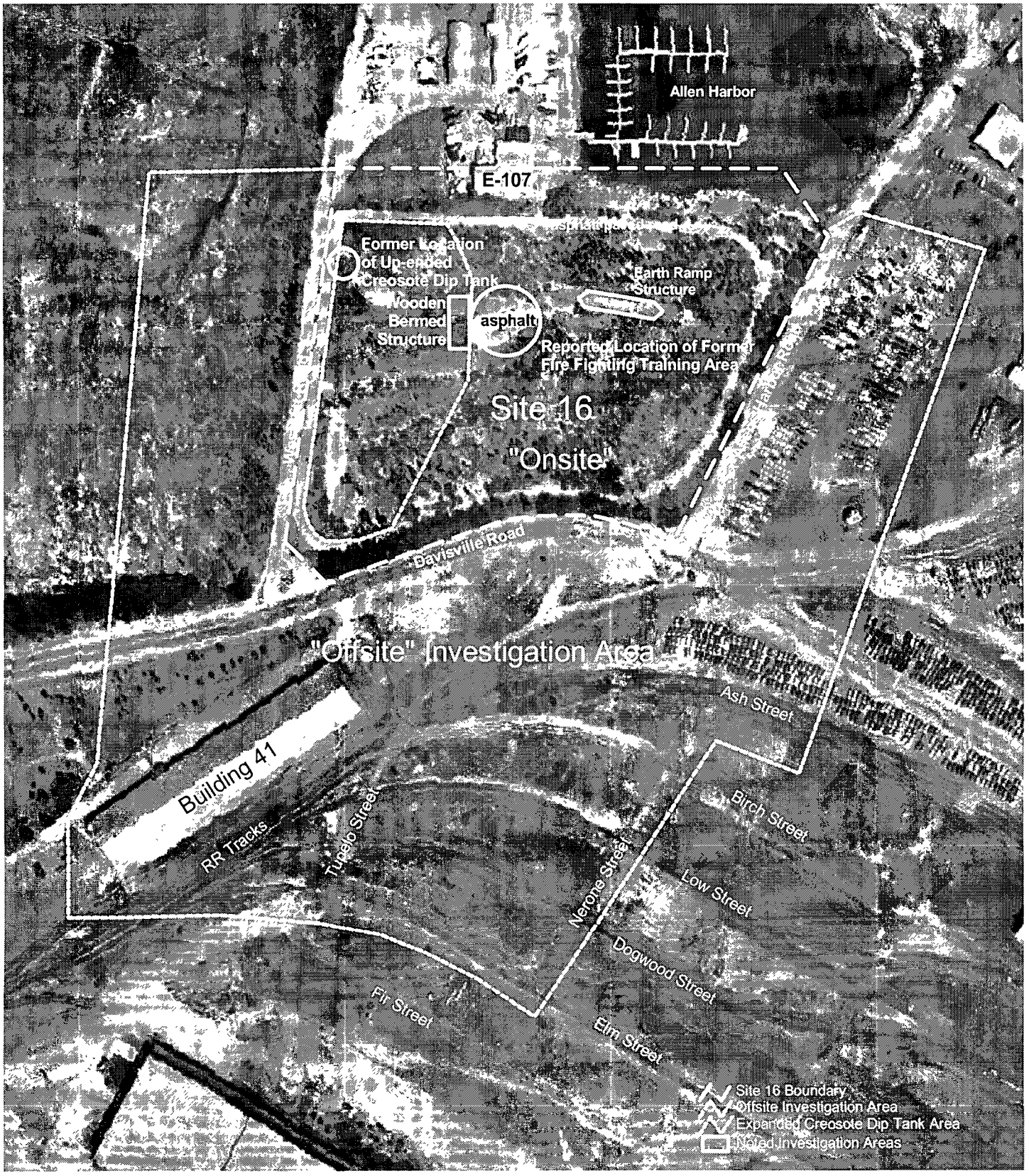
14. SPILL CONTAINMENT PROCEDURES

Refer to Section 14 of Appendix B, Final Work Plan (March 2000).



Approximate Scale 1" = 3000 ft.

FIGURE 1
SITE LOCUS MAP - NCBC DAVISVILLE, RI



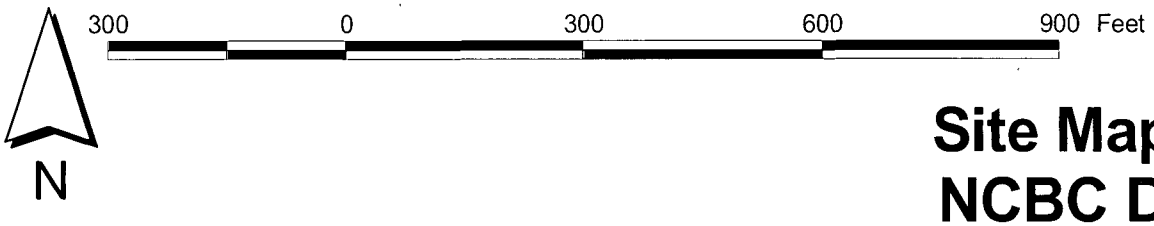


Figure 2
Site Map, Site 16
NCBC Davisville

TABLE 5-1 REPORTED MAXIMUM CONCENTRATIONS OF PREVIOUSLY DETECTED ANALYTES SITE 16, NCBC DAVISVILLE, RI

Chemical Analyte	Soil mg/kg	Ground Water µg/L
Acenaphthene	—	0.8*
Acetone	75	—
Anthracene	—	0.4*
Antimony	6.4	—
Arsenic	2.8	—
BEHP	—	13*
Beryllium	0.57	—
Benzo(a)anthracene	2.7	0.4*
Benzo(b)fluoroanthene	1.2	—
Benzo(k)fluoroanthene	1.5	0.1J*
Benzo[g,h,i]perylene	2.7	—
Benzo(a)pyrene	2.7	0.2*
Chrysene	2.7	0.6*
cis-Dichloroethylene	—	250*
Trans- Dichloroethylene	—	53*
Total Dichloroethylene	—	250*
Dibenz[a,h]anthracene	0.42	—
Dieldrin	—	0.02
Dioxin TEQ**	Surface soil = 45.2 ppt Subsurface soil = 496.7 ppt	—
Endrin	—	0.0039
Fluoranthene	—	2*
Fluorene	—	0.2*

Chemical Analyte	Soil mg/kg	Ground Water µg/L
Heptachlor Epoxide	—	0.02
Indeno[1,2,3-cd]pyrene	1.6	—
Lead	339	29.3
2-Methylnaphthalene	—	21*
Phenanthrene	—	7
Pyrene	0.260	2*
Trichloroethylene	—	5,300*
TPH	1750	—
Vinyl Chloride	—	14*

Notes:

—	=	either data was not available or analyte concentration was not detected above the laboratory method detection limit.
mg/kg	=	milligrams per kilogram
µg/L	=	micrograms per liter
ppt	=	parts per trillion
*	=	Probe collected ground-water sample, April - May 2000. Data not validated.
**	=	The ATSDR action level is 1 ppb in residential soil

TABLE 6-1 SITE WORKER TRAINING AND PHYSICAL EXAMINATION RECORD

SITE: NCBC Davisville Site 16

Name	HAZWOPER 40-Hour Initial	HAZWOPER Annual	Respirator Fit Test	First Aid[a]	CPR[a]	Supervisor[b]	Medical Exam
James Shultz	1984	3/00	---	12/91	11/93	2/93	4/99
Robin Clark	1995	6/00	---	6/00	6/00	10/96	8/00*
Kevin Baum	2000	1/00	1/00	5/00	5/00	---	3/00*
Stella Kiras	1997	3/00	2/00	11/97	10/98	---	1/99*
Sam Whitin	2000	2/00	2/00	2/00	2/00	---	2/00*
James Gatherer	1999	2/00	--	8/99	8/00	--	12/99
Tom Biolsi	1997	11/99 (1/01)	2/99	10/00	10/00	12/98	9/00*
Mike Chase	1996	4/00	--	3/99	3/99	--	5/00
Stephanie D'jimas	1998	2/00	--	8/99	8/99	--	8/99
Sue Chase	1993	4/00	--	3/99	3/99	4/93	6/99
Kim Shutty	1989	2/00	---	8/99	8/99	12/94	4/00
John Clark	5/98	3/00	--	5/99	6/00	8/00	2/00
Robert Wasserman	2000	4/00	---	8/99	8/99	---	4/00
Jennifer Martin	1999	3/00	---	5/99	5/99	8/00	5/00
Stephen Cackowski	1989	2/00	10/00	10/00	10/00	3/90	3/00
Dan Bishuk	1991	3/00	---	5/99	6/00	---	6/00

(a) At least one person onsite must have current certification in first aid/CPR for all tasks.
(b) At a minimum, the Site Manager must have had supervisor's training.
* Respirator clearance was issued at time of medical exam
11/99 (1/01) = Date of last Annual Refresher course (Date of next scheduled Annual Refresher course)
NOTE: No employees other than those listed above are permitted to work onsite without prior written approval by the Project Manager or SHSO.

TABLE 8-1 PERSONAL PROTECTIVE EQUIPMENT REQUIREMENTS

Equipment	Level D	Level C
Hard hat	X[a]	X
Safety glass	X	X
Splash shield	O	O
Work clothes	X	O
Boots, safety with steel toe/steel shank	X	NR
Boots, chemical resistant with steel toe and shank, or boot covers to go over safety boots	O[b]	X
Gloves, inner and outer, chemical resistant (nitrile)	O	X
Air-purifying full-face or half-face respirator	O[c]	X
Chemical-resistant clothing	O[d]	X
Disposable boot protectors	NR	O
Hearing protection	O	O
Two-way radio communication	NR	X*

(a) Hard hat will be required while within the Exclusion Zone of the drilling rig, due to overhead hazards.
(b) Disposable boot covers required onsite in areas where soil is exposed due to dioxin in surface soils.
(c) Required when drilling results in a dust hazard due to dioxin in surface soils.
(d) Required onsite when field activities result in dust hazard due to dioxin in surface soils.

NOTE: X = Required.
O = Optional.
NR = Not required.
X* = If permitted.

ATTACHMENT B
POTENTIAL HAZARDOUS SUBSTANCES

Substance	Maximum Levels in Media (Soil, Water, Air)	PEL (O) or TWA(A), STEL(S)	IDLH	Route of Exposure	Symptoms
Acenaphthene	0.8 ppb (water)	NA	NA	Inhalation	Mucous membrane and upper respiratory tract irritation.
Acetone	75 ppm (soil)	1000 ppm (O) 500 ppm (A)	2500 ppm [10%LEL)	Inhalation, Ingestion, Contact: skin, eyes	Irritant: eyes, nose, throat. Dizziness, CNS depression, dermatitis.
Antimony	6.4 ppm (soil)	0.5 mg/m^3 (O)(A)	50 mg/m^3	Inhalation; Ingestion; Skin and/or eye contact	Irritation eyes, skin, nose, throat, mouth; cough; headaches; dizziness; nausea; vomiting; diarrhea; stomach cramps; insomnia; anorexia; unable to smell properly
Anthracene	0.4 ppb (water)	0.2 mg/m3 (A,O), Ca	[80 mg/m^3] Ca	Inhalation, Contact: skin, eyes	Dermatitis, bronchitis, [carcinogen]
Arsenic	2.8 ppm (soil)	0.01 mg/m^3 (O,A) (Inorganic forms)	5 mg/m^3 Ca	Inhalation; Ingestion; Skin absorption; Skin and/or eye contact	Ulceration of nasal septum; dermatitis; GI disturbances; peripheral neuropathy; respiratory irritation; hyperpigmentation of skin
Benzo(a)anthracene	2.7 ppm (soil) 0.4 ppb (water)	NA, Ca	NA, Ca	NA	NA
Benzo(b)fluoranthene	1.2 ppm (soil)	NA, Ca	NA, Ca	NA	NA
Benzo(g,h,i)perylene	2.7 ppm (soil)	NA,	NA	NA	NA
Benzo(k)fluoranthene	1.5 ppm (soil) 0.1J (water)	NA	NA	NA	NA
Beryllium	0.57 ppm (soil)	0.002 mg/m^3 (O,A)	[4 mg/m^3 (as Be)] Ca	Inhalation; Skin and/or eye Contact	Berylliosis (chronic exposure): anorexia, low-weight, weak, chest pain, cough, clubbing of fingers, cyan, pulm insufficiency; irritable eyes; dermatitis; [carcinogen]

Substance	Maximum Levels in Media (Soil, Water, Air)	PEL (O) or TWA(A), STEL(S)	IDLH	Route of Exposure	Symptoms
Benzo(a)pyrene	2.7 ppm (soil) 0.2 ppb (water)	0.1 mg/m^3 (3) 0.5 mg/m^3 (2)	80 mg/m^3 Ca	Inhalation; Skin and/or eye Contact	Dermatitis, bronchitis, [carcinogen]
Chrysene	2.7 ppm (soil) 0.6 ppb (water)	0.2 mg/m3 (A,O), Ca	[80 mg/m^3] Ca	Inhalation, Contact: skin, eyes	Dermatitis, bronchitis, [carcinogen]
Cis-Dichloroethylene	250 ppb (water)	200 ppm (3)	1000 ppm	Inhalation, Ingestion, Contact: skin, eyes	Irritation to eyes, CNS, respiratory system, depression
Dibenz[a,h]anthracene	0.42 ppm (soil)	NA	NA, Ca	NA	NA
Dieldrin	0.02 ppb (water)	0.25 mg/m^3 (2)(3) Ca	50 mg/m^3 Ca	Inhalation; Ingestion; Skin absorption; Skin and/or eye contact	Head, dizziness; vomit, sweat, myoclonic limb jerks, tonic convulsions; [carcinogen]
Dioxin (TEQ)	Surface soil = 45.2 ppt, Subsurface soil = 496.7 ppt	Ca*	Ca	Inhalation; Absorption; Ingestion; Skin and/or eye contact	Irritation to eyes, allergic dermatitis, chloracne porphyria, gastrointestinal disturbance, possible reproductive teratogenic effects, liver and kidney damage, hemorrhage, [potential occupational carcinogen]
Fluoranthene	2 ppb (water)	NA	NA	NA	NA
Fluorene	0.2 ppb (water)	NA	NA	NA	Irritation of eyes, nose, and respiratory system; laryngeal spasm and bronchitis spasm; pulmonary edema; eye and skin burns; in animals, liver and kidney damage
Endrin	0.0039 ppb (water)	0.1 mg/m^3 (2)(3)	2 mg/m^3	Inhalation; Skin Absorption; Ingestion; Skin and/or eye Contact	Epileptic convulsions; stupor, head, dizziness, abdominal discomfort, vomit, insomnia, aggressiveness, weak
Gasoline	1750 ppm (soil)	[N.D.]	Ca [N.D.]	Inhalation; Ingestion; Skin absorption; Skin and/or eye	Irritable eyes, skin, mucus membranes, dizziness, slurred speech, convulsions, possible liver, kidney damage

Substance	Maximum Levels in Media (Soil, Water, Air)	PEL (O) or TWA(A), STEL(S)	IDLH	Route of Exposure	Symptoms
				contact	
Heptachlor Epoxide	0.02 ppb (water)	0.5 mg/m^3 (2)(3)	35 mg/m^3 Ca	Inhalation; Ingestion; Skin and/or eye Contact	Light-headed, giddiness, stupor, loss of appetite, dermatitis
Indeno[1,2,3-cd]pyrene	1.6 ppm (soil)	NA	NA	NA	NA
Lead	339 ppm (soil) 29.3 ppb (water)	0.5 mg/m^3 (A) 0.05 mg/m^3 (O)	100 mg/m^3 Pb	Inhalation; Ingestion; Skin and/or eye Contact	Weak; insomnia; facial pallor; low-weight; constipation; abdominal pain; anemia; gingival lead line; tremor; encephalopathy; kidney disease; irritable eyes
2-Methylnaphthalene	21 ppb (water)	NA	NA	NA	Eye, skin, and mucous membrane irritation.
Phenanthrene	7 ppb (water)	0.2 mg/m3 (A,O), Ca	[80 mg/m^3] Ca	Inhalation, Contact: skin, eyes	Dermatitis, bronchitis, [carcinogen]
Pyrene	0.260 ppm (soil) 2 ppb (water)	0.2 mg/m3 (A,O), Ca	[80 mg/m^3] Ca	Inhalation, Contact:skin, eyes	Dermatitis, bronchitis, [carcinogen]
Trans-Dichloroethylene	53 ppb (water)	200 ppm (3)	1000 ppm	Inhalation, Ingestion, Contact: skin, eyes	Irritation to eyes, CNS, respiratory system, depression
Total Dichloroethylene	250 ppb (water)	200 ppm (3)	1000 ppm	Inhalation, Ingestion, Contact: skin, eyes	Irritation to eyes, CNS, respiratory system, depression
Trichloroethylene (TCE)	5300 ppb (water)	25 ppm	1000 ppm Ca	Inhalation; Ingestion; Skin absorption; Skin and/or eye contact	Irritation to eyes, skin; head vertigo; visual disturbance; fatigue; giddiness; tremors; drowsiness; headaches; vomiting; dermatitis; cardiac arrhythmias; paresthesia; liver injury [potential carcinogen]
Vinyl Chloride	14 ppb (water)	1 ppm (O, A) 5 ppm (S)	N.D. [Ca]	Inhalation, Contact [liquid]: skin, eyes	Weakness, abdominal pain, GI bleeding, enlarged liver, cyanosis of extremities, [liquid]: frostbite. [carcinogen]

Substance	Maximum Levels in Media (Soil, Water, Air)	PEL (O) or TWA(A), STEL(S)	IDLH	Route of Exposure	Symptoms

NOTE:
- IDLH = Immediately Dangerous to Life and Health.
- N.D. = Not Determined.
- O PEL = Permissible Exposure Limit.
- A TWA = American Conference of Governmental Industrial Hygientists –Threshold Limit Value - Time Weighted Average
- S STEL = Short-Term Exposure Limit (15 min)
- Ca = Carcinogen
- NA = Data not available

Media Description:

1. Soil (Surface to 10-Ft Below Grade) (mg/kg)
2. Surface Soil (mg/kg)
3. Sediment (mg/kg)
4. Ground Water Shallow (ug/L)
5 Ground-Water Deep (ug/L)
6. Ground-Water Bedrock (ug/L)