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Environmental Geophysics at Beach Point, Aberdeen Proving Ground, Maryland

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Preface

This report provides administrative and technical staff, responsible for environmental planning and remediation at Beach Point, with the final results and conclusions drawn from geophysical studies begun in May 1993. During the course of the study, the work scope was expanded from that outlined in the Geophysics Work Plan, which emphasized the hydrogeologic framework beneath Beach Point, to include several technologies designed to determine the presence or former presence of contaminants, including surface spills, buried tanks, pipes, and trenches. In addition, the relationship between current aquifer contaminants and disposed liquid wastes was investigated. The work scope and its objectives were guided by staff at Aberdeen Proving Ground, Directorate of Safety, Health, and the Environment; Jacobs Engineering Group, Inc.; and Argonne National Laboratory, Reclamation Engineering and Geosciences Section. Field assistance was provided by Lisa Sachnoff and Robert Pell. Reviews of early versions of the manuscript were provided by Michelle Lorah-Devereux, U.S. Geological Survey; Dennis T. Burton, University of Maryland; and David Diodato, Pennsylvania State University.

Contents

Abstract	1
1 Introduction	1
1.1 Physiographic Setting and Site Survey	3
1.2 Site Geology and Hydrogeology	8
1.3 Outcrops	11
1.4 Instrumentation and Software	13
2 Magnetic Surveys	15
2.1 Magnetic Gradiometer Scan	15
2.2 Continuous Profiling Magnetometry	15
3 Electrical Surveys	19
3.1 Horizontal Conductivity Profiling - EM31	21
3.2 Horizontal Conductivity Profiling - EM34	25
3.3 Horizontal Resistivity Profiling - Octapod	25
3.4 Vertical Resistivity Sounding	27
4 Ground Penetrating Radar Surveys	30
4.1 Monostatic Ground Penetrating Radar	30
4.2 Bistatic Ground Penetrating Radar	33
5 High-Resolution Seismic Surveys	38
5.1 Seismic Refraction Profiling	38
5.2 Seismic Reflection Profiling	43
5.2.1 Shallow Reflection Analysis	44
5.2.2 Deep Reflection Analysis	44
6 Discussion	48
6.1 Hydrogeologic Framework	48
6.2 Possible Point Sources of Contaminants	48
6.3 Possible Contaminant Plume	50
7 Summary and Conclusions	52
8 References	53
Appendix A: Resistivity Depth Sounding Curves	57
Appendix B: Ground Penetrating Radar Profile Line Coordinates	79
Appendix C: Seismic Reflection Profiles	85
Appendix D: Area Magnetic Maps	95

Tables

1	Activities, Time-Frame, and Effort	3
2	Shoreline Outcrops	11
3	Magnetic Line Acquisition Parameters	15
4	Magnetic Anomalies with Nonsurface Source	17
5	EM31 Line Acquisition Parameters.....	23
6	Vertical Electrical Soundings at Beach Point.....	28
7	Refraction Profiles at Beach Point.....	39
8	Reflection Profiles at Beach Point.....	43

Figures

1	Beach Point Location Map in the Canal Creek Area, Aberdeen Proving Ground	2
2	Topography, Roads, and Major Buildings at Beach Point and Land Areas West of Beach Point	4
3	Location of Geophysical Survey Area for the Southern Portion of Beach Point.....	5
4	Location of Geophysical Survey Area for the Central Portion of Beach Point.....	6
5	Location of Geophysical Survey Area for the Northern Portion of Beach Point.....	7
6	Hydrogeologic Cross Section beneath the Canal Creek Area, Aberdeen Proving Ground	9
7	Lithology from Well Data in the Canal Creek Area.....	10
8	Beach Point Stratigraphy of the Upper 12 Feet from Outcrop Mapping.....	12
9	Beach Point Base Line Resistivity Profiles from ABEM/Octapod Resistivity and EM31 Data	20
10	Beach Point EM31 Anomalies.....	22
11	Beach Point EM34 Anomalies with 20-Meter Coil Spacings	24

Figures (Cont.)

12	Overlay Map of EM31 and EM34 Data Showing the Shift of Anomaly Minima to the East with Increasing Depth	26
13	Regional Resistivity Map Constructed from Horizontal Resistivity Data Collected with the Octapod	26
14	Resistivity Cross Section beneath the Beach Point Base Line	29
15	GPR Profile over a Dune-Shaped Reflector Containing Strong Internal Reflectors	31
16	GPR Profile over a Possible Buried Pit or Trench	32
17	GPR Anomaly Produced by a Buried Tank East of the Concrete Slab	33
18	GPR Profile at the North End of the Base Line	34
19	GPR Profile between 250S and 600S along the Base Line	34
20	GPR Profile between 600S and 800S along the Base Line	36
21	GPR Profile between 800S and 1050S along the Base Line	36
22	Relationship between EM31 Anomalies and GPR Reflectors	37
23	Location of Seismic Survey Lines at Beach Point.....	39
24	Seismic Refraction Interpretation along the Access Road to Beach Point	40
25	Seismic Refraction Interpretation along the Beach Point Base Line	41
26	Facies below Beach Point Peninsula on the Basis of Seismic Data	42
27	Configuration of the Pleistocene-Age Unconformity Developed on Cretaceous Coastal Plain Sediments on the Basis of High-Resolution Seismic Reflection Data	45
28	Facies below Beach Point Road on the Basis of Seismic Data	46
29	Magnetic Map of Beach Point with Conductivity Overlay	49
30	Conductivity Map of Beach Point with Magnetic Overlay	49
C.1	Stacked Seismic Section for BCHNS-DP	89
C.2	Stacked Seismic Section for BCHEW-DP	90
C.3	Stacked Seismic Section for BCHEW-SH	90
C.4	Stacked Seismic Sections for BCHNS000, BCHNS50B, BCHNS50A, and BCHNS100	91

Figures (Cont.)

C.5	Stacked Seismic Sections for BCHEW450, BCHEW650, and BCHEW1000	92
C.6	Stacked Seismic Section for BCHXWELL	93
D.1	Beach Point Area 1 Magnetism	97
D.2	Beach Point Fine Grid: Southeast.....	99
D.3	Beach Point Area 2 Magnetism	101
D.4	Beach Point Area 3 Magnetism	103
D.5	Beach Point Fine Grid: Northwest.....	105
D.6	Beach Point Area 4 Magnetism	107
D.7	Beach Point Area 5 Magnetism	109
D.8	Beach Point Area 6 Magnetism	111
D.9	Beach Point Area 7 Magnetism	113
D.10	Beach Point Area 8 Magnetism	115
D.11	Beach Point Area 9 Magnetism	117

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Abstract

Geophysical studies at Beach Point Peninsula, in the Edgewood area of Aberdeen Proving Ground, Maryland, provide diagnostic signatures of the hydrogeologic framework and possible contaminant pathways. These studies permit construction of the most reasonable scenario linking dense, nonaqueous-phase liquid contaminants introduced at the surface with their pathway through the surficial aquifer. Subsurface geology and contaminant presence were identified by drilling, outcrop mapping, and groundwater sampling and analyses. Suspected sources of near-surface contaminants were defined by magnetic and conductivity measurements. Negative conductivity anomalies may be associated with unlined trenches. Positive magnetic and conductivity anomalies outline suspected tanks and pipes. The anomalies of greatest concern are those spatially associated with a concrete slab that formerly supported a mobile clothing impregnating plant. Resistivity and conductivity profiling and depth soundings were used to identify an electrical anomaly extending through the surficial aquifer to the basal Pleistocene unconformity, which was mapped by using seismic reflection methods. The anomaly may be representative of a contaminant plume connected to surficial sources.

1 Introduction

An environmental geophysical study was conducted at Beach Point, Aberdeen Proving Ground (APG), Edgewood Area (Figure 1), during early summer 1993 in order to define the hydrogeologic framework; to determine the location of near-surface, point-source contaminants; and to determine contaminant pathways. Most of the geophysical surveys were done on Beach Point Peninsula, although seismic reflection and refraction profiles were obtained to the west of the peninsula on Beach Point Road. Activities, time-frame, and effort are detailed in Table 1.

Geophysical activities were spurred by the use history of Beach Point (see Table 7 ID no. 25, Lorah and Clark, in preparation; and Jacobs Engineering Group, Inc., 1992). Major activities in the area included liquid rocket fuel tests, rocket fuel fire suppression tests, pyrotechnic material and smoke generator tests, and the use of solvents at a mobile clothing

FIGURE 1 Beach Point Location Map in the Canal Creek Area, Aberdeen Proving Ground (Source: Oliveros and Vroblesky 1989)

TABLE 1 Activities, Time-Frame, and Effort

Activity	Submitted/Time Window	Comment
Geophysics Work Plan	October 1992	Includes seismic reflection, refraction, resistivity profiling, vertical electrical sounding, electromagnetic profiling, magnetics, and ground penetrating radar.
Health and Safety Plan	March 1993	Final approval by APG, 5/15/93.
Mobilization	May 6-12, 1993	
Transport	May 13-14, 1993	
Site effort	May 15-16, 1993	

impregnating plant. Some of the wastes were discharged into unlined pits or directly onto the ground surface and either ran off into surface water or percolated into the subsurface. Buildings located at the test site were used for small-scale chemical agent storage (G agents), laboratories, storehouses, offices, and machine shops. Several of these structures were built with sewer systems that discharged directly to Kings Creek and Bush River. A few of the buildings were constructed with septic systems, which allowed septic system effluent to percolate into the subsurface (Lorah and Clark, in preparation).

An original objective of the study was to determine the local hydrogeologic framework down to the crystalline basement beneath Beach Point. Following initiation of the field study, a decision was made, with the concurrence of personnel of the Directorate of Safety, Health, and Environment (DSHE) and Jacobs Engineering Group, Inc., to expand the Geophysics Work Plan to include a search for possible buried tanks, pipes, and trenches.

1.1 Physiographic Setting and Site Survey

Beach Point Peninsula lies within the Atlantic Coastal Plain physiographic province of Maryland. The long axis of the peninsula (Figure 2), oriented approximately 45° east of north, measures 1,200 ft. The peninsula is a remnant of subareal erosion that occurred during a low sea level stand followed by sea level rise and estuarine encroachment into Kings Creek, which is a tributary of Bush River. Bush River is one of the major tidal estuarine channels on the western shores of Chesapeake Bay. Elevations range from 25 ft above sea level in the western approaches to the site, to sea level at the shoreline. Average elevation of the site is approximately 10 ft above mean sea level (Figure 2).

FIGURE 2 Topography, Roads, and Major Buildings at Beach Point and Land Areas West of Beach Point

The area surveyed covers approximately 70% of Beach Point Peninsula, measuring approximately 1,250 ft along the axis of the peninsula with a maximum width of 250 ft. The geophysical survey coordinate 00N-00W is located 150 ft south of the northern tip of the peninsula. Figures 3, 4, and 5 show details of the southern, central, and northern sections of the survey area. A 1,050-ft-long north-south geophysical Base Line, extending from 00N-00W to 1050S-00W, was used repeatedly for instrument calibration and to compare results of the various instruments. Reference to the *Base Line* will occur repeatedly throughout the report.

A 50-ft grid of wooden survey stakes was used to guide the geophysical surveys. The grid was laid out using 300-ft surveyor's tapes and a Brunton compass. Two benchmarks (B) on the peninsula, located at geophysical survey coordinates 250S-0W and 983S-0W, provide location control. (Figures 3 and 5 show the locations of benchmarks.)

FIGURE 3 Location of Geophysical Survey Area for the Southern Portion of Beach Point

Explanation

FIGURE 4 Location of Geophysical Survey Area for the Central Portion of Beach Point

FIGURE 5 Location of Geophysical Survey Area for the Northern Portion of Beach Point

1.2 Site Geology and Hydrogeology

A late Precambrian crystalline basement platform, lying approximately 560 ft beneath the northeast tip of Beach Point Peninsula, is composed of rocks similar to those found at the surface in the Piedmont Province northwest of the Fall Line (Oliveros and Vroblesky 1989). The crystalline basement surface dips to the southeast at an angle of less than one degree (Bennett and Meyer 1952; Dingmen et al. 1956; Southwick and Owens 1969). East of the Fall Line, including all of the area in this report, unconsolidated Atlantic Coastal Plain sediments overlie Piedmont basement rocks.

Atlantic Coastal Plain sediments beneath the Edgewood area of APG were deposited during the Cretaceous Period and the Pleistocene Epoch (Oliveros and Vroblesky 1989). Most of the unconsolidated sediments comprise the Potomac Group, deposited during the Cretaceous Period. Although sediments of the Potomac Group have been further subdivided into formations near Baltimore City, they have not been differentiated beneath APG, where they are referred to collectively as the Potomac Group (Oliveros and Vroblesky 1989).

Sediments that overlie the Potomac Group consist primarily of the Talbot Formation of Pleistocene age with minor amounts of Quaternary alluvium. The Talbot Formation is relatively thin and horizontally discontinuous in the western areas of Edgewood, but it thickens to the east to approximately 60 ft in the area of Aberdeen Proving Ground (Oliveros and Vroblesky 1989). Beneath the Edgewood area, the Talbot Formation is thickest where it occurs as fill in a paleochannel that is cut to a depth of at least 50 ft into the Potomac Group sediments.

A generalized hydrogeologic section beneath the Canal Creek area, taken from Lorah and Vroblesky (1989), is shown in Figure 6. Lorah and Vroblesky (1989) describe the section as follows: "Hydrogeologic units were defined partly on the basis of hydrologic characteristics of the units; therefore, the boundaries between the hydrogeologic units do not necessarily correspond with contacts between geologic units. The surficial aquifer sediments are primarily composed of the Talbot Formation but are a composite of both the Talbot Formation and Potomac Group in some areas. The upper confining unit, the Canal Creek aquifer, the lower confining unit, and the lower confined aquifer are composed of Potomac Group sediments."

Lithologies and gamma logs in three wells on Beach Point Peninsula (and others pertinent to this study) are shown on Figure 7, with locations shown on Figures 1 through 4. Lithologies consist of alternating silty sand and clay layers with interbeds of coarse-grained, sandy gravels, indicative of a fluvial environment. Using our seismic reflection and refraction data, we interpret sediments down to a clay aquitard, at depths ranging from 40-67 ft, as the surficial aquifer of Lorah and Vroblesky (1989).

An angular unconformity of Pleistocene age is developed on the clay aquitard, which is a member of the Potomac Group sediments. The unconformity, referred to here as the P-K

EXPLANATION

 Ground-Water Flow

FIGURE 6 Hydrogeologic Cross Section beneath the Canal Creek Area, Aberdeen Proving Ground (Source: Lorah and Vroblesky 1989)

Legend

FIGURE 7 Lithology from Well Data in the Canal Creek Area (Source: Oliveros and Gernhardt 1989)

unconformity, will be discussed further in Subsection 5.2.1, *Shallow Reflection Analysis*. In discussions to follow, the terms "base of the Pleistocene," "P-K unconformity," "base of the surficial aquifer," and "top of the Potomac Group" all refer to the contact at the sand/clay base of the thick sands near the bottom of well CC-33.

From observations at Beach Point and from studies elsewhere in the Canal Creek area, it is evident that a well-integrated tributary system of Pleistocene age was deeply incised into Potomac Group sediments as a result of successive episodes of sea level lowering of 300 ft or more. The tributary system provides the framework for shallow groundwater flow and for potential recharge into Potomac Group aquifers. Mapping the configuration of this system is one of the objectives of geophysical studies at Beach Point.

1.3 Outcrops

The peninsula surface slopes gently toward the shoreline bordering the mouth of Kings Creek on the northwest and Bush River on the southeast. Outcrops occur only on the shoreline at the locations indicated in Table 2. Outcrop lengths, generally measuring 12 ft or less, were cleaned of debris, and a cross section was drawn showing the dominant facies (Figure 8).

TABLE 2 Shoreline Outcrops

Location	Length of Exposed Outcrop (ft)	Lithologies Present
East Side		
1750S	12	Sand, gray-brown clay
1700S	15	Sand, gray-brown clay
1425S	12	Sand, gray-brown clay
1225S	12	Gray-brown clay only
550S	10	Sand, gray-brown clay
475S	10	Sand, gray-brown clay
200S	4	Gray-brown clay only
West Side		
600S	6	Sand, gray-brown clay, clayey sand
525S	8	Sand, gray-brown clay
400S	7	Sand, gray-brown clay

FIGURE 8 Beach Point Stratigraphy of the Upper 12 Feet from Outcrop Mapping

Outcrops are represented by alternating sands, sandy gravels, clays, and clayey-sands. Thin lenses of well-rounded, boulder-sized igneous rocks, at a sand/clay contact, were also found in outcrops. The coarse clastic sediments suggest an overbank deposit in a fluvial environment of high energy. The upper clay is very dense, hard, and nonorganic. The lower sand is a well-rounded, well-sorted, uncemented, quartz-arenite with clay lenses varying in size. Only one area had no well-defined boundary between the sand and clay, which otherwise was clearly identified.

1.4 Instrumentation and Software

The Schonstedt MAC-51B magnetic gradiometer and cable locator is a dual-mode instrument designed for use in detection of shallow buried iron and steel objects and for tracing underground cables and pipes. The system consists of a transmitter and a dual-function receiver designed to detect anomalous magnetic gradients.

Magnetic data were acquired with an EG&G Geometrics G-822L cesium vapor magnetometer. The magnetometer is a continuously recording, total field, microprocessor-based instrument capable of resolution of anomalies to one nanotesla (1 nT).

Electrical conductivity measurements were made with the Geonics EM31 and EM34 electromagnetic instruments, which provide mean values of conductivity, in millisiemens per meter (mS/m), of soils ranging from 0 to approximately 100 ft in depth. Apparent conductivities are averaged over the depth range.

Horizontal electrical resistivity profiling data were acquired with an ABEM Terrameter and Booster interfaced with a modified Wenner electrode array positioned on a rigid frame and towed behind an all-terrain vehicle. The array was designed by Argonne National Laboratory (ANL) staff and is referred to as the *Octapod*. Data acquired with the Octapod provide mean resistivities in the upper six feet. These data are unaffected by spurious atmospheric electrical noise or by close proximity to metallic buildings. For this reason, resistivity data can be used for quality control of electrical measurements. Wenner a-spacing (electrode separation) was held at a constant two meters.

Electrical depth soundings were also made with the ABEM Terrameter. A Bison BOSS electrode array, an "offset" Wenner technique (Barker 1981), was used in the soundings to enhance data quality. Electrode separations ranged from 0.5 to 64 m for a maximum current electrode separation of 192 m. All cable arrays for depth soundings were oriented parallel with the long axis of the peninsula. RESIXP software developed by Interpex was used in processing sounding data.

Ground penetrating radar (GPR) surveying was accomplished using a Geophysical Survey Systems, Inc. (GSSI), model SIR-3 unit, with a model 38 video display, connected to either variable-frequency transceivers or to a bistatic antenna system. Data were recorded on a

digital audio tape through the model 38 system, which was downloaded to a personal computer. The control unit/video display was located in the transport vehicle. An IBM-compatible processing computer was located in a field office, so that radar profiles could be downloaded, data-tape quality checked, and preliminary data processing performed on the profiles. Radan III computer software written by GSSI was used for processing the GPR data.

A 24-channel reflection/refraction seismograph (EG&G ES-2401), with geophone cables of 2, 5, and 10 m geophone spacings, and various sound sources were used to determine depths and velocities beneath Beach Point. Geophones having natural frequencies of 12 Hz were used for refraction profiles. Sound sources consisted of both a 16-lb sledgehammer and a trailer-mounted Bison elastic-wave generator (EWG). On-site analyses and quality control of the seismic data were conducted using SIPT refraction programs developed by Rimrock Software.

Common depth point (CDP) seismic reflection techniques were used to image the sedimentary units and crystalline basement underlying Beach Point Peninsula and to map the configuration of the Pleistocene P-K unconformity at the base of the surficial aquifer. The CDP method uses one shotpoint per receiver array. The entire array and shotpoint are moved with the use of a roll-along-switch after each shot. To calculate depths to reflectors, two-way times (TWTs) are converted to depths by using interval velocities determined from refraction profiling and from static corrections.

Eavesdropper reflection software produced by Interactive Concepts, Inc., was used for reflection data processing. On-site processing consisted of (1) trace-editing, (2) CDP sorting, and (3) velocity analysis. Trace-editing removes unwanted information, such as the air wave, and bad traces. CDP sorting groups the seismic data into blocks of information and assembles the resultant depths into a common horizontal location. Velocity analysis examines the velocities required to correct the seismic data for spatial distortions and gives a preliminary velocity-depth function for final corrections applied to the data.

Final processing steps include (1) editing to remove refracted first arrivals, surface waves, and air waves; (2) bandpass filtering; (3) CDP sorting; (4) velocity analysis; (5) normal-move-out (NMO) corrections; and (6) CDP stacking. Both refraction and reflection software packages are designed for use on an IBM-compatible personal computer.

The Bison EWG was used as the energy source to image deep reflectors, and the 16-lb hammer was the source for shallow reflectors. Geophones having natural frequencies of 40 Hz were used for the reflection profiles.

2 Magnetic Surveys

2.1 Magnetic Gradiometer Scan

The Schonstedt Gradiometer was used (1) to avoid shallow magnetic debris during emplacement of geophones or stakes and (2) at impact locations for seismic studies. The instrument does not record data or give a quantifiable reading, but simply emits a tone that represents differences in the magnetic field strength as measured by two sensors in the wand end of the instrument. The area was swept with the wand and anomalous locations were marked with spray paint. The gradiometer sweep was also used to indicate areas that required detailed coverage with the more quantitative geophysical equipment.

2.2 Continuous Profiling Magnetometry

Beach Point was divided into nine areas to facilitate processing and to permit a better view of isolated anomalies. Figures D.1 through D.11, Appendix D, show the area magnetic maps for the nine areas. Magnetic line acquisition parameters for the nine areas are described in Table 3. Data were acquired at a rate of 10 readings per second at a walking pace, resulting in less than 1 ft spacing along traverses spaced 10 ft apart. Two areas having anomalies that required more detailed scans were surveyed with profiles spaced 5 ft apart; these are shown in Figures D.2 and D.5. The magnetic maps are used to identify ferrous metal objects, including pipes, drums, and buried tanks, which might be associated with point sources of contaminants.

TABLE 3 Magnetic Line Acquisition Parameters

Area	No. of Stations	No. of Survey Lines	Line Length (ft)	Total Line Footage (ft)
1	5,100	17	100	1,700
2	12,000	20	200	4,000
3	11,340	21	180	3,780
4	5,280	11	160	1,760
5	1,980	6	110	660
6	1,620	6	90	540
7	2,475	11	75	825
8	1,080	6	60	360
9	1,260	21	20	420
Totals	42,135	119		14,045

Errors introduced into the magnetic data due to uncorrected diurnal variations, errors in location, or insufficient response speed to a changing signal are small in comparison with anomaly amplitudes. Therefore, the anomalies displayed on the magnetic maps are qualitatively significant. Some error, however, is introduced through inadvertent changes in instrument position or attitude relative to the ground surface. Moving around surface obstacles, changes in walking pace, or failure to trigger fiducial markers at the proper location will also produce some positioning error. Marks were placed on the data at 50-ft intervals and at the beginnings and ends of survey lines. Careful control of acquisition and processing procedures kept errors to a minimum.

Magnetic anomalies can, in many cases, be explained by surface or near-surface ferrous objects; however, others remain unexplained. Anomalies are observed throughout the Edgewood area where iron-rich amphibolite was used as road fill. Twenty-two anomalies of unknown origin are listed in Table 4, with coordinates given at their centers. Anomalies associated with the roadway system on Beach Point, and with other obvious surface debris, are not listed.

The shoreline on the east side of the Beach Point Peninsula consists of concrete rubble and steel rebar, which causes large-amplitude, high-frequency anomalies. The rubble extends from approximately 200S to the farthest southern point surveyed. The western half of the area consists of dense woods littered with metal debris that produces many small anomalies. All surficial metal objects in the area were noted as to location, size, and type. Two of eight concrete foundations present on Beach Point Peninsula contain rebar and also produce anomalies.

The eastern third of the site, beginning with survey Area 1 (Figures D.1 and D.2) at the southern end of the peninsula, is dominated by anomalies produced by road fill. Isolated anomalies west of the road are caused by surface debris, unless they are specifically identified in Table 4. An example of an unexplained anomaly is located at 1020S-70W, although it is located near the road and may be associated with road debris. An area with profiles spaced 5 ft apart was surveyed west of the road (Figure D.2) to examine the magnetic detail displayed on the Area 1 map. It is probable that all anomalies within 20 ft of the road edge are associated with fill material.

Area 1 magnetics (Figure D.1). The southeastern two-thirds of the area, including anomalies along lines 70W and 80W, is dominated by anomalies associated with road fill or by construction fill along the southeastern shore of Beach Point. The anomaly in the northwest quarter on line 130W is produced by surficial debris. See Figure D.2 for additional detail.

Area 2 magnetics (Figure D.3). Area 2 contains five unexplained anomalies observed along N-S lines 100W and 110W. The anomalies are observed only on one line and have widths ranging from 5 to 20 ft. The remainder of the anomalies to the east are associated with the University of Maryland bio-assay trailer, with the access road, or with slope-stability debris on the southeast shoreline. Anomalies in the western half of the area are caused by unknown, buried sources, as listed in Table 4.

TABLE 4 Magnetic Anomalies with Nonsurface Source

Area	Anomaly No.	Coordinates		Anomaly Dimensions and Orientation
		X	Y	
1	1	70W	1020S	Source unknown line 70W, 8 ft long
2	2	110W	910S	Mound at surface (buried trench?) seen only on line 110W, 12 ft long
	3	103W	867S	Source unknown line 100W, 20 ft long
	4	110W	817S	Source unknown 110W, 15 ft long
	5	111W	767S	Source unknown 110W, 10 ft long
	6	110W	750S	Source unknown 110W, 5 ft long
3	7	75W	560S	Possible buried tank next to slab
	8	60W	580S	Possible buried tank next to slab
	9	130W	622S	Anomalies (130W, 133W, and 145W) possibly associated with a trench
	10	133W	579S	
	11	145W	557S	
	12	111W	720S	Series of anomalies (111W, 114W, 127W, 144W, and 150W) along E-W linear trend
	13	114W	741S	
	14	127W	730S	
	15	144W	710S	
	16	150W	690S	
4	17	130W	468S	Gravel fill at surface on line 470S
	18	37W	491S	On two lines, 480S and 490S
	19	15W	530S	Possible buried tank next to slab
	20	30W	530S	Possible buried tank next to slab
6	21	65W	390S	On line 390S, 5 ft wide
7	22	18W	330S	Source unknown

Area 3 magnetics (Figure D.4). Anomalies on the east are associated with road fill. Area 3 contains two clusters of unexplained anomalies, one in the northwest corner and one along an east-west linear trend between 710S and 730S. Both features may be associated with burial trenches and should receive further examination. The large anomaly complex at 690S-40W is located at a surface disturbance. Anomalies in the northwest quarter are caused partially by surface debris. An anomaly centered at 560S-75W lies near the edge of a concrete slab and may represent a buried tank associated with a former mobile clothing impregnating plant (Jacobs Engineering Group, Inc. 1992). (The slab area is discussed further in the following paragraph on Area 4). See Figure D.5 for additional detail.

Area 4 magnetics (Figure D.6). Area 4 is surveyed over an area containing a large concrete slab extending from 10W to 85W and from 580S to 525S. The slab served as the foundation for a mobile clothing impregnating plant (noted in the previous paragraph). The slab does not generate a significant anomaly, which indicates rebar was not used in its construction. Several magnetic anomalies are located peripherally to the slab and may indicate buried tanks, pipes, or trenches. See Figure D.5 for additional detail.

Area 5 magnetics (Figure D.7). All anomalies are associated with the access road fill.

Area 6 magnetics (Figure D.8). Anomalies are caused primarily by road fill. One small anomaly at 390S-65W remains unexplained.

Area 7 magnetics (Figure D.9). Anomalies are caused by road fill. The anomaly at 330S-0W is of unknown origin.

Area 8 magnetics (Figure D.10). Anomalies are caused by road fill.

Area 9 magnetics (Figure D.11). Anomalies are caused by road fill.

3 Electrical Surveys

Electrical properties of the earth were measured at Beach Point Peninsula with a combination of horizontal profiling and vertical electrical sounding (VES) techniques. Electrical methods are dependent on potential fields induced through noncontact, electromagnetic (EM) induction or by fields induced through grounded electrodes. Data can be converted to either resistivity or conductivity for use in defining both the hydrogeologic framework and pore water chemistry. The chemistry of interstitial water plays the dominant role in electrical variations in the earth, and for this reason electrical methods are particularly suited for tracking contaminants. The characterization of three-dimensional electrical properties, in combination with other geophysical methods, is used to identify locations of point sources and to infer water movement from point sources to aquifers in natural groundwater flow systems.

Three instruments have been used to determine electrical properties at Beach Point Peninsula: two EM systems, the EM31 and EM34; and one resistivity instrument, the ABEM Terrameter. Figure 9 shows a comparison of the electrical response of the EM31 and the ABEM/Octapod in a horizontal profile along the Base Line.

Resistivity data (Figure 9) recorded with the ABEM/Octapod represent apparent resistivity values averaged over the upper 6 ft. Because of the extremely high amplitude of near-surface resistivity, the anomaly amplitudes were truncated at 100 $\Omega \cdot m$.

Two resistivity curves, calculated from the EM31, are also displayed in Figure 9: one with the EM transmitter-receiver pair oriented longitudinal (parallel) to the direction of the Base Line, and a second with the pair orthogonal (at a right angle) to the Base Line. In both orientations, EM data represent mean values averaged over 0 to 20 ft depth. Conductivities are measured along orthogonal azimuths in order to evaluate the electrical anisotropy of the subsurface, such as might be associated with linear pipes, trenches, or plumes. Conductivities are converted to resistivity using the equation:

$$\text{resistivity } (\Omega \cdot m) = \frac{1000}{\text{conductivity}} \text{ (mS/m)}.$$

Inspection of the three resistivity curves leads to the following observations:

1. The ABEM/Octapod apparent resistivity values are generally much higher than EM resistivities. This indicates that mean resistivities of the upper 6 ft are much higher than mean resistivities of the upper 20 ft. In other words, resistivities decrease with depth.

FIGURE 9 Beach Point Base Line Resistivity Profiles from ABEM/Octapod Resistivity and EM31 Data (EM31 data were acquired with the transmitter receiver boom longitudinal [parallel] and orthogonal [at right angles] to the line axis.)

2. EM resistivities for the longitudinal orientation and the orthogonal orientation are nearly identical, except for minor excursions on the south end of the Base Line (i.e., anisotropy is not a factor in the upper 20 ft).
3. Resistivities determined with the EM31 and the ABEM/Octapod are nearly identical in the northern 80 ft of the Base Line (i.e., the low-resistivity buried layer present along the central and southern Base Line rises to the surface in the northern 80 ft).

Resistivity differences between the ABEM/Octapod and the EM31 measurements are explained by the fact that soil saturation and water chemistry change with depth. Increased saturation and chloride content cause apparent resistivities to be *less* than those of the same sediments when dry or partially saturated. The similarity of resistivity values calculated using two orientations of the EM31 boom indicates that lateral anisotropy of surficial materials is essentially absent along the Base Line in the upper 20 ft. Finally, where the land surface approaches sea level at the northern end of the Base Line, the ABEM and EM31 provide nearly identical resistivities. This observation suggests that resistivity change is due to increased saturation or to chloride content (or both), since GPR data suggest that the subsurface is homogeneous to depths greater than 30 ft at the northern end of the line. Figure 9 provides quality control through a cross-check of electrical methods.

3.1 Horizontal Conductivity Profiling - EM31

EM31 data were collected in nine data sets along east-west profiles, spaced 10 ft apart, with profile lengths decreasing to the north, from 180 ft in length in the south to about 50 ft in the north. The nine areas coincide with magnetic areas shown in Figures D.1 through D.11. The Base Line serves as a tie line to link the nine data areas. Line locations and the configuration of EM31 conductivities are shown on Figure 10. Data were acquired on a digital data logger at a 0.5-s sampling rate, resulting in a mean station spacing of 1.5 ft. Electromagnetic data acquisition parameters are shown in Table 5.

The configuration of the EM31 surface is marked by high-amplitude, short-wavelength anomalies of anthropogenic origin and by low-amplitude, longer-wavelength anomalies characteristic of natural changes in subsurface soils. The large-amplitude anomalies are easily explained by surficial features, such as the University of Maryland bio-assay trailer, the access road, metal debris strewn about the site, and two concrete slabs north of 650S.

Conductivities, ranging from 10 to 40 mS/m, are largely explained by natural variations in electrical properties of the subsurface at Beach Point Peninsula. Conductive areas to the east

FIGURE 10 Beach Point EM31 Anomalies (Conductive areas to the east are produced by surficial objects, including road fill and a trailer. Conductive areas to the west are associated with highly saturated clays and organic soils in the wooded portion of beach point. Less conductive anomalies in the central areas may be in response to a deeper water table. High-intensity, low-conductivity anomalies centrally located north of 730S may be related to activities associated with a former building on the concrete slab in that area. Intense minima, particularly along Lines 520S and 530S, may signify gravel pits and trenches into which contaminants were dumped.)

TABLE 5 EM31 Line Acquisition Parameters

Area	No. of Stations	No. of Lines	Line Length (ft)	Total Line Footage (ft)
1	1,332	11	180 E-W	1,980
2	2,560	21	180 E-W	3,780
3	2,350	21	170 E-W	3,570
4	974	11	150 E-W	1,650
5 & 6	721	11	100 E-W	1,100
7 & 8	832	16	60 E-W	960
9	465	3	200 E-W	600
Base Line (tie line)	444	1	1,050 N-S	1,050
Totals	9,677	95		14,690

are produced by surficial objects, including road fill and a trailer. Conductive areas to the west are associated with highly saturated clays and organic soils in the wooded portion of Beach Point Peninsula. The axis of the peninsula, except for small circular or elliptical positive anomalies, is associated with a sinuous trend of low conductivities. An anomaly in this trend, centered at 810S-125W, cannot be explained by surface topography or anthropogenic surface features. A possible cause of this anomaly is observed on a GPR profile discussed in Section 4.1.

Two concrete slabs lying between 520S and 640S are associated with a broad negative in the central negative trend. A positive anomaly at 580S to 590S-25 W and an unusually negative anomaly at 527S-85W are probably of anthropogenic origin. The positive anomaly is located near the southeast corner of the larger slab. The cause of the positive anomaly is uncertain; the negative anomaly, however, may indicate the presence of a burial pit or trench.

An area extending from approximately 480S to 780S in the western wooded area, near the northern tip, is relatively more conductive than the axial region. The more conductive areas to the west reach 30 mS/m, whereas the axial area is associated with conductivities of less than 15 mS/m. High-intensity, low-conductivity anomalies centrally located north of 730S may be related to activities associated with the former building on the concrete slab discussed in the preceding paragraph. Intense minima, particularly along lines 520S and 530S, may signify gravel pits and trenches into which contaminants were dumped. Less conductive anomalies in the central areas may be in response to a deeper water table.

The access road is associated with a triplicate, parallel, linear anomaly in the southern area of study, with a negative anomaly being flanked by two positive anomalies (Figure 10). The

FIGURE 11 Beach Point EM34 Anomalies with 20-Meter Coil Spacings (The conductivities are the result of mean electrical properties of sediment and interstitial pore fluids between the surface and a depth of approximately 50 ft.)

triplicate signature is a common trait of EM mapping where the instrument crosses a long, narrow conductor, such as that caused by road fill. The central minimum is simply an artifact of antenna/receiver geometry.

3.2 Horizontal Conductivity Profiling - EM34

EM34 data were collected in the horizontal dipole mode with coil spacings at 32.8, 65.6, and 131.2 ft, providing mean conductivities over depth ranges of 24.6, 49.2, and 98.4 ft, respectively. Data were acquired along the north-south Base Line for all three coil separations. Additional data were recorded at the 65.6-ft (20-m) coil spacing at locations shown on the EM34 map (Figure 11). The EM34 data were acquired in order to develop a better understanding of the distribution of electrical conductivities at greater depths than could be provided with the EM31.

The configuration of mean conductivities over a depth range of 0 to 49.2 ft (Figure 11) is similar to the map of EM31 data shown in Figure 10. However, the centrally located, sinuous trend of low conductivities observed on the EM31 map is shifted to the east 40-50 ft on the EM34 map. The relationship between the mean conductivities is shown on Figure 12, where EM34 data are overlaid on EM31 data. The association of low conductivities with the concrete slabs noted in the previous section for EM31 data is no longer observed on the EM34 map. EM34 conductivity trends are more closely associated with facies and pore water chemistry variations in the deeper parts of the surficial aquifer than in the near-surface clays.

3.3 Horizontal Resistivity Profiling - Octapod

A map of horizontal resistivity values based on 194 stations is shown in Figure 13. The map mimics, in a general way, the map of EM31 data (Figure 10), although the access road across the site is represented by a much more prominent resistivity anomaly, reflecting its shallower sensing range. The low-resistivity, sinuous lineament, oriented N-S, is produced by road fill. The most prominent resistivity feature, other than the road anomaly, is a large, low-amplitude minimum, centered at approximately 650S-100W. It is probable that this anomaly is produced by natural differences in near-surface resistivity, such as increasing saturation and thickening of near-surface clay.

The high-resistivity linear trend in the central and north-central parts of the map may be a result of natural change due to less saturated conditions in the central peninsula; however, this area is located in an area of waste-liquid disposal pits. If waste liquids were associated with high resistivities, the waste could also contribute to the anomaly. High-resistivity areas, over 150 Ω -m in the north, coincide with low-conductivity features associated with the former building site.

FIGURE 12 Overlay Map of EM31 and EM34 Data Showing the Shift of Anomaly Minima to the East with Increasing Depth

FIGURE 13 Regional Resistivity Map Constructed from Horizontal Resistivity Data Collected with the Octapod (A low-resistivity sinuous lineament, oriented N-S, is produced by road fill. High-resistivity areas, over 150 $\Omega\cdot m$ in the north, coincide with low-conductivity features associated with the former building site.)

3.4 Vertical Resistivity Sounding

Vertical electrical soundings (VES) at Beach Point Peninsula were centered at 15 sites, located as listed in Table 6. Resistivity data were determined within the depth range extending from the surface to approximately 200 ft. Resistivity-depth curves and their inversions are shown in Appendix A.

Analyses of VES curves provide resistivities and depths, which in combination with EM and horizontal resistivity data are used to construct a resistivity cross section beneath the Base Line, as shown in Figure 14. Resistivities are obtained from converted EM31 and EM34 data, ABEM/Octapod profiling, and VES. Mean resistivity at the total sensing depths of the EM31, EM34, and ABEM/Octapod are used.

A thin skin of high surficial resistivities in Figure 14 defines the electrical characteristics of the vadose zone above the water table. An abrupt drop in resistivities at the water table and below is defined by data derived from the deeper EM sounding measurements. Below depths of 100 ft, the cross-section characteristics are controlled by data obtained from VES.

An electrical anomaly, reaching approximately 60 Ω -m, in a background of values less than 40 Ω -m, is located between 700S and 550S. The anomaly is observed on EM31, EM34, and VES stations located along the Base Line. The field curves of resistivity versus electrode separation at stations located between 650S and 750S are characterized by rapidly rising apparent resistivities at maximum electrode spacings (see Appendix A). Because of the inherent ambiguity in the interpretation of electrical depth sounding curves, due to possible horizontal resistivity changes, a single depth sounding interpretation would not conclusively define the deep anomaly. However, the anomaly is also observed with EM34, at 30-m and 40-m coil spacings, for three independent measurements. The shape of the anomaly, its lack of conformity with flat-lying stratigraphy, and its depth suggest the presence of a high-resistivity zone contained in the surficial aquifer. The high resistivities may be associated with a plume that originated at sources outlined by low-conductivity anomalies described earlier in the discussion on the EM31 survey, Section 3.1, *Horizontal Conductivity Profiling*. Lower resistivities in the surficial aquifer are probably caused by high chloride content due to saltwater intrusion from tidal action in Bush River.

Composition of the contaminants contained in pore liquids producing the electrical anomaly is uncertain; however, concentrations up to 20 parts per million (ppm) volatile organics, consisting of tetrachloroethane and trichloroethene, among others, have been reported in Beach Point groundwater (Burton 1993). Since volatile organics have high resistivities, it is possible that the resistivity anomaly does correspond with a dense, nonaqueous-phase liquid (DNAPL) plume. Further study is needed to investigate the level of electrical response and chemical interactions at low concentration levels (a few ppm) and with different types of clay minerals.

**TABLE 6 Vertical Electrical
Soundings at Beach Point**

Site Sounding No.	Location of Center
1	650S - 10W
2	1050S - 5W
3	950S - 0W
4	850S - 0W
5	750S - 0W
6	550S - 0W
7	450S - 0W
8	350S - 0W
9	250S - 0W
10	150S - 0W
11	450S - 50W
12	850S - 50W
13	750S - 50W
14	650S - 50W
15	1400S - 0W

FIGURE 14 Resistivity Cross Section beneath the Beach Point Base Line (Resistivities are obtained from converted EM data, Octapod profiling, and electrical depth soundings. The surficial aquifer is a relatively low-resistivity lens pierced by high-resistivity "plumes" that may indicate descending dense, nonaqueous-phase liquids.)

4 Ground Penetrating Radar Surveys

4.1 Monostatic Ground Penetrating Radar

Depth of penetration using monostatic ground penetrating radar at Beach Point Peninsula ranged from 5 to 15 ft, with surface conditions playing a major role. In general, the best penetration was achieved in undisturbed wooded areas on the west side of the Peninsula. A range setting of 150 nanoseconds (ns) was used for the regional survey at a scan rate of 32 scans per second. The transceiver was pulled by hand at approximately 2 ft/s.

Prior to running the production lines for the survey, replicate runs were made over the same line to determine whether a 100- or 300-MHz antenna would provide the greater penetration. A secondary consideration was the resolution of thin beds. Following several scans, it was decided that the 100-MHz transceiver would provide optimal results for studying regional geologic structure. The 100-MHz antenna has a virtual resolution (VR) of 4 ft, where VR is the minimum thickness of a layer that is resolvable. The 300-MHz antenna was used around and over selected areas in order to better locate anomalies of anthropogenic origin. Wave-velocity characteristics of the subsurface soils were determined by running profiles over a buried waterline in southeastern Beach Point Peninsula. The pipe, buried 3.5 ft below the ground surface, indicated that wave velocities must be 7-9 ns/ft for the fill material overlying the pipe. (Velocities over the pipe may not be representative of native soils underlying Beach Point.)

GPR profiles were collected along east-west lines spaced 50 ft apart. South-to-north profiles, spaced 10 ft apart, were acquired where unusual anomalies were observed. A more detailed survey was performed around and over the large concrete pad centrally located on Beach Point Peninsula. Several areas along the western portion of Beach Point Peninsula were inaccessible due to dense vegetation. A total of 19,415 linear feet was surveyed along 132 profiles.

Inspection of GPR data reveals a wavy reflector underlying a strong horizontal reflector in the western portion of the survey in the area of 800S, running from 190W to 30E (Figure 15). A valley or trough, approximately 10 ft deep, underlies the horizontal reflector at the western end of the profile. The horizontal reflector is probably the result of a sharp contrast in soil type or soil chemistry. The wavy reflector may correlate with the contact between a surficial clay and a lower sand unit observed in outcrops along the shoreline. Its high reflectivity may also be due to higher concentrations of iron in the sand, which were also observed in some of the outcrops.

The GPR data may also indicate a trench or pit centered at grid coordinates 925S-140W, near a small berm, which may be the material dug from the trench. This trench was seen only in one south-north profile along 140W, running from 980S to 900S (Figure 16).

FIGURE 15 GPR Profile over a Dune-Shaped Reflector Containing Strong Internal Reflectors

FIGURE 16 GPR Profile over a Possible Buried Pit or Trench

Many GPR anomalies of anthropogenic origin were detected. Most of them are single, one-point anomalies, but a few were detected in more than one profile. In the northern portion of the survey area, possible pipes were seen. These pipes trend from east to west and appear to end at the western shoreline. Several GPR profiles collected around the large concrete pad revealed a possible underground storage tank (UST) located just east of the northeast corner of the large concrete slab (Figure 4). The suspected UST is roughly centered at grid coordinates 540S, 8W and is approximately 12.5 ft long, oriented north-south. Figure 17 shows the GPR anomaly over the suspected UST. This profile was collected east-to-west along 537.5S.

4.2 Bistatic Ground Penetrating Radar

A majority of the GPR profiles were collected with the 100-MHz antenna in the monostatic mode; however, selected profiles were also collected in the bistatic mode, using both the 100- and 300-MHz antennas. In the bistatic mode, the transmitter and receiver were separated by a fixed distance of 4.5 ft. The bistatic configuration was used to establish the hydrostratigraphic framework to depths of 30 ft. Range settings of 150 and 300 ns were used. A total of 4,750 linear feet was surveyed along 17 profiles in the bistatic mode. A list of GPR profiles collected in the bistatic mode is provided in Appendix B.

Bistatic GPR data are used to illustrate stratigraphic detail to 30-ft depths along the Base Line from 0N to 1,000S (Figures 18 to 21). This profile has been enhanced by computer processing, which included deconvolution and Kirchhoff migration. The deconvolution helped eliminate flat-lying, ringing multiples in the shallower part of the section; the Kirchhoff migration removed some of the diffraction and bowtie patterns originating in the troughs of dune-shaped reflectors.

FIGURE 17 GPR Anomaly Produced by a Buried Tank East of the Concrete Slab

FIGURE 18 GPR Profile at the North End of the Base Line (The wavy reflector descends rapidly to the north.)

FIGURE 19 GPR Profile between 250S and 600S along the Base Line

A series of shallow lenses in the upper 10 to 12 ft of the Base Line cross section were seen in the monostatic mode. The top of a deeper undulating reflector, however, was seen only in the bistatic configuration. This reflector is characteristic of topography observed in a dune terrain near shorelines. The dune-shaped reflectors rest on a gently-dipping reflector, with a northeast apparent dip at depths greater than 20 ft.

Figure 22 shows the relationship between the dune-shaped reflector and EM31 anomalies. EM data have been converted to resistivities to be consistent with resistivities shown in the cross section in Figure 14. A direct correlation between the reflector and resistivity is observed on the north end of the profile, where the reflector approaches the surface. To the south, where surface elevations increase, the relationship disappears. Since the EM31 has a maximum sensing depth of 20 ft, it is probable that the reflector is beyond the detection depth of the EM31 to the south. Since the correlation is strong to the north, where the reflector is only 10 ft deep, it is probable that the lithology below the reflector is a sand.

FIGURE 20 GPR Profile between 600S and 800S along the Base Line

FIGURE 21 GPR Profile between 800S and 1050S along the Base Line

FIGURE 22 Relationship between EM31 Anomalies and GPR Reflectors

5 High-Resolution Seismic Surveys

An integral part of the seismic programs at Beach Point is the determination of the stratigraphy and structure of the Atlantic Coastal Plain sediments down to the Precambrian crystalline basement. Seismic refraction and reflection surveys provide the most precise geophysical information on depths to lithologic units comprising the hydrogeologic framework below a depth of 30 ft. The following section provides a description of the subsurface based on seismic surveys. Locations of all seismic lines are shown on Figure 23.

5.1 Seismic Refraction Profiling

Refraction profiles provide velocity and depth information to about 300 ft depth. The longest shot-detector distance of 1,624 ft was not adequate to obtain a refracted arrival from the crystalline basement. Velocity data calculated from the refraction profiles were used to constrain velocities used in reflection profiling.

Four 24-channel seismic refraction profiles were recorded in the Beach Point Peninsula area at two sites (Table 7). Two profiles (BCHNS-5M and BCHNS-10M) are aligned N-S on the peninsula Base Line with five meter and 10 meter take-out separations, respectively. Two additional profiles (BCHEW-5M and BCHEW-10M) are aligned E-W on the Beach Point Road (see Figure 23). Table 7 indicates shot and receiver geometries and field recording parameters for the refraction profiles.

Figure 24 shows the velocity-depth distribution determined from refraction profiles on Beach Point Road. Maximum shot-detector distance was 1,624 ft. Average velocities between major refractors are 2,015 ft/s for the vadose zone, 5,480 ft/s for saturated Pleistocene sediments of the surficial aquifer below the water table, and 6,025 ft/s for the top of the Cretaceous immediately beneath the P-K unconformity. The water table refractor descends in elevation to the east, from 10 ft below land surface on the west to 20 ft on the east, where it is approximately at sea level. The P-K unconformity also has an apparent slope downward to the east.

Seismic refraction soundings along the Base Line also provide data for construction of a velocity-depth profile beneath Beach Point Peninsula (Figure 25). A velocity increase from 1,245 ft/s for the vadose zone to 5,395 ft/s for the surficial aquifer has been determined. Water table depth remains a constant 13 ft beneath the profile. The apparent rise of the water table to the north is an artifact caused by a drop in surface elevation. Depth to crystalline basement shown in Figure 26 is based upon reflection data.

FIGURE 23 Location of Seismic Survey Lines at Beach Point

TABLE 7 Refraction Profiles at Beach Point

Line ID	Geophone Interval (m)	No. of Spreads ^a	Total Spread Length (m)	Longest Shot-Receiver Dist.	No. of Shots
BCHNS-5M	5	4	295	145	13
BCHNS-10M	10	2	350	450	12
BCHEW-5M	5	3	235	120	12
BCHEW-10M	10	1	230	495	7

^a Multiple spreads overlap by 12 geophones. A single spread consists of 24 geophones.

BCHEW-10M

FIGURE 24 Seismic Refraction Interpretation along the Access Road to Beach Point

BCHNS-5M

FIGURE 25 Seismic Refraction Interpretation along the Beach Point Base Line

FIGURE 26 Facies below Beach Point Peninsula on the Basis of Seismic Data

5.2 Seismic Reflection Profiling

A total of 11 seismic reflection profiles, two deep and nine shallow ones comprising 5,340 linear feet, were recorded at Beach Point Peninsula and along the access road to Beach Point. Reflection profiles are divided into two data sets on the basis of depth of interest. Shallow profiles map the sedimentary section from the water table down to the P-K unconformity at the base of the surficial aquifer. Deep reflection profiles image sediments from the P-K unconformity to the Precambrian crystalline basement.

Eight shallow reflection profiles were recorded on Beach Point Peninsula and one on Beach Point Road (see Figure 23). One NW-SE profile was located between wells CC-33 and CC-34. Background noise within a 100-ft radius of a pump in well CC-33 had an adverse effect on seismic data quality, although it was possible to map reflectors and to correlate reflectors with subsurface information from the lithologic and gamma-ray logs.

One deep profile was oriented N-S along the axis of the peninsula on the Base Line. A second deep profile was shot along Beach Point Road. The deep reflection profiles used a group interval of 2 m and had the shot point offset 30 m from the end of the geophone array. The distance from shot to furthest detector was 249 ft. Table 8 shows reflection profiles at Beach Point and lists the shot-point geometries. (Note that some profiles were shot in feet and some in meters.) Stacked seismic sections of all reflection lines are included in Appendix C.

TABLE 8 Reflection Profiles at Beach Point

Line ID	Type and Orientation	Offset	Shot Point and Geophone Interval	No. of Shots	CDP Line Length (ft)
BCHNS-DP	Deep NS	30 m	2 m	240	1,605
BCHEW-DP	Deep EW	30 m	2 m	113	797
BCHNS000	Shallow NS	40 ft	3 ft	312	954
BCHNS50A	Shallow NS	10 m	1 m	72	252
BCHNS50B	Shallow NS	8 m	1 m	70	249
BCHNS100	Shallow NS	5 m	1 m	190	644
BCHEW1000	Shallow EW	42 ft	3 ft	31	98
BCHEW650	Shallow EW	48 ft	3 ft	25	96
BCHEW450	Shallow EW	34 ft	2 ft	42	100
BCHEW-SH	Shallow EW	10 m	1 m	132	453
BCHXWELL	Shallow ^a	10 ft	1 ft	84	92

^a Line runs N from Borehole CC-34 to Borehole CC-33.

The longest reflection lines provide coherent reflections down to the Precambrian crystalline basement at 500-600 ft depth. Shorter lines, such as the line between wells CC-33 and CC-34 (BCHXWELL seismic line), produced coherent reflections as shallow as 10 ft but predominantly in the 40-70 ft range.

5.2.1 Shallow Reflection Analysis

Stacked seismic profiles for shallow reflection lines are processed from variable-fold (6-12 fold) data (Appendix C). Prior to stacking, each section was bandpass-filtered (generally 100-300 Hz); edited to remove early refracted arrivals, surface waves, and air waves; CDP-sorted; and corrected for normal moveout. Normal moveout velocities used for correcting the data were obtained from average velocities (calculated from refracted arrivals) and from normal moveout analysis of the CDP-sorted but unstacked reflection data. Depth estimates, as labeled along the right vertical axis for each section, were obtained from normal moveout velocities and refraction data and were averaged to a one-dimensional velocity-depth model for Beach Point. Note that in Figures C.1 to C.6 (Appendix C) the depth scale is nonlinear because of increasing velocities with depth. A discussion of profile reflection detail is contained in Appendix C.

Reflectors are correlated with gamma-ray logs in wells CC-33 and CC-34 (see Figure 7). A continuous reflector at about 30-40 ms is observed on all sections, corresponding to a depth of about 40-70 ft. An interpretation of reflection data on the Base Line is shown in Figure 26. Depths to reflectors approximate those expected down to the base of the surficial aquifer at the P-K unconformity. A map of the unconformity constructed from reflection times is shown in Figure 27. The configuration of the surface does not appear to be associated with sediments dipping uniformly to the southeast, but rather to an erosional surface more representative of an unconformity. This interpretation suggests an early Pleistocene age for this reflector. The reflector deepens to at least 70 ft below sea level along the baseline between about 600S-850S.

5.2.2 Deep Reflection Analysis

Deep reflection profile BCHEW-DP was recorded west-to-east along Beach Point Road and is shown in Appendix C (Figure C.2). The profile includes nearly the entire line occupied by shallow profile BCHEW-SH (Figure C.3, Appendix C). The location of the shallow line is indicated by the arrows on the top of Figure C.2. The shallowest reflectors imaged by this seismic section range in two-way travel time from 40 to 50 ms, which is approximately 82-107 ft in depth. Continuous reflection events are observable to at least 180 ms for two-way travel time, corresponding to depths of 500 ft (see Figure 28).

The depth scale for the deep lines is obtained from average velocities calculated for velocities of refracted arrivals and from normal moveout analysis of the CDP-sorted but

Elevation of P-K Unconformity (ft) (Cnst Stk $V=4210$ ft/s)

FIGURE 27 Configuration of the Pleistocene-Age Unconformity Developed on Cretaceous Coastal Plain Sediments on the Basis of High-Resolution Seismic Reflection Data

FIGURE 28 Facies below Beach Point Road on the Basis of Seismic Data

unstacked reflection data. However, depth estimates below approximately 150 ft are poorly constrained because of the uncertainty of interval and stacking velocities. Therefore, the depth estimates listed for relatively deep features should be regarded with caution.

Preliminary interpretation suggests at least two distinct seismic facies on profile BCHEW-DP. The shallowest seismic facies is characterized by high-amplitude reflection events that are horizontally continuous for 165 ft or more. The base of this facies is at a 105-ms two-way travel time at CDP 500, shallows to 95-ms two-way travel time at CDP 400, and becomes obscured by poorer-quality data on the western part of the profile. The second seismic facies underlies the previous unit and is marked by lower-amplitude reflection events that are also horizontally continuous. These facies probably represent Cretaceous strata.

The general character of the deep reflectors reveals some relief. A down-shift of about 18 ms in the deep reflector at a horizontal distance of about 295 ft in the W-E section (Figure C.2, Appendix C) suggests the presence of a fault with a drop of about 50-80 ft in the Cretaceous rocks. An up-shift of about the same amount at a horizontal distance of about 1,300 ft in the N-S section (Figure C.1, Appendix C) may also be a fault. However, lower data coherency and the presence of a bend in the line at a horizontal distance of about 1,348 ft make the cause of the shift in the N-S line less certain. A deep, semicontinuous reflector is visible in both sections in the two-way travel-time range of 170-210 ms. The most continuous of these reflectors is believed to correspond to the second unconformity, separating Atlantic Coastal Plain sediments and the Precambrian crystalline basement.

6 Discussion

6.1 Hydrogeologic Framework

Well logs and outcrops provide the basic subsurface geologic control for this study. Geophysical applications, including ground penetrating radar, EM31, EM34, electrical resistivity, seismic refraction, and seismic reflection, complement the basic geologic studies and define the hydrogeological and hydrogeochemical framework.

GPR imaging provides a detailed display of reflectors to a depth of 30 ft. The reflectors represent a depositional contact separating surface clays from underlying sands and a thin gravel lens seen in outcrops. Where a prominent reflector rises close to the surface, resistivity increases (Figure 22), indicating that the lithologic unit below the reflector is a sand. A good correlation between GPR imaging and electrical response is noted at 800S-150W, where a strong reflector approaches the surface in an area of low conductivity values, suggesting a thinning clay overburden. The good correlation indicates that EM31 data can be used as a first approximation to locations where the surficial clays are thin. This observation is important where contaminants have been introduced as surface spills, in trenches, or in unlined pits.

Seismic imaging gives detail on the facies beneath the area, as shown in Figures 26 and 28. Seismic imaging on Beach Point Road provides excellent detail on the geological development of the surficial aquifer. A succession of fluvial terraces, declining in elevation toward the east, are representative of episodic and constructive channel filling of alluvium during Pleistocene-age sea level rise (Figure 28). The terraces rest upon a surface ranging in elevation from 60 to 120 ft below sea level. The surface is probably an erosional unconformity of Pleistocene age that formed during low sea level stands. Channels cut into the surface have local relief of 20 to 30 ft, with thalwegs sloping to the southeast toward Bush River (Figure 27).

Easterly dipping reflectors, below the P-K unconformity (Figure 28), mark undifferentiated depositional sequences of Cretaceous-age, Atlantic Coastal Plain strata. The sequences of easterly dipping reflectors contain wedges of strata thickening to the south and east. On the basis of reflection data alone, and given the lack of deep borehole control, a positive identification of the Canal Creek aquifer cannot be made. The dipping Cretaceous strata rest on a faulted crystalline basement ranging in depth from 500 ft on the Beach Point Road reflection profile (Figure 28) to 600 ft on the south end of the Beach Point Peninsula profile (Figure 26).

6.2 Possible Point Sources of Contaminants

Evidence of the disturbances of near-surface strata is clearly displayed by magnetic and electrical conductivity maps of Beach Point Peninsula (Figures 29 and 30). Although the access

FIGURE 29 Magnetic Map of Beach Point with Conductivity Overlay

FIGURE 30 Conductivity Map of Beach Point with Magnetic Overlay

road to Beach Point is the dominant geophysical feature, additional point sources of magnetic, conductive, and resistive areas appear as subcircular or elliptical images. Unidentified anomalies that should receive further investigation because they could be interpreted as being caused by buried tanks, pipes, pits, or trenches are listed in Table 4 (Section 2.2) and in the discussion of conductivities (Section 3.1).

The area most likely containing point sources of contaminants is in proximity to the concrete slabs located between the coordinates 600S to 520S and 10W to 100W.

Specific coordinates of magnetic anomaly centers are:

530S-15W
530S-30W
560S-75W
580S-60W

Coordinates for conductivity anomaly centers are:

580S to 590S-25W (good conductor)
520S to 540S-85W (circular poor conductor)

The positive magnetic anomalies and highly conductive areas may indicate metal tanks or pipes, whereas the poorly conductive areas may indicate a burial pit or trench. (It should also be pointed out that trenching and mounds were observed on the surface at 910S-110W, 420S to 500S-90W.) A circular poor conductor is located at the southern extension of the trenching observed at the surface northwest of the concrete slab. The high resistivities may indicate the surficial point sources for possible contaminants imaged in electrical depth sounding. (This is discussed in the next section).

6.3 Possible Contaminant Plume

A distance-vs.-depth cross section, displaying electrical resistivity along the Base Line, is illustrated in Figure 14. Conversion of all electrical data, including conductivity and resistivity, into one resistivity data set indicates that the surficial aquifer is a relatively low-resistivity lens sandwiched between higher resistivities above and below. The low-resistivity lens is noncontinuous where higher resistivities extend through the lens at approximately 650S.

The unusual appearance of the anomaly, its lack of continuity in the flat-lying surficial aquifer, and the absence of structure, as observed on the Base Line seismic profile, suggest the presence of saltwater intrusion from tidal action in Bush River. A dense, nonaqueous-phase liquid, such as 1,1,2,2-tetrachloroethane ($C_2H_2Cl_4$) observed in well CC-33 at Beach Point,

could produce the noncontinuous effect. It has been found that traces of contaminant can drastically alter electrical current flow through saturated media. Introduction of a contaminant into the subsurface may have been through point-source locations outlined by nonconducting areas 527S-85W and 520S and 530S, described in Section 3.1.

7 Summary and Conclusions

Buildings located at the Beach Point test site were used for small-scale chemical agent storage (G agents), laboratories, storehouses, offices, and machine shops. Several of these structures were built with sewer systems that discharged directly to Kings Creek and Bush River. A few of the buildings were constructed with septic systems, which allowed effluent to percolate into the subsurface (Jacobs Engineering Group, Inc., 1992).

A series of geophysical surveys, supported by drilling and outcrop mapping, has defined the hydrogeologic framework, possible point sources of contaminants, and a possible contaminant plume beneath Beach Point Peninsula. Some of the point sources are believed to be associated with activities in and adjacent to the building that rested on the large concrete slab centered at 550S-50W. The slab served as the foundation for a mobile clothing impregnation plant. Wastes were discharged into unlined pits and were allowed to percolate into the subsurface. Some of the wastes generated from rocket fuel fire suppression tests were discharged directly on the ground surface and either ran off into the streams or percolated into the subsurface. Areas where discharge occurred and where pits were dug resulted in anomalous zones on resistivity and conductivity maps.

Specific conclusions are as follows:

1. The general hydrogeologic framework in the Chesapeake Bay area beneath Beach Point has been described. Fine sands, silts, and clays, 40 to 80 ft thick, rest on the P-K unconformity incised onto sediments of Cretaceous age.
2. Cretaceous sediment thicknesses ranging up to 500 ft thick are observed from seismic reflection profiling. Gentle southeast dips are observed and conform to published descriptions of Cretaceous structure.
3. The Precambrian crystalline basement lies at a depth of 500 to 600 ft beneath the Beach Point Peninsula.
4. Possible point sources of contaminants are outlined by high-intensity, negative-conductivity anomalies. Some of the anomalies are located around a concrete slab that served as the foundation for a former clothing impregnation plant. Other anomalies are observed throughout the site. Interactions between some volatile organic compounds and clays are known to increase the electrical resistivity of clays.
5. Contaminant pathways from point, surficial sources to the base of the surficial aquifer may be outlined by a high-resistivity anomaly that penetrates the surficial aquifer. The contaminants may be DNAPLs, consisting of volatile organic compounds, resting on the Pleistocene-age unconformity defined by the reflection profile (see Conclusion 1). DNAPLs could migrate along the topographic gradient of the erosional contact.

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Appendix A:
Resistivity Depth Sounding Curves

R150S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	122.7	1.32	2.67	0.0107	162.3
2	56.99	3.00	-0.326	0.0526	171.1
3	23.35	35.63	-35.95	1.52	832.0
4	8.99				

R450S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	111.2	0.433	3.56	0.00390	48.24
2	36.09	0.922	2.64	0.0255	33.31
3	97.75	2.07	0.567	0.0212	202.9
4	36.38	47.07	-46.51	1.29	1,712.9
5	72.61				

R550S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	95.59	1.61	2.38	0.0169	154.8
2	588.2	1.48	0.895	0.00252	873.6
3	27.94	16.41	-15.51	0.587	458.6
4	55.08				

R650S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	147.6	0.509	3.49	0.00345	75.25
2	46.03	0.900	2.58	0.0195	41.45
3	160.3	8.35	-5.76	0.0521	1,340.0
4	19.33	30.36	-36.13	1.57	587.2
5	895.3				

R750S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	314.1	0.500	3.49	0.00159	157.1
2	35.88	0.982	2.51	0.0273	35.26
3	201.4	4.16	-1.64	0.0206	839.3
4	22.16	24.04	-25.69	1.08	532.9
5	3,056.4				

R850S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	252.1	0.303	3.69	0.00120	76.55
2	45.93	0.841	2.85	0.0183	38.66
3	350.1	1.85	0.999	0.00530	649.8
4	54.80				

R950S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	294.0	0.625	3.37	0.00213	183.9
2	78.73	1.42	1.95	0.0180	111.9
3	156.3	5.28	-3.33	0.0338	826.5
4	50.86	37.96	-41.29	0.746	1,931.1
5	95.98				

R1050S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	302.6	0.814	3.18	0.00269	246.6
2	112.0	8.66	-5.48	0.0773	970.7
3	30.06	12.00	-17.48	0.399	361.0
4	103.6				

R1400S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	47.61	0.785	3.21	0.0164	37.38
2	37.80	1.98	1.23	0.0524	74.97
3	0.771	1.86	-0.635	2.41	1.44
4	14,759.8	83.23	-83.86	0.00564	1.228E + 06
5	177.2				

R450S; 50W

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	333.9	0.480	3.51	0.00144	160.3
2	152.1	0.581	2.93	0.00382	88.49
3	121.7	8.37	-5.43	0.0688	1,019.9
4	18.07				

R650S; 50W

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	535.2	0.479	3.52	8.951E-04	256.4
2	98.38	1.39	2.12	0.0142	137.5
3	181.3	6.13	-4.01	0.0338	1,113.2
4	45.83				

R700S; OW

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	83.49	0.893	3.10	0.0107	74.64
2	39.00	2.67	0.427	0.0686	104.4
3	206.6	4.43	-4.01	0.0214	917.3
4	25.59	18.86	-22.87	0.737	482.8
5	107.8				

R750S; 50W

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	544.8	0.543	3.45	9.979E-04	296.2
2	122.9	6.62	-3.16	0.0538	813.8
3	43.82	58.27	-61.44	1.32	2,554.2
4	658.4				

R850S; 50W

L #	Resistivity ($\Omega \cdot m$)	Thickness (m)	Elevation (m)	Long. Cond. (S)	Trans. Res. ($\Omega \cdot m^2$)
			4.00		
1	303.1	0.247	3.75	8.167E-04	75.04
2	109.9	6.35	-2.60	0.0578	699.4
3	47.89	27.00	-29.61	0.563	1,293.3
4	57.47				

R750S50W

Appendix B:
Ground Penetrating Radar Profile
Line Coordinates

**APG-Beach Point Ground Penetrating Radar
Profile Line Coordinates**

Line #	Start Coordinate		End Coordinate	
	South	West	South	West
Lines 1-5 Misc. test profiles over fire-hydrant line				
6	1050	00	1050	120
7	1000	-10	1000	130
8	950	-40	950	130
9	900	-30	900	100
10	850	-40	850	100
11	800	-30	800	140
12	800	-30	800	190
13	000	-20	000	10
14	050	-20	050	10
15	100	-20	100	00
16	150	-40	150	10
17	200	-30	200	40
18	250	-30	250	65
19	300	-20	300	80
20	350	-10	350	80
21	400	-20	400	100
22	450	-30	450	110
23	500	-30	500	130
24	550	-30	550	150
25	600	-40	600	140
26	650	-40	650	180
27	700	-40	700	180
28	700	-40	700	180
29	750	-40	750	150
30	000	000	200	000
31	150	000	400	000
32	400	000	600	000
33	600	000	800	000
34	800	000	1000	000
35	250	050	520	050
36	650	050	850	050
37	850	050	1050	050
38	1000	050	1200	050
39	860	000	860	180
40	870	000	870	180
41	880	000	880	210
42	880	000	880	220
43	890	000	890	160
44	900	000	900	170
45	650	010	800	010
46	650	020	750	020
47	650	030	750	030
48	650	040	800	040
49	650	060	800	060
50	650	070	800	070
51	650	080	800	080
52	650	090	800	090

**APG-Beach Point Ground Penetrating Radar
Profile Line Coordinates (Cont.)**

Line #	Start Coordinate		End Coordinate	
	South	West	South	West
53	650	100	730	100
54	650	110	730	110
55	650	120	800	120
56	650	130	800	130
57	650	140	800	140
58	650	150	800	150
59	650	160	800	160
60	650	170	800	170
61	650	180	810	180
62	500	-10	650	-10
63	500	-20	650	-20
64	500	10	650	10
65	500	20	650	20
66	500	30	650	30
67	500	40	650	40
68	500	50	610	50
69	500	60	610	60
70	500	70	650	70
71	500	80	650	80
72	500	90	650	90
73	500	100	650	100
74	500	110	650	110
75	500	120	650	120
76	500	130	650	130
77	500	140	650	140
78	350	-10	500	-10
79	350	00	500	00
80	350	10	500	10
81	350	20	500	20
82	350	30	500	30
83	350	40	500	40
84	350	50	500	50
85	350	60	500	60
86	350	70	500	70
87	350	80	500	80
88	350	90	500	90
89	400	100	500	100
90	400	110	500	110
91	450	120	500	120
92	200	-20	300	-20
93	200	-10	350	-10
94	200	00	350	00
95	200	10	350	10
96	200	20	350	20
97	200	30	350	30
98	200	40	350	40
99	250	50	350	50

**APG-Beach Point Ground Penetrating Radar
Profile Line Coordinates (Cont.)**

Line #	Start Coordinate		End Coordinate	
	South	West	South	West
100	250	60	350	60
101	250	70	350	70
102	000	-10	200	-10
103	000	-20	200	-20
104	1730	00	1550	00
105	1550	00	1350	00
106	1050	190	960	190
107	1050	180	900	180
108	1050	170	900	170
109	1050	160	900	160
110	1050	150	900	150
111	1050	140	900	140
112	1050	130	900	130
113	1050	120	900	120
114	1050	110	900	110
115	1050	100	900	100
116	1050	90	800	90
117	1050	80	800	80
118	1050	70	800	70
119	1050	60	800	60
120	1050	50	800	50
121	1050	40	800	40
122	1050	30	800	30
123	1050	20	800	20
124	1050	10	800	10
125	1000	-10	800	-10
126	900	100	800	100
127	900	110	800	110
128	900	120	800	120
129	900	130	800	130
130	900	140	800	140
131	900	150	800	150
132	900	160	800	160

Lines 106-132 Collected with 100-MHz transceiver in
monostatic mode with range = 150 ns

133	800	50	650	50
134	800	30	650	30
135	800	70	650	70
136	800	90	650	90
137	800	190	800	-30
138	750	190	750	-30
139	700	170	700	-50
140	650	190	650	-40
141	000	000	1000	000

Lines 133-141 Collected with 300-MHz bistatic antennas with
range = 150 ns

**APG-Beach Point Ground Penetrating Radar
Profile Line Coordinates (Cont.)**

Line #	Start Coordinate		End Coordinate	
	South	West	South	West
142	800	50	650	50
143	820	190	800	-30
144	800	90	650	90
145	750	190	750	-30

Lines 142-145 Collected with 300-MHz bistatic antennas with
range = 300 ns

146	800	50	650	50
147	800	30	650	30
148	700	170	700	-50
149	000	000	1000	000

Lines 146-149 Collected with 100-MHz bistatic antennas with
range = 300 ns

150	585	0	585	100
151	582.5	0	582.5	40
152	580	0	580	100
153	575	0	575	100
154	570	0	570	100
155	565	0	565	90
156	560	0	560	90
157	555	0	555	100
158	550	0	550	100
159	545	0	545	100
160	540	0	540	100
161	555	0	555	10
162	552.5	0	552.5	10
163	550	0	550	10
164	547.5	0	547.5	10
165	545	0	545	10
166	542.5	0	542.5	10
167	540	0	540	10
168	537.5	0	537.5	10
169	535	0	535	10
170	532.5	0	532.5	10
171	532.5	0	532.5	20
172	530	0	530	20
173	527.5	0	527.5	20
174	525	0	525	20
175	535	0	535	100
176	540	80	540	100
177	532.5	70	532.5	100
178	537.5	70	537.5	100
179	537.5	80	537.5	100
180	530	70	530	100
181	525	70	525	100
182	520	70	520	100
183	515	70	515	100
184	510	70	510	100

Lines 150-184 Collected with 300-MHz transceiver in
monostatic mode with range = 50 ns

Appendix C:
Seismic Reflection Profiles

.

1

Appendix C: Seismic Reflection Profiles

Stacked seismic profiles for deep reflection lines are shown as Figures C.1 and C.2 for profiles BCHNS-DP and BCHEW-DP, respectively. A stacked seismic profile for the shallow reflection line on Beach Point Road (line BCHEW-SH) is shown as Figure C.3. Stacked seismic profiles for shallow reflection lines aligned with the geophysics survey coordinates on Beach Point Peninsula are shown as Figure C.4 for profiles BCHNS000, BCHNS50A, BCHNS50B, and BCHNS100 and Figure C.5 for profiles BCHEW450, BCHEW650, and BCHEW1000. A stacked seismic profile for the shallow reflection line extending from monitoring wells CC-33 to CC-34 (line BCHXWELL) is shown in Figure C.6.

Line BCHXWELL (Figure C.6) uses relatively short offset and geophone spacings. The shortened recording parameters permit recognition of visible reflectors in the 10-40 ms range, corresponding to depths as shallow as 6-50 ft. The reflector at 10-15 ms likely corresponds with the water table at 6-12 ft depth. The reflector at about 30 ms, or a depth of about 25 ft, corresponds with a sharp increase in the gamma count for the log of well CC-33 in the depth range 20-26 ft, suggesting the reflector is caused by the presence of a clay-rich layer that is continuous between the two wells, CC-33 and CC34.

A reflector at about 45 ms at the west edge of line BCHEW-SH along Beach Point Road (Figure C.3) corresponds with a depth of about 80 ft. The gamma log for well CC-12, located approximately 450 ft west of the profile, indicates a significant increase in gamma count at 80 ft, suggesting that the reflector corresponds with the top of a clay-rich layer, probably the top of Cretaceous sediments. Another interesting set of features observed for BCHEW-SH is the presence of on-lapping or apparent cross-bedding above the 80-ft reflector. The on-lap reflectors are prominent at distances of 630, 690, and 790 ft and indicate cross-bed dipping toward the east.

Shallow reflection profile BCHNS50A (shown in Figure C.4, center right) was recorded along a south-to-north traverse along the 50W survey coordinate. The south end of the profile is located at coordinate 1000S. The north end of the profile is adjacent to the location of the University of Maryland bio-assay trailer. The profile was not extended farther north because of noise (from pumping) associated with well CC-33, which was in continuous operation at the time of the survey.

Profile BCHNS50A images a reflecting horizon at approximately 60 ft in depth (31-ms two-way travel time) which correlates with the lower Pleistocene P-K unconformity. Two other reflection wavelets are also imaged on the seismic section. Maximum penetration depth is approximately 100 ft.

Figure C.5, top, represents shallow reflection profile BCHEW450, which was recorded along an east-to-west traverse along the geophysical coordinate 450S. As with profile BCHNS50A, the lower Pleistocene P-K unconformity was also imaged. The depth to this interface is slightly shallower than that shown on BCHNS50A. Like profile BCHEW-SH, the

present profile shows on-lap or apparent cross-bedding dipping toward the east. The on-lap is slightly deeper (approximately 100 ft deep) and is in Cretaceous rather than Pleistocene sediments. The on-lap reflectors are most prominent at about 25E.

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2 of 2

BCHNS-DP

FIGURE C.1 Stacked Seismic Section for BCHNS-DP

BCHEW-DP

FIGURE C.2 Stacked Seismic Section for BCHEW-DP

BCHEW-SH

FIGURE C.3 Stacked Seismic Section for BCHEW-SH

FIGURE C.4 Stacked Seismic Sections for BCHNS000, BCHNS50B, BCHNS50A, and BCHNS100

FIGURE C.5 Stacked Seismic Sections for BCHEW450, BCHEW650, and BCHEW1000

FIGURE C.6 Stacked Seismic Section for BCHXWELL

Appendix D:
Area Magnetic Maps

FIGURE D.1 Beach Point Area 1 Magnetics (The southeastern two-thirds of the area, including anomalies along lines 70W and 80W, is dominated by anomalies associated with road fill or by construction fill along the southeastern shore of Beach Point. The anomaly in the northwest quarter on Line 130W is produced by surficial debris.)

FIGURE D.2 Beach Point Fine Grid: Southeast (All anomalies are produced by road fill.)

FIGURE D.3 Beach Point Area 2 Magnetics (Anomalies on the east are produced by road fill and shoreline stabilization fill. The large negative anomaly area and associated anomalies in the northeast quadrant are caused by the bio-assay trailer and by other surficial debris. Anomalies in the western half of the area are caused by unknown, buried sources, as listed in Table 4.)

FIGURE D.4 Beach Point Area 3 Magnetics (Anomalies on the east are associated primarily with road fill. The source of an east-west string of anomalies along 720S is unknown. The source of the large anomaly complex at 690S-40W is unknown. Anomalies in the northwest quarter are caused partially by surface debris. Anomalies in the north central area are associated with a concrete slab.)

FIGURE D.5 Beach Point Fine Grid: Northwest
 (Anomalies are unexplained and are probably associated with trenches and activities during operation of the former building associated with the buried concrete slab.)

FIGURE D.6 Beach Point Area 4 Magnetics (Anomalies are unexplained and are probably associated with trenches, buried tanks, and activities during operation of the former building on the concrete slab.)

FIGURE D.7 Beach Point Area 5 Magnetics (All anomalies are associated with the access road fill.)

FIGURE D.8 Beach Point Area 6 Magnetics (Anomalies are caused primarily by road fill.)

FIGURE D.9 Beach Point Area 7 Magnetics (Anomalies are caused by road fill.)

FIGURE D.10 Beach Point Area 8 Magnetics (Anomalies are caused by road fill.)

FIGURE D.11 Beach Point Area 9 Magnetics
(Anomalies are caused by road fill.)

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