# Final Report of Seismic Refraction Survey
# Melville North Landfill - NETC
# Newport, Rhode Island

Prepared for
Halliburton NUS Corporation
July 1995

File No. NAVY-IN-189

GEOPHYSICAL APPLICATIONS
INCORPORATED

Received
JUL 28 1995
Halliburton NUS Corporation
Wilmington, Massachusetts
01887

July 27, 1995

Mr. Kevin Scully, CPG
HALLIBURTON NUS CORPORATION
55 Jonspin Road
Wilmington, MA 01887

Subject: Final Report of Seismic Refraction Survey
Melville North Landfill - NETC
Newport, Rhode Island
Subcontract No. GCDB-95-307-1298

Dear Mr. Scully:

Geophysical Applications has performed seismic refraction profiling at the above-noted site, to measure bedrock depths in support of Halliburton NUS' remedial investigation. Field work was performed between June 21 through 24, 1995 by Mark Blackey and Matthew McMillen of Geophysical Applications. Halliburton NUS geologist Kayleen Jalkut observed all field activities, and assisted with data collection.

**METHODS OF INVESTIGATION**

Survey Control

Traverse locations were determined by taped distance measurements and compass bearings referenced to the railroad tracks, a paved access road, and the beach.

Vertical survey control was performed by Geophysical Applications using a digital Pentax 10-second electronic theodolite and an electronic distance measuring (EDM) unit to measure elevation differences between shot points along all traverses. Elevation differences between geophones were estimated visually along Lines 1 and 2, and part of Line 3 The theodolite and EDM measured geophone elevations at Line 4 and along the steeper portion of Line 3, where visual estimates might have been inaccurate.

A ground surface elevation of 14.53 feet at MW-4 (provided by NUS) was the referenced vertical elevation datum for this survey

Seismic Refraction

Refraction data were acquired using an ABEM Terraloc Mark 6 seismograph with 24-channel, 10-foot geophone arrays. Each geophone array was 250 feet long, except at Line 4 where some

Post Office Box 568 • Bellingham • MA • 02019
508-966-5125 • FAX 508-966-5102

5-foot geophone intervals were utilized (Line 4 was only 186 feet long). Seismic energy was generated by a Betsy® firing rod with 12-gauge, 350-grain blank-load shotgun shells. Refraction seismograms were recorded using 0.25 millisecond sampling intervals, with record lengths of 128 milliseconds. Interference from wind noise was minimized by using 30-hertz geophones, and high-pass (low-cut) filters set to 12 hertz. Recorded seismograms were stored on the seismograph's internal hard drive, and also on floppy diskette.

Dig Safe clearance was obtained for public utilities, and also from the Naval base, before beginning this geophysical survey.

Seismic shot points were located at approximately 80-foot intervals along each geophone array. Additional offset shots were placed up to 200 feet beyond the geophone array endpoints, as permitted by site conditions, to help profile bedrock at depths up to about 65 feet below ground surface. Four to six shot points were occupied along each 24-channel geophone array, to provide reversed profiles. Depending upon ambient noise and signal transmission conditions, up to three shots were stacked at each shot point to produce seismograms with adequate signal to noise ratios. Each shot point was marked with a stake flag, labelled with the line number and shot station (in feet). Adjacent geophone arrays were overlapped by at least one geophone position to provide continuous bedrock profiling.

Refraction data analysis was performed by picking first arrival times with the seismograph, followed by modeling with SIPT2 delay-time interpretation software. SIPT2 uses a ray-tracing algorithm, in which calculated layer thicknesses beneath each geophone (i.e. at 10-foot intervals) are varied to obtain good agreement between observed and modeled arrival times. Calculated layer depths are estimated to be accurate within ±10 percent (or ±3 feet, whichever is greater) along Lines 1, 2, and 4 Line 3 probably traversed landfill materials of significant thickness, resulting in less accurate arrival time measurements. Calculated bedrock depths are estimated to be accurate within ±20 percent along Line 3.

**RESULTS**

Seismic traverse locations are shown on Figure 1, and interpreted seismic cross sections are shown on Figures 2 and 3. Nearby boring and monitoring well positions are also shown on Figures 2 and 3. Ground water elevations shown at monitoring wells MW-1 through MW-5 were recorded by others on July 17, 1990.

Line 1

Line 1 was positioned 5 to 10 feet west of the railroad tracks (Figure 1), on railroad ballast or other fill materials. Data quality was generally very good, despite the fill materials. A near-surface low-velocity layer (Figure 2) is judged to represent unsaturated fill or overburden less than 12 feet thick. A layer of intermediate velocity (4,500 to 6,600 ft/sec) is interpreted to represent saturated overburden, and possibly till or weathered bedrock. Well MW-5 was the closest monitoring well, located approximately 85 feet east of Line 1 Station 2+10. Ground surface and ground water elevations at MW-5 are 4 to 6 feet higher than at Line 1.

Bedrock velocities along Line 1 varied from approximately 10,000 ft/sec at the north end of the traverse to more than 13,000 ft/sec at the southern end. Bedrock elevations are between -37 feet and -15 feet between stations 0+00 and 7+00, where bedrock velocity values of 10,200 to 12,300 ft/sec indicate sedimentary rock strata or moderately weathered/fractured metamorphic rock. Bedrock elevations increase to approximately -10 to +5 feet between stations 7+50 through 11+70, coincident with bedrock velocity values greater than 13,000 ft/sec. These higher velocity values may represent less weathered or fractured metamorphic strata

Line 2

This traverse was positioned along the beach (Figure 1), near or below the high-tide line, to minimize interference from landfill materials. An unsaturated (or partly saturated) overburden and fill layer less than 11 feet thick is interpreted at ground surface along this traverse (Figure 3). Saturated overburden 23 to 57 feet thick, possibly including till or limited amounts of weathered bedrock, was interpreted along the entire length of Line 2. Monitoring well MW-1 was located approximately 40 feet east of Line 2 Station 0+95, and well MW-3 was located approximately 75 feet east of Line 2 Station 4+60. Ground surface and ground water elevations were 7 to 8 feet higher at MW-1 and 11 to 14 feet higher at MW-3 compared to Line 2.

Bedrock elevations and seismic velocity values exhibit a pattern similar to Line 1. Bedrock elevations between -63 feet and -35 feet were interpreted between Stations 0+00 and 9+00. Low bedrock velocity values in this area (10,300 to 12,000 ft/sec) indicate sedimentary rock or moderately fractured/weathered metamorphic rock. A distinct bedrock trough is located near Station 3+80. Bedrock elevations are higher, approximately -25 feet, between Stations 9+00 and 11+20. Higher bedrock velocity values south of Station 9+00 (13,600 ft/sec) may represent less weathered/fractured metamorphic bedrock.

Line 3

Line 3 was located near the north end of the landfill, between Lines 1 and 2 (Figure 1). This traverse probably crossed landfill materials of significant thickness, resulting in less accurate arrival time measurements compared to Lines 1, 2, or 4. Consequently, calculated bedrock depths and elevations may be less accurate than the other traverses (estimated depth uncertainties are ±20 percent).

Unsaturated overburden and fill materials are up to 28 feet thick along this traverse, probably due to the landfill. The thickest low-velocity materials, likely to represent landfill deposits, were observed between Stations 1+40 through 2+40. Unsaturated overburden thickness shown on

Figure 2 was smoothed, at NUS' request, in an effort to more closely represent the ground water surface that might be observed in the field.

Saturated overburden is interpreted to be 23 to 40 feet thick Interpreted bedrock elevations range from -45 feet at Station 0+00 to -22 feet at Station 4+00. Monitoring well MW-2 was located 190 feet south of Line 3 Station 2+15. Ground surface and ground water elevations were 4 to 11 feet higher at MW-2 than at Line 3.

Bedrock velocity values were difficult to estimate along Line 3 due to weaker seismic arrivals through the landfill deposits. Consequently, the bedrock seismic velocity range of 10,000 to 11,000 ft/sec shown on Figure 2 is based upon nearby measurements at Lines 1 and 2. Furthermore, the bedrock surface shown on Figure 2 is based upon the intersecting points at Lines 1 and 2, and crossover-distance depth computations at several Line 3 shot points (Line 3 SIPT2 bedrock elevation models were judged to be unreliable, due to the limited number of refracted arrival times from the bedrock surface). The bedrock surface shown on Figure 3 is thus more generalized compared to Lines 1, 2 or 4. The lowest bedrock elevations along Line 3 may be near Stations 1+20 to 1+40, where a subtle trough is interpreted.

Line 4

This traverse was located near the southern end of the landfill, between Lines 1 and 2 (Figure 1) Data quality along this traverse was generally good, even though some fill materials (particularly small asphalt piles) were observed nearby.

Unsaturated overburden or fill is less than 13 feet thick, and saturated overburden ranges from 10 to 28 feet thick. Ground water at monitoring well MW-4 coincides with the interpreted top of saturated overburden at Line 4 Station 0+65.

Till or weathered bedrock is not indicated by the saturated overburden velocity value of 4,800 ft/sec. Bedrock elevations range from -26 feet near Line 2 to -7 feet near Line 1. An average bedrock velocity of 12,100 ft/sec is slightly lower than values measured on nearby portions of Lines 1 and 2, possibly indicating slight weathering or fracturing.

**SUMMARY**

Bedrock is generally deepest (and possibly more weathered or fractured) north of Line 1 Station 7+00 and north of Line 2 Station 9+00. Bedrock is interpreted 54 feet below ground surface at Line 1 Station 1+20, and 66 feet below ground surface at Line 2 Station 3+80.

Shallower bedrock exhibiting higher velocities (and therefore less likely to exhibit significant fracturing) is interpreted south of Line 1 Station 7+50 and south of Line 2 Station 9+00.

Bedrock in these areas is as shallow as 13 feet below ground surface at Line 1 Station 8+00, and 27 feet below ground surface near Line 2 Stations 10+00 through 11+00.

Bedrock slopes downward from east to west, from elevation -7 feet to elevation -26 feet along Line 4 A similar downward slope towards the west was observed along Line 3, from elevation -22 feet to elevation -45 feet.

Near-surface landfill materials were judged to be present at the following areas based upon visual observations, low overburden seismic-velocity values, or attenuation of seismic energy: a) along the beach at Line 2 between Stations 0+00 through 7+00; b) along Line 3 between Stations 0+00 through 3+80; and c) along Line 4 between Stations 0+20 through 1+40. Line 1 and the eastern ends of Lines 3 and 4 are judged to be underlain by railroad ballast. Line 2 is probably outside the landfill boundary between Stations 7+00 through 11+20.

* * * * *

We appreciate this opportunity to provide geophysical services to Halliburton NUS, and we welcome any questions or comments regarding this report. Please call the undersigned principal at (508)966-5125 if we may provide any additional information that would benefit your remedial investigation.

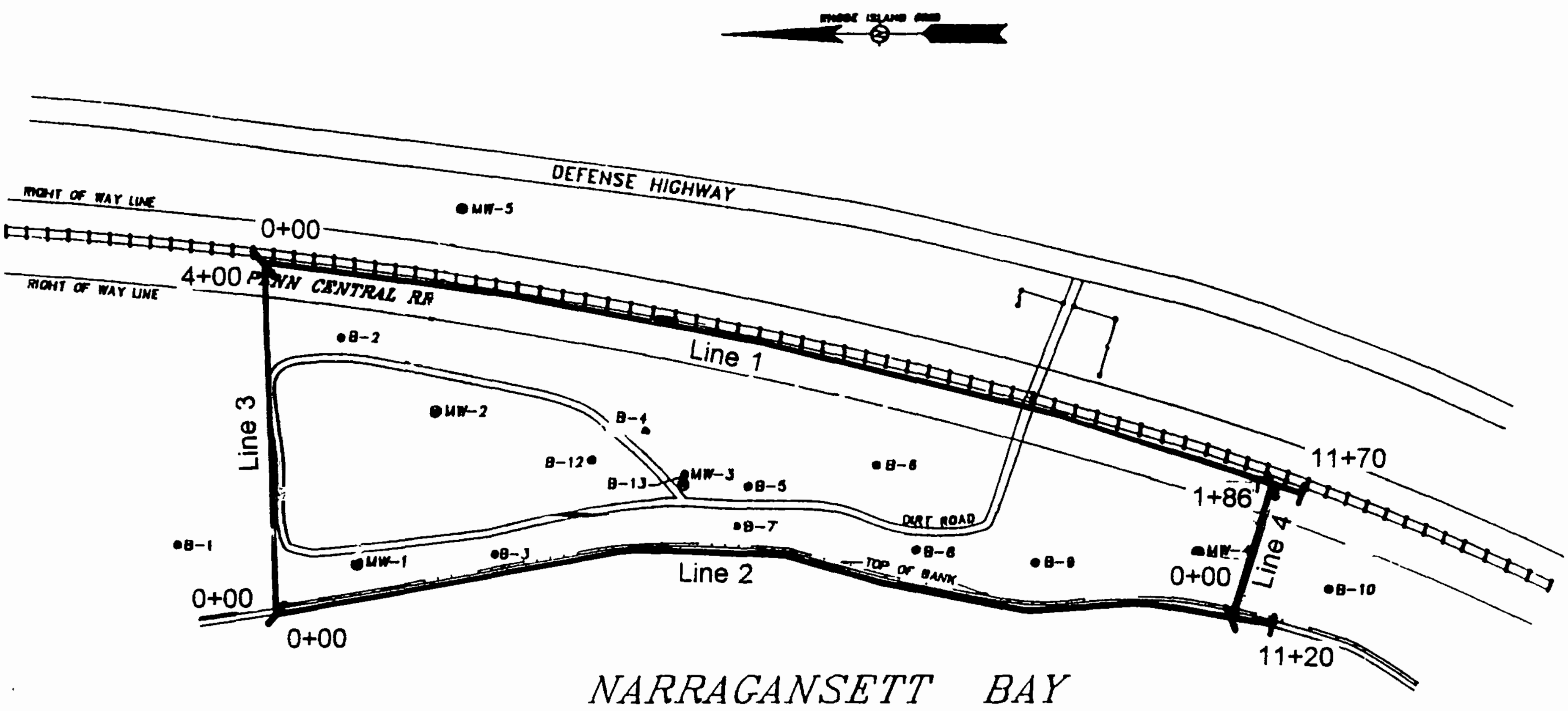
Sincerely,

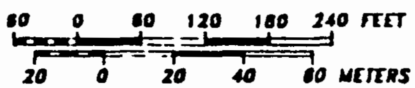
GEOPHYSICAL APPLICATIONS, INC.

M. Blackey

Mark E. Blackey
Principal and Geophysicist

95018 - nus_1b rpt




**LEGEND**

MW-1 ● MONITORING WELL LOCATION

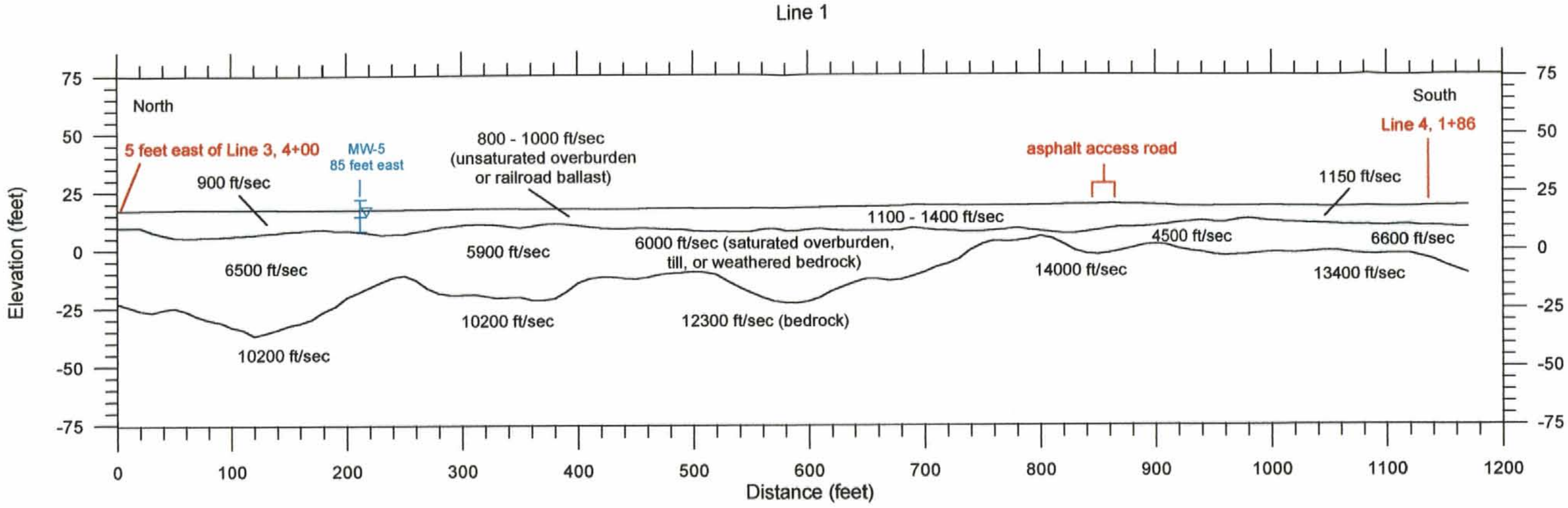
B-3 ● BORING LOCATION

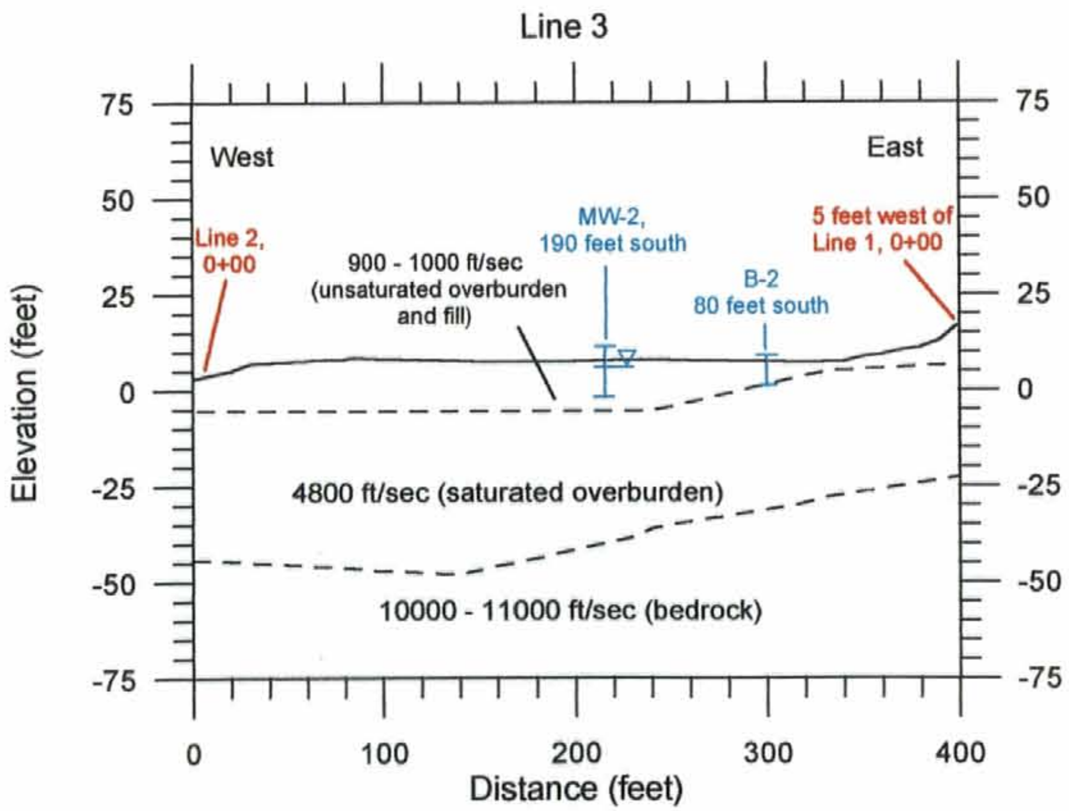
SEISMIC TRAVERSE

Bas map provided by Halliburton NUS Corporation.

Figure 1
Seismic Refraction Survey Traverses
Melville North Landfill
Newport, Rhode Island
prepared for
Halliburton NUS Corporation
July 1995

GEOPHYSICAL APPLICATIONS, INC.
P.O. Box 568 Bellingham, MA 02019




Notes:

1) Seismic velocity values are in units of feet per second (ft/sec).

2) Horizontal scale: 1 inch = 100 feet
Vertical scale: 1 inch = 50 feet

Vertical exaggeration = 2:1

3) Interpreted layer depths are estimated to be accurate within +/- 3 feet, or 10 percent, whichever is greater. Bedrock interfaces represented by dashed lines are less certain (possibly +/- 20 percent) due to thick landfill deposits near the ground surface.

4) Groundwater table interfaces represented by dashed lines were smoothed at Halliburton NUS' request, to more closely reflect probable field conditions.

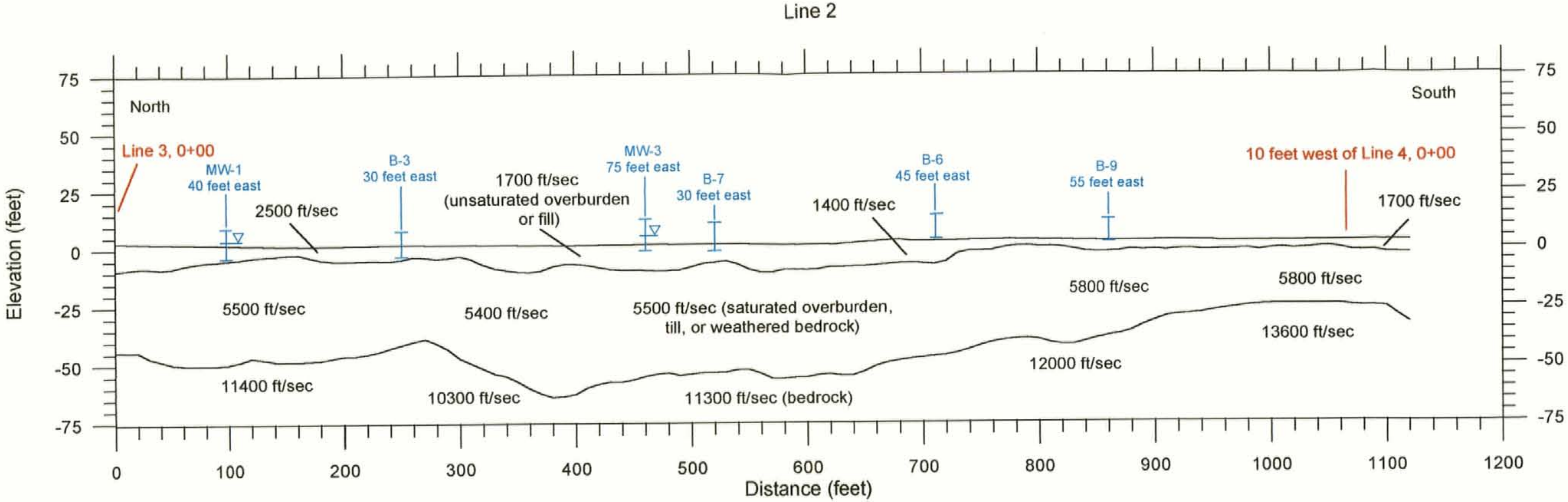
5) Boring and monitoring well positions are approximate, measured from the base map provided by Halliburton NUS.

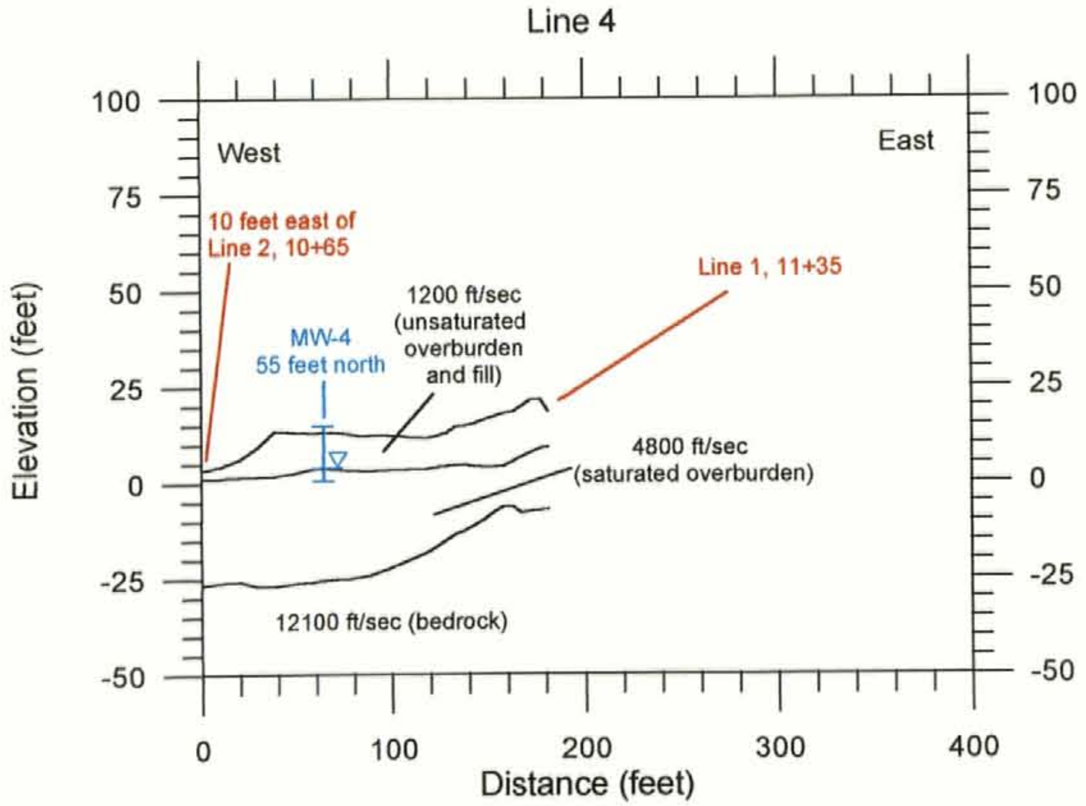
6) Ground water elevations shown at monitoring wells were recorded 7/17/90 by others.

nus_1_3b.grf

Figure 2
Seismic Refraction Profiles, Lines 1 and 3
Melville North Landfill - NETC
Newport, Rhode Island
prepared for
Halliburton NUS Corporation
July 1995

GEOPHYSICAL APPLICATIONS, INC.
P.O. Box 568 Bellingham, MA 02019




Notes:

1) Seismic velocity values are in units of feet per second (ft/sec).

2) Horizontal scale: 1 inch = 100 feet
Vertical scale: 1 inch = 50 feet

Vertical exaggeration = 2:1

3) Interpreted layer depths are estimated to be accurate within +/- 3 feet, or 10 percent, whichever is greater.

4) Boring and monitoring well positions are approximate, measured from the base map provided by Halliburton NUS.

5) Ground water elevations shown at monitoring wells were recorded 7/17/90 by others.

Figure 3
Seismic Refraction Profiles, Lines 2 and 4
Melville North Landfill - NETC
Newport, Rhode Island
prepared for
Halliburton NUS Corporation
July 1995

GEOPHYSICAL APPLICATIONS, INC.
P.O. Box 568 Bellingham, MA 02019

nus_2_4b.grf