GEOPHYSICS GPR INTERNATIONAL INC.

GEOPHYSICAL INVESTIGATION

GENERAL ELECTRIC NEWELL STREET PARKING LOT SITE PITTSFIELD, MASSACHUSETTS

Prepared for:

BLASLAND, BOUCK & LEE, INC.
6723 Towpath Road
Syracuse, New York 13214

Prepared by:

GEOPHYSICS GPR INTERNATIONAL, INC.
13 Highland Circle, Suite E
Needham Heights, Massachusetts 02194

May 8, 1996 B96121

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May 8, 1996

Our Project No. B96121
Your Project No. 201.37#2

Blasland, Bouck & Lee, Inc.
6723 Towpath Road
Syracuse, NY 13214-0066

Attention: Lynette Mokry

In accordance with your General Contract, Geophysics GPR International, Inc. has conducted a geophysical investigation at the General Electric Newell Street Parking Lot site, Pittsfield, Massachusetts.

This report contains the results of our findings, and is intended for the use of Blasland, Bouck & Lee.

Sincerely,

GEOPHYSICS GPR INTERNATIONAL, INC.

Lester M. Tyrala,
District Manager

LMT/hp
Att - 3 copies

GEOPHYSICAL INVESTIGATION

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B96121

CONTENTS

FIGURES

LIST OF MAPS

APPENDIX

1.0 INTRODUCTION

Geophysics GPR International, Inc., under a directive of Blasland, Bouck & Lee, Inc. (BBL), performed several geophysical methods at the General Electric Newell Street Parking Lot site. The plan of activities are set out in our proposal of April 4, 1996.

Ground penetrating radar, seismic reflection, and seismic refraction surveys were conducted under the direction of a BBL representative at specified locations at the site. These surveys were conducted during the period of April 16 to 19, 1996. The primary objectives of these surveys were to delineate and map a silt layer occurring in the glacial overburden and determine the depths to the bedrock surface. The area investigated by the methods is flatlying and was free of obstructions during the time of the survey.

The Newell Street Parking Lot site is located on Newell Street, Pittsfield, Massachusetts. The site is generally bounded on the northerly side by the Housatonic River, the easterly and westerly sides by residential properties, and the southerly side by Newell Street (Fig. 1).

2.0 SITE AND AREA CONDITIONS

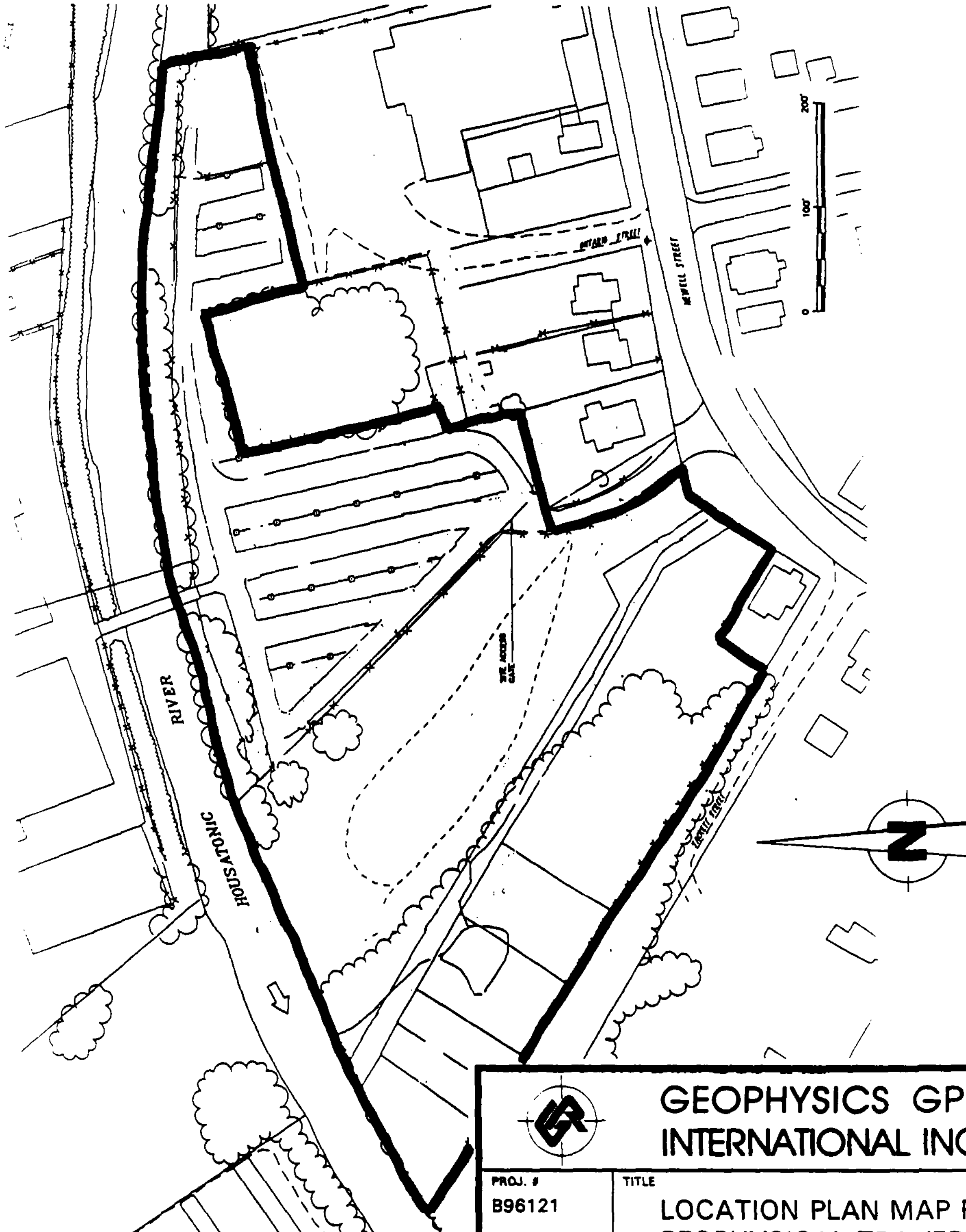
The site is flatlying with a gentle northeasterly slope toward the river. The site consists of an asphalt paved parking area, grassy areas, and wooded patches adjacent to the river and along the westerly side of the site.

The surficial materials consist of loose, graded sand and gravel and unconsolidated glacial materials away from the parking lot. The area is well drained and the underlying materials consist of a sequence of glacial deposits occupying a valley generally coincident with the course of the river. The water table is about ten feet below ground surface with the depth of overburden ranging up to sixty feet. Cultural disturbance has slightly altered the natural topography and soil composition within the top few feet at the site.

The bedrock at the site consists of metasedimentary rocks. The provided boring logs of the site borings did not penetrate to bedrock. This information was taken from data provided by BBL and observed conditions.

3.0 METHODS OF INVESTIGATION

A number of geophysical methods were employed to characterize the subsurface conditions at specified traverse locations at the site (Fig. 2). The methods were selected on the basis of conversations with BBL and provided subsurface information.



GEOPHYSICS GPR INTERNATIONAL INC.

PROJ. #	TITLE		
B96121	LOCATION PLAN MAP FOR GEOPHYSICAL TRAVERSES		
DRAWN BY	CLIENT		
A. Beaudoin	BLASLAND, BOUCK & LEE, INC.		
CHECKED BY	PROJECT		
C. Robillard	GENERAL ELECTRIC NEWELL STREET PARKING LOT SITE, PITTSFIELD, MASSACHUSETTS		
APPROVED BY	DRAWING DATE	SCALE	Fig. 1
L. Tyrala	04/25/96	1" = 150'	

3.1 Ground Penetrating Radar Method

Ground penetrating radar (GPR) employs high resolution radar to detect buried objects and subsurface stratigraphy. Many of the principles of GPR are similar to that of the seismic reflection method used in oil and gas exploration. The transmitting antenna emits brief pulses of electromagnetic energy into the ground, then pauses between pulses with the receiving antenna recording energy which has been reflected back to the surface.

Radar waves are reflected by interfaces between media with differing dielectric constants, such as geologic contacts, buried objects, or voids. The dielectric constant is controlled by factors such as water content, density, and composition. The depth of penetration is limited by the operating frequency of the transmitter and the electrical conductivity of the ground.

The GPR unit records the two-way travel time and the amplitude of the reflected signals. The typical radar anomaly produced by a layer of stratum is a coincidence of radar wave forms producing a defined reflector in the records as a band. The source of the radar anomaly is located at the upper surface of the stratum.

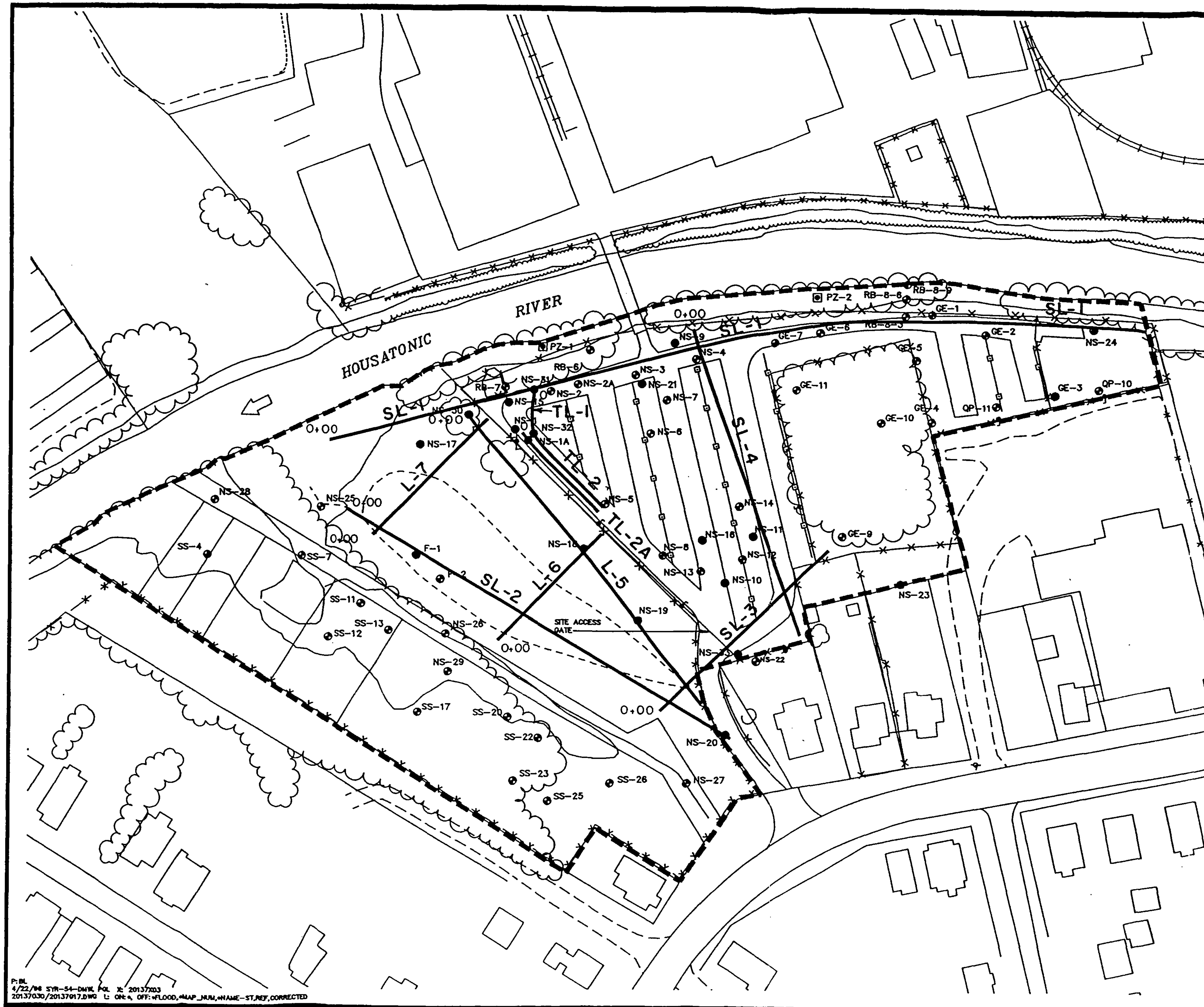
3.1 Seismic Refraction Survey

A 24-channel digital seismograph, an EG&G SmartSeis, was used and set up in the seismic refraction mode with a geophone spacing of about eight feet. The objectives of the refraction survey were to try to profile the silt layer and determine the depths to the bedrock surface. These traverses were coincident with the reflection traverses with five to seven energy points (shots) along each spread for our quality control of field data collection: forward and reverse offset (far) shots, end shots, a center shot, and quarter shots. A two geophone overlap was laid out for contiguous spreads.

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

3.2 Seismic Reflection Survey

The same 24-channel digital seismograph was employed, an EG&G SmartSeis, and configured for a reflection survey. The seismic reflection survey, about an eight foot spacing at all locations, was configured to determine the silt layer in the glacial overburden and define the bedrock surface. Interfaces which exhibit a contrast in acoustic impedance (the product of velocity and density) will reflect seismic energy back to the surface. Seismic reflection has the potential of detecting units of glacial strata and the detailed configuration of the bedrock surface (see App. B).



LEGEND

- GE-3 MONITORING WELL
- PZ-1 PIEZOMETER
- NS-2A SOIL BORING
- APPROXIMATE SITE BOUNDARY
- APPROXIMATE EXISTING FENCE LOCATION
- APPROXIMATE PARCEL BOUNDARY

NOTES:

1. THE BASE MAP FEATURES PRESENTED ON THIS FIGURE WERE PHOTOGRAMMETRICALLY MAPPED FROM APRIL 1990 AERIAL PHOTOGRAPHS.
2. ALL SAMPLING LOCATIONS ARE APPROXIMATE.

0 100' 200'

SCALE: 1"=100'

GENERAL ELECTRIC COMPANY
PITTSFIELD, MASSACHUSETTS

NEWELL STREET PARKING LOT/USEPA AREA 5B

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 2

The performed seismic reflection survey employed common depth point (CDP) data acquisition with multi-fold coverage (up to 12-fold (1,200% coverage)). Refer to Appendix B for each profile displaying the fold coverage.

4.0 DATA ACQUISITION

Each geophysical method utilized at this site had its own requirement for equipment and manner of conducting the survey. The surveys required laying out traverse lines to control data collection points.

4.1 Equipment

The GPR survey was performed with a GSSI SIR System-10 radar system, with a 100 mHz high-power antenna. Lower frequency antennas permit greater depths of exploration while reducing spatial resolution. All field data were viewed on a monitor and stored on magnetic tape.

A digital seismograph was employed for this investigation. Amplification of the signals from the geophones is accomplished using integrated floating point technology, which allows maximum trace size throughout the record. Each seismogram is recorded digitally on the seismograph hard drive, transferred to floppy disk, and printed onsite.

For the seismic reflection survey, a roll-along switch was used to select the appropriate 24 geophone position for each shotpoint from the total 48 geophone positions laid out as one spread. This switch allows for "rolling in and out" of the spread to efficiently increase the fold coverage and for continuous common-midpoint recording within the spread. For the refraction survey, a 24 geophone array was used.

A sledge hammer was used for the refraction and reflection surveys. Typically, ambient acoustic noise was at acceptable levels and, where at higher levels, overcome by stacking and filtering of the seismic records.

4.2 Survey Design and Procedures

Trial traverse lines were performed at selected locations using ground penetrating radar as the first method to determine its application at this site. The method showed an inconsistent and discontinuous response from the top of the silt layer. As was the schedule of activities, a seismic refraction survey was then performed to test its application to the detection of the silt layer and bedrock. The results of the method did not define the silt layer, but did determine the top of water saturated zone and the bedrock surface.

Seismic reflection was then performed with the field records indicating detection of reflectors at depth. Based upon these results, the specified traverse lines were completed using seismic reflection and refraction (at no additional cost) with some fill radar traverses run at the completion of the specified program (at no additional cost).

Traverse lines were established at the specified locations. Areas within the parking lot and open ground were investigated with the methods, and referenced to fixed structures and monitoring well locations.

The specified program for the site required that traverses be performed at several locations (see pocket map). The seismic surveys were performed with an 8 1/4 foot geophone spacing along the specified locations, yielding a spread length of 190 feet.

5.0 INTERPRETATION

The results of the geophysical surveys were correlated with the relevant borehole data at the time of the interpretation of the data. Not all of the borings that were consulted during the interpretation were plotted on profiles, primarily due to its distance from a traverse line and/or shallow depth of the boring.

Preliminary interpretation of the seismic refraction data was accomplished with the cross-over distance method. This method provides the depth to significant interfaces beneath the shotpoints. The reciprocal method of L.V. Hawkins (also known as Hawkins Method) was used to provide the detailed interpretation. Unlike the cross-over distance method, the reciprocal method allows the calculation of the depth to bedrock beneath each geophone. The concurrent use of both interpretive methods provides an important means of checking the validity of the interpretation.

The interpretation of the seismic reflection data involved 2-D inverse computer modeling. Full CDP data processing was accomplished including normal move out (NMO), filtering, and terrain correction. Each trace on the processed seismic section was spaced at one-half of the geophone spacing and represent the summation of the traces that receive reflections from the same subsurface point. Depth conversion for the seismic reflection data was performed by using average velocities derived from the refraction data and calibrated with the relevant borehole information.

6.0 RESULTS

Overall, the methods used at this site, when combined and integrated, gave very good results. The silt layer was imaged with ground penetrating radar and seismic reflection, and the bedrock was determined with seismic refraction, seismic reflection, and radar.

6.1 Ground Penetrating Radar

Radar records obtained in the field are time sections. In order to convert the two-way travel times to depth, the velocity of radar waves in the subsurface must be determined. Velocities can be calculated by surveying objects of known depth or by materials velocity averaging. Depth calibration at this site was accomplished by surveying over monitoring well NS-31 at which the silt layer is at a known depth.

This velocity determination was used in generating the depth scales for the cross-sections. While the estimated depths are expected to be accurate in unsaturated materials, the site condition, the depth scale will be less accurate below the water table, where the velocity of radar waves is considerably slower. The average depth of our GPR penetration across the site was 15 feet (at the parking lot) to 55 feet (at the grassy areas at the western side of the site).

In general, GPR data of good quality were collected at the site (Fig. 3). The composition of the placed fill and natural materials allowed for good penetration of the GPR signal within a portion of the site. However, for most of the site where the radar trial was conducted the method could not achieve the required penetration. Typically, a stratigraphic layer is distinguished by its continuity as a flatlying radar reflector.

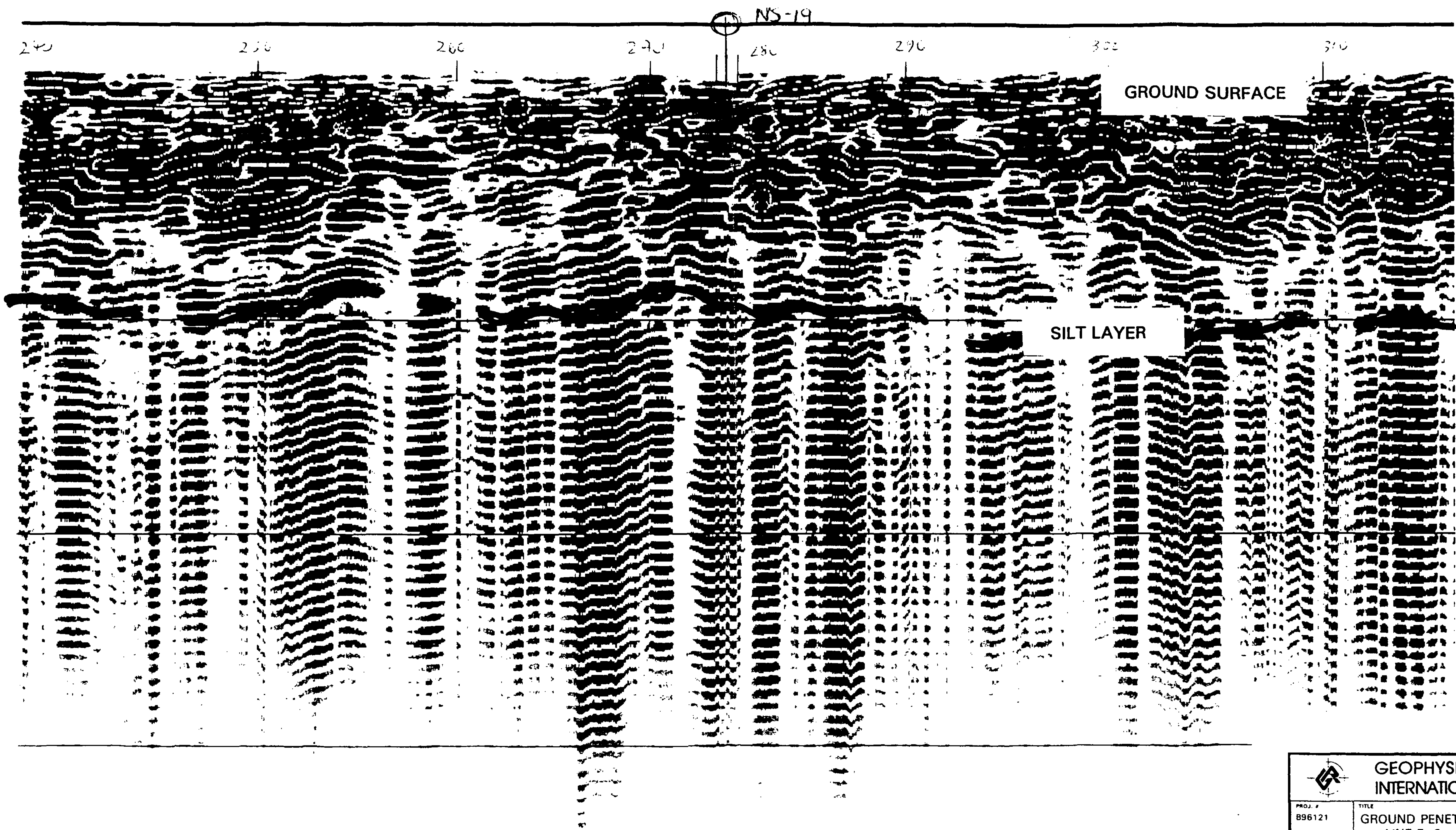
6.2 Seismic Reflection and Refraction Surveys

Approximately 1,825 linear feet of combined seismic reflection and refraction profiling was accomplished along four line traverses during the field surveys (foldout map, pocket). The seismic surveys were performed at specified locations and modified in the field, as required, to conform to the specified positions with a BBL representative present for this fieldwork. Information provided by relevant boring logs were integrated into the final geophysical interpretation.

The results of the seismic refraction and reflection surveys are presented as integrated cross-sections (foldout map). A layer of dry surficial soils was determined along all traverses with deeper unconsolidated overburden being fully water saturated. The top of this layer is well defined continuously as a reflector in the reflection records and as a higher velocity layer in the refraction records. The top of the silt layer was imaged to a moderate degree on every traverse. The velocities of the bedrock are in distinct contrast to the overlying materials. Due to the lengths and orientations of the reflection and refraction traverses, the subsurface layers could be contoured, if desired, in a meaningful way.

6.3 Precision and Limitations

The typical velocities for sound, unweathered metasedimentary in southern New England range from 7,500 to 15,000 ft/s and for weathered and/or fractured metasedimentary from 6,000 to



GEOPHYSICS GPR INTERNATIONAL INC.

PROJ. #	TITLE
B96121	GROUND PENETRATING RADAR LINE 5, 2+40 TO 3+10
DRAWN BY	CLIENT
A. Beaudoin	BLASLAND, BOUCK & LEE, INC.
CHECKED BY	PROJECT
C. Robillard	GENERAL ELECTRIC NEWELL STREET PARKING LOT SITE, PITTSFIELD, MASSACHUSETTS

APPROVED BY	DRAWING DATE	SCALE	
L. Tyrala	04/25/96	Record Marks	Fig 3

10,000 ft/s. The bedrock velocity values are shown on the profiles, and those in parentheses are interpolated values.

The precision of a ground penetrating radar survey depends upon the subsurface conditions within the interval of the traverse where the survey was performed. The precision for a radar traverse is based upon the accuracy of electromagnetic travel time measurement, accuracy of the reflector (anomaly) selection, and accuracy of the depth conversion process. Typically, a radar traverse with quality records will yield a high precision of ±7 to 10 percent, and with moderate quality records will yield a moderate precision of ±10 to 12 percent. The precision at this site is high to moderate for the reflection traverses.

The precision of seismic reflection and refraction surveys depends upon the conditions within the interval of the traverse where the reflection and/or refraction was performed. The precision for a reflection traverse is based upon the accuracy of acoustic travel time measurement, accuracy of the reflector (time pick) choice, and accuracy of the depth conversion process. Typically, a reflection traverse with all shots collected and high quality records will yield a high precision of ±8 to 10 percent, and with most shots and/or moderate quality records will yield a moderate precision of ±10 to 12 percent. The precision at this site is high to moderate for the reflection traverses.

Typically, a refraction traverse with all seven shots collected and high quality records will yield a high precision of ±7 to 10 percent for depths greater than thirty feet and a precision of ±3 to 5 percent for bedrock velocities, and with five to seven shots and/or moderate quality records will yield a moderate precision of ±10-15 percent for depths greater than thirty feet and a precision of ±4 to 6 percent for bedrock velocities. The precision at this site is high to moderate for the refraction traverses.

Altogether, the quality of the interpretation for this combined seismic reflection and refraction investigation at this site is high to moderate, due to the combination of the methods and correlation with the results of previous borings. Calculated depths to bedrock correlated within three feet with the cross seismic spreads. As explained in the Appendices, each method does have certain constraints with respect to detection of particular layers.

As with all geophysical methods, there are minimum detectible limits. Major limitations for seismic reflection and radar are thickness and/or size of the objectives, and for seismic refraction are velocity inversions and hidden layers (see App. B). Calibration with borehole data can define and overcome most of these limitations. With respect to widths of low velocity bedrock intervals that could correlate to open fracture zones, widths greater than ±five feet should be detectible with the refraction configuration that was used here.

For the surveys at this site, the minimum thickness of a layer that could be defined is about five feet near-surface and about 15 feet within the deeper portions of the investigated area. This resolution corresponds to the minimum thickness of more or less parallel layers which allow detection of the lower interface. Thinner dipping layers and fracture zones ±two feet or more in width should be recognizable in the records.

6.4 Geophysical Traverse Lines

Geophysical trial traverse lines 1, 2, and 2A were conducted with radar only. Geophysical traverse lines 1 to 4 were conducted using all three methods, while traverse lines 5 to 7 were conducted using radar only as an addition and at the completion of the survey.

Traverse Line 1

The subsurface horizons mapped on Line 1 (west to east), chainage 0+00 to 8+60, are derived primarily from the seismic refraction and reflection methods, as the ground penetrating radar did not yield good results along this traverse. Chainage 0+00 is positioned on the grass near the large wooded area at the western end of the site adjacent to the riverbank, and the traverse extends more or less parallel to the river, mostly on the paved surfaces, to the eastern end of the site.

The overburden portion of the profile shows about 12 to 18 feet of placed fill and unsaturated surficial soils (1,300 ft/s), 10 to 17 feet of saturated sediments (5,000 ft/s), and the top of the silt layer. The silt surface appears to be nearly horizontal having minor topographic relief with depths below ground surface ranging from 26 to 34 feet. The silt layer appears well defined in the reflection records and was imaged almost continuously as a seismic reflector.

The bedrock surface, from west to east, is at a depth of about 60 feet, inclined slightly upward to a depth of 42 feet at about chainage 5+60, then is inclined downward to 70 feet at the end of the traverse at chainage 8+60. A good correlation was obtained by both seismic methods in determining the bedrock surface. This line shows a moderate bedrock velocity (10,500 to 13,500 ft/s) indicative of sound, unweathered bedrock. The depths show a good correlation to our crossline L-4.

Traverse Line 2

The subsurface horizons mapped on Line 2 (northwest to southeast), chainage 0+00 to 4+65, are derived from the seismic refraction and reflection methods, and the ground penetrating radar as it did yield some results along this traverse. Chainage 0+00 is positioned near the large wooded area at the western end of the site adjacent to the riverbank (southerly of chainage 0+00 on Line 1), and the traverse extends on the grassy area nearly to Newell Street.

The overburden portion of the profile shows about 10 to 16 feet of placed fill and unsaturated surficial soils (1,300 ft/s), 7 to 16 feet of saturated sediments (5,000 ft/s), and the top of the silt layer. The silt surface appears to be inclined to the north having some topographic relief with depths below ground surface ranging from 22 to 38 feet. The silt layer appears marginally defined in the reflection records and discontinuously in the radar records.

The bedrock surface, from northwest to southeast, is at a depth of about 50 feet, horizontal to about chainage 3+90, then is inclined upward to 45 feet at the end of the traverse at chainage 4+65. A good correlation was obtained by the seismic refraction and radar methods in determining the bedrock surface. This line shows a moderate bedrock velocity (10,200 to 12,500 ft/s) indicative of sound, unweathered bedrock. The depths show a good correlation to boring F-1 and to our crosslines, L-3, L-6, and L-7.

Traverse Line 3

The subsurface horizons mapped on Line 3 (southwest to northeast), chainage 0+00 to 2+35, are derived from the seismic refraction and reflection, and the ground penetrating radar method. No one method mapped the silt or bedrock surface continuously along this traverse. Chainage 0+00 is positioned on the grass near the end of Line 2 and the traverse extends across the edge of the parking lot.

The overburden portion of the profile shows about 7 to 15 feet of placed fill and partially saturated surficial soils (1,300 to 3,600 ft/s), 14 to 18 feet of saturated sediments (5,000 ft/s), and the top of the silt layer. The silt surface appears to be inclined slightly to the east having some topographic relief with depths below ground surface ranging from 26 to 32 feet. The silt layer appears marginally defined in the reflection and radar records.

The bedrock surface, from southwest to northeast, is at a depth of about 52 feet, and nearly horizontal within this short interval. A correlation was obtained by the seismic refraction and radar methods in determining the bedrock surface. This line shows a moderate bedrock velocity (10,200 to 12,500 ft/s) indicative of sound, unweathered bedrock. The depths show a good correlation to our crosslines, L-2, L-4, and L-5.

Traverse Line 4

The subsurface horizons mapped on Line 4 (north to south), chainage 0+00 to 3+30, are derived from the seismic refraction and reflection, and the ground penetrating radar method. As with Line 3, no one method mapped the silt or bedrock surface continuously along this traverse. Chainage 0+00 is positioned on the grass near the end chainage of Line 2 and the traverse extends across the edge of the parking lot to the site property line.

The overburden portion of the profile shows about 15 to 19 feet of placed fill and partially saturated surficial soils (1,300 to 3,600 ft/s), 13 to 17 feet of saturated sediments (5,000 ft/s), and the top of the silt layer. The silt surface appears to be nearly horizontal having no topographic relief with depths below ground surface ranging from 32 to 36 feet. The silt layer appears marginally defined in the reflection and radar records.

The bedrock surface, from north to south, is at a depth of about 50 feet, and nearly horizontal within this short interval. A correlation was obtained by the seismic refraction and radar methods in determining the bedrock surface. This line shows a moderate bedrock velocity (12,100 ft/s) indicative of sound, unweathered bedrock. The depths show a good correlation to borings NS-9, 11, 12, and 14 and to our crosslines, L-1 and L-3.

Traverse Lines 5, 6, and 7

The subsurface horizons mapped on Lines 5, 6, and 7 were acquired with ground penetrating radar only. The silt layer could be mapped fairly consistently along these three lines. The data appears to be of better quality in areas closer to the river. Line 5 (northwest to southeast) chainage 0+00 is positioned on the grass near the start of Line 1 and the traverse extends across the grassy area almost to the end of line 2. Lines 6 and 7 (southwest to northeast) chainages 0+00 are positioned on the grass near the wooded area and extend almost to the parking lot.

The overburden portions of the profiles show about 19 to 37 feet of placed fill, partially and fully saturated surficial soils and sediments on top of the silt layer. The silt surfaces display some inclination and relief; Line 5 shows a slight inclination to the north, Line 6 shows a nearly horizontal surface, and Line 7 shows a slight inclination to the south. There were no interpretable radar reflections from the bedrock along these three lines.

7.0 CONCLUSIONS

The specified objectives of this geophysical investigation were to identify geologic surfaces, such as the silt layer and bedrock. The results of this investigation identified and traced these features. Overall, the combination of the three methods detected the top of the water saturated zone, the top of the silt layer, and bedrock surface.

A certain amount of stratigraphic detail was defined within the overburden. The lack of continuity of several of these layers in the seismic and radar records is probably due to the discontinuous nature of these layers recognized in the borings.

- Overall, the silt layer is overlain by placed fill and glacial deposits with a total thickness ranging from 19 to 36 feet.

- Most of the traverse lines detected a continuous silt layer, displayed as a reflector in the seismic reflection and/or ground penetrating records.

○ The ground penetrating radar method located intermittently the top of the water saturated zone, silt layer, and the bedrock surface.

○ The complementary nature of ground penetrating radar, seismic reflection, and seismic refraction surveys defined, with a high to moderate degree of precision, layers in the overburden and the bedrock surface.

○ Seismic reflection and refraction and radar imaged several different overburden layers as well as the bedrock surface.

○ Seismic Refraction and reflection delineated the top of the water saturated zone.

○ The seismic refraction and reflection surveys showed that the overburden at this site consists of unsaturated and saturated glacial materials overlying the silt layer. These overburden layers have a velocity range of 1,300 ft/s to 5,000 ft/s.

○ Overall, relatively sound bedrock is overlain by placed fill and glacial deposits with a total thickness ranging from 42 to 63 feet.

○ The bedrock velocities are generally indicative of sound rock (10,200 to 13,500 ft/s).

○ The bedrock surface was generally shown to have moderately uniform and gentle relief.

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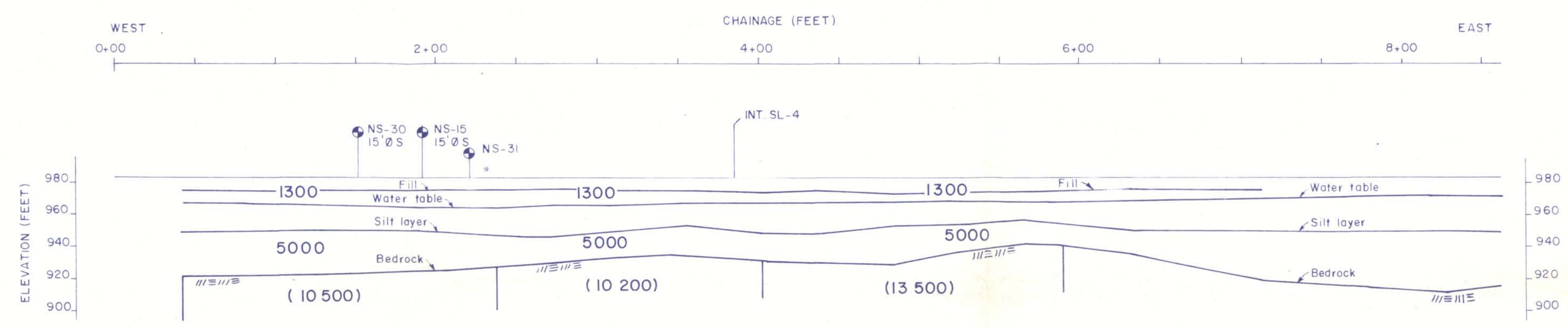
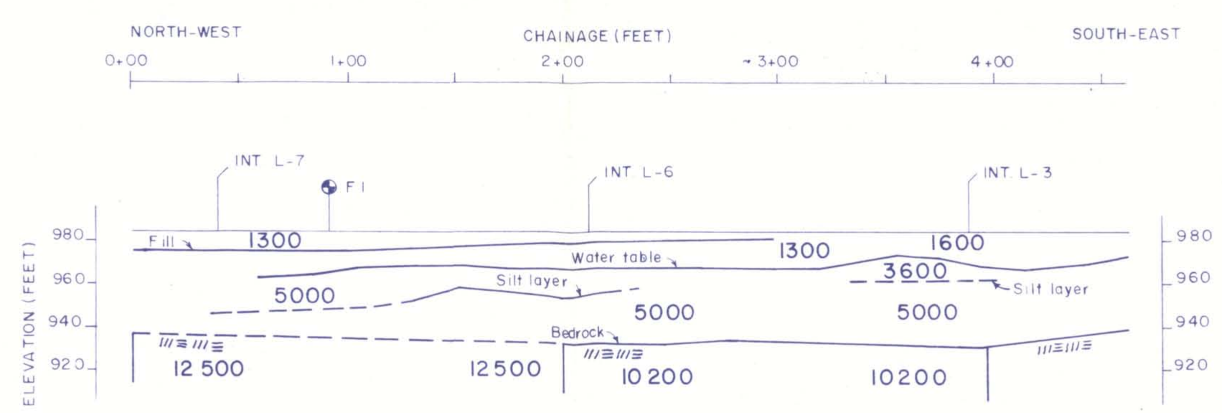
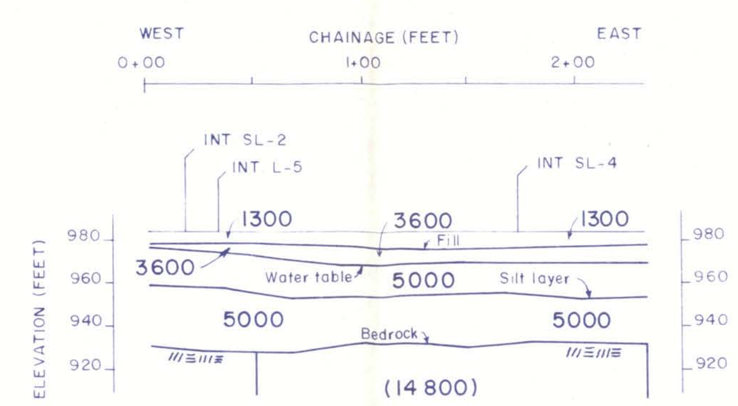


SL-1



SL-2



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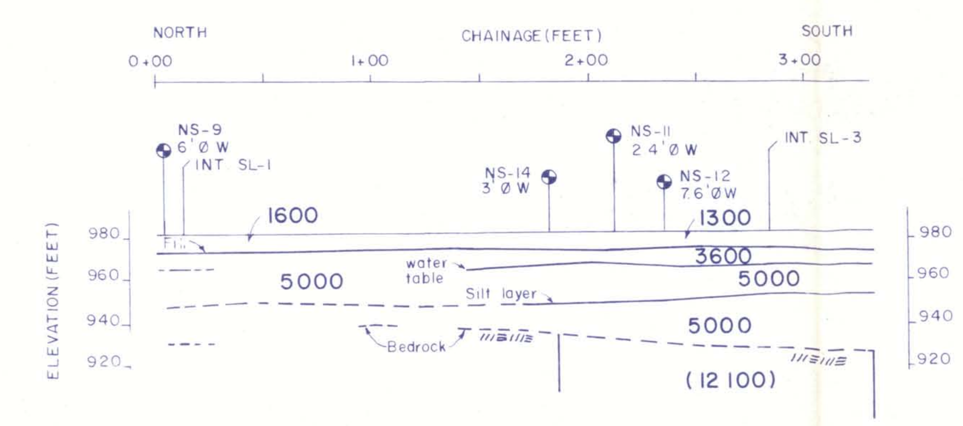

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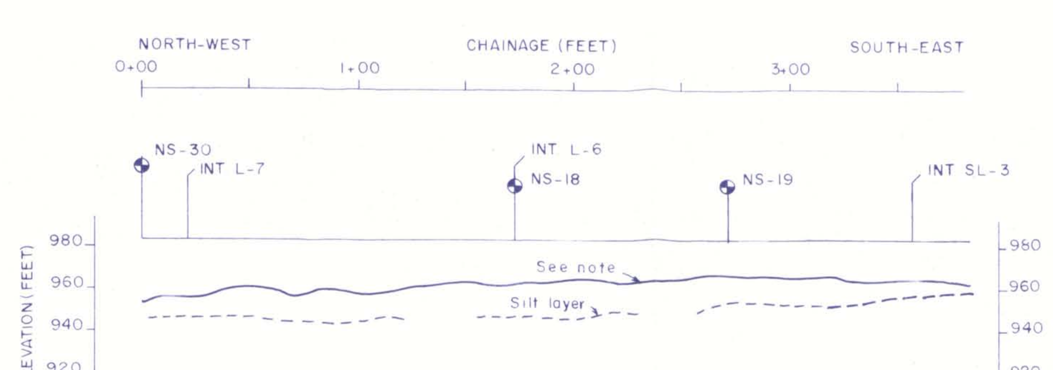
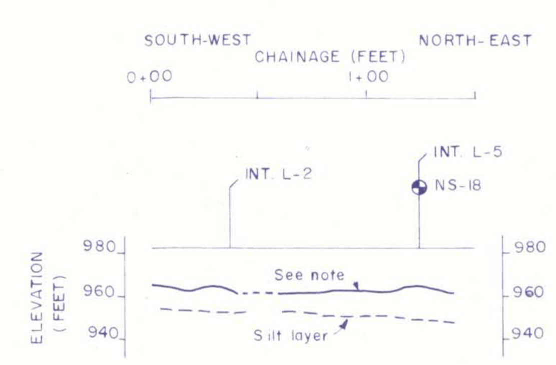


L-5

NOTE

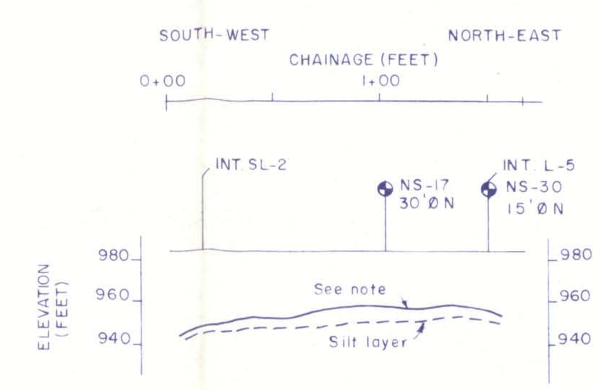
GRAY FINE SAND AND GRAVEL CONTACTS ABOVE SILT LAYER



L-6

NOTE

GRAY FINE SAND AND GRAVEL CONTACTS ABOVE SILT LAYER



L-7

NOTE

GRAY FINE SAND AND GRAVEL CONTACTS ABOVE SILT LAYER

LOCATION PLAN

LEGEND

- TOPOGRAPHIC PROFILE
- (5 000) SEISMIC VELOCITY IN FEET / SECOND
- (14 800) EXTRAPOLATED SEISMIC BEDROCK VELOCITY IN FEET / SECOND
- BOREHOLE
- INT. SL- INTERSECTION SEISMIC LINE OR GEORADAR LINE
- EXTRAPOLATED BEDROCK PROFILE

N°	NOTES
1	THE RESULTS PRESENTED ON PROFILES SL-1, SL-2, SL-3 AND SL-4 ARE A COMBINATION OF 3 METHODS; SEISMIC REFRACTION, SEISMIC REFLECTION AND GEORADAR SURVEYS
2	THE GEOPHYSICAL SURVEY WAS PERFORMED BETWEEN THE 16th AND 19th OF APRIL 1996
3	THE ELEVATIONS WERE TAKEN FROM THE BOREHOLE INFORMATION SUPPLIED BY THE GENERAL ELECTRIC CO/BBL

N°	DESSINS DE REFERENCE DRAWINGS	N°	DATE	MODIFICATIONS	G.P.R. APP.

SCEAU PROFESSIONNEL / PROFESSIONAL SEAL

GEOPHYSICS GPR INTERNATIONAL INC.

DESSINE PAR / DRAWN BY	A. Beaudoin, tech
VERIFIE PAR / CHECKED BY	M. Poulin, geol.; C. Robillard, geoph
APPROUVE PAR / APPROVED BY	L. Tyrala, geol.
N° CONTRAT / CONTRACT N°	B-96121
DATE	May, 1996
ECHELLE / SCALE	Hor. 1" : 50'; Vert. 1" : 50'
N° DESSIN / DRAWING N°	96-05-200

CLIENT: BLASLAND, BOUCK & LEE INC.

PROJET / PROJECT: GENERAL ELECTRIC NEWELL STREET PITTSFIELD, MASSACHUSETTS

TITRE / TITLE: GEOPHYSICAL INVESTIGATION

APPROUVE PAR / APPROVED BY — DATE

APPENDIX A

THE SEISMIC REFRACTION METHOD

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

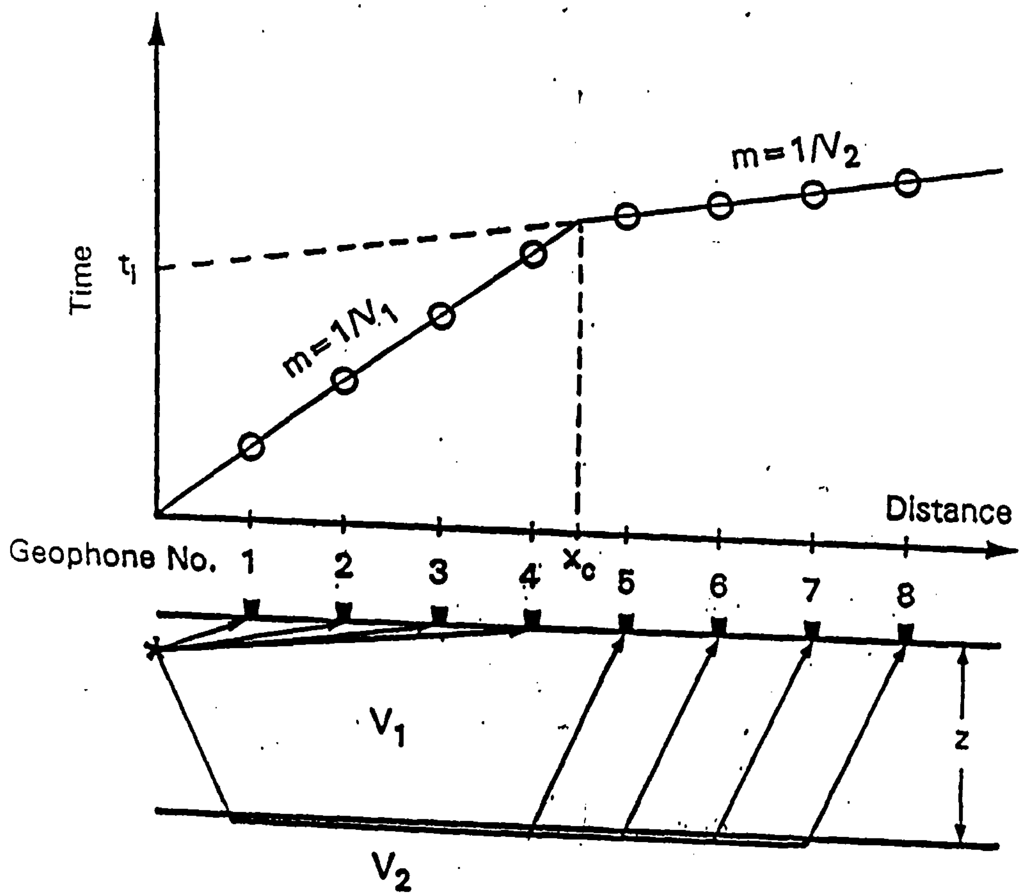
INSTRUMENTATION

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

FUNDAMENTAL PRINCIPLES

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

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



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

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

Principles of Seismic Refraction

Figure 1

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

INTERPRETATION

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

LIMITATIONS

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

DESCRIPTIVE CLASSIFICATION
OF BEDROCK SEISMIC VELOCITIES WITH RQD VALUES

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

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

TABLE

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

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

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

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

APPENDIX B

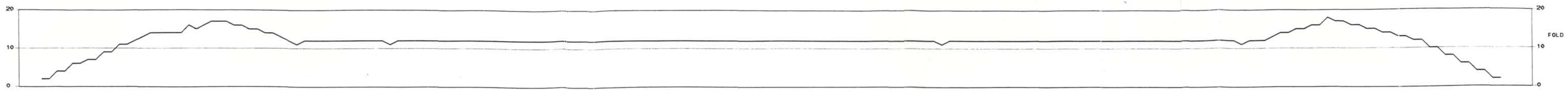
SEISMIC REFLECTION PROFILES

The interpretation of the seismic reflection data involved 2-D inverse computer modeling. Full CDP data processing was accomplished including normal move out (NMO), filtering, and terrain correction. Each trace on the processed seismic section was spaced at one-half of the geophone spacing and represent the summation of the traces that receive reflections from the same subsurface point.

The attached profiles are the processed and interpreted reflection data sets, together with a plot of fold and static values, along each traverse. The prominent reflectors are colored:

- Green marks the top of the saturated layer
- Violet marks the top of the silt layer
- Orange marks the bedrock surface

The horizontal scale is the distance along the traverse, chainage position 0+00 at mark 1, and each vertical trace is approximately 4.1 feet apart. The vertical scale is in milliseconds (two-way travel time). The profiles shown on the foldout map (pocket) are the integrated sections composed of the combined seismic refraction, seismic reflection, and radar results.



TRAV	VRMS	VINT
8	676	676
22	1140	1334
31	1398	1885
50	1587	1854
66	1673	1917

TRAV	VRMS	VINT
8	676	676
22	1140	1334
32	1467	2006
50	1587	1780
66	1673	1917

TRAV	VRMS	VINT
8	676	676
23	1037	1185
34	1312	1752
51	1518	1862
66	1673	2116

TRAV	VRMS	VINT
8	676	676
24	1157	1333
36	1398	1784
52	1673	2167
69	1759	1999

TRAV	VRMS	VINT
8	676	676
24	1088	1243
37	1467	1984
52	1673	2096
69	1759	1999

TRAV	VRMS	VINT
8	676	676
24	1157	1333
35	1553	2180
52	1759	2121
70	1879	2189

TRAV	VRMS	VINT
8	676	676
24	1157	1333
35	1553	2180
52	1759	2121
70	1879	2189

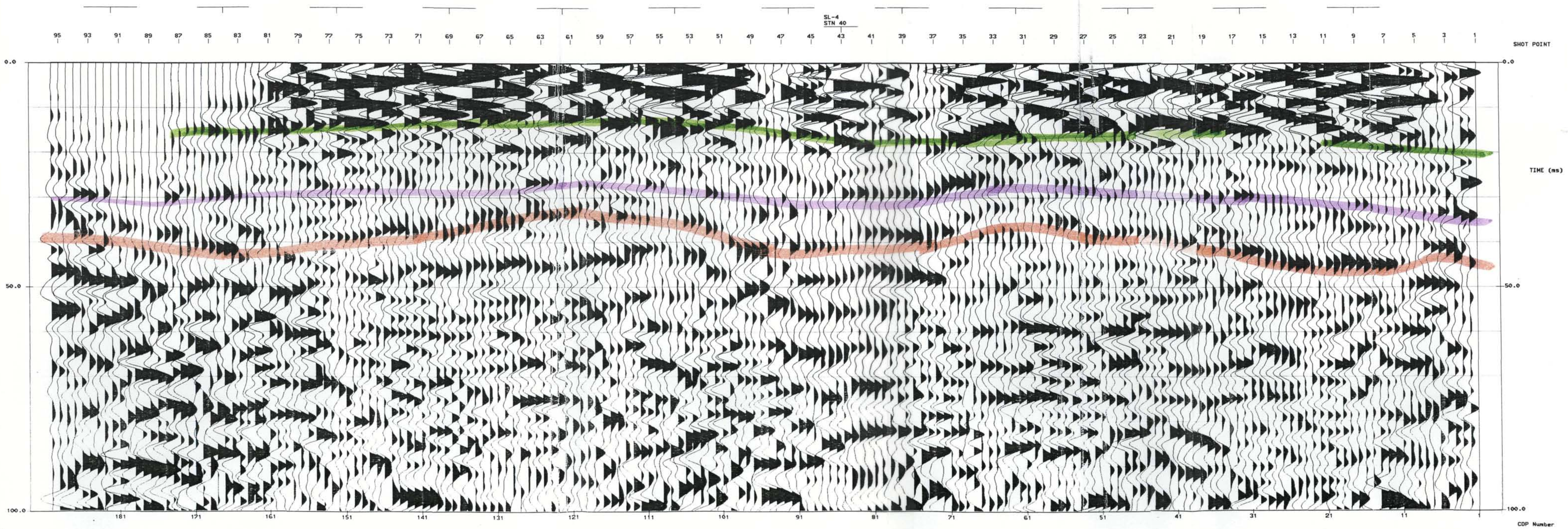
TRAV	VRMS	VINT
8	676	676
19	1140	1382
33	1621	2104
48	1811	2171
67	1914	2152

TRAV	VRMS	VINT
8	676	676
21	1226	1465
33	1621	2143
48	1811	2171
67	1914	2152

TRAV	VRMS	VINT
8	676	676
21	1226	1465
33	1621	2143
48	1811	2171
67	1914	2152

TRAV	VRMS	VINT
8	676	676
23	1346	1591
31	1639	2280
48	1897	2293
67	2034	2344

TRAV	VRMS	VINT
8	676	676
19	1157	1407
31	1639	2195
48	1897	2293
67	2034	2344



GÉOPHYSIQUE GPR INTERNATIONAL INC.

AREA: GE Pittsfield, Massachusetts

LINE: SL-1

SP 96 EAST SP 1

NORMAL POLARITY

STRUCTURE STACK

FIELD PARAMETERS

Date shot:	April 1996
Instruments:	EG&G
Filter:	60 Hz NOTCH
Spread:	24 trace, 1 - 12 X 13 - 24 60 - 2.5 X 2.5 - 60 metres
Source:	Sledgehammer
Spacing:	2.5 m.
Geophones:	Mark Products 40 Hz.
Spacing:	2.5 m.

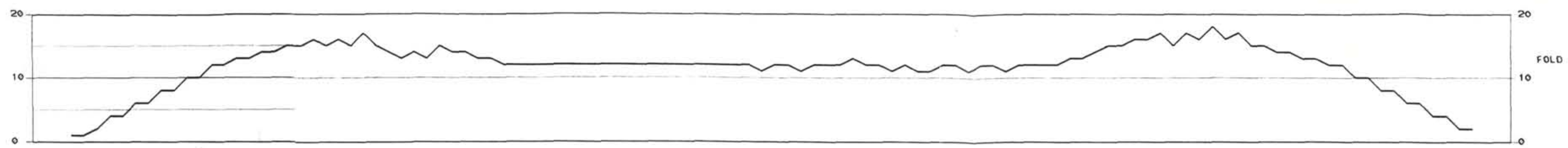
PROCESSING PARAMETERS

Date:	April 1996
Trace Edits	
Exponential Scaling	A*t*exp(B*t)
Trace Equalization	Mean amplitude scale
Deconvolution	Spiking 32ms. operator 0.1% Pre-whitening
Equalization Scaling	First break region
Trace Gathers	
Structure Statics	Relative 980 m., Vr 1500 m/s.
Residual Statics	Shot + Station, hand picked
Velocity analysis	Semblance
Mute	6 10 60 m. 0 15 40 ms.
Stack	12 fold
Filter	70/90 - 280/310 Hz.
Trace Equalization	Mean amplitude scale 10 - 100 ms.
Post Stack Noise Red.	Common signal extraction 80 msec. operator

SCALE:
Horizontal 10 Traces/in Vertical 60 in/second

PROCESSED BY:

Geophysical Applications Processing Services
GUELPH, ONTARIO



TRAV	VRMS	VINT
16	641	641
26	1054	1493
39	1570	2274
53	1759	2201
83	1931	2202

TRAV	VRMS	VINT
13	590	590
27	1157	1502
41	1725	2476
60	2051	2619
80	2292	2897

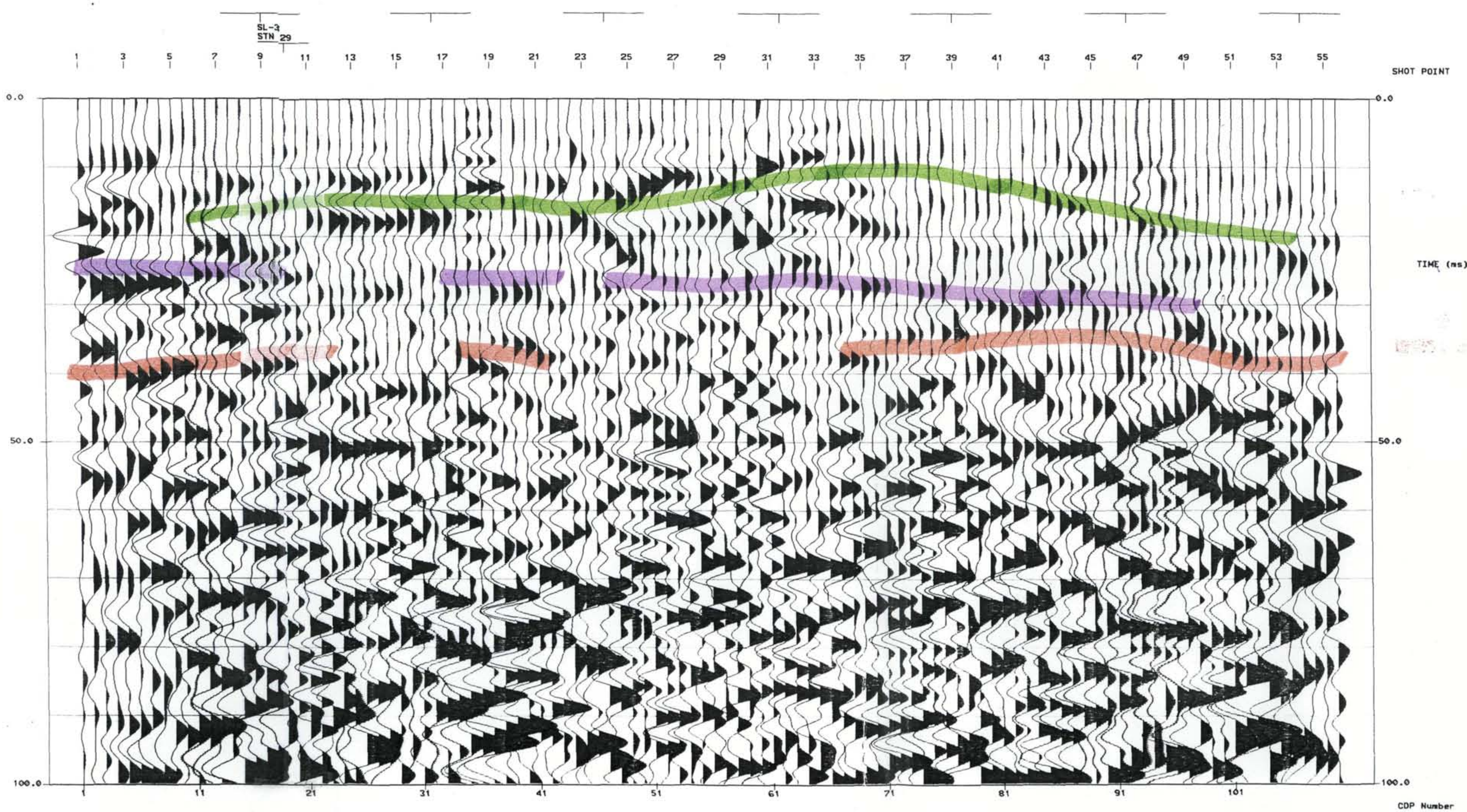
TRAV	VRMS	VINT
13	590	590
24	1088	1473
43	1484	1867
60	1811	2450
81	1965	2350

TRAV	VRMS	VINT
13	590	590
27	1157	1502
43	1484	1913
60	1811	2450
81	1965	2350

TRAV	VRMS	VINT
13	590	590
26	1123	1474
43	1484	1908
60	1811	2450
81	1965	2350

TRAV	VRMS	VINT
13	590	590
26	1123	1474
39	1673	2423
60	1811	2042
81	1965	2350

TRAV	VRMS	VINT
13	590	590
26	1123	1474
37	1604	2381
60	1811	2101
81	1965	2350



GÉOPHYSIQUE GPR INTERNATIONAL INC.

AREA: GE Pittsfield, Massachusetts

LINE: SL-2

SP 1 NORTH SP 56

NORMAL POLARITY

STRUCTURE STACK

FIELD PARAMETERS

Date shot:	April 1996
Instruments:	EG&G
Filter:	60 Hz NOTCH
Spread:	24 trace, 1 - 12 X 13 - 24 60 - 2.5 X 2.5 - 60 metres
Source:	Sledgehammer
Spacing:	2.5 m.
Geophones:	Mark Products 40 Hz.
Spacing:	2.5 m.

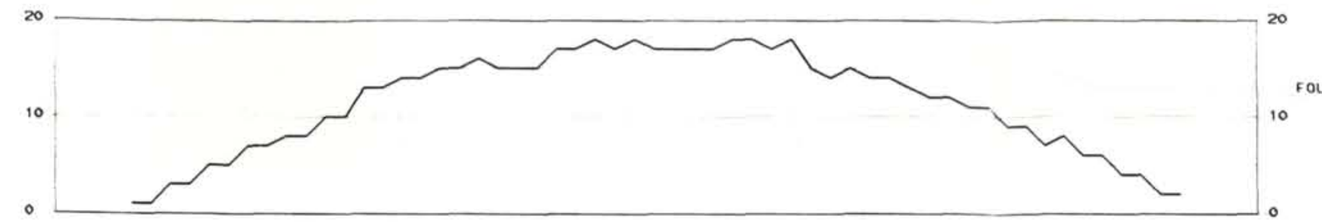
PROCESSING PARAMETERS

Date:	April 1996
Trace Edits	
Exponential Scaling	A*t*exp(B*t)
Trace Equalization	Mean amplitude scale
Deconvolution	Spiking 32ms. operator 0.1% Pre-whitening
Equalization Scaling	First break region
Trace Gathers	
Structure Statics	Relative 980 m., Vr 1500 m/s.
Residual Statics	Shot + Station, hand picked
Velocity analysis	Semblance
Mute	6 10 60 m. 0 15 40 ms.
Stack	12 fold
Filter	70/90 - 280/310 Hz.
Trace Equalization	Mean amplitude scale 10 - 100 ms.
Post Stack Noise Red.	Common signal extraction 80 msec. operator

SCALE:
Horizontal 10 Traces/in Vertical 60 in/second

PROCESSED BY:

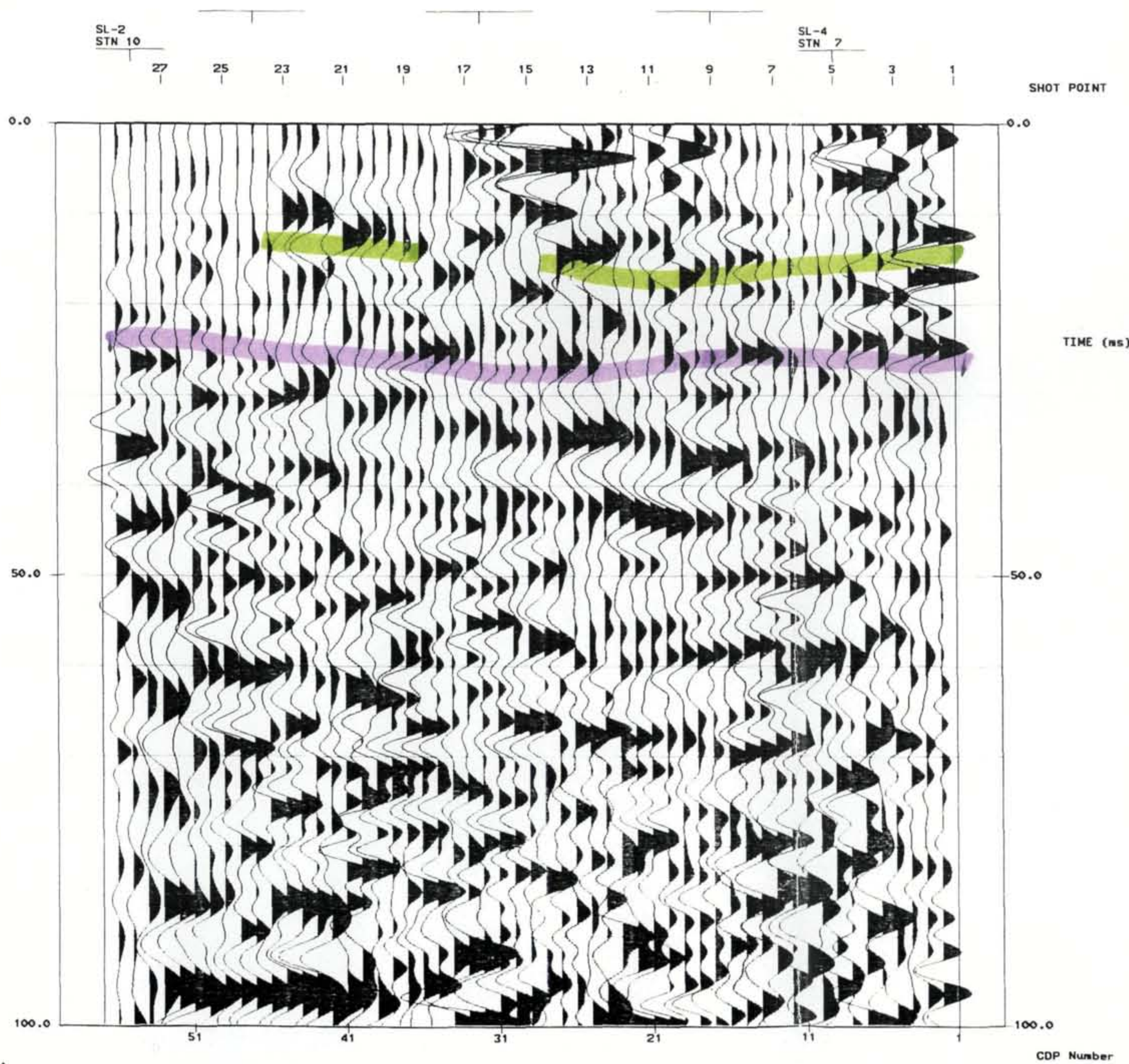
gaps Geophysical Applications Processing Services
GUELPH, ONTARIO



TRAV	VRMS	VINT
6	727	727
17	1157	1334
30	1467	1793
57	1690	1907
75	1811	2149

TRAV	VRMS	VINT
6	727	727
17	1157	1334
28	1656	2216
55	1811	1958
77	1879	2039

TRAV	VRMS	VINT
6	727	727
17	1209	1403
34	1725	2118
58	1948	2225
80	2086	2412



GÉOPHYSIQUE GPR INTERNATIONAL INC.

AREA: GE Pittsfield, Massachusetts

LINE: SL-3

SP 29 EAST SP 1

NORMAL POLARITY

STRUCTURE STACK

FIELD PARAMETERS

Date shot:	April 1996
Instruments:	EG&G
Filter:	60 Hz NOTCH
Spread:	24 trace, 1 - 12 X 13 - 24 60 - 2.5 X 2.5 - 60 metres
Source:	Sledgehammer
Spacing:	2.5 m.
Geophones:	Mark Products 40 Hz.
Spacing:	2.5 m.

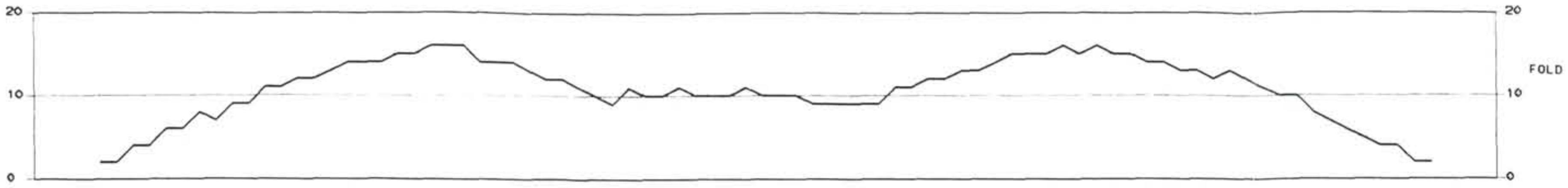
PROCESSING PARAMETERS

Date:	April 1996
Trace Edits	
Exponential Scaling	A*t*exp(B*t)
Trace Equalization	Mean amplitude scale
Deconvolution	Spiking 32ms. operator 0.1% Pre-whitening
Equalization Scaling	First break region
Trace Gathers	
Structure Statics	Relative 980 m., Vr 1500 m/s.
Residual Statics	Shot + Station, hand picked
Velocity analysis	Semblance
Mute	6 10 60 m. 0 15 40 ms.
Stack	12 fold
Filter	70/90 - 280/310 Hz.
Trace Equalization	Mean amplitude scale 10 - 100 ms.
Post Stack Noise Red.	Common signal extraction 80 msec. operator

SCALE:
Horizontal 10 Traces/in Vertical 60 in/second

PROCESSED BY:

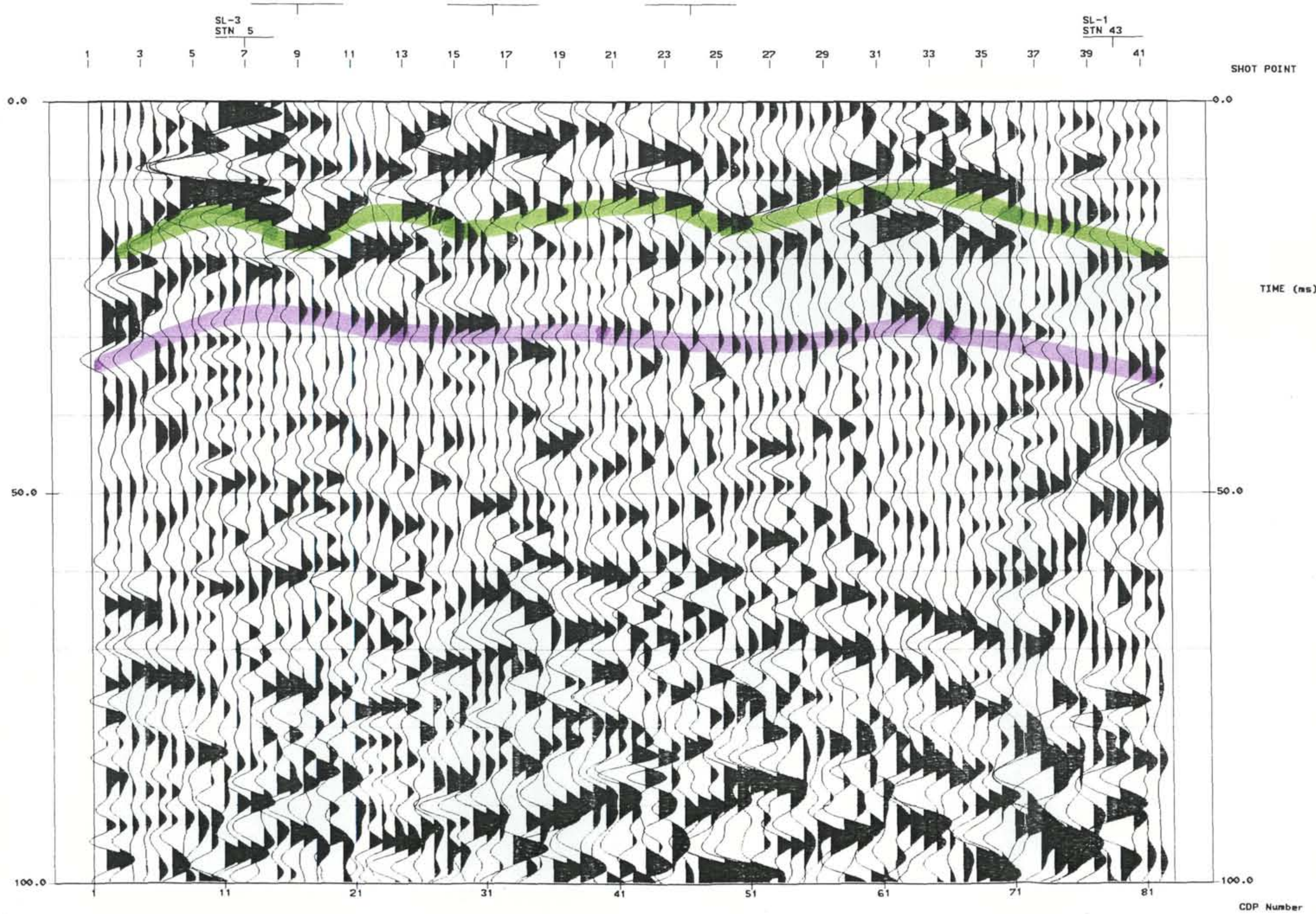
Geophysical Applications Processing Services
GUELPH, ONTARIO



TRAV	VRMS	VINT
6	424	424
22	682	756
34	1043	1493
43	1541	2689
61	1954	2695

TRAV	VRMS	VINT
8	527	527
23	716	798
35	1026	1444
43	1387	2394
60	1713	2343

TRAV	VRMS	VINT
8	527	527
22	733	828
35	1232	1782
46	1524	2209
61	1696	2138



GÉOPHYSIQUE GPR INTERNATIONAL INC.

AREA: GE Pittsfield, Massachusetts

LINE: SL-4

SP 1 NORTH SP 42

NORMAL POLARITY

STRUCTURE STACK

FIELD PARAMETERS

Date shot:	April 1996
Instruments:	EG&G
Filter:	60 Hz NOTCH
Spread:	24 trace, 1 - 12 X 13 - 24 60 - 2.5 X 2.5 - 60 metres
Source:	Sledgehammer
Spacing:	2.5 m.
Geophones:	Mark Products 40 Hz.
Spacing:	2.5 m.

PROCESSING PARAMETERS

Date:	April 1996
Trace Edits	
Exponential Scaling	A*t*exp(B*t)
Trace Equalization	Mean amplitude scale
Deconvolution	Spiking 32ms. operator 0.1% Pre-whitening
Equalization Scaling	First break region
Trace Gathers	
Structure Statics	Relative 980 m., Vr 1500 m/s.
Residual Statics	Shot + Station, hand picked
Velocity analysis	Semblance
Mute	6 10 60 m. 0 15 40 ms.
Stack	12 fold
Filter	70/90 - 280/310 Hz.
Trace Equalization	Mean amplitude scale 10 - 100 ms.
Post Stack Noise Red.	Common signal extraction 80 msec. operator

SCALE:
Horizontal 10 Traces/in Vertical 60 in/second

PROCESSED BY:

Geophysical Applications Processing Services
GUELPH, ONTARIO

THE SEISMIC REFLECTION METHOD

The basic technique of the seismic reflection method consists of generating energy source waves and measuring the time required for the waves to travel from the source to an array of geophones place along a straight line directed towards the energy source. The measurement of travel time to each geophone or cluster of geophones, together with the energy wave velocities, allow the reconstruction of the paths of the seismic waves.

Subsurface structural information is principally derived from the energy paths which fall in two main categories: refracted paths in which the principal portion of the path is along the interface between two rock layers, and reflected paths in which the wave travels downward initially and at some point is reflected back to the surface. The energy travel times depend upon physical properties of the rocks and the orientation of transected strata.

Depths to reflecting interfaces can be determined from the travel times using velocity information that can be obtain from surveys in borings such as, uphole or downhole surveys or by using seismic refraction data over the same area.

The reflection method is based on the measurement of time taken for the acoustic energy to travel from a source (shot location) to a receiver (geophone) location. The acoustic energy is produced by a seismic source, which can be either sledgehammer striking a steel plate, weight drops of different of different weights and designs, or from percussive sources such as, Betsy seisgun, or detonation of explosives.

This energy will travel downward and be reflected back towards the surface from any subsurface interface across which there is a contrast in density and/or seismic velocity.

The arrivals of these seismic waves causes displacements of the ground which are picked up by geophones and recorded as a function of time by the seismograph. The analysis of these arrival times, which have traveled through the subsurface, will allow identification of subsurface features.

Typically, the output of the reflection survey is a series of seismic records that are processed to produce a seismic section. The seismic section is a plot of two-way travel time versus the distance along the ground surface and can be interpreted as a geological cross-section when the two-way travel time is converted to a depth scale (the calculation of a depth scale requires information about the seismic velocity).

MULTIPLE COVERAGE IN SEISMIC REFLECTION

When using simple coverage, only one reflection of the subsurface point is recorded (figure 1). The sampling of this point is referred to as "fold," in this case, 1-fold and is frequently expressed as a percentage (1-fold equals 100%). When a coverage of 600% is planned (figure 2), six reflections are recorded at the same subsurface point. However, the distance between the energy source and each geophone is different. A correction factor is applied to the time of the wave travelling path from its shotpoint to the seismograph so that it can be converted to the line of the vertical trajectory by six oblique time measurements. These are then added together to obtain the most precise average.

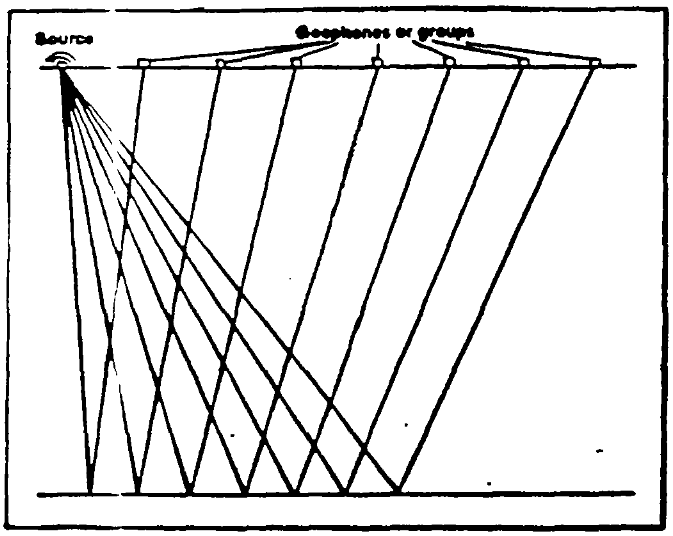


FIGURE 1

100% Coverage
Single-ended spread

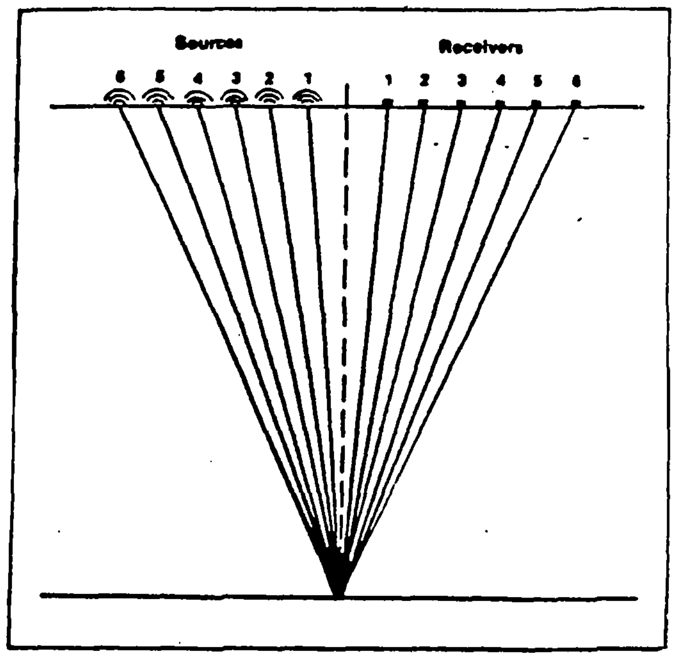


FIGURE 2

600% Coverage
Common Depth Point (CDP)

A 1200% coverage involves shotpoints at every geophone along the spread, keeping the same distance between shots and geophones. A detailed discussion of this technique can be found in Telford & Al (1976).

FIELD ACQUISITION

When using obtaining a coverage of 300%, the cable and geophone setup remains the same (figure 3). However, three more shotpoints are required.

Therefore, the accuracy of data recording when using multiple coverage is largely dependant on obtaining shotpoints. Data are digitally recorded to facilitate calculations of time values.

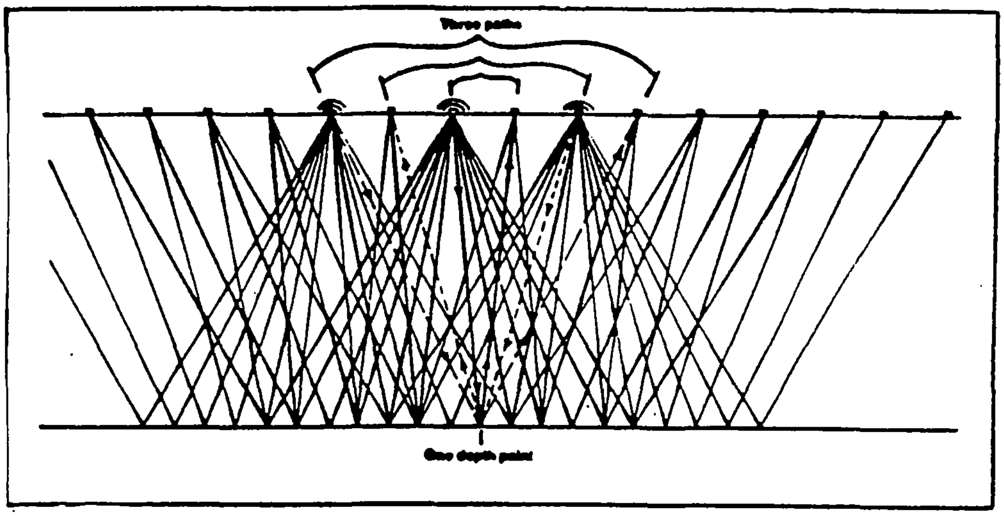


FIGURE 3

SCHEMATIC DIAGRAM FOR 300% COVERAGE

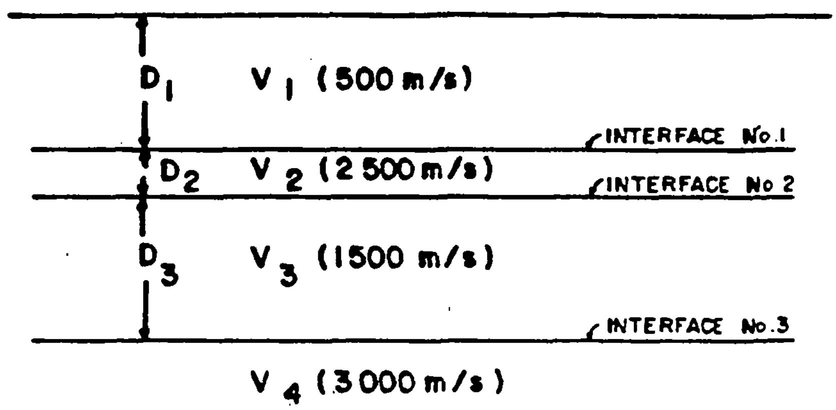
DATA PROCESSING

1) Gather all relative trajectories, referred to as a "gather," corresponding to the same common depth point (CDP).

2) Perform all obliquity corrections, referred to as "normal move out." This is done by making successive approximations using hyperbolic functions. The best approximate value gives the velocity down to the geological unit.

3) Stack the corrected trajectories and take an average.

SEISMIC REFLECTION



100% coverage	:	determines interfaces 1 to 3 and V1
600% multiple coverage	:	determines interfaces 1 to 3, V1 to V4, D1 to D3.

FIGURE 4

SCHEMATIC CROSS-SECTION

ADVANTAGE

The advantages of multiple coverage are very significant:

The quality improvement of reflection quality is generally dramatic since the reflectivity is multiplied by the factor of the fold with the spectrum of random "noise" remaining at initial levels or cancelling out.

TOPOGRAPHIC CORRECTION

The precision is increased when the influence of topographic corrections is reduced.

KNOWLEDGE OF VELOCITIES

Resolution with increase depth have been greatly improved. A variation in lateral velocity can then be identified (figure 4).

INTERPRETATION

The interpretation of seismic data in geological terms is the objective and end product of seismic work.

The basic task of interpreting seismic records is that of selecting those events on the record which represent primary reflections, translating the arrival times for these reflections into depths and dips, and mapping the reflecting horizons.

In addition, the interpreter must be alert to other types of events which may yield valuable information such as multiple reflections and diffractions.

Recognition and identification of seismic events are based upon different characteristics of the reflected signal, such as its amplitude, its coherence from trace to trace, its frequency content and its waveform appearance.

Drawing of horizons on the seismic section and conversion to depth yields a two-dimensional geological profile of the subsurface.