A SEISMIC REFLECTION SURVEY:

DATA ACQUISITION, PROCESSING AND INTERPRETATION REPORT
PORT PERRY, ONTARIO

PROJECT 06-4007

September 15, 2007

PRESENTED TO:

Steve Holysh
Conservation Authorities Moraine Coalition
70 Canuck Ave.; Bldg 100
Downsview, Ontario
M3K 2C5

Beata Golas
The Regional Municipality of Durham
Works Department, Engineering Planning & Studies
605 Rossland Road East, Whitby ON, L1N 0B7

PREPARED BY:

David Schieck

Seismic Solutions
#301, 1324-11th Avenue S.W.
Calgary, Alberta
T3C 0M6

TABLE OF CONTENTS

1.0 *INTRODUCTION*

BACKGROUND

Port Perry Urban Area (Port Perry) is located in the Township of Scugog, the Regional Municipality of Durham (Durham) near Lake Scugog. Conquest Seismic Services was retained by the York, Peel, Durham, Toronto and Conservation Authorities Coalition (YPDT CAMC) to shoot four (4) seismic lines in Scugog Township. The purpose of these seismic lines was to detect buried glacial channel and to identify potential future sources of groundwater for municipal Water Supply Systems (WSS). Port Perry WSS is supplied by three municipal wells; however, due to the elevated levels of iron and hydrogen sulphide Durham is presently exploring potential for new groundwater sources.

Port Perry lies at the North-eastern extent of glacial sediments known as the Oakridges Moraine (ORM). This is an area of thick glacial deposits with structures controlled by glacial and melt-water processes. The ORM is comprised of sand, gravel, silt and clays deposited by numerous periods of advancing and recessing glacial periods. A regional till sheet known as the Newmarket Till underlies the moraine and serves as an aquitard. It has been surmised that beneath this aquitard are mainly fine grained glacio-lacustrine sediments. The bedrock is generally Paleozoic Ordovician shale (Blue Mountain Formation) and limestone (Lindsay Formation). Based on the research of GSC it was suspected that there is a network of South-southwest trending buried valleys which is the target for the potential groundwater resources. Shallow multi-fold seismic reflection techniques can be used to image these channels.

In the summer months of 2004 the first two (2) seismic data lines were shot along Scugog 4th and 6th lines. In late October of 2006 two additional lines were acquired by Conquest Seismic Services along Scugog 2nd and 8th . These two new lines were shot to the north and south of the seismic line conducted in 2004 with a view to establishing at least two other drillable locations into the buried valleys. It is likely that at least along one of these lines there are gravel channels, which may become suitable drilling target to explore potential for municipal water supply.

Seismic Solution was retained by the Regional Municipality of Durham to summarize the interpretation and results from the acquired four seismic lines conducted to date. Included in this analysis was also a short line shot by the geological survey along Scugog 3rd line just to the east of the existing four lines.

OBJECTIVES

After the initial 2004 seismic program the subsequent drilling was carried out to confirm the presence of the identified by seismic line buried gravel channel. Number of wells {OW05-1 (bedrock), OW05-2 (aquifer) OW05-3 (shallow) and TW05-1 (test well)} were drilled in 2005 for the purpose of identifying the valley and testing the aquifer within a targeted buried valley. The borehole OW05-1 is 125.3 metres (411 feet) deep and encounter approximately 16 m of sand and gravel water bearing aquifer with initial water production rates of as much as 325 imperial gallons per minute (igpm). However, the final pumping tests indicated the limited extent of the reservoir thereby negating the use of this well as a potential municipal water supply well.

Additional seismic lines were commissioned in late October of 2006 along Scugog 2nd and 8th with the hopes of finding one or even two additional drill targets (buried valleys) that can be drilled and exploited as a good local water supply.

LOCATION

The project area is just Southeast of the Port Perry and Lake Scugog (Figure 1) and the four seismic lines are located as follow:

Line	Year	Scugog Line	Length	Stations
04-CAMC-01	2004	6th	3.96 km	960-1950
04-CAMC-02	2004	4th	3.20 km	101-900
06-CAMC-01	2006	8th	4.72 km	101-1280
06-CAMC-02	2006	2nd	6.12.km	101-1631
96-GSC	1996	3rd	1.2.km	

During the summer of 2004 data was acquired along Scugog 6th and 4th lines (04-CAMC-01 and 04-CAMC-02), respectively. Following interpretation the test well was drilled in August, 2005 at SP location 1406 along line 04-CAMC-02. September 2006 two additional lines were acquired using the same equipment along Scugog 8th and 2nd lines (06-CAMC-01 and 06-CAMC-02 respectively). The locations of these lines were strategically chosen to locate other potential glacial valleys. Locations along roads permitted good access for the seismic equipment. These roads were relatively low in traffic flow, paved and/or with gravel surfaces. Scugog line 8 did have commuter traffic beginning and end of each day. The locations and length of these lines were chosen by the YPDT CAMC team. as depicted in Figure 1. A full scale map (1:75,00) scale is also included in the appendix as a pull out section.

Divestco Inc.

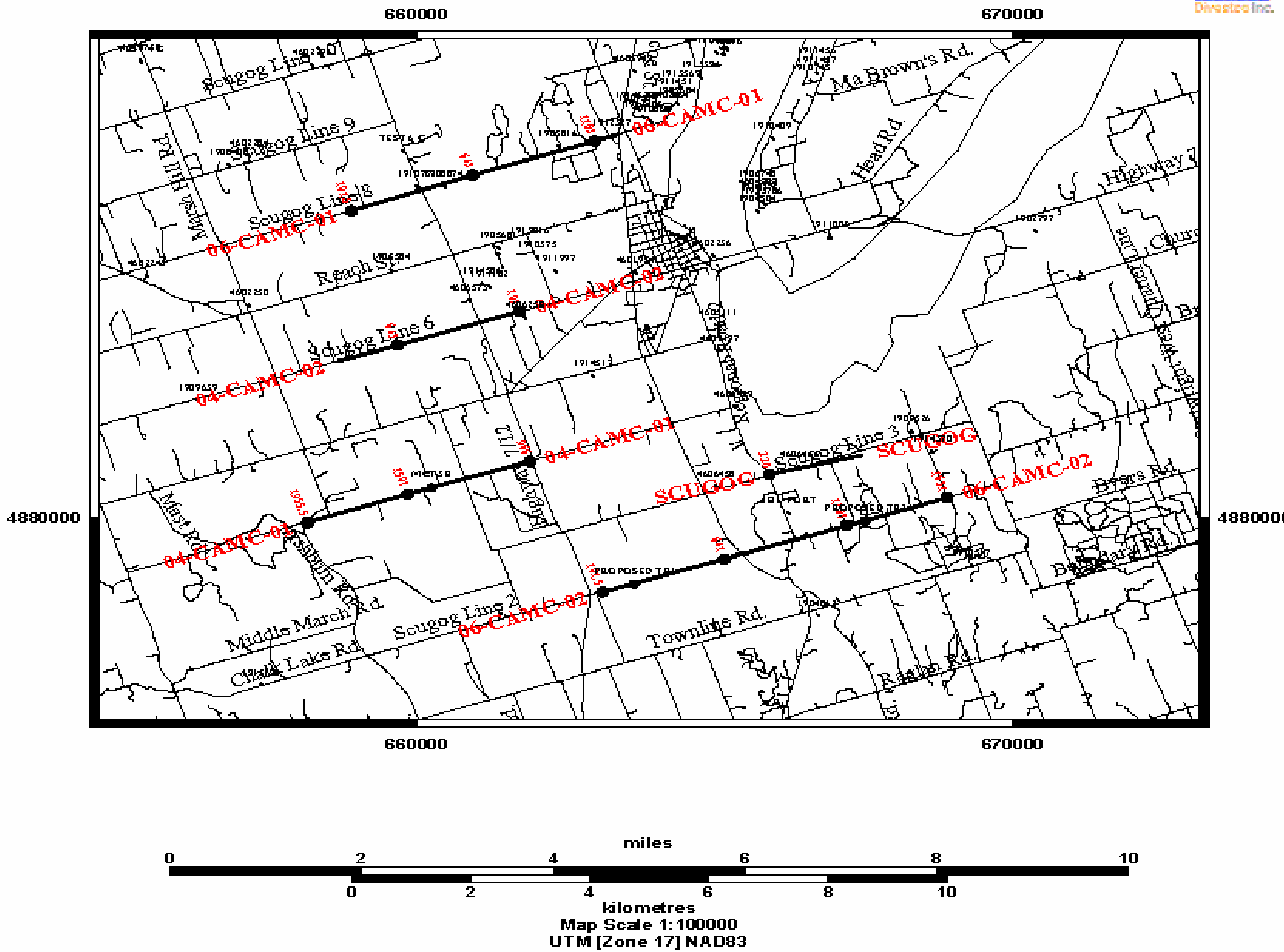
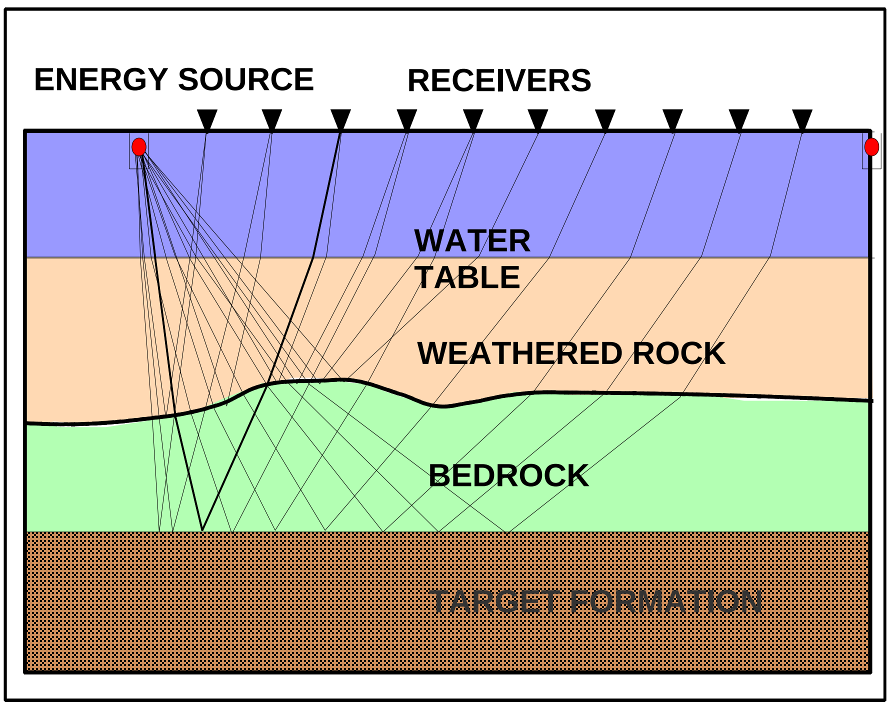


Figure 1 Line Location showing 2004, 2006 and GSC line (1995)

2.0 METHODOLOGY

SEISMIC REFLECTION METHODS

Reflection seismic utilizes seismic energy that returns to the ground surface after travelling along refracted or reflected ray paths, and is typically used for locating interfaces of different acoustic impedances (products of velocity and density contrasts). The seismic energy can be generated by any number of sources, including a weight-drop (i.e. sledge hammer or EWG), a vibrator, or an explosive charge. The energy source is used to generate an acoustic pulse that propagates through a geological medium. As the energy moves away from the source it will reflect from acoustical boundaries. An acoustic boundary is a change in acoustic impedance (velocity X density) usually corresponding to lithologic boundaries such as a clay/sand interface. The resulting ground motion is detected at the geophones placed on surface (a.k.a., receivers) and digitally recorded by the seismograph. A large number of live channels (usually ranging from 96 to 240) are recorded each time a seismic source is detonated. These live channels are recorded in a straight line usually in a symmetrical pattern with the same number of live channels on each side of the source location. The resulting measurements are made relative to time and can be converted to depth using an inferred velocity. It must be noted that this information provides little direct materials information but rather and indication that an acoustical change has occurred. Thin lithologic boundaries, les then ¼ wavelength will not be resolvable using these techniques and sometimes significant lithological changes can occur that result in only weak acoustical contrasts hence poor reflection on the resulting seismic section.



Two dimensional (2D) reflection data is acquired by recording a source record inline with the geophones at a tight interval (usually every second or third receiver station) in order to build a high fold common mid point data set. Fold refers to the number of times a subsurface point is sampled by the geophones. Fold is determined by the number of channels recorded and the ratio of source spacing to receiver spacing. Typically, the higher the fold count the better the resolution of the seismic data because of the increased sampling of each subsurface point. Reflection energy arrives at times later then the arrival of refraction energy and is processed by a series of computer algorithms to provide 2D cross sections of geological events along the profile line. Refraction data is often acquired in conjunction with reflection data to provide support for structural anomalies and confirm depth calculations as well as generate static models of the near surface. Ground roll is also a normal component of all seismic data. This refers to the low frequency, low velocity surface waves generated by seismic sources. See figure 2 for an example 2D shot record where the key components of a shot record are identified. In most cases, for reflection seismic data to be beneficial the depth of target should be greater than 30m. If a target is less than this then most reflection energy will arrive at nearly the same time as ground roll and refraction arrivals thus obscuring the resolution of the reflector.

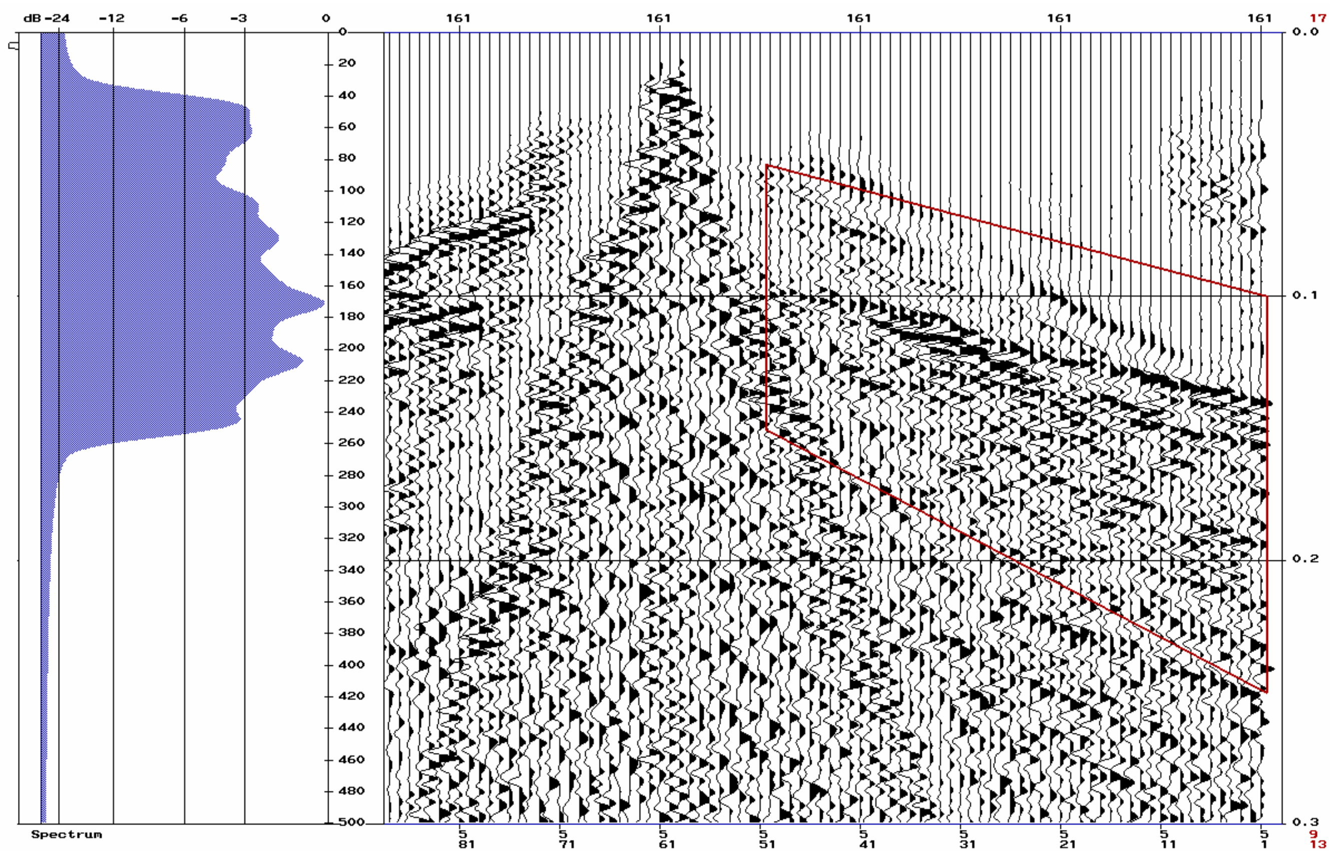


Figure 3 Typical 2D shot record showing key elements of seismic data. Vertical axis is time in millisecond (ms) while the horizontal axis are trace numbers (geophone location). Left panel is the frequency (HZ) within a window of data shown in ride outline.

SEISMIC ACQUISITION

Field equipment included two IVI 12,000 lb buggy mounted vibroseis unit s(figure 3), 120 channel water-tight cables, Mark Product 40Hz. Close tolerance single geophones and an ARAM-CMP 24 bit (160 channel) seismograph This source is repeatable at the same location in order to stack several sweeps together. In this case 2 sweeps per source point location. Multiple sweeps per station helps to eliminate background noise and enhance the signal to noise ratio. The following table summarizes the acquisition parameters for the 2006 lines.

Seismic Source	Two IVI Mini-vibe II's 12,000lb each
Source Pattern	Centred on the half station, stacked (0 drag)
Sweep Parameter	30-250 Hz, +3dB with 0.3sec tapers, 2sweeps x 8 seconds each.
Source (Vibe points) interval	8m.
Receiver (Geophone) Interval	4 m.
Recording System	ARAM-24 CMP 24bit recording system
Data Format	SEGY
Sample Interval	0.5 ms
Record Length	2000 ms.
Number of recorded channels	Up to 120 rolled through spread
Offsets	2-240m
Auxiliary Traces	3
Geophones	Mark 40Hz. Single at the flag

During data acquisition, the seismograph truck (recorder) was located at an accessible location and offline from the geophones to avoid creating background noise with the truck generator running. Since the ARAM-24 CMP recording system uses 120 trace cables it was possible to “plug” the truck in anywhere along the line and still record all stations live. The seismic survey was designed to optimize resolution of reflection events greater than 20m depth to a maximum depth of 240m. Bedrock depths (basement in this case) were estimated to be in the range of 100 to 250m.

Initial field preparation and permitting commenced prior to field crew mobilization. Prior to data acquisition, all seismic lines were chained and surveyed. Chaining involves marking individual station locations on the ground with pin flags or survey stakes. These flags are used during acquisition to indicate receiver and shotpoint locations. Surveying is completed to accurately determine the surface position and the elevation differences of individual stations along the line. This information is used for data processing and interpretation and is represented as easting, northing and elevation coordinates.

Field conditions were good throughout the project and weather conditions were favourable for seismic acquisition with clear skies, mild temperatures, moderate traffic and light to medium winds. Background noise generated by overhead power lines and traffic was nominal for these line locations. Overall, data quality was moderate to good with coherent reflection signal and clean first break arrivals.

The following photos display the various seismic operations and equipment during the course of data acquisition.

Figure 4 Two Mini-vibe seismic sources, vibrating road within seismic bandwidth twice per source point location on every 2nd receiver flag .

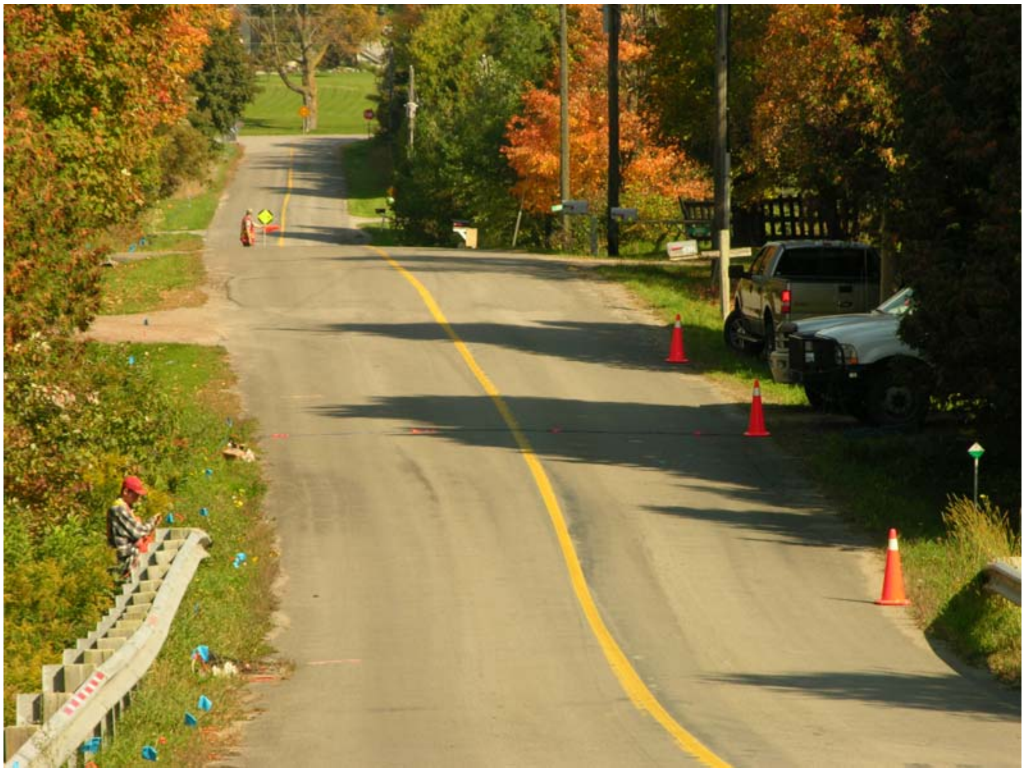


Figure 5 Seismic along roads, blue flags to locate receiver points, flag-man to control traffic, cable crossing to recording instruments, recording truck located off to the right (white vehicle) in the trees, Line 06-CAMC-02

DATA PROCESSING

Before interpreting seismic data, it is necessary to perform a series of processing steps after the raw data is downloaded from the field. The processing techniques address near-surface effects such as ground coupling and static's, lateral velocity variations and image enhancements. In addition, advanced processing techniques applied to the data set include surface-consistent deconvolution, scaling and residual static analysis, and structural modelling to enhance velocity and static analysis. The general steps involved in reflection data processing are briefly described as follows:

Step 1: Geometry

This step involved creating a database file that contains all information related to shot positions, shot depths, geophone spacing, shot elevations and any other acquisition parameters.

Step 2: **Data Quality Control & First Break Interpretation (FBI)**

After the geometries are applied the data is input into an interactive program designed to analyze geometry accuracy and edit bad traces and reversed geophones. At this stage, FBI, an interactive slope-intercept refraction analysis program, is used to perform preliminary velocity and depth calculations. FBI allows the user to directly view the shot record in its proper relative spatial location and assess data quality (i.e. strength of first breaks, dead traces). With a sloping line the velocity of the first arrivals on a shot record can be approximated thus calculating depth estimates to each layer characterized by differing velocities *(See Figure 6).*

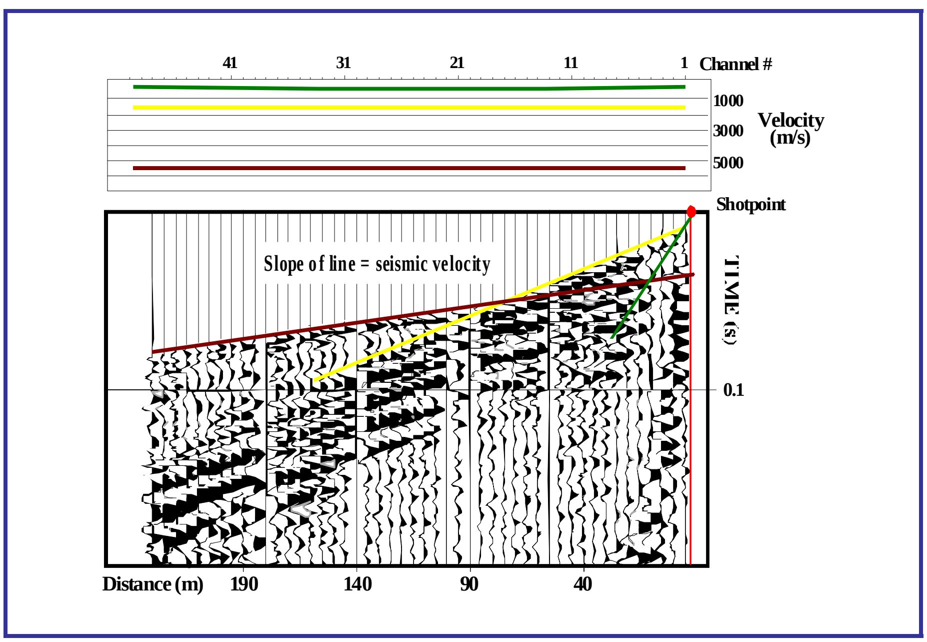


Figure 6: **Slope intercept method of picking velocities.**

Step 3: **Picking First Breaks**

At this stage the geophysicist will pick the first arrival of refraction energy on each trace of every shot record. These time picks are stored in a database and will be used to calculate more accurate weathering layer thicknesses then just the slope intercept method. By picking individual traces it becomes possible to model minor highs and lows in the depths to each layer. (*See Figure 7, as an example of a shot record with first breaks picked.)*

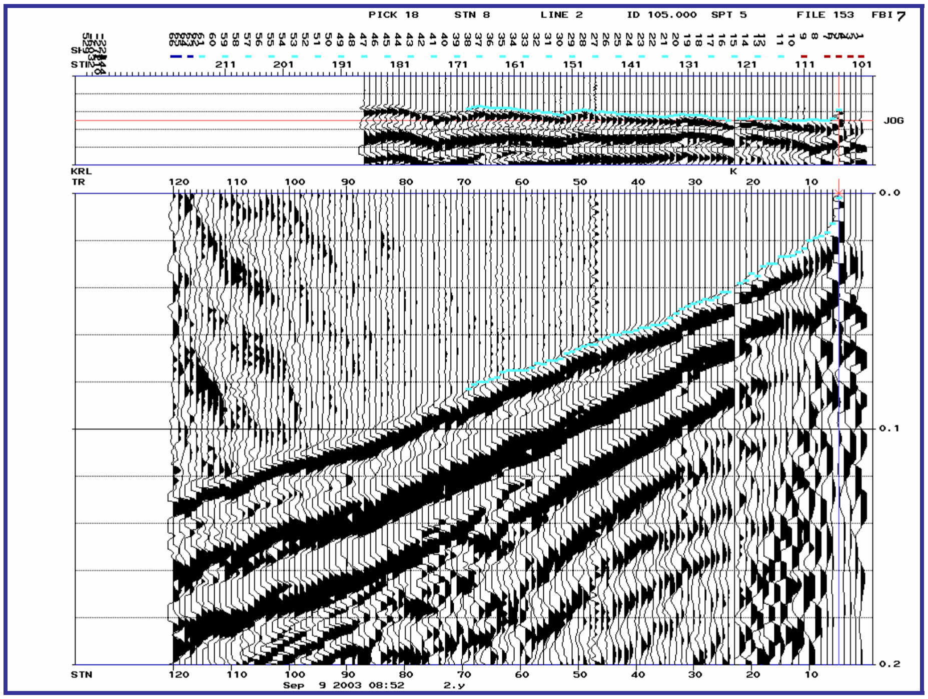


Figure 7: **Example of first break picks on source record.**

Step 4: **Generalized Reciprocal Method (GRM)**

The generalized reciprocal method is used to calculate time-depth models and depths below the surface to the different acoustical boundaries. GRM uses time picks from 2 shot records simultaneously but from different locations. These source records do overlap but in opposite directions with a cross over in the centre of the two spreads. The crossover distance is the source-to-receiver distance at which refracted waves following a deep higher velocity layer overtake the direct or refracted waves from the overlying (slower) layers. This allows for depth calculations to be made even if there is a dipping layer.

Step 5: **Create Refraction Data Tables & Plotting**

Once the geophysicist is satisfied with the continuous profile calculated from the first breaks using GRM they will export the values of depth at each station to a spreadsheet for use in other software packages. Scaled paper plots displaying the bedrock profile are also generated.

It is important to note that data quality is a key element to successful interpretation. Some uncertainty in depth will arise if data is noisy or first breaks are weak. This will cause inaccuracies in determining crossover times, velocities, and ultimately depths.

Following refraction processing the data is then processed to create cmp stacks using the reflection data. *Step 6:* Scaling, Deconvolution, & Trace Gathers

After edits and refraction analysis, the data is scaled to correct for energy losses as a function of time from the shot, followed by a surface-consistent root-mean-square amplitude correction. A deconvolution operator is applied, in order to whiten the frequency spectrum of the data for a more balanced picture of the reflectivity sequence.

The data are then gathered into common-depth point (CDP) bins by assigning each trace to a gather corresponding to the midpoint between shot and receiver locations. At this time common receiver gathers are also created.

Normal moveout correction removes the effects of differing source-receiver offsets and a sub-surface common-midpoint stack yields a geological like profile in time. It is important to realize the data are presented in time and variable velocities will effect the transformation to depth. Processing velocities help to identify approximate depths of reflection events.

Step 7: Velocity and Static Analysis

Common shot and receiver gathers are used to create surface stacks to analyze surface-consistent residual static's, while the CDP gathers are used for velocity analysis and final output stacks. At this point in the processing stream, a loop of velocity analysis, followed by surface stacks for static analysis and a CDP stack, will simultaneously resolve the best velocity function and static's. This loop typically requires 2 or 3 iterations before converging. Generally the convergence is determined by comparing the results of each loop on the CDP stack.

Step 8: CDP model & Post Stack enhancement

After determining the best CDP stack, a final first break mute, to remove unwanted refraction noise is chosen by examining the velocity corrected common offset stacks. An inside, or surgical, mute may also be applied to remove low velocity ground roll or air blasts.

Finally, a post-stack noise reduction filter is applied to enhance coherent acoustical signal, and a final display is created.

It is important to note that data quality is a key element to successful interpretation. Some uncertainty in depth will arise if data is noisy or reflectors are weak. This will cause inaccuracies in determining crossover times, velocities, and ultimately depths. As well, if the target feature is similar in acoustical properties to the surrounding host material or is not thick enough to be resolved by the frequency content of the seismic data then it will be more difficult identify on the seismic sections.

DATA INTERPRETATION

Interpretation of the seismic reflection sections involves identifying the major acoustical boundaries in this case the bedrock surface or a till/gravel interface. Till/gravel layers typically have velocities in the range or 1,200-1,800 m/s where as the bedrock which is shale in this case will have velocities in excess of 3,500 m/s. This contrast in velocity provides a large amplitude acoustical boundary easily interpreted on the reflection seismic section. Further interpretation of the varying subsurface layers is inferred by the velocities and depositional patterns on the seismic time sections. Coarse grained such as sand and gravels tend to be deposited in high energy environments such as tunnel channels hence have irregular patterns. Fine grained materials on the other hand are usually deposited in quiet environments in more or less laminate sheets that would infer tills, clays and/or silts. In this case we are looking for laminar sheets of clays or tills that have been cut into with a channel infilled with sands and gravels. Ideally these channels would be underlain by an aquitard such as competent bedrock or tills.

Lithologic boundaries are interpreted to exist where there is a lateral continuity of reflectors or “markers” This acoustic boundary represents a change in acoustic impedance usually corresponding to a silt/clay or sand/silt type boundary. It is important to note that these boundaries must be thick enough relative to the wavelength of the reflection marker. In this case the layer must be at least ¼ wavelength or minimum thickness of 3m to be “seen” with the seismic wavelet. Data quality is a key element to successful interpretation. Some uncertainty in depth will arise if data is noisy or reflectors are weak. This will cause inaccuracies in determining crossover times, velocities, and ultimately depths. As well, if the target feature is similar in acoustical properties to the surrounding host material or is not thick enough to be resolved by the frequency content of the seismic data then it will be more difficult identify on the seismic sections. As well significant lithologic changes may occur that result in only weak acoustical contrast hence poor reflectivity on the seismic section and therefore un-interpretable based on seismic sections.

3.0 *DESCRIPTION OF SEISMIC PROFILES*

An important question in the over-all dating of these channels is raised by the existence of the Newmarket Till at surface. This is important because if it is present then it indicates that the channel features we are looking at pre-date the Newmarket Till. If they are, it is indeed different than the other features the (GSC) were investigating back in the 1990's. If they are not present at surface or the channels in fact cut through the Newmarket Till it suggests these channels could be the same age as the others on the moraine and that they could be more readily hydraulically connected to the surface than if they were below the Newmarket Till. The GSC were pretty sure they saw a high velocity unit on their Scugog line 3 just one concession north of our south line (06-02) but this has not been drilled for confirmation. Just to the West and North BH2 was drilled on an interpreted valley location and did not drill through Newmarket Till. The 2006 lines having just been processed were available for the evaluation of the possibility of a high velocity shallow layer that is indicative of higher velocities (2,200 – 2,800 m/s) characteristic of the Newmarket Till. Unfortunately the 2004 lines were not available for this evaluation due to the fact that these data were processed by a company that is no longer operating in this capacity and the costs of re-processing were considered un-necessary for this purpose.

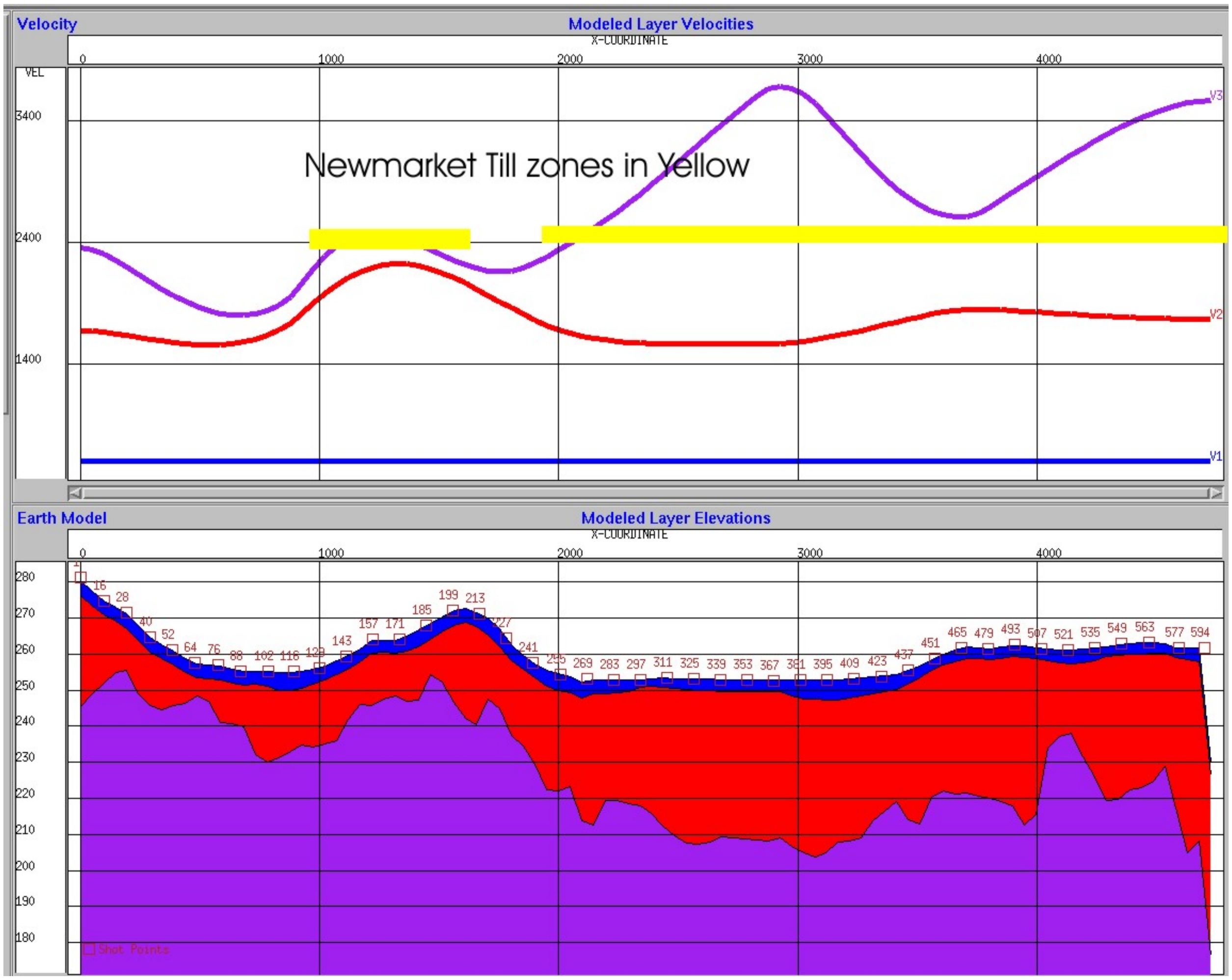


Figure 8 06-CAMC-01 refraction interpretation showing zones of high velocity likely Newmarket Till (Yellow) Stn 330 – 500 and Stn 580 to EOL Stn 1283

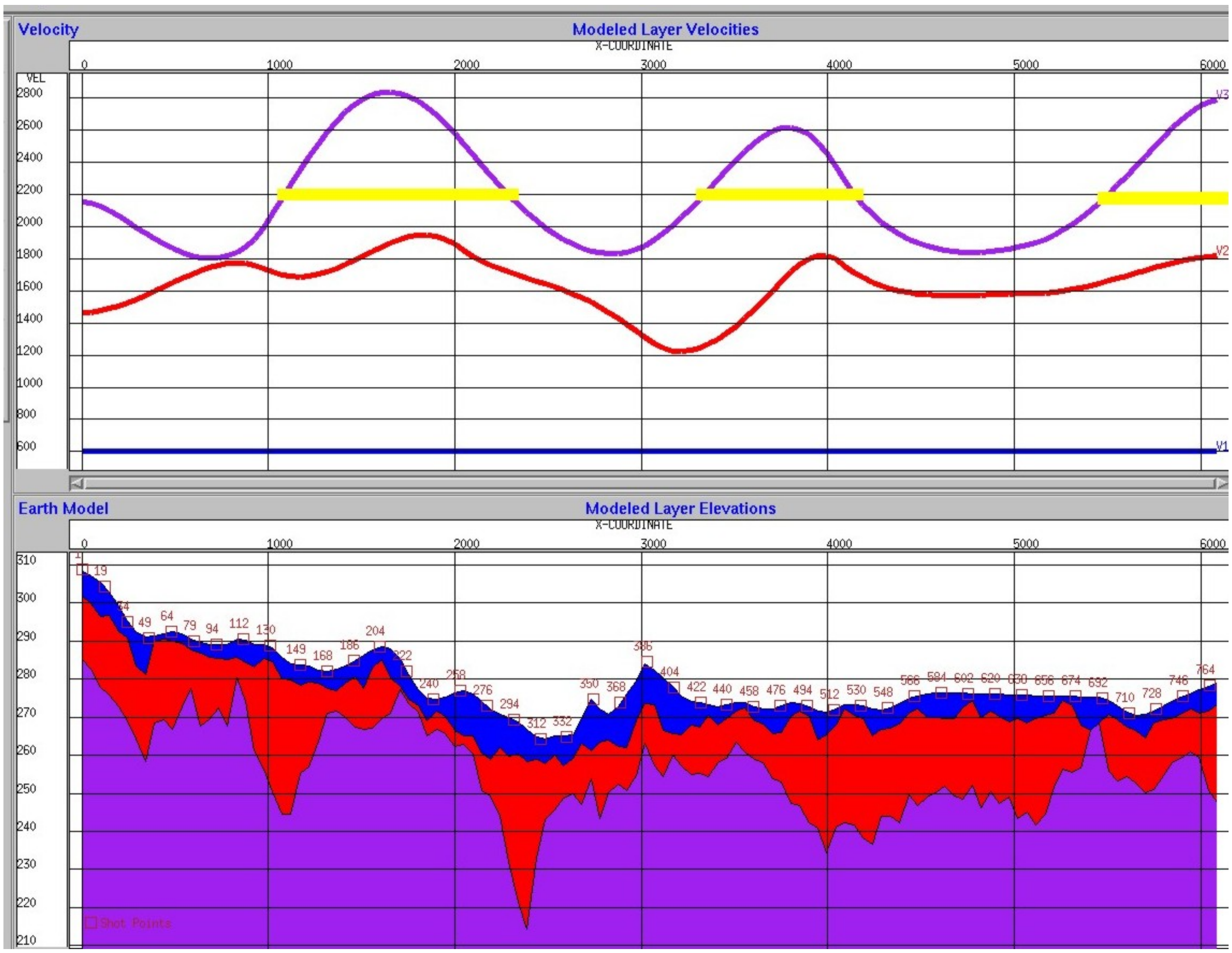


Figure 9 06-CAMC-02 refraction interpretation showing zones of high velocity (yellow) Stn 360-670, Stn 950-1153 and Stn 1475 – EOL Stn 1631

Bedrock in time

Figure 10 depicts the gridded bedrock surface in time (ms). Additional work involving estimating velocities to convert to depth then including the wells to estimate this surface in depth is beyond the scope of this project. The bedrock surface is shallow in the NE and dips to the South and SW. There is a bedrock high/ridge apparent through the center of the area mapped with seismic.

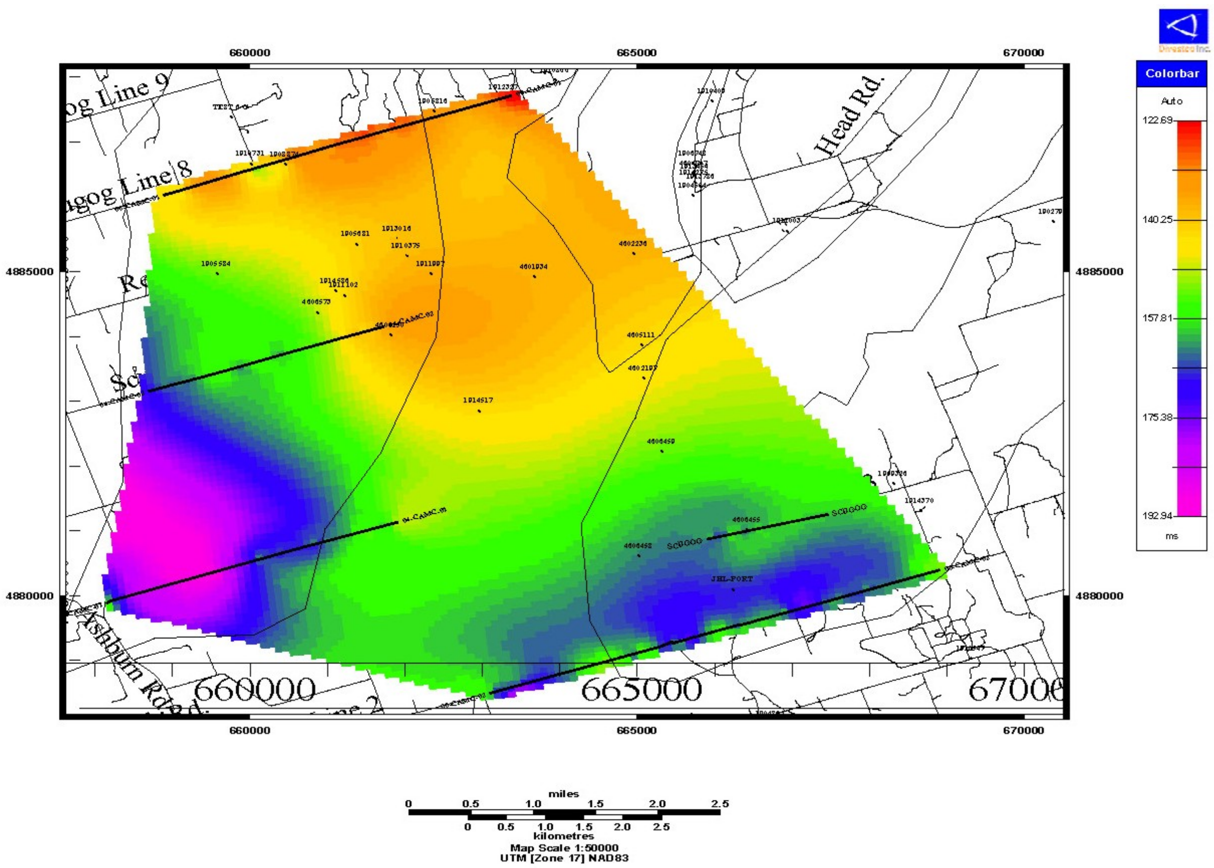


Figure 10 Bedrock Surface in time (ms) from seismic interpretation As depicted on the colour bar on the right (milliseconds) the lower times indicate shallower bedrock while the greater or darker colours indicate a deepening of the bedrock in time.

Line 06-CAMC-01

This most northerly line, 06-CAMC-01 was 4.72 km in length and ran West-East (stations 101-1280) acquired October 2006 along Scugog 8th line start in the west at just west of highway 7/12 and ending in the East at Old Simcoe Road. A portion of the Western end of the processed/interpreted section is depicted in Figure 11. Note that the 2006 lines were evaluated as well using refraction analysis to attempt to determine the extent/presence of the Newmarket Till as discussed previously. The refraction interpretation has been overlain on the reflections section as a discontinuous layer in purple. It appears that the western most interpreted tunnel channels have cut through the Newmarket Till hence occur later in time then the deposition of this Till. While the second channel (station to station) appears overlain with the Newmarket Till. This channel is thinner (~12m) then the channel on line 04-CAMC-01 (MCI-3B) and interpreted to be the Northern extension of this channel. Details are represented in the Table within Key findings for this potential drill target TB3.

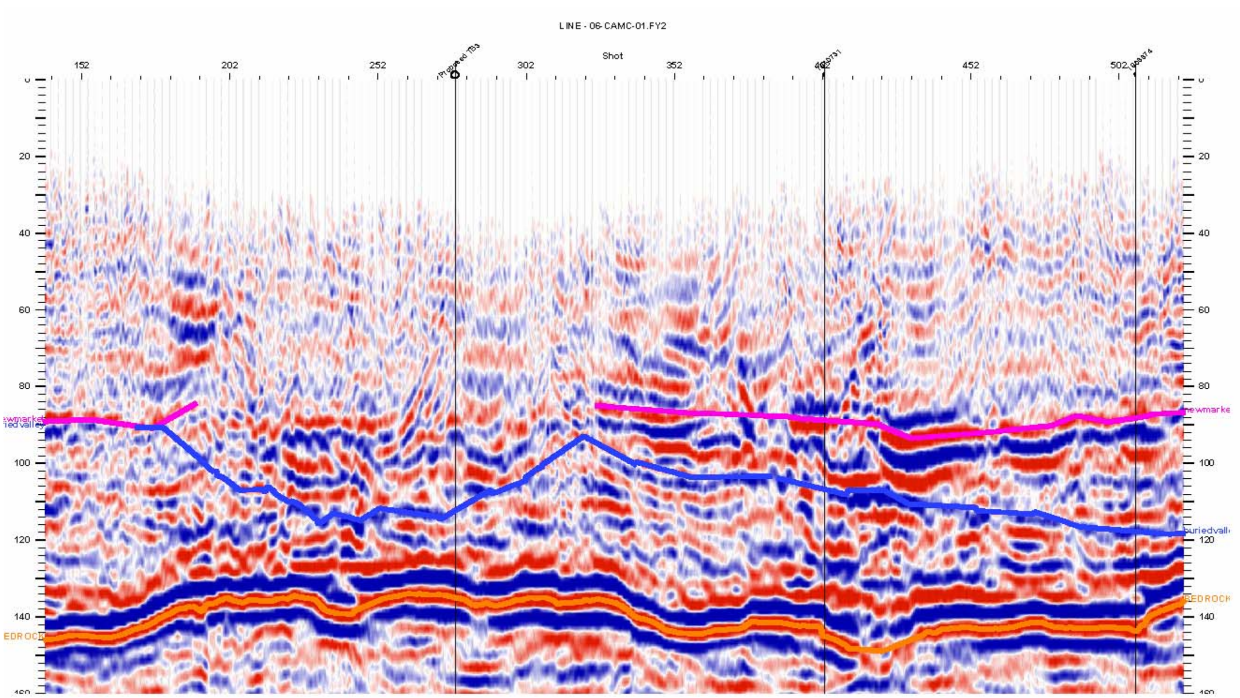


Figure 11 Seismic section 06-CAMC-01 eastern portion of line

Line 04-CAMC-02

The next line south, 04-CAMC-02 was 3.2 km in length and ran East-West (stations 101-900) acquired December 2004 along Scugog 6th line commencing just East of Marsh Hill Rd and ending East of Hwy 7/12. Possible drill target within this channel thought to be an extension of the original drilled channel MCI-3 is represented by proposed location TB4 in Figure 12 below.

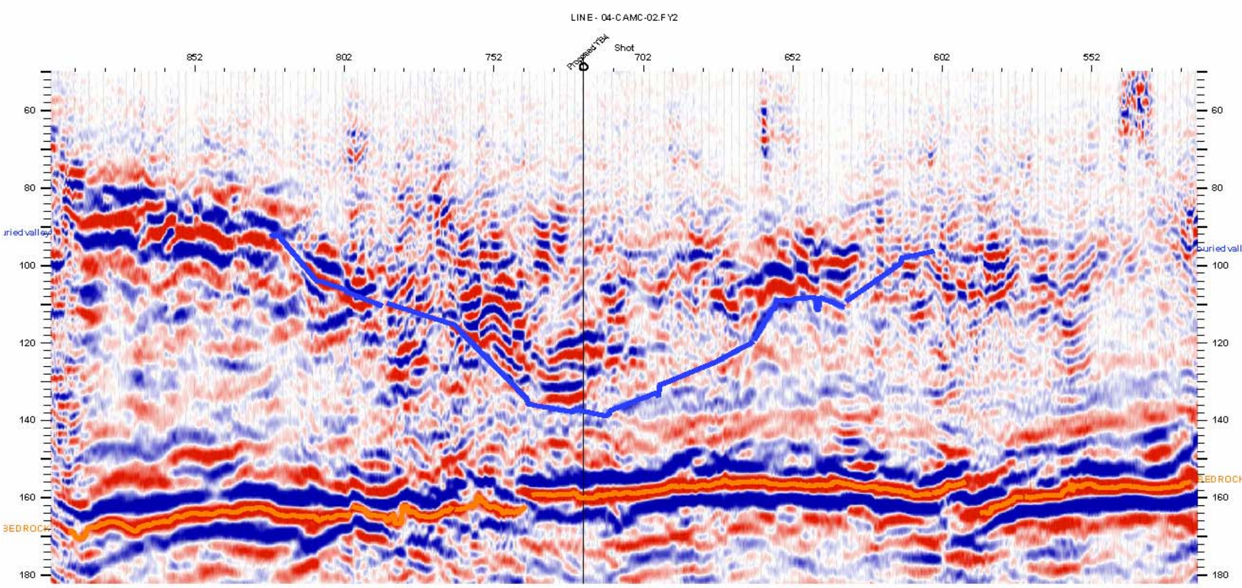


Figure12 04-CAMC-02 seismic section

Line 04-CAMC-01

This line, 04-CAMC-01, was 3.96 km in length and ran from hwy 7/12 in the East ending at Ashburn Rd. In the West (stations 960-1950) .

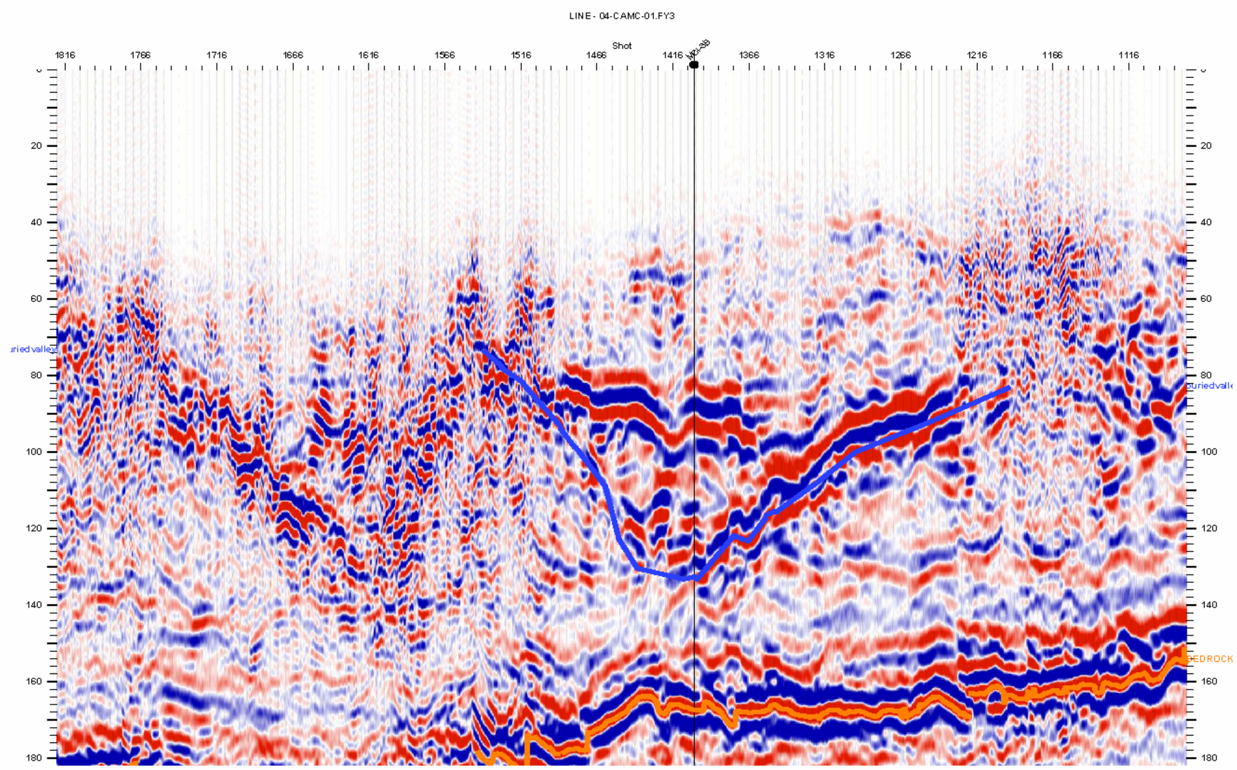


Figure 13 Seismic section 04-CAMC-01 showing location of the test borehole drilled in 2005 to a depth of 400 feet and encountered ~50 feet of water bearing substances.

The well drilled did not encounter any Newmarket Till and the prior data processing of the 2004 lines was not available for further evaluation of the refraction layers. The lack of refraction detail is troublesome as the methodology to confirm this analysis of the 2006 lines can not be confirmed. This tunnel channel appears to extend north onto the 04-02 and the 06-01 lines as shown in the map Figure 16.

Line 06-CAMC-02

The most Southern line, 06-CAMC-02, was 6.12km in length starting in the West at Diamond Sideroad to Old Simcoe Rd. at which point it went cross country along a hydro corridor before continuing along a busy regional rd 29 and ending at Russell Rd. (Stations 101-1631). Two channels have been recognized on this line with proposed drill locations “TB1” and “TB2”. In both instances the refraction interpretation seems to indicate these channels have been eroded through the previously deposited Newmarket Till which is encouraging as it would indicate the potential for a greater lateral extent.

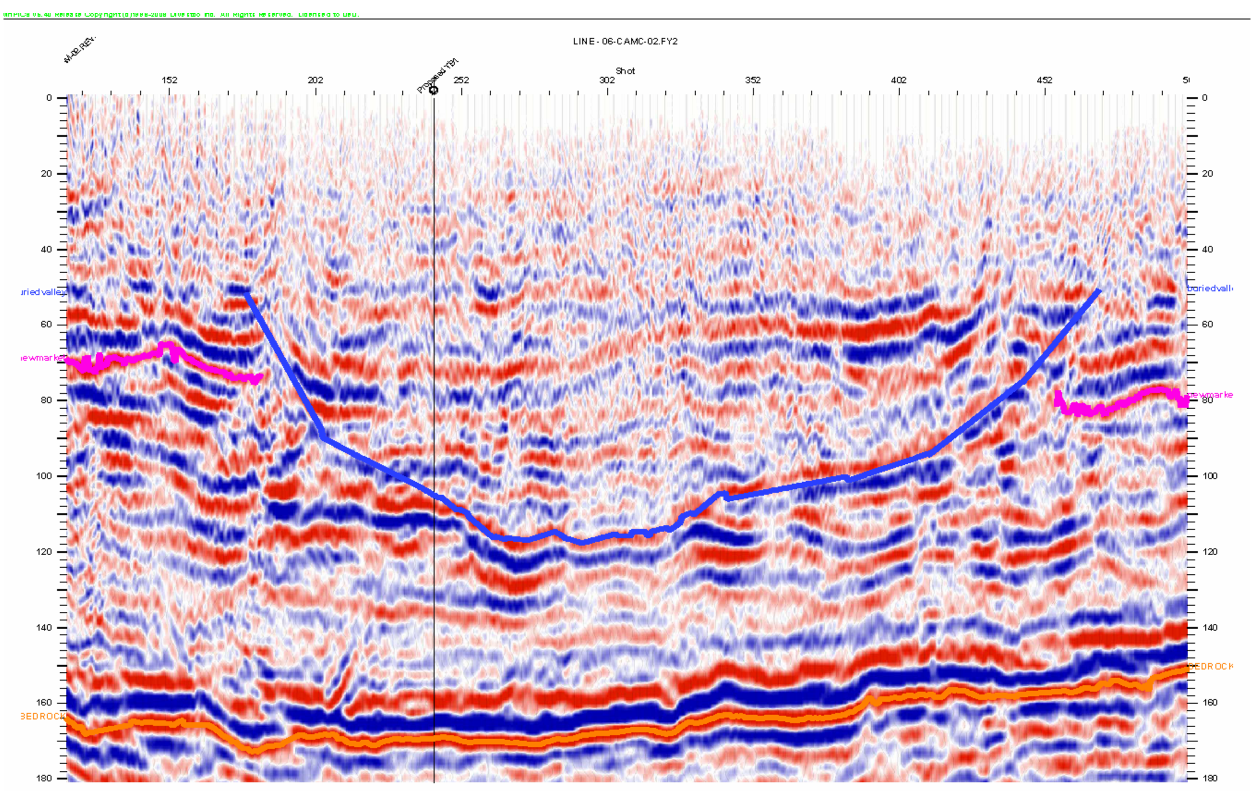


Figure 14 Western target TB1 location, complete seismic line also depicted in Appendix

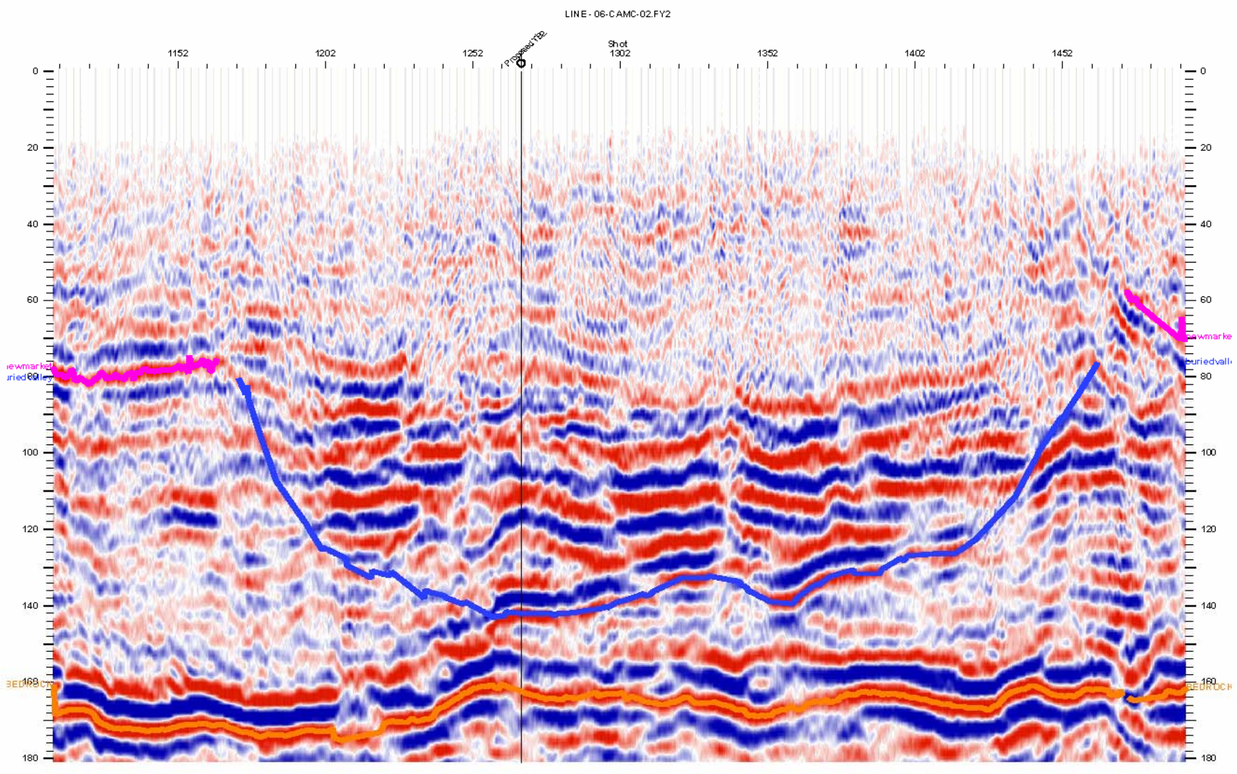


Figure 15 Eastern target TB2, 06-CAMC-02

Line Scugog-GSC

Just to the north of the 06-CAMC-02 line GSC shot their line in the early 1990's using an in-hole shotgun and 24 channel seismograph. . This line is 1.2km in length between Simcoe Street and Sandy Rd. along Scugog 3rd line. (Annals of Glaciology 22 1996, Observations of tunnel channels in glacial sediments with shallow lad-based seismic reflections). GSC interpreted a channel feature at the western part of the line. This channel was interpreted below Newmarket Till. (Refer to section in Appendix)

This line was made available to us from GSC.

4.0 *KEY FINDINGS*

Figure 15 depicts Tunnels channels interpreted from the seismic as well as larger, less detailed estimates of where the tunnel channel "fairways" would be on the basis of water wells. Interestingly these locations correspond indicating confidence in the methodology. Line 06-CAMC-02 shows two potential drill locations. Location "TB1" appears to be outside the known water well corridors. .Location "TB2" may be an extension of the existing municipal water wells which have proven to be high in iron and sulphides and therefore less desirable. "TB3" is a very thin channel and may be the northern extension of the original MCI-3B channel drilled on 04-CAMC-01 whilst "TB4" is also thought to be an extension of this channel.

		UTM NAD83 17N			Bedrock		Channel			
				Source	Depth		Top		Thickness	
Line	**Well**	**Easting**	**Northing**	**Point**	**(ms)**	**(m)**	**(ms)**	**(m)**	**ms**	**(m)**
04-CAMC-01	MCI-3B	660243	4880598	1400	160	120	80	50	50	30
06-CAMC-02	SEISTB1	663644	4878671	242	150	114	40	~38	40	25
06-CAMC-02	SEISTB2	667517	4879933	1268	160	120	80	50	60	36
06-CAMC-01	SEISTB3	659561	4886415	278	140	105	90	56	20	12
04-CAMC-02	SEISTB4	659375	4883370	722	160	120	80	50	50	30

Table 1 Estimated locations of drillable targets, bedrock depth at this point, top of channel and thickness. Note these are estimates based on approximate velocities, interpreted valley locations based on the reflection sections in time. Depth estimates can be out as much 20% due to the inherent difficulty in accurately estimating these velocities based on seismic reflection techniques.

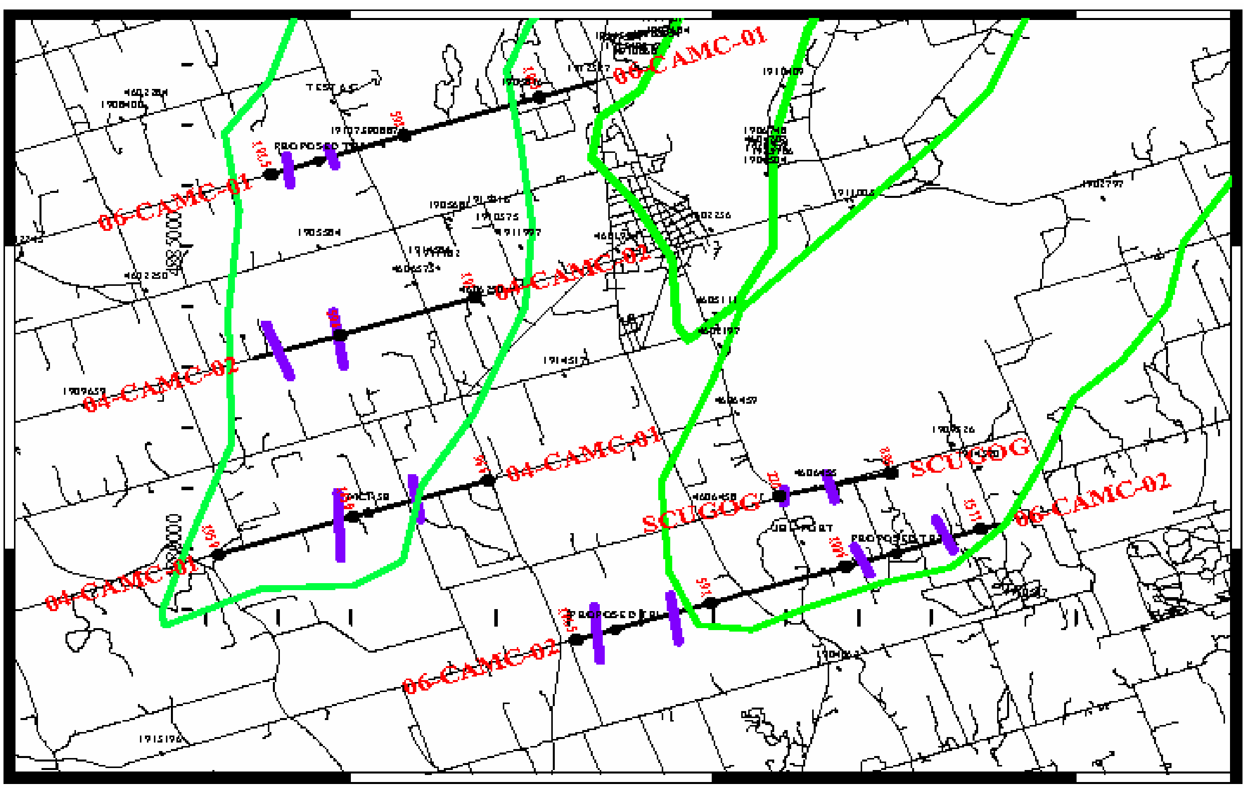


Figure 15 Line map depicting tunnel channels picked on seismic (purple) and regional channels interpreted from water wells (green)

This report has been prepared by Mr. David G. Schieck

David G. Schieck, MSc., Geophysicist, P.Geoph (AB)

This report was prepared by Seismic Solutions for The Regional Municipality of Durham Works Department. The material in this report reflects Seismic Solutions best judgement in context of the information available at the time of preparation. This report is based on data and information collected during the investigation conducted by David G. Schieck and is based solely on the conditions of the property at the time of site, as described in this report. No intrusive or direct sampling was conducted as part of this survey.

Any use that a third party makes of this report, or any reliance on or decision to be made based on it, are the responsibilities of such third parties. Seismic Solutions accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Seismic Solutions makes no warranty, expressed or implied, and assumes no liability with respect to the use of information contained within this report. No changes to the report form or content can be made without the written permission of David G. Schieck.

APPENDIX