Geotechnical Report
Proposed Sun Dale Subdivision
Portions of Sections 28 and 29-21-22-W2M
Sunset Cove, Saskatchewan

Val Lane Ltd.

File R3985.1 18 January 2008

Ministry of Municipal Affairs
JAN 31 2008
Received by
Community Planning

Clifton Associates Ltd.
engineering science technology

18 January 2008
File R3985.1

Attention:

Dear Sir:

Subject: Geotechnical Report
Proposed Sun Dale Subdivision
Portions of Sections 28 and 29-21-22-W2M
Sunset Cove, Saskatchewan

We are pleased to present to you our geotechnical report regarding the above subject. The principal geotechnical issue in this area is development on the valley wall that has been created as a result of landsliding, with the potential of reinitiating old or creating new failures.

Safe building sites can be developed on this area. We have provided preliminary geotechnical commentary and recommendations related to the development based on a visual assessment of the land and landforms and the results of stability analyses. We will be pleased to provide additional consultation as you develop and finalize the subdivision plan.

We thank you for the opportunity to work with you on this project. If you have any questions regarding this report, please contact me.

Yours truly,

Clifton Associates Ltd.

Richard T. Yoshida, P.Eng.
RTY/ic

Distribution: Val Lane Ltd. – 6 copies
Clifton Associates Ltd. – 2 copies

340 Maxwell Crescent
Regina, Saskatchewan
Canada S4N 5Y5

Tel: 306 721.7611
Fax: 306 721.8128

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1.0 Introduction

Val Lane Ltd. has proposed the subdivision of portions of NW28-21-22-W2M, NE29-21-22-W2M, SE29-21-22-W2M and SW29-21-22-W2M, which will be known as Sun Dale. The Sun Dale subdivision is located on the north valley wall of Last Mountain Lake between Pelican Point to the west and Sunset Cove to the east in the R.M. of McKillop (No. 220). This report provides geotechnical commentary and recommendations related to the development of this area and is based on a visual assessment of the land and landforms, and the results of stability analyses. The principal geotechnical issue in this area is development on the valley wall that has been created as a result of landsliding, with the potential of reinitiating old or creating new failures.

This report provides preliminary recommendations for development. Development of the subdivision plan will consider and incorporate many of the recommendations provided in this report. However, because the subdivision plan and this report were being developed in parallel, this report may not consider specific features of the development and the subdivision plan may not incorporate recommendations that are provided in this report. Recommendations can be revised based on future assessment of specific areas along the valley wall.

2.0 Proposed Development

It is our understanding that the proposed subdivision will consist of a variety of single and multi-family dwellings on lots of varying sizes with a minimum frontage of about 23 m (75 ft). The development will include beaches and other public areas. Services being considered include water distribution and sewage collection systems, with a waste water treatment system. The construction of roadways will require site grading, as will the preparation of some lots for construction of residences. Most of the issues addressed in this report are a concern for development on the valley wall and that portion of the development immediately adjacent the top of the valley.

3.0 Description of the Site

Some landslide features and other features of interest are shown on Drawing No. R3985.1-2. The drawing also shows the locations of some photographs taken in the area. Numbers on the drawing relate to photographs appended in the Photographs Section of this report.

3.1 Subsurface Conditions

For purposes of discussion, general subsurface conditions are described in this section. More detail is provided in subsequent sections after a description of the field investigation conducted at this site.

Subsurface conditions consist of glacial till overlying bedrock clay shale. Occasional gravel or sandy zones are often present within till. Landslide movement occurs on low strength zones or soil strata within the bedrock clay shale. Glacial till is a relatively strong material consisting of a mixture of clay, silt, sand and gravel sized particles. Cobbles, defined as rock with an average diameter of 75 mm to 300 mm and boulders, rock with an average diameter of more than 300 mm, are common.

Bedrock clay shale is a dark gray, fine grained soil and is generally a relatively hard material when intact. However, once it has been disturbed or when a failure plane has developed, it has a much reduced strength and movement is easily re-initiated along the old failure plane. In areas were landslide movement has occurred, valley wall slopes are quite gentle and may be as flat as 6° to 8° (about 7 horizontal to 1 vertical to about 10:1). In contrast, where failures have not occurred, valley walls created in glacial till or shale can be as steep as 32°, which is equivalent to a slope of 1.6 horizontal to 1 vertical (1.6:1).

Groundwater is not known to exist in any great quantity (or quality) in this area, although water may be present in sand or gravel strata within glacial till, or within fractures in bedrock clay shale. It is possible that trees or groups of trees along the valley wall have grown adjacent gravel or sand seams where more water may be present.

3.2 Landslide Features

The area being subdivided is shown on Drawing No. R3985.1-1. Slopes in this area measured from the shoreline to the top of the valley are relatively gentle, with slope angles ranging from about 7° to 9°. The valley walls are similar in form to most of Last Mountain Lake and have typical characteristics of landslide topography. During deglaciation of this area approximately 12,500 years ago, Last Mountain Lake and its valley was part of a spillway system, with water flowing from the northwest through this valley and into the Qu'Appelle River valley. Landsliding and slumping were mechanisms that were part of the development of the valley, with landsliding occurring as a result of erosion into the weaker bedrock clay shale that underlies glacial till.

Landslides occur in a retrogressive fashion, meaning that a block of soil on the slope nearest the lake first moves, with successive failure of blocks of soil occurring farther up the slope, resulting in a stair-step pattern from the lake to the top of the valley. As the soil blocks move, they often rotate backwards so that the front of the block (the portion closest to the lake) is pitched upwards, leaving a low area at the back of the block. Surface water often becomes trapped in these low areas. Landslide blocks will move at different rates, with blocks closest to the lake moving faster than the blocks farther up slope.

Cross sections of this area are shown on Drawing No. R3985.1-3. The locations of the cross sections are shown on Drawing No. R3985.1-1. Cross sections illustrate the relatively flat slope and the step-like profile that is consistent with slopes created by landslides common in this area.

Drawing No. R3985.1-2 shows the approximate location of landslide scarps and other features of interest in the area. A landslide scarp is the upslope edge of a landslide block and will, therefore, define the boundary between two separate landslide blocks. Scarp locations illustrated are approximate and based on a visual assessment of the ground surface from aerial photographs and a surface reconnaissance. Erosion of the surface over time has muted much of the surface detail that likely existed in the past. Thus, unless movement is occurring and ground displacement is visible, landslide scarps can be difficult to precisely locate.

Several depressions exist on the valley wall, generally coinciding with landslide scarps. These areas generally support the growth of bushes and trees, since water will accumulate in these areas. Although water is often present in most of the depressions only after precipitation or snow melt, some areas where water will pond for a greater length of time may be fed by water from gravel seams within the till stratum.

3.2 Shoreline

In general, shoreline areas are covered with sand and gravel sized particles with some cobbles and boulders present in varying quantities. The presence of trees in some locations would indicate that the shorelines are relatively stable.

Waves and wave action erodes soil at the shoreline. In addition, the ground surface can erode due to surface runoff. Wave action will wash away the smaller and lighter clay and silt sized particles, leaving the coarser and heavier sand, gravel, cobbles and boulders. In some areas shown on Drawing No. R3985.1-2, the shoreline is well protected by a tight-knit collection of cobbles which have accumulated. In other areas, the shoreline is covered predominantly with sand and gravel. Large accumulations of cobbles can be indicative of the presence of glacial till at the shoreline where till continues to be eroded. Where absent, the predominant soil at lake level is clay shale.

In some areas noted on the drawing near the east and west boundaries of the proposed development, high, steep slopes of clay shale stand over the shoreline area. It is estimated that these slopes are standing at about 1.6 horizontal to 1 vertical (1.6:1) to 1.8:1 and are from 15 m to 18 m high. Surface runoff on the steep slopes erodes clay soil onto the shoreline area, where it can cover the sand and gravel. Subsequent wave action removes the clay soil and exposes the sand and gravel. When lake levels rise above the current shoreline and above the concentrations of cobbles that normally provide protection to the shore, wave action will erode the toe of these slopes, resulting in higher rates of erosion.

3.3 Current Stability

At present, slopes appear to be stable, with no obvious signs of large scale, deep-seated landslide movement such as fresh landslide scarps or cracking. Steep and high clay shale slopes at the shoreline are indicative of relative stability. At this site, these slopes erode since vegetation cannot be easily established.

4.0 Geotechnical Issues

Geotechnical issues related to development in this area include:

- identification of areas of instability;
- identification of landslide blocks and scarps;
- determination of site grading criteria for the development of stable lots and roadways; and,
- determination of general site development criteria related to slope stability.

Large scale movement of a series of landslide blocks occurred as part of valley formation. The base of the landslide movement was within bedrock clay shale. Landsliding occurred as the valley was eroded and deepened. Slopes at this site appear to be stable, which has been attributed to changes that have occurred at the toe of the slope. Over time, there has been some infilling of the valley and perhaps an increase in lake level, both of which have stabilized slopes, with soil deposited at the toe of the slope acting like a berm to increase resistance to movement.

Two different types of slope failure may occur in this area:

- creation of a new slip plane and associated failure; and,
- re-initiation of movement on an old or pre-existing slip plane.

In general, intact clay shale possesses relatively good shear strength, commonly called the 'peak shear strength'. However, once failure has occurred, the shear strength along the failure surface is significantly reduced to a lower 'residual shear strength'. Thus, even though landslide movement may be arrested after a new failure, movement is more easily re-initiated because the soil strength is now significantly lower.

Landslide movement can be initiated or re-initiated most commonly by the following:

- oversteepening the slope;
- removal or erosion of soil at the toe of the slope (at the shoreline);
- excavation of soil near the toe of the slope;
- construction of a fill near the scarp or upslope portion of a landslide block;
- increasing groundwater levels; or,
- a combination of these factors.

The relative stability of a slope may be calculated considering the location of the slip surface, geometry of the slope, soil shear strength and location of groundwater. The relative stability is often expressed as a calculated factor of safety. If the landslide is moving, the factor of safety will be 1.0. Values less than 1.0 are meaningless in this context, while values greater than 1.0 are indicative of a stable slope. Determination of the factor of safety for any slope requires knowledge of all of the factors mentioned above. If the slope is known to be moving, we know that the factor of safety is 1.0 and analyses can be done to confirm soil strength parameters and other factors.

In contrast, the calculation of the factor of safety for a stable slope can be more difficult. The analysis of a stable slope can assume that soil strength and groundwater levels are accurate; however, the calculated factor of safety is not a unique value, and is anything greater than 1.0.

In technical terms, the factor of safety for a slope is the reduction applied to the actual soil shear strength along an assumed slip plane that will bring the slope being analyzed to a state of limiting equilibrium or imminent failure. Thus, a calculated factor of safety of 1.5 means that for a slope to fail, the shear strength of the soil along an assumed failure plane or slip surface must be reduced by a factor of 1.5 for failure to occur.

In simple non-technical terms, stability of a slope can be considered in terms of a ratio between an activating force and a resisting force. The activating force would be the mass of soil on the upslope portion of the slope acting under gravity to move towards the toe of the slope. The resisting force would be the mass of soil on the downslope portion of the slope resisting movement along a slip surface due to frictional forces on the slip surface. If a fill is placed on the upslope portion, the activating forces would be increased, which would reduce stability. If soil is excavated from the downslope portion of the slope that is resisting the movement, stability would be reduced. The stability of the slope would generally be increased if fill was placed on the toe, or the upslope portion of the slope were excavated.

What constitutes an acceptable factor of safety will depend on the reliability of the parameters used for analyses and the consequences of failure. A higher factor of safety is desirable if the data utilized for analyses incorporate significant error or if there is a potential for loss of life, should a failure occur. For data of reasonable quality, the desirable factor of safety for a slope in a residential development would be about 1.25 to 1.30 or greater. The quality of data for this work and factors of safety will be discussed in more detail in subsequent sections.

Since a cut or fill, changes in groundwater levels or any other change will change the factor of safety of a slope, the amount of cut or fill that can be tolerated will depend on the relative impact on the factor of safety, as well as the stability of the slope prior to the change. A decrease in factor of safety of 5 percent can be considered as acceptable, except, of course, if the current factor of safety is 1.1 or less.

5.0 Field and Laboratory Investigations

The purpose of the field investigation was to determine subsurface soil conditions and piezometric levels for analyses. Engineering parameters for design were determined on the basis of laboratory testing on samples collected in the field.

An examination of the Saskatchewan Watershed Authority water well database resulted in one log for a well in SE28-21-22-W2M. Stratigraphy reported in this log consisted of clay and sandy clay overlying glacial till to a depth of 6 m and sand and gravel to the depth of exploration, which was 14 m.

Subsurface conditions on the valley wall in Section 29 were investigated by seven test borings drilled across the site as shown in Drawing No. R3985.1-1. Bore holes were drilled on 02 to 05 October 2007 using a truck mounted Failing 1250 rotary drill rig and a Brat 22 dry auger drill rig. Bore holes were drilled to depths varying from 12.2 m to 36.6 m below existing ground surface. Deeper bore holes were drilled using wet rotary drilling techniques. Dry auger drilling utilized 125 mm diameter continuous flight auger.

Representative disturbed and undisturbed samples were recovered for laboratory analysis. The natural water content of each sample was determined. Testing was done to determine Unified Soil Classification and Atterberg Limits of selected representative samples. The undrained shear strength was estimated using laboratory vane shear and standard penetration apparatus.

Standpipe piezometers to monitor groundwater levels were installed in all of the bore holes, with the exception of BH101. Piezometers were typically constructed with 50 mm diameter Schedule 40 or Schedule 80 PVC pipe and 50 mm diameter slotted PVC screens. The piezometer screen was surrounded with silica sand and backfilled to the surface with bentonite chips. Bore hole construction details are shown in the Bore Hole Logs. Water levels in piezometers were monitored on 11 December 2007.

In addition, slope inclinometers were installed in BH104 and BH107 to depths of 18.3 m below existing ground surface. The purpose of the inclinometers was to determine the location of the slip surface if landslide movement was occurring. The bottom of the inclinometers were at an approximate elevation of 478 m to 482 m, which is below lake level. Inclinometers were initialized on 11 December 2007. Movement is detected on the basis of periodic measurements and comparison between readings. A second set of readings will be made in spring when slopes can be most active.

Horizontal control was established using a handheld GPS unit, which has an estimated accuracy of about 5 m to 7 m. Bore hole elevations were referenced to elevations on the topographic plan for the site developed by Harding Boss & McLeod Surveys Ltd.

Observations made during the field investigation, visual descriptions and the results of laboratory tests are recorded in the Bore Hole Logs, and the Summary of Sampling and Laboratory Test Data appended to this report. An explanation of the symbols and terms used in the bore hole logs is included in the Symbols and Terms section of this report.

6.0 Subsurface Soil and Groundwater Conditions

6.1 Stratigraphy

Stratigraphy consisted of glacial till overlying bedrock clay shale. Some gravel was encountered in BH101. Glacial till was absent in some areas close to the lake. Stratigraphy is illustrated on Stratigraphic Cross Sections A–A' and B–B' on Drawing No. R3985.1-3. Deep stratigraphy is illustrated in B102 and BH105, which were two of the wet rotary bore holes. The stratigraphic sections show subsurface soil and groundwater levels and the assumed location for failure planes or slip surfaces.

Where present, glacial till extended from the surface to a depth of about 7 m to 22 m. Till was generally oxidized, although unoxidized till was encountered at a depth of 12 m in BH105 located at the top of the valley. Till had a silty, sandy clay matrix with a trace of gravel and possessed medium to high plasticity, with liquid limits of 40 and 57 measured in the laboratory. Cobbles and boulders were commonly encountered and were often present at the surface. Boulders can be as much as few metres in diameter. Drilling in BH101 encountered a large boulder at a depth of about 1.5 m. The boulder extended to at least a depth of 2.7 m, with additional boulders and gravel encountered below that depth.

Bedrock clay shale had some silt and possessed medium to high plasticity near the till contact. Clay shale became highly plastic below a depth of about 7 m below the till contact. Liquid limits varied from 50 to 97. Shale was hard in consistency.

No evidence of preshearing such as slickensides or bentonitic seams typically associated with landslide movement were noted during the field investigation.

6.2 Groundwater Regime

Little seepage was noted during drilling. Piezometers were installed in all bore holes, with the exception of BH101. Groundwater levels are summarized in Table 6.1. Groundwater levels appear to coincide with lake level in BH104 and BH107 located near the toe of the slope. No water was present in BH106.

Table 6.1
Summary of Groundwater Levels
(11 December 2007)

Piezometer Designation	Estimate Elevation (m) Top of Pipe	Ground	Tip	Water Level Depth below Ground (m)	Elevation (m)
102	516.4	515.7	500.7	7.4	508.3
103	501.9	500.9	482.3	7.6	493.3
104	493.0	492.4	482.3	6.7	485.7
105	529.6	528.9	504.4	9.9	519.0
106	504.3	503.5	485.2	dry	-
107	496.7	496.0	482.4	5.8	490.2

Groundwater encountered exists within fractures and fissures in the till and clay shale strata and are likely the result of infiltration from precipitation. Water levels close to the lake may be the result of infiltration of lake water. Quantities are generally small and would not constitute a viable groundwater supply. Groundwater levels will fluctuate in response to precipitation and infiltration.

7.0 Analysis of Stability

As discussed in previous sections, the five parameters for stability analyses are:

- ground profile;
- soil shear strength;
- location of the piezometric surface (groundwater surface);
- location of the failure plane (slip surface); and,
- factor of safety.

Four of these parameters are required to allow the calculation of the fifth. Usually, the factor of safety is calculated. However, if movement is occurring, the soil shear strength can be confirmed or the location of the failure plane determined since it is known that the factor of safety is 1.0. This is generally referred to as a back analysis. The model used for back analysis can then be used to examine the impact of various changes in the soil profile such as cuts and fills or changes in the piezometric or groundwater levels.

For this site, the field investigation and laboratory testing program has provided enough information to characterize the strength parameters for soil encountered. Water levels have been measured to provide an indication of the piezometric surface. Determination of the ground profile was obtained from survey work done by Harding Boss & McLeod Surveying Ltd.

Two unknown factors are the location of the failure plane or slip surfaces and the present factor of safety. As discussed previously, since it appears that the area is stable, the factor of safety is known to be greater than 1.0. Clay shale encountered in the bore holes was generally very stiff to hard in consistency, with no apparent shear planes or bentonitic zones generally associated with a failure plane noted. Landsliding along river valleys in Saskatchewan often occur along a plane which is a weak zone within the stratified soil. As discussed previously, slope inclinometers installed in BH104 and BH107 near the toe of the slope will be monitored in the future to determine whether movement is occurring.

The software application SLOPE/W published by Geo-Slope International was utilized for analyses. This software utilizes the limit equilibrium approach of analysis with the method of slices.

7.1 Methodology for Analyses

Two cross sections shown on Drawing Nos. R3985.1-1 and R3985.1-3 were analyzed. Back analyses of the cross sections were initially done to determine a reasonable location for the failure plane. The ground surface profile near the toe was altered along with the location of the assumed failure plane so that the analyses produced a calculated factor safety of 1.0. Once a reasonable location for the failure plane was established, the same model was utilized to determine the relative change associated with an increase in the piezometric level and site grading.

All graphical output from analyses have been compiled in Appendix A of this report. Some of the output are included as figures in subsequent sections. Figure 7.1 provides a brief explanation of the main features in the graphics. The figure shows the ground profile and the assumed stratigraphy based on the field investigation. Different soil strata are shown as different shadings. The piezometric or groundwater levels are shown as a broken line.

The slip surface analyzed is generally circular, although in these cases, it becomes composite in shape, with a flat or planar bottom surface corresponding to a common failure plane defined by geology. Specific landslide blocks are analyzed assuming that a circular arc passes through the same point in the cross section. A grid of 100 points as shown on the figure represents centres of rotation for the circular arcs. The figure shows the lowest factor of safety calculated from the 100 analyses conducted. Here, the lowest or critical calculated factor of safety is 1.015, which can be rounded to 1.02.

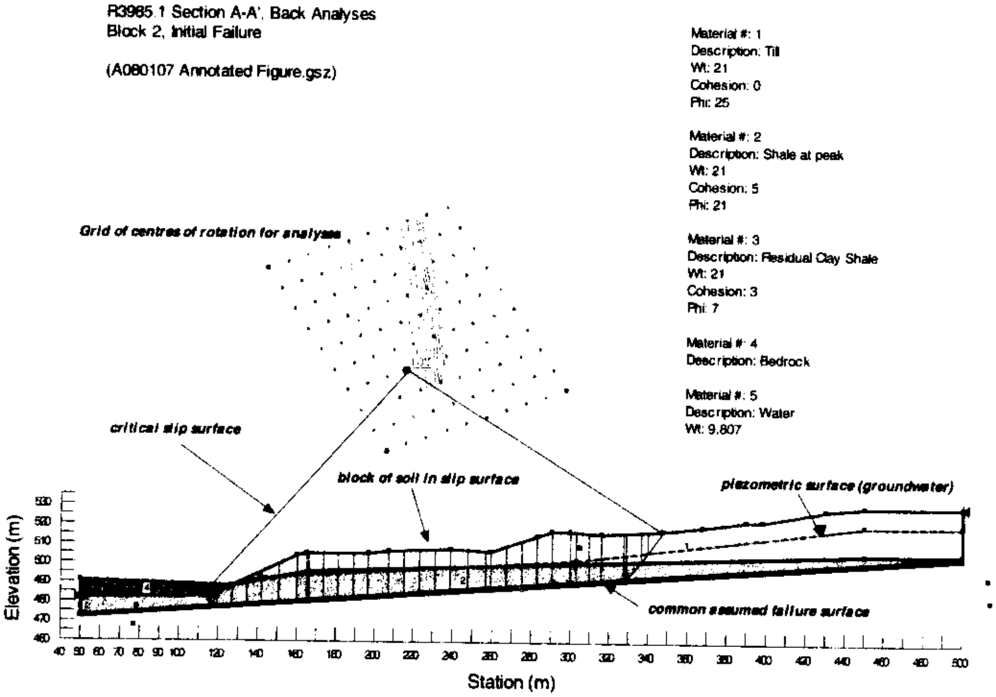


Figure 7.1: Typical Graphical Output for Stability Analyses

7.2 Soil Parameters

Soil shear strength parameters were based on a correlation with index properties such as plasticity, and estimates based on experience with the same materials around Last Mountain Lake and from other sites in the province, particularly river valleys where similar types of landslides have occurred. Soil parameters used for analyses are summarized in Table 7.1. Shear strength parameters for till and shale tabulated would be slightly reduced from peak values associated with intact material and are considered to be representative of shear strength along pre-existing failure planes.

Table 7.1
Summary of Soil Properties

Soil	Unit Weight (kN/m^3)	Effective Cohesion (kPa)	Effective Angle of Internal Friction (°)
Till at peak	21.0	5	30
Till, reduced	21.0	0	25
Shale at peak	21.0	15	21
Shale, reduced	21.0	5	21
Shale (at residual)	21.0	3	7

As determined in the field investigation, stratigraphy consisted of glacial till overlying bedrock clay shale. However, the precise delineation of these two separate soil types was not considered to be too critical, since properties were similar. The failure plane consisting of clay shale with residual shear strength parameters was assumed to be 1.0 m thick. The location of the failure plane was determined through back analyses.

7.3 Back Analyses

The results of back analyses for Cross Section A-A' are illustrated on Figures 7.2 and 7.3. Results of back analyses are tabulated in Table 7.2. Figure 7.2 shows the analysis of Block 1, which is the landslide block closest to the lake. Figure 7.3 illustrates the analysis of Block 2, which includes Block 1 and a failure plan extending farther from the lake.

Both of these analyses and analyses for Cross Section B-B' required definition of a common failure plane that slopes down towards the lake. In addition, the soil profile at the toe of the slope was reduced by several metres to simulate the case where the lake bottom was lower in the vicinity of the toe prior to infilling. Without these assumptions, the soil strength parameters necessary to calculate a factor of safety close to 1.0 were unreasonably low.

Although values of exactly 1.0 were not determined, these values are considered to be adequate for additional analyses.

Table 7.2
Results of Back Analyses

Case	Calculated Factor of Safety
Cross Section A-A'	
• Block 1	0.99
• Blocks 1 and 2	1.02
Cross Section B-B'	
• Block 1	1.06
• Blocks 1 and 2	0.99

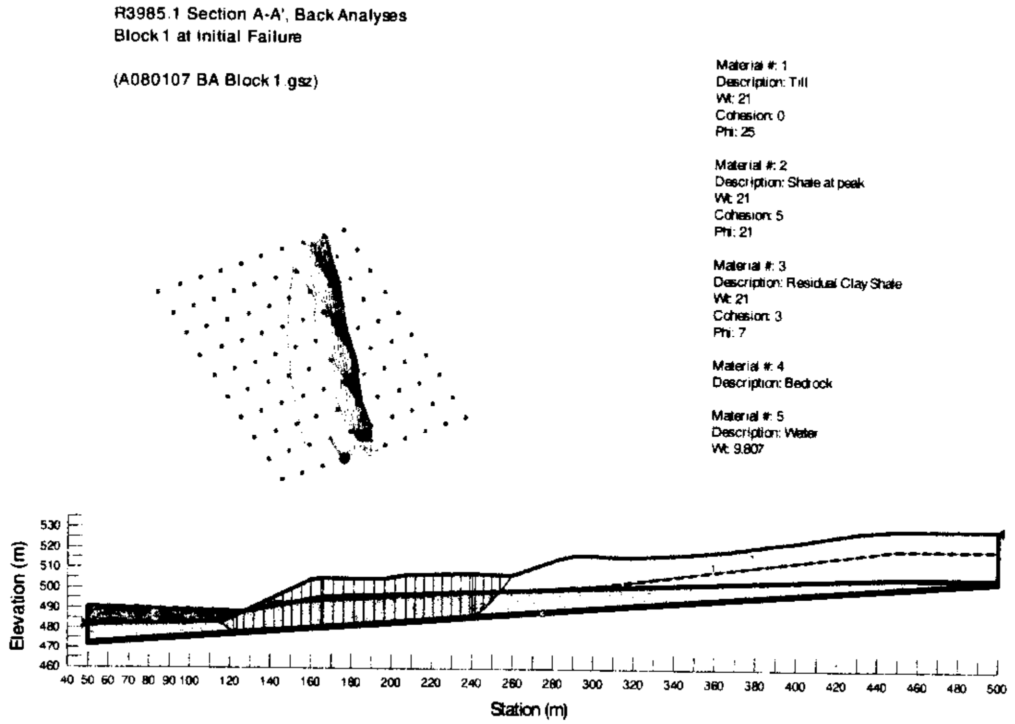


Figure 7.2: Back Analysis of Block 1 for Cross Section A-A'

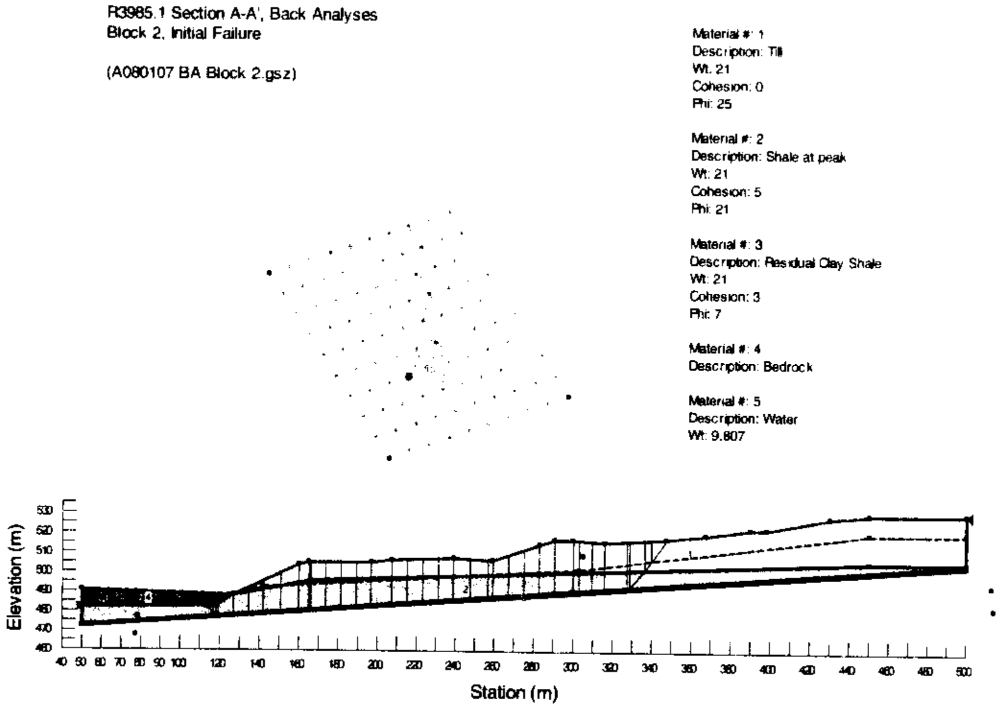


Figure 7.3: Back Analysis of Blocks 1 and 2 for Cross Section A-A′

7.4 Present Day Conditions

As discussed previously, it has been assumed that infilling of the lake has stabilized these landslides. Infilling has resulted from a reduction in flow velocity as the meltwater channel became a lake, as well as from erosion of the shoreline into the lake. With this assumption, the factor of safety for the landslide blocks has been calculated and summarized in Table 7.3. In addition, the calculated factor of safety for a new slip surface at the toe has been determined assuming the same reduced shear strength parameters. These values are greater than 1.0 for the stability models, which provides additional confidence in the conceptual model utilized.

Again, the calculated factors of safety illustrate that the model is consistent with the assumed mechanism of initial failure, although the precise value of the actual factor of safety cannot be known without more data. However, a relative change in the calculated factor of safety associated with grading and increases in groundwater levels can be assessed.

For these models, the calculated factor of safety for a new failure appear to be reasonable. In general terms, the actual factor of safety would be higher than these values because the failure surface would be through intact soil with a higher shear strength.

Table 7.3
Summary of Calculated Factor of Safety,
Present Day Conditions

Case	Calculated Factor of Safety
Cross Section A-A'	
• Block 1, present day conditions	1.29
• Blocks 1 and 2, present day conditions	1.19
• New failure	1.21
Cross Section B-B'	
• Block 1, present day conditions	1.30
• Blocks 1 and 2, present day conditions	1.18
• New failure	1.33

7.5 Potential Changes Related to Development

The potential impact on stability has been assessed by considering several general scenarios assuming that the cross sections being analyzed are representative. However, the area being subdivided is large and will, by its nature, contain many local variations that could impact local stability. These analyses are intended to provide general direction for development.

A 2.0 m fill or excavation was examined, as was a 2.0 m increase in the piezometric or groundwater elevation. We do not mean to suggest that a 2.0 m fill or excavation is desirable or recommended. These values were intended to be representative of possible regrading, but more to examine the impact of regrading. Although the groundwater level can rise or fall depending on seasonal climatic changes, an increase is expected as a result of development as traditional drainage patterns are altered and homeowners irrigate their lawns and gardens. In addition, groundwater levels can increase locally or over a larger area as a result of uncontrolled leaks from services or other sources. A 2.0 m increase in groundwater level is considered to be reasonable for this development.

The general scenarios analyzed included:

- a 2.0 m fill over a 20 m to 30 m area;
- a 2.0 m excavation over a 20 m to 30 m area;
- a 2.0 m increase in the piezometric (groundwater) levels; and,

- a combination of a groundwater increase and a fill or cut.

These changes were applied to three different and potential slip surfaces on each of Cross Sections A-A' and B-B':

- Block 1 near the toe of the slope;
- Blocks 1 and 2; and,
- a potential new slip surface near the toe of the slope.

Results of analyses are summarized in Tables 7.4 and 7.5. Representative graphic results are provided in Figures 7.4 to 7.7, illustrating an excavation near the toe of the slope, a fill near the scarp of the landslide block, a fill near the toe of the slope and a fill on a potential new landslide block near the toe.

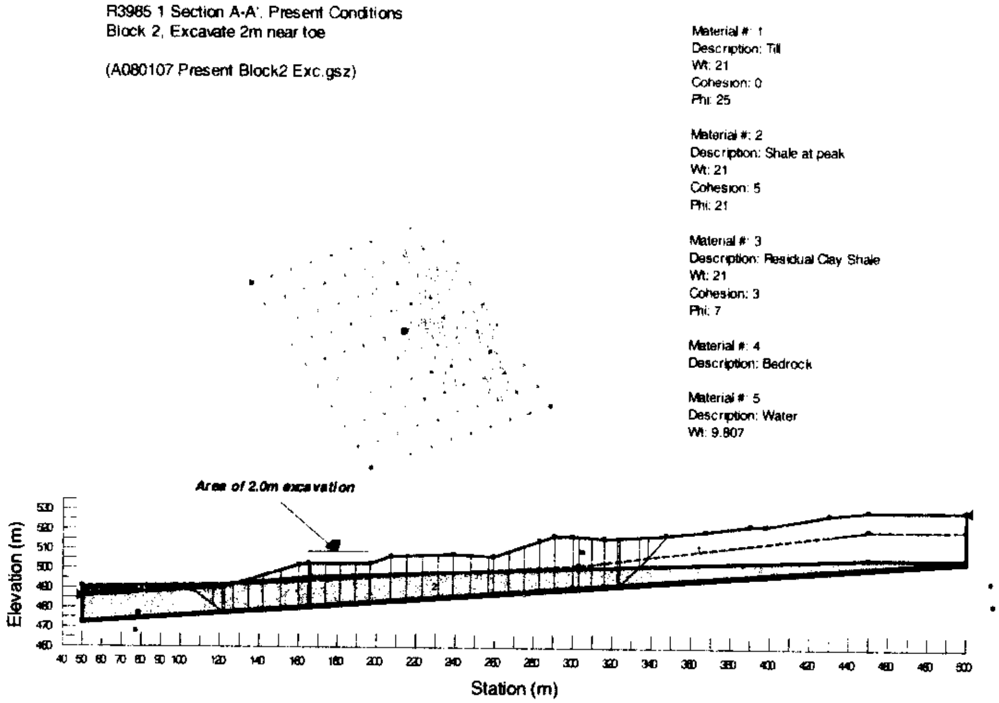
Although the calculated factors of safety have been tabulated, the percentage change in the calculated factor of safety relative to the base case is more significant, since the present factor of safety of the slope cannot be determined.

Table 7.4
Summary of Calculated Factor of Safety, Cross Section A-A'
Grading and Groundwater Changes

Case	Calculated Factor of Safety	% Change from Base Case
Cross Section A-A', Block 1		
• Base Case	1.29	
• 2.0m fill near toe	1.30	+0.8
• 2.0m fill near scarp	1.25	-3.1
• 2.0m increase in groundwater level	1.23	-4.7
• 2.0m excavation near toe	1.28	-0.8
• 2.0m fill near toe and 2.0m increase in groundwater	1.24	-3.9
• 2.0m fill near scarp and 2.0m increase in groundwater	1.19	-7.8
Cross Section A-A', Block 1 and 2		
• Base Case	1.19	
• 2.0m fill near toe	1.20	+0.8
• 2.0m fill near scarp	1.17	-1.7
• 2.0m excavation near toe	1.19	0.0
• 2.0m increase in groundwater level	1.14	-4.2
• 2.0m excavation and 2.0m increase in groundwater	1.13	-5.0
• 2.0m fill near scarp and 2.0m increase in groundwater	1.12	-5.9
Cross Section A-A', New Failure at Toe		
• Base Case	1.17	
• 2.0m fill	1.13	-6.6
• 2.0m groundwater increase	1.17	-3.3
• 2.0m fill and 2.0m groundwater increase	1.09	-9.9

Table 7.5
Summary of Calculated Factor of Safety, Cross Section B-B' Grading and Groundwater Changes

Case	Calculated Factor of Safety	% Change from Base Case
Cross Section B-B', Block 1		
• Base Case	1.30	
• 2.0m fill near toe	1.21	-6.9
• 2.0m increase in groundwater level	1.24	-4.6
• 2.0m fill near scarp and 2.0m increase in groundwater	1.16	-10.8
Cross Section B-B', Block 1 and 2		
• Base Case	1.18	
• 2.0m fill near scarp	1.16	-1.7
• 2.0m excavation near toe	1.17	-0.8
• 2.0m increase in groundwater level	1.12	-5.1
• 2.0m excavation and 2.0m increase in groundwater	1.11	-5.9
Cross Section B-B', New Failure at Toe		
• Base Case	1.33	
• 2.0m fill	1.29	-3.0
• 2.0m groundwater increase	1.20	-9.8
• 2.0m fill and 2.0m groundwater increase	1.21	-9.0



R3985 1 Section A-A', Present Conditions
Block 2, Excavate 2m near toe

(A080107 Present Block2 Exc.gsz)

Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

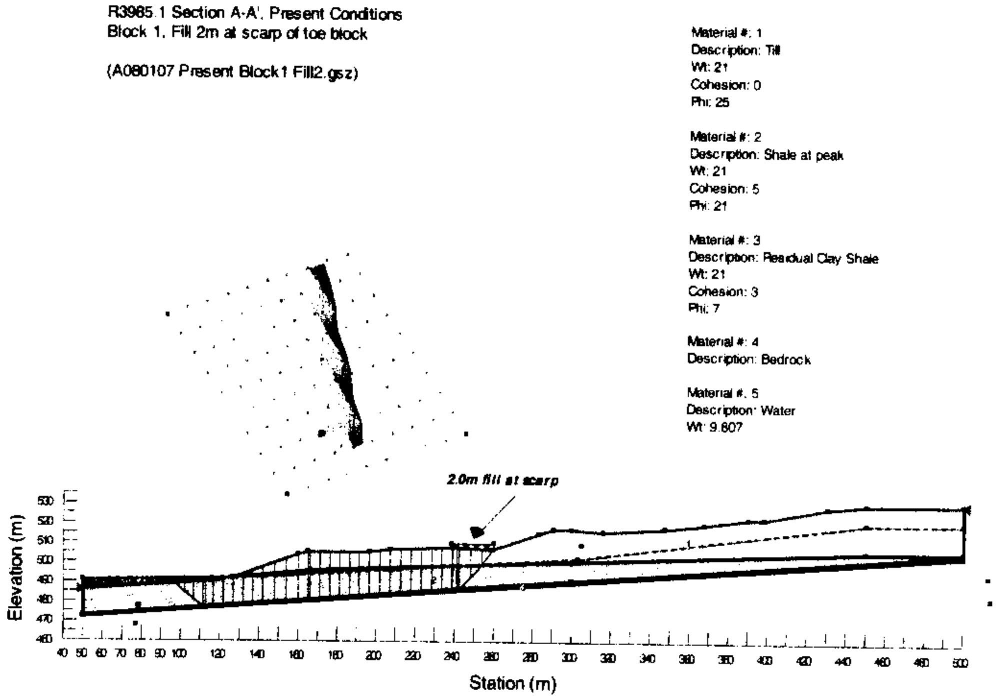
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

Area of 2.0m excavation

Figure 7.4: **Blocks 1 and 2, Cross Section A-A' with 2.0m Excavation at Toe of Slope Resulting in Little Change in Calculated Factor of Safety**



R3985.1 Section A-A', Present Conditions
Block 1, Fill 2m at scarp of toe block

(A080107 Present Block1 Fill2.gsz)

Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

2.0m fill at scarp

Figure 7.5: **Block 1, Cross Section A-A' with 2.0 m Fill at Scarp Resulting in a 3 percent Decrease in Calculated Factor of Safety**

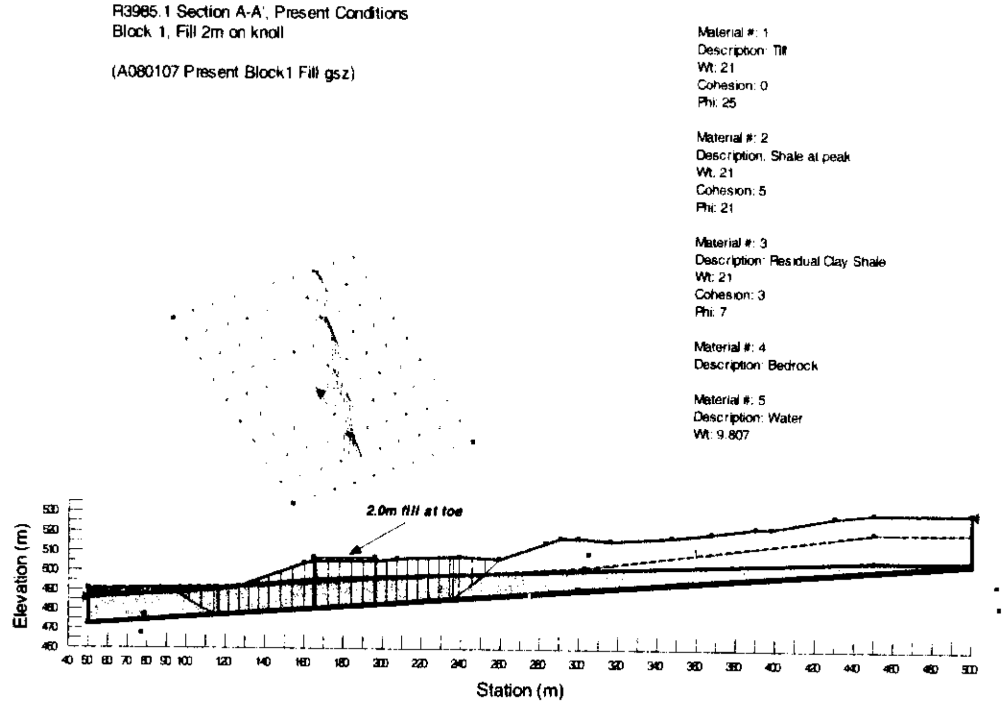


Figure 7.6: Block 1, Cross Section A-A' with 2.0 m Fill at Toe Resulting in a 1 percent Increase in Calculated Factor of Safety

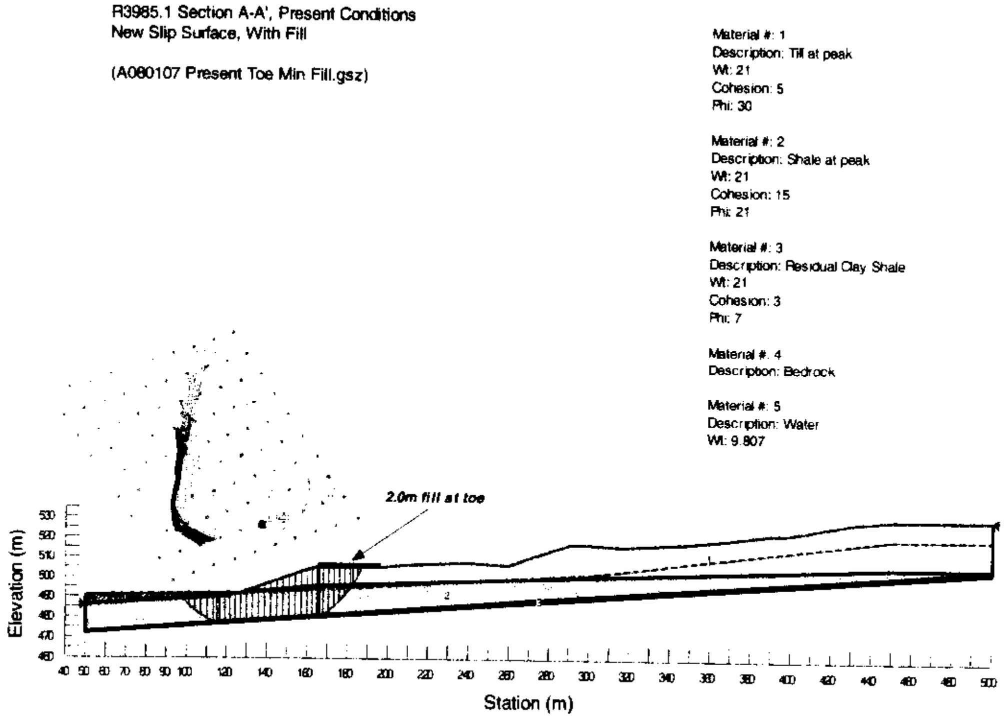


Figure 7.7: New Potential Block, Cross Section A-A' with 2.0 m Fill Resulting in 6 percent Decrease in Calculated Factor of Safety

In general, results of the analyses are consistent with expectations, that is, a fill on the upslope portion of a landslide block will decrease stability, while a fill near the toe would generally increase stability. An increase in groundwater levels will decrease stability.

The most significant change occurred for an increase in groundwater levels. A 2.0 m increase generally resulted in a decrease of 4 percent to 5 percent for the calculated factor of safety.

Fill placed on the upslope portion of a landslide block resulted in a decrease of about 3 percent or less, although decreases of up to 7 percent were calculated for smaller landslide blocks when the fill covered a significantly larger portion of the area.

The calculated factor of safety decreased by as much as 10 percent when an increase in groundwater was combined with a fill or excavation.

Changes in stability associated with grading or an increase in groundwater level became most significant for smaller landslide blocks near the toe of the slope that may be associated with the formation of a new landslide block.

As illustrated in Figures 7.6 and 7.7, a fill near the toe might appear to improve stability of an upslope landslide block. However, the same fill will also result in a decrease in the factor of safety of a downslope landslide block.

8.0 Discussion

Stability analyses were conducted for two cross sections from this site. The shape of the ground profile was determined from survey information provided by others. Subsurface soil and groundwater conditions were determined from a field investigation. Relevant engineering properties of soil encountered were evaluated by visual assessment and laboratory testing, and based on other investigations in this area and in similar stratigraphy in the province.

Analyses considered the stability of three different landslide blocks for each section and the impact of a fill, excavation, and an increase in the groundwater level. The location of the slip surfaces associated with pre-existing failures was estimated on the basis of back analyses.

The values for factor of safety calculated in the analyses are only representative of actual conditions, since the precise value cannot be determined. We have concluded that pre-existing or old landslides in this area are currently stable based on field observations. This implies that the current factor of safety is 1.0 or greater. The value of the analyses conducted is the determination of the relative change in calculated factor of safety, which is expressed as a percentage of the base case, that is, the current ground profile and groundwater conditions.

8.1 Shoreline Changes

Deposition of soil at the toe of the slope has resulted in a stable slope with respect to movement of existing landslide blocks. Over hundreds or thousands of years, surficial till has continued to become eroded, resulting in a predominantly sandy or gravelly sand beach with cobbles and occasional boulders. In some areas, significant accumulations of cobbles has provided very good shoreline protection at current lake levels. Changing lake levels and increased erosion at the shoreline may result in creation of new landslide blocks or re-initiation of movement of old landslide blocks. Thus, while it may be impossible to control lake levels in the long term, it is important to ensure that the shoreline is not altered, since any changes will likely result in an increased rate of erosion, potential landsliding and loss of property.

At present, there are a number of areas shown on Drawing No. R3985.1-2 along the shoreline where clay shale and some till are exposed on relatively steep slopes. These are generally near the west and east edges of the proposed development. Slopes are from 15 m to 18 m high and stand at a slope of about 1.6:1 to 1.81. These slopes will continue to erode, with the primary agent being surface water runoff. Eroded soil moves down the slope and covers the shoreline area. With time, much of the clay deposited in this fashion is eroded or washed away by wave action. In addition, some small block failures will occur as portions of the banks break away along naturally occurring fissures and fractures. Although this type of earth movement are not deep seated landslide movement, this type of mechanism will result in loss of ground for lots in this area.

Protection of slopes, particularly where bedrock clay shale has been exposed and is eroding, should be considered as part of development. This may require the application of topsoil or a mulch and seed mixture to enhance germination and improve survival on hot, dry southern exposures. Slopes such as these tend to resist vegetation due to their steepness. Slopes will be more easily vegetated and protected if they can be flattened to about 2.5 horizontal to 1 vertical or flatter. Any earthwork done must ensure that fugitive soil is not washed into the lake.

Bedrock clay shale was deposited in a marine environment. Thus, it typically contains a high concentration of salts and is nutrient poor. This results in a challenging environment for the establishment of vegetation.

To account for potential erosion of these slopes, it is prudent to consider a setback from the edge of the slope if permanent structures are being considered in these areas. The amount of setback will depend on the present slope and the height of the slope. For the highest slopes near the east and west sides of the proposed development, a setback of at least 7.5 m to 15 m is recommended. This setback coincides with a line drawn at a slope of 2:1 to 2.5:1 from the shoreline. The setback criteria can be relaxed if measures are taken to flatten these slopes. Setback will depend on the height of the slope and the existing slope angle.

Structures closest to the lake may be impacted by any new landslide caused by significant erosion and undercutting of the shoreline associated with unforeseen changes in lake levels or wave action. It is impossible to predict how much additional erosion may occur along the shoreline, since we do not know how the environment might change in the future.

Public beach areas should be selected on the basis of naturally occurring sand and gravel. The addition of features such as gabion walls or other means to protect existing slopes from additional wave erosion can be considered. Shore line development or alteration must consider all regulatory issues.

8.2 Groundwater Levels

Groundwater levels will vary with time as a result of seasonal climatic changes, irrigation of lawns and gardens, and any leaks from services, pools or other sources. At present, there are no sources of water in this area except for precipitation and snowmelt. It is anticipated that a minimum 1.0 m to 2.0 m increase in groundwater levels can be expected in the long term. Thus, the overall factor of safety of the area is expected to decrease by about 3 percent to 5 percent with time.

Development and development criteria should ensure that measures are undertaken to minimize infiltration of water. Property owners must understand that the area is a landslide areas, that landslides have occurred in the past and may occur in the future. At present, the area appears to be stable. However, excessive water can contribute to instability, or re-initiate movement. The type of development should be consistent with a desire to minimize the amount of irrigation and other sources of groundwater. Landslides have been initiated in some developed areas around Last Mountain Lake due to increase groundwater levels associated with leaking services or irrigation systems left on over night.

Distributed water supplies should be metered so that any leaking lines might be detected. Any pools should incorporate leak detection systems. Irrigation should be minimized so that it is adequate to support plant growth. It would be prudent to adopt xeriscape concepts in this area and discourage extensive lawns that will require irrigation.

Low areas where water currently tends to pond should be graded to provide an outlet for drainage. If complete drainage of the depressions is not possible due to the amount of grading required, grading to create swales or other drainage pathways should be designed so that the water level in the depression is minimized.

8.3 Grading

Regrading of portions of the area for roadways and portions of lots for development will be required.

An average excavation associated with the construction of a basement for a residential structure will not significantly impact stability of a slope. Also, the weight of a residential structure is generally not significant with respect to overall slope stability. The weight of an average two storey wood frame structure would be equivalent to about 300 mm of soil over the footprint of the house. Thus, there is a much greater impact if 500 mm or more soil is placed over a large area. Grading of lots should be only that necessary to provide a suitable construction site. Excess material should be disposed of carefully and preferably removed from the lot.

Analyses have shown that application of a 2.0 m fill or excavation on portions of the slope can result in a decrease of about 3 percent, although the magnitude of the change will depend on both the size of the area covered by fill or excavated and the location of the fill or excavation relative to the landslide block. The most sensitive areas with respect to grading will be those areas closest to the shoreline. In particular, construction of a fill near the toe which effectively creates a steeper slope at the shoreline may result in a failure.

For general grading over areas that are about 20 m to 25 m square, excavations or fill less than about 1.0 m will generally result in a 1 percent to 2 percent decrease in stability, which is reasonable and acceptable when considered with a decrease in stability associated with an increased groundwater table that is anticipated. Larger fills or excavations can be considered over very limited areas, although we can review these cases for sensitivity on an 'as required' basis.

8.4 Locating Roadways, Lots and Permanent Structures

The locations of landslide scarps that could be identified from aerial photographs are shown on Drawing No. R3985.1-2. Areas suitable for construction of homes are generally high areas on separate landslide blocks. Permanent structures that are susceptible to damage associated with differential vertical or horizontal movement should not be located on or close to these areas. When a structure is located on one landslide block, the risk of damage, should instability occur, will be minimized.

In addition, caution must be exercised when buried services cross these areas, since movement in the future may result in damage. It is desirable to align services parallel to scarps which are generally parallel to the shoreline and to minimize crossings of potential scarps. In addition, materials and construction methods suitable for areas subject to potential movement should be incorporated into design.

In general, roadways can be aligned with the ground surface to minimize fill and cut sections. Since those areas close to landslide scarps are not desirable for construction of structures, these areas may be best suited for roadways.

8.5 Foundation Conditions

Foundation conditions can be variable across this area, with glacial till in some areas and high plasticity bedrock clay shale in others. Foundation alternatives include augered cast-in-place concrete piles or shallow spread footings for structures supported on glacial till. Spread footings are not recommended for structures on high plasticity clay shale due to the potential for significant heave associated with an increase in soil moisture.

The site classification for seismic site response as described in NBCC 2005 (Table 4.1.8.4A) has been defined on the basis of the average estimated undrained shear strength for the upper 30 m. Design can assume Site Class C conditions for seismic response based on an average undrained shear strength of more than 100 kPa in the upper 30 m.

Soil at footing elevation consists of glacial till with a silty, sandy clay or clayey sand matrix. It possesses non plastic or low plasticity. As such, the amount of vertical movement associated with heave will be minor. Till possessed an undrained shear strength of about more than 200 kPa.

In general, shallow spread footings should be constructed below a depth of about 1.8 m, which is the estimated depth of freezing. This depth can be reduced if the foundation design incorporates insulation. Footings will be subject to some vertical movement. The amount of movement that occurs will depend on the size of the footing, applied pressure and environmental factors. For an estimated total settlement of about 25 mm, an allowable bearing pressure of 300 kPa may be used.

Augered cast-in-place concrete piles may be designed to develop their capacity on the basis of skin friction or end bearing, but not both, since the amount of deformation that the pile undergoes varies depending on the type of pile. An allowable skin friction value of 45 kPa may be used for design of piles in till or hard bedrock clay shale. The skin friction contribution of the upper 1.8 m of pile should be ignored in the calculation of capacity.

Construction of grade supported floor slabs should avoid fill material of unknown composition and condition, and organics. Basement floors may be supported on till with a silty, sandy clay or clayey sand matrix, or on high plasticity clay shale. Grade supported floors constructed on till will experience minor vertical movement. Floor construction on high plasticity clay shale will experience significant vertical movement, estimated to be 150 mm or more due to heave.

Excavations must be executed carefully. Significant dewatering will not be required for excavations; however, this may change significantly as a result of precipitation and infiltration. Excavations should be no steeper than about 1 horizontal to 1 vertical (1:1) and conform to OHS guidelines and regulations. Although excavations through these materials may stand in the short term at near vertical angles, oversteepened slopes will slough and collapse if they are left open for long periods of time or if water is allowed to infiltrate. Failure may be sudden.

Although static groundwater levels do not appear to exist above a depth of about 3 m, water from precipitation, snow melt and irrigation will move through fractures within the surficial soil. Groundwater levels will vary depending on the season and may increase with development as a result of irrigation. Some perimeter drainage should be considered for basements and if a deep granular fill is placed under the floor, since water will have a tendency to accumulate above the relatively low permeability till and clay shale. Waterproofing of basement walls and floor should be considered with a perimeter drainage system. Wall backfill can consist of free draining granular soil topped with clay. An alternative will be one of many products available that incorporate a drainage system and filter fabric that may reduce the necessity for higher quality backfill material. These systems must follow manufacturers' or suppliers' recommendations for use and installation to ensure that they remain effective.

9.0 Development Recommendations

Safe building sites exist in this area, despite the fact that landsliding has occurred in the past. This report provides preliminary recommendations for development. Recommendations can be revised based on future assessment of specific areas along the valley wall and in conjunction with the development of the subdivision plan.

Geotechnical recommendations for this development are summarized below:

- Development should endeavour to minimize infiltration of groundwater. Development is expected to result in an overall increase in groundwater levels which will reduce stability by about 5 percent or less. Depressions should be graded to drain, and pools and services should be equipped with systems to allow detection of leaks. Irrigation should be kept to a minimum; landscaping that minimizes the use of water is preferred.

- Shoreline development must ensure that erosion does not occur. Natural armouring should be left intact, since removal will inevitably result in an increase in the rate of erosion.

- Naturally occurring sand and gravel areas should be utilized for beaches. Removal of large accumulations of cobbles or boulders should be avoided, since the result will be increased rates of erosion.

- Flattening of steep and high slopes should be considered to improve stability and to reduce the amount of surface erosion. Vegetation should be encouraged to reduce the rate of erosion on slopes. Growing plants on the usually nutrient poor bedrock clay shale can be challenging. Suitable resources should be consulted for additional information.

- Grading of most areas should be restricted to less than about 1.0 m of fill or excavation. Areas adjacent the shoreline will be most sensitive to changes. Fills and cuts greater than 1.0 m may be contemplated for small areas.

- Permanent or any other structures sensitive to differential vertical and horizontal movement must avoid areas identified as landslide scarps. Residential and other permanent structures are best located on knolls or high areas, since these are typically single landslide blocks.

- Roadways may be best located in lower areas identified as scarps, since any damage associated with movement can usually be repaired easily. Fills and cuts should be minimized and drainage improved where necessary.

- Foundation conditions for developments should be determined on a 'site by site' basis. Surficial soil conditions consist of either glacial till or high plasticity clay shale. Foundation alternatives include augered cast-in-place concrete piles for either soil type or shallow spread footings for foundation supported on glacial till. Significant heave can be expected for grade supported floors constructed on high plasticity clay shale.

- A setback in shoreline areas is recommended to account for some erosion that may occur. The setback determined on the basis of a line rising from the shoreline at a slope of about 2:1 to 2.5: 1, which will be about 7.5 m to 15 m for the highest banks currently standing at a slope of about 1.6:1 to 1.8:1. Setback will depend on the height of the slope, as well as the existing slope angle.

10.0 Statement of General Conditions

This report was prepared by Clifton Associates Ltd. for the use of Val Lane Ltd. and their agents for specific application to the development of the Sun Dale subdivision in parts of Sections 28 and 29-21-22-W2M and located between Sunset Cove and Pelican Point, Saskatchewan on the north shore of Last Mountain Lake. The material in this report reflects Clifton Associates Ltd. best judgment available at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Clifton Associates Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

This report has been prepared in accordance with generally accepted engineering practice common to the local area. No other warranty, expressed or implied is made.

Our conclusions and recommendations are preliminary and based upon the information obtained from the referenced subsurface exploration. The test borings and associated laboratory testing indicate subsurface and groundwater conditions only at the specific locations and times investigated, only to the depth penetrated and only for the soil properties tested. The subsurface conditions may vary between the bore holes and with time. The subsurface interpretation provided is a professional opinion of conditions and not a certification of the site conditions. The nature and extent of subsurface variation may not become evident until construction or further investigation. If variations or other latent conditions do become evident, Clifton Associates Ltd. should be notified immediately so that we may re-evaluate our conclusions and recommendations. Although subsurface conditions have been explored, we have not conducted analytical laboratory testing on samples obtained nor evaluated the site with respect to the potential presence of contaminated soil or groundwater.

The enclosed report contains the results of our investigations as well as certain recommendations arising out of such investigations. Our recommendations do not constitute a design, in whole or in part, of any of the elements of the proposed work. Incorporation of any or all of our recommendations into the design of any such element does not constitute us as designers or co-designers of such elements, nor does it mean that such design is appropriate in geotechnical terms. The designers of such elements must consider the appropriateness of our recommendations in the light of all design criteria known to them, many of which may not be known to us. Our mandate has been to investigate and recommend which we have completed by means of this report. We have had no mandate to design, or review the design of, any elements of the proposed work and accept no responsibility for such design or design review.

Clifton Associates Ltd.

Richard T. Yoshida, P.Eng.

Association of Professional
Engineers and Geoscientists of Saskatchewan
Certificate of Authorization No. 238

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engineering science technology

Symbols and Terms

Soil Descriptive Terms

A soil description for geotechnical applications includes a description of the following properties:

- texture
- color, oxidation
- consistency and condition
- primary and secondary structure

Texture

The soil texture refers to the size, size distribution and shape of the individual soil particles which comprise the soil. The Unified Soil Classification System (ASTM D2487-00) is a quantitative method of describing the soil texture. The basis of this system is presented overleaf. The following terms are commonly used to describe the soil texture.

Particle Size
(ASTM D2487-00)

Boulder	300 mm plus
Cobble	75 - 300 mm
Gravel	4.75 - 75 mm
Coarse	19 - 75 mm
Fine	4.75 - 19 mm
Sand	0.075 - 4.75 mm
Coarse	2 - 4.75 mm
Medium	0.425 - 2 mm
Fine	0.075 - 0.425 mm
Silt and Clay	Smaller than 0.075 mm

Relative Proportions
(CFEM, 3rd Ed., 1992)

Trace	1 - 10 %
Some	10 - 20 %
Gravelly, sandy, silty, clayey, etc.	20 - 35 %
And	>35 %
Gravel, Sand, Silt, Clay	>35 % and main fraction

Gradation

Well Graded	Having a wide range of grain sizes and substantial amount of all intermediate sizes.
Uniform or Poorly Graded	Possessing particles of predominantly one size.
Gap Graded	Possessing particles of two distinct sizes.

Particle Shape

Angular	Sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Similar to 'angular' but have rounded edges.
Subrounded	Well-rounded corners and edges, nearly plane sides.
Rounded	No edges and smoothly curved sides.

Also may be flat, elongated or both.

The term "TILL" may be used as a textural term to describe a soil which has been deposited by glaciers and contains an unsorted, wide range of particle sizes.

Color And Oxidation

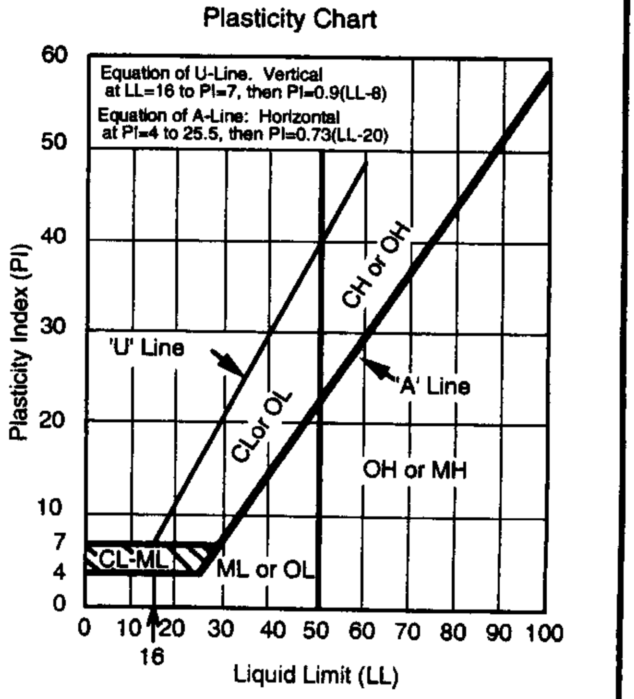
The soil color at its natural moisture content is described by common colors and, quantitatively, in terms of the Munsell color notation; (eg. 5Y 3/1). The notation combines three variables, hue, value and chroma to describe the soil color. The hue indicates its relation to red, yellow, green, blue and purple. The value indicates its lightness. The chroma indicates its strength of departure from a neutral of the same lightness.

Departure of the soil color from a neutral color indicates the soil has been oxidized. Oxidation of a soil occurs in a oxygen rich environment where most commonly metallic iron, oxidizes and turns a neutral colored soil 'rusty' or reddish brown. Oxidized manganese gives a purplish tinge to the soil. Oxidation may occur throughout the entire soil mass or on fracture/joint/fissure surfaces.

Classification of Soils for Engineering Purposes

ASTM Designation D 2487-00 (Unified Soil Classification System)

Major divisions			Group Symbols	Typical names	Classification criteria			
Coarse-grained soils More than 50% retained on No. 200 sieve* (>0.075 mm)	Gravels More than 50% of coarse fraction retained on No. 4 sieve(≥4.75 mm)	Clean gravels <5% fines	GW	Well-graded gravel	If ≥ 15% sand add "with sand" to group name	Classification on basis of percentage of fines Less than 5% pass No. 200 sieve.......GW, GP, SW, SP More than 12% pass No. 200 sieve.....GM, GC, SM, SC 5 to 12% pass No. 200 sieve.......Borderline classifications requiring use of dual symbols	$C_u = \frac{D_{60}}{D_{10}} \geq 4$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly graded gravel			Not meeting either C_u or C_c criteria for GW	
		Gravels with fines >12% fines	GM	Silty gravel			Atterberg limits below "A" line or PI less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols If fines are organic add "with orgnic fines" to group name
			GC	Clayey gravel			Atterberg limits on or above "A" line and PI > 7	
	Sands 50% or more of coarse fraction passes No. 4 sieve(<4.75 mm)	Clean sands <5% fines	SW	Well-graded sand	If ≥ 15% gravel add "with gravel" to group name		$C_u = \frac{D_{60}}{D_{10}} \geq 6$; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly graded sand			Not meeting either C_u or C_c criteria for SW	
		Sands with fines >12% fines	SM	Silty sand			Atterberg limits below "A" line or PI less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols If fines are organic add "with orgnic fines" to group name
			SC	Clayey sand			Atterberg limits on or above "A" line and PI > 7	
Fine-grained soils 50% or more passes No. 200 sieve* (≤0.075 mm)	Silts and Clays Liquid limit <50%	Inorganic	ML	Silt	If 15 to 29% coarse-grained, add "with sand" or "with gravel" as appropriate If > 30% coarse-grained , add "sandy" or "gravelly" as appropriate Class as organic when oven dried liquid limit is < 75% of undried liquid limit			
			CL	Lean Clay -low plasticity				
		Organic	OL	Organic clay or silt (Clay plots above 'A' Line)				
	Silts and Clays Liquid limit ≥50%	Inorganic	MH	Elastic silt				
			CH	Fat Clay -high plasticity				
		Organic	OH	Organic clay or silt (Clay plots above 'A' Line)				
	Highly organic soils		PT	Peat, muck and other highly organic soils				



Plasticity Chart

*Based on the material passing the 3 in.(75 mm) sieve, if field samples contain cobbles or boulders, add "with cobbles or boulders" to group name

Consistency And Condition

The consistency of a cohesive soil is a qualitative description of its resistance to deformation and can be correlated with the undrained shear strength of the soil. The condition of a coarse grained soil qualitatively describes the soil compactness and can be correlated with the standard penetration resistance (ASTM D1586-99).

Consistency Of Cohesive Soil (CFEM, 3rd Edit., 1992)

Consistency	Undrained Shear Strength (kPa) (CFEM, 3rd Edt., 1992)	Field Identification (ASTM D 2488-00)
Very Soft	<12	Thumb will penetrate soil more than 25 mm.
Soft	12-25	Thumb will penetrate soil about 25 mm.
Firm	25-50	Thumb will indent soil about 6 mm.
Stiff	50-100	Thumb will indent, but penetrate only with great effort (CFEM).
Very Stiff	100-200	Readily indented by thumbnail (CFEM).
Hard	>200	Thumb will not indent soil but readily indented with thumbnail.
Very Hard	N/A	Thumbnail will not indent soil.

Condition Of Coarse Grained Soil (CFEM, 3rd Edt., 1992)

Compactness Condition	SPT N - Index (Blows/300mm)
Very Loose	0 - 4
Loose	4 - 10
Compact	10 - 30
Dense	30 - 50
Very Dense	over 50

Moisture Conditions (ASTM D2488-00)

Description	Criteria
Dry	Absence of moisture, dusty, dry to touch
Moist	Damp but no visible water
Wet	Visible, free water, usually soil is below water table

Structure

The soil structure is the manner in which the individual soil particles are assembled to form the soil mass. The primary soil structure is the arrangement of soil particles as originally deposited. The secondary soil structure refers to any rearrangement of the soil such as deformation and cracking which has taken place since deposition.

Primary Soil Structure (Depositional)

A. Geometry

Stratum	A single sedimentary 'layer', greater than 10 mm in thickness, visibly separable from other strata by a discrete change in lithology and/or sharp physical break.
Homogeneous	Same color and appearance throughout.
Stratified	Consisting of a sequence of layers which are generally of contrasting texture or color.
Laminated	Stratified with layer thicknesses between 2 mm and 10 mm.
Thinly laminated	Stratified with layer thickness less than 2 mm.
Bedded	Stratified with layer thicknesses greater than 10 mm.
Very Thinly Bedded (Flaggy)	Stratified with layer thicknesses between 10 and 50 mm.
Thinly Bedded (Slabby)	Stratified with layer thicknesses between 50 and 600 mm.
Thickly Bedded (Blocky)	Stratified with layer thicknesses between 600 and 1200 mm.
Thick-Bedded (Massive)	Stratified with layer thicknesses greater than 1200 mm.
Lensed	Inclusions of small pockets of different soils, such as small lenses of sand material throughout a mass of clay.

B. Bedding Structures

Cross-bedding	Internal 'bedding' inclined to the general bedding plane.
Ripple-bedding	Internal 'wavy bedding'.
Graded-bedding	Internal gradation of grain size from coarse at base to finer at top of bed.
Horizontal bedded	Internal bedding is parallel and flat lying

Secondary Soil Structure (Post-Depositional)

A. Accretionary Structures

Includes nodules, concretions, crystal aggregates, veinlets, color banding and

Cementation	Chemically precipitated material, commonly calcite ($CaCO_3$), binds the grains of soil, usually sandstone. Described as weak, moderate, strong (ASTM D2488-00).
Salt Crystals	Groundwater flowing through the soil/rock often precipitates visible amounts of salts. Calcite ($CaCO_3$), glauber salts ($Na_2Ca(SO_4)_2$), and gypsum ($CaSO_4*2H_2O$) are common.

B. Fracture Structures

Fracture	A break or discontinuity in the soil or rock mass caused by stress exceeding the materials strength.
Joint	A fracture along which no displacement has occurred.
Fissure	A gapped fracture, which may open and close seasonally. Usually an extensive network of closely spaced fractures, giving the soil a 'nuggetty' structure.
Slickensides	Fractures in a clay that are slick and glossy in appearance, caused by shear movements.
Brecciated	Contains randomly oriented angular fragments in a finer mass, usually associated with shear displacements in soils.
Fault	A fracture or fracture zone along which there has been displacement.
Blocky	A cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Symbols Used on Bore Hole Logs

Lithology Type

- ▤ CLAY
- ▦ SILT
- ▒ SAND
- ▩ GRAVEL
- ▩ COBBLES
- ⊠ TILL-oxidized
- ⊠ TILL-unoxidized
- ▒ PEAT
- ▒ TOPSOIL or ORGANIC SOIL
- ▒ COAL
- ▒ FILL (Undifferentiated)
- ▩ CONCRETE
- ■ ASPHALT
- ▤ CLAY SHALE
- ▤ SANDSTONE
- ▨ MUDSTONE
- ▨ BEDROCK (Undifferentiated)

Borehole Completion and Backfill Materials

- ■ Bentonite
- ▩ Concrete
- ▦ Cover
- ▒ Cuttings
- ▩ Grout
- ▒ Sand
- ▧ Slough
- □ Solid Pipe
- ▤ Slotted Pipe

Soil Sample Type

- ■ Thin Walled Tube
- ⊠ Driven Spoon
- ▤ Disturbed
- ▥ Core (any type)
- ▨ No Recovery

Groundwater Symbols

▼ Piezometric elevation as determined by a piezometer installation

▽ Water levels measured in borings at the time and under the conditions noted

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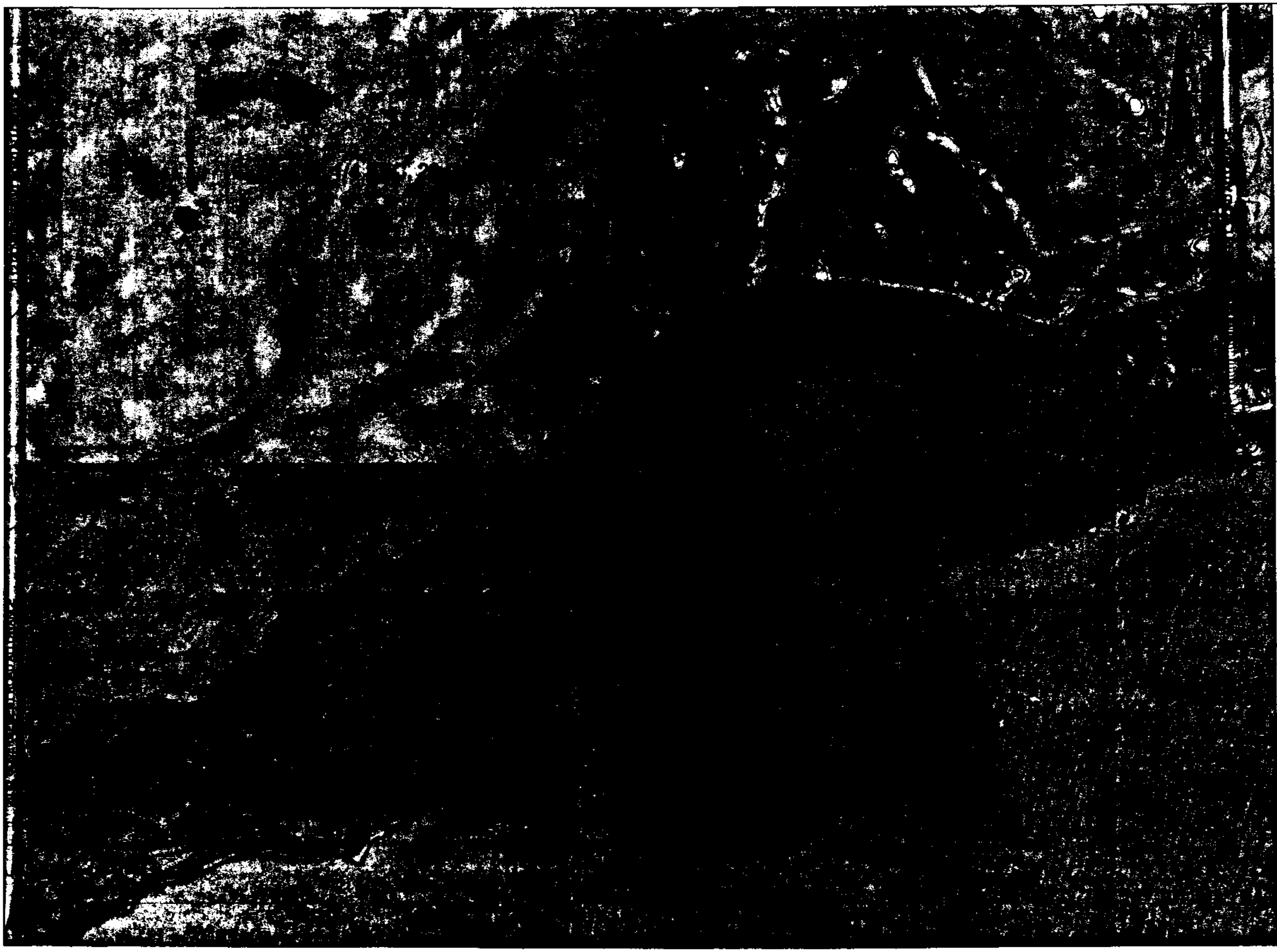
Drawings



LEGEND:

BORE HOLE LOCATION ⊕

PEIZOMETER ▣

MINOR CONTOUR (0.5m)

MAJOR CONTOUR (2.5m)

NOTES:

1. BASE DRAWING FROM HARDING BOSS & MCLEOD SURVEYS LTD.

DRAWING REVISIONS

6
5
4
3
2
1
NO DD/MM/YY DESCRIPTION BY

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engineering science technology

CLIENT

VAL LANE LTD.

PROJECT TITLE

GEOTECHNICAL ASSESSMENT
PROPOSED SUN DALE SUBDIVISION

DRAWING TITLE

BORE HOLE LOCATION PLAN

PROJECT NO. [illegible]

FILE NO. R3985101c

DATE [illegible]

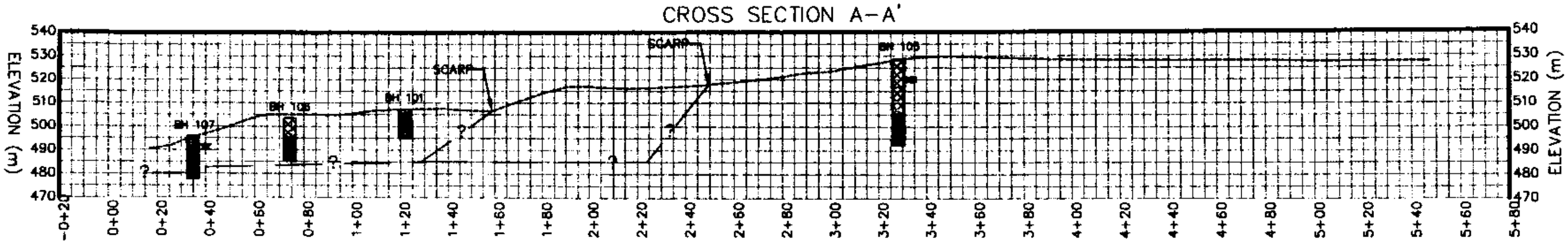
SCALE [illegible]

DRAWN [illegible]

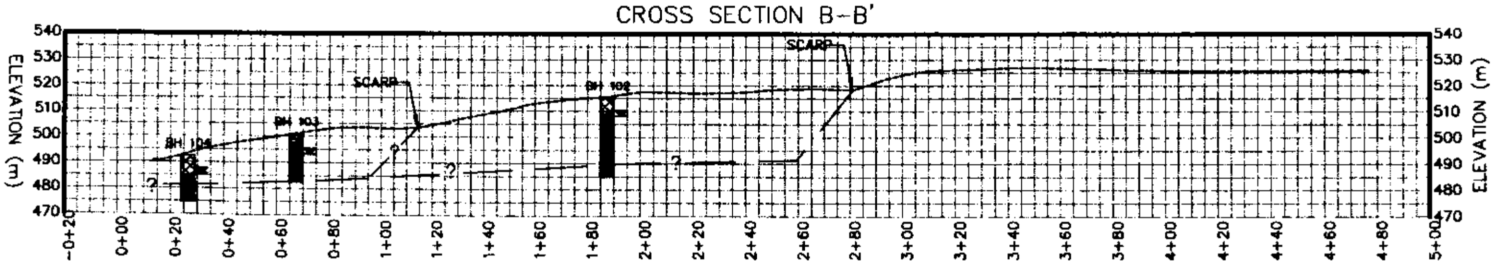
CHECKED

DWG. NO. R3985.1–1

CROSS SECTION A–A'



CROSS SECTION B–B'



LEGEND:

TOPSOIL	■
CLAY	■
SAND	■
OXIDIZED TILL	▨
UNOXIDIZED TILL	▨
LIMESTONE	■
COBBLES	■
GRAVEL	▨
SHALE	■
ESTIMATED LOCATION OF SLIP SURFACES	— ? —

6
5
4
3
2
1
NO DD/MM/YY DESCRIPTION BY

VAL LANE LTD.

GEOTECHNICAL ASSESSMENT
PROPOSED SUN DALE SUBDIVISION

STRATIGRAPHIC CROSS SECTIONS
A–A' AND B–B'

R3985.1
R3985101c
NTS
LLT
R3985.1–3

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Bore Hole Logs and Laboratory Test Data

Geotech BH m Elev CAL v03.ldt

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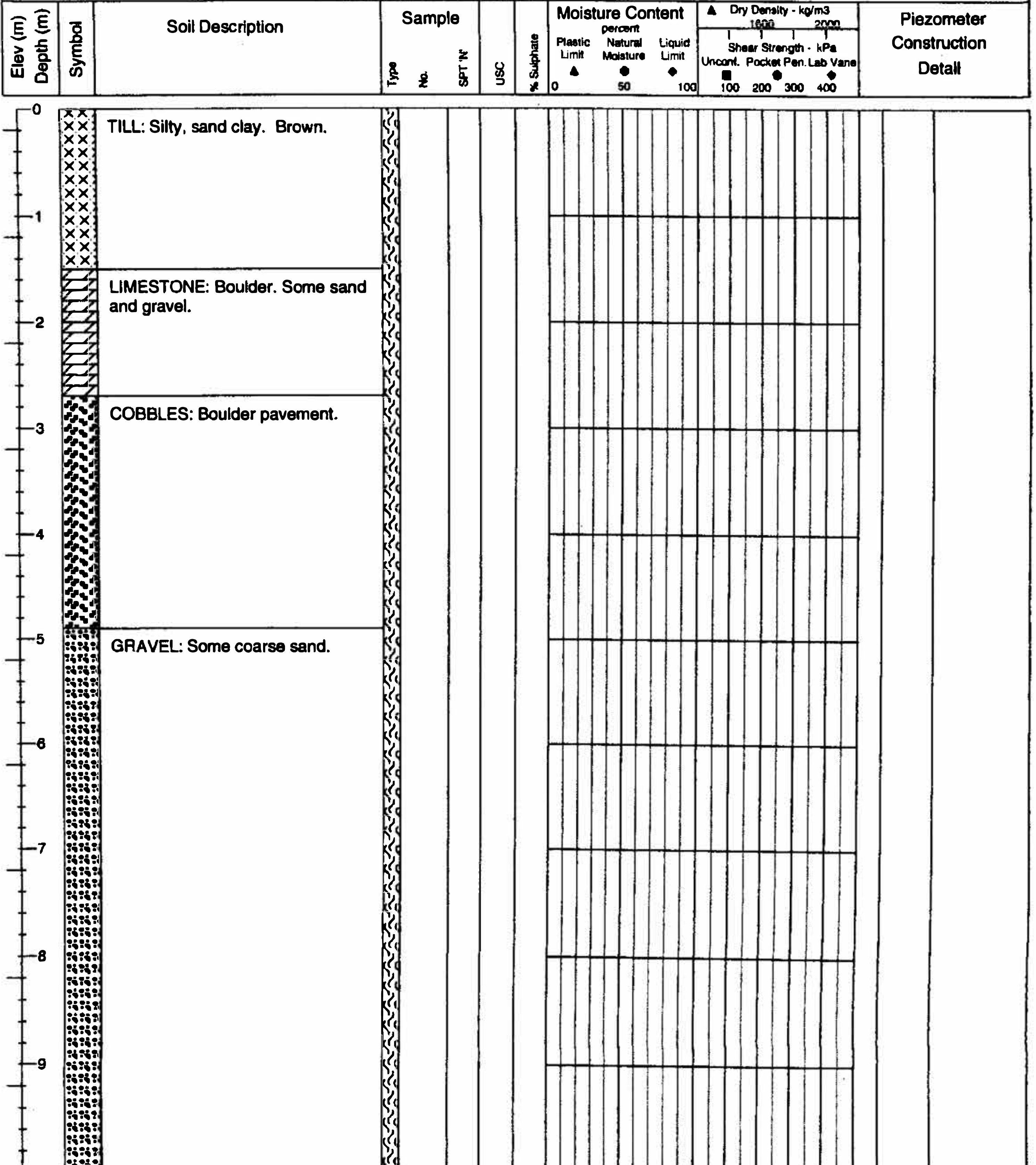
BORE HOLE LOG

Bore Hole: 101
Page: 1 of 2

Client:	Val Lane Ltd.	Northing:	5628952	Date Drilled:	02 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499190	Drill:	12-50 Failing
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	507.2m	Drilling Method:	Rotary Rig
Project No.:	R3985.1	Top Casing Elev.:		Logged by:	MDP



TILL: Silty, sand clay. Brown.

LIMESTONE: Boulder. Some sand and gravel.

COBBLES: Boulder pavement.

GRAVEL: Some coarse sand.

Geotech BH m Elev CAL v03.ldf

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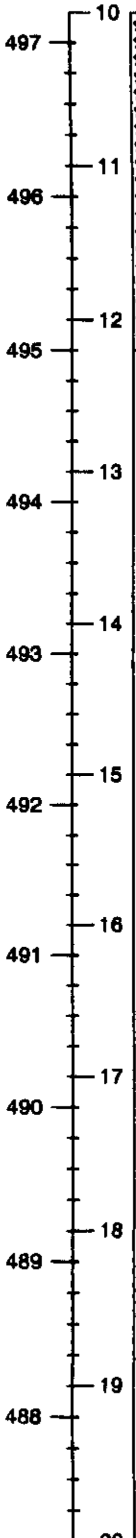
BORE HOLE LOG

Bore Hole: 101
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628952	Date Drilled:	02 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499190	Drill:	12-50 Failing
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	507.2m	Drilling Method:	Rotary Rig
Project No.:	R3985.1	Top Casing Elev.:		Logged by:	MDP



Elev (m) Depth (m)	Symbol	Soil Description	Sample Type	Sample No.	Sample SPT 'N'	USC	% Sulphate	Moisture Content percent: Plastic Limit ▲ Natural Moisture ● Liquid Limit ◆ (0 50 100)	▲ Dry Density - kg/m3 (1600 2000) Shear Strength - kPa: Unconf. ■ Pocket Pen. ● Lab Vane ◆ (100 200 300 400)	Piezometer Construction Detail
		GRAVEL: Some coarse sand.								
		NOTES: End of hole at 12.2m. Rotary drill used.								

SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE					CONSISTENCY				GRADATION					SHEAR STRENGTH			
DEPTH	NUMBER	TYPE	RECOVERY	WATER CONTENT	PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY	SULPHATE CONTENT	COMPRESSION TEST	LAB VANE	POCKET PEN	DRY DENSITY
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
1.52	MP1	BAG															
2.29	MP2	BAG															
3.05	MP3	BAG	No Testing														
3.81	MP4	BAG															
6.10	MP5	BAG															
6.86	MP6	BAG															
7.62	MP7	BAG															

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.
101

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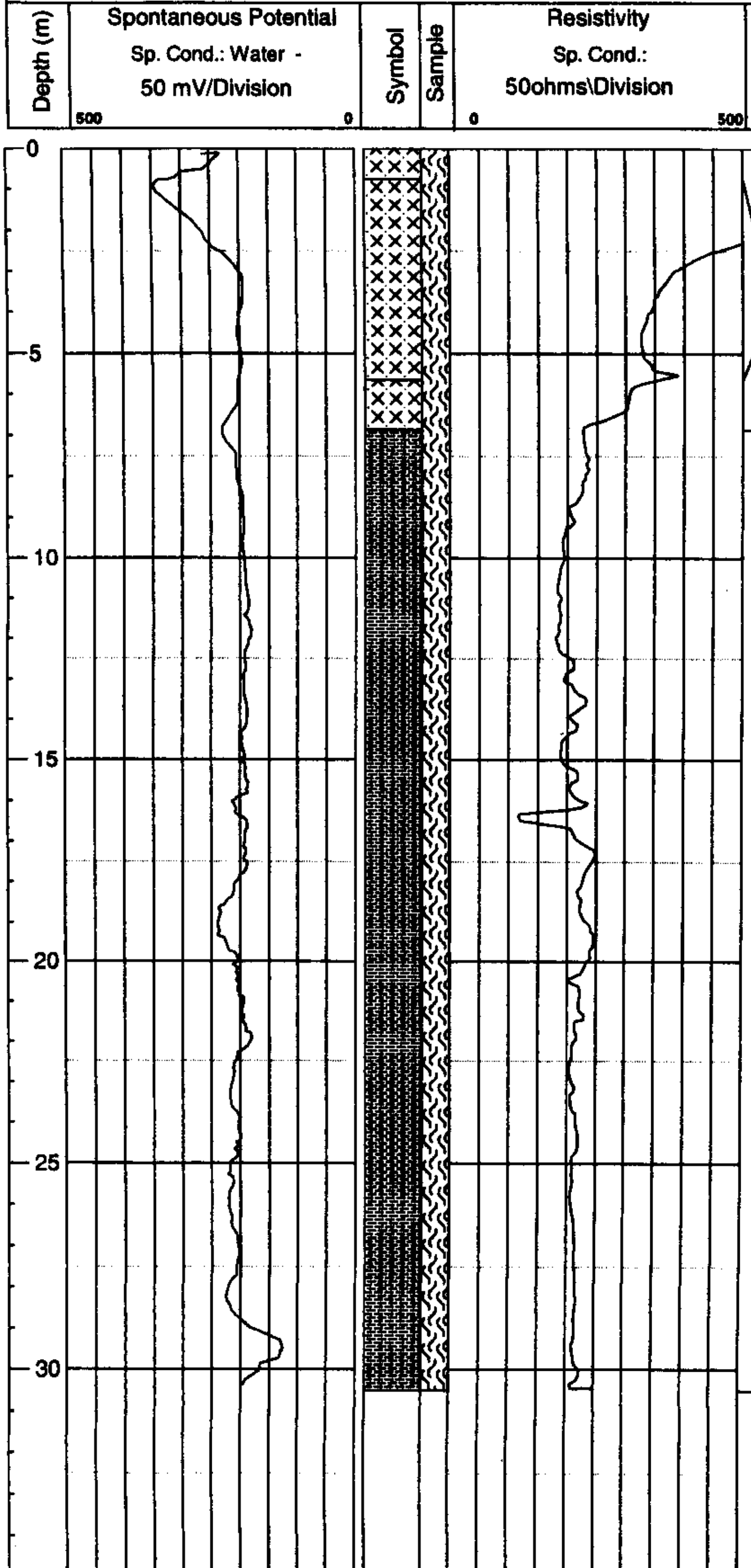
BORE HOLE LOG

Bore Hole: 102
Page: 1 of 1

Client:	Val Lane Ltd.	Northing:	5628663	Contractor:	Stauber Drilling Inc.
Project:	Proposed Sun Dale Subdivision	Easting:	498208	Drill:	12-50 Failing
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	515.73	Drilling Method:	Rotary Rig
Project No.:	R3985.1	Date Drilled:	03 Oct 2007	Logged by:	MDP



Soil Description

TILL, OXIDIZED: Sandy clay. Some silt. Brown.

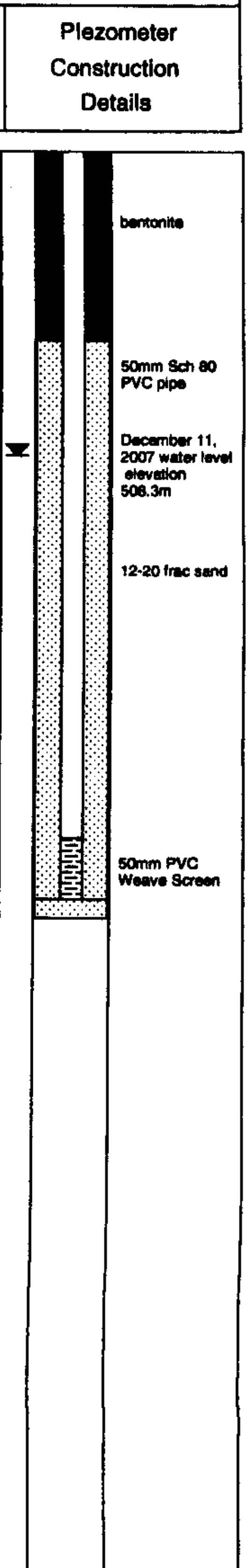
TILL, OXIDIZED: Silty clay. Trace sand and gravel. Brown.

@ 5.65m: boulders.

TILL, OXIDIZED: Clay. Some silt. Trace sand. Brown.

SHALE: Dark grey.

NOTES: End of hole at 30.5m. Rotary rig used. Samples collected @ 0.75m intervals. Piezometer installed in new bore hole 2m to the west.



SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE				WATER CONTENT	CONSISTENCY				GRADATION				SULPHATE CONTENT	SHEAR STRENGTH			DRY DENSITY
DEPTH	NUMBER	TYPE	RECOVERY		PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY		COMPRESSION TEST	LAB VANE	POCKET PEN	
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
0.76	MP8	BAG															
1.52	MP9	BAG															
2.29	MP10	BAG	No Testing														
3.05	MP11	BAG															
3.81	MP12	BAG															
4.57	MP13	BAG															
5.33	MP14	BAG															
6.10	MP15	BAG															
6.86	MP16	BAG															
7.62	MP17	BAG															
8.38	MP18	BAG															
9.14	MP19	BAG															
9.91	MP20	BAG															
10.67	MP21	BAG															
11.43	MP22	BAG															
12.19	MP23	BAG															
12.95	MP24	BAG															

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.
102

SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE					CONSISTENCY				GRADATION					SHEAR STRENGTH			
DEPTH	NUMBER	TYPE	RECOVERY	WATER CONTENT	PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY	SULPHATE CONTENT	COMPRESSION TEST	LAB VANE	POCKET PEN	DRY DENSITY
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
13.72	MP25	BAG															
14.48	MP26	BAG															
15.24	MP27	BAG		No Testing													
16.00	MP47	BAG															
16.76	MP28	BAG															
17.53	MP29	BAG															
18.29	MP30	BAG															
19.05	MP31	BAG															
19.81	MP32	BAG															
20.57	MP33	BAG															
21.34	MP34	BAG															
22.10	MP35	BAG															
22.86	MP36	BAG															
23.62	MP37	BAG															
24.38	MP38	BAG															
25.15	MP39	BAG															
25.91	MP40	BAG															

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.
102

SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE					CONSISTENCY				GRADATION					SHEAR STRENGTH			
DEPTH	NUMBER	TYPE	RECOVERY	WATER CONTENT	PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY	SULPHATE CONTENT	COMPRESSION TEST	LAB VANE	POCKET PEN	DRY DENSITY
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
26.67	MP41	BAG															
27.43	MP42	BAG		No Testing													
28.19	MP43	BAG															
28.96	MP44	BAG															
29.72	MP45	BAG															
30.48	MP46	BAG															

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.
102

Geotech BH m Elev CAL v03.ldf

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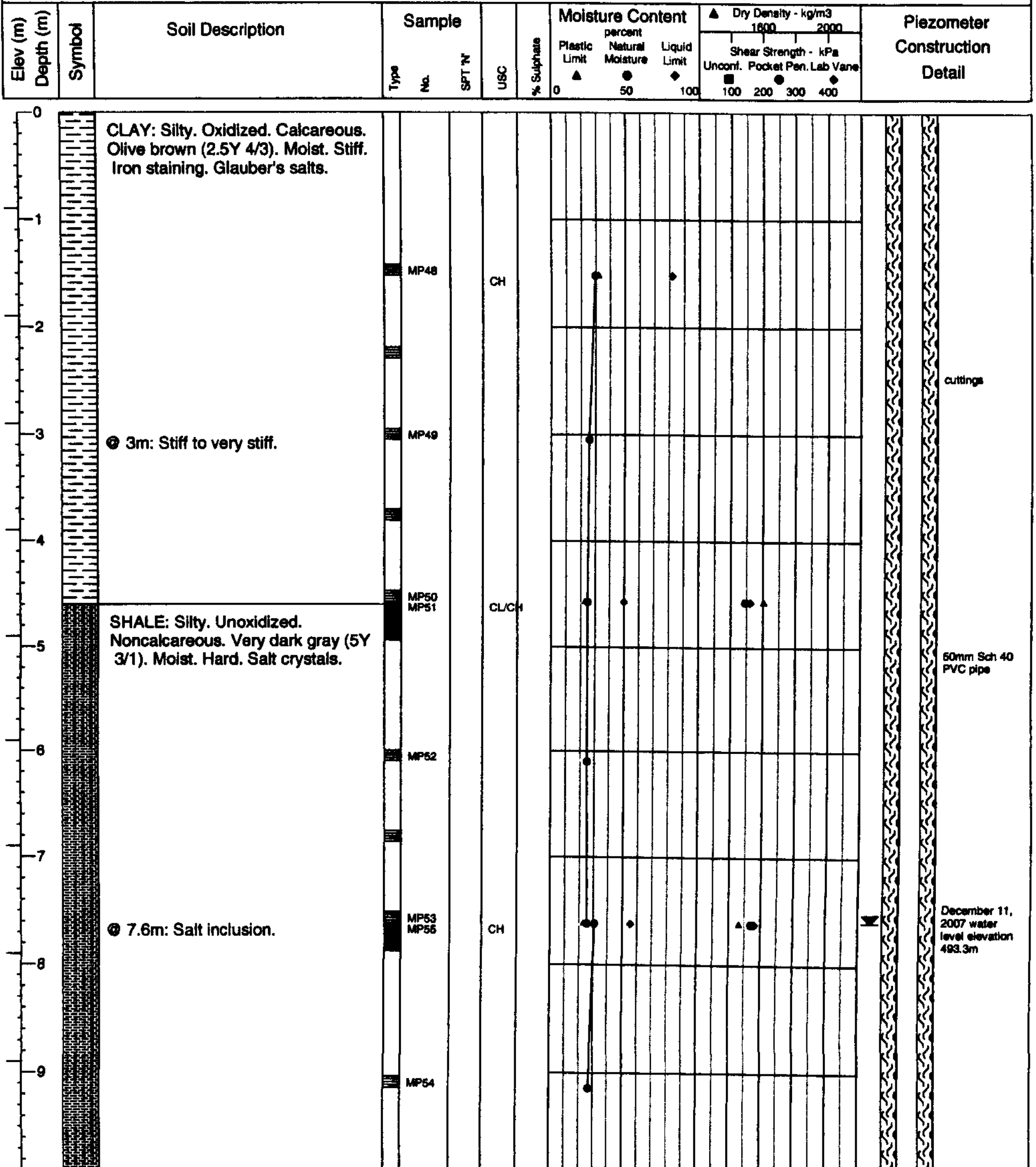
BORE HOLE LOG

Bore Hole: 103
Page: 1 of 2

Client:	Val Lane Ltd.	Northing:	5628573	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	498288	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	500.9m	Drilling Method:	Auger Drilling
Project No.:	R3985.1	Top Casing Elev.:	501.9	Logged by:	MDP



CLAY: Silty. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist. Stiff. Iron staining. Glauber's salts.

@ 3m: Stiff to very stiff.

SHALE: Silty. Unoxidized. Noncalcareous. Very dark gray (5Y 3/1). Moist. Hard. Salt crystals.

@ 7.6m: Salt inclusion.

Geotech BH m Elev CAL v03.ldf

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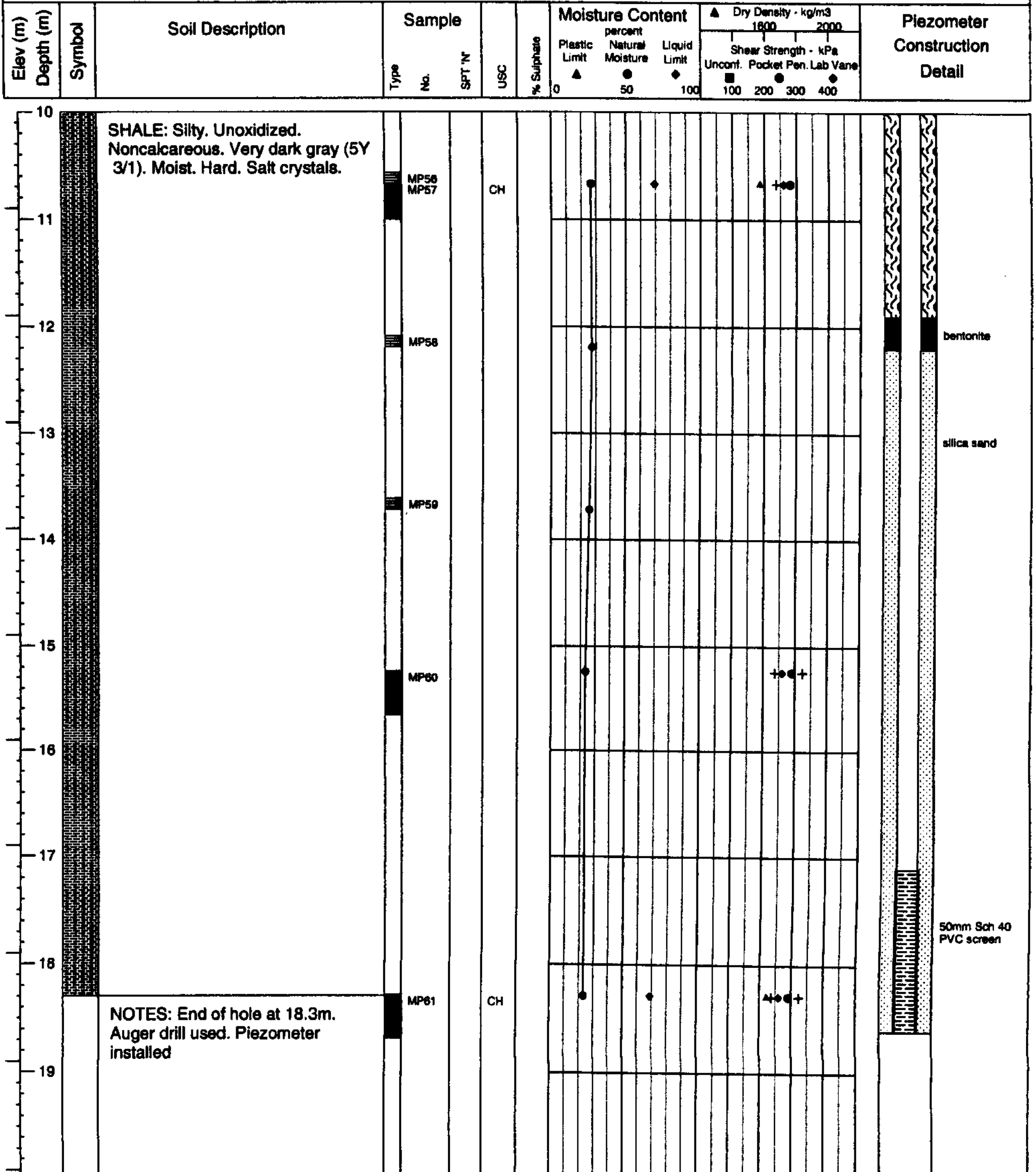
BORE HOLE LOG

Bore Hole: 103
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628573	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	498288	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	500.9m	Drilling Method:	Auger Drilling
Project No.:	R3985.1	Top Casing Elev.:	501.9	Logged by:	MDP



SHALE: Silty. Unoxidized. Noncalcareous. Very dark gray (5Y 3/1). Moist. Hard. Salt crystals.

NOTES: End of hole at 18.3m. Auger drill used. Piezometer installed

SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE					CONSISTENCY				GRADATION					SHEAR STRENGTH			
DEPTH	NUMBER	TYPE	RECOVERY	WATER CONTENT	PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY	SULPHATE CONTENT	COMPRESSION TEST	LAB VANE	POCKET PEN	DRY DENSITY
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m³
1.52	MP48	BAG		29.5	31.9	81.8	49.8	CH	0.0	1.7	98.3						
3.05	MP49	BAG		25.6													
4.57	MP50	BAG		24.6													
4.57	MP51	SY	370	24.7	23.1	49.7	26.6	CL/CH	0.0	21.5	78.5				160	145	1604
6.10	MP52	BAG		24.7													
7.62	MP53	BAG		25.4													
7.62	MP55	SY	260	30.9	23.1	55.4	32.2	CH	0.0	15.6	84.4				180	170	1465
9.14	MP54	BAG		26.7													
10.67	MP56	BAG		26.8													
10.67	MP57	SY	330	26.3	26.1	69.1	43.0	CH	0.0	0.8	99.2				260+	280	1573
12.19	MP58	BAG		27.2													
13.72	MP59	BAG		25.7													
15.24	MP60	SY	420	23.2											260+	290+	
18.29	MP61	SY	400	23.1	22.5	68.7	46.2	CH	0.0	25.4	74.6				260+	290+	1644

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.

103

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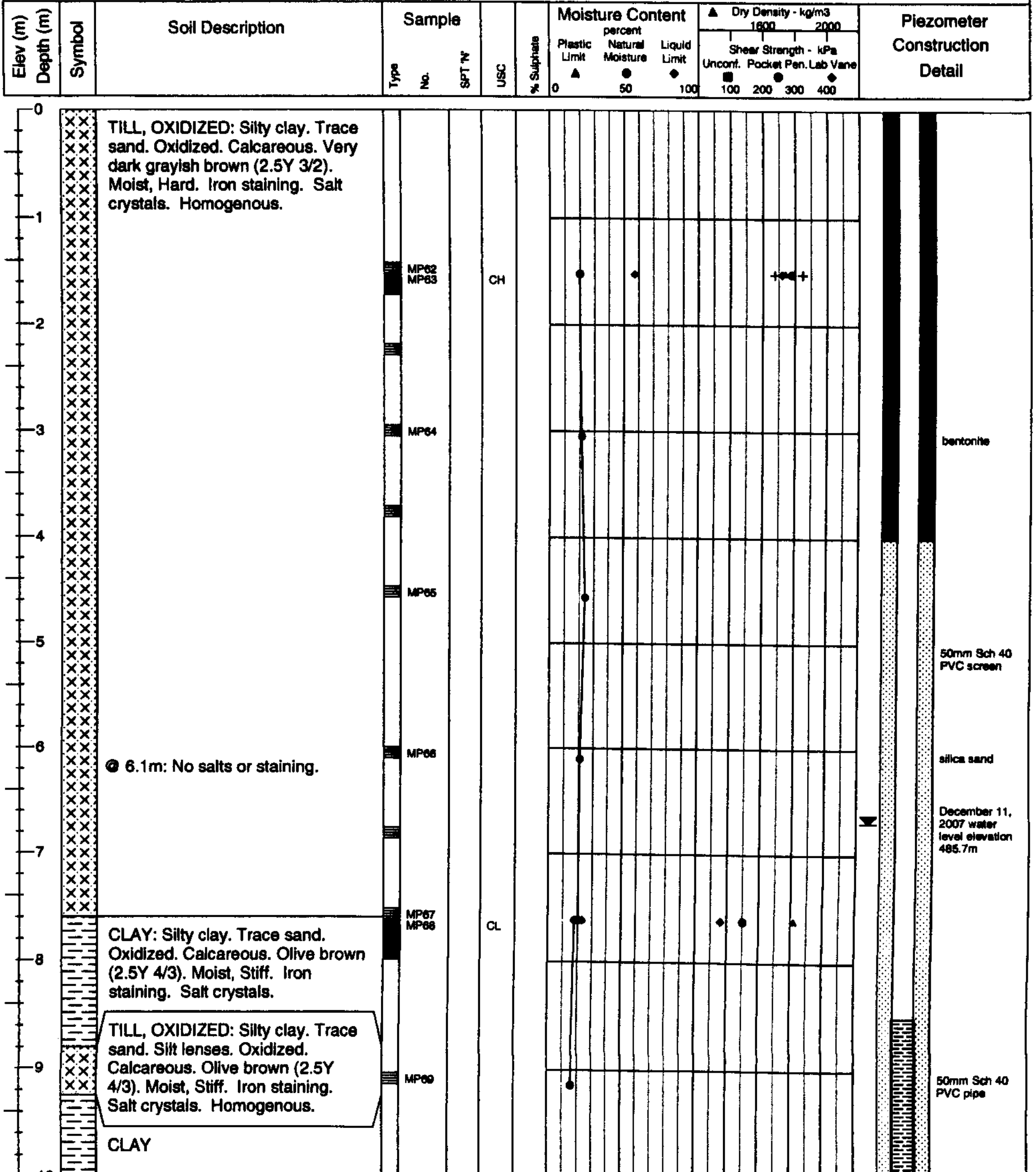
engineering science technology

BORE HOLE LOG

Bore Hole: 104
Page: 1 of 2

Client:	Val Lane Ltd.	Northing:	5628540	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	498312	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	492.4m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:	493.0m	Logged by:	MDP



TILL, OXIDIZED: Silty clay. Trace sand. Oxidized. Calcareous. Very dark grayish brown (2.5Y 3/2). Moist, Hard. Iron staining. Salt crystals. Homogenous.

@ 6.1m: No salts or staining.

CLAY: Silty clay. Trace sand. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist, Stiff. Iron staining. Salt crystals.

TILL, OXIDIZED: Silty clay. Trace sand. Silt lenses. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist, Stiff. Iron staining. Salt crystals. Homogenous.

CLAY

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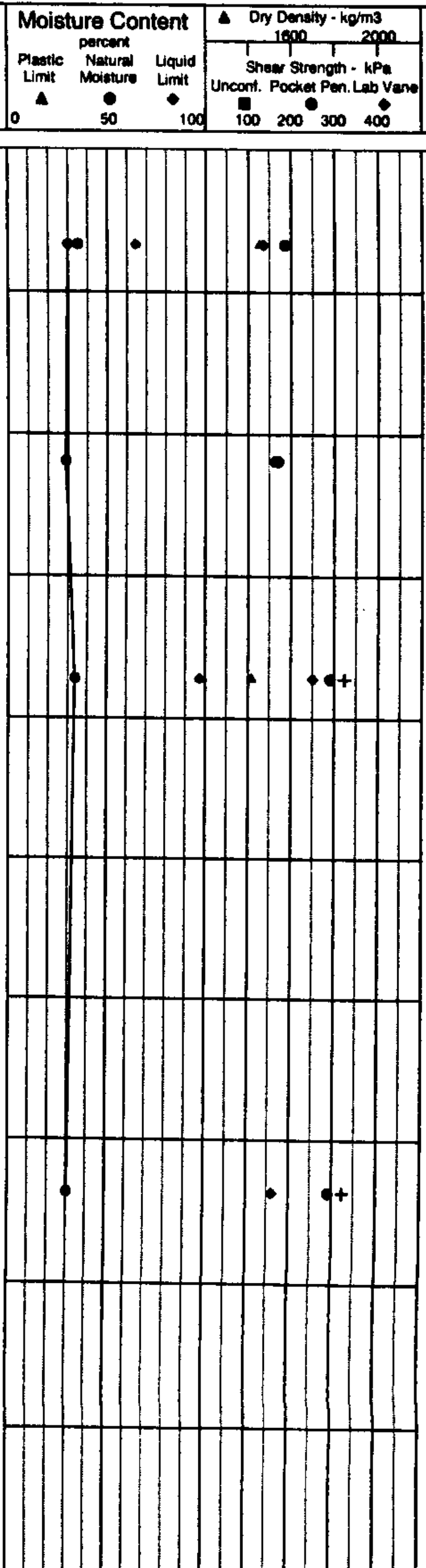
BORE HOLE LOG

Bore Hole: 104
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628540	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	498312	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	492.4m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:	493.0m	Logged by:	MDP

Elev (m)	Depth (m)	Symbol	Soil Description	Sample Type	Sample No.	SPT 'N'	USC	% Sulphate	Piezometer Construction Detail
482	10		CLAY: Silty clay. Oxidized. Calcareous. Dark grayish brown (2.5Y 4/2). Moist. Very stiff. Black streaks. Iron staining.		MP70 MP71		CH		
481	11		SHALE: Silty clay. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist, Very stiff. Iron staining.						
480	12		@ 12.2m: Turns very dark grayish brown (2.5Y 3/2).		MP72				
479	13		@ 13.7m: Turns very dark gray (5Y 3/1).		MP73		CH		
478	14								
477	15								
476	16								
475	17				MP74				
474	18		NOTES: End of hole at 18.3m. Auger drill used. Piezometer installed in new borehole 2m to the west.						
473	19								
	20								



Geotech BH m Elev CAL v03.tbl

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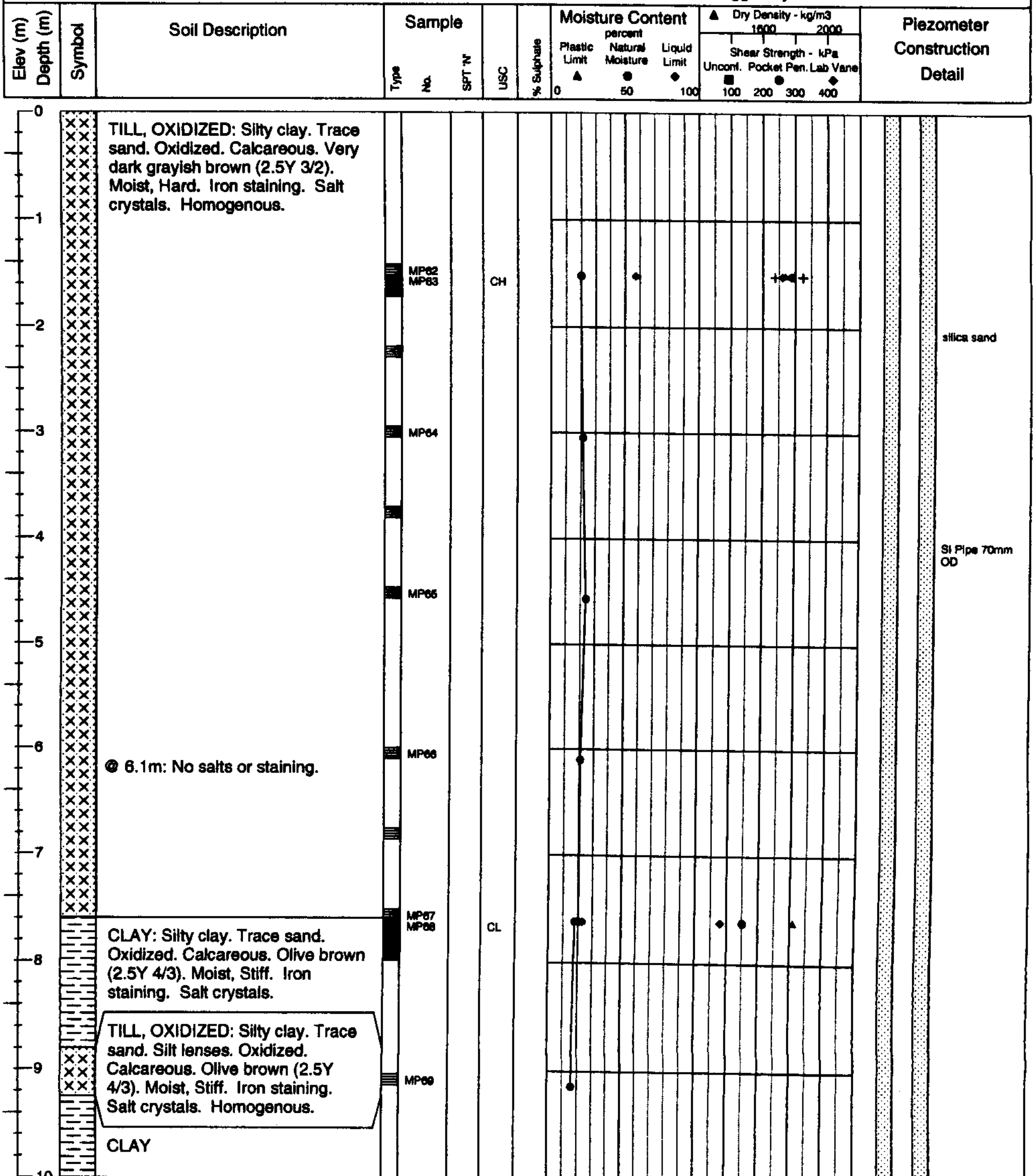
BORE HOLE LOG

Bore Hole:	104			**Page:**	1 of 2
Client:	Val Lane Ltd.	Northing:	5628540	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	498312	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	492.4m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:		Logged by:	MDP



TILL, OXIDIZED: Silty clay. Trace sand. Oxidized. Calcareous. Very dark grayish brown (2.5Y 3/2). Moist, Hard. Iron staining. Salt crystals. Homogenous.

@ 6.1m: No salts or staining.

CLAY: Silty clay. Trace sand. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist, Stiff. Iron staining. Salt crystals.

TILL, OXIDIZED: Silty clay. Trace sand. Silt lenses. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist, Stiff. Iron staining. Salt crystals. Homogenous.

CLAY

Geotech BH m Elev CAL v03.ldf

Clifton Associates Ltd.
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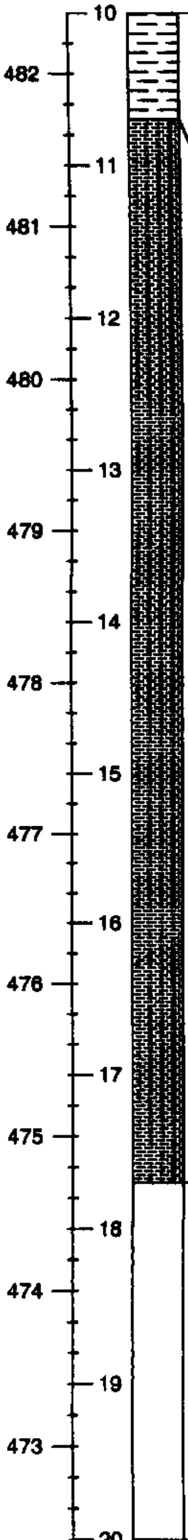
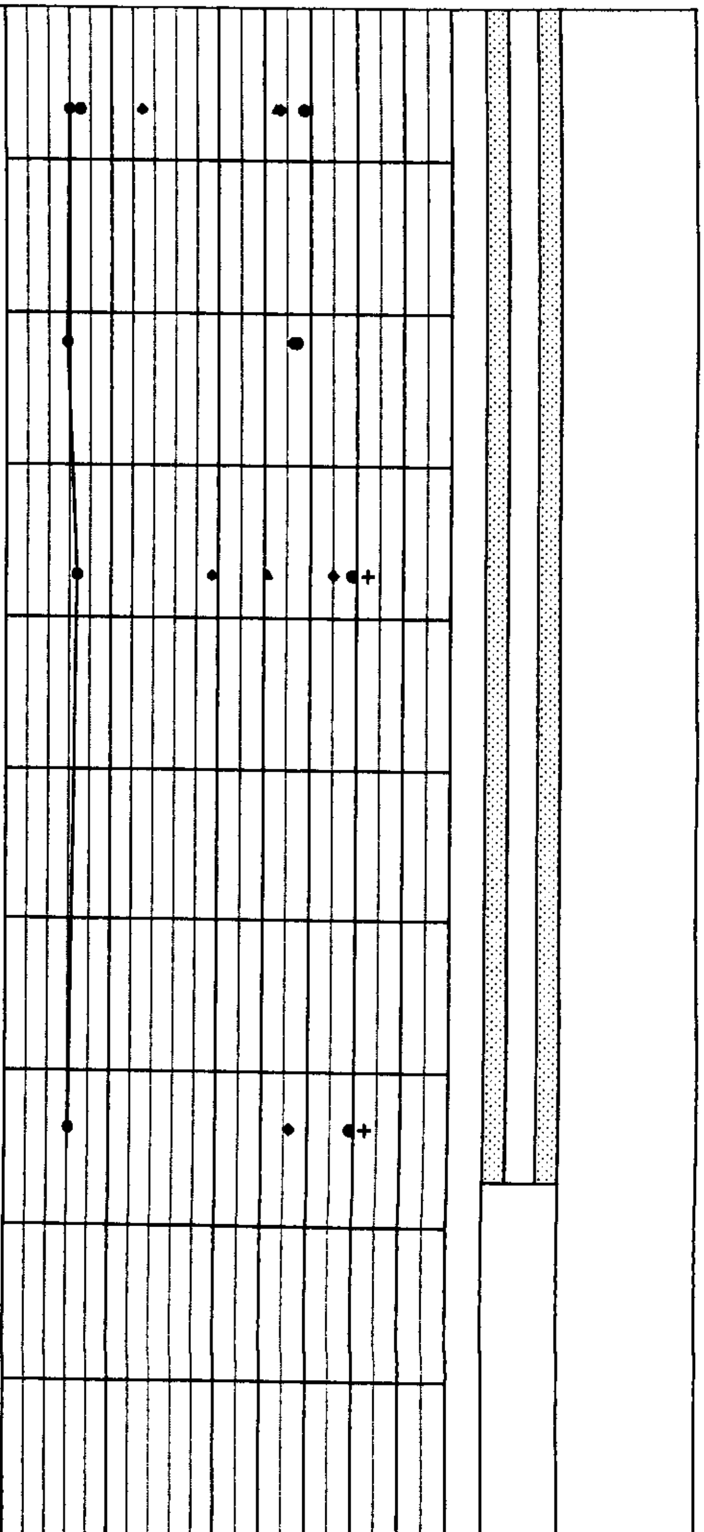
BORE HOLE LOG

Bore Hole: 104
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628540	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	498312	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	492.4m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:		Logged by:	MDP

Elev (m) Depth (m)	Symbol	Soil Description	Sample Type	No.	SPT 'N'	USC	% Sulphate	Moisture Content percent: Plastic Limit ▲, Natural Moisture ●, Liquid Limit ◆ (0 – 50 – 100)	▲ Dry Density - kg/m3 (1600 – 2000); Shear Strength - kPa: Unconf. ■, Pocket Pen. ●, Lab Vane ◆ (100 – 200 – 300 – 400)	Piezometer Construction Detail
		CLAY: Silty clay. Oxidized. Calcareous. Dark grayish brown (2.5Y 4/2). Moist. Very stiff. Black streaks. Iron staining.		MP70 MP71		CH				
		SHALE: Silty clay. Oxidized. Calcareous. Olive brown (2.5Y 4/3). Moist, Very stiff. Iron staining. @ 12.2m: Turns very dark grayish brown (2.5Y 3/2). @ 13.7m: Turns very dark gray (5Y 3/1).		MP72 MP73 MP74		 CH 				
		NOTES: End of hole at 18.3m. Auger drill used. SI installed in new bore hole.								





SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE				WATER CONTENT	CONSISTENCY				GRADATION				SULPHATE CONTENT	SHEAR STRENGTH			DRY DENSITY
DEPTH	NUMBER	TYPE	RECOVERY		PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY		COMPRESSION TEST	LAB VANE	POCKET PEN	
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
1.52	MP62	BAG		20.0													
1.52	MP63	SY	200	19.6	21.5	57.1	35.6	CH	0.0	11.4	88.6				260+	290+	1739
3.05	MP64	BAG		21.3													
4.57	MP65	BAG		24.0													
6.10	MP66	BAG		20.8													
7.62	MP67	BAG		20.2													
7.62	MP68	SY	370	17.6	14.0	23.0	9.0	CL	0.0	34.8	65.2				80	150	1819
9.14	MP69	BAG		15.9													
10.67	MP70	BAG		35.1													
10.67	MP71	SY	370	29.9	23.2	64.2	41.0	CH	0.0	15.8	84.2				135	185	1453
12.19	MP72	SY	390	28.9											160	170	
13.72	MP73	SY	430	33.8	35.3	97.2	61.9	CH	0.0	2.3	97.7				250	290+	1416
17.37	MP74	SY	360	30.3											160	290+	

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.

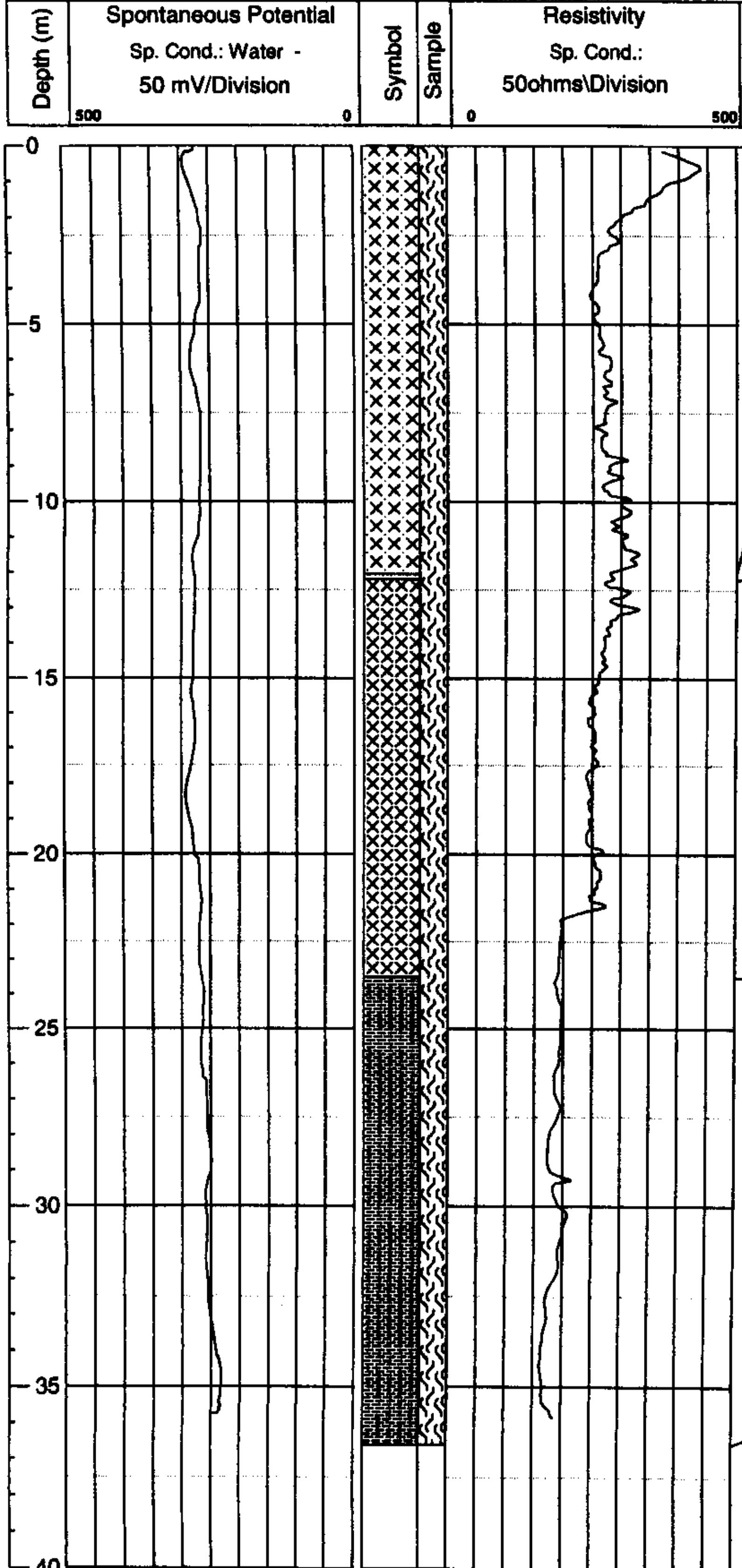
104

Clifton Associates Ltd.
engineering science technology

BORE HOLE LOG

Bore Hole: 105
Page: 1 of 1

Client:	Val Lane Ltd.	Northing:	5629136	Contractor:	Stauber Drilling Inc.
Project:	Proposed Sun Dale Subdivision	Easting:	499064	Drill:	12-50 Failing
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	528.8m	Drilling Method:	Rotary Rig
Project No.:	R3985.1	Date Drilled:	04 Oct 2007	Logged by:	MDP



Soil Description

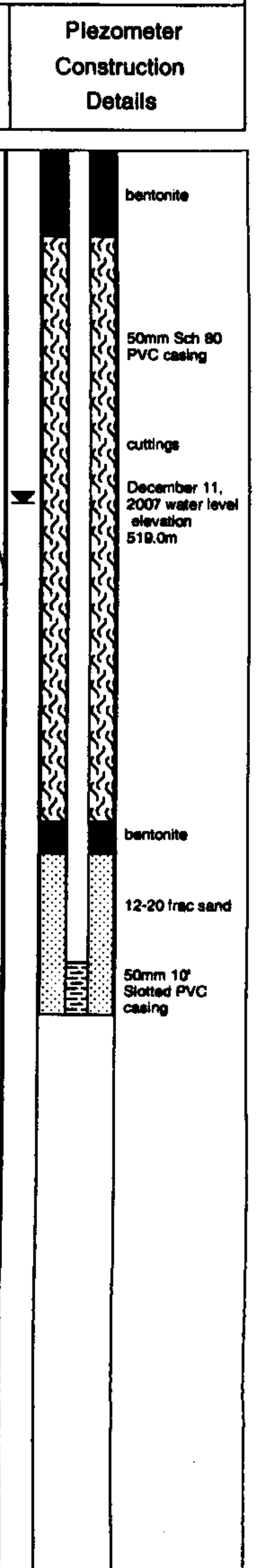
TILL, OXIDIZED: Clay. Some silt. Trace sand. Brown.

SAND: Grey.

TILL, UNOXIDIZED: Clay. Some silt. Trace sand. Gray.

SHALE: Clay. Some silt. Gray.

NOTES: End of hole at 36.6m. Rotary rig used. Samples collected @ 0.75m intervals. Piezometer installed in new bore hole 2m to the west.



SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE					CONSISTENCY				GRADATION					SHEAR STRENGTH			
DEPTH	NUMBER	TYPE	RECOVERY	WATER CONTENT	PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY	SULPHATE CONTENT	COMPRESSION TEST	LAB VANE	POCKET PEN	DRY DENSITY
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
	No Sampling																

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PROJECT	Proposed Sun Dale Subdivision
LOCATION	Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO.	R3985.1

BORE HOLE NO.

105

Geotech BH m Elev CAL v03.ldf

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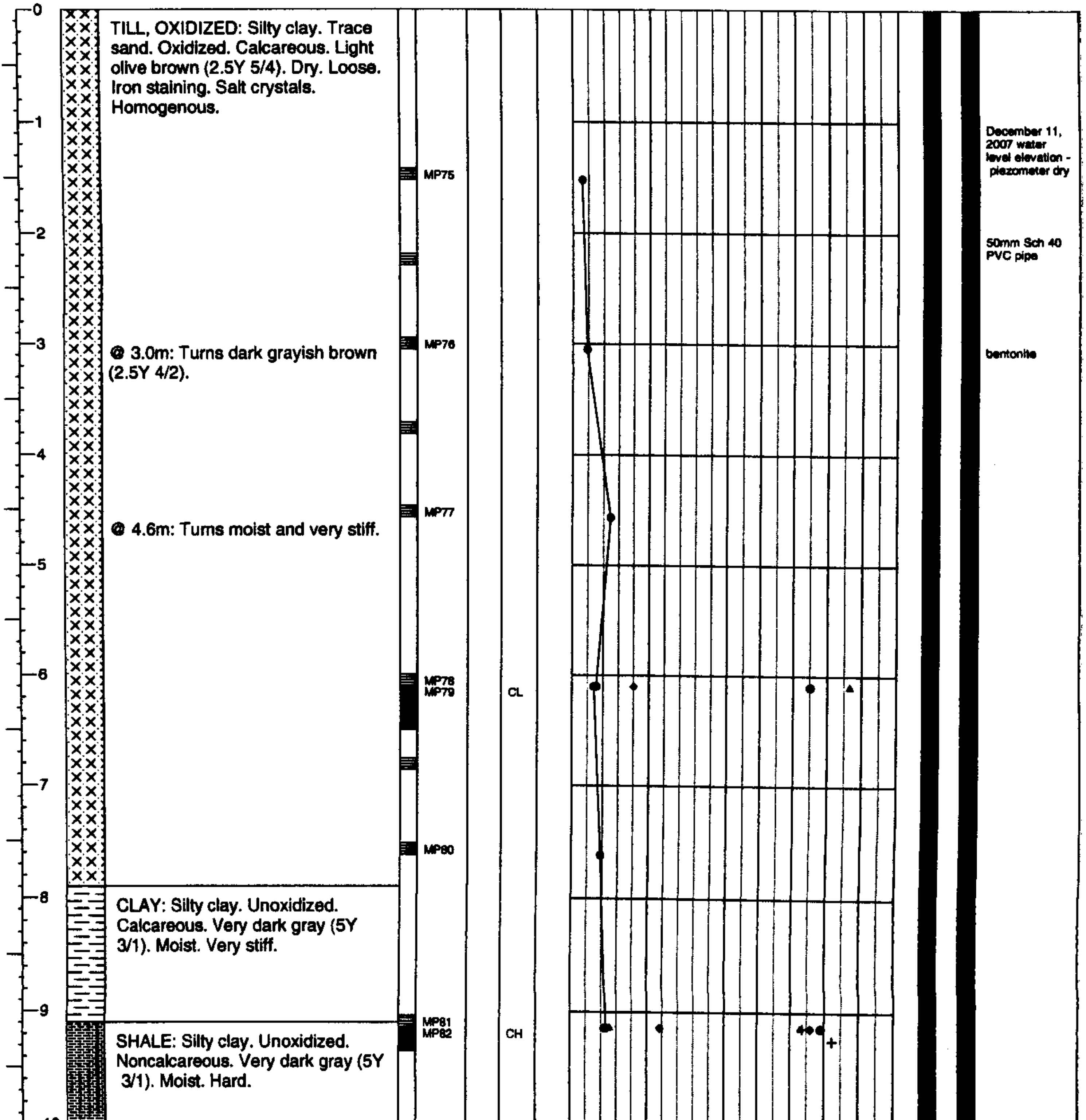
BORE HOLE LOG

Bore Hole: 106
Page: 1 of 2

Client:	Val Lane Ltd.	Northing:	5628906	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499207	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	503.5m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:	504.3m	Logged by:	MDP

Elev (m)	Depth (m)	Symbol	Soil Description	Sample: Type	Sample: No.	Sample: SPT 'N'	USC	% Sulphate	Moisture Content percent: Plastic Limit ▲ Natural Moisture ● Liquid Limit ◆ (0 50 100)	▲ Dry Density - kg/m3 (1600 2000); Shear Strength - kPa: Unconf. ■ Pocket Pen. ● Lab Vane ◆ (100 200 300 400)	Piezometer Construction Detail



TILL, OXIDIZED: Silty clay. Trace sand. Oxidized. Calcareous. Light olive brown (2.5Y 5/4). Dry. Loose. Iron staining. Salt crystals. Homogenous.

@ 3.0m: Turns dark grayish brown (2.5Y 4/2).

@ 4.6m: Turns moist and very stiff.

CLAY: Silty clay. Unoxidized. Calcareous. Very dark gray (5Y 3/1). Moist. Very stiff.

SHALE: Silty clay. Unoxidized. Noncalcareous. Very dark gray (5Y 3/1). Moist. Hard.

Geotech BH m Elev CAL v03.ldf

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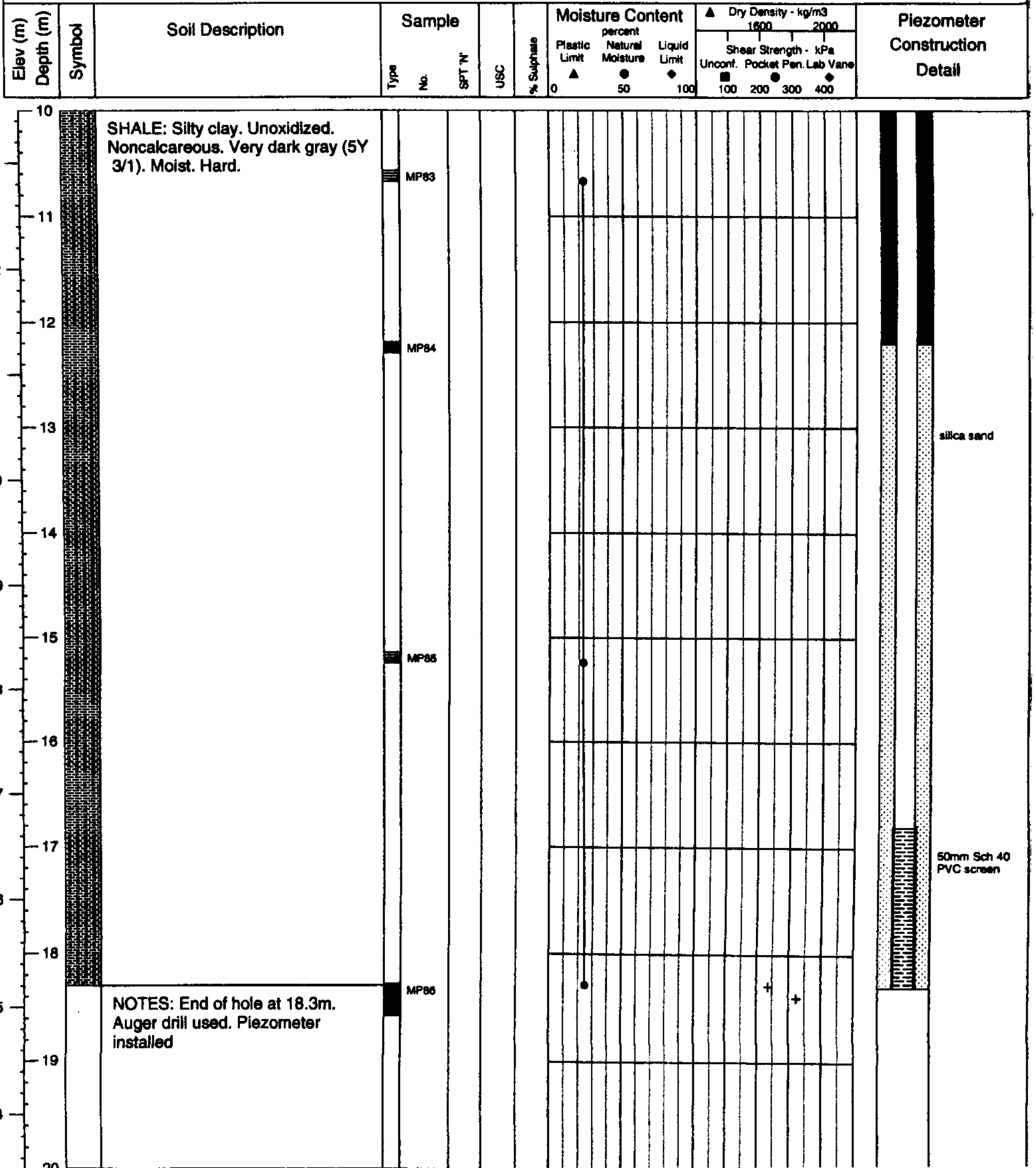
BORE HOLE LOG

Bore Hole: 106
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628906	Date Drilled:	04 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499207	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	503.5m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:	504.3m	Logged by:	MDP



SHALE: Silty clay. Unoxidized. Noncalcareous. Very dark gray (5Y 3/1). Moist. Hard.

NOTES: End of hole at 18.3m. Auger drill used. Piezometer installed

SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE				WATER CONTENT	CONSISTENCY				GRADATION				SULPHATE CONTENT	SHEAR STRENGTH			DRY DENSITY
DEPTH	NUMBER	TYPE	RECOVERY		PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY		COMPRESSION TEST	LAB VANE	POCKET PEN	
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
1.52	MP75	BAG		5.9													
3.05	MP76	BAG		9.1													
4.57	MP77	BAG		24.6													
6.10	MP78	BAG		15.6													
6.10	MP79	SY	400	14.0	15.8	40.0	24.2	CL	0.8	27.8	71.4				250	250	1932
7.62	MP80	BAG		18.8													
9.14	MP81	BAG		23.2													
9.14	MP82	SY	210	22.0	25.6	58.3	32.7	CH	0.0	5.4	94.6				260+	290+	1661
10.67	MP83	BAG		23.1													
12.19	MP84	SY	NR												N/A	N/A	
15.24	MP85	BAG		22.9													
18.29	MP86	SY	290	24.8											260+	290+	

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PROJECT	Proposed Sun Dale Subdivision
LOCATION	Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO.	R3985.1

BORE HOLE NO.

106

Geotech BH m Elev CAL v03.ldf

Clifton Associates Ltd.
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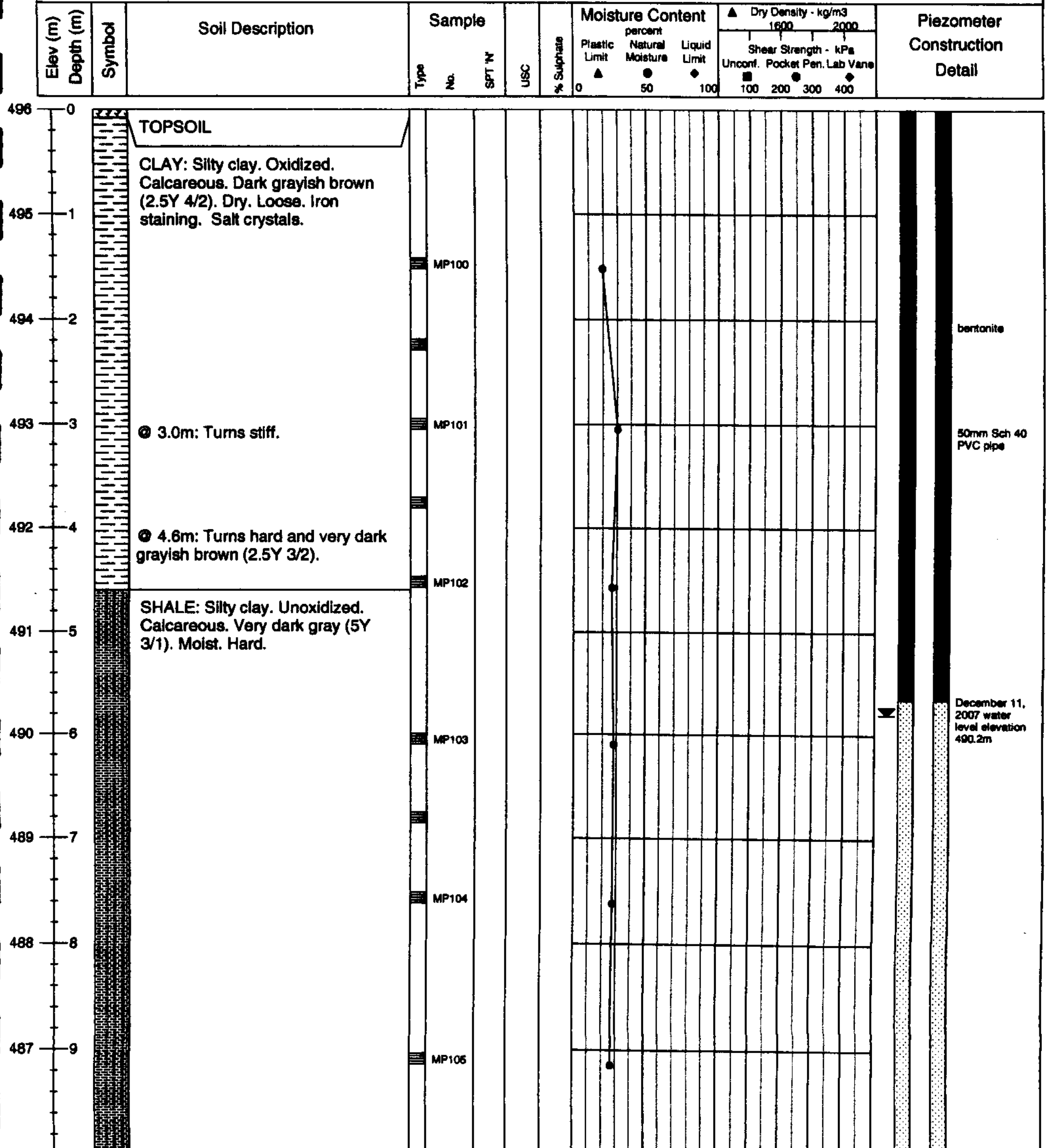
BORE HOLE LOG

Bore Hole: 107
Page: 1 of 2

Client:	Val Lane Ltd.	Northing:	5628882	Date Drilled:	05 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499244	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	496.0m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:	496.7m	Logged by:	MDP



TOPSOIL

CLAY: Silty clay. Oxidized. Calcareous. Dark grayish brown (2.5Y 4/2). Dry. Loose. Iron staining. Salt crystals.

@ 3.0m: Turns stiff.

@ 4.6m: Turns hard and very dark grayish brown (2.5Y 3/2).

SHALE: Silty clay. Unoxidized. Calcareous. Very dark gray (5Y 3/1). Moist. Hard.

Geotech BH m Elev CAL v03.ldf

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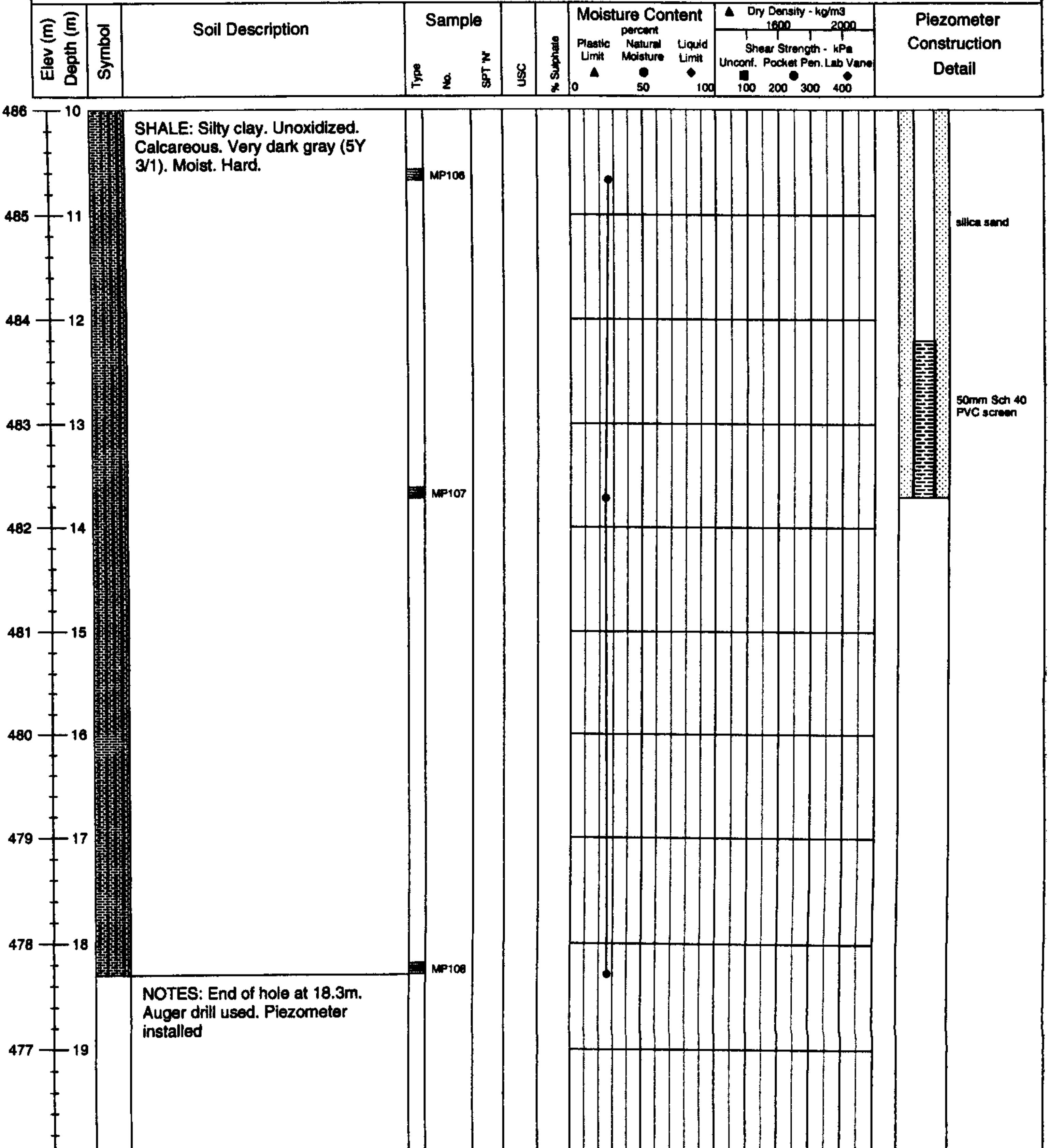
BORE HOLE LOG

Bore Hole: 107
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628882	Date Drilled:	05 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499244	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	496.0m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:	496.7m	Logged by:	MDP



SHALE: Silty clay. Unoxidized. Calcareous. Very dark gray (5Y 3/1). Moist. Hard.

NOTES: End of hole at 18.3m. Auger drill used. Piezometer installed

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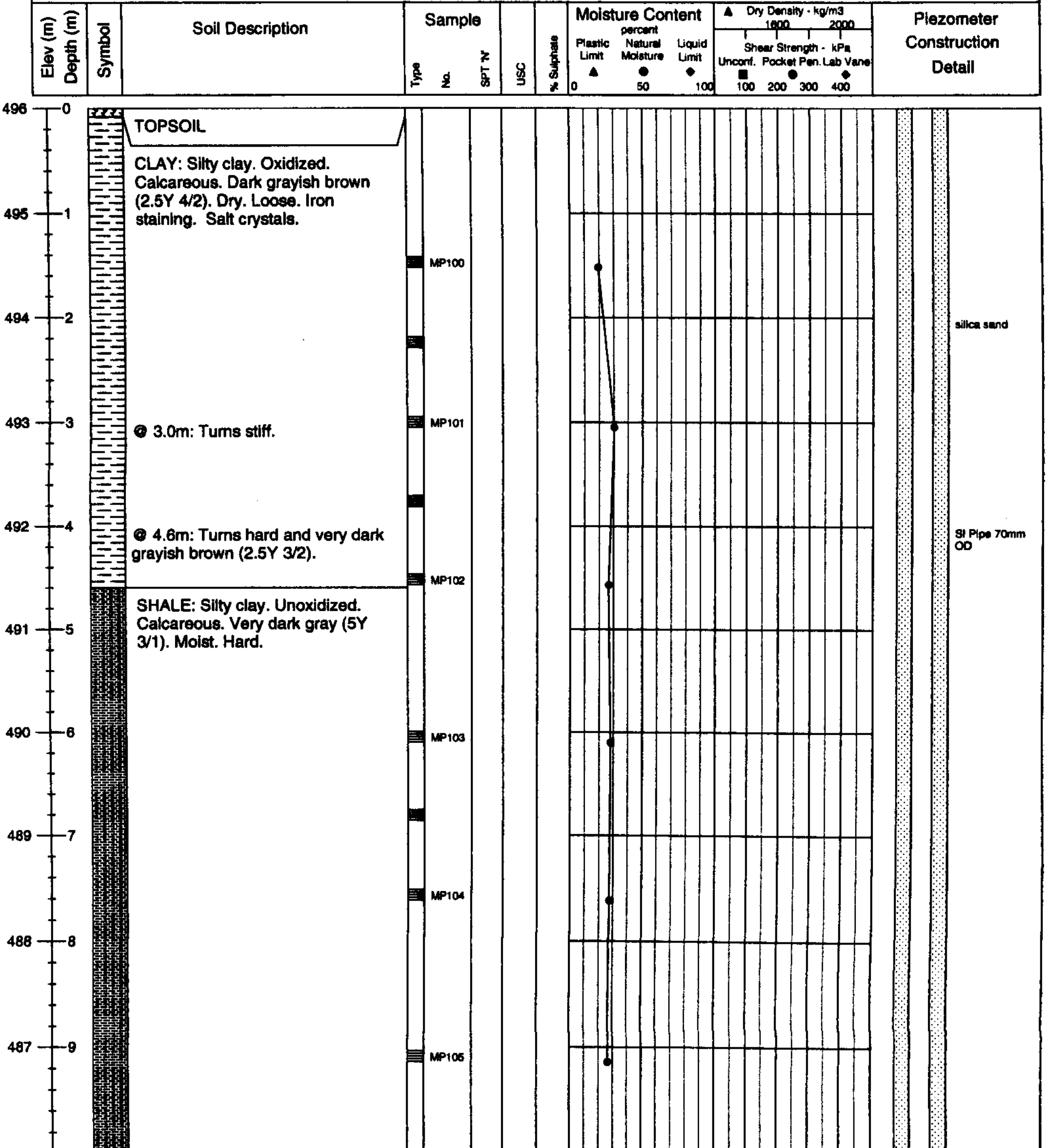
BORE HOLE LOG

Bore Hole: 107
Page: 1 of 2

Client:	Val Lane Ltd.	Northing:	5628882	Date Drilled:	05 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499244	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	496.0m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:		Logged by:	MDP



TOPSOIL

CLAY: Silty clay. Oxidized. Calcareous. Dark grayish brown (2.5Y 4/2). Dry. Loose. Iron staining. Salt crystals.

@ 3.0m: Turns stiff.

@ 4.6m: Turns hard and very dark grayish brown (2.5Y 3/2).

SHALE: Silty clay. Unoxidized. Calcareous. Very dark gray (5Y 3/1). Moist. Hard.

Geotech BH m Elev CAL v03.tdf

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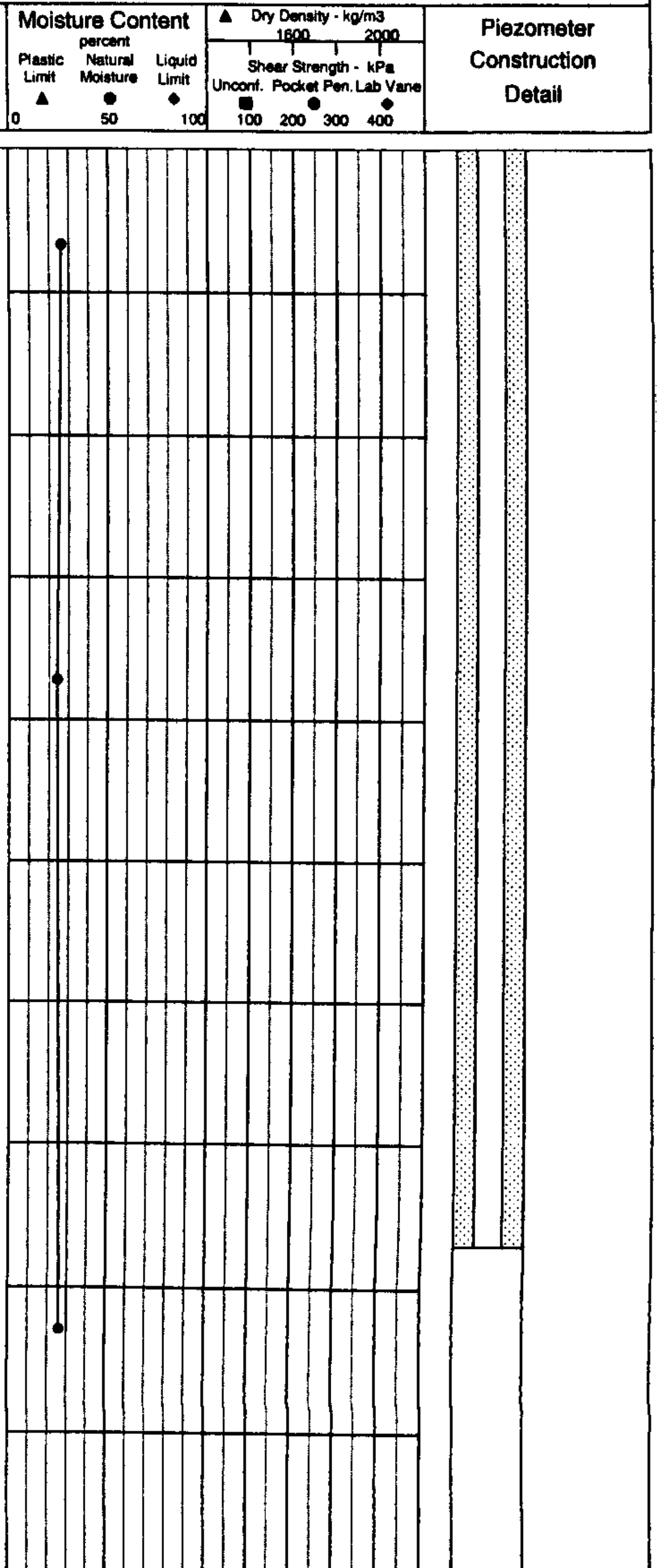
BORE HOLE LOG

Bore Hole: 107
Page: 2 of 2

Client:	Val Lane Ltd.	Northing:	5628882	Date Drilled:	05 Oct 2007
Project:	Proposed Sun Dale Subdivision	Easting:	499244	Drill:	Brat 22
Location:	Parts of Sec28 and Sec29-21-22-W2M	Ground Elev.:	496.0m	Drilling Method:	Solids Stem Auger
Project No.:	R3985.1	Top Casing Elev.:		Logged by:	MDP

Elev (m)	Depth (m)	Symbol	Soil Description	Sample Type	Sample No.	SPT 'N'	USC	% Sulphate
486	10	▨	SHALE: Silty clay. Unoxidized. Calcareous. Very dark gray (5Y 3/1). Moist. Hard.	▤	MP106			
485	11	▨						
484	12	▨						
483	13	▨		▤	MP107			
482	14	▨						
481	15	▨						
480	16	▨						
479	17	▨						
478	18	▨	NOTES: End of hole at 18.3m. Auger drill used. SI installed in new bore hole.	▤	MP108			
477	19							



SUMMARY OF SAMPLING AND LABORATORY TEST DATA

SAMPLE				WATER CONTENT	CONSISTENCY				GRADATION				SULPHATE CONTENT	SHEAR STRENGTH			DRY DENSITY
DEPTH	NUMBER	TYPE	RECOVERY		PLASTIC LIMIT	LIQUID LIMIT	PLASTICITY INDEX	USC	GRAVEL	SAND	SILT	CLAY		COMPRESSION TEST	LAB VANE	POCKET PEN	
meters			mm	%	%	%	%		%	%	%	%	%	kPa	kPa	kPa	kg/m^3
1.52	MP100	BAG		19.3													
3.05	MP101	BAG		30.3													
4.57	MP102	BAG		26.5													
6.10	MP103	BAG		28.0													
7.62	MP104	BAG		27.3													
9.14	MP105	BAG		26.4													
10.67	MP106	BAG		26.2													
13.72	MP107	BAG		24.2													
18.29	MP108	BAG		26.0													

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PROJECT Proposed Sun Dale Subdivision
LOCATION Parts of Sec28 and Sec29-21-22-W2M
PROJECT NO. R3985.1

BORE HOLE NO.

107

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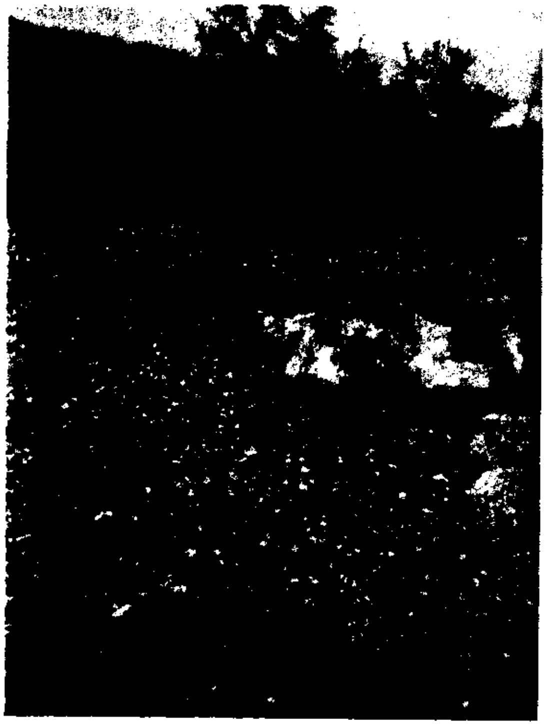
Photographs

1. East across point, well developed rip rap
071002 to 05 Field Trip 007.jpg

2. West from point, good rip rap armour
071002 to 05 Field Trip 008.jpg

3. East from point, good rip rap on shore
071002 to 05 Field Trip 009.jpg

4. West near beach area, thinner rip rap, sand
071002 to 05 Field Trip 010.jpg



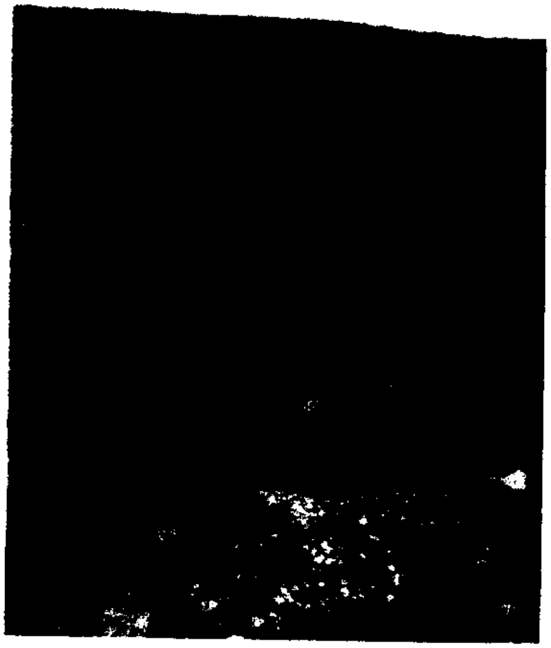
5. Sandy gravel beach w/cobbles
071002 to 05 Field Trip 011.jpg

6. Sand transition to cobbles to east
071002 to 05 Field Trip 012.jpg

7. View west, sandy beach area
071002 to 05 Field Trip 013.jpg

8. Inland from beach area
071002 to 05 Field Trip 014.jpg

9. Shale exposure
071002 to 05 Field Trip 015.jpg



10. Exposed shale slope, sandy beach w/cobbles
071002 to 05 Field Trip 016.jpg

11. View east of west point, dense rip rap
071002 to 05 Field Trip 017.jpg

12. Row of trees below BH102
071002 to 05 Field Trip 018.jpg

13. Exposed shale, east of BH102
071002 to 05 Field Trip 019.jpg

14. Shale slope above graben (meadow) east of pool area
071002 to 05 Field Trip 020.jpg

15. view west, east of BH104 across eroded shale
071002 to 05 Field Trip 021.jpg

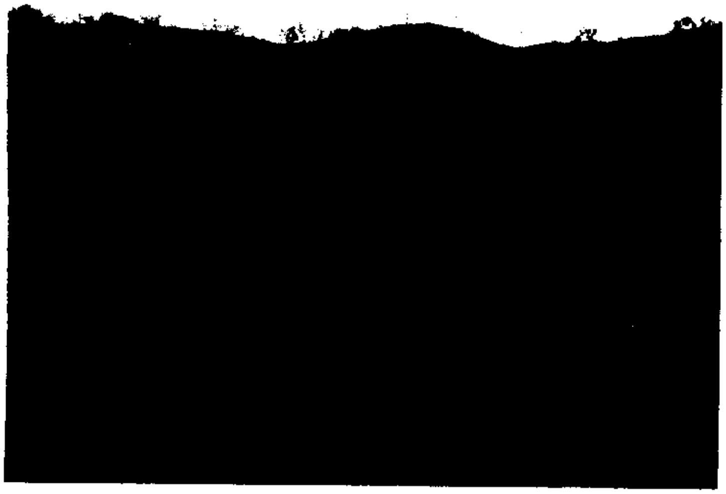
16. View east, shale slope and beach
071002 to 05 Field Trip 022.jpg

17. Eroded slope, wide beach has formed
071002 to 05 Field Trip 023.jpg

18. Shale slope mid picture eroded to form scalloped shore
071002 to 05 Field Trip 024.jpg

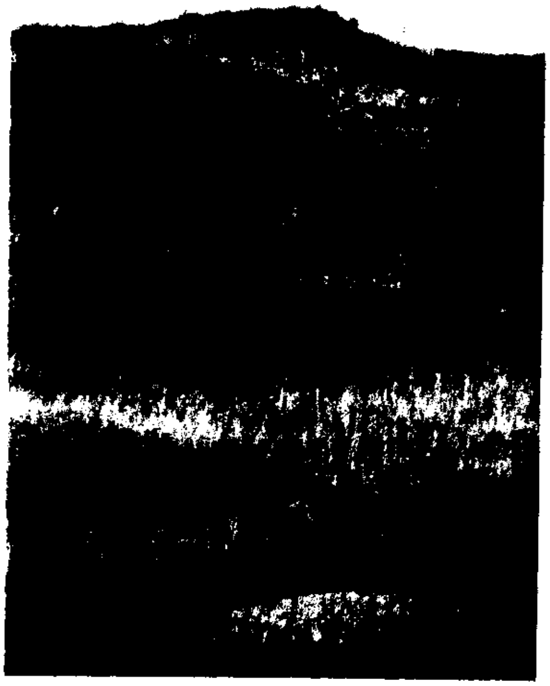
19. boulders at shoreline
071002 to 05 Field Trip 025.jpg

20. View east to high bluff across bouldery shoreline
071002 to 05 Field Trip 026.jpg



21. Exposed shale near shoreline
071002 to 05 Field Trip 027.jpg

22. Large slabs on shoreline
071002 to 05 Field Trip 028.jpg

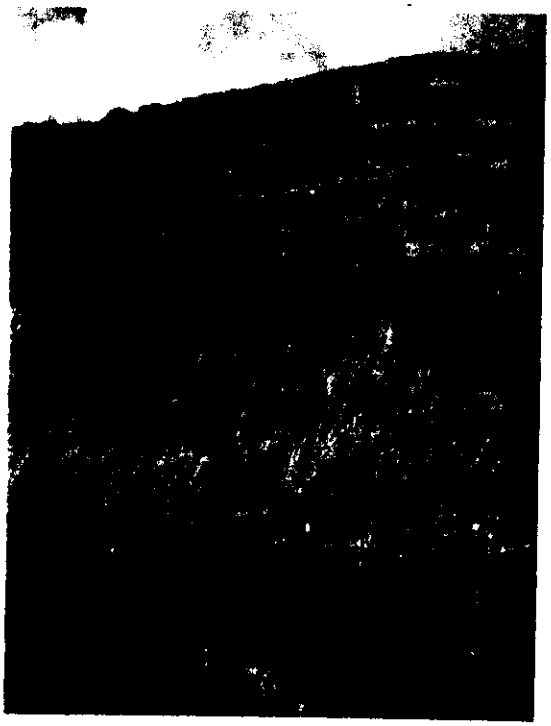


23. Small block of till at surface at east end
071002 to 05 Field Trip 029.jpg

24. 50mm clay overlying sand at beach
071002 to 05 Field Trip 030.jpg

25. 300mm to 600mm of eroded clay overlies beach sand
071002 to 05 Field Trip 031.jpg

26. Moderate cobble rip rap on beach protects shale slope
071002 to 05 Field Trip 032.jpg



27. Approx. 3m of till on top of bluff, east end
071002 to 05 Field Trip 033.jpg

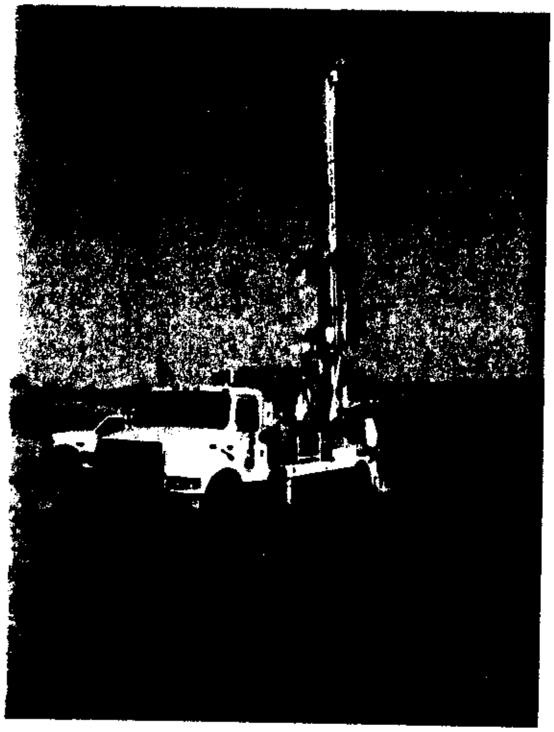
28. Shale excavated from bluff by animals
071002 to 05 Field Trip 034.jpg

29. West along bluff, thin till at surface
071002 to 05 Field Trip 035.jpg

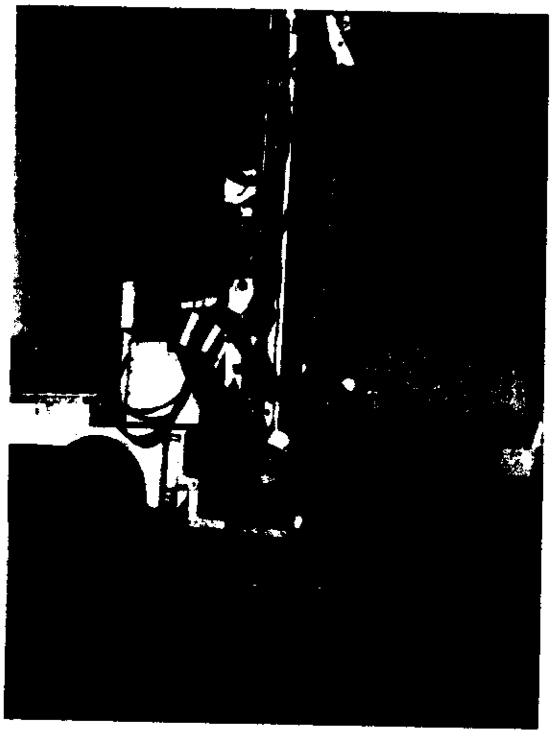
30. Bouldery knoll (BH101)
071002 to 05 Field Trip 036.jpg

31. BH102
071002 to 05 Field Trip 037.jpg

32. Stauber Drilling at BH102
071002 to 05 Field Trip 038.jpg



37. Auger drilling BH105
071002 to 05 Field Trip 043.jpg



38. Installing inclinometer in BH105
071002 to 05 Field Trip 044.jpg

39. Installing inclinometer, piezometer in foreground (...
071002 to 05 Field Trip 045.jpg

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Appendix A

Appendix A
Summary of Calculated Factor of Safety, Cross Section A-A'

Case	Calculated Factor of Safety	% Change from Base Case
Cross Section A-A', Block 1		
• Back Analysis	0.99	
• Base Case	1.29	
• 2.0m fill near toe	1.30	+0.8
• 2.0m fill near scarp	1.25	-3.1
• 2.0m increase in groundwater level	1.23	-4.7
• 2.0m excavation near toe	1.28	-0.8
• 2.0m fill near toe and 2.0m increase in groundwater	1.24	-3.9
• 2.0m fill near scarp and 2.0m increase in groundwater	1.19	-7.8
Cross Section A-A', Block 1 and 2		
• Back Analysis	1.02	
• Base Case	1.19	
• 2.0m fill near toe	1.20	+0.8
• 2.0m fill near scarp	1.17	-1.7
• 2.0m excavation near toe	1.19	0.0
• 2.0m increase in groundwater level	1.14	-4.2
• 2.0m excavation and 2.0m increase in groundwater	1.13	-5.0
• 2.0m fill near scarp and 2.0m increase in groundwater	1.12	-5.9
Cross Section A-A', New Failure at Toe		
• Base Case	1.17	
• 2.0m fill	1.13	-6.6
• 2.0m groundwater increase	1.17	-3.3
• 2.0m fill and 2.0m groundwater increase	1.09	-9.9

R3985.1 Section A-A', Back Analyses
Block 1 at Initial Failure

(A080107 BA Block 1.gsz)

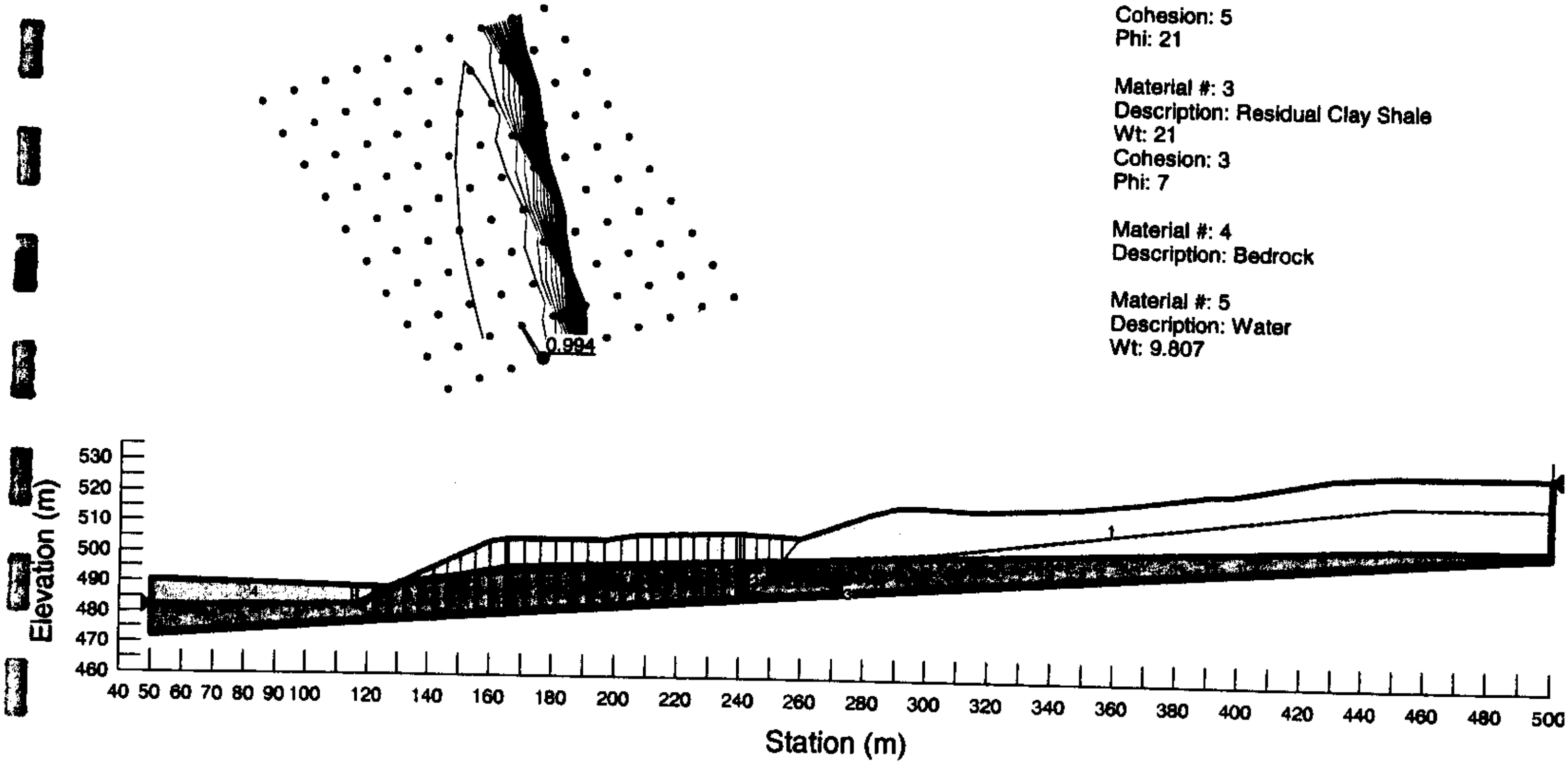
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
Block 1

(A080107 Present Block1.gsz)

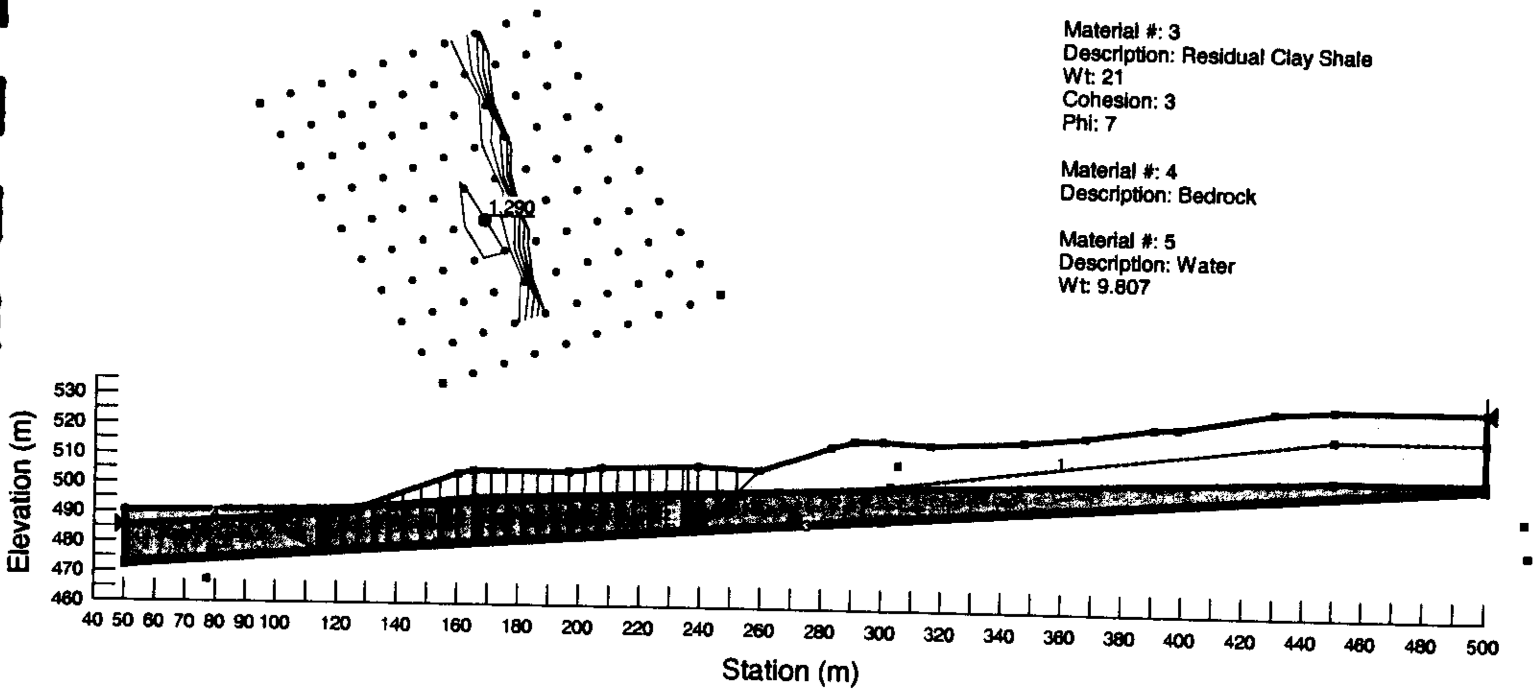
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
Block 1, Fill 2m on knoll

(A080107 Present Block1 Fill.gsz)

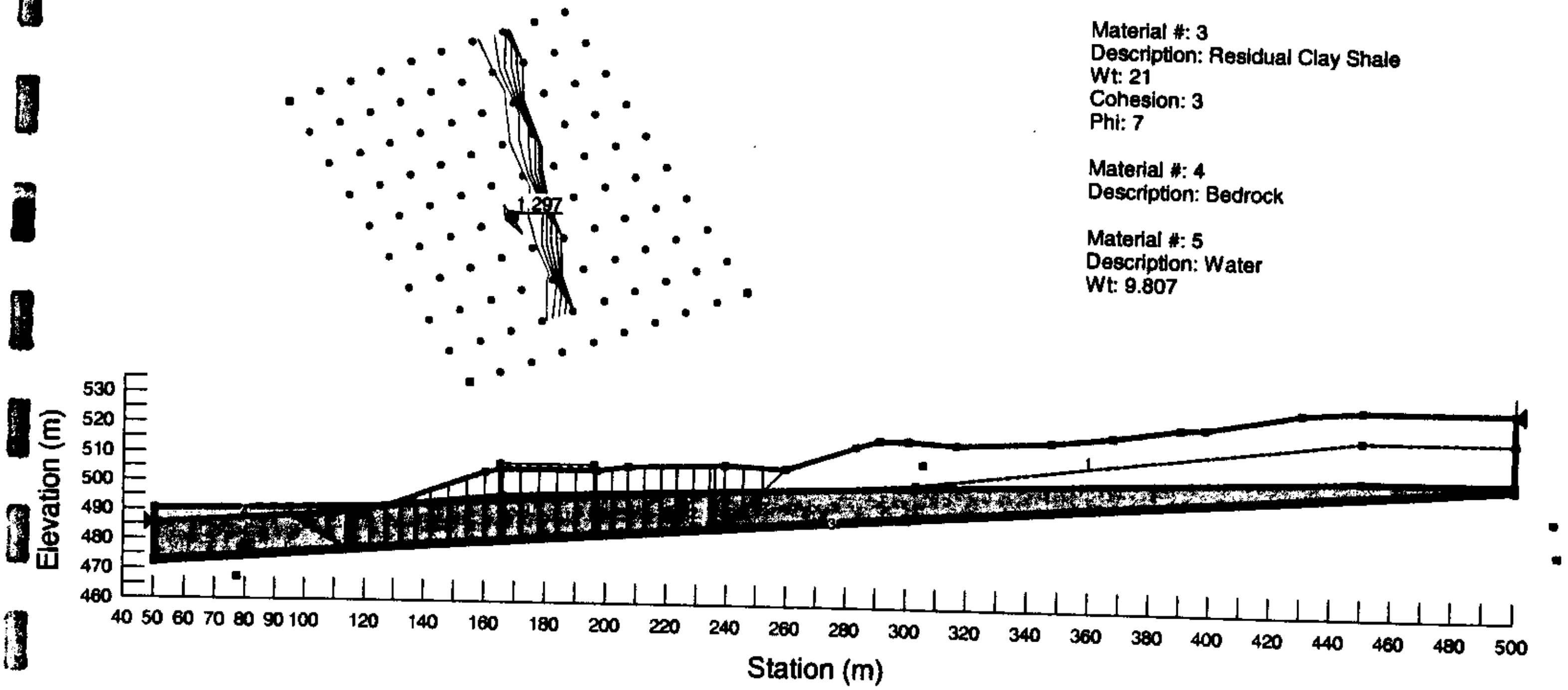
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

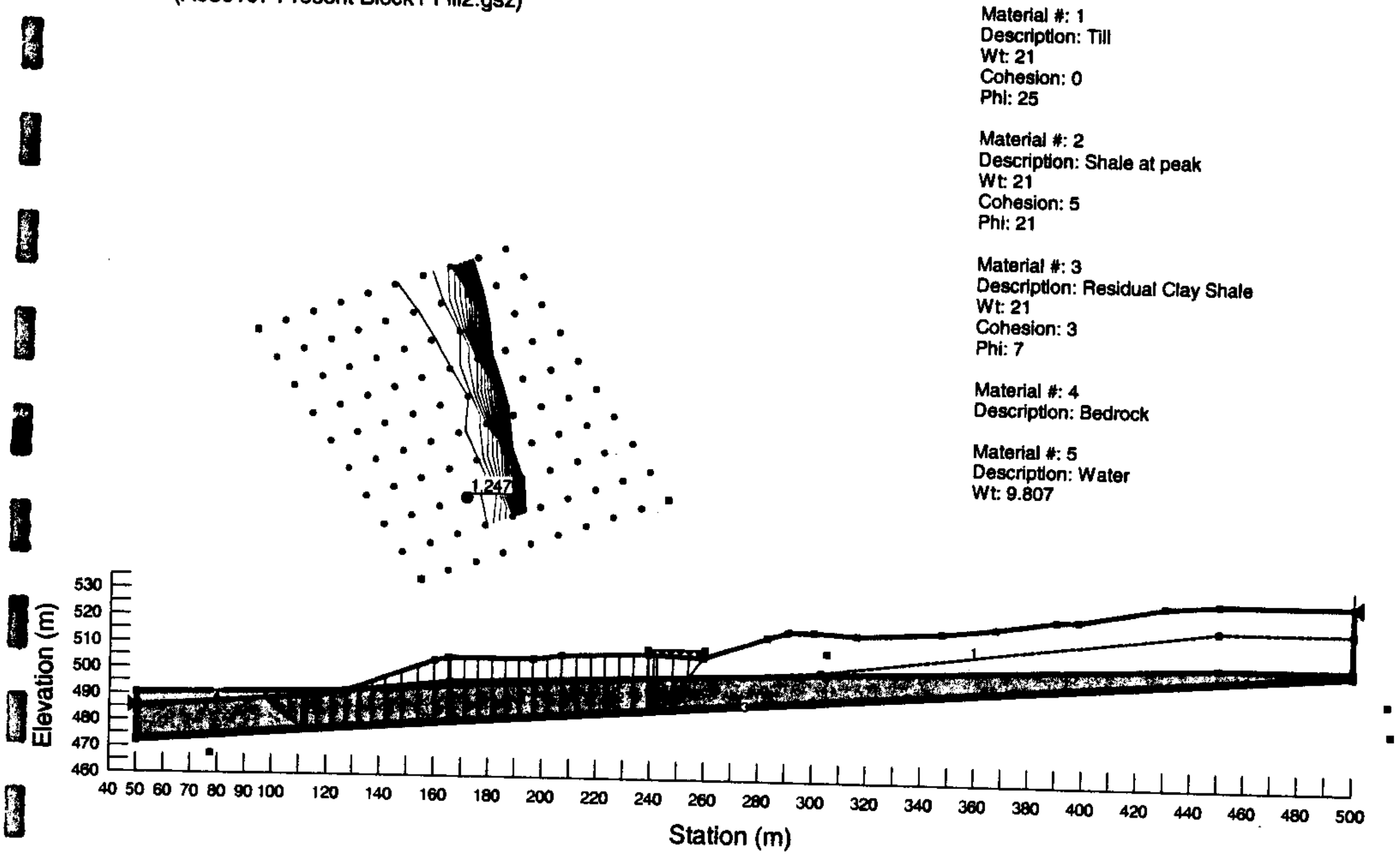
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
Block 1, Fill 2m at scarp of toe block

(A080107 Present Block1 Fill2.gsz)



R3985.1 Section A-A', Present Conditions
Block 1, 2.0m increase in piezo levels

(A080107 Present Block1 water.gsz)

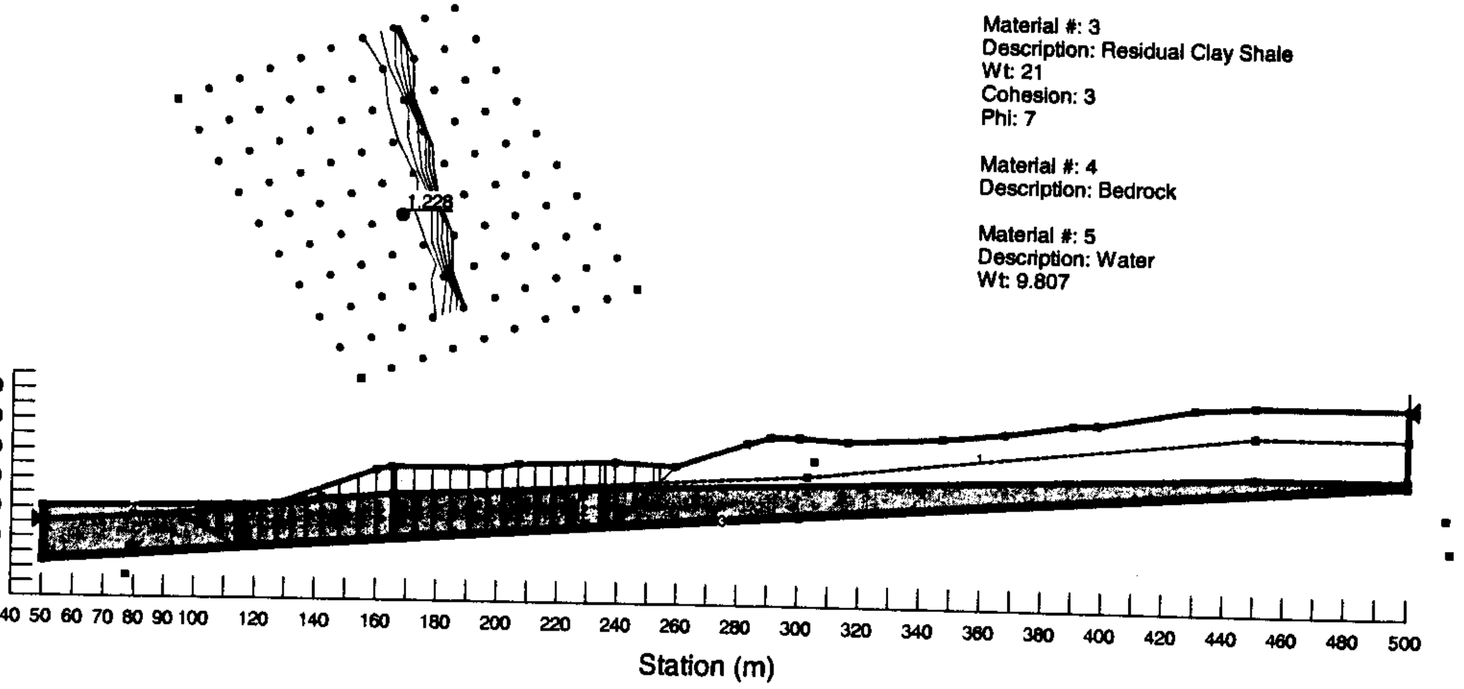
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

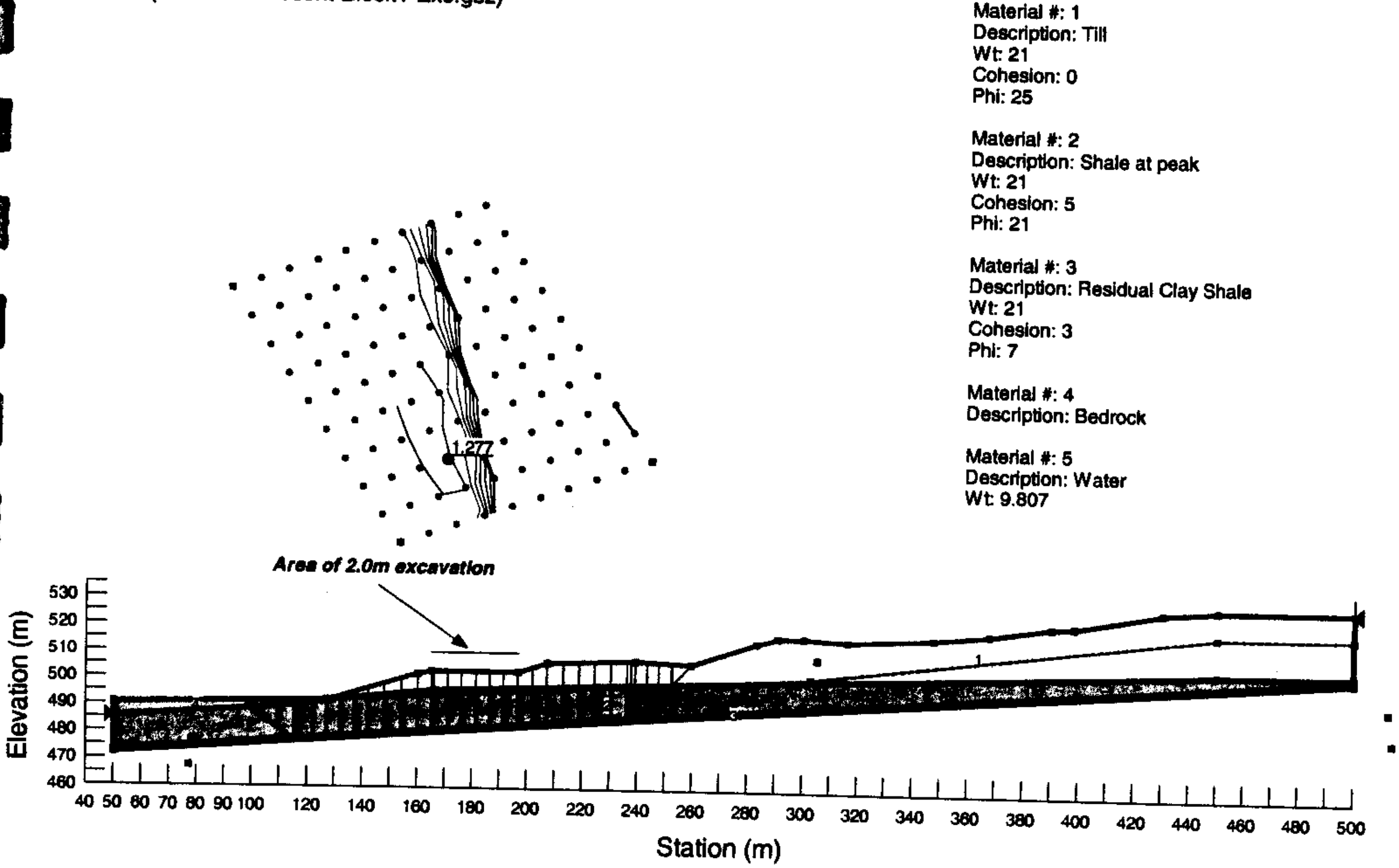
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
Block 1, Excavate 2m near toe

(A080107 Present Block1 Exc.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 1, Fill 2m on knoll, 2m increase in piezo level

(A080107 Present Block1 Fill Water.gsz)

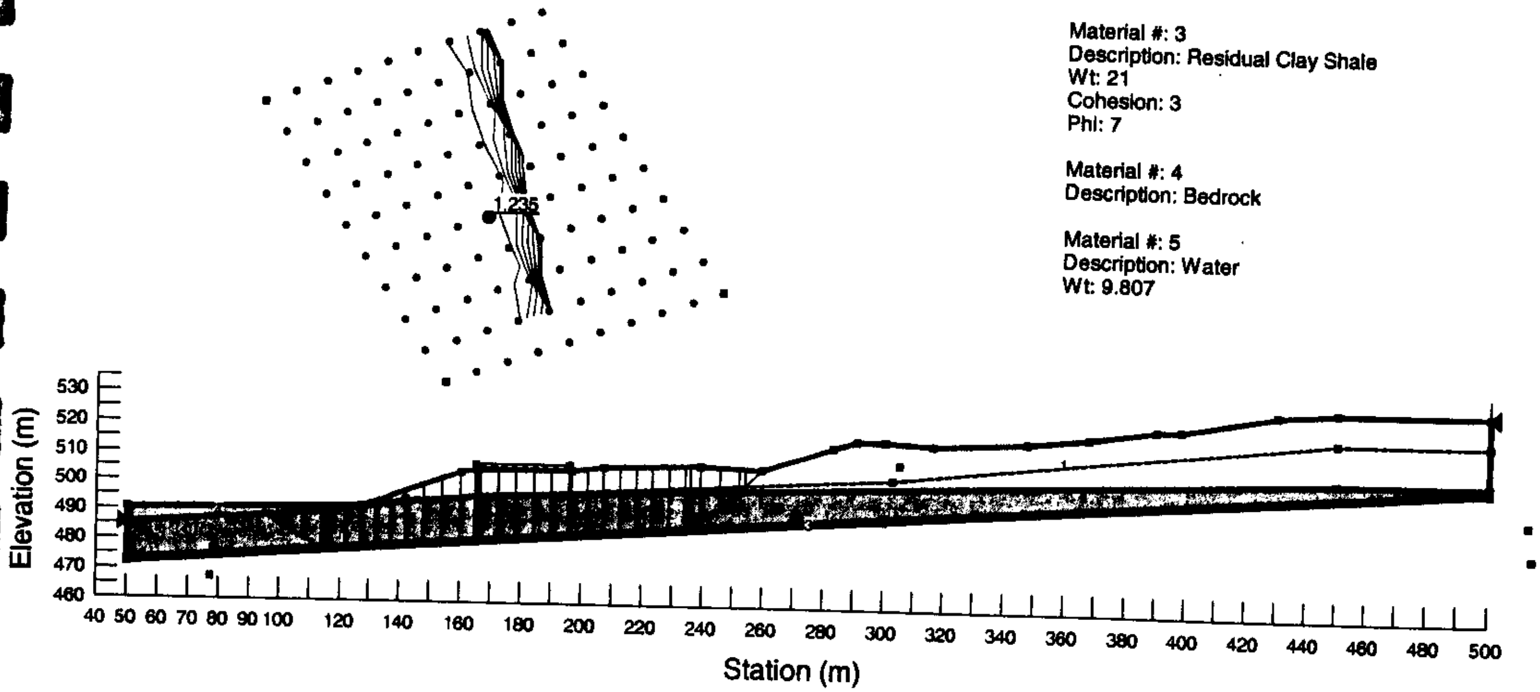
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

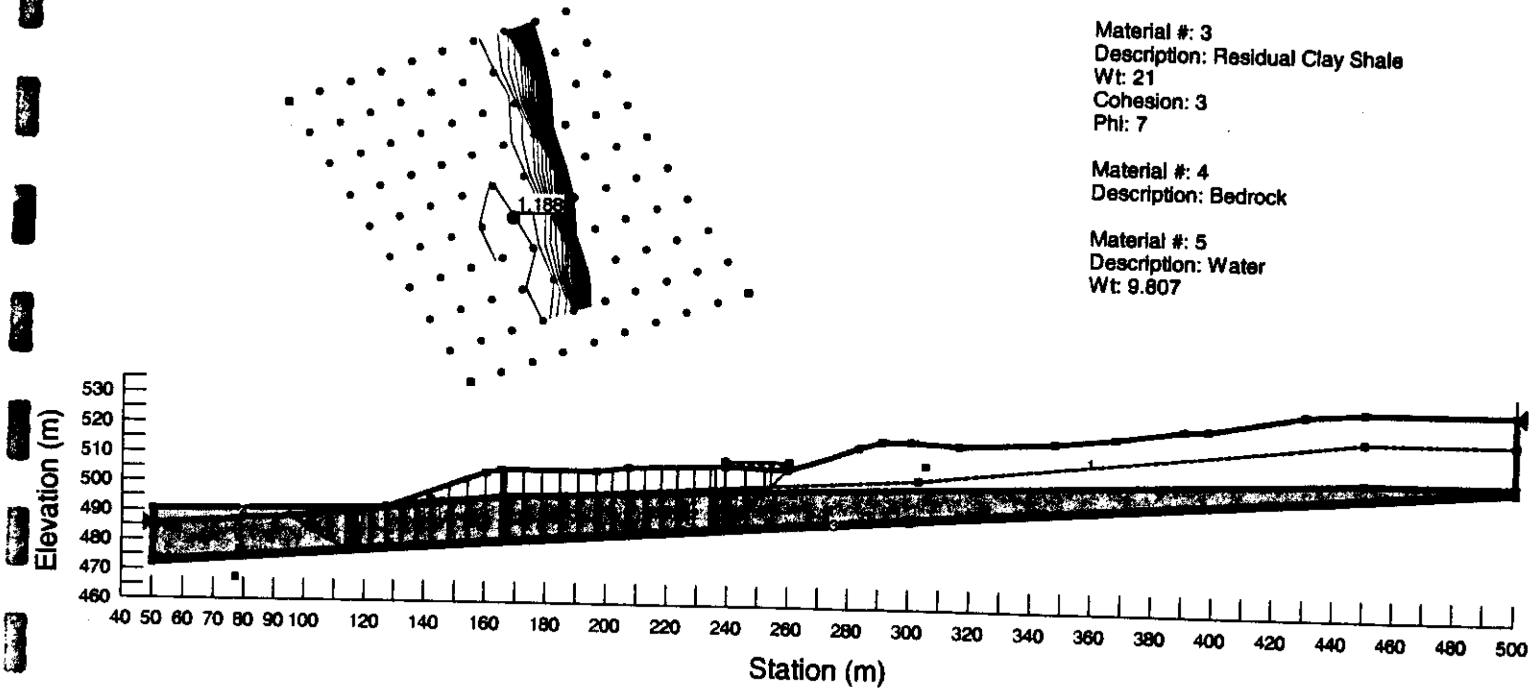
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
Block 1, Fill 2m at scarp of toe block, 2m increase in piezo level

(A080107 Present Block1 Fill2 Water.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

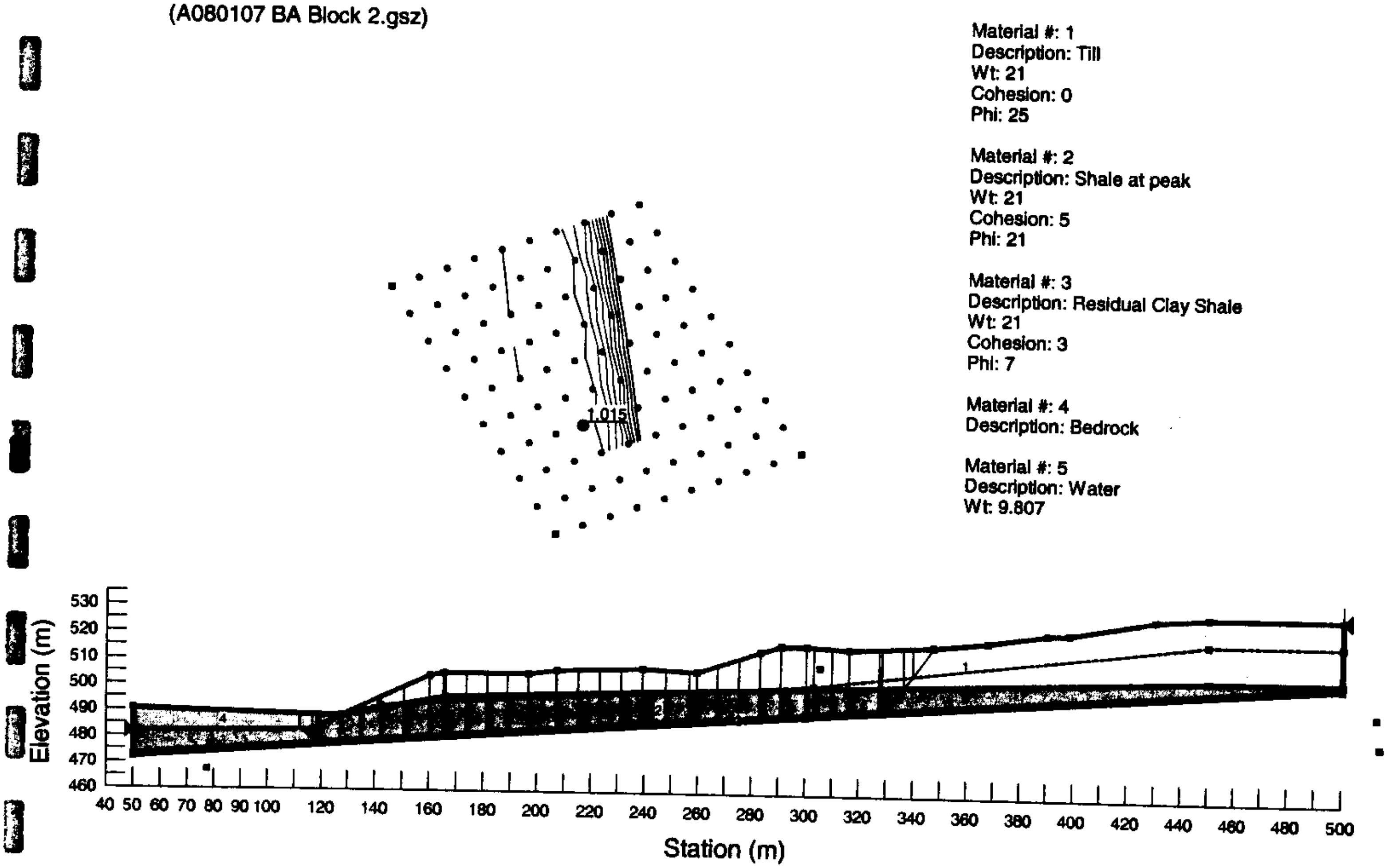
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Back Analyses
Block 2, Initial Failure

(A080107 BA Block 2.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

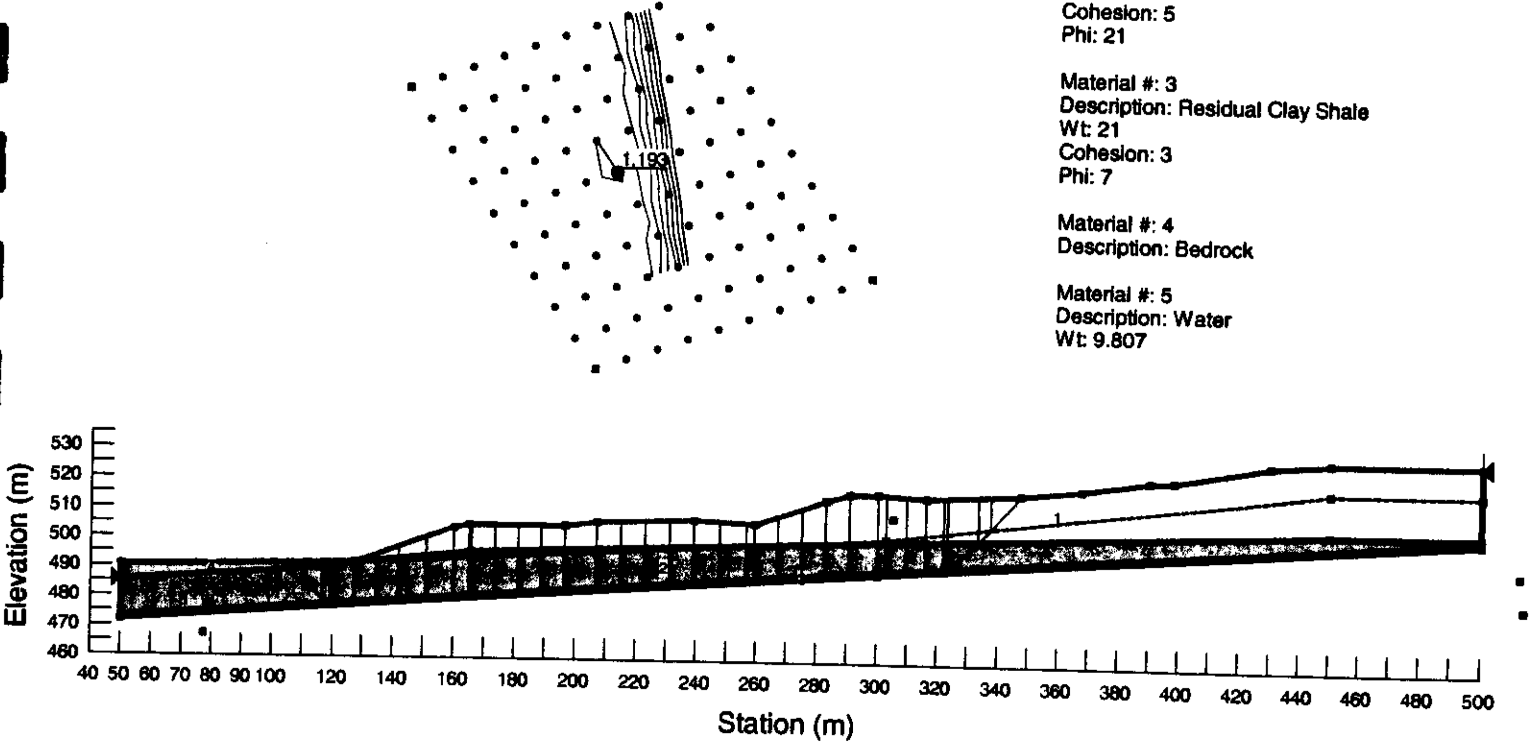
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 2

(A080107 Present Block2.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

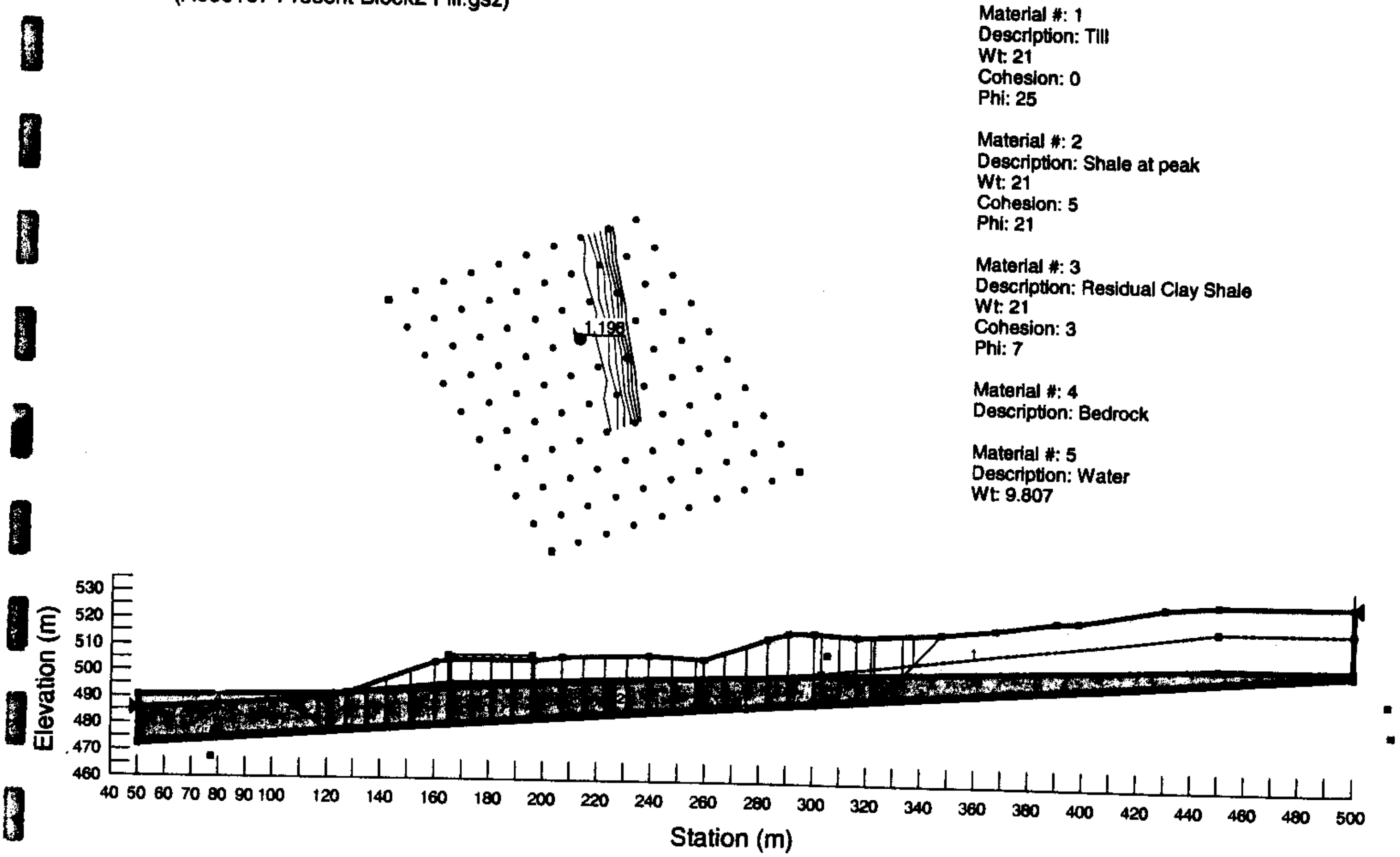
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 2, Fill 2m on knoll

(A080107 Present Block2 Fill.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 2, 2.0m fill at top

(A080107 Present Block2 Fill2.gsz)

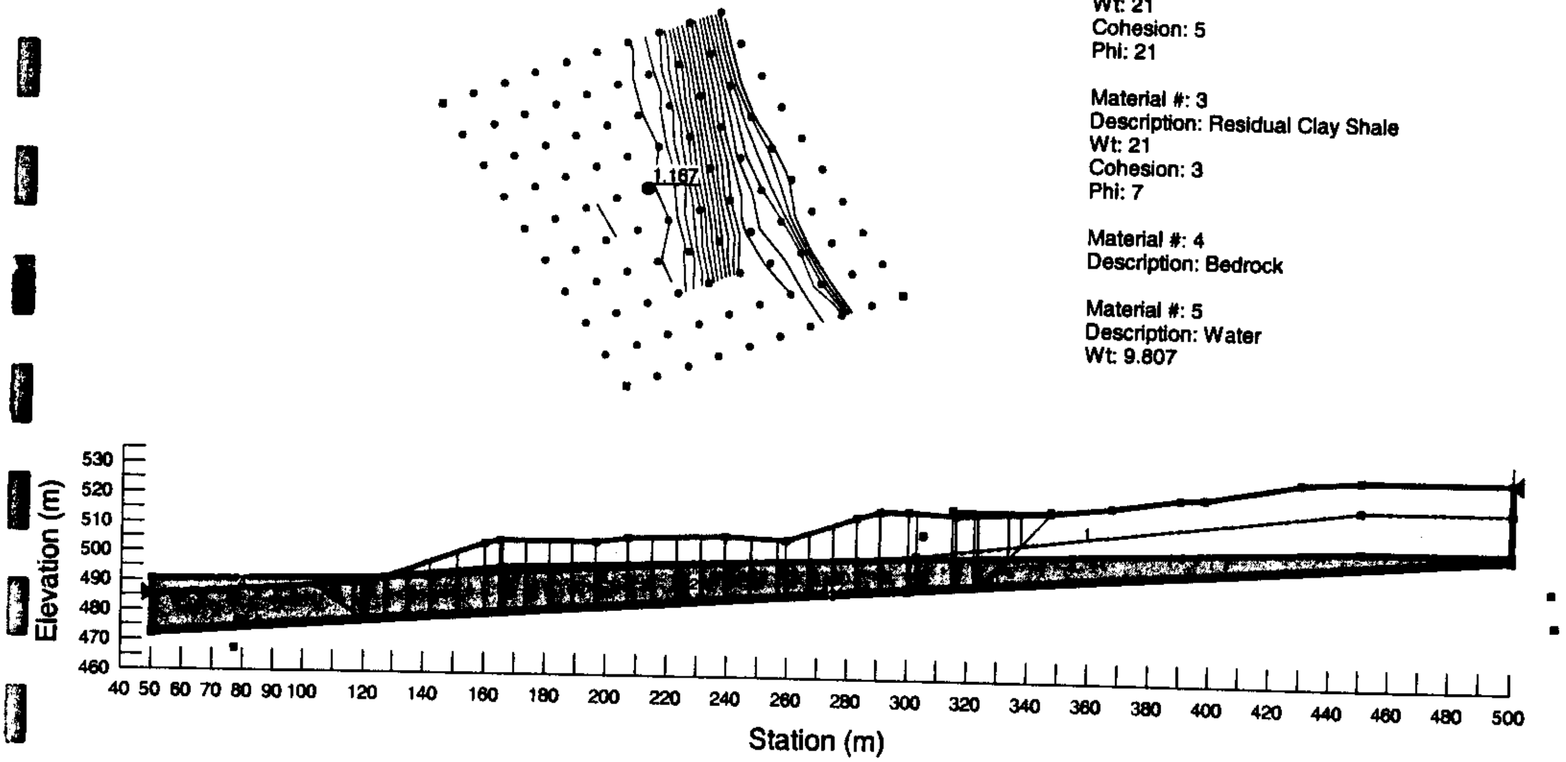
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

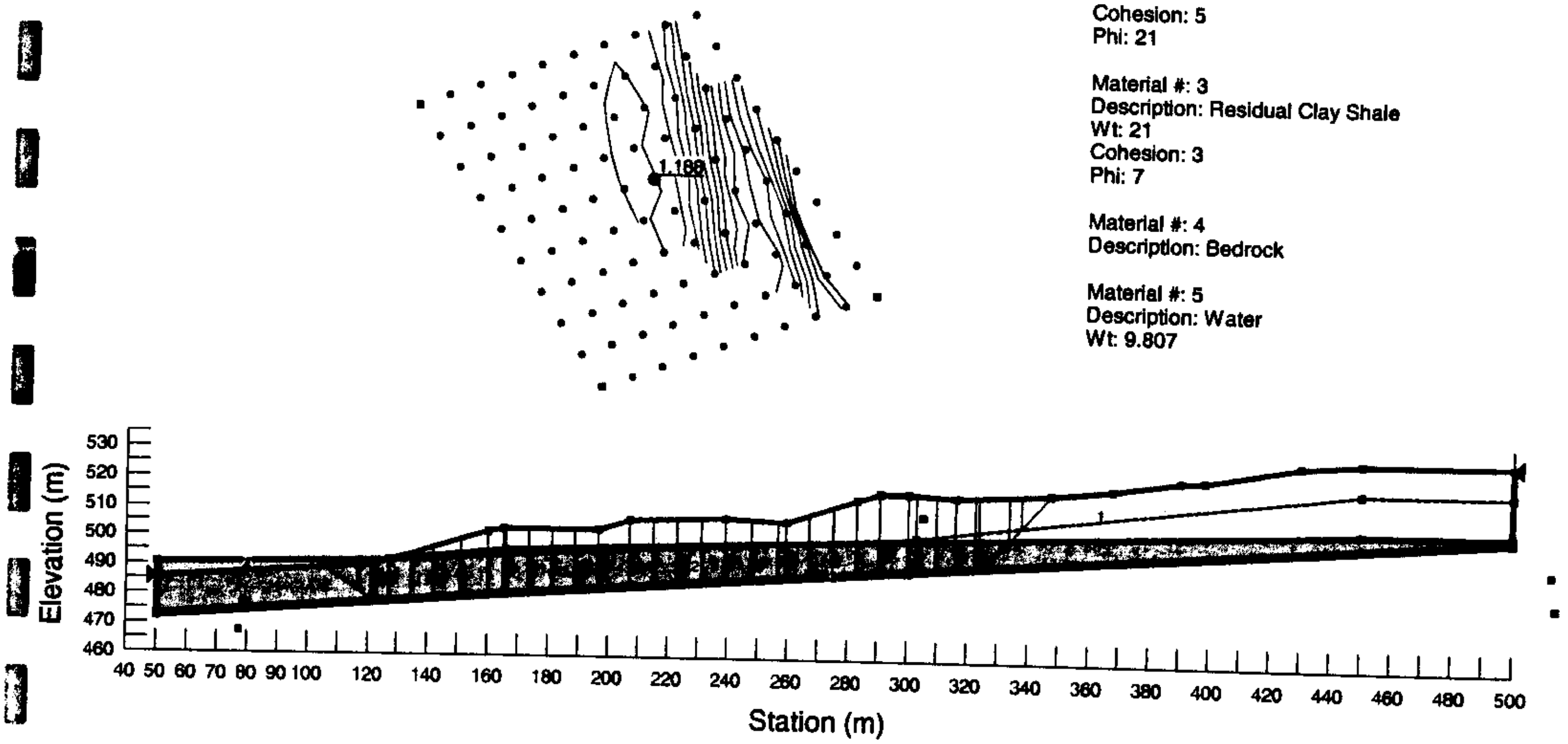
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
Block 2, Excavate 2m near toe

(A080107 Present Block2 Exc.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

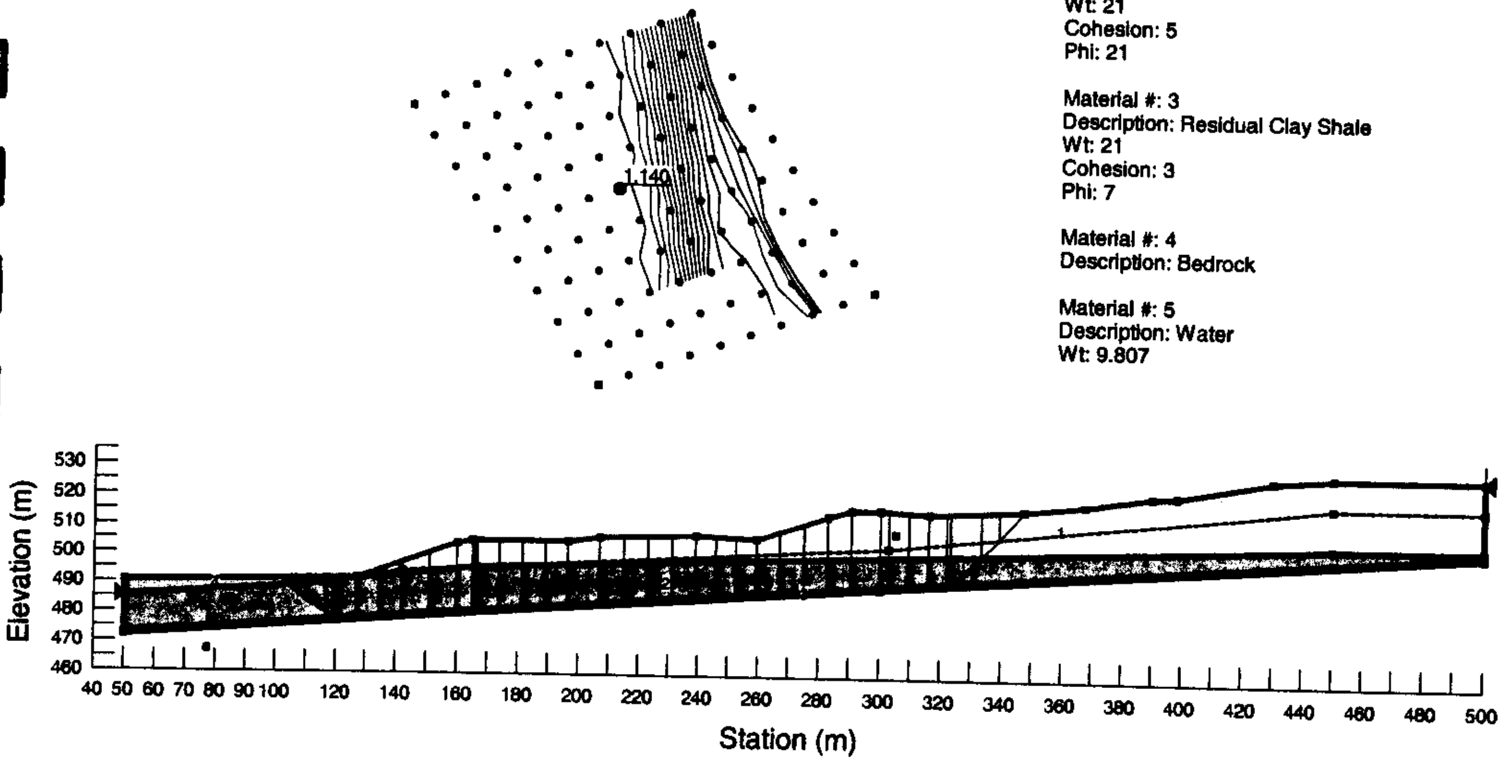
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 2, 2.0m increase in piezo level

(A080107 Present Block2 water.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

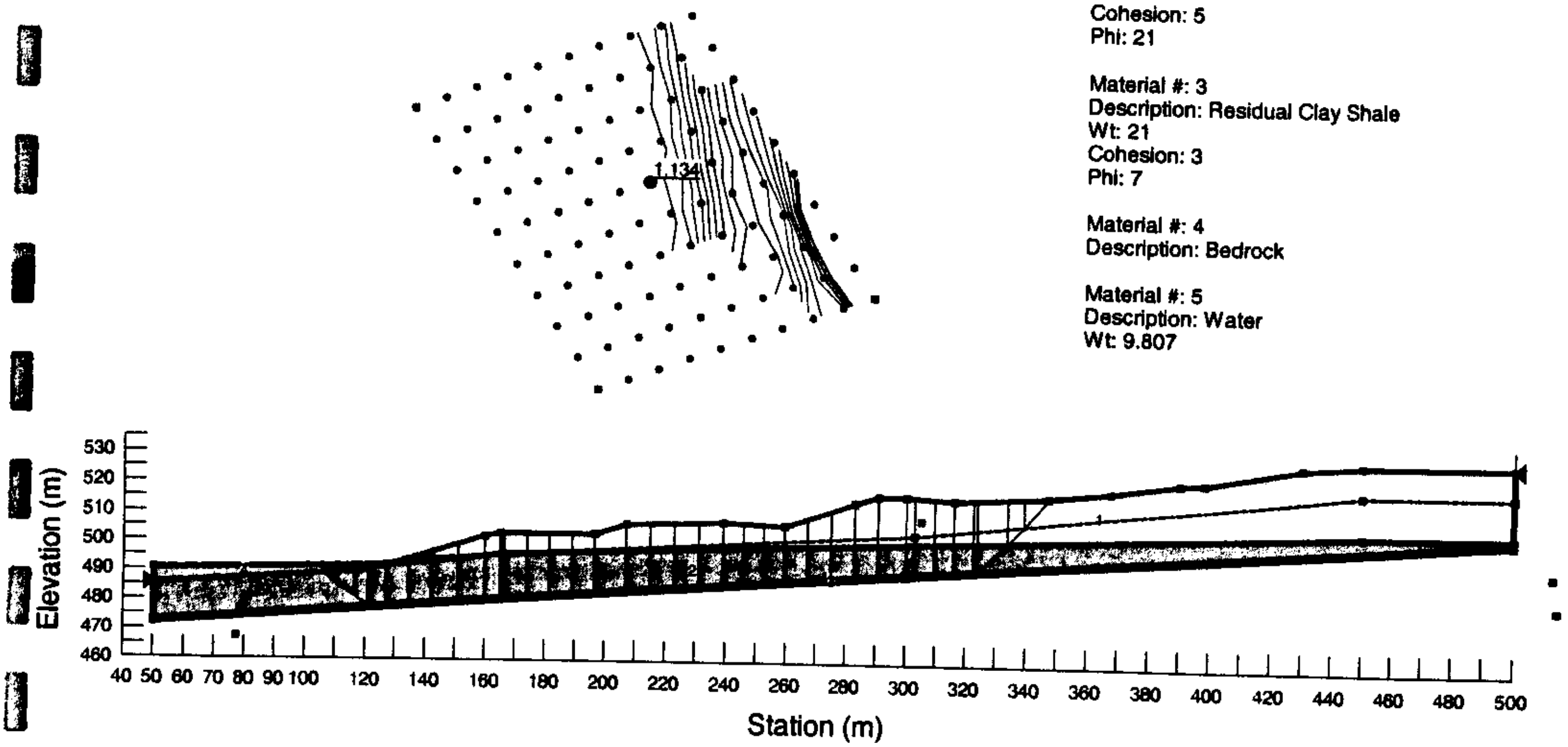
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 2, Excavate 2m near toe, 2m increase in piezo level

(A080107 Present Block2 Exc water.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

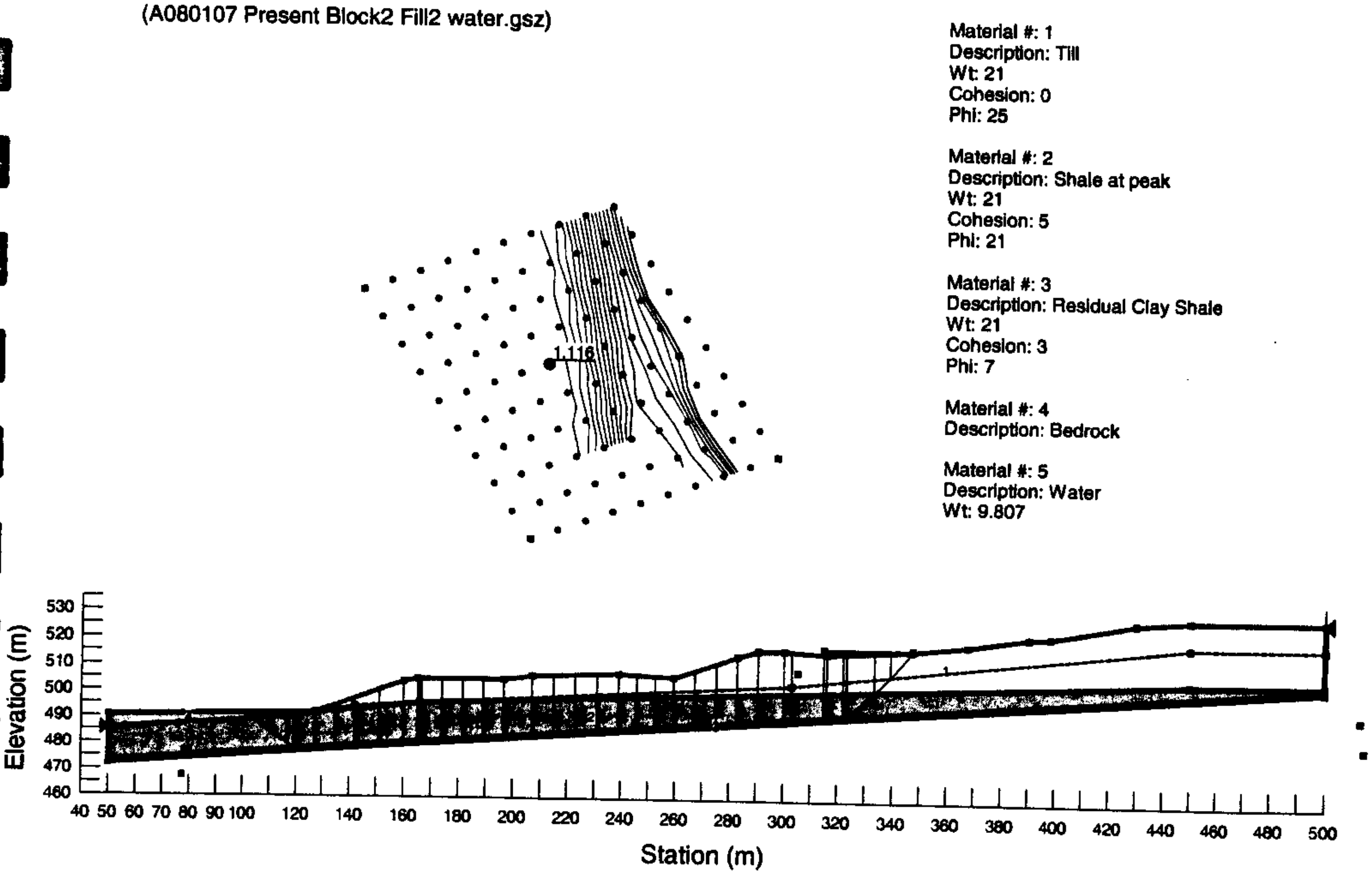
Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
Block 2, 2.0m fill at top, 2.0m increase in piezo level

(A080107 Present Block2 Fill2 water.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section A-A', Present Conditions
New Slip Surface at Toe

(A080107 Present Toe Min.gsz)

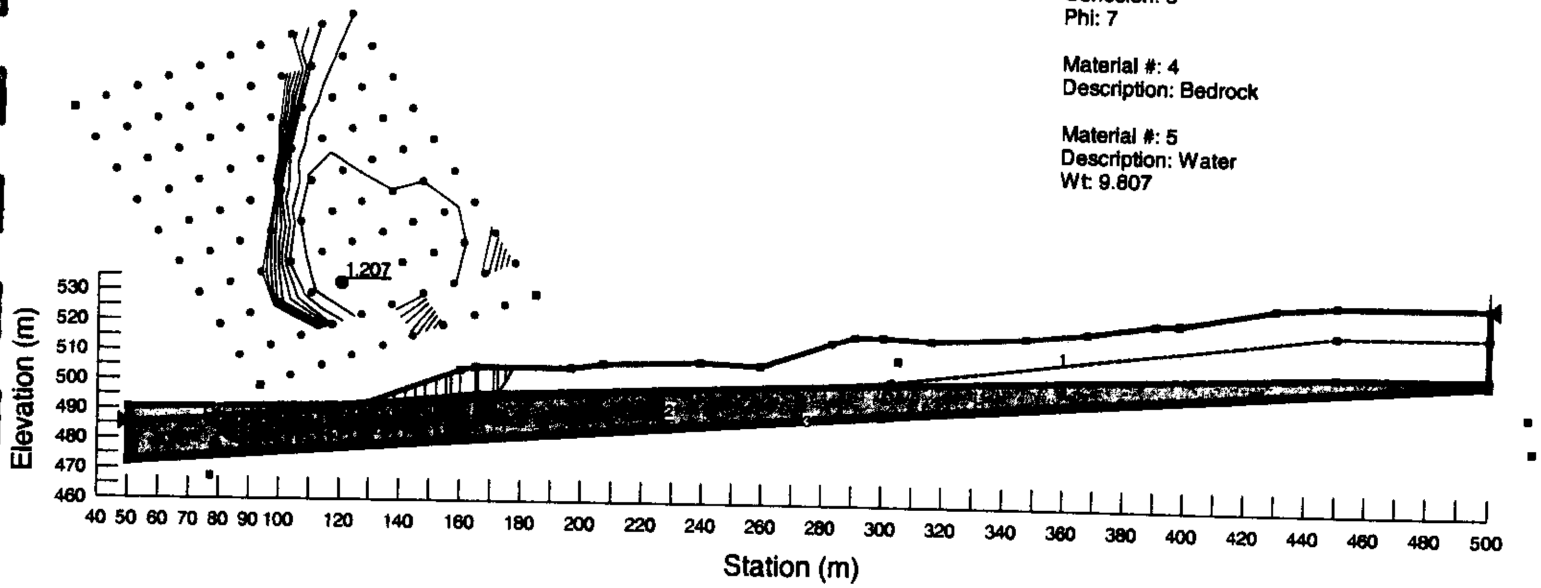
Material #: 1
Description: Till
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
New Slip Surface, With Fill

(A080107 Present Toe Min Fill.gsz)

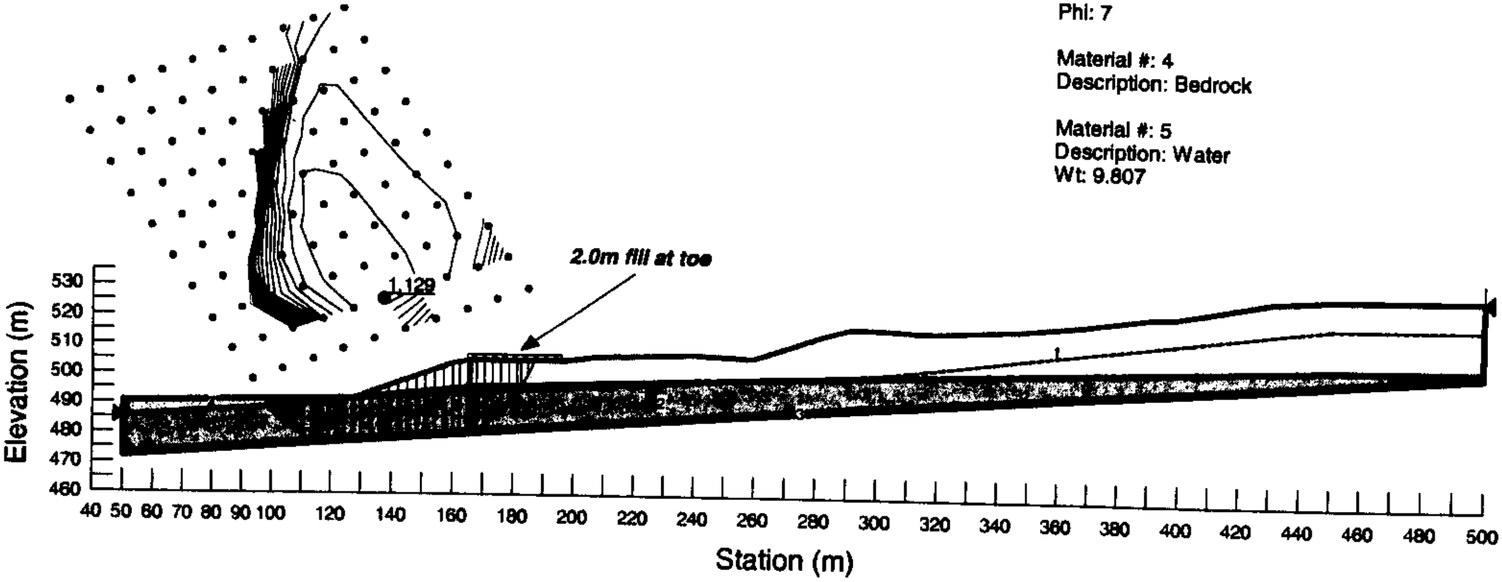
Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
New Slip Surface, Increase Piezo by 2.0m

(A080107 Present Toe Min Water.gsz)

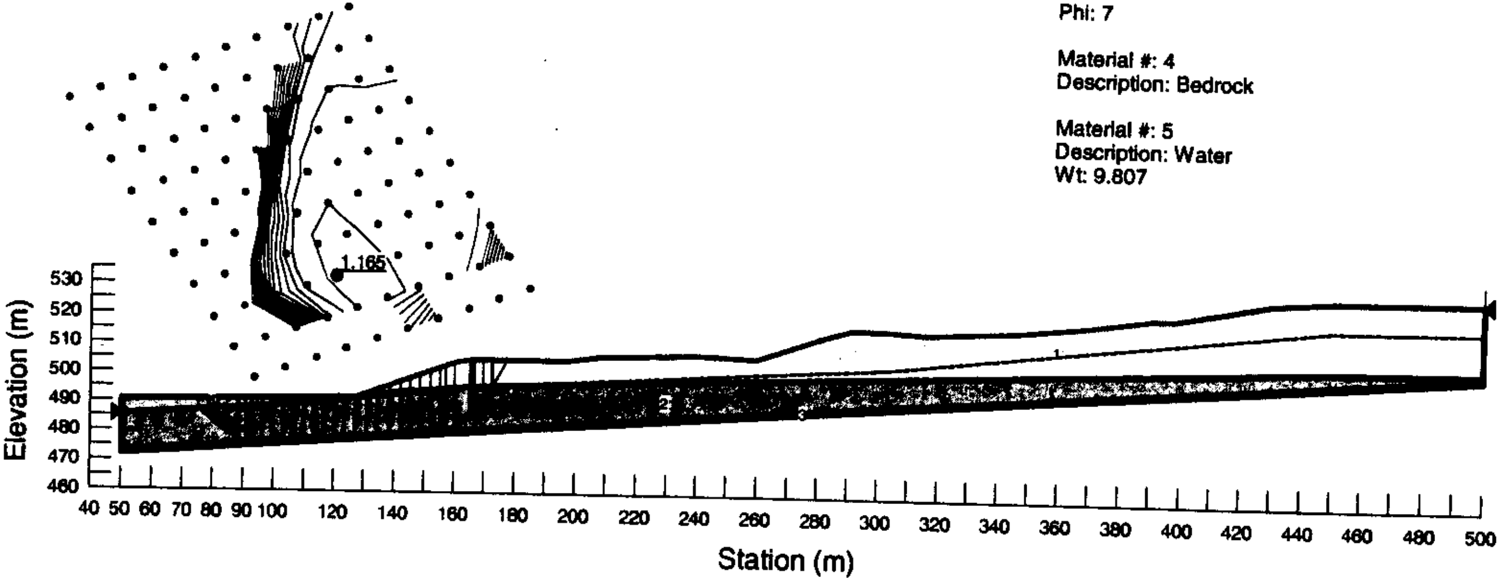
Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

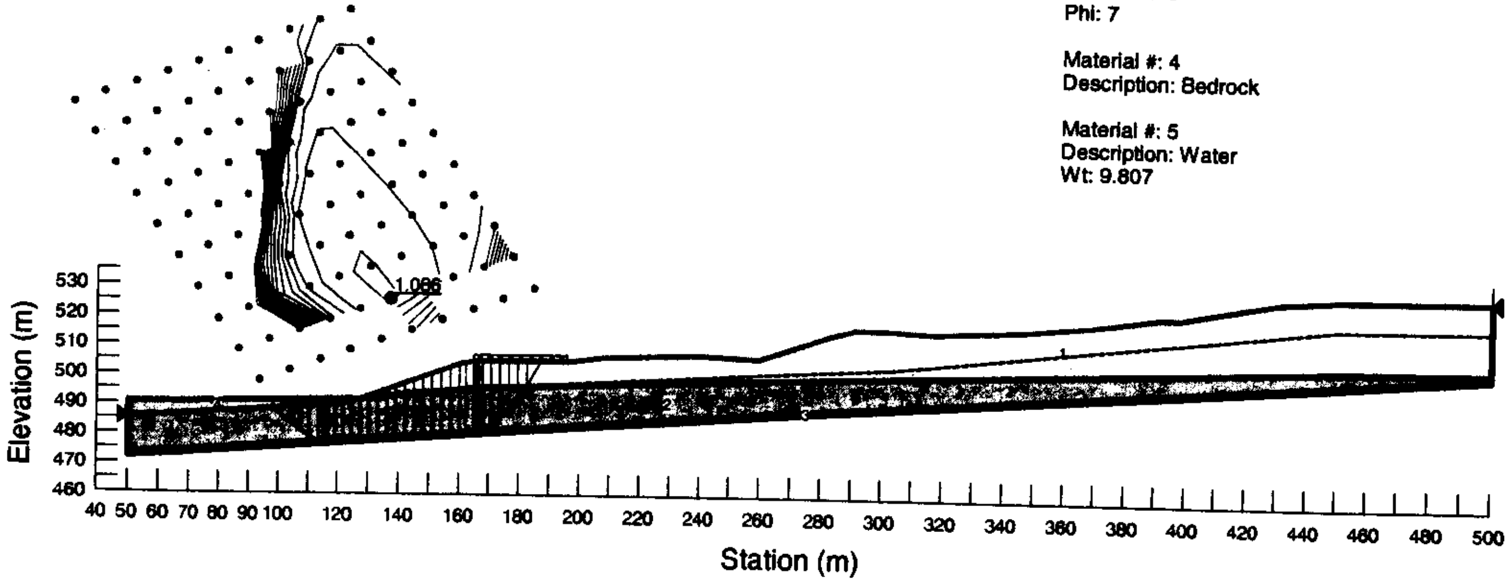
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section A-A', Present Conditions
New Slip Surface, With 2.0m Fill, Increase Piezo by 2.0m

(A080107 Present Toe Min Fill Water.gsz)



Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

Appendix A
Summary of Calculated Factor of Safety, Cross Section B-B'

Case	Calculated Factor of Safety	% Change from Base Case
Cross Section B-B', Block 1		
• Back Analysis	0.99	
• Base Case	1.30	
• 2.0m fill near toe	1.21	-6.9
• 2.0m increase in groundwater level	1.24	-4.6
• 2.0m fill near scarp and 2.0m increase in groundwater	1.16	-10.8
Cross Section B-B', Block 1 and 2		
• Back Analysis	1.06	
• Base Case	1.18	
• 2.0m fill near scarp	1.16	-1.7
• 2.0m excavation near toe	1.17	-0.8
• 2.0m increase in groundwater level	1.12	-5.1
• 2.0m excavation and 2.0m increase in groundwater	1.11	-5.9
Cross Section B-B', New Failure at Toe		
• Base Case	1.33	
• 2.0m fill	1.29	-3.0
• 2.0m groundwater increase	1.20	-9.8
• 2.0m fill and 2.0m groundwater increase	1.21	-9.0

R3985.1 Section B-B', Back Analysis
Block 1

(B080109 BA Block1.gsz)

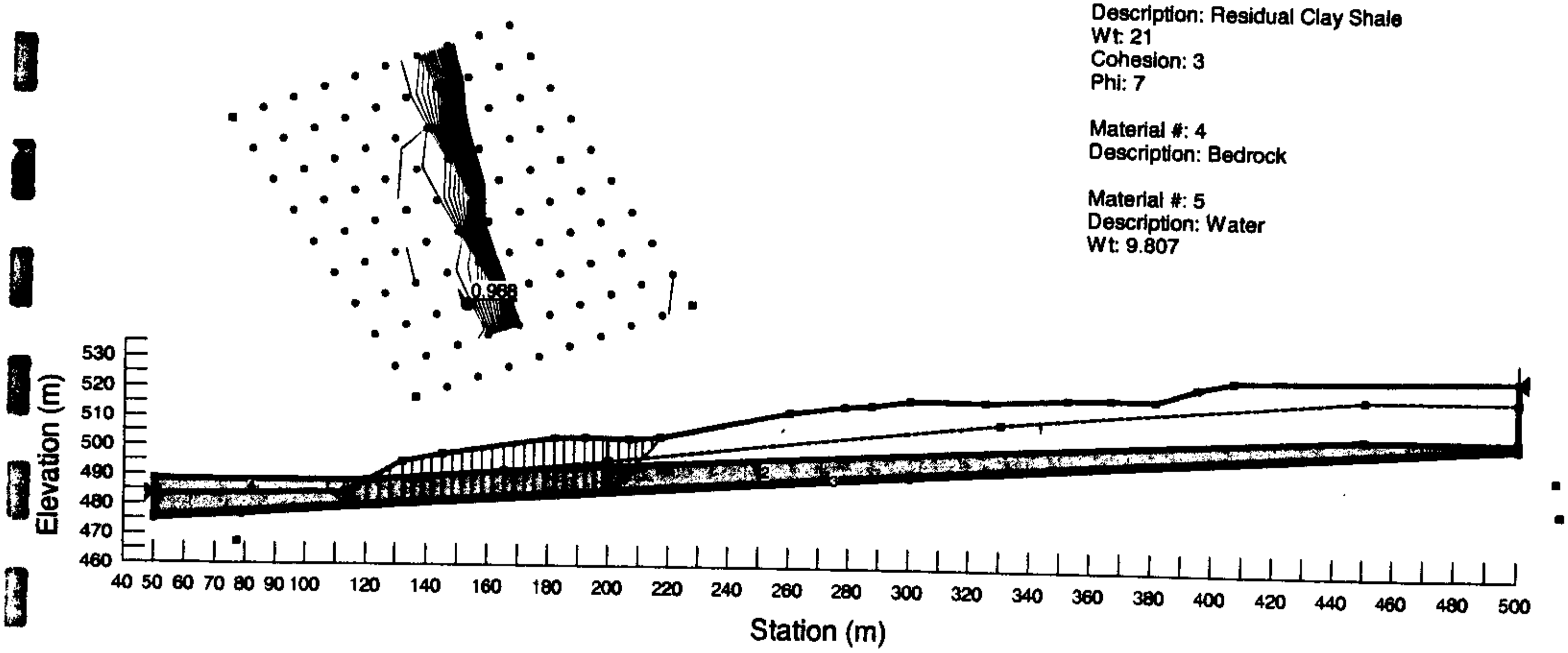
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
Block 1

(B080109 Present Block1.gsz)

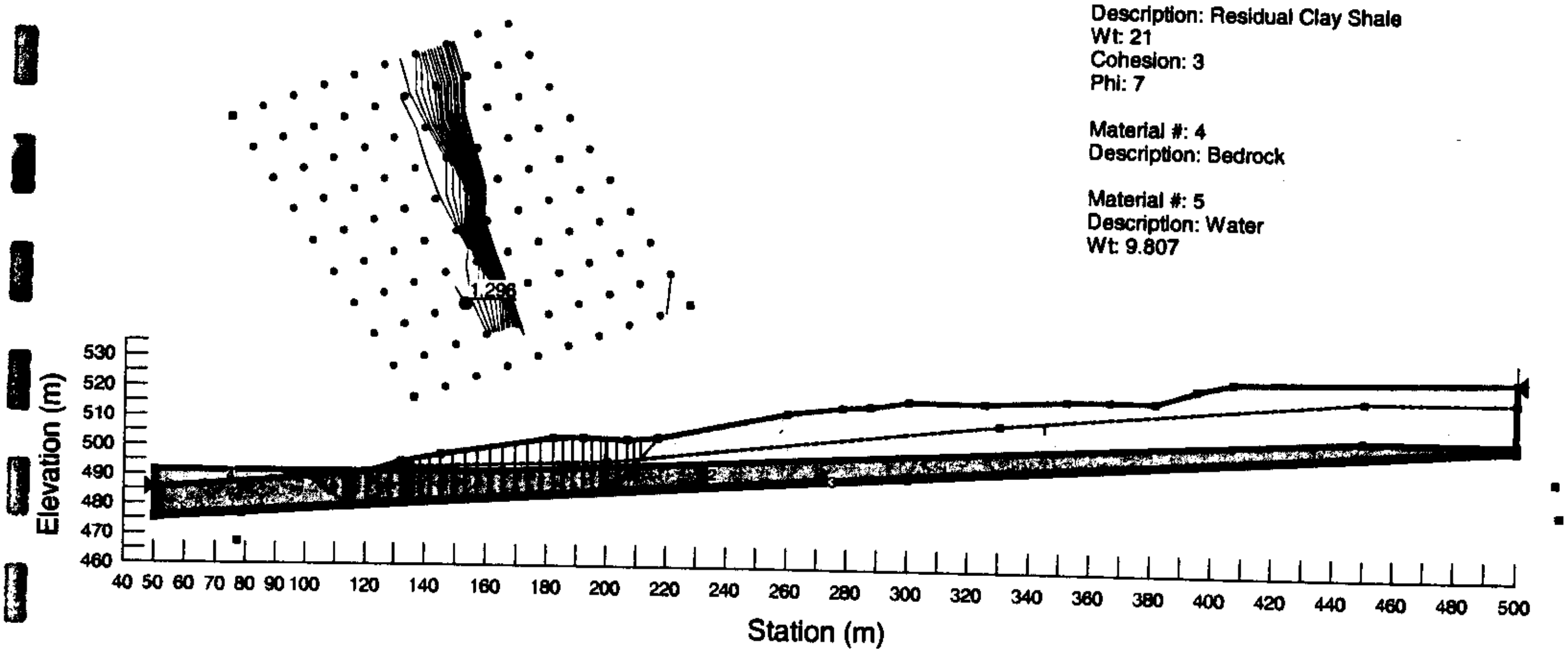
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
Block 1, 2.0m fill

(B080109 Present Block1 fill.gsz)

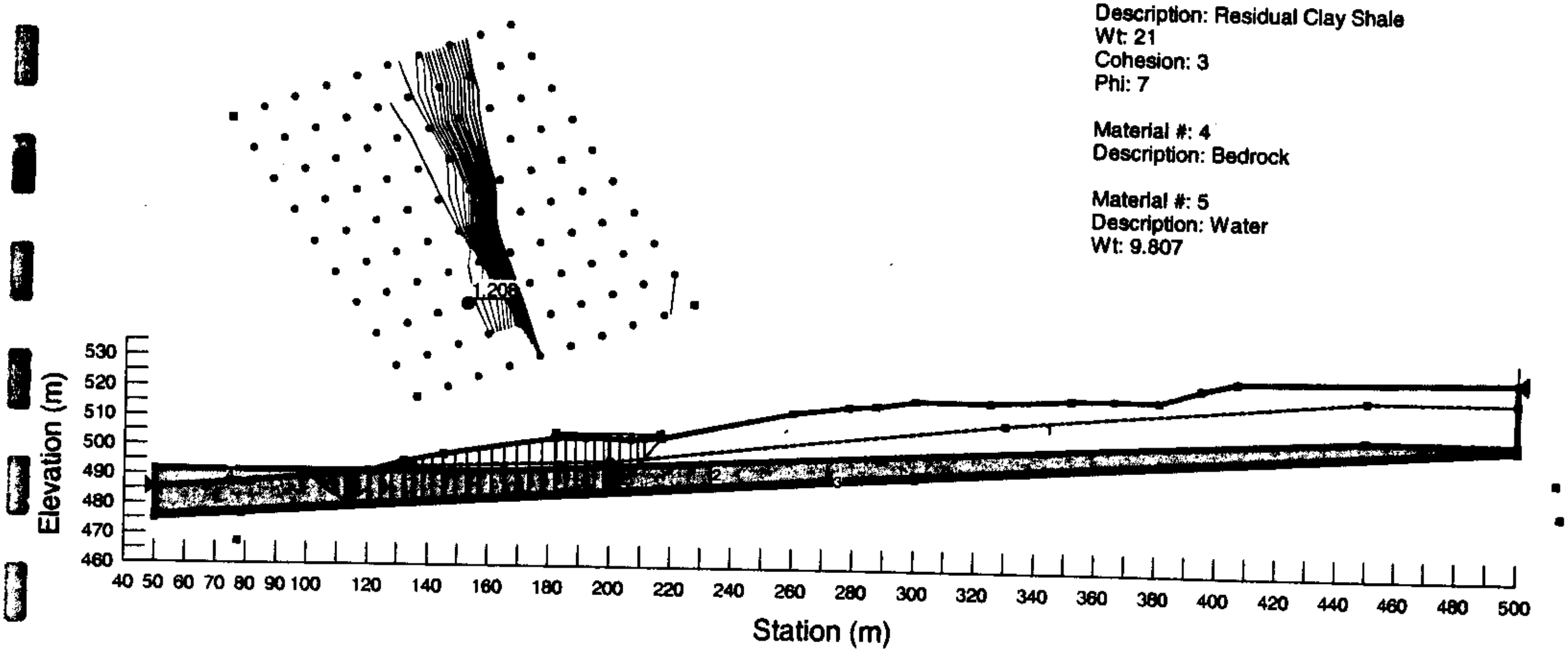
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

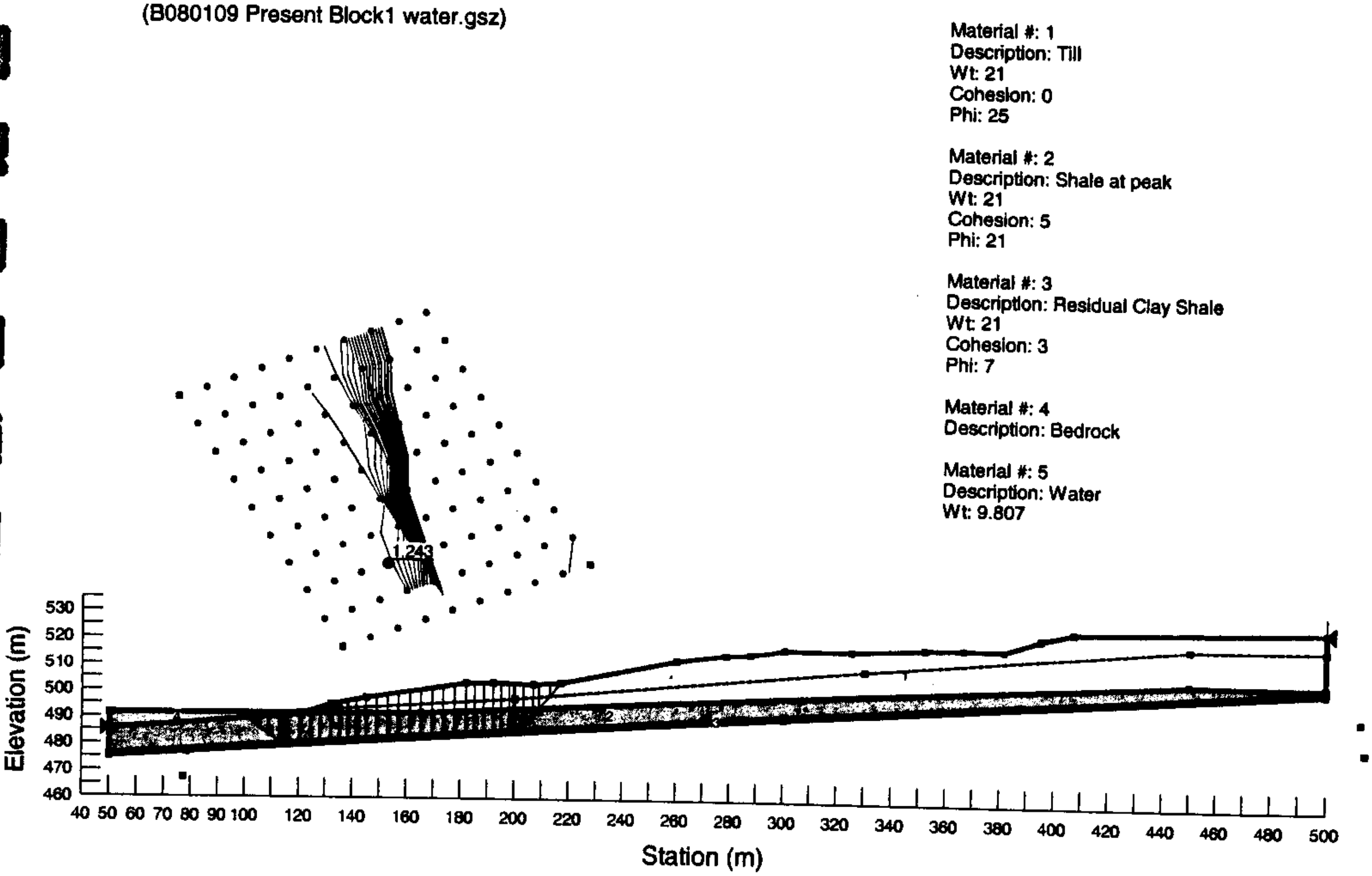
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



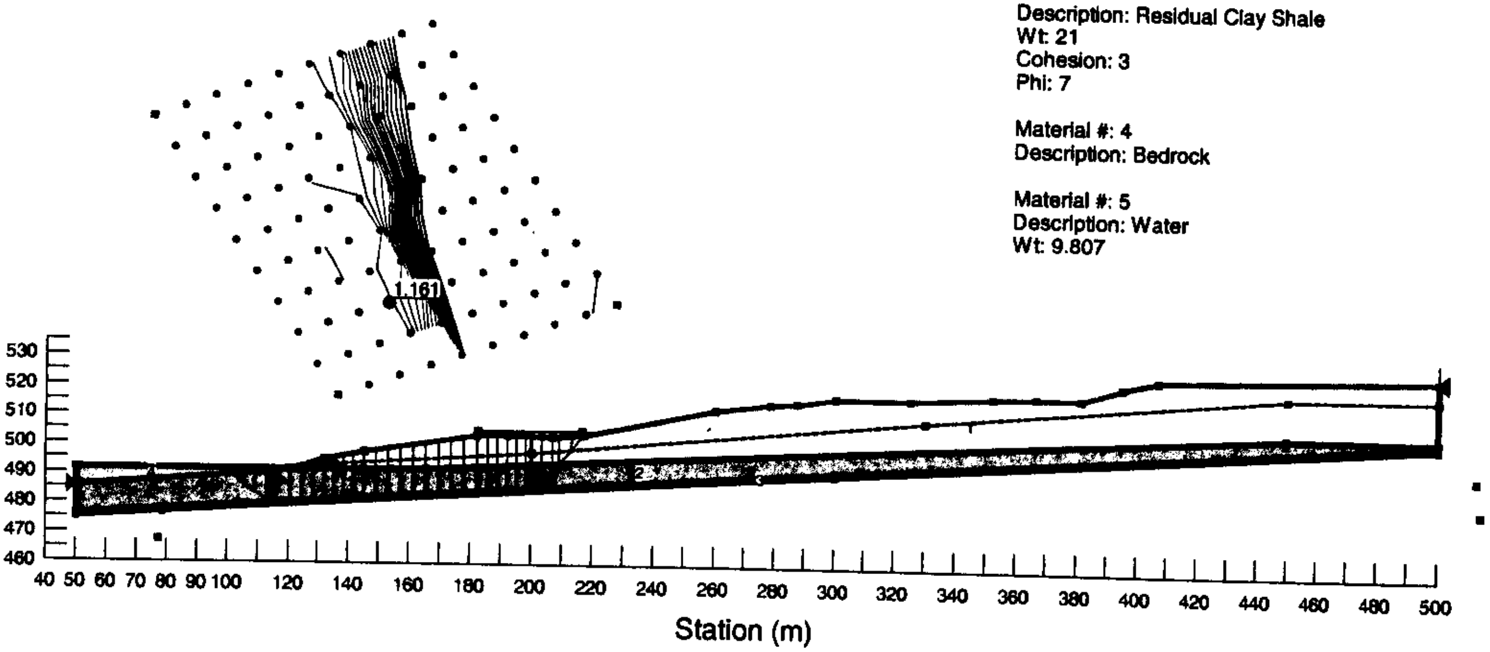
R3985.1 Section B-B', Present Day
Block 1, 2.0m increase in piezo levels

(B080109 Present Block1 water.gsz)



R3985.1 Section B-B', Present Day
Block 1, 2.0m fill, 2.0m increase in piezo levels

(B080109 Present Block1 fill water.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section B-B', Back Analysis
Block 2

(B080109 BA Block2.gsz)

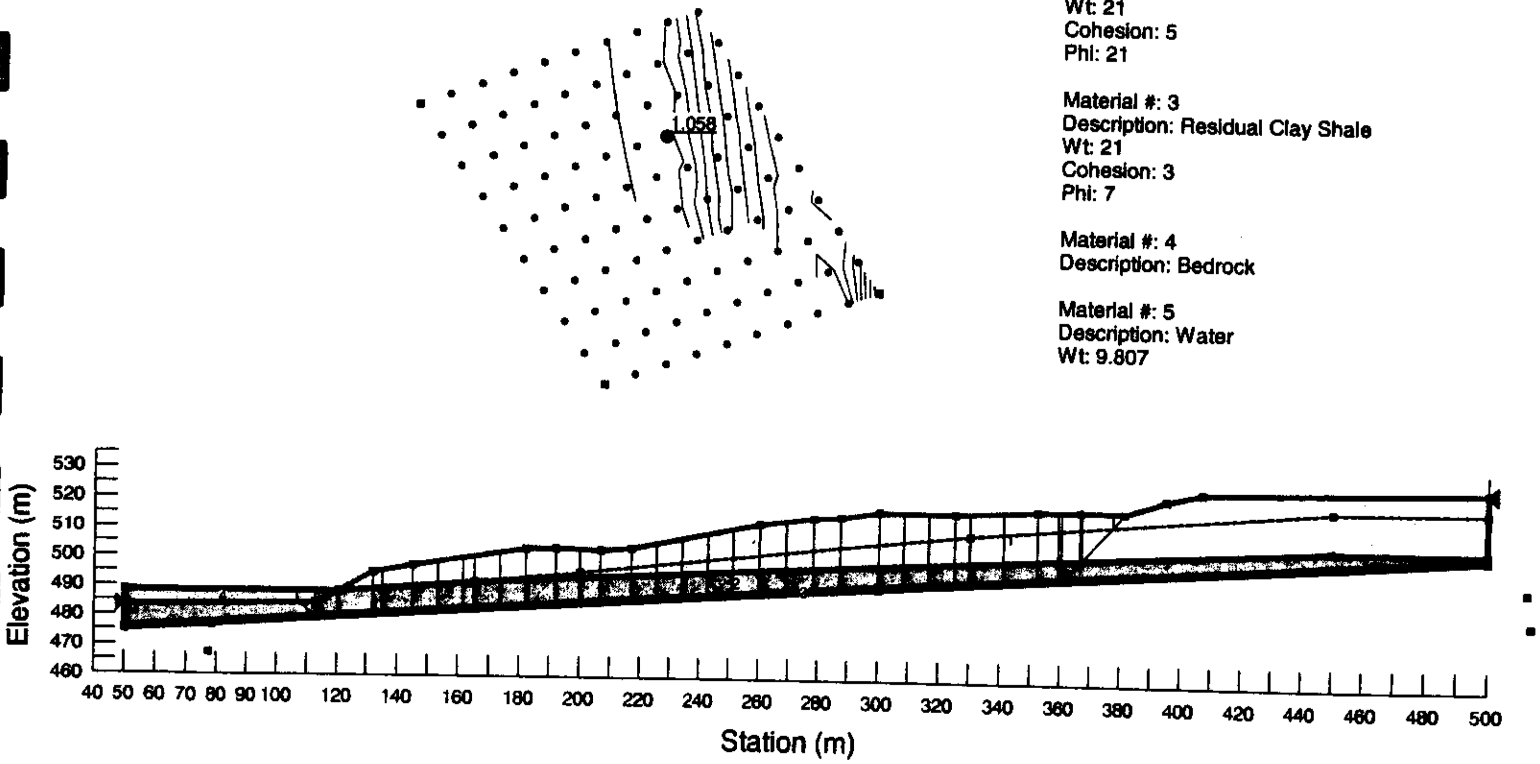
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

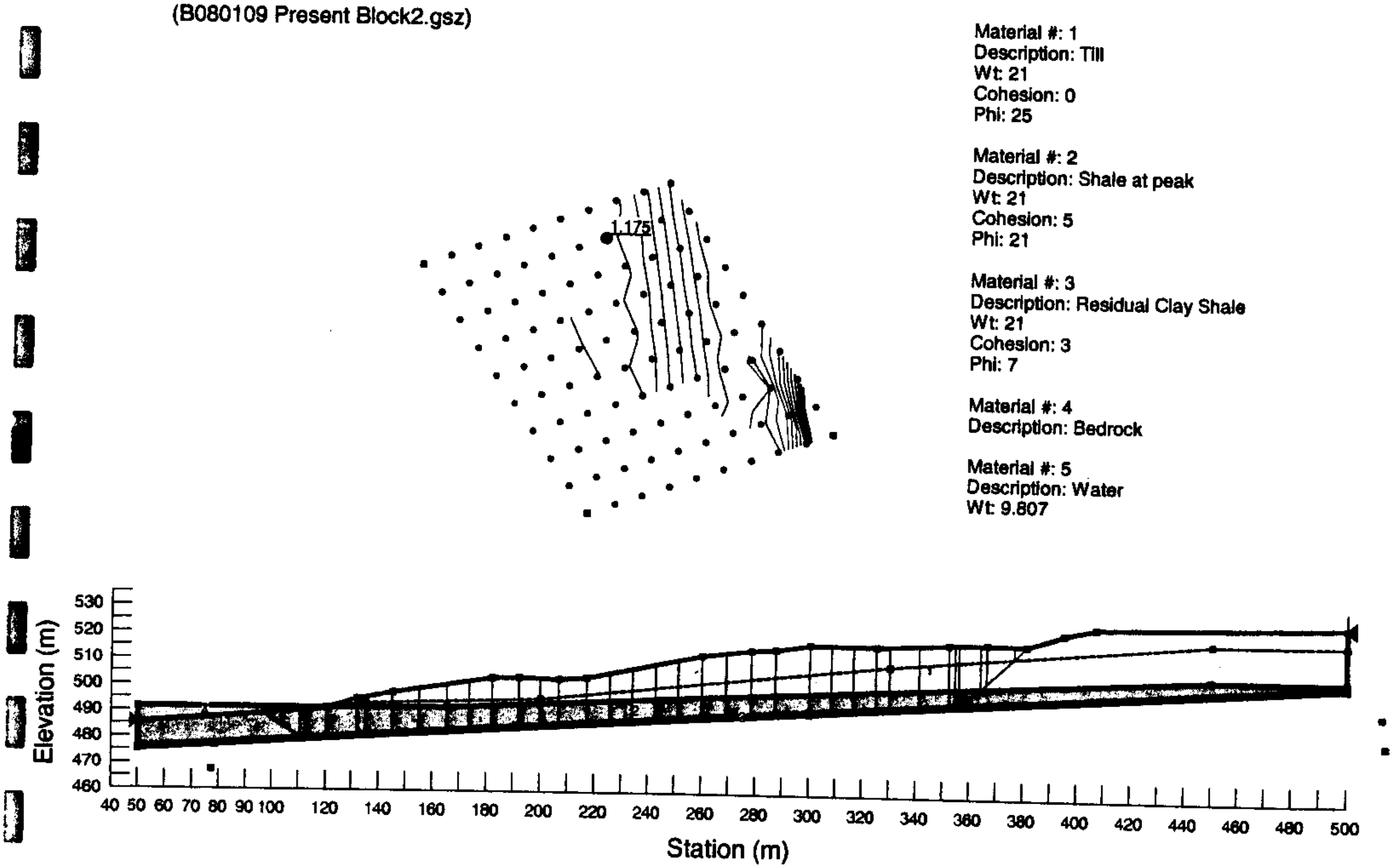
Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
Block 2

(B080109 Present Block2.gsz)



Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807

R3985.1 Section B-B', Present Day
Block 2, 2.0m fill at top

(B080109 Present Block2.gsz)

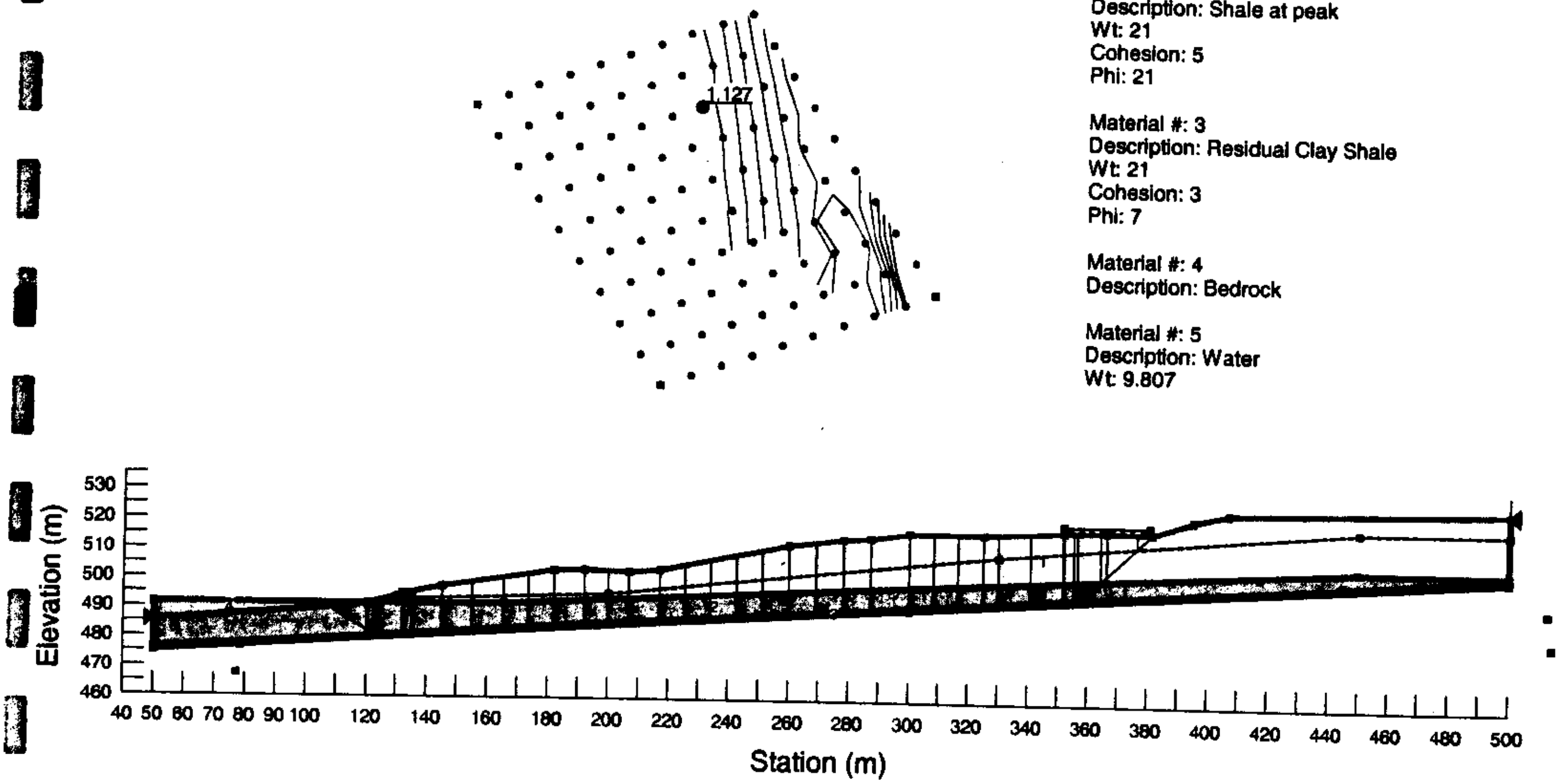
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
Block 2, 2.0m cut near toe

(B080109 Present Block2 cut.gsz)

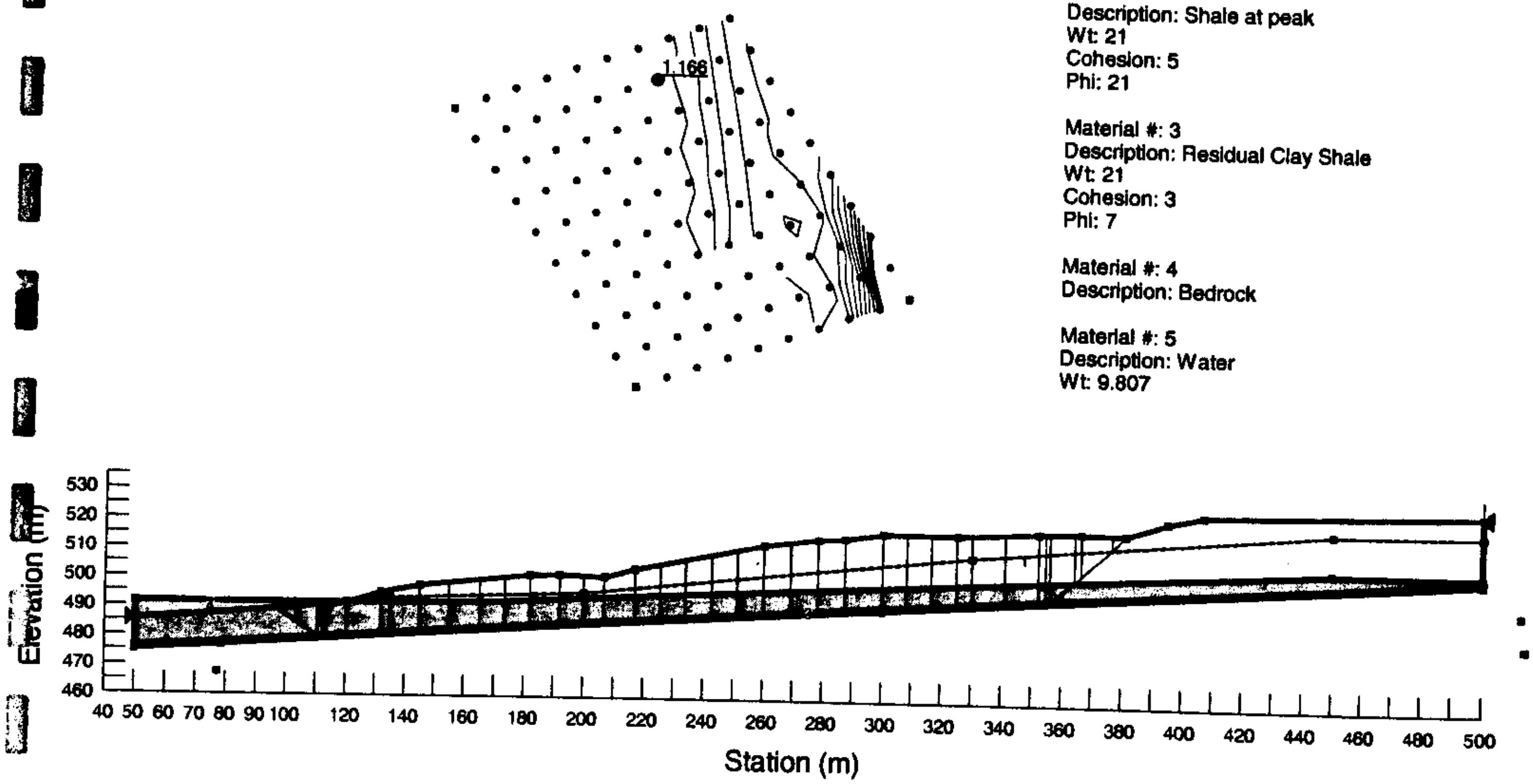
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
Block 2, 2.0m increase in piezo levels

(B080109 Present Block2 water.gsz)

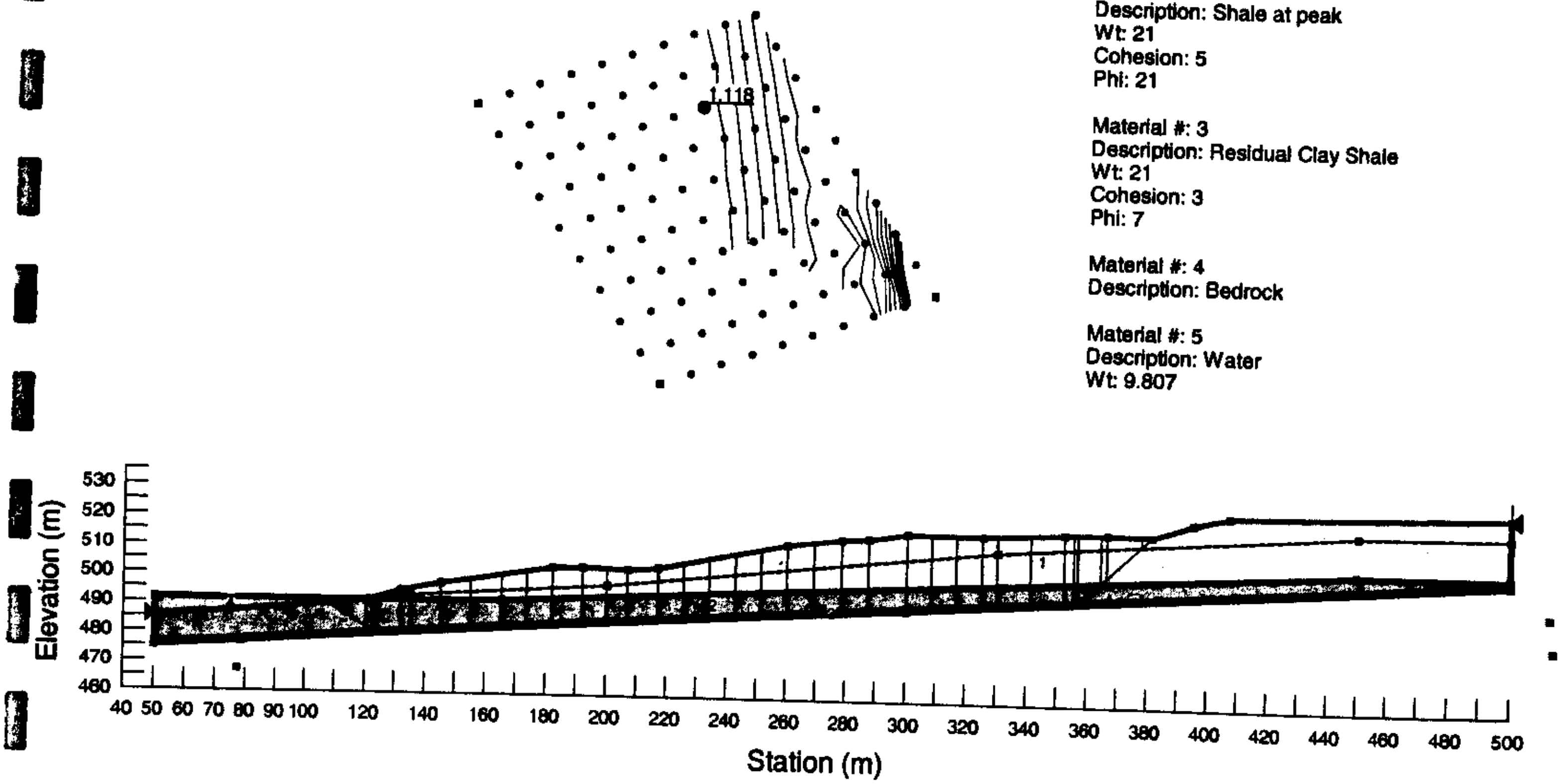
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
Block 2, 2.0m cut near toe, 2.0m increase in piezo levels

(B080109 Present Block2 cut water.gsz)

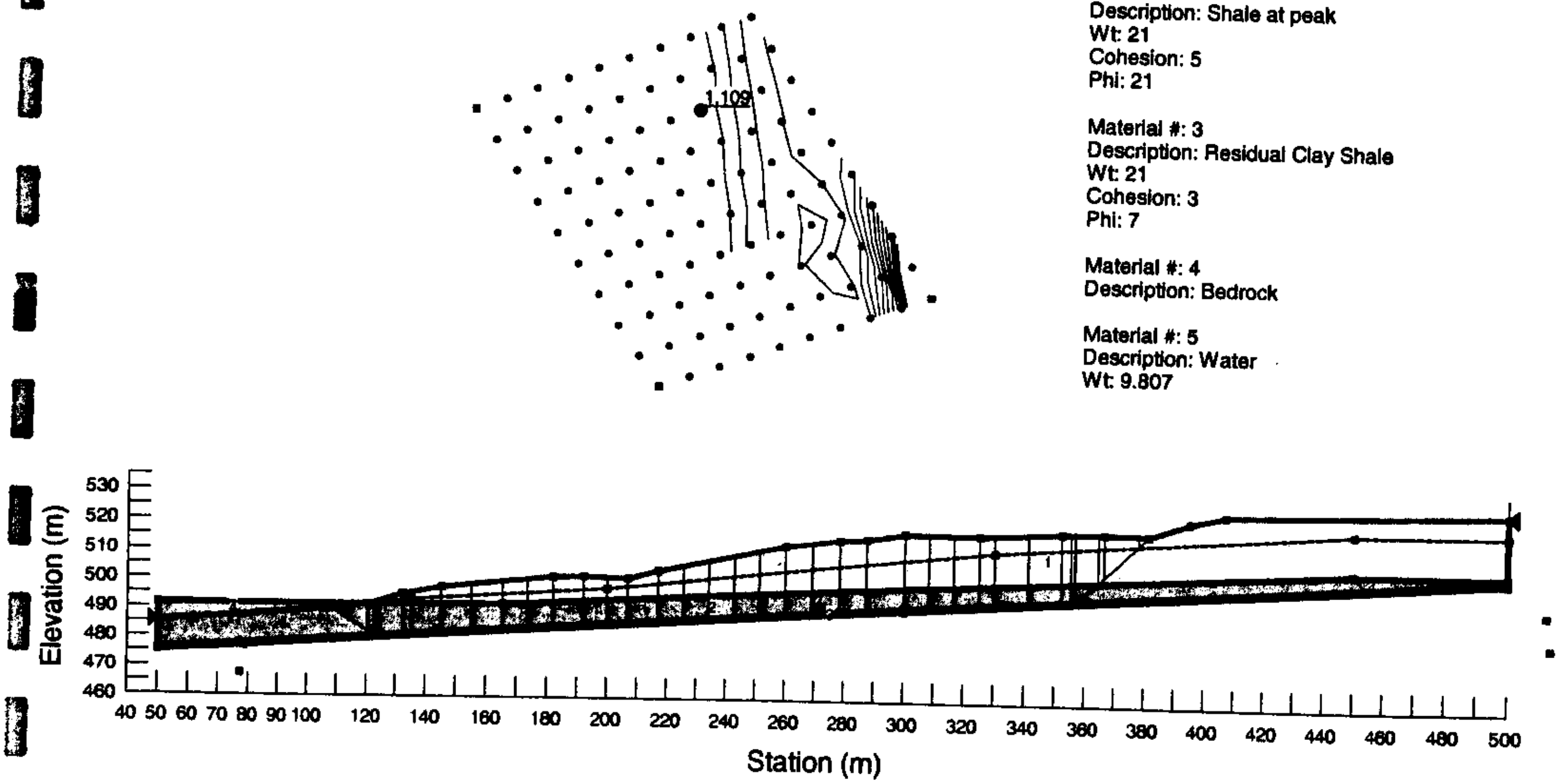
Material #: 1
Description: Till
Wt: 21
Cohesion: 0
Phi: 25

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 5
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
New Slip Surface at Toe

(B080109 Present Min toe.gsz)

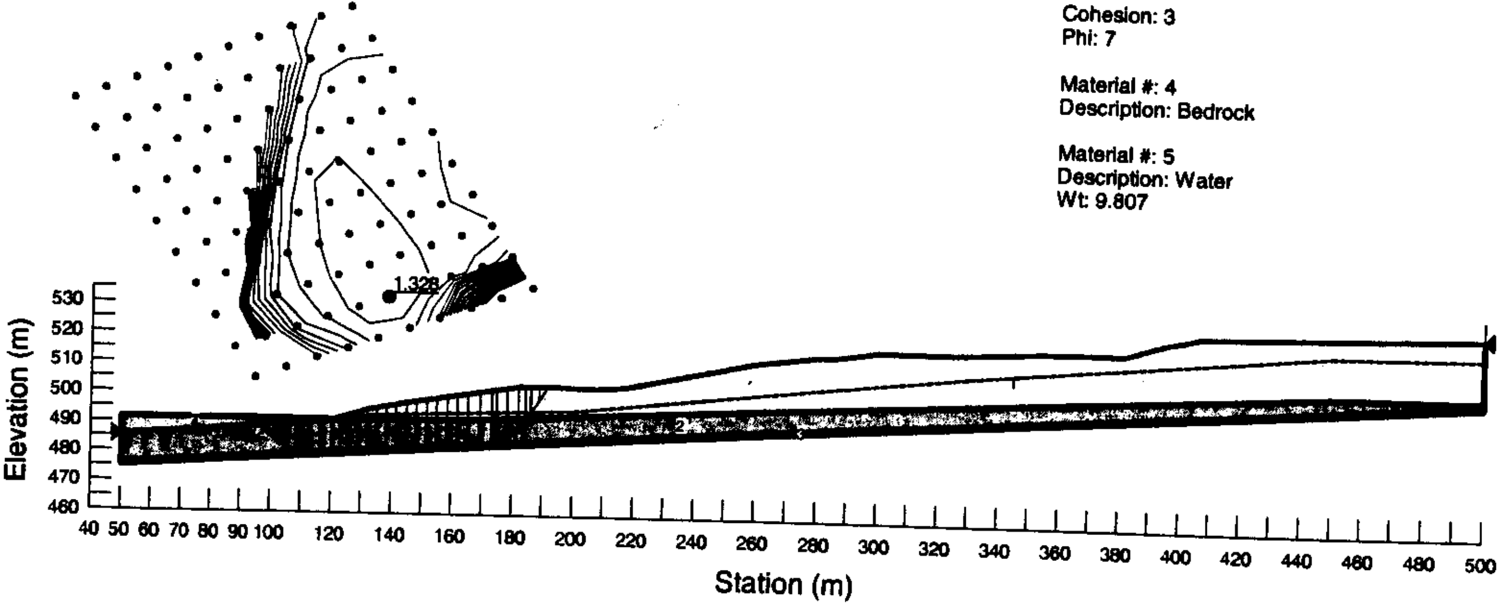
Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
New Slip Surface at Toe, 2.0m fill

(B080109 Present Min toe fill.gsz)

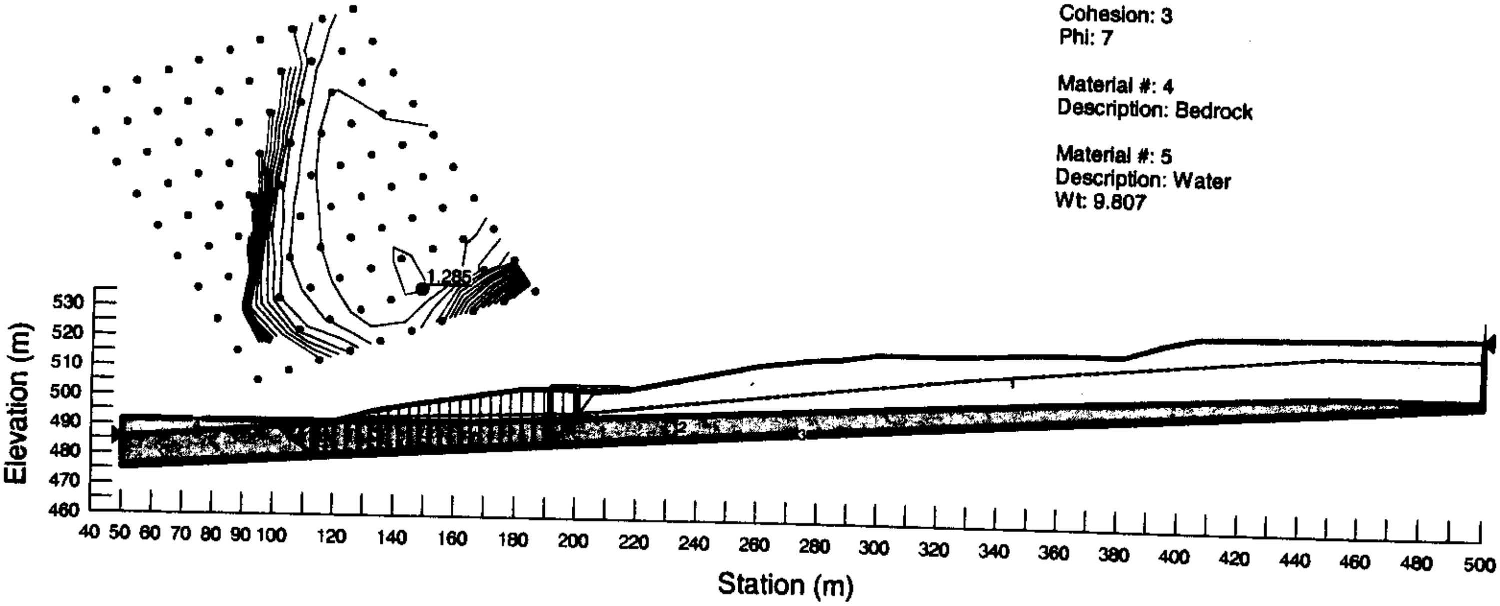
Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
New Slip Surface at Toe, 2.0m increase in piezo

(B080109 Present Min toe water.gsz)

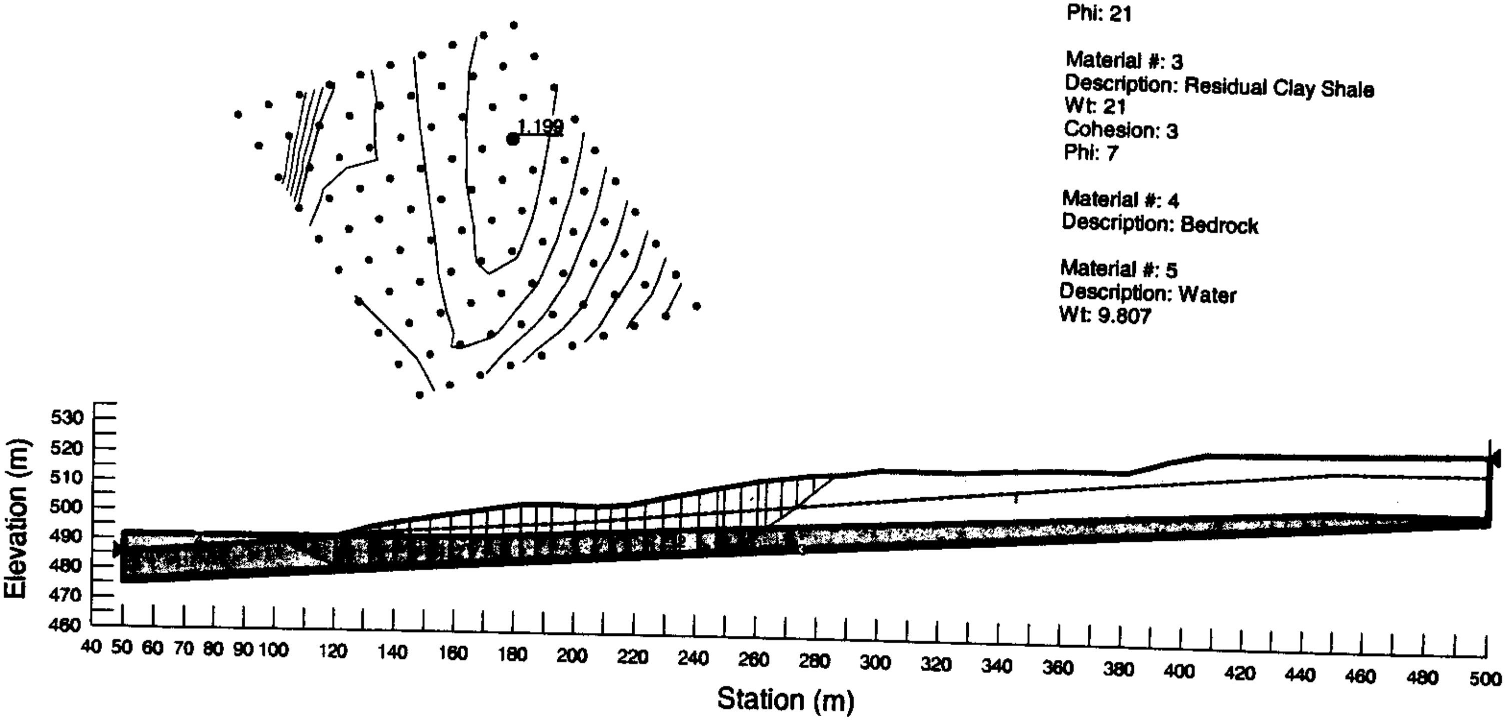
Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



R3985.1 Section B-B', Present Day
New Slip Surface at Toe, 2.0m fill, 2.0m increase in piezo

(B080109 Present Min toe fill water.gsz)

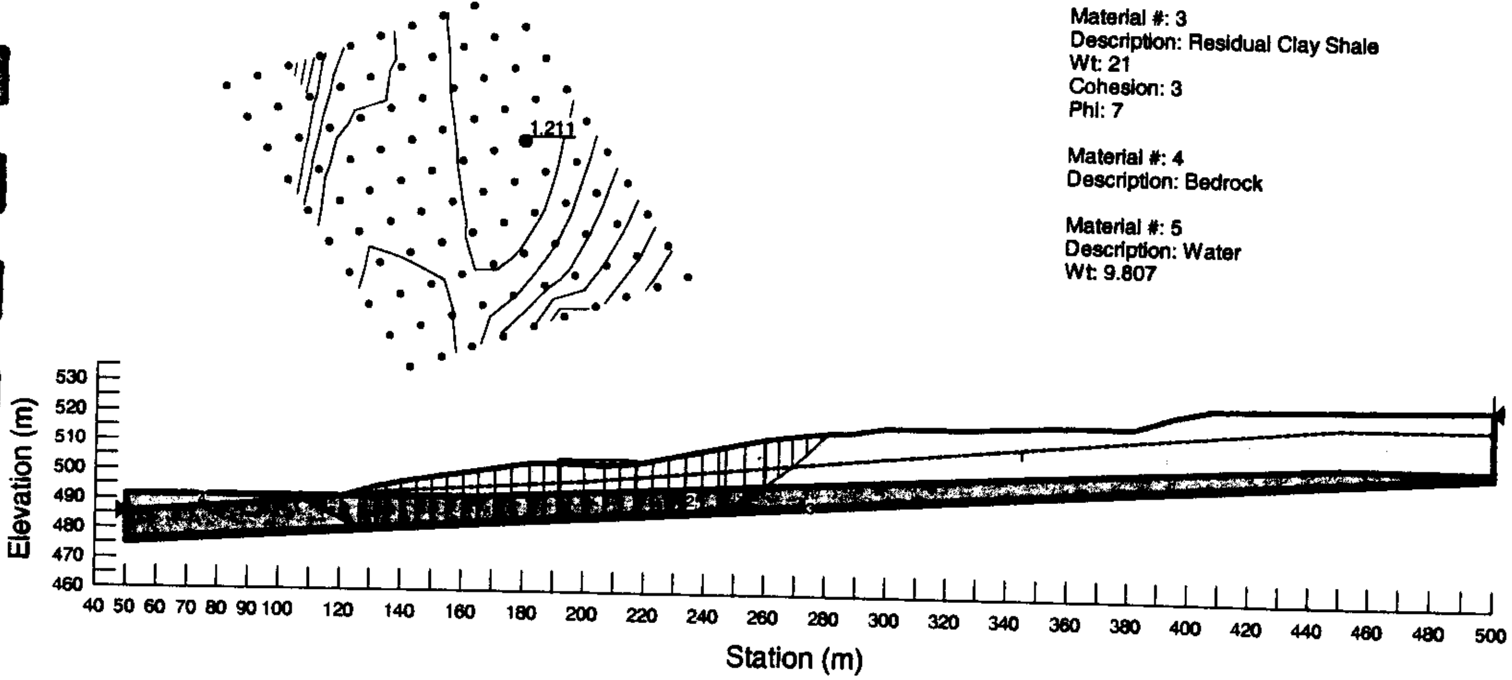
Material #: 1
Description: Till at peak
Wt: 21
Cohesion: 5
Phi: 30

Material #: 2
Description: Shale at peak
Wt: 21
Cohesion: 15
Phi: 21

Material #: 3
Description: Residual Clay Shale
Wt: 21
Cohesion: 3
Phi: 7

Material #: 4
Description: Bedrock

Material #: 5
Description: Water
Wt: 9.807



Clifton Associates Ltd.
engineering science technology

Ministry of Municipal Affairs
JUN - 6 2008
Received by
Community Planning

05 June 2008
File R3985.2

Attention:

Dear Sir:

Subject: Additional Commentary,
Geotechnical Assessment
Sun Dale Subdivision
E29-21-22-W2M (RM of McKillop No. 220)
Last Mountain Lake, Saskatchewan

This letter provides some commentary of revisions to our drawing showing suitable areas for development for this proposed subdivision and road grades. Revisions were developed on the basis of an additional field reconnaissance conducted on 25 April and 01 June 2008, and examination of aerial photography for the area. At the time of the reconnaissance, some surface work had been undertaken, with survey stakes providing some horizontal control. This improves the ability to locate significant landform features utilized in the assessment of geotechnically suitable development areas.

Areas examined were in the eastern portion of the proposed development in the vicinity of the bareland condominium and along Kiiswa Ridge. The reassessment of these areas shifted some of the boundaries of landslide blocks and eliminated others identified from aerial photography. It also expanded the size of some areas designated as 'suitable for buildings', not due to the re-evaluation of existing data, but to more accurately reflect actual conditions on the ground.

The accuracy of drawings based on examination of aerial photography and field reconnaissance without detailed horizontal control such as pins showing the locations of lot boundaries is limited. Similarly, the determination of setbacks from slopes can be more accurately calculated in the field from survey information. Assessment of slope angles and setbacks for this assessment have been based on existing topographic information. A more accurate assessment of features in any area can be made on a 'block by block' or 'lot by lot' basis. Staking of approximate property boundaries and setbacks would be useful, as well, to illustrate areas suitable for development for prospective buyers.

Suitable Building Areas

Bareland Condominium Area

Lots identified as having limited or no safe building in this area included Lots 7, 9, 10, 11, 12, 15 and 17 of Block 1. The areas identified as 'suitable for buildings' in this area were expanded in size, as the areas indicated on previous drawings did not accurately reflect actual conditions, particularly considering the scale of the drawing relative to the size of lots. It is noted that Sun Dale has shifted the location of Lot 7 of this group to the southwest to maximize the size of the area suitable for a building on the south portion of the lot.

340 Maxwell Crescent
Regina, Saskatchewan
Canada S4N 5Y5

Tel: 306 721.7611
Fax: 306 721.8128

All of the Bareland Condominium lots have adequate areas suitable for buildings.

Shoreline lots in this area must consider a suitable setback from the edge of the slope, particularly those lots closest to the east edge of the development. A suitable setback must consider the potential for erosion. In this area, an eroded shale slope as steep as 1.4:1 is present. As configured, a setback equivalent to a 2:1 slope from the toe will result in a minimum of 15 m from the property line to the setback line in the centre lots, increasing to 18 m on the east side and 22 m on the west side.

Lots 9, 10 and 11 have front slopes that are approximately 1.9:1. Setbacks from the slopes in this area will be 1 m to 2 m. Slopes in Lots 12 to 14 are flatter, ranging from 2.5:1 to 4:1, requiring a nominal setback for erosion, estimated to be perhaps 2 m.

Block 3

Lots identified as having limited or no safe building in this area included Lots 10, 11, 15, 16, 20, 22, 23, 24, 25, 26, 27, 30, 31 and 33. This area in general is gently sloping and is more typical of an area that has undergone extensive landsliding; however, it appears to be heavily eroded, which tends to mask all but the most durable features. Areas identified as landslide block boundaries have been shifted after the reconnaissance while considering apparent drainage patterns and topographic mapping. This leaves much of the area as suitable for development.

On this basis, Lots 10, 11 and 15 are part of a continuous area, with the boundary between Lots 15 and 16 coinciding largely to a potential landslide block boundary. In this area, it is noted that Sun Dale has extended Lot 16 to the west. The area suitable for development in Lot 16 appears to be adequate, with a 1 m to 2 m setback from the edge of the slope required; the slope in this area is about 2.1:1.

As a result of these changes, all of the lots in Block 3 have adequate areas suitable for buildings.

Lots 25, 26, 27, 31 and 33 are within a continuous area identified as suitable for development.

Lot 30 is bisected diagonally by an old landslide scarp, leaving two separate areas that would be suitable for development.

The estimated setback for Lots 22 and 23 is about 1 m to 2 m. Slopes in this area are estimated to be about 2.2:1 to 2.7:1.

Lots 20 and 24 are bisected diagonally by an old landslide scarp. On Lot 24, development can be considered relatively close to the edge of the slope, which is estimated to be 2.6:1.

Lots 28 and 29 appear to have adequate space for development, extending to the edge of the slope, with a setback of about 2 m or so required near the southwest corner of the lot where the slope is about 1.8:1.

Lot 31 is largely located on a 4:1 slope consisting of clay shale. It is eroded and relatively devoid of vegetation. This area was not included as an area suitable for development primarily for nongeotechnical reasons; it is aesthetically unattractive compared to the majority of the development. Any development in this area will have to consider the potential for erosion and gullying, with measures to stabilize the surface required that consider the relatively nutrient-poor soil at surface.

Road Grades

Grades at the top of the valley for Sun Dale Ridge, the main roadway into the development, were examined. In its current state, there may be some short sections that are greater than 7 percent to 8 percent; however, after having driven on this road, the steeper sections are limited to short distances and do not appear to be an issue. It is our understanding that this roadway and others have been graded to minimize slopes. As discussed in our report, we reiterate that large cuts and fills that could reduce stability and impact drainage must be avoided. If necessary, we can examine specific cases, should they arise.

Closure

Should you have any questions regarding this matter, please contact me at this office.

Yours truly,

Clifton Associates Ltd.

Richard T. Yoshida, P.Eng.
RTY/ic

Enclosure Drawing No. R3985.2-2

Clifton Associates Ltd.
engineering science technology

21 July 2008
File R3985.2

Ministry of Municipal Affairs
JUL 2 1 2008
Received by
Community Planning

Attention: Project Engineer

Dear Sir:

Subject: Additional Commentary,
Estimated Setback
Sun Dale Subdivision
E29-21-22-W2M (RM of McKillop No. 220)
Last Mountain Lake, Saskatchewan

This letter provides the estimated setbacks from the top or crest of the slope at the shoreline for lots in the condominium area on Mihr and lots along Kiiswa farther to the west.

The setback was calculated as the distance from the crest of the slope corresponding to a 2.25 horizontal to 1 vertical (2.25:1) line starting at the toe of the steep portion of the slope, which is generally back from the waterline and above the beach area.

In previous correspondence, a setback corresponding to a 2:1 line was discussed. A 2.25:1 slope was selected to account for erosion of the slope over time. It should be noted that the shoreline in this area is generally protected by natural armour (riprap) at present water levels. Erosion of the slopes by wave action may occur should water levels increase significantly from these levels so that it is above the riprap. Where slopes were already at about 2.25:1 or flatter, a minimum 2.0 m setback has been specified.

Results of calculations for setback are summarized in Tables 1 and 2. For lots situated along Mihr, the setback is at the minimum of 2.0 m. The setback is larger for Lots 15, 16 and 29 of Block 3 along Kiiswa.

340 Maxwell Crescent
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Table 1
Estimated Setback for Mihr

Lot	Elevation Base	Elevation Top	Height (m)	Distance (m)	Existing Slope	Req'd Setback (m)
14E						
14W	491.00	493.50	2.50	7.00	2.80	2.00
13E	491.00	493.50	2.50	7.00	2.80	2.00
13W	491.25	493.00	1.75	7.00	4.00	2.00
12E	491.25	493.00	1.75	7.00	4.00	2.00
12W	491.00	493.00	2.00	8.00	4.00	2.00
11E	491.00	493.00	2.00	8.00	4.00	2.00
11W	491.50	493.50	2.00	5.00	2.50	2.00
10E	491.50	493.50	2.00	5.00	2.50	2.00
10W	491.50	494.50	3.00	6.00	2.00	2.00
9E	491.50	494.50	3.00	6.00	2.00	2.00
9W	494.50	497.00	2.50	8.00	3.20	2.00

Table 2
Estimated Setback for Kiiswa

Lot	Elevation		Height (m)	Distance (m)	Existing Slope	Req'd Setback (m)
	Base	Top				
15E	492.00	502.00	10.00	16.00	1.60	6.00
15W	491.50	501.50	10.00	20.00	2.00	2.50
16E	491.50	501.50	10.00	20.00	2.00	2.50
16W	491.00	501.00	10.00	21.50	2.15	2.00
17E	491.00	501.00	10.00	21.50	2.15	2.00
17W	491.50	497.50	6.00	16.80	2.80	2.00
18E	491.50	497.50	6.00	16.80	2.80	2.00
18W	490.50	499.00	8.50	18.50	2.18	2.00
19E	490.50	499.00	8.50	18.50	2.18	2.00
19W	491.50	498.50	7.00	15.00	2.14	2.00
21E	491.50	498.50	7.00	15.00	2.14	2.00
21W	491.50	499.00	7.50	13.50	1.80	3.40
22E	491.50	499.00	7.50	13.50	1.80	3.40
22W	491.50	497.50	6.00	15.00	2.50	2.00
23E	491.50	497.50	6.00	15.00	2.50	2.00
23W	491.00	496.50	5.50	16.00	2.91	2.00
24E	491.00	496.50	5.50	16.00	2.91	2.00
24W	491.00	496.00	5.00	14.00	2.80	2.00
28E	491.00	496.00	5.00	14.00	2.80	2.00
28W	491.50	498.00	6.50	11.80	1.82	2.90
29E	491.50	498.00	6.50	11.80	1.82	2.90
29W	491.00	494.00	3.00	7.00	2.33	2.00
30E	491.00	494.00	3.00	7.00	2.33	2.00
30W	491.00	494.50	3.50	7.20	2.06	2.00
31E	491.00	494.50	3.50	7.20	2.06	2.00
31W	491.00	494.50	3.50	7.00	2.00	2.00

Should you have any questions regarding this matter, please contact me at this office.

Yours truly,

Clifton Associates Ltd.

Richard T. Yoshida, P.Eng.
RTY/ic