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Mount Polley Mine Project: Tailings Storage Facility 2011 Geotechnical Site Investigation: Draft Report

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IMPORTANT NOTICE

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1.0 INTRODUCTION

Mount Polley is a copper and gold mine owned by Imperial Metals Corporation and operated by the Mount Polley Mining Corporation (MPMC). The design and construction monitoring of the Tailings Storage Facility (TSF) embankment from mine start up to early 2011 had been completed under the direction of Knight Piesold Limited (KP). AMEC Environment and Infrastructure, a division of AMEC Americas (AMEC), assumed the role of engineer-of-record for the TSF embankment as of 28 January 2011.

A geotechnical investigation was undertaken in October 2011, based on the review of existing site instrumentation and as required to conform to TSF monitoring recommendations. The investigation comprised geotechnical drilling, installation of three slope indicators, eleven vibrating wire piezometers (VWP) and was followed up by laboratory testing on selected samples. In conjunction with the investigation, the installation of four groundwater monitoring wells was also completed at the request of MPMC to address issues not related to geotechnical stewardship of the TSF.

2.0 BACKGROUND

2.1 General

The Mount Polley mine is located 56 km northeast of Williams Lake, British Columbia. Operations began in 1997 and have continued to the present, with the exception of a prolonged shutdown for economic reasons occurring between 2001 and 2005. The mine currently processes ore at a mill throughput rate of approximately 20,000 tonnes per day. Tailings from this process are deposited as slurry into a TSF comprised of a 4.2 km long earth and rockfill embankment, as shown in Drawing 2011.01. The embankment, being raised annually via a modified centerline geometry, is formed of three sections:

1. Main, up to 45 m high;
2. Perimeter, up to 27 m high; and
3. South, up to 17 m high.

The Stage 7 embankment raise, constructed in the summer of 2011, uniformly increased the TSF embankment crest elevation to approximately 960.1 m, a height increase of 2.0 m relative to the previous year's crest raise.

As of June 2011, 93 piezometers had been installed along nine monitoring planes within the three embankment sections. Also as of June 2011, of the 93 piezometers, approximately 40% were functioning. Piezometers have been installed in the TSF embankment fills, foundations, and the impounded tailings upstream of the compacted till core zone. Five slope inclinometers were installed near the downstream toe of the Main embankment, four of which currently function. Given the nature of the TSF, monitoring embankment response to raising and ongoing tailings placement is an essential component of sound tailings management. A full review of the nature and number of instruments present in the dam was originally completed by AMEC during a dam safety review (DSR) completed in 2006 (AMEC, 2006). Based upon that review, replacement of non-functioning instrumentation in key locations was recommended in the 2006 DSR (AMEC, 2006). This recommendation was reiterated in the 2011 TSF review and recommendations memorandum (AMEC, 2011). Both these documents also recommended further characterization of glaciolacustrine soils within the foundations of the dams as this had been postulated from very early in the mine life as being a potential stability concern but was not effectively addressed prior to the 2011 TSF review and recommendations..

2.2 Basis for 2011 Investigation

Based on AMEC's review of the existing Mount Polley TSF information, and instrumentation coverage (AMEC, 2011), it was determined there was need for an improved characterization of foundation soil conditions, pore pressures and potential movements within foundation glaciolacustrine soils. The 2011 investigation was proposed to MPMC on that basis and was approved. The investigation as specifically undertaken with efforts focussed on enhancing the understanding of these issues and in particular, the following three geotechnical issues:

1. *Glaciolacustrine foundation soils (GLU)*: The 2006 Dam Safety Review (AMEC, 2006) and 2010 Dam Safety Inspection (KP, 2011) both highlighted the significance of any potential for pre-shearing (i.e. low strength) within the glaciolacustrine soils present within the Mount Polley TSF foundation soils and recommended additional investigation and testing be undertaken to improve characterisation of these soils. Specifically, the concern would be associated with any laterally continuous, high plastic clay varves within the glaciolacustrine soils that, if pre-sheared to a low residual shear strength, would represent a weak planar feature within the foundation that would largely govern dam stability. Further, even if not pre-sheared, such clay varves could be driven to a low shear strength as a result of movements induced by the ongoing raising of the dam, thus making it important to monitor displacement patterns within these soils. Movement (about 4 mm) within this foundation soil type was noted by KP (2011) to have occurred in inclinometer SI01-02.

2. *Perimeter embankment crack:* The 2010 Dam Safety Inspection (KP, 2011) observed a longitudinal crack (i.e. parallel to the axis of the dam) at the eastern portion of the Perimeter embankment (at station 3+400 m) within the downstream rockfill shell. It is unknown whether this crack is indicative of embankment slope movement (possibly related to till borrow excavation operations to the downstream, and/or foundation glaciolacustrine soils), or merely reflects localized rockfill settlement. No further cracking has been observed in this area.

3. *South embankment foundation conditions*: AMEC's review of foundation conditions concluded little information existed within the ultimate South embankment downstream toe area.

2.3 Previous Investigations

A review of previous site investigations was carried out for the Tailings Storage Facility which included the following:

- Geotechnical Drilling, November 1989 (Wright 1990)
- Geotechnical Investigation, 1995 (KP 1995)
- Groundwater Monitoring Well Installation, February 1997 (KP 1997a)

- Geological Investigations, 1997 (KP 1997b)
- Slope Inclinometer Installation, May 2006 (KP 2007)
- Borrow Site Investigation, May 2008 (KP 2009)

The previous investigations consisted of excavating test pits and advancing drill holes by various drilling methods including air rotary, diamond drilling and sonic drilling. Complete detailed report information for all of the previous investigations was not available for AMEC's review. This includes the following investigations:

- 1989 Test Pit Investigation
- 1995 Test Pit Investigation
- 1996 CPT Program and Pressure Relief Well Installations
- 1997 Borehole Investigation
- 2001 Slope Inclinometer Installation
- 1996-2010 Piezometer Installations

A plan illustrating the location of previous site investigations is presented on Drawing 2011.11.

3.0 SITE INVESTIGATION PROGRAM

3.1 Scope

The site investigation program was carried out from September 29 to October 11, 2011, inclusive. The investigation was carried out using a Sonic drill rig and included completion and installation of 11 vibrating wire piezometers, and 3 slope inclinometers. The Sonic drilling technology typically involves a rotary vibratory drill head which utilizes both rotary motion and high frequency resonant vibrations to advance the drill hole.

The piezometer and inclinometer holes were advanced to final depths ranging from 11.0 m to 48.0 m, and from 43.0 m to 50.0 m, respectively. In each of the holes, retrieval of continuous overburden core samples was undertaken. The sample retrieval allowed characterisation of foundation soils (in particular, examination of the glaciolacustrine unit) and identification of appropriate piezometer tip installation locations.

Characterisation of the GLU within the field was based on various observations including (but not limited to), the presence of fine grained soil as the primary constituent, presence of varves and laminations, and separation between till and/or fluvial units. Photographs of the core samples characterised as GLU are presented in Appendix C.

A summary of the completed site investigation program is presented in Table 3.1, and a summary of installed instrumentation details in Table 3.2.

Laboratory tests including Atterberg Limits, moisture content determinations and grain size distributions for samples of overburden soil were carried out in AMEC's Prince George Materials Lab and are presented in Appendix A. Detailed visual inspection was also performed in the lab on selected samples. Results from laboratory testing are presented in Section 3.3 as well as in the drill hole logs provided in Appendix B.

3.2 Drilling

All holes were advanced within the TSF in the three embankments: Main, Perimeter and South.

The drill holes were advanced in the following locations based on the three geotechnical conditions mentioned in Section 2.1:

1. *Glaciolacustrine foundation soils*: Six piezometers and two inclinometers were advanced in the downstream toe area of the Main embankment, using the existing rockfill buttress as a platform. Two piezometers were advanced in the downstream toe area of the Perimeter embankment.

2. *Perimeter embankment crack:* Drill holes were advanced both on the embankment crest and adjacent to the downstream embankment toe at chainage 3+400. One inclinometer was installed at the crest while one piezometer was installed at the toe.

3. *South embankment foundation conditions:* Two piezometers were installed adjacent to the downstream toe area of the South embankment.

Locations of the drill holes are shown in plan view on Drawing 2011.01. Instrumentation sections are presented on Drawings 2011.02 through 2011.09.

Table 3.1: 2011 Drill Holes Summary

Hole ID	Coordinates		Instrumentation	Surface Elevation (m)	Total Drillhole Depth (m)	Location
	Northing	Easting				
VW11-01	5818480	594463	Piezometer	941.0	11.1	South Embankment
VW11-02	5818343	594786	Piezometer	945.1	17.4	
VW11-03	5818272	595467	Piezometer	927.0	23.2	Main Embankment
VW11-04	5818309	595533	Piezometer	921.6	29.3	
VW11-05	5818410	595605	Piezometer	920.6	32.3	
VW11-06	5818423	595686	Piezometer	916.3	35.4	
VW11-07	5818554	595850	Piezometer	919.8	43.3	
VW11-08	5818697	596027	Piezometer	927.7	47.5	
VW11-09	5819415	595928	Piezometer	936.6	41.7	Perimeter Embankment

VW11-10	5819783	595410	Piezometer	931.8	42.4	
VW11-11	5820031	594892	Piezometer	940.9	23.5	
SI11-01	5818353	595527	Inclinometer	921.1	44.8	Main Embankment
SI11-02	5818716	595998	Inclinometer	928.3	49.4	Main Embankment
SI11-04	5819780	595408	Inclinometer	931.9	43.3	Perimeter Embankment

Table 3.2: Summary of Instrumentation Details

Hole ID	Instrumentation ID	Instrumentation Serial No.	Installation Depth (m)	Tip Location (Soil Unit)
VW11-01 (FX3)	F5	1119797	7.0	Foundation Till
VW11-02 (IX3)	I5	1119796	7.6	Foundation Till
	I6	1119792	10.4	Glaciolacustrine
VW11-03 (EX4)	E6	1119794	15.2	Glaciolacustrine
	E7	1119801	18.9	Glaciofluvial
VW11-04 (CX4)	C11	1119798	12.5	Glaciolacustrine
	C12	1119795	21.0	Foundation Till
VW11-05 (AX5)	A16	1119799	12.2	Glaciolacustrine
	A17	09-2810	16.8	Glaciolacustrine
	A18	09-2808	24.4	Foundation Till
VW11-06 (AX6)	A19	09-2811	10.7	Glaciolacustrine
	A20	09-2809	15.2	Glaciolacustrine
	A21	1119786	22.9	Foundation Till
VW11-07 (BX4)	B11	1119793	13.7	Glaciolacustrine
	B12	1119791	25.9	Foundation Till
	B13	1119785	31.1	Glaciolacustrine
VW11-08 (KX2)	K1	1119788	15.2	Glaciofluvial
	K2	1119784	33.8	Glaciofluvial
VW11-09 (JX1)	J1	1119800	19.4	Foundation Till

VW11-10 (DX4)	D6	1119790	18.4	Glaciolacustrine
	D7	1119802	24.4	Glaciofluvial
VW11-11 (GX2)	G4	1119789	6.1	Foundation Till
	G5	1119787	10.7	Glaciolacustrine

Note: ID in brackets (eg. (FX3)) corresponds with existing Mount Polley instrumentation identification.

Drill hole depths ranged from 11.1 to 49.4 m below ground surface (at the drill hole collar). Each of the inclinometer holes was terminated a minimum of 2 m into the weathered rock or bedrock unit to ensure the instrumentation was installed in a secure unit. The vibrating wire piezometers were grouted in, allowing for rapid installation of multiple VWP's in a single borehole. Slope inclinometers were grouted into completed sonic drill holes. Typical piezometer installation details are shown on Figure 3.1.

Calibration reports for the VWP's are provided in Appendix D. Readings of new instrumentation are presented in Appendix E. A summary of piezometer readings from February 4, 2012 are shown in Table 3.3.

Figure 3.1: Typical Piezometer Installation Details

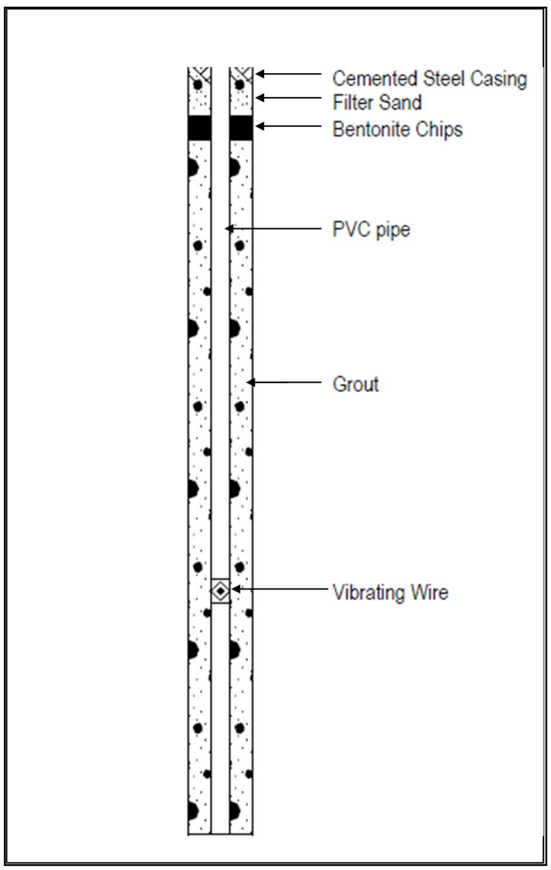


Table 3.3: Summary of Piezometer Data (February 4, 2012)

<table>
<tr><th>Location</th><th>Hole ID</th><th>Instrumentation ID</th><th>Tip Material</th><th>Tip Elevation (m)</th><th>Fill Elevation (m)</th><th>Elevation Head (m)</th></tr>
<tr><td>7+52</td><td>VW11-01</td><td>F5</td><td>Foundation Till</td><td>934.0</td><td>941</td><td>942.3</td></tr>
<tr><td rowspan="2">11+00</td><td rowspan="2">VW11-02</td><td>I5</td><td>Foundation Till</td><td>937.5</td><td rowspan="2">945.1</td><td>946.6</td></tr>
<tr><td>I6</td><td>Glaciolacustrine</td><td>934.7</td><td>946.6</td></tr>
<tr><td rowspan="2">17+60</td><td rowspan="2">VW11-03</td><td>E6</td><td>Glaciolacustrine</td><td>911.8</td><td rowspan="2">927</td><td>917.7</td></tr>
<tr><td>E7</td><td>Glaciofluvial</td><td>908.1</td><td>918.1</td></tr>
<tr><td rowspan="2">18+45</td><td rowspan="2">VW11-04</td><td>C11</td><td>Glaciolacustrine</td><td>909.1</td><td rowspan="2">921.6</td><td>914.8</td></tr>
<tr><td>C12</td><td>Foundation Till</td><td>900.6</td><td>906.2</td></tr>
<tr><td rowspan="3">19+60</td><td rowspan="3">VW11-05</td><td>A16</td><td>Glaciolacustrine</td><td>908.4</td><td rowspan="3">920.6</td><td>913.7</td></tr>
<tr><td>A17</td><td>Glaciolacustrine</td><td>903.8</td><td>913.5</td></tr>
<tr><td>A18</td><td>Foundation Till</td><td>896.2</td><td>915.4</td></tr>
<tr><td rowspan="3">20+30</td><td rowspan="3">VW11-06</td><td>A19</td><td>Glaciolacustrine</td><td>905.7</td><td rowspan="3">916.3</td><td>910.2</td></tr>
<tr><td>A20</td><td>Glaciolacustrine</td><td>901.1</td><td>911.7</td></tr>
<tr><td>A21</td><td>Foundation Till</td><td>893.5</td><td>914.5</td></tr>
<tr><td rowspan="3">22+40</td><td rowspan="3">VW11-07</td><td>B11</td><td>Glaciolacustrine</td><td>906.1</td><td rowspan="3">919.8</td><td>916.7</td></tr>
<tr><td>B12</td><td>Foundation Till</td><td>893.9</td><td>918.1</td></tr>
<tr><td>B13</td><td>Glaciolacustrine</td><td>888.7</td><td>917.8</td></tr>
<tr><td rowspan="2">24+70</td><td rowspan="2">VW11-08</td><td>K1</td><td>Glaciofluvial</td><td>912.4</td><td rowspan="2">927.7</td><td>934.7</td></tr>
<tr><td>K2</td><td>Glaciofluvial</td><td>893.8</td><td>937.3</td></tr>
<tr><td>32+80</td><td>VW11-09</td><td>J1</td><td>Foundation Till</td><td>917.2</td><td>936.6</td><td>921.6*</td></tr>
<tr><td rowspan="2">39+15</td><td rowspan="2">VW11-10</td><td>D6</td><td>Glaciolacustrine</td><td>913.4</td><td rowspan="2">931.8</td><td>916.1</td></tr>
<tr><td>D7</td><td>Glaciofluvial</td><td>907.4</td><td>915.6</td></tr>
<tr><td rowspan="2">44+60</td><td rowspan="2">VW11-11</td><td>G4</td><td>Foundation Till</td><td>934.8</td><td rowspan="2">940.9</td><td>941.8</td></tr>
<tr><td>G5</td><td>Glaciolacustrine</td><td>930.2</td><td>938.4</td></tr>
</table>

*Piezometer inaccessible, last reading from November 27, 2011

3.3 Index Property Testing – Overburden Samples

3.3.1 General

Index property testing conducted on collected samples included moisture content tests, grain size analyses (including hydrometer analysis on selected samples), and Atterberg limits testing on samples with measurable plasticity. Detailed visual inspection was also performed in the lab on selected samples from various drill holes.

Laboratory results are presented in Appendix A as well as in the drill hole logs in Appendix B. A summary of laboratory testing for each drill hole is presented below in Table 3.4.

Table 3.4: Summary of Laboratory Tests Undertaken

Hole ID	Total Drillhole Depth (m)	No. of samples Tested			
		Grain size Analysis	Moisture Content	Atterberg Limits	Detailed Visual Inspection
VW11-01	11.1	1	4	0	0
VW11-02	17.4	0	5	1	0
VW11-03	23.2	0	5	1	3
VW11-04	29.3	1	10	2	0
VW11-05	32.3	0	9	2	0
VW11-06	35.4	0	19	1	7
VW11-07	43.3	0	17	3	0
VW11-08	47.5	4	31	1	6
VW11-09	41.7	3	18	0	1
VW11-10	42.4	2	25	4	2
VW11-11	23.5	1	18	0	2
SI11-01	44.8	3	8	1	3
SI11-02	49.4	2	26	5	9
SI11-04	43.3	1	4	0	3

***Note**: 23 samples were tested from collected boxed core or Shelby tubes at VW11-06, VW11-08 and SI11-04. All other samples were grab samples.*

3.3.2 Detailed Visual Inspection

A detailed visual inspection was performed on selected samples in AMEC's Prince George laboratory following the investigation program. The inspections involved observations of soil composition, varve thickness, plasticity, consistency, colour, moisture content and structure. These observations are included within the drill hole logs in Appendix B.

3.3.3 Atterberg Limits

Atterberg Limits testing gives numerical values to soil plastic and liquid limits, thus classifying the soil. From these values, the plasticity index (PI) and liquidity index (LI) can be determined. Plasticity index is the size of the range of moisture contents where a soil exhibits plastic properties. (for example, typically if PI=0, the soil is classified as non-plastic) Liquidity index is a measure of the stiffness within the soils plasticity index range. (for example, soils with LI>1, typically exhibit a very low shear strength).

Out of a total of 20 Atterberg limits tests completed, 19 were performed on samples from within the GLU. Samples chosen for Atterberg limits testing were generally selected from areas indicating a thick GLU. The testing interval was decreased in some holes where similar units were observed and in close proximity to each other. Results from Atterberg limits testing are discussed below and are also presented in Table 3.5.

- Samples tested from within the glaciolacustrine unit which appeared to have a varved structure, yielded plasticity index results ranging from 1 to 33%, the majority of fines generally classifying as clay of intermediate plasticity (CI). The highest plasticity index result of 33%, fines classifying as clay of high plasticity (CH), occurred in a sample from drill hole SI11-02 (Main Embankment) at approximate elevation 900.6 m. Moisture contents typically ranged from 20% to 32% (with the exception of sample C2 from VW11-06 with a moisture content of 38%).

- Samples tested from within the glaciolacustrine unit which appeared to have a massive structure, yielded plasticity index results ranging from 0 to 16%, the fines generally classifying as either silt with low plasticity (ML) or clays with low to intermediate plasticity (CL-CI).

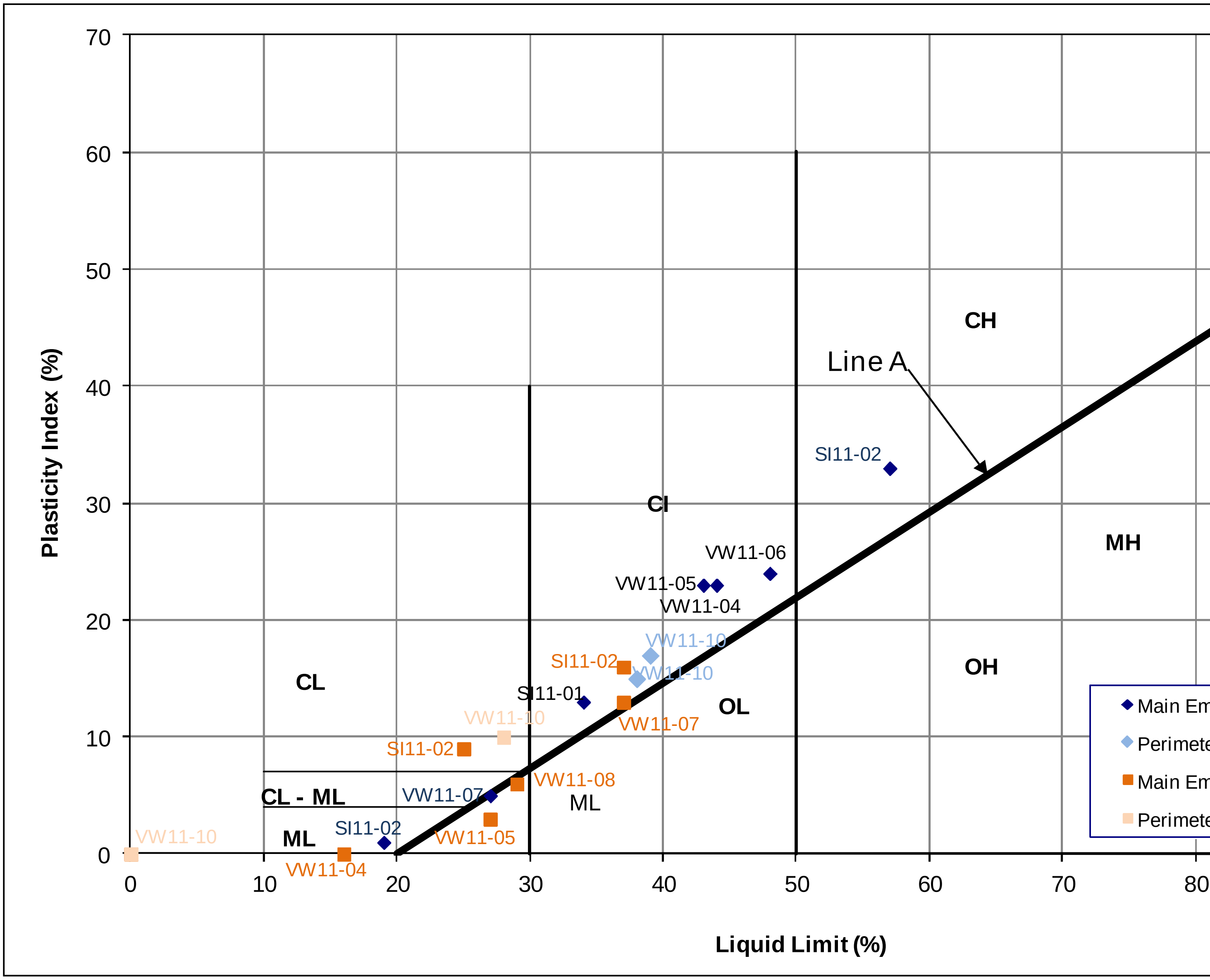
- One sample was tested within a glaciofluvial unit in VW11-03. The sample yielded a moisture content of 22.2% with fines classifying as non-plastic.

Table 3.5: Summary of Atterberg Limits Testing Results

Hole ID	Sample Depth (m)	Location	Soil Classification	Moisture Content	Plastic Limit (%)	Liquid Limit (%)	Liquidity Index	Comments
VW11-03	18	Main Embankment	SM*	22.2	0	0	-	Non-plastic
VW11-04	10		CI	23.4	21	44	0.10	Varved
	15		CM	32.4	26	16	-	Non-plastic
VW11-05	13.7		CI	29.8	20	43	0.43	Varved
	16.6		ML	24.8	24	27	0.27	
VW11-06	11		CI	37.9	24	48	0.58	Varved
VW11-07	13.2		CI	26.1	24	37	0.16	
	20.2		CM	26.7	25	0	-	Non-plastic
	30.8		CL-ML	25.5	22	27	0.70	Varved
VW11-08	17.2		ML	26.4	23	29	0.57	
SI11-01	11.7		CI	27.6	21	34	0.51	Varved
SI11-02	16.5		ML	18.4	18	19	0.40	Varved
	21.5		CL	15.4	16	25	-	
	27.6		CH	31.8	24	57	0.24	Varved
	31.3		CI	30.4	21	37	0.59	
VW11-10	17	Perimeter Embankment	CI	23	22	39	0.06	Varved
	18.2		CI	24.7	23	38	0.11	Varved
	20		CM	22.4	25	0	-	Non-plastic
	35.8		CL	20.1	18	28	0.21	
VW11-02	10.5	South Embankment	CL	17.3	20	28	-	

*Sample from Glaciofluvial unit. All other samples are from Glaciolacustrine unit.

Figure 3.2: Atterberg Limits Test Results (Glaciolacustrine Unit)



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3.3.4 Grain Size Analyses

Grain size analyses were conducted on selected samples from the each of the glaciolacustrine, glaciofluvial and till units.

- Hydrometer analyses conducted on samples from the glaciolacustrine unit (massive structure) indicated clay contents (% by dry weight finer than 2 microns) in the range of 8.1% to 33.7% with total fines contents (% by dry weight finer than 74 microns) typically in the range of 72.9% to 99.5%, based on the 75-mm minus sample fraction.

- Hydrometer analyses conducted on samples from the glaciofluvial unit indicated sand contents (% by dry weight between 74 microns and 4.75mm) of approximately 35% to 68% with total fines contents in the range of 26.2% to 52.4%.

- Hydrometer analyses conducted on samples from the till unit indicated clay contents in the range of 4.7% to 21.6% with total fines contents in the range of 40.7% to 88.1%.

4.0 KEY RESULTS AND IMPLICATIONS

Key information obtained from the investigation is discussed below.

4.1 Main Embankment

Information obtained from the investigation indicates that within the foundation soils there exists a continuous glaciolacustrine unit with interbedded glaciofluvial units between an upper and lower till unit overlying bedrock.

The GLU is generally characterised as:

1. Silty CLAY to Clayey SILT to SILT
    - Occasional sand layers (2-20 mm thick)
    - Low to high plasticity
    - Stiff to hard
    - Moist to wet (moisture content = 15-32%)
    - Clay varves (3-30 mm thick) and silt varves (1-50 mm thick)

overlying,

2. SILT to Sandy SILT
    - Non-plastic to low plasticity
    - Dense
    - Wet to saturated (moisture content = 20-34%)
    - Massive structure with occasional clay varves

The glaciofluvial unit is generally characterised as:

- SAND to Silty SAND
    - Trace to some gravel, trace clay
    - Non-plastic
    - Compact to dense
    - Moist to wet (moisture content = 4-28%)

The till is generally characterised as:

- Sandy SILT to Clayey SILT
    - Trace to some gravel
    - Occasional sand seams and/or lenses
    - Non-plastic to low plasticity
    - Dense to stiff-hard
    - Moist (moisture content = 7-30%)

Photographs of samples collected within the GLU from the Main embankment drill holes are presented in Appendix C, Photos 2 through 36 and 47 through 62. Sections displaying interpreted stratigraphic profiles of the drill holes are presented in Drawings 2011.02 through 2011.06.

4.1.1 Glaciolacustrine Foundation Soils

The GLU within the main embankment foundation appears to be thickest along the east and central regions of the embankment (approx. Sta.22+40 to 24+70 m) with thicknesses ranging from 15.0 m to 18.1 m. The unit appears to thin moving west towards the south embankment (approx. Sta. 20+30 to 17+60 m) with thicknesses decreasing from 8.7 m to 2.5 m.

Consistency

The GLU containing a greater percentage of clay was generally considered to have a consistency of very stiff to hard. This conclusion is consistent with that of historical data from previous Knight Piesold investigations. Table 4.1 provides a summary of foundation soil characteristics of selected nearby holes encountering the GLU.

Table 4.1: Summary of Foundation Soil Characteristics – Main Embankment

Hole ID/Location	Elevation (m)/ Depth (mbgs*)	Consistency/Density	Soil Unit
GW96-3[1]	907 900	Stiff to very stiff	Silt, some clay to clayey (GLU)
	900 895	Very stiff to hard	Silt, trace sand (GLU)
GW96-9[1]	911 910	Stiff to very stiff	Silt, trace sand (GLU)
SI06-1[2]	909 901	Compact to very dense	Silt, trace clay
SI06-2[2]	909 900	Compact to dense	Silt, trace clay
SI06-3[2]	911 901	Dense to very dense	Silt, trace clay, trace sand
TPB11[3]	1.8 3.7	Dense	Silt, some sand
TPB13[3]	1.1 4.9	Dense	Silt, trace to some sand, trace gravel, trace clay
TPB14[3]	1.1 4.9	Dense	Silt, some sand to sandy
MP89-234[4]	909 900	Dense	Clay and Silt, trace pebbles
Cross Section 3[5]	varies	Very stiff	Silt, lesser Clay, rare sand seams (GLU)

*Meters below ground surface
1 Air rotary drilled Ground water monitoring well holes (KP 1997a)
2 Air rotary drilled Slope Inclinometer holes (KP 2007)
3 Test Pit excavation (Wright 1990)
4 Diamond Drill holes. Report notes “It was not possible to distinguish between the dense alluvial silts and glacial tills in the drilling program”. (Wright 1990)
5 Geological summary cross-section through Main embankment centerline (KP 1997b)

Where the GLU consists primarily of non-plastic silts (typically below the upper, more clay-rich portion of the unit), it was generally observed to be loose to compact upon sample retrieval. An example of this material unit was found in samples G4 and G5 in drill hole VW11-05 (See Photos 12 and 13). This condition was found in a majority of the drill holes along the main embankment and is also described in the following historical investigations:

- Drill logs from the 1996 investigation (GW96-3) note a "*coarse silt, quickens under vibration*" (KP 1997a).

- A cone penetration testing (CPT) program was conducted in 1996 due to low SPT N-values (encountered during a prior investigation) within a non-plastic silt layer. The CPT investigations confirmed that the N-values were due to drilling disturbance and not weak foundation soils. (KP 1997b)

It should be noted that, during the 2011 drilling program, at least three attempts were made to push a Shelby tube sampler (0.76m length) within the GLU closer to the east end of the main embankment, obtaining only 0.15-0.25m of recovery due to high penetration resistance. Based on the above information, the apparently loose condition within the recovered sonic core is not reflective of the in situ condition, but is instead a result of vibration and sample disturbance caused by the sonic drilling method. The relatively low moisture contents of the silt further attest to this conclusion.

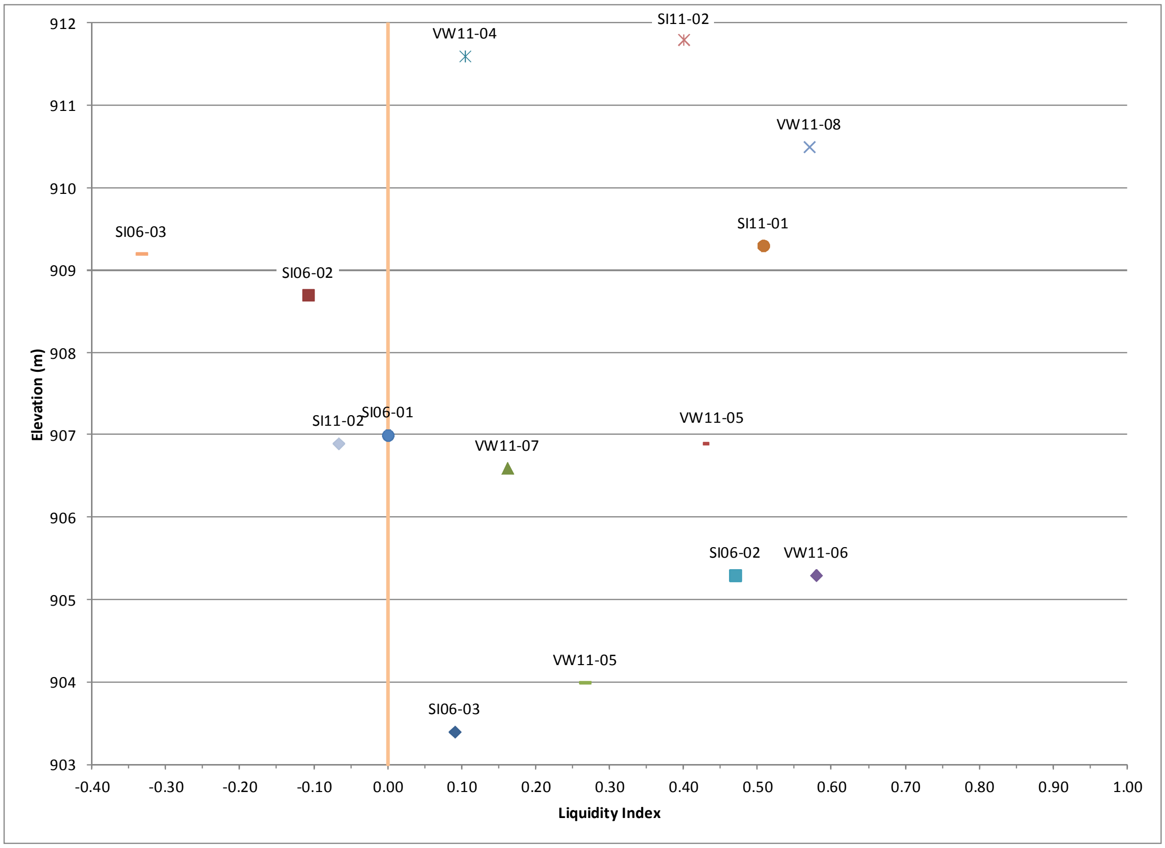
<u>Over-consolidated condition</u>

There are a number of indications to suggest that GLU along the main embankment is in an over-consolidated state. Soils that are over-consolidated typically have higher peak strength (at a given effective stress), than normally consolidated soils. Moreover, for heavily over-consolidated soils with high fines contents (such as the GLU) that will shear in an undrained manner due to low hydraulic conductivity, the undrained shear strength will typically exceed the drained shear strength, owing to negative shear-induced pore pressures.

Figure 4.1 presents a plot of liquidity index results for various drill holes along the main embankment. The plot shows a number of samples with a liquidity index (LI) near zero (moisture content = plastic limit), which is typically consistent with an overconsolidated condition. For example, in VW11-04, testing of the silt GLU near elevation 911.5m (top of the unit) resulted in a LI equal to 0.1. (See Photo 4) This condition was also found to exist in several other locations along the Main Embankment from the 2011 investigation as well as earlier investigations. Table 4.2 presents a summary of available lab data for investigation holes located along the main embankment, 2011 and earlier. Note that some negative LI values were obtained, indicating natural moisture contents below the plastic limit.

A summary of GLU descriptions from Stage 2A Tailings Facility Construction report indicates that the "*glaciolacustrine (silt, clay) sediments are often highly overconsolidated and very stiff to hard*". (KP 1997b)

Figure 4.1: Elevation vs. Liquidity Index – Drill holes along Main Embankment



*Note: SI06 drill holes are from the 2006 slope inclinometer installation program.

Table 4.2: Summary of Available Lab Results – Main Embankment

Hole ID	Location	Sample Elevation (m)	Moisture Content (%)	Plasticity Index	Liquidity Index	Friction Angle (Φ)	Cohesion (c')	Soil Description
TP95-37[2]	16+55[4]	-	18.8	11	0.2	35	0	Sand and Silt, some gravel and clay (Till)
TP95-39[2]	17+90[4]	-	28.5	-	-	33	0	Silt, some clay and sand, trace gravel (Till)
VW11-04	18+45	911.6	23.4	23	0.1	-	-	Silt, some clay to clayey, trace sand (GLU)
		906.6	32.4	-	-	-	-	Silt, trace clay, trace sand (GLU)
SI11-01	18+65	909.3	27.6	13	0.5	-	-	Silty Clay to Clayey Silt (GLU)
TP95-38[2]	19+20[4]	-	28.4	14	0.7	-	-	Silt, some clay, trace sand and gravel (GLU)
VW11-05	19+60	906.9	29.8	23	0.4	-	-	Silty Clay, trace gravel (GLU)
		904	24.8	3	0.3	-	-	Silt (GLU)
SI06-01[3]	19+85	907	16	4	0.0	-	-	Sandy Silt, some clay (GLU)
		904	30.7	12.8	0.3	-	-	Silt, some clay, trace sand (GLU)
VW11-06	20+30	905.3	37.9	24	0.6	-	-	Silty Clay to Clayey Silt, trace sand (GLU)
TPB13/14[1]	20+30	-	25.1	14	0.6	-	-	Clayey Silt, some sand, trace gravel (Till)
SI06-02[3]	20+95	908.7	24.2	17.6	-0.1	-	-	Silt and Clay (GLU)
		905.3	40.3	23.2	0.5	-	-	Silt and Clay (GLU)
		900.4	27.3	0	-	-	-	Silt, trace clay (GLU)
SI06-03[3]	21+95	918	13.6	7.9	-0.4	-	-	Silt, some Gravel, sand, clay (GLU)
		909.2	14.4	10.2	-0.3	-	-	Clayey Silt, trace sand, gravel (GLU)
		906.4	23.3	13.5	0.0	-	-	Clayey Silt, trace sand (GLU)
		903.4	25.9	17.7	0.1	-	-	Clayey Silt (GLU)
		900.3	23.6	0	-	-	-	Silt, trace clay (GLU)
VW11-07	22+40	906.6	26.1	13	0.2	-	-	Silt, trace clay to clayey (GLU)
		899.6	26.7	0	-	-	-	Silt, some sand, trace clay (GLU)
		889	25.5	5	0.7	-	-	Silt, trace to some clay (GLU)
SI11-02	24+55	911.8	18.4	1	0.4	-	-	Silty Clay, trace sand (GLU)
		906.9	15.4	9	-0.1	-	-	Silty Clay, trace sand (GLU)
		900.9	31.8	33	0.2	-	-	Clay, some silt to silty, some sand (GLU)
		897.1	30.4	16	0.6	-	-	Clayey Silt, trace sand (GLU)
VW11-08	24+70	910.5	26.4	6	0.6	-	-	Silty Clay to Clayey Silt (GLU)

TPB1[1]	25+30[4]	-	13.7	10	-0.5	-	-	Silt, some clay and sand

[1] Geotechnical Investigation (Wright 1990)
[2] Geotechnical Investigation (KP 1995)
[3] Slope Inclinometer Installation (KP 2007)
[4] Locations are approximate

Soil Structure and Slickenside Features

The presence of laterally extensive and continuous clay varves (high plasticity) of any appreciable thickness within the unit, if pre-sheared to a low residual shear strength, would represent a weak planar feature within the foundation. Slickenside features within the clay varves would constitute evidence of pre-shearing, and if continuous and pervasive would result in an operative shear strength near the residual strength of the clay. Further, even if not pre-sheared, such clay varves could be driven to low shear strength as a result of movements induced by the ongoing raising of the dam.

Prior to the 2011 investigation, there was limited description of specifics regarding these aspects of the GLU. For example, there was little to no information found during the review of previous investigations describing the soil type, thickness, quantity or continuity of laminations/varves present within the foundation soils.

The follow layering features were noted during the 1996 investigation:

- Within the silt GLU in drill hole **GW96-3**
  - Coarse silt-fine sand laminations, light grey to brown, overlying irregular layers of slight composition change and color change (grey to grey-brown), overlying laminated with rare fine sand/coarse silt layers (1mm thick) overlying silt and clay (1-3 mm thick).
- Within the silt GLU in drill hole **GW96-9**
  - Layered silt with lesser thin fine sand and silt laminations, as well as silt and clay layers.

The follow layering features were noted during the 2011 investigation:

- Within the upper silt unit in drill hole **VW11-04**
  - Few alternating brown and grey varves
- Within the upper silty clay unit in drill hole **VW11-05**
  - Moderate number of brown and grey varves
- Within the silty clay to clayey silt unit in drill hole **VW11-06**
  - Changing with depth, clay layers (3 mm thick), overlying clay, silt, and sand layers (10-15 mm thick), overlying silt and sand layers (50 mm thick), overlying clay layers (10-30 mm thick) and silt (1-5 mm thick), overlying silt layers (5 mm thick)
- Within the lower clayey silt unit in drill hole **VW11-07**
  - Few silt and clay layers.
- Within the lower silt GLU **VW11-08**
  - Distinct sand (2-20 mm thick) and silt (2-10 mm thick) layers within silt unit overlying few varves
- Within the lower clayey silt GLU in drill hole **SI11-02**
  - Distinct sand and silt layers within silty clay unit overlying few varves
- Within the GLU in drill holes **VW11-04** through **VW11-07**
  - Sand layers (300-600 mm thick)

It appears that the main concentration of clay layers occurs within the area of station 19+00 to 21+00 m, with thicknesses ranging from approximately 3 mm to 30 mm (see Photos 11 and 16) The samples were closely examined, peeling them apart along the varves by a pocket knife, to check for any indications of slickenside features: none were found in any of the samples. The clay layers appear to become fewer, with sand layers increasing in occurrence and thickness, moving northeast along the Main Embankment. The sand layers are particularly noted in drill holes VW11-08 and SI11-02. (See Photos 29, 52-54) The sand and silt layers were typically 2-20 mm thick and 2-10 mm thick, respectively. This change might suggest a depositional environment transitional between glaciolacustrine and glaciofluvial moving from southwest to northeast along the Main Embankment alignment.

Inclinometer Records

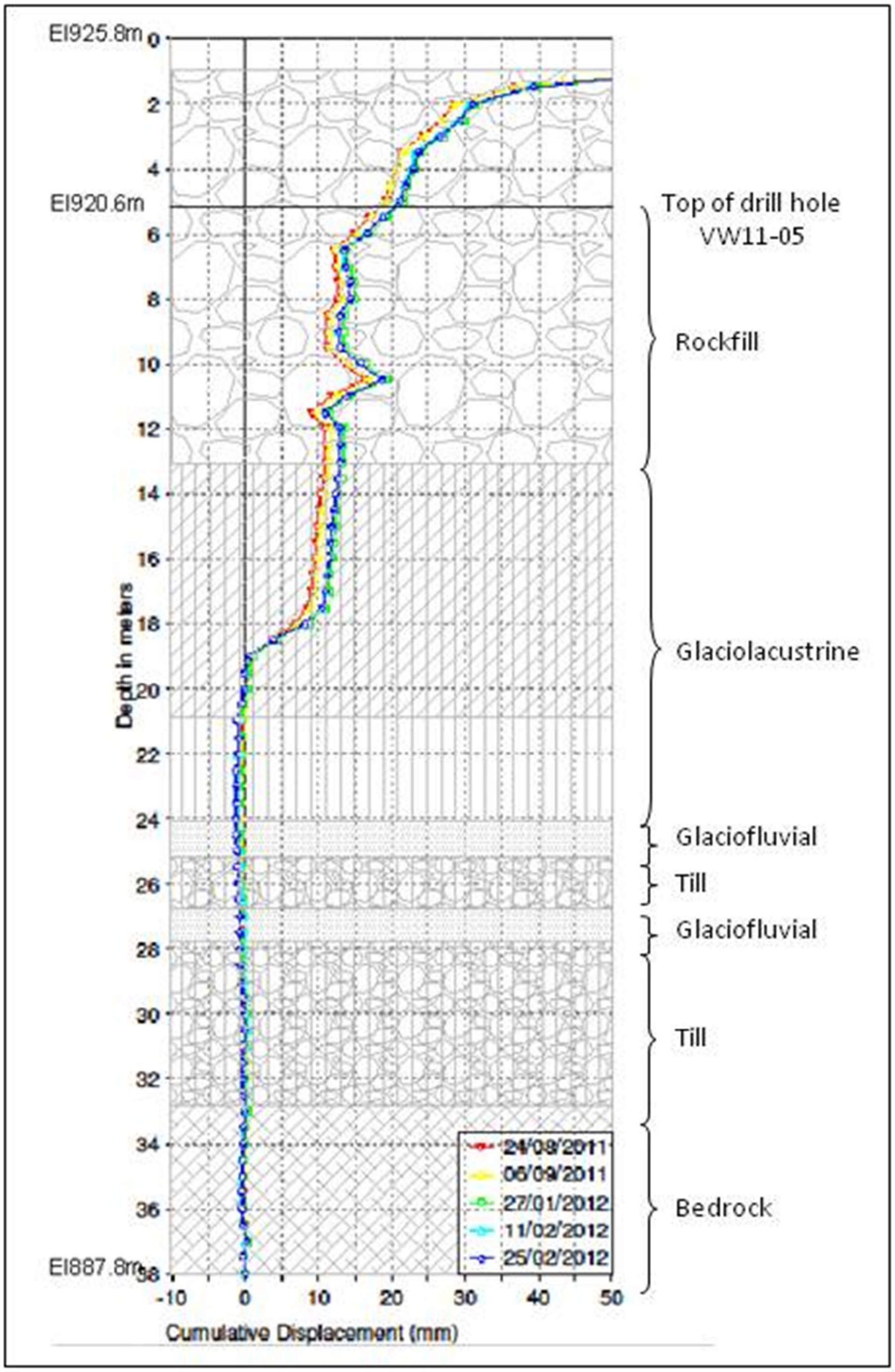
The central region of the main embankment encompasses slope inclinometer SI01-02, which recorded movement (about 4 mm), at an approximate depth of 10 m below ground in the lacustrine silts (KP, 2011). The 2011 investigation indicates that the GLU in this area consists of soils of low to medium plasticity with a liquidity index ranging from approximately 0.3 to 0.4. Comparing the inclinometer displacement plot with the closest drill hole log in this location (VW11-05), the section of recorded movement occurred within the glaciolacustrine silty clay unit, at about Elev. 908 m. A plot of recent cumulative displacement data from SI01-02 and stratigraphy from VW11-05 is presented on Figure 4.2. Photographs of the GLU within the section of movement (represented by VW11-05) are presented in Photos 11 and 12.

Inclinometer SI01-02 has indicated a total of about 10 mm of cumulative displacement over a depth interval of 1 m over a period of about 5 years, an average rate of displacement of about 2 mm/year, and a cumulative shear strain of about 1%. This degree of movement is well within tolerable limits, and is inconsistent with pre-sheared weak planes within the GLU.

Inclinometer SI06-01 is located near SI01-02, and has indicated essentially zero movement over about a five year period, suggesting that the movement within SI01-02 is limited in extent. Other inclinometers along the Main Embankment (SI06-02 and SI06-03), installed prior to 2011 and for which there is sufficient record to discern trends, show zero movement (SI06-02), and cumulative displacement of about 3 mm (in the GLU) over five years (SI06-03), with a cumulative shear strain of about 0.6%.

In summary, inclinometer data to date is consistent with the GLU comprising a competent foundation for the dams. This is no indication of pervasive pre-shearing nor is there indication there would be significant brittle behaviour upon shearing (loss of strength and, as a result, accelerated movements induced by shear strains).

Figure 4.2: Cumulative Displacement vs. Depth (SI01-02) and VW11-05 stratigraphy



GLU Shear Strength

The GLU is in an over-consolidated state, but based on detailed visual inspections (field and lab), there appears to be no evidence of pre-shearing (slickensided structure) within the GLU induced by glacial drag. Stability analyses to date have assigned the GLU a drained shear strength value as follows:

- Effective cohesion (c') = 0
- Effective friction angle (ϕ') = 28°

The 2011 investigation program, information from previous geotechnical investigations undertaken by KP, and the inclinometer data to date indicate that these shear strength parameters remain appropriate, and potentially somewhat conservative. Continued monitoring of inclinometer displacements within the GLU are required to provide ongoing evaluation and, if necessary, reassessment of the operative shear strength within the foundations of the dams.

4.2 Perimeter Embankment

The details below give a description of the general units encountered during the investigation.

The GLU encountered below the Perimeter Embankment is generally characterised as follows:

- Clayey SILT to Silty CLAY to SILT
  - Trace sand
  - Low to medium plasticity
  - Very stiff to hard
  - Moist to wet (moisture content = 16-29%)
  - Clay and silt varves (< 5 mm thick)

The glaciofluvial unit is generally characterised as:

- SAND to Silty SAND
  - Trace to some gravel, trace clay
  - Non-plastic
  - Compact to dense
  - Moist to wet (moisture content = 15-29%)

The till is generally characterised as:

- Sandy SILT to Silty CLAY
  - Trace to some gravel
  - Non-plastic to low plasticity
  - Dense, stiff to hard
  - Moist (moisture content = 8-21%)
  - Occasional sand and silt seams

Photographs of samples collected within the GLU from the Perimeter embankment drill holes are presented in Appendix C, Photos 38 through 46. Sections displaying drill hole stratigraphy conditions are presented on Drawings 2011.07 and 2011.08.

Investigation results indicate that discontinuous glaciolacustrine and glaciofluvial units exist within the glacial till units of the Perimeter Embankment foundation soils. A review of previous investigations confirms these observations. Table 4.3 provides a summary of foundation soil characteristics of selected nearby holes encountering a GLU. Drawing 2011.11 presents a plan view of the location of these drill holes.

Table 4.3: Summary of Foundation Soil Characteristics – Perimeter Embankment

Hole ID	Elevation (m)/ Depth (mbgs)	Consistency/Density	Soil Unit
GW96-1[1]	922.8 919.4	Firm	Clay and Silt (GLU)
	900.2 897.7	Very stiff	Silt, trace fine sand and clay (GLU)
GW96-2[1]	920.4 913.1	Very dense	Silt, trace fine sand, some clay (GLU)
	907.2 904.6	Very stiff	Sand and Silt (GLU)
KP08-01[2]	916.5 916	Very dense	Clayey Silt (GLU)
KP08-02[2]	924.5 920.4	Dense	Sand with some clay (GLU)
KP08-06[2]	931.5 930.9	Dense	Clay and Silt (GLU)
	930.5 926	Dense	Sand and Silt (GLU)
KP08-12[2]	920.5 909.2	Very dense	Silty Sand (GLU)

1 Air rotary drilled Ground water monitoring well holes (KP 1997a)
2 Sonic drilled borrow drill holes (KP 2008)

Based on the information presented in Table 4.3, the GLU along the Perimeter embankment is described as very stiff and dense to very dense, with one exception. The upper GLU in GW96-1 is described as firm, but is not of significant concern in this instance as the drill hole location is approximately 140m further downstream from the current toe of the dam.

The following were noted during the 1996 and 2006 investigations with respect to soil structure and stratigraphy along the Perimeter Embankment alignment:

- Within the clay and silt unit in drill hole **GW96-1**
  - Fine silty sand laminations (1-100 mm thick), contains till-like layers (20-100 mm thick).

- Within the silt unit in drill hole **GW96-2**
  - May contain thin fine sand laminations, overlying thinly to irregular laminated (2-10 mm thick) fine sand layers, some clay in thin layers, overlying fine-medium grained silt with laminations of more clay rich layers (1-2 mm thick), occasional (20-30 mm) layers of till-like sand/silt layers with fine gravel, overlying

horizontally stratified, light brown, fine-medium grained sand seams (<20 mm thick).

- Within the sand and silt unit in drill hole **KP08-06**
  - Stratified, 150 mm clay seam is present in center of interval, dividing wet and dry portions of unit.

Layering of clay and silt (<5 mm thick) was observed in only one of the three drill holes along the Perimeter Embankment, VW11-10. (See Photos 38 through 41) In general clay layers within the GLU appear to be discontinuous and less than 5 mm in thickness with the GLU along the embankment generally observed as having a massive structure. These observations suggest a distinct facies change relative to the GLU along the Main Embankment alignment.

In general, the results above present no indication that the crack observed in the downstream rockfill near station 3+400 m (KP, 2011) was due to the presence of weak soil conditions in the area. Based upon available information, foundation conditions along the Perimeter Embankment appear more favourable than those along the Main Embankment, in terms of the presence and extent of clay-rich zones within the GLU.

4.3 South Embankment

The foundation soils along the south embankment generally consisted of a glacial till unit overlain by a thin GLU, approximately 0.6 m thick (observed in the hole closest to the main embankment).

The overlying till unit ranged from 6 to 10 m in thickness, and is described as a brown to grey sandy silt of low plasticity, compact to dense with moisture contents ranging from about 11 to 16%. The GLU generally consists of brown clayey silt, trace sand, low plasticity with occasional varves. The consistency was hard with a moisture content of about 17%. Clay rich zones were not present.

A photograph of the sample collected within the GLU from the South embankment is presented in Appendix C, Photo 1. A stratigraphic profile section of the drill holes displaying these conditions is presented on Drawing 2011.09.

4.4 Summary

In summary, the 2011 investigations, previous investigations, and the inclinometer records indicate that the GLU is over-consolidated, not extensively pre-sheared if it is at all, has not exhibited displacements of any concern in response to the loading imposed by the dam construction. For stability evaluation purposes, the GLU can be characterized, and perhaps conservatively so, with drained shear strength parameters of $c' = 0$ and $\phi' = 28°$. Continued regular monitoring of inclinometer displacements is important going forward to validate this conclusion and re-evaluate it should increased rates of displacement be noted.

5.0 MONITORING WELLS

At the request of MPMC, the installation of four monitoring wells was completed during the site investigation program. These four wells were comprised of one deep and one shallow monitoring well installed at each of the two drill sites, designated G1 and G2. Site G1 is located along the Bootjack Access road while G2 is located along the old Polley Lake pump road. The well locations are presented in Drawing 2011.12.

Drill hole logs describing the encountered soil stratigraphy and well installation details are presented in Appendix F.

6.0 LIMITATIONS AND CLOSURE

This report has been prepared for the exclusive use of Mount Polley Mining Corporation for specific application to the area within this report.

Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

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DRAWINGS

APPENDIX A

2011 Laboratory Testing Data

APPENDIX B

2011 Drill hole Site Investigation Logs

APPENDIX C

Drill Core Photographs

APPENDIX D

Vibrating Wire Calibration Reports

APPENDIX E

Instrumentation Readings

APPENDIX F

Monitoring Well Drill Hole Logs