GEOTECHNICAL INVESTIGATION
EMBRO DAM EMBANKMENT STABILITY ASSESSMENT
843970 ROAD 84
MUNICIPALITY OF ZORRA, ONTARIO
for
UPPER THAMES RIVER CONSERVATION AUTHORITY

7607G1.R02
September 2008

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7607G1.R02

September 19, 2008

Upper Thames River Conservation Authority
1424 Clarke Road
London, Ontario
N5V 5B9

Attention: Mr. David Williams

Dear Sir:

Re: Geotechnical Investigation
Embro Dam Embankment Stability Assessment
843970 Road 84
Municipality of Zorra, Ontario

Naylor Engineering Associates Ltd. is pleased to submit this report for the geotechnical investigation recently carried out for the above referenced project. The project involves the embankment stability assessment of the Embro Dam in the Municipality of Zorra, Ontario.

The purpose of the geotechnical investigation was to review the structural integrity of the existing dam embankment and provide recommendations for retrofitting the embankment to meet current dam safety guidelines.

This Geotechnical Engineering Report provides details of the investigation methodology, summary of the subsurface soil and groundwater conditions, results of laboratory tests, engineering analysis, site plans, cross-sections, borehole logs, dam details and photographs.

We believe that this report has been completed within our terms of reference and trust that the information provided herein is sufficient for your present requirements. We would be pleased to be of further assistance during the retrofit of the Embro Dam Embankment.

Yours truly,

Dennis Kelly, P.Eng.
Senior Geotechnical Engineer
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1. Introduction

1.1 Background

Naylor Engineering Associates Ltd. was retained by the Upper Thames River Conservation Authority (UTRCA) to carry out an Embankment Stability Assessment for the Embro Dam in the Municipality of Zorra, Ontario at the location shown on Drawing 1, appended. This work was authorized in a Contract Document dated May 5, 2008.

The Embro Dam is located approximately 2 km north of the Village of Embro on Spring Creek, a tributary of the North Branch Creek, which flows into the Middle Thames River. The dam and reservoir were built for recreational and water supply purposes in 1959. The Embro Dam is a small earth dam approximately 100 m long and 1.0 to 4.5 m high with a head of water of approximately 3.4 m acting across the dam. The dam contains water year round and the freeboard at the dam is approximately 1.1 m.

The purpose of the geotechnical investigation was to assess the geotechnical stability of the Embro Dam embankment and to provide geotechnical recommendations to upgrade the dam embankment to meet current dam safety guidelines as required.

1.2 Dam Safety Assessment Objectives

A dam safety review according to the Ontario Dam Safety Guidelines (DRAFT), published by the Ministry of Natural Resources in 1999, involves;

"a phased process beginning with the collection and review of exiting information, proceeding to detailed inspections and analyses and culminating with formal documentation."

The objectives of this investigation follow the general provisions stated in the Lakes and Rivers Act (Ontario Regulation 44/96);

"the protection of persons and of property by ensuring that dams are suitably located constructed, operated and maintained are of an appropriate nature..."

To accomplish this a systematic evaluation of the dam will include:

- performing detailed site inspections
- classifying the dam based on hazard and flood potential
- assessment of current embankment stability
- assessment of current foundation stability
- assessment of seepage flow through the embankment and foundation
- recommending safe slopes of embankments
- recommending dam retrofitting and continuing maintenance requirements

2. Investigation Procedure

2.1 Previous Work

In October 2002 Acres International Limited (Acres) was retained by the Upper Thames River Conservation Authority (UTRCA) and Ausable Bayfield Conservation Authority to undertake an independent dam safety review of fifteen dams and control structures located in the Upper Thames and Ausable/Parkhill basins. An inspection of the Embro Dam was conducted in November 2002 and the Dam Inspection Report is provided in Appendix A.

In March 2004 Acres submitted a letter to the UTRCA with recommendations for rehabilitation measures for the Embro Dam emergency spillway. The letter report is included in Appendix B.

A Dam Safety Assessment Report for Embro Dam was prepared by Acres in July 2007. The investigation and report included comprehensive site inspections and condition assessments, one exploratory borehole (EM BH1), geotechnical laboratory testing comprising an Atterberg Limits test and particle size distribution analysis, hydrotechnical assessment, civil/structural assessment, geotechnical assessment, operations maintenance and safety recommendations and an emergency preparedness plan. The borehole log, laboratory test results, and Civil/Structural and the Geotechnical Assessment are provided in Appendix C of this report. Acres dam remedial work recommendations and cost estimates are provided in Appendix D.

In February 2008 Naylor Engineering Associates Ltd. carried out a visual inspection of the Embro Dam as requested by the UTRCA. The inspection report and preliminary recommendations are provided in Appendix E.

2.2 Field Program

The fieldwork for this investigation was carried out on June 9 and 10, 2008 and involved the drilling of five boreholes (Boreholes 1 to 4 and 4A) to depths ranging from 3.05 to 6.40 m at the locations shown on Drawing 2, appended. The boreholes were advanced with a CME-75 track mounted drillrig equipped with continuous flight solid stem augers supplied and operated by Geo-Environmental Drilling Inc.

Soil samples were recovered from the boreholes at regular 0.75 m depth intervals using a 50 mm O.D. split spoon sampler driven into the soil according to the specifications for the Standard Penetration Test (SPT) (ASTM D1586). Vane Shear Tests (VST) (ASTM D2573) and pocket penetrometer tests were performed to assess the shear strength of the cohesive deposits. The VST and pocket penetrometer test results, and SPT N-values recorded are plotted on the borehole logs.

Thin walled (Shelby) tube sampling (ASTM D1587) was carried out at Boreholes 3 and 4 to recover relatively undisturbed samples of the silt and clay.

Piezometers were installed in the boreholes to determine the hydraulic head of the groundwater at specific stratigraphic levels. The piezometer installations comprised 19 mm diameter pipe with slotted and filtered screens that were surrounded with filter sand. Bentonite seals were provided to separate the screens of the double piezometers as well as seal the boreholes near the ground surface. Details of the installations and groundwater observations and measurements are provided on the borehole logs and the water level measurements are summarized in Table 1.

Two 50 mm diameter monitoring wells were installed for the purpose of hydraulic conductivity testing. The wells had 1.5 m long screens which were surrounded with a sand pack. Single well hydraulic response of slug tests were carried out at Boreholes 2 and 3. The slug tests consist of removing a volume of groundwater, then measuring the water level response back to static conditions in the well. The data was analyzed using the methods of Hvorslev and the results are provided on Table 2, appended.

The piezometers and monitoring wells were installed and tagged in accordance with R.R.0. 1990 Reg. 903 as amended to Ontario Reg. 128/03 under the Ontario Water Resources Act. Well records were submitted to the Ministry of Environment and the Owner. A licensed well technician must properly decommission the piezometers and wells within 6 months of last use (water level measurements or sampling).

The fieldwork was supervised by our geotechnical engineering staff who directed the drilling procedures; conducted SPT, VST and pocket penetrometer tests; documented the soil stratigraphies; monitored the groundwater conditions; installed the piezometers and monitoring wells; and, cared for the recovered soil samples.

A total station survey was completed by R.J. Burnside & Associates Limited on May 15, 2008. The borehole locations and ground surface elevations were surveyed by Naylor Engineering Associates Ltd. The boreholes were located relative to existing site features, and the ground surface elevations are referred to the following temporary benchmark supplied by R.J. Burnside & Associates Limited:

TBM: Top centre of concrete base for post at southeast corner of pavillion

Elevation: 53.045 m (assumed local datum)

A survey of the pond bottom near the dam was conducted by Naylor Engineering Associates Ltd. on September 11, 2008. The approximate elevations of top of sediment and bottom of sediment are provided on the cross-sections shown on Drawing 3, appended.

2.3 Laboratory Testing

All soil samples secured during this investigation were returned to our laboratory for moisture content tests (ASTM D2216) (LS-701); the results of which are plotted on the borehole logs. The geotechnical laboratory tests carried out on selected samples of the major subsurface soils from this investigation comprised the following:

- one Atterberg Limits test (ASTM D4318) with results summarized in Subsection 3.4.5;
- four particle size distribution analyses (ASTM D422 or C139) with results plotted on Figure 1; and,
- one soil unit weight test (ASTM D2937) with results summarized in Subsection 3.4.2.

It is noteworthy that the particle size distribution analyses were conducted on soil samples from the split spoon sampler that excluded particles larger than 37 mm in diameter.

The soil samples will be stored for a period of four months from the date of sampling. After this time, they will be discarded unless prior arrangements have been made for longer storage.

3. Summarized Conditions

3.1 Site Description

The Embro Dam is located approximately 2 km north of the Village of Embro on Spring Creek, a tributary of the North Branch Creek at the Embro Conservation Area in the Municipality of Zorra, Ontario. The dam and pond were built for recreational purposes as well as water supply in 1959.

Embro Pond has a surface area of about 6500 m^2 and the dam is located at the south end of the pond (see Photograph 1 in Appendix F). Flow releases from the dam outlet into a small creek and flow in a southerly direction for approximately 1.6 km before entering the North Branch Creek which then empties to the Middle Thames River 4 km away.

The Embro Dam is a small earth fill dam approximately 100 m long and 1.0 to 4.5 m high. The head of water acting across the dam is approximately 3.5 m and the freeboard on the pond side of the dam is approximately 1.1 m.

The upstream (pond) slope of the dam is inclined between 3 and 4 horizontal to 1 vertical with the outer thirds flatter than the centre third. The pond side of the earth dam is not protected with rip-rap and is overgrown with cattails and marsh type vegetation (see Photograph 2). Wave scour erosion has occurred up to 0.5 m. No displacement settling, cracking, or sink holes were noticed on the upstream slope.

The crest of the dam is 4.0 to 5.0 m wide and is vegetated with grass (see Photograph 2). The crest showed no cracking, sink holes or settlement at the time of the fieldwork.

The downstream slope of the dam is inclined at between 2 and 3 horizontal to 1 vertical with the outer thirds flatter than the center third. Typical cross-sections of the dam are shown on Drawing 3. The downstream slope is vegetated with grass, bushes and some trees (see Photograph 3).

The discharge facilities at the dam consist of a concrete bottom draw inlet structure and an inverted V-shaped trash rack anchored to the top of the inlet (see Photograph 7). A 762 mm ID precast concrete outlet pipe passes through the centre of the dam and has formed a small pool at the top of the creek channel (see Photograph 3). Hydrotechnical aspects of the dam structure are provided in Section 4.3 of the 'Dam Safety Assessment Report for Embro Dam' produced by Acres International in July 2007.

The creek channel south of the dam is about 3.0 m wide and 500 mm deep and situated within forest and field areas (see Photograph 3). Minor erosion was evident along the sides of the creek at the time of the investigation.

An emergency overflow spillway is located about 50 m east of the midpoint of the dam. The spillway comprises a grass swale and the depth of the swale is approximately 0.5 m below the surrounding ground. The ground surface at the crest of the swale was only 0.3 m above the pond water level at the time of our fieldwork and the swale runs parallel and eventually outlets to the creek to the southeast of the dam. Some soil erosion was noted along the swale.

On the downstream slope on the east side of the dam an eroded gully is present as result of emergency spillway overflow (see Photograph 4). The gully provides a topographical low point for water to be diverted from the emergency spillway along the downstream top of the slope ending up near the concrete outlet pipe. It is approximately 0.9 m deep and 1.6 m wide at the discharge point.

It should be noted the dam was previously over-topped in the summer of 2000 with minor damage. Photographs of the site conditions are provided in Appendix F.

3.2 Pleistocene Geology

The Embro Dam is situated on Spring Creek which flows south to North Branch Creek, eventually entering the Middle Thames River. The Dam is located within the physiographic region of Southern Ontario known as the Oxford Till Plain. The region is occupied by a drumlinized till plain with glacial meltwater valleys. The dominant soil materials are silt and sand tills.

The region is underlain by Middle Devonian bedrock of the Paleozoic System. The predominant rock type is limestone of the Dundee Formation. The soil cover over these rocks is approximately 30 m thick, although the bedrock is exposed in the ancient river valleys notably in Beachville. The bedrock is approximately 400 million years old and was formed in a shallow sea environment.

3.3 Dam Classification

The Embro Dam is classified overall as a very low hazard potential based on the non-existent potential for loss of life. The damage from a dam breach would not inflict major economic or social losses as well as environmental impacts (see *Figure 1-7: Hazard Potential Classification for Dams* in Appendix G).

The size of the dam is governed by a minimum inflow design flood of a 50 year, 8-day spring snowmelt. The inflow design flood is the largest flood that was selected for the initial design of the dam (see *Figure 4-1: Minimum Inflow Design Floods for Dams* in Appendix G). At this time there have been no large changes in development to justify changing these original classifications.

3.4 Subsoil Conditions

We refer to the appended borehole logs for detailed soil descriptions and stratigraphies; results of SPT, VST and pocket penetrometer testing; moisture content profiles; groundwater observations and measurements; and details of piezometer and monitoring well installations. We also refer to Drawing 3 for geological cross-sections of the subsurface stratigraphy.

In general the subsurface stratigraphy at the site comprises fill overlying native glacial till. Descriptions of the soil deposits encountered are provided in the following subsections.

3.4.1 Pond Sediment

Sediment was encountered below the normal pond level at thicknesses ranging from 300 to 700 mm throughout the general slope of the embankment. The sediment thicknesses are illustrated on Drawing 3. It is noteworthy that the actual thickness of the sediment will vary and the measured thicknesses are inferred from end resistance to manual probing. No sediment or subsoil sampling was done below the pond.

3.4.2 Fill

Fill material was encountered in all the boreholes that were drilled on the crest of the dam. The fill is 0.90 to 1.80 m thick and typically comprises sandy silt, with some gravel and some clay. The results of two particle size distribution analyses carried out on samples of the fill are plotted on Figure 1 and reveal the samples contain 5 to 27% gravel, 19 to 31% sand, 30 to 57% silt, and 12 to 19% clay.

SPT N-values recorded in the non-cohesive sandy silt fill typically ranged from 6 to 13 blows per 300 mm, indicating a loose to compact relative density.

The results of a soil unit weight test carried out on a sample of the cohesive fill from Borehole 3 indicated a wet unit weight of 19.7 kN/m^3. The moisture content of the fill ranges from 10 to 24% indicating that the soil is moist to wet.

3.4.3 Peat

Peat was encountered from 2.2 m to 3.4 m below existing grade in Borehole 4 that was drilled on the west embankment of the dam. The peat comprises black amorphous peat with wood. The moisture content of the peat was 108% indicating saturated conditions.

3.4.4 Silt and Clay

Silt and clay deposits were contacted beneath the fill and/or silt till in the dam embankment (Boreholes 2, 3, and 4). The silt ranges from 0.3 to 1.4 m thick and extends to a depth of 2.1 m in Boreholes 2 and 4. It comprises loose to dense brown silt with trace clay and sand, changing in Borehole 4 to a grey sandy silt at a depth of 1.8 m. One particle size distribution analysis for a sample of silt is plotted on Figure 1, and shows the sample contains 6% gravel, 31% sand, 47% silt, and 16% clay.

Undrained shear strength values of the silt deposits, as measured by VST and pocket penetrometer tests, ranged from 50 to 100 kPa. The SPT N-values recorded in the non-cohesive silt deposits typically ranged from 3 to 8 blows per 300 mm, indicating a very loose to loose relative density. Insitu moisture contents of the silt ranged from 11 to 25% indicating that the deposits ranged from drier than the plastic limit to wetter than the plastic limit, or very moist to wet.

The clay deposit extends from 2.3 to 3.2 m below ground surface in Borehole 3 comprising brown silty clay. Undrained shear strength values of the clay deposit as measured by VST and pocket penetrometer tests ranged from 50 to 100 kPa. Moisture contents of the clay stratum ranged from 29 to 30%, indicating that the deposit is wetter than the plastic limit.

3.4.5 Glacial Till

Glacial till was encountered beneath the fill, peat, silt and/or clay in all of the boreholes. The glacial till extends below the termination depths of the boreholes.

The glacial till texture ranges from silty clay with some sand and trace gravel, to sandy silt with some gravel and trace clay. The till contains occasional sand layers as well as cobbles. A particle size distribution analysis for a sample of the glacial till is plotted on Figure 1, and shows the sample contains 6% gravel, 10% sand, 33% silt, and 51% clay. The presence of cobbles and boulders can always be expected in the glacial till deposits due to its deposition process.

SPT N-values recorded in the non-cohesive silt till deposits typically ranged from 35 to 57 blows per 300 mm, indicating a dense to very dense relative density. Shear strengths determined with a pocket penetrometer in the cohesive till ranged from 50 to 200 kPa indicating a stiff to hard relative consistency. Insitu moisture contents of the glacial till soils range from 10 to 31%, indicating that the deposit ranges from drier than the plastic limit to wetter than the plastic limit, or moist to wet.

The clay till has low plasticity and is moderately over-consolidated based on one Atterberg Limits test with results provided in the following table:

Borehole Number	Sample Depth (m)	Water Content (%)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Liquidity Index
2	3.05 – 3.50	22	19	37	19	0.17

3.5 Groundwater

We refer to the appended borehole logs and Table 1 for groundwater observations and measurements carried out in the piezometers and monitoring wells.

The groundwater level in Boreholes 2, 3 and 4 ranges from 1.20 to 1.65 m below the top of the dam embankment. In general the groundwater occurs in the fill above the glacial till. The groundwater level in the fill is approximately 0.40 m below the pond water level but it is above the existing creek level on the downstream side of the dam.

The horizontal hydraulic gradient is towards the south and a possible seepage zone was noted on the south side of the dam at the time of the fieldwork. The vertical hydraulic gradient is upward (discharge conditions).

The hydraulic conductivity of the subsurface soils has been estimated using the single well hydraulic response of slug tests with results provided on Table 2. The inferred hydraulic conductivity of the native soil ranges from 1.2×10^{-6} to 2.7×10^{-6} m/s.

4. Dam Structure and Stability

4.1 General

The project involves the geotechnical assessment of the Embro Dam in the Municipality of Zorra, Ontario. The Embro Dam and Pond were built for recreational purposes and water supply purposes in 1959. It is a small earth dam approximately 100 m long and 4.0 to 5.0 m wide at the crest. The sides of the dam are inclined at between 2 and 4 horizontal to 1 vertical, and the freeboard on the pond side is approximately 1.1 m (see *Figure 4-2: Minimum Freeboard for Low Hazard Potential Dam* in Appendix G).

The Embro Dam earth embankment comprises silt and sand fill material placed over native silt and glacial till. Peat was encountered below the dam at Borehole 4 and soft to firm clay was contacted at Borehole 3. Groundwater occurs in the fill soil at 1.20 to 1.65 m below the top of the earth embankment.

Embro Pond has a surface area of about 6500 m^2. The embankment dam is approximately 4.5 m high and impounds a total estimated storage volume of 26×10 m^3. This classifies the structure as a small dam on the basis of height and a small dam on the basis of storage impounded.

The discharge facilities at the dam consist of a concrete drop inlet structure with an inverted V-shaped trash rack anchored to the top of the inlet. There is an emergency grassed spillway located east of the abutment. The crest elevation of the spillway is about 0.5 m above the pond level and there is evidence of soil erosion.

The following subsections of this report contain geotechnical information pertaining to the existing dam including soil parameters, bearing capacity, settlement, liquefaction, seepage, uplift and dam stability. A similar geotechnical assessment was carried out by Acres International Limited and we have provided the results of their work in Appendix C. Their recommendations and cost estimates are provided in Appendix D.

4.2 Soil Parameters

Using the results from the exploratory boreholes, slug testing, and geotechnical laboratory testing, engineering parameters where determined for the different soil types in and below the dam embankment. These parameters contribute largely to the understanding of the soil characteristics and their subsequent behaviour. Soil parameters pertaining to Embro Dam are provided in the following table:

Soil Type	Hydraulic Conductivity (m/s)	Cohesion (kPa)	Friction Angle (Degrees)	Unit Weight (kN/m^3)
Fill	2.0×10^{-05}	0	25	19.7
Clay	2.7×10^{-06}	20	25	19.0
Silt	1.2×10^{-06}	5	28	18.0
Peat	1.0×10^{-07}	10	20	12.0
Glacial Till	1.2×10^{-06}	5	28	21.0

4.3 Bearing Capacity

The undisturbed native glacial till soils are considered to have a net allowable bearing capacity of 200 kPa. The embankment applies a maximum total pressure of approximately 65 kPa therefore the current foundation provides a suitable bearing capacity for the majority of existing conditions. It should be noted that soft clay and peat occur beneath the embankment at Boreholes 3 and 4, respectively. The clay and peat have acceptable strength to support the weight of the embankments without undergoing shear failure and are not expected to further consolidate/settle under existing conditions.

4.4 Settlement

The Embro Dam showed no cracking, sink holes or settlement at the time of the fieldwork on and around the embankment. This may indicate no differential vertical movements have occurred since construction. Despite this the soft clay and peat layers provide a higher possibility of past settlement in the embankment which may not be currently obvious. Due to the low potential for seismic impact on the downstream or upstream slopes future settlement is not probable.

4.5 Liquefaction

Liquefaction is the process of soil liquefying often inflicting vast damage on the surrounding area. At the Embro Dam liquefaction of the embankment and subsoil is not a large concern due to low seismic potential for impact and the present soil characteristics. These soil characteristics include grain size, grain size distribution, moisture content, liquid limit characteristics, soil density, confining stresses and the soil's shear strength.

4.6 Seepage and Uplift

Seepage and uplift in a dam structure is caused by excessive porewater pressure through the embankment, thus leading to high instability. There were no signs of free groundwater seepage and/or uplift during the site investigation for the Embro Dam. It should be noted that excessive vegetation, including small bushes and trees along the downstream slope, may have concealed minor seepage occurring through the embankment. The dam was previously overtopped in the summer of 2000 with only minor damage, indicating a relatively stable embankment.

4.7 Results of Stability Analysis

The long-term stability of the dam embankment must meet the requirements of the Canadian Dam Safety Association and Ministry of Natural Resources. In order to evaluate the safety of this relatively homogeneous berm, the engineering properties of the major soil components were estimated as noted in Subsection 4.2.

Stability analyses were carried out using the Slope/W computer program and three different scenarios were evaluated for the dam configuration, as follows:

1. The long term stability of the embankment under full reservoir head.
2. Rapid (i.e. unplanned) drawdown of the reservoir at a rate significantly in excess of the rate at which pore pressures in the embankment fill are able to dissipate.
3. A pseudostatic horizontal seismic load was incorporated into the stability analysis using a seismic coefficient of 0.04g, a conservative value for this area of Canada (Canadian Foundation Engineering Manual, 1992).

The results of these analyses are summarized in the following table:

Loading Conditions	Slope	Minimum Factor of Safety	Calculated Factor of Safety
Steady State Seepage with maximum storage pool	Downstream	1.5	0.9 to 2.7
Full or partial rapid drawdown	Upstream	1.2 to 1.3	0.7 to 1.5
Horizontal seismic load	Downstream and Upstream	1.3	1.0 to 3.6

Based on the stability evaluation, it is concluded that satisfactory factors of safety are not maintained for undrained and drained (long-term) cases, and that the embankment has low stability under rapid draw-down and seismic conditions (Refer to *Figure 6-1: Factors of Safety, Static Assessment* in Appendix G and Appendix H for Geo-Slope Modelling Results).

4.8 Assessment

The existing dam does not meet current standards and is not considered stable under existing conditions. The main problems with the dam are the underlying peat and soft clay, the low strength of the fill, the wave erosion that is occurring on the pond side, erosion occurring through the gully in the emergency spillway, and erosion at the pipe outlet. The erosion could eventually cause erosion at the downstream toe of the dam. The following remedial/retrofit work is recommended to ensure long-term stability and satisfactory performance.

5. Dam Remedial Work Recommendations

5.1 General

The project involves the geotechnical assessment and subsequent recommendations for remedial/retrofit work of the Embro Dam embankments. The Embro Dam is located in the Municipality of Zorra, Ontario on Spring Creek, a tributary of the North Branch Creek. It is a small earth dam approximately 100 m long and 4.0 to 5.0 m wide at the crest. The area examined includes the entire dam embankment, surrounding geotechnical features, the emergency spillway, Embro Pond and the area of the creek immediately downstream of the dam.

The following subsections of this report contain geotechnical information pertaining to the remedial/retrofit dam recommendations including erosion protection, dam shell, toe drains, outlet pipe, emergency spillway, stability of the dam and construction sequence.

5.2 Erosion Protection

Vegetation with large root systems must be removed from slopes and from the emergency spillway channel. Excessive growth of deep root system trees can be ripped out in high winds thus damaging the face of the embankment. These root systems can also decay and encourage unwanted animal populations. Several trees are located just downstream of the outlet pipe (see Photograph 5). Desirable grasses with topsoil grading should replace these types of vegetation to better trap fine particles that are susceptible to erosion. Topsoil should be 300 mm thick and extend to the entire downstream slope and the dam crest.

Rip-rap erosion protection is required on the north (reservoir) face of the dam and erosion protection is recommended in the creek channel where it is close to the downstream toe of the dam. The rip-rap on the north face of the dam must extend over the entire freeboard and to the top of the embankment.

The outlet stream channel must be lined with Granular 'B' and rip-rap from the end of the outfall pipe to at least 10 m downstream of the pipe. The rip-rap or Granular 'B' should be sized depending on the velocities expected. The downstream toe protection must extend at least 500 mm above the stream bed. It must not be placed such that it blocks any part of the outlet pipe.

The rip-rap must be composed of well-graded good quality angular broken rock (100 to 300 mm size) placed carefully to form an interlocking surface. The rip-rap should be placed over a filter cloth and sand and gravel fill (OPSS Granular 'B' Type II). The filter cloth will prevent scour and undercutting of the rip-rap.

5.3 Dam Shell

A sand and gravel 'shell' should be constructed on both sides of the existing dam in order to stabilize the existing fill, provide a stable base for rip-rap protection, and act as a filter medium for seepage on the downstream side. The sand and gravel should extend outwards and downwards from the crest of the dam at minimum 5 horizontal to 1 vertical on the north (pond) face and at minimum 4 horizontal to 1 vertical on the south (creek) face as shown on Drawing 5, and should comprise OPSS Granular 'B' Type II material.

The granular fill should be placed after the water level in the pond is lowered as required. The fill should be stepped/benched into the existing dam on both sides. The fill should be placed in 300 mm thick horizontal lifts and compacted to minimum 95% SPMDD under engineering supervision. The fill on the pond side of the dam should be lined with filter cloth and rip-rap as noted in the previous section. The south face of the dam should be topsoiled and seeded.

It is recommended that galvanized wire mesh be placed beneath the topsoil on the south face and beneath the rip-rap on the north face in order to prevent animal burrows. The galvanized wire mesh should have a maximum 62.5 mm size opening and be buried 150 to 300 mm below the surface.

5.4 Toe Drain

Toe drains are recommended for the south side of the dam in order to prevent possible seepage piping erosion. The toe drains should extend about 25 m east and 50 m west from the outlet pipe of the Embro Dam. The toe drains should be constructed as shown on Drawing 5, appended.

The toe drains should comprise 150 mm diameter perforated tiles complete with filter sock (OPSS 1860 geotextile Class 1) and bedded in filter sand comprising OPSS 1002 Fine Aggregate for Concrete (Concrete Sand).

The filter sand must extend at least 150 mm below the pipe invert level and at least 150 mm each way on the sides of the pipe. Sand must extend above the pipe to minimum 300 mm from the surface of the north face of the dam. The filter sand should be compacted to 95% standard Proctor maximum dry density (SPMDD).

The toe drains must be set to at least 1% draining to a positive outlet. If the drains outlet to the stream, the final 1.5 m should consist of galvanized steel pipe with a rodent gate. The upstream end of the pipe should be capped.

5.5 Outlet Pipe

It was anticipated that the existing outlet pipe through the Embro Dam will be maintained; however, it will have to be extended on the downstream side because of the new sand and gravel shell. The existing headwall could be left in place to act as seepage cutoff collar.

Pipe bedding for the culvert extension should be placed in accordance with OPSD 802.010 and should comprise a minimum 150 mm thick layer of OPSS Granular 'A' aggregate placed below the pipe. The bedding should be shaped to receive the bottom of the pipe and the granular material placed under the haunches must be compacted prior to placement of the embedment material. The embedment material for the culvert should comprise homogeneous granular material and shall be placed and compacted uniformly around the pipe. The pipe bedding and embedment material should be compacted to minimum 95% standard Proctor maximum dry density (SPMDD).

If an outlet headwall structure is proposed, then the support for this structure must be derived from the native glacial till deposits. An allowable bearing pressure of 150 kPa is available in this deposit. The headwall should be backfilled using free-draining granular material and may be designed using an active earth pressure coefficient of 0.35 and a unit weight of 21 kN/m^3. Any footings must be protected with a minimum 1.2 m of earth cover or equivalent insulation to provide protection against potential frost damage (concrete headwall as per OPSD 804.030).

5.6 Emergency Spillway

The emergency spillway on the east side of the dam should be upgraded. The top of the spillway is only 300 mm above the pond water level and there were indications of soil erosion at the time of the fieldwork. A gully has formed diverting water from the spillway to the creek around the outlet. Excessive flow through the spillway could cause severe scour and substantial drainage of the pond. For this reason we recommend that the spillway be lined to prevent erosion and the gully filled in. The lining could comprise cable-concrete, geoweb, rip-rap, and/or river stone, depending on the velocities expected (rip-rap treatment as per OPSS 511 and OPSD 810.01). The rip-rap must be pre-approved and comprised of well-graded good quality angular broken rock placed carefully to form an interlocking surface. The rip-rap should be placed over filter fabric conforming to OPSS 1680 for geotextile.

5.7 Results of Stability Analyses

Using the requirements of the Canadian Dam Safety Association and Ministry of Natural Resources, a dam retrofit plan was recommended as outlined in previous Sections 5.2 to 5.6.

Stability analyses were carried out using the Slope/W computer program and the same three scenarios were evaluated for the dam retrofit as from its original condition. The results are as follows:

Loading Conditions	Slope	Minimum Factor of Safety	Calculated Factor of Safety
Steady State Seepage with maximum storage pool	Downstream	1.5	3.0
Full or partial rapid drawdown	Upstream	1.2 to 1.3	2.7
Horizontal seismic load	Downstream and Upstream	1.3	2.2 to 5.2

Based on the stability evaluation, it is concluded that satisfactory factors of safety are maintained for the dam retrofit for undrained and drained (long term) cases and that the embankment has sufficient stability under steady state seepage, rapid drawdown, and seismic conditions. (Refer to *Figure 6-1: Factors of Safety Static Assessment* in Appendix G and Appendix H for Geo-Slope Modelling results).

The existing dam does not meet current standards and is not considered stable under existing conditions. The problems with the dam can be overcome by the recommended retrofit work. This will help ensure long-term stability and satisfactory performance

5.8 Construction Sequence

Based on our understanding of the project and the subsurface soil and groundwater conditions, the following construction sequence for the Embro Dam Retrofit work is suggested:

- lower pond levels as much as possible by pumping prior to construction;
- remove sediment from upstream face with tracked hydraulic shovel;
- excavate topsoil from downstream face of berm and stockpile on site;
- cut small benches into existing berm material;
- construct berm shell with imported Granular 'B' fill as required to achieve minimum 4 horizontal to 1 vertical slope on the south (creek) side and 5 horizontal to 1 vertical slope on the north (pond) side of the embankment;
- place wire mesh on surface of Granular 'B';
- extend outlet pipe at same time as berm shell construction;
- install toe drains;
- place filter cloth and rip-rap protection on upstream side and in spillway as required;
- cover downstream side with topsoil;
- conduct a condition survey of the completed berm;
- monitor berm during reservoir fill; and,
- monitor outlets and conduct berm inspections after construction (see *Figure 3.1: Minimum Suggested Frequency for Dam Safety Review, Inspection and Maintenance* in Appendix G).

5.9 Construction Inspection and Testing

Geotechnical inspections and insitu density testing must be conducted during Granular 'B' placement and toe drain construction in order to verify that all organic materials have been stripped from the subgrade and to ensure that all fill materials meet the specifications and are being adequately compacted. Naylor Engineering Associates Ltd. should be represented on-site at all times during retrofitting of the dam.

Appropriate laboratory and field testing of the dam components must be conducted during all phases of construction. The laboratory testing should be carried out by Naylor Engineering Associates Ltd.

5.10 Material Quantities

For the recommended dam remedial work, material quantity estimates were developed based on an assessment of the general scope of work. As details of the final design are not known at this time the quantities should be considered approximate.

Item	Quantity
Sediment Subexcavation	170 m^3
Topsoil Removal	400 m^3
Earth Removal for Benching	300 m^3
Granular 'B' North Side	170 m^3
Granular 'B' South Side	250 m^3
Toe Drain Pipe	100 m
Toe Drain Pipe Bedding	70 m^3
Filter Cloth for Dam	800 m^2
Wire Mesh for Dam	2000 m^2
Rip Rap for Dam	230 m^3
Filter Cloth for Emergency Spillway	500 m^2
Rip Rap for Emergency Spillway	250 m^3
Outlet Pipe Extension	10 m
Topsoil Placement	400 m^3

6. Conclusions

The subsurface conditions at the site have been investigated by means of borings, monitoring wells, piezometers, and geotechnical laboratory tests. On the basis of the results, the following conclusions can be drawn:

1. The dam at Embro Pond comprises silt and sand fill over native silt, peat, clay, and glacial till;
2. Groundwater was measured within the fill in the dam at the time of the fieldwork;
3. The Embro Dam Embankment does not meet current standards, and is not considered stable under existing conditions; and,
4. In order to ensure long-term stability of the dam, it is recommended that a granular shell be constructed on both sides of the dam, deep root vegetation be removed from embankment, a toe drain be installed along the south side of the dam, the outlet pipe be extended, river stone or rip-rap be placed downstream of the outlet pipe and on the north face of the embankment, the gully be filled in and the emergency spillway be regraded and lined.

The geotechnical recommendations provided in this report are applicable only to the project described in the text and are intended for the use of the project designer. They are not intended as specifications or instructions to contractors. Any use which a contractor makes of this report, or decisions made based on it, are the responsibility of the contractor. The contractor must also accept the responsibility for means and methods of construction, seek additional information if required, and draw their own conclusions as to how the subsurface conditions may affect them.

It is important to know that the geotechnical investigation involved a limited sampling of the site gathered at specific test hole locations and the conclusions in this report are based on the information gathered. The subsurface conditions between and beyond the test holes will differ from those encountered at the test holes. Should subsurface conditions be encountered which differ materially from those indicated from the test holes we request that we be notified in order to assess the additional information and determine whether or not changes should be made as a result of the conditions.

Respectfully submitted,

Montana Brown, B.Sc.

LICENSED PROFESSIONAL ENGINEER
D.J. KELLY
Apr 22 2008
PROVINCE OF ONTARIO

Dennis Kelly, P.Eng.
Senior Geotechnical Engineer

LIST OF ABBREVIATIONS

The abbreviations commonly employed on the borehole logs, on the figures, and in the text of the report, are as follows:

Sample Types	
AS	auger sample
CS	chunk sample
RC	rock core
SS	split spoon
TW	thin-walled, open
WS	wash sample

Soil Tests and Properties	
SPT	Standard Penetration Test
UC	unconfined compression
FV	field vane test
ø	angle of internal friction
γ	unit weight
w_p	plastic limit
w	water content
w_l	liquid limit
I_L	liquidity index
I_p	plasticity index
PP	pocket penetrometer

Penetration Resistances	
Dynamic Penetration Resistance	The number of blows by a 63.5 kg (140 lb.) hammer dropped 0.76 m (30 in.) required to drive a 50 mm (2 in.) diameter 60 ° cone a distance 0.30 m (12 in.). The cone is attached to 'A' size drill rods and casing is not used.
Standard Penetration Resistance, N (ASTM D1586)	The number of blows by a 63.5 kg (140 lb.) hammer dropped 0.76 m (30 in.) required to drive a standard split spoon sampler 0.30 m (12 in.)
WH	sampler advanced by static weight of hammer
PH	sampler advanced by hydraulic pressure
PM	sampler advanced by manual pressure

Soil Description

Cohesionless Soils	**SPT 'N' Value**	**D_r (%)**
Relative Density (D_r)	(blows per 0.30 m)	
Very Loose	0 to 4	0 to 20
Loose	4 to 10	20 to 40
Compact	10 to 30	40 to 60
Dense	30 to 50	60 to 80
Very Dense	over 50	80 to 100

Cohesive Soils	Undrained Shear Strength (C_u)	
Consistency	**kPa**	**psf**
Very Soft	less than 12	less than 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1000
Stiff	50 to 100	1000 to 2000
Very Stiff	100 to 200	2000 to 4000
Hard	over 200	over 4000

DTPL	Drier than plastic limit
APL	About plastic limit
WTPL	Wetter than plastic limit

TABLE 1

GROUNDWATER LEVEL MEASUREMENTS

Embro Dam Embankment Stability Assessment
843970 Road 84
Municipality of Zorra, Ontario

Borehole Number	Ground Elevation (m)	June 16, 2008		July 25, 2008	
		Groundwater Depth (m)	Groundwater Elevation (m)	Groundwater Depth (m)	Groundwater Elevation (m)
1 Upper	48.89	1.51	47.38	1.63	47.26
1 Lower	48.89	0.78	48.11	0.33	48.56
2 Upper	50.04	Dry	Dry	Dry	Dry
2 Lower	50.04	1.45	48.59	1.41	48.63
3	50.01	1.39	48.62	1.65	48.36
4	49.95	1.12	48.83	1.21	48.73
4A	49.95	N/A	N/A	1.20	48.75

Notes:

Ground elevations referenced to TBM supplied by R.J. Burnside & Associates Limited.

TBM: Top centre of concrete base for post at southeast corner of pavillion

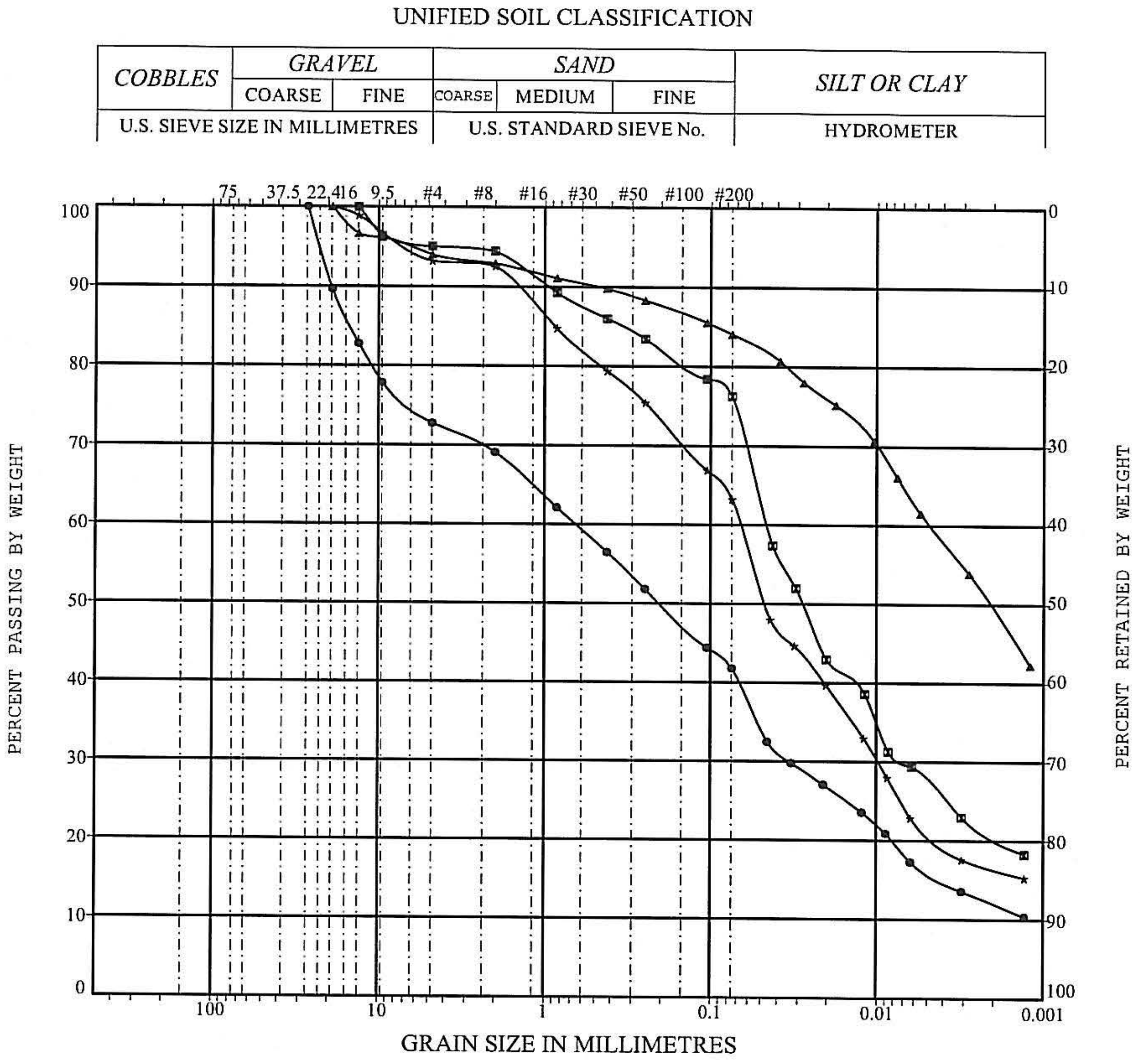
Elevation: 53.045 m (assumed local datum)

TABLE 2

SUMMARY OF SLUG TEST ANALYSES

Embro Dam Embankment Stability Assessment
Municipality of Zorra, Ontario

Monitoring Well Number	Screen Depth (m)	Soil Type	Hydraulic Conductivity (m/s)
2	4.42-5.94	Silt Till	1.2×10^{-06}
3	2.29-3.81	Clay	$2.7\text{x}10^{-06}$



PROJECT Embro Dam Embankment Stability Study

LOCATION County Road 6, Township of Zorra, Ontario JOB NO. 7607G1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	BH3	Sa2	0.76-1.37	Gravelly SILT and SAND FILL, trace Clay
⊠	BH2	Sa3	1.52-2.13	SILT, some Clay and Sand, trace Gravel
▲	BH2	Sa5	3.05-3.51	CLAY and SILT TILL, trace Sand and Gravel
★	BH4	Sa2	0.76-1.37	Sandy SILT, some Clay, trace Gravel

REMARKS ____________________

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Figure No. 1

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Borehole Number: 1

Ground Elevation: *48.89 m*

Project: *Embro Dam Embankment Stability Assessment*

Job No.: *7607G1*

Location: *County Road 16, Township of Zorra, Ontario*

Drill Date: *June 9, 2008*

SOIL PROFILE

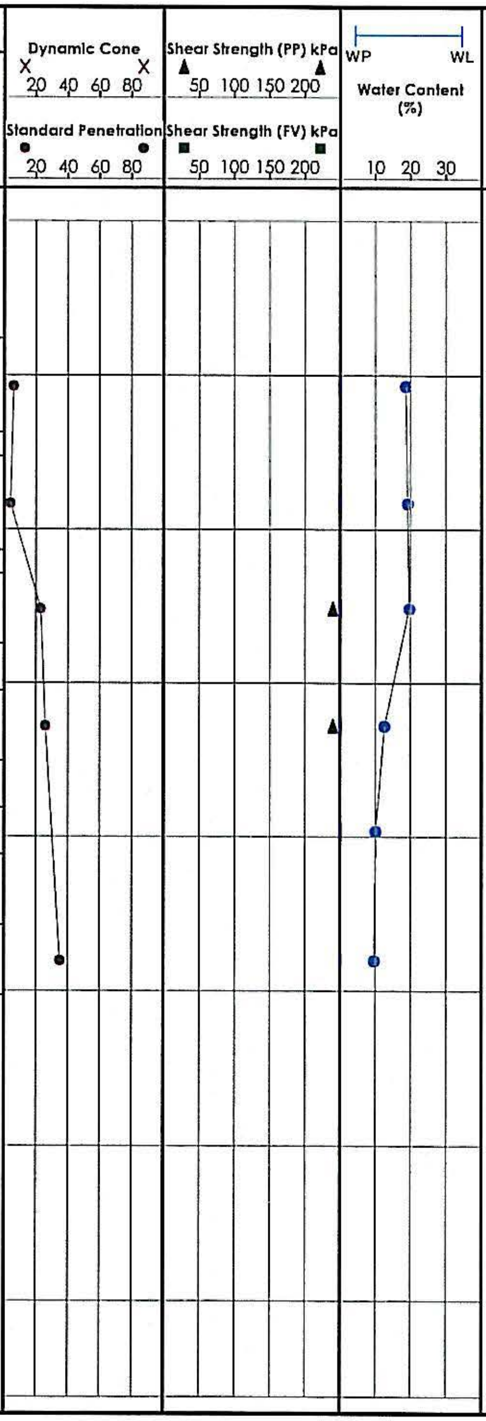
Depth (m)	Description	Symbol	Elevation (m)
0.00	Ground Elevation		48.89
	FILL: dark brown silt cobbles and boulders, pieces of brick, some topsoil, very moist	▨	
	SILT TILL: loose brown sandy silt, some gravel, saturated	▨	
	CLAY TILL: hard grey silty clay, trace sand and fine gravel, APL DTPL	▨	
	SILT TILL: very dense grey sandy silt, some gravel, moist	▨	
	Borehole terminated at 5.03 m		

Depth (m): 0.00, 1.00, 2.00, 3.00, 4.00, 5.00, 6.00, 7.00

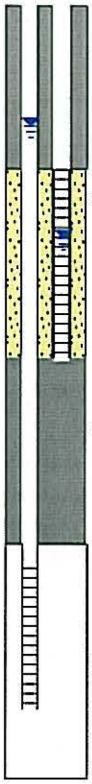
Elevation (m): 48.89, 48.00, 47.00, 46.00, 45.00, 44.00, 43.00, 42.00

SAMPLE

Number	Type	N-Value
1	SS	6
2	SS	4
3	SS	23
4	SS	26
5	SS	30\150mm
6	SS	35



Groundwater Observations and Standpipe Details



At drilling completion wet cave at 3.51 m

June 16, 2008
Upper standpipe water level at 1.51 m (Elev. 47.38 m)

Lower standpipe water level at 0.78 m (Elev. 48.11 m)

Reviewed by: *DK*
Drill Method: *Solid Stem Auger*
Notes:

Field Tech.: *RM*
Sheet: *1 of 1*
Drafted by: *SM (01a)*

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Borehole Number: 2

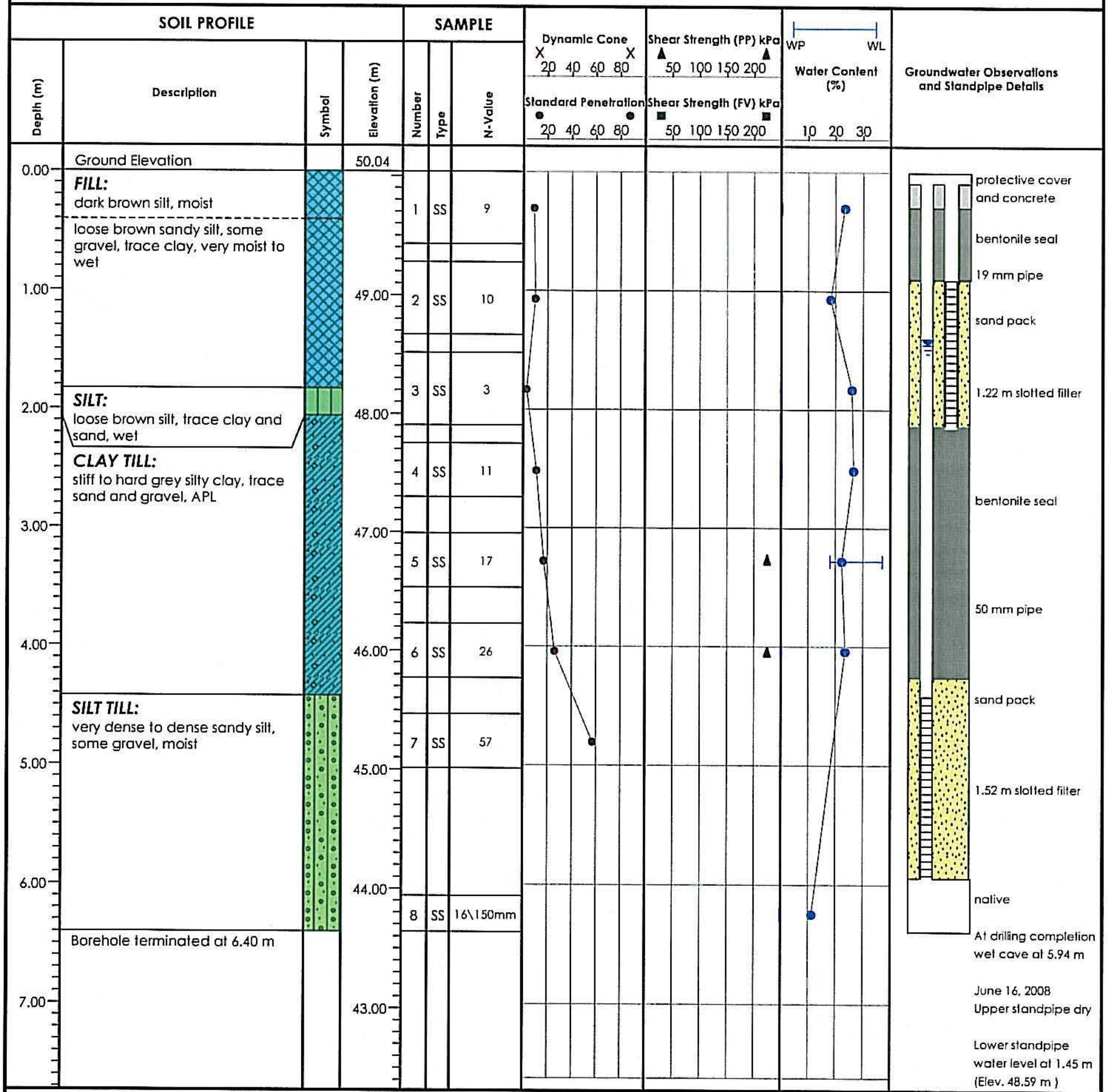
Ground Elevation: *50.04 m*

Project: *Embro Dam Embankment Stability Assessment*

Location: *County Road 16, Township of Zorra, Ontario*

Job No.: *7607G1*

Drill Date: *June 9, 2008*



Depth (m)	Description	Elevation (m)
0.00	Ground Elevation	50.04
	FILL: dark brown silt, moist	
	loose brown sandy silt, some gravel, trace clay, very moist to wet	
	SILT: loose brown silt, trace clay and sand, wet	
	CLAY TILL: stiff to hard grey silty clay, trace sand and gravel, APL	
	SILT TILL: very dense to dense sandy silt, some gravel, moist	
	Borehole terminated at 6.40 m	

Number	Type	N-Value
1	SS	9
2	SS	10
3	SS	3
4	SS	11
5	SS	17
6	SS	26
7	SS	57
8	SS	16\150mm

protective cover and concrete
bentonite seal
19 mm pipe
sand pack
1.22 m slotted filter
bentonite seal
50 mm pipe
sand pack
1.52 m slotted filter
native

At drilling completion wet cave at 5.94 m

June 16, 2008
Upper standpipe dry

Lower standpipe water level at 1.45 m (Elev. 48.59 m)

Reviewed by: *DK*
Drill Method: *Solid Stem Auger*
Notes:

Field Tech.: *RM*
Sheet: *1 of 1*
Drafted by: *SM (01a)*

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Borehole Number: 3

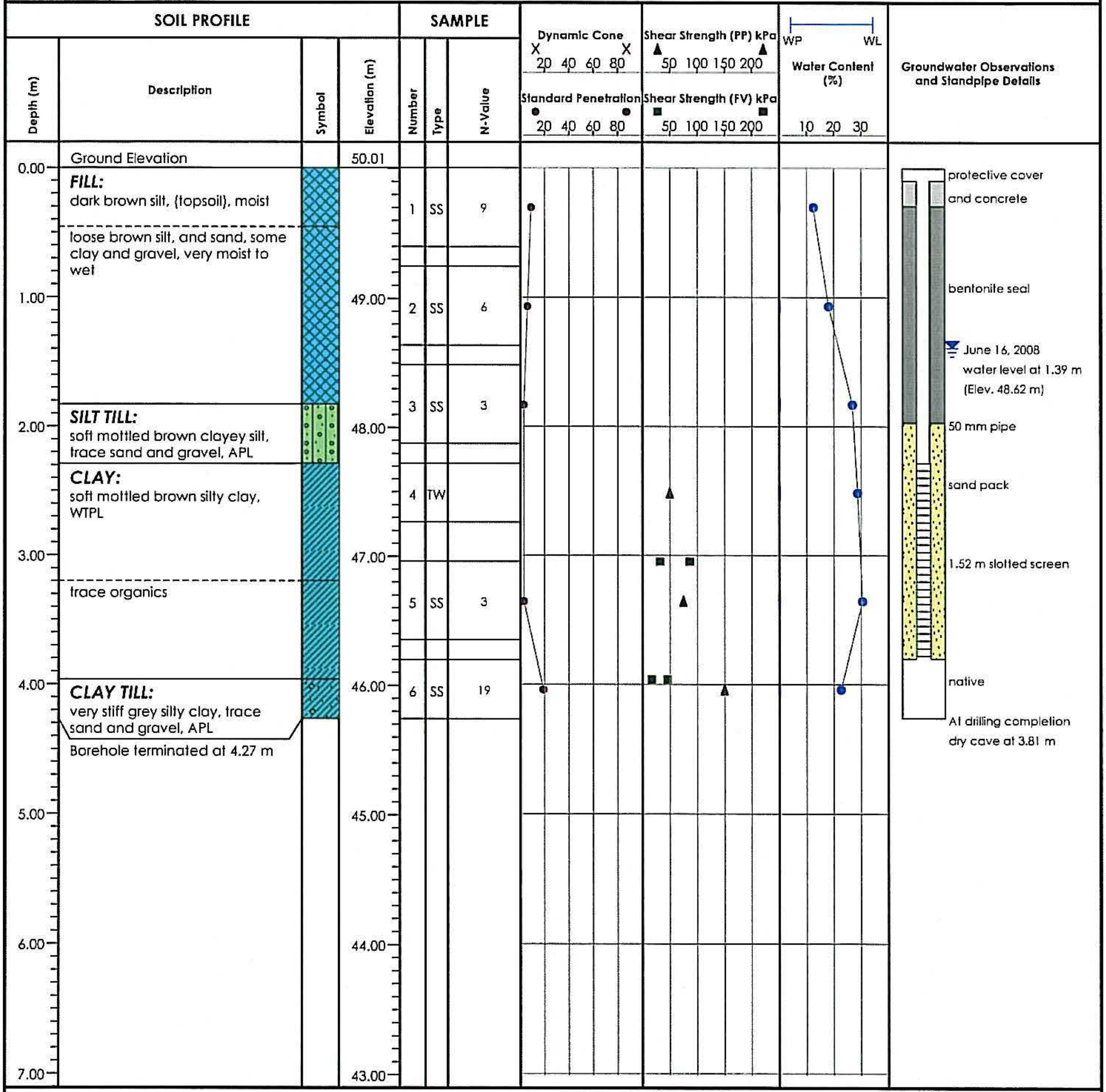
Ground Elevation: *50.01 m*

Project: *Embro Dam Embankment Stability Assessment*

Location: *County Road 16, Township of Zorra, Ontario*

Job No.: *7607G1*

Drill Date: *June 9, 2008*



Ground Elevation 50.01

FILL:
dark brown silt, (topsoil), moist

loose brown silt, and sand, some clay and gravel, very moist to wet

SILT TILL:
soft mottled brown clayey silt, trace sand and gravel, APL

CLAY:
soft mottled brown silty clay, WTPL

trace organics

CLAY TILL:
very stiff grey silty clay, trace sand and gravel, APL

Borehole terminated at 4.27 m

Number	Type	N-Value
1	SS	9
2	SS	6
3	SS	3
4	TW	
5	SS	3
6	SS	19

protective cover and concrete

bentonite seal

June 16, 2008
water level at 1.39 m
(Elev. 48.62 m)

50 mm pipe

sand pack

1.52 m slotted screen

native

At drilling completion
dry cave at 3.81 m

Reviewed by: *DK*

Drill Method: *Solid Stem Auger*

Notes:

Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *SM (01a)*

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Borehole Number: 4

Ground Elevation: *49.95 m*

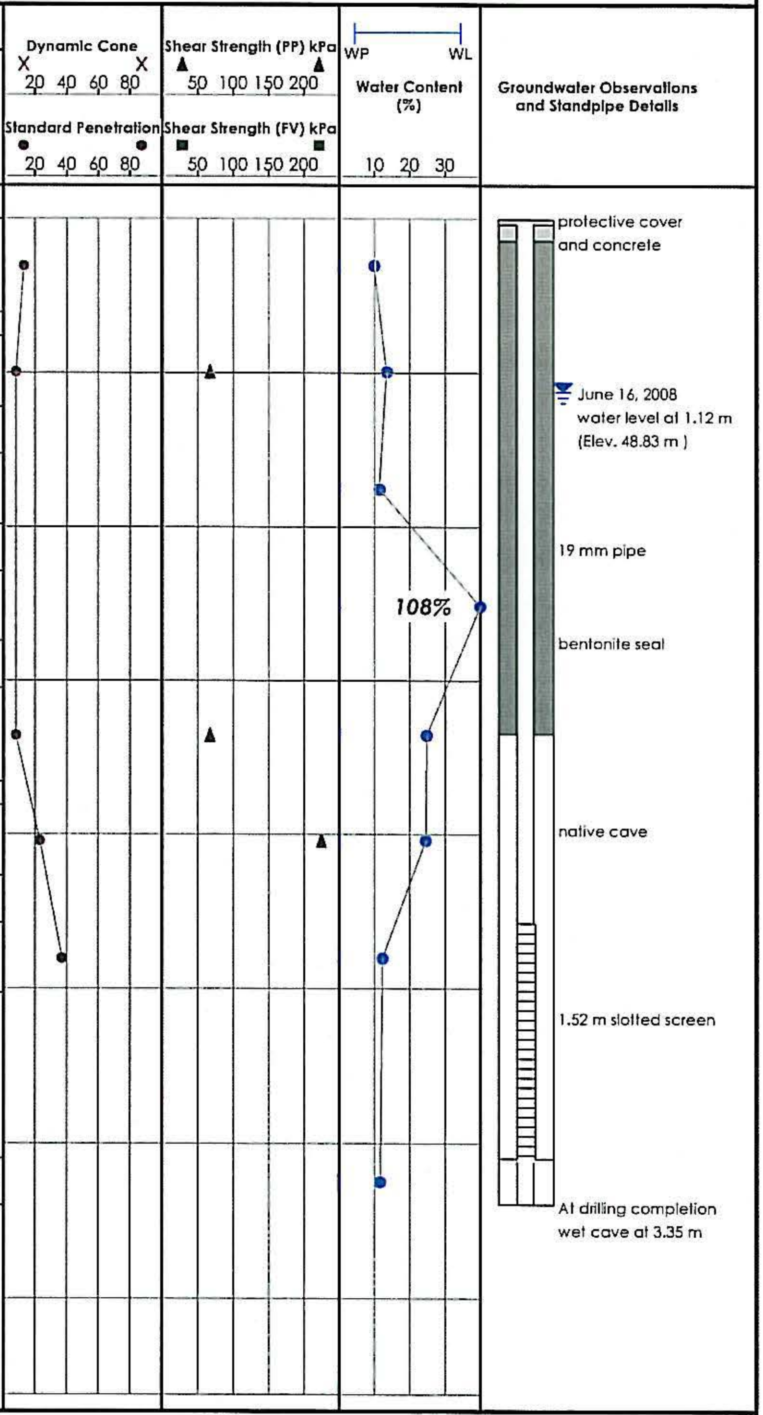
Project: *Embro Dam Embankment Stability Assessment*

Location: *County Road 16, Township of Zorra, Ontario*

Job No.: *7607G1*

Drill Date: *June 10, 2008*

SOIL PROFILE			SAMPLE		
Depth (m)	Description	Elevation (m)	Number	Type	N-Value
	Ground Elevation	49.95			
0.00	***FILL:*** dark brown silt, moist;		1	SS	13
	compact brown sandy silt, some gravel, trace clay, moist				
1.00	***SILT:*** stiff brown silt, some clay, some sand, APL	49.00	2	SS	8
			3	TW	
	grey sandy silt, moist				
2.00	***PEAT:*** black amorphous peat, WTPL	48.00	4	SS	*
3.00		47.00			
	CLAY TILL: grey silty clay, trace sand and gravel, WTPL		5	SS	8
4.00	hard, APL	46.00	6	SS	23
	SILT TILL: dense brown silt, some sand and gravel, moist		7	SS	37
5.00		45.00			
6.00		44.00			
	very dense brown sandy silt, some gravel, moist		8	SS	35\150mm
	Borehole terminated at 6.40 m				
7.00		43.00			



Reviewed by: *DK*

Drill Method: *Solid Stem Auger*

Notes: **Sampler driving on wood*

Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *SM (01a)*

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Borehole Number: 4A

Ground Elevation: *49.95 m*

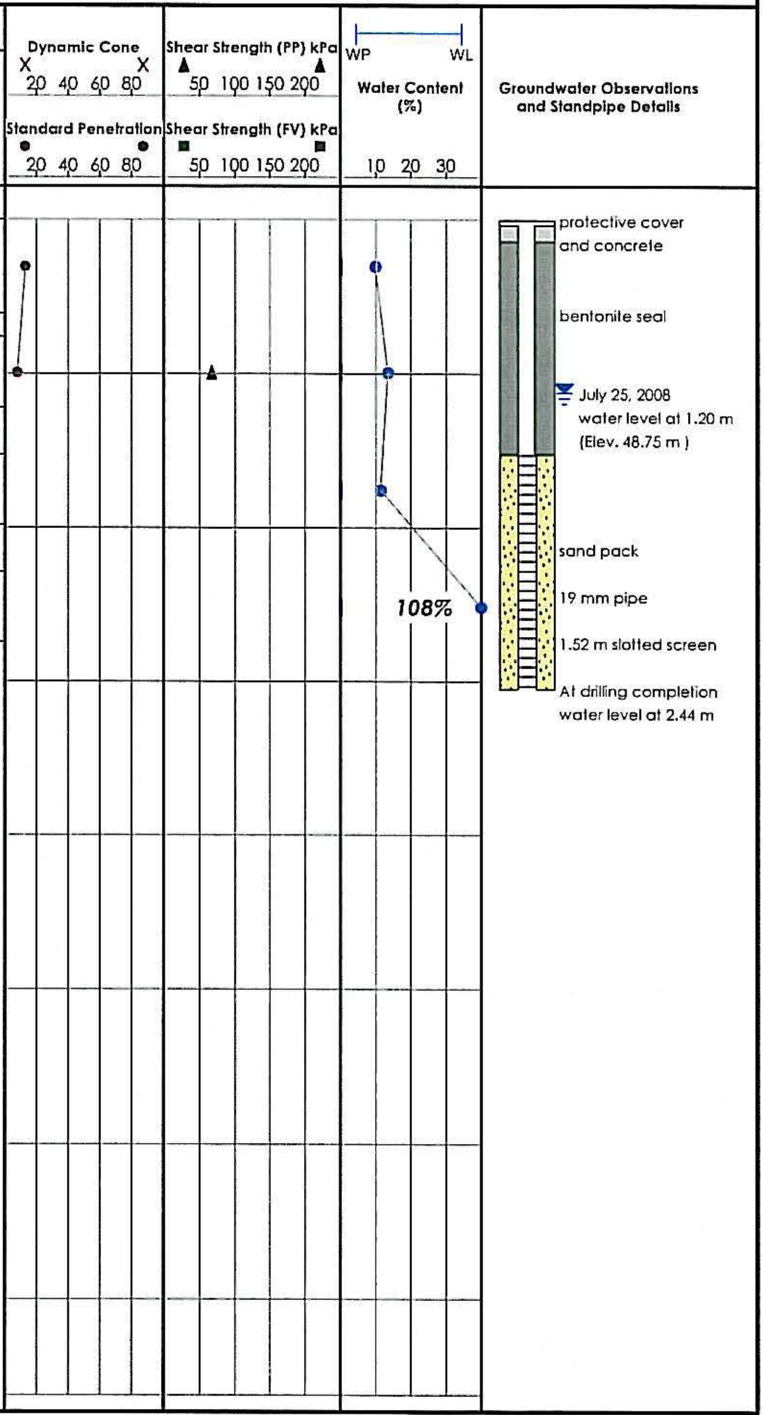
Project: *Embro Dam Embankment Stability Assessment*

Job No.: *7607G1*

Location: *County Road 16, Township of Zorra, Ontario*

Drill Date: *June 10, 2008*

SOIL PROFILE				SAMPLE		
Depth (m)	Description	Symbol	Elevation (m)	Number	Type	N-Value
	Ground Elevation		49.95			
0.00	***FILL:*** dark brown silt, moist;			1	SS	13
	compact brown sandy silt, some gravel, moist					
1.00	***SILT:*** stiff brown silt, some clay, trace sand, APL		49.00	2	SS	8
	grey sandy silt, moist			3	TW	
2.00	***PEAT:*** black amorphous peat, WTPL		48.00	4	SS	*
3.00	Borehole terminated at 3.05 m		47.00			
4.00			46.00			
5.00			45.00			
6.00			44.00			
7.00			43.00			



Reviewed by: *DK*

Drill Method: *Solid Stem Auger*

Notes: **Sampler driving on wood. Soil stratigraphy inferred from Borehole 4.*

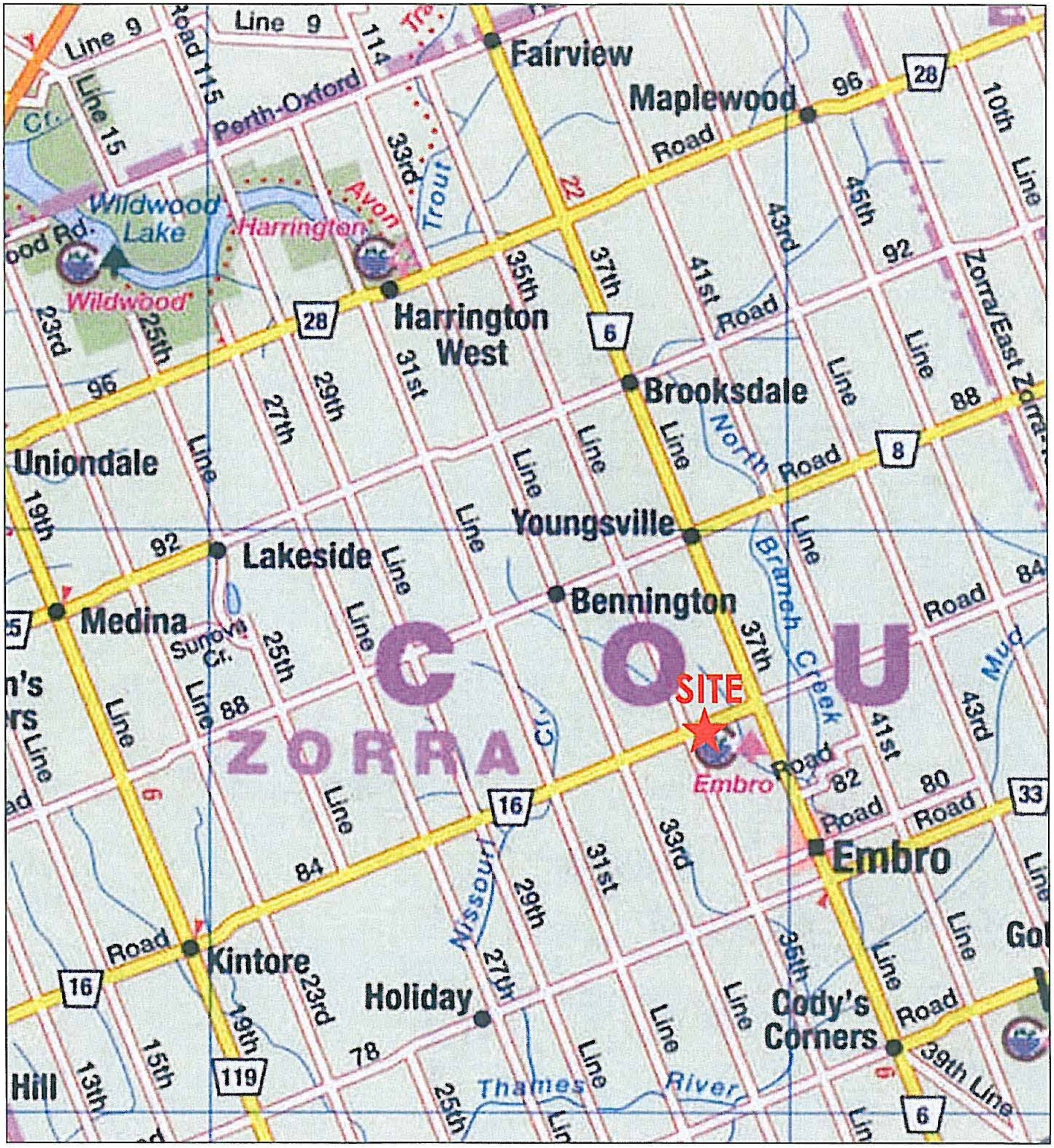
Field Tech.: *RM*

Sheet: *1 of 1*

Drafted by: *SM (01a)*

NORTH

No.	Revisions	Date
0	**Report Issued**	**Sept. 2008**
1		
2		
3		



Drawing Reference: Base drawing from page 15 of MapArt's Ontario Road Atlas (2007).

0 1000 2000 3000 4000 m

SCALE 1:100000

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June 12, 2008 (5m)

Embro Dam Embankment Stability Assessment

County Road 16

Township of Zorra, Ontario

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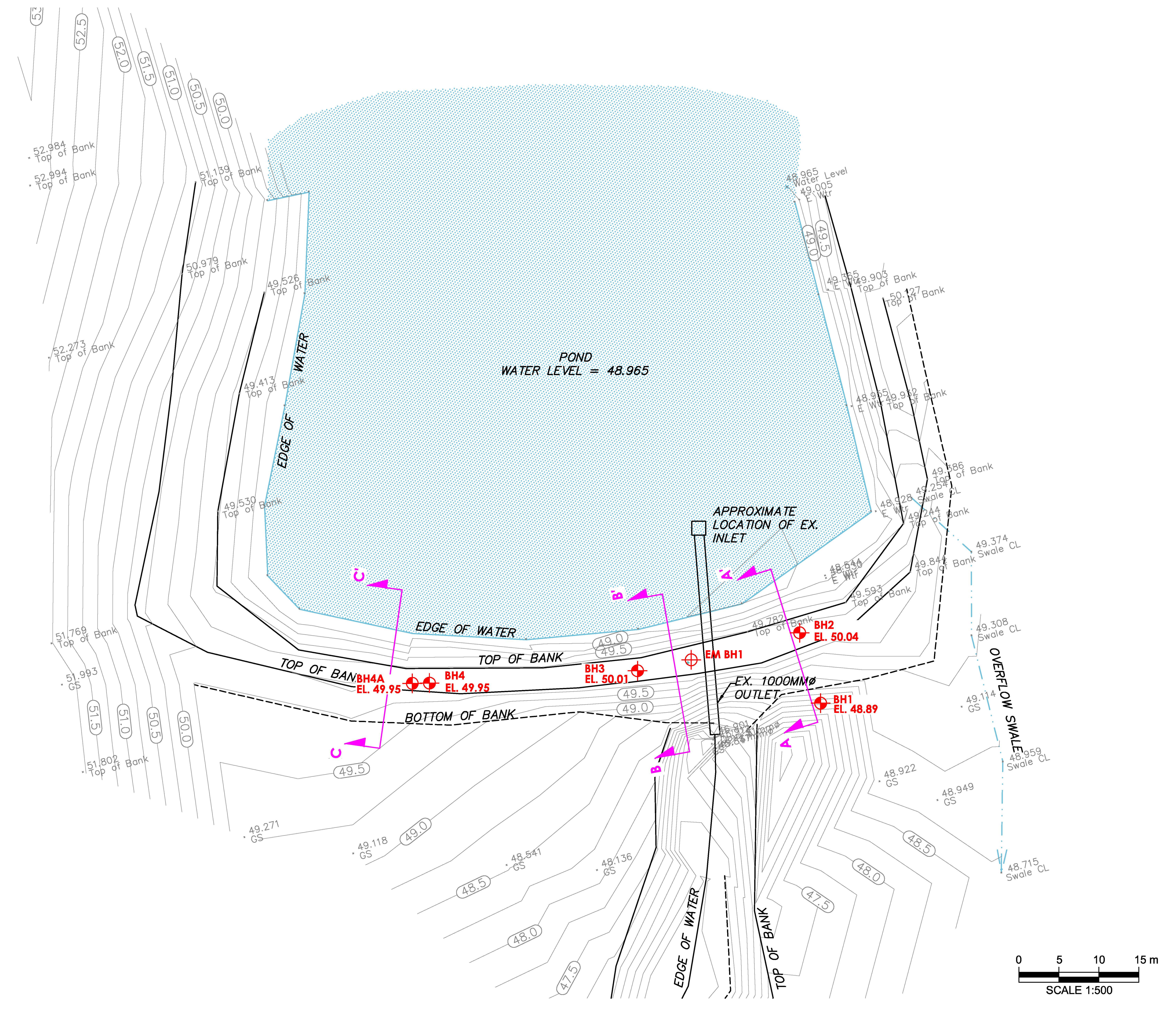
LOCATION PLAN

Date	Scale	Job No.	Drawing No.
Sept. 2008	**1:100000**	**7607G1**	**1**



Drawing Reference: Base drawing provided by R. J. Burnside Associates Ltd.

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August 5, 2008

No.	Revisions	Date
0	**Report Issued**	**Sept. 2008**
1		
2		
3		

Legend

⊕	Borehole Location (Current Investigation)
⊕	Approximate Borehole Location (Acres International)
EL.48.89	Ground Surface Elevation (m)
A A'	Geologic Cross-Sections (See Drawing No. 3)

Temporary Benchmark
Top centre of concrete base for post at southeast corner of pavillion
Elevation 53.045 m (assumed local datum)

NORTH

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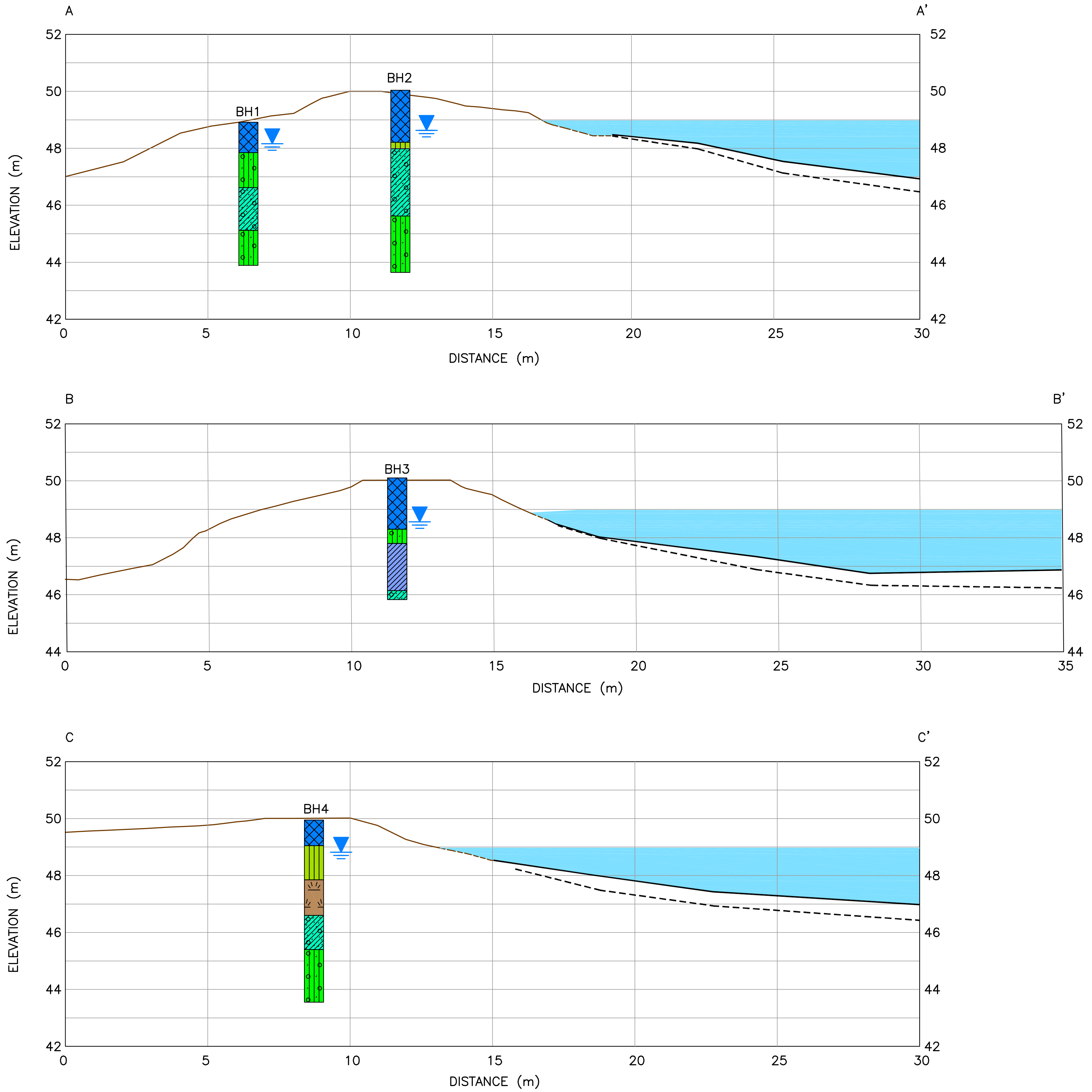
Embro Dam Embankment Stability Assessment

County Road 16

Township of Zorra, Ontario

SITE PLAN

Date	Scale	Job No.	Drawing No.
Sept. 2008	**1:500**	**7607G1**	**2**



No.	Revisions	Date
0	**Report Issued**	**Sept. 2008**
1		
2		
3		

Legend

▨ Fill

▨ Peat

▥ Silt

▨ Clay Till

▥ Silt Till

▨ Clay

▼ Groundwater Table
June 16, 2008

——— Existing Grade

——— Approximate Top of Sediment (m)
(Bottom of Pond)

- - - - - Approximate Bottom of Sediment (m)

Notes:

Seasonal fluctuations in groundwater levels would be expected.
The inferred stratigraphy shown on this cross-section is based on the subsurface stratigraphy contacted at the boreholes. The subsurface conditions between the boreholes will vary.

The ground surface under the water is based on depth (to refusal) measurements taken with a steel survey rod.

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Embro Dam Embankment Stability Assessment

County Road 16

Township of Zorra, Ontario

CROSS-SECTIONS A - A', B - B' and C - C'

Date	Scale	Job No.	Drawing No.
Sept. 2008	**1:150**	**7607G1**	**3**

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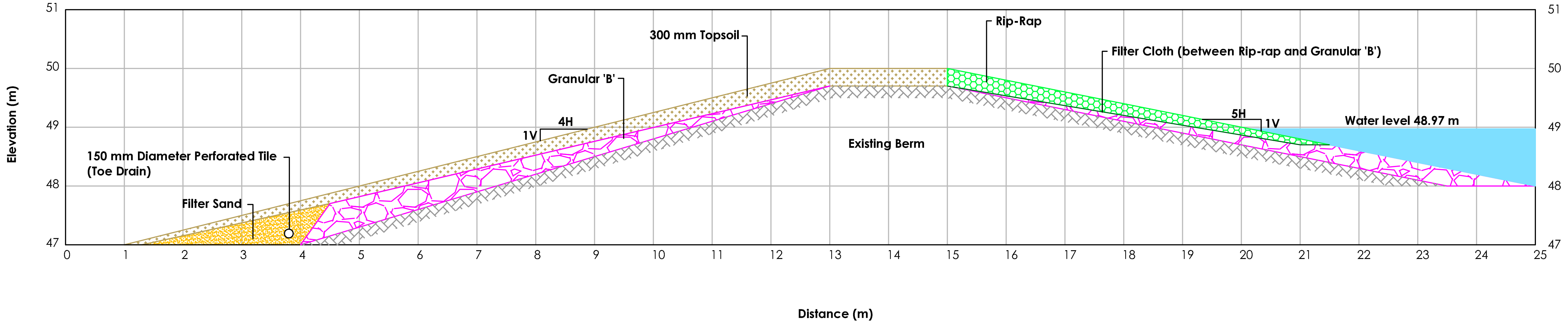
July 16, 2008 (sm) /Aug.5, 2008 (ks)



NOTES:

1. Perforated corrugated polyethylene drainage pipe shall meet the requirements of OPSS 1840.
2. Pipe filter fabric conforming to OPSS 1860 for geotextile Class 1 with a filtration opening size of 150 to 450 microns shall be supplied on all sections of the perforated pipe.
3. Subdrain pipes to be set on at least 1% draining to a positive outlet. If the pipe is outletted to the stream then the last 1.5m should consist of a corrugated steel pipe with a rodent gate.
4. Subdrain bedding and backfill material shall be concrete sand meeting the gradation requirements of OPSS 1002 (fine aggregate for concrete)
5. The upstream end of the pipe should be capped.
6. Granular 'B' fill shall be placed in 300 mm thick lifts and compacted to 95% SPMDD.
7. Rip-rap shall be 100 to 300 mm size.
8. Galvanized wire mesh shall be placed beneath the topsoil on the south face and beneath the rip-rap on the north face in order to prevent animal burrows.
9. Filter cloth must be placed between the rip-rap and Granular 'B'.
10. Topsoil shall be 300 mm thick.

Legend

▨	Topsoil Cover (300 mm)
▨	Sand Filter
▨	Rip Rap
▨	Granular 'B' Fill (OPSS Type 2)

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August 7, 2008 /ks

No.	Revisions	Date
0	**Report Issued**	**Sept. 2008**
1		
2		
3		

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Township of Zorra, Ontario

Embro Dam Embankment Stability Assessment

County Road 6

DAM RETROFIT DETAIL

Date	Scale	Job No.	Drawing No.
Sept. 2008	**1:75**	**7607G1**	**4**