GEOTECHNICAL INVESTIGATION
FULLARTON DAM EMBANKMENT STABILITY ASSESSEMENT
MUNICIPALITY OF WEST PERTH, ONTARIO
for
UPPER THAMES RIVER CONSERVATION AUTHORITY

6031G1.R01
February 2006

Naylor Engineering Associates Ltd.

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6031G1.R01

February 16, 2006

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

Attention: Mr. Rick Goldt, C.E.T.

Dear Sir:

Re: Geotechnical Investigation
Fullarton Dam Embankment Stability Assessment
Municipality of West Perth, Ontario

Naylor Engineering Associates Ltd. is pleased to submit this Geotechnical Engineering Report for the geotechnical investigation recently carried out for the above referenced project. The project involves the embankment stability assessment of the Fullarton Dam in the Municipality of West Perth, 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.

The 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 Fullarton Dam Embankment.

Yours truly,

Dennis Kelly, P.Eng.
Senior Geotechnical Engineer
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TABLE OF CONTENTS

1. Introduction

Naylor Engineering Associates Ltd. was retained by the Upper Thames River Conservation Authority to carry out an Embankment Stability Assessment on the Fullarton Dam in the Municipality of West Perth, Ontario at the location shown on Drawing 1, appended. This work was authorized in a Contract Document dated November 28, 2005.

The Fullarton Dam is located approximately 2 km south of the Town of Fullarton on an unnamed tributary of the North Thames River. The dam and reservoir were built for recreational purposes and are adjacent to Township Road 163A. The Fullarton Dam is a small earth dam approximately 110 m long which has a head of water of approximately 2.0 m acting across the dam. The dam contains water year round and the freeboard at the dam is approximately 0.7 m.

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

2. Investigation Procedure

2.1 Previous Work

A Dam Safety Assessment Report for the Fullarton Dam was prepared by Acres International in March 2004. The investigation and report included comprehensive site inspections and condition assessments, site investigations, hydrotechnical assessment, civil/structural assessment, geotechnical assessment, and operations maintenance and safety recommendations.

Two boreholes were drilled for the investigation on November 24 to 26, 2003. Laboratory testing was done on some of the soil samples retrieved from the boreholes. The borehole logs and laboratory test results are provided in Appendix A of this report.

2.2 Field Program

The fieldwork for this investigation was carried out on November 11, 2005 and involved the drilling of four boreholes (Boreholes 101 to 104) to depths between 3.4 and 7.6 m at the locations shown on Drawing 2 appended. The boreholes were advanced with a CME-55 track mounted drillrig equipped with continuous flight solid stem augers supplied and operated by a specialist drilling contractor.

Soil samples were recovered from the boreholes at regular 0.75 and 1.50 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 to recover relatively undisturbed samples of the dam embankment fill.

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 pipes with slotted and filtered screens. The screens 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.

Monitoring wells were installed with the piezometers on the dam embankment at Boreholes 101 and 102. The monitoring wells comprise 50 mm diameter trilock pipe with 760 mm long slotted filters and protective steel flush mount covers and lockable caps. The purpose of the monitoring wells was to allow installation of data loggers for long term continuous monitoring of the groundwater level.

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 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.

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:

TBM: Base plate of steel iron post for gate on dam at location shown on Drawing 2, appended

Elevation: 100.00 m (assumed local datum)

Groundwater samples were measured in the piezometers by Naylor Engineering Associates Ltd. on November 28 and December 12, 2005. The water level measurements are provided on the appended borehole logs and on Table 1.

A data logger was installed in the 50 mm diameter standpipe at Borehole 102. The purpose of the data logger was to provide continuous groundwater level measurements over a 28 day period.

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:

- two Atterberg Limits tests (LS-703 and LS-704) (ASTM D4318) with results provided on Table 2;
- five particle size distribution analyses (MTO LS-702) (ASTM D422 or C139) with results plotted on Figures 1 and 2; and,
- one soil direct shear test (ASTM D3080) with results summarized in Subsection 3.2.1.

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 Fullarton Dam is located approximately 2 km south of the Town of Fullarton on an unnamed tributary of the North Thames River at the Fullarton Conservation Area in the Municipality of West Perth, Ontario. The dam and pond were built for recreational purposes. The dam was completed in November 1955 and the pond in the spring of 1958.

Fullarton Pond has a surface area of about 2 ha and the dam is located at the north end of the pond. Flow releases from the dam outlet into a narrow channel and flow in a northeasterly direction for approximately 0.45 km before entering the main stem of the North Thames River.

The discharge facilities at the dam consist of a concrete drop inlet structure with a set of stop logs at the upstream face and an inverted V-shaped trash rack anchored to the top of the inlet. There is an emergency spillway located on the east bank. The emergency spillway is partially lined with cable concrete and has a grass discharge channel that runs parallel to the creek before joining it.

The Fullarton Dam is a small earth fill dam approximately 110 m long with side slopes inclined at between 2 and 3 horizontal to 1 vertical. The head of water acting across the dam is approximately 2.0 m and the freeboard on the pond side of the dam is approximately 0.7 m.

The pond side of the earth dam is not protected with rip-rap and is overgrown with cattails and marsh type vegetation. Wave scour erosion has occurred up to 0.5 m and possible muskrat burrows were evident. No displacement settling or sink holes were noticed on the upstream slope.

The crest of the dam is about 6 m wide and is vegetated with grass. 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 centre third. The centre third in the area of the outlet pipe is covered with loose rip-rap. No seepage areas were noticed on the downstream slope although the rip-rap appears to have settled unevenly around the outlet.

The outlet pipe consists of a pre-cast concrete pipe with an inside diameter of 762 mm. The downstream edge of the pipe was chipped and damaged and rip-rap has been placed at the end of the outlet pipe.

The stream channel north of the dam is about 3 m wide and 300 mm deep and situated within a low lying marsh area. Minor erosion was evident along the sides of the stream channel at the time of the investigation.

Photographs of the site conditions are provided in Appendix B.

3.2 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 and/or topsoil overlying native deposits of silt, sand and glacial till. Descriptions of the various soil deposits encountered are provided in the following subsections.

3.2.1 Fill

Fill material was encountered in Boreholes 101 and 102 that were drilled on the crest of the dam. The fill is about 2.0 m thick and typically comprises silt with some clay, trace to some sand and trace to some gravel. 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 1 to 13% gravel, 9 to 23% sand, 51 to 73% silt, and 13 to 17% clay. Pocket penetrometer tests carried out on cohesive samples of the fill indicate shear strengths of between 100 and 200 kPa. The moisture content of the fill ranges from 10 to 24% indicating moist to wet conditions.

The results of an Atterberg Limits test carried out on a sample of the cohesive fill from Borehole 102 are provided on Table 2, appended. Based on the test results the fill has low plasticity and is moderately over consolidated. A direct shear test carried out on a sample of the fill indicated an angle of internal friction of 34 degrees.

3.2.2 Topsoil

Topsoil was encountered beneath the fill at Borehole 102, and at the ground surface in Boreholes 103 and 104 that were drilled on the downstream side of the dam. The topsoil is 300 to 600 mm thick and comprises dark brown to black silt. The topsoil has a stiff consistency based on a pocket penetrometer measurement of the shear strength of 100 kPa. The natural moisture content of the topsoil is about 26%.

3.2.3 Silt

A native deposit of silt was encountered beneath the fill and/or topsoil at Boreholes 101 and 102 and within a glacial till unit at Borehole 104. The silt deposit is 0.5 to 1.0 m thick and contains some clay. The silt has a firm to stiff consistency and is about the plastic limit.

3.2.4 Sand

A significant deposit of sand was contacted at about 3.0 m depth beneath the embankment at Boreholes 101 and 102, and about 0.6 m depth at the north side of the embankment at Borehole 103. The sand is 0.7 to 2.4 m thick and has a compact relative density based on SPT N-values that range from 15 to 35 blows per 300 mm penetration of the split spoon sampler.

The results of a particle size distribution analysis carried out on a sample of the sand are plotted on Figure 2, appended and indicates that the sample contains 17% silt, 56% sand and 27% gravel. The sand deposit is saturated and the natural moisture content is about 10%.

3.2.5 Glacial Till

Glacial till was encountered beneath the sand in Boreholes 101, 102 and 103 and underlying the topsoil in Borehole 104. The surface of the glacial till is about 3.8 to 5.5 m below the top of the dam embankment and the glacial till extends below the termination depths of the boreholes.

The texture of the glacial till is typically silt and sand with some clay and gravel. The results of two particle size distribution analyses carried out on samples of the glacial till are plotted on Figure 2 and indicate that the samples contain 10 to 12% clay, 34 to 40% silt, 28 to 33% sand and 15 to 28% gravel.

The relative density of the glacial till is typically compact in the upper 1.0 to 2.0 m becoming dense to very dense with depth. The insitu moisture content of the glacial till ranges from 7 to 10% indicating moist or drier than the plastic limit conditions.

The results of an Atterberg Limits test carried out on a sample of the glacial till are provided on Table 2, appended and indicate that the deposit has low plasticity and is heavily over consolidated.

3.3 Groundwater

We refer to the appended borehole logs for groundwater observations and measurements carried out in the open boreholes and in piezometers and monitoring wells installed in the boreholes. The groundwater levels measured in the piezometers and monitoring wells are also summarized on Table 1, appended.

The groundwater levels in Borehole 101 and 102 are 2.3 to 2.8 m below the top of the dam embankment. The groundwater levels in the boreholes drilled on the north side of the embankment are 0.1 to 0.4 m below existing grade.

In general the vertical hydraulic gradient at the site is downward; however, subartesian conditions were noted within the native sand deposits. In particular the sand units beneath the dam are about 3.0 m deep; however, the static water levels in piezometers installed within the sand deposits are about 2.6 to 2.8 m below the top of the dam.

The horizontal hydraulic gradient is towards the north and seepage zones would be expected on the north side of the dam based on the water levels measured in Boreholes 103 and 104.

The hydraulic conductivity of the subsurface soils has been estimated using Hazens Formula. The inferred hydraulic conductivity of the sand ranges from $1x10^{-3}$ to $1x10^{-4}$ cm/sec. The hydraulic conductivity of the fill and silt is about $1x10^{-5}$ cm/sec, and the hydraulic conductivity of the glacial till is less then $5x10^{-6}$ cm/sec.

4. Discussion and Recommendations

4.1 General

The project involves the geotechnical assessment of the Fullarton Dam in the Municipality of West Perth, Ontario.

The Fullarton Dam comprises a small earth embankment constructed with silt fill material placed over native deposits of silt and sand which in turn overlies glacial till. Topsoil occurs beneath the fill at one of the boreholes drilled on the dam. Groundwater occurs under subartesian conditions in native sand soil at 3.0 m below the top of the earth embankment.

The following subsections of this report contain geotechnical recommendations pertaining to existing dam stability, subgrade soil conditions and bearing capacity, groundwater levels, and dam modifications to meet safety criteria.

4.2 Existing Dam Stability

4.2.1 Existing Conditions

The Fullarton Dam and pond were built for recreational purposes in 1955. The Fullarton Dam is a small fill dam approximately 110 m long and 6.0 m wide at the crest. The sides of the dam are inclined at between 2 and 3 horizontal to 1 vertical, and the freeboard on the pond side is approximately 0.7 m.

Fullarton Pond has a surface area of about 2 ha. The embankment dam is approximately 3.0 m high and impounds a total estimated storage volume of 2000 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 a set of stop logs at the upstream face and an inverted V-shaped trash rack anchored to the top of the inlet. There is an emergency spillway located on the east bank. The mouth of the spillway measured 9.5 m in length and is covered with cabled concrete. The emergency spillway has a grass discharge channel that runs parallel to the creek before joining it.

4.2.2 Dam Stability

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 homogeneous berm, the engineering properties of the major soil components were estimated as noted in the following paragraphs.

The undrained shear strength of the compacted silt used for the homogeneous earth dam is estimated from field and lab testing to be 100 kPa. To account for the affect of weathering and desiccation, and to be conservative, a value of 50 kPa was used for the undrained analysis.

The coefficient of friction was determined by laboratory testing to be 34 degrees for the remolded and recompacted silt fill material. A unit weight was taken to be 20 kN/m^3 for the fill.

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. Consideration was given to very rapid (i.e. unplanned) drawdown of the reservoir at a rate significantly in excess of the rate at which pore pressures in the core and embankment fill are able to dissipate.

3. A pseudostatic horizontal seismic load was incorporated in to the stability analysis using a seismic coefficient of 0.04g, a conservative value for this area of Canada (Canadian Foundation Engineering Manual, 1992).

Loading Conditions	Slope	Minimum Factor of Safety	Calculated Factor of Safety
Steady State Seepage with maximum storage pool	Downstream	1.5	2.7 to 3.2
Full or partial rapid drawdown	Upstream	1.3	1.5 to 1.7
Horizontal seismic load	Downstream and Upstream	1.3	1.3 to 2.6

Based on the stability evaluation, it is concluded that factors of safety of greater than 1.3 are maintained for both undrained and drained (long-term) cases, and that the embankment maintains high stability under rapid draw down and seismic conditions.

The existing dam does not meet current standards in some respects but is considered stable under existing conditions. The moderate width of the dam with relatively low water level difference from the south to the north means that the dam is intrinsically stable against sliding. The factor of safety against sliding for the embankment is greater than 2.0. Also, since the resulting forces act within the middle third of the embankment, adequate safety against overturning is ensured. Also, the fill material within the dam comprises mostly silt that has a low hydraulic conductivity and medium strength.

The problem with the dam is the discontinuous topsoil that underlies the fill, the permeable sand deposits that are part of the foundation, and the wave erosion that is occurring on the pond side. Also we expect steady seepage conditions to be occurring through the dam although it was not evident at the time of our fieldwork. The steady seepage could eventually cause piping erosion at the downstream toe of the dam. The following remedial/retrofit work is recommended to ensure long-term stability and satisfactory performance.

4.3 Erosion Protection

Rip-rap is required on the south (pond) face of the dam and at the outlet where the creek channel is close to the outside toe of the dam. The rip-rap on the south face of the dam must extend over the entire freeboard and to the top of the embankment.

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 existing rip-rap may be reused subject to inspection and approval by Naylor Engineering Associates Ltd. at the time of construction. The rip-rap should be placed over a filter cloth and sand and gravel base (OPSS Granular 'A'). The filter cloth will prevent scour and undercutting of the rip-rap. The granular base should contain galvanized wire mesh to prevent animal burrows.

The outlet stream channel must also be lined with river stone or rip-rap from the end of the outfall pipe to at least 10 m downstream of the pipe. The rip-rap or river stone should be sized depending on the velocities expected. The downstream toe protection must extend at least 600 mm above the stream level. Rip-rap must not be placed such that it blocks any part of the pipe.

Wire mesh or gabions are also recommended along the downstream slopes of the dam to guard against burrowing animals. The protection should extend about 5.0 m each way from the outlet pipe.

4.4 Toe Drain

Toe drains are recommended for the north side of the dam in order to prevent seepage piping erosion. The toe drains should extend about 50 m each way from the outlet pipe of the Fullarton Dam. The toe drains should be constructed as shown on Drawing 4, appended.

The toe drains should comprise 150 mm diameter perforated tiles complete with filter sock 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.

4.5 Outlet Pipe

It was anticipated that the existing outlet pipe through the Fullarton Dam will be maintained. The existing outlet appears satisfactory, although there is a risk of deterioration and piping erosion beneath or on the sides of pipe over time. We suggest that if the pipe is replaced then a clay or concrete cutoff collar be installed as required.

Any new spillways constructed for the Fullarton Pond must be carefully designed and lined with concrete and/or rip-rap. The lining must extend beyond the toe of the dam.

4.6 Construction Inspection and Testing

Geotechnical inspections and insitu density testing must be conducted during rip-rap 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.

4.7 Conclusions

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

- The dam at Fullterton Pond comprises compacted silt fill over discontinuous topsoil, silt and sand, which in turn overlies glacial till.

- Groundwater with subartesian pressure was measured within the sand below the dam at the time of the fieldwork.

- The Fullarton Dam Embankment does not meet current standards, but is considered stable under existing conditions.

- In order to ensure long-term stability of the dam, it is recommended that the rip-rap be placed over the entire freeboard on the south face of the dam, a toe drain be installed along the north side of the dam, and river stone or rip-rap be placed around the outlet pipe and in the stream channel.

It is important to know that the geotechnical investigation involved a limited sampling of the site gathered at specific borehole locations and the conclusions in this report are based on the information gathered. The subsurface conditions between and beyond the boreholes will differ from those encountered at the boreholes. Should subsurface conditions be encountered which differ materially from those indicated from the boreholes 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.

Respectively submitted,

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		Soil Tests and Properties	
AS	auger sample	SPT	Standard Penetration Test
CS	chunk sample	UC	unconfined compression
RC	rock core	FV	field vane test
SS	split spoon	ø	angle of internal friction
TW	thin-walled, open	γ	unit weight
WS	wash sample	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 º 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

SUMMARY OF GROUNDWATER LEVELS

Fullarton Dam Embankment Stability Assessment
Municipality of West Perth, Ontario

Borehole Number	November 28, 2005		December 12, 2005	
	Groundwater Depth (m)	Groundwater Elevation (m)	Groundwater Depth (m)	Groundwater Elevation (m)
101 Upper (MW)	Dry	Dry	Dry	Dry
101 Lower	2.57	97.45	2.74	97.28
102 Upper (MW)	2.31	97.85	2.47	97.69
102 Lower	2.75	97.41	2.85	97.31
103 Upper	0.13	97.43	0.24	97.32
103 Lower	Blocked	Blocked	Blocked	Blocked
104 Upper	0.20	98.02	0.54	97.68
104 Lower	0.46	97.76	0.59	97.63

Notes: Reservoir level measured on November 28, 2005 at Elevation 99.31 m

TABLE 2

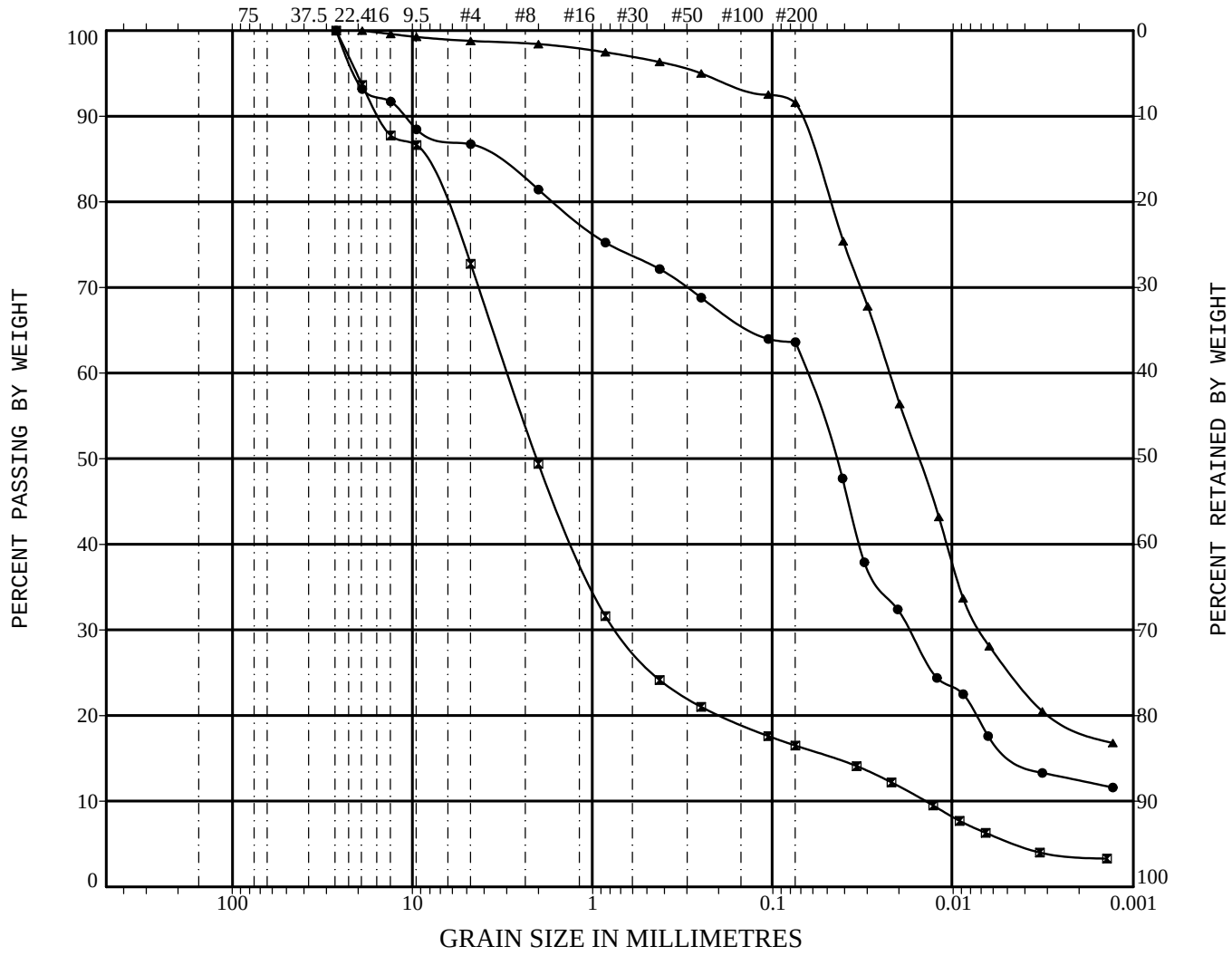
ATTERBERG LIMITS TEST RESULTS

Fullarton Dam Embankment Stability Assessment
Municipality of West Perth, Ontario

Borehole Number	Sample Depth (m)	Water Content (%)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Liquidity Index
102	1.52 – 1.98	24	21	31	10	0.3
102	4.57 – 5.03	9	11	14	3	-0.6

UNIFIED SOIL CLASSIFICATION

COBBLES	*GRAVEL*		*SAND*			*SILT OR CLAY*
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Fullarton Dam Embankment Stability Assessment

LOCATION 2999 Road 163a, Municipality of West Perth, Ontario JOB NO. 6031G1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	BH101	Sa3	1.52-1.98	FILL
⊠	BH101	Sa7	4.57-5.03	SAND
▲	BH102	Sa3	1.52-1.98	FILL

REMARKS

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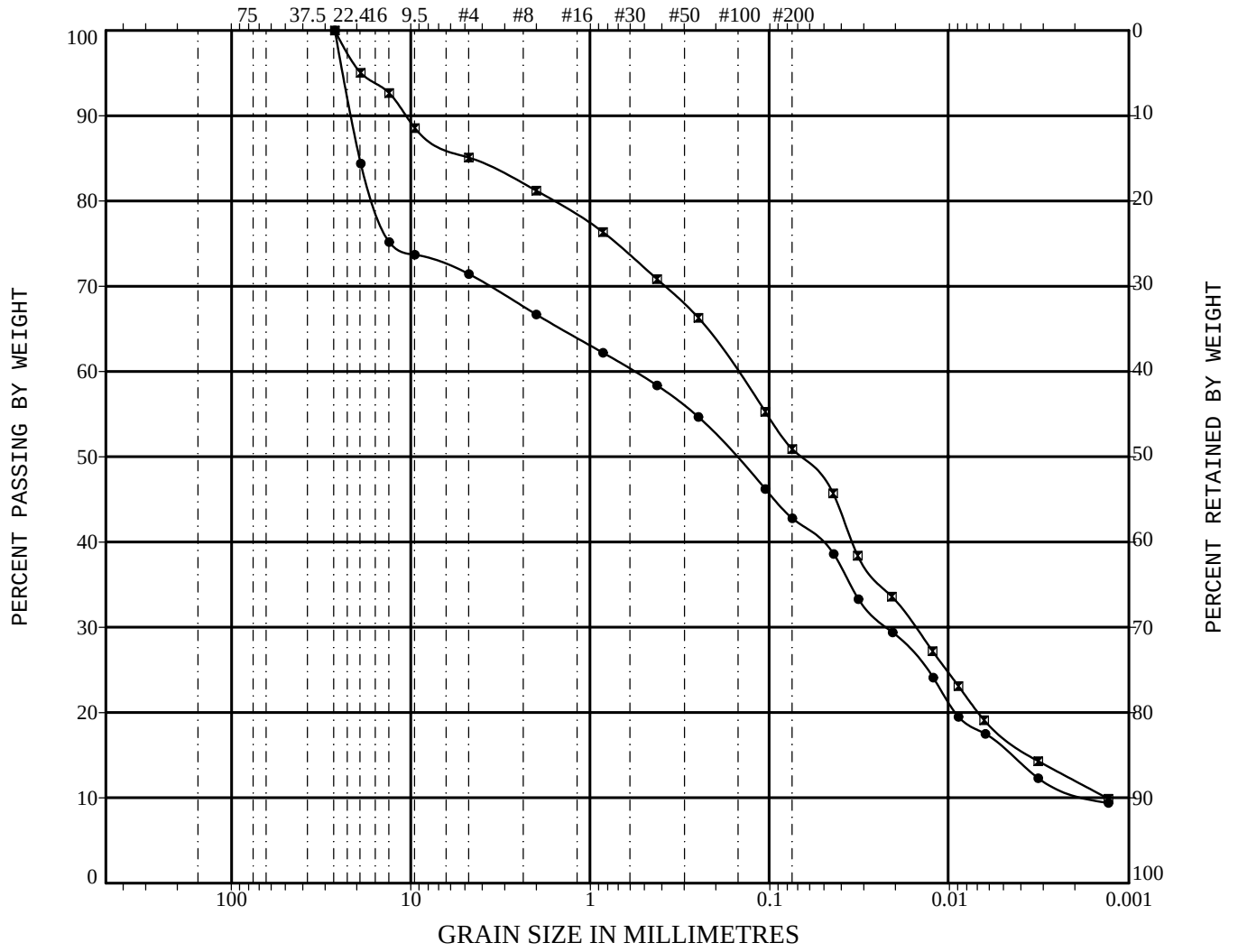
Figure No. 1

UNIFIED SOIL CLASSIFICATION

COBBLES	*GRAVEL*		*SAND*			*SILT OR CLAY*
	COARSE	FINE	COARSE	MEDIUM	FINE	
U.S. SIEVE SIZE IN MILLIMETRES			U.S. STANDARD SIEVE No.			HYDROMETER



PROJECT Fullarton Dam Embankment Stability Assessment

LOCATION 2999 Road 163a, Municipality of West Perth, Ontario JOB NO. 6031G1

CURVE ID	BOREHOLE/ TEST PIT	SAMPLE NO.	DEPTH (m)	SOIL DESCRIPTION
●	BH102	Sa7	4.57-5.03	SILT TILL
⊠	BH104	Sa3	2.29-2.90	SILT TILL

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Figure No. 2

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Borehole Number: 101

Ground Elevation: *100.02 m*

Project: *Fullarton Dam Embankment Stability Assessment*

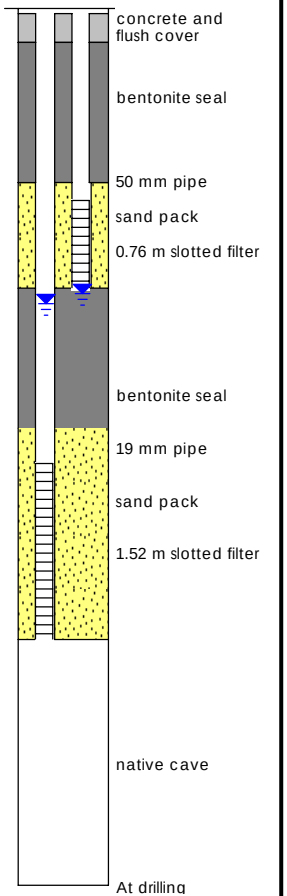
Job No.: *6031G1*

Location: *2999 Road 163a, Municipality of West Perth, Ontario*

Drill Date: *November 11, 2005*

Depth (m)	Description	Elevation (m)	Number	Type	N-Value
0.00	Ground Elevation	100.02			
0.00	***FILL:*** dark brown silt (topsoil), some sand, trace gravel, moist		1	TW	
1.00	brown silt, some sand, clay and gravel, moist	99.00	2	SS	11
	firm to stiff brown and grey silt, some clay and sand, APL-DTPL; some topsoil pockets		3	TW	
2.00		98.00	4	SS	11
	SILT: firm to stiff grey silt, some clay, APL; root penetration				
3.00		97.00	5	SS	35
	SAND: compact grey silty fine to coarse sand, some gravel, saturated				
4.00	grey silt layer	96.00	6	SS	15
5.00		95.00	7	SS	28
	SILT TILL: very dense grey sand and silt, some clay and gravel, moist				
6.00		94.00	8	SS	51
7.00		93.00	9	AS	
	Borehole terminated at 7.62 m				
8.00		92.00			
9.00		91.00			
10.00		90.00			

Dynamic Cone: 20 40 60 80
Standard Penetration: 20 40 60 80
Shear Strength (PP) kPa: 50 100 150 200
Shear Strength (FV) kPa: 50 100 150 200
Water Content (%): WP WL; 10 20 30



At drilling completion, water level at 2.84 m

Nov. 28, 2005 upper standpipe dry

Nov. 28, 2005 water level in lower standpipe at 2.57 m (Elev. 97.45 m)

Reviewed by: *CF*

Field Tech.: *RM*

Drill Method: *Solid Stem Auger*

Sheet: *1 of 1*

Notes: *Bulk sample taken from 0.31 to 1.52 m.*

Drafted by: *DC (01a)*

Naylor Engineering Associates Ltd.
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Borehole Number: 102

Ground Elevation: *100.16 m*

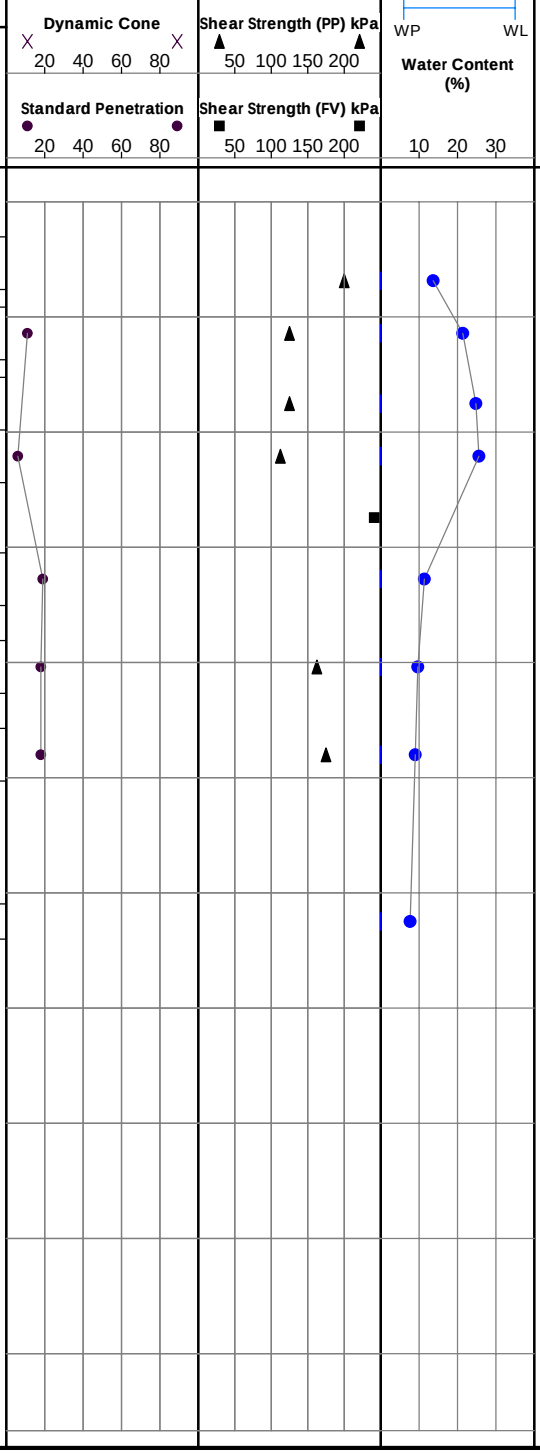
Project: *Fullarton Dam Embankment Stability Assessment*

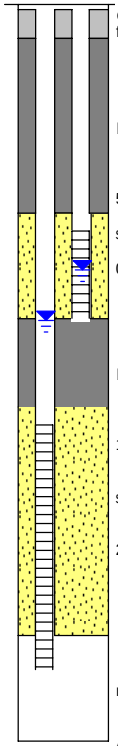
Job No.: *6031G1*

Location: *2999 Road 163a, Municipality of West Perth, Ontario*

Drill Date: *November 11, 2005*

Depth (m)	Description	Elevation (m)	Number	Type	N-Value
0.00	Ground Elevation	100.16			
	FILL: dark brown silt (topsoil), some sand, moist		1	TW	
1.00	stiff brown silt, some clay, DTPL	99.00	2	SS	11
	grey/brown and dark brown silt, some clay, trace sand, trace topsoil, very moist		3	TW	
2.00	***TOPSOIL:*** dark brown silt, very moist	98.00	4	SS	6
3.00	***SILT:*** stiff grey silt, some clay, APL	97.00	5	SS	19
	SAND: compact grey fine to coarse sand, some silt and gravel, saturated		6	SS	18
4.00	***SILT TILL:*** very stiff brown sandy silt, some clay and gravel, APL-DTPL	96.00			
	grey		7	SS	18
5.00		95.00			
6.00	very dense grey silt, some sand and gravel, trace clay, moist	94.00	8	SS	40\150mm
	Borehole terminated at 6.40 m				
7.00		93.00			
8.00		92.00			
9.00		91.00			
10.00		90.00			





At drilling completion, wet cave at 5.49 m

Nov. 28, 2005 water level in upper standpipe at 2.31 m (Elev. 97.85 m)

Nov. 28, 2005 water level in lower standpipe at 2.75 m (Elev. 97.41 m)

Reviewed by: *CF*

Field Tech.: *RM*

Drill Method: *Solid Stem Auger*

Sheet: *1 of 1*

Notes: *Bulk sample taken from 0.31 to 1.52 m.*

Drafted by: *DC (01a)*

Naylor Engineering Associates Ltd.
CONSULTING ENGINEERS

Borehole Number: 103

Ground Elevation: ***97.56 m***

Project: ***Fullarton Dam Embankment Stability Assessment***

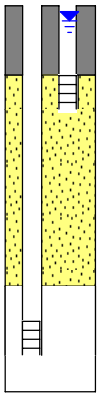
Job No.: ***6031G1***

Location: ***2999 Road 163a, Municipality of West Perth, Ontario***

Drill Date: ***November 11, 2005***

Depth (m)	Description	Symbol	Elevation (m)	Sample Number	Sample Type	N-Value
0.00	Ground Elevation		97.56			
	TOPSOIL: dark brown to black clayey silt, wet					
1.00	***SAND:*** compact brown silty sand, some gravel, saturated		97.00	1	SS	17
2.00			96.00	2	SS	23
	SILT TILL: very stiff grey silt, some clay, sand and gravel, moist					
3.00	very dense grey sandy silt, some clay and gravel, moist		95.00	3	SS	16
	Borehole terminated at 3.35 m		94.00	4	SS	35\150mm
4.00			93.00			
5.00			92.00			
6.00			91.00			
7.00			90.00			
8.00			89.00			
9.00			88.00			
10.00			87.00			

Dynamic Cone: 20 40 60 80
Standard Penetration: 20 40 60 80
Shear Strength (PP) kPa: 50 100 150 200
Shear Strength (FV) kPa: 50 100 150 200
Water Content (%): WP WL; 10 20 30



Groundwater Observations and Standpipe Details

At drilling completion, water level at 0.91m

Nov. 28, 2005 water level in upper standpipe at 0.13 m (Elev. 97.43 m)

Reviewed by: ***CF***

Field Tech.: ***RM***

Drill Method: ***Solid Stem Auger***

Sheet: ***1 of 1***

Notes: ***Lower standpipe blocked at 0.31 m below top of pipe.***

Drafted by: ***DC (01a)***

Naylor Engineering Associates Ltd.
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Borehole Number: 104

Ground Elevation: ***98.22 m***

Project: ***Fullarton Dam Embankment Stability Assessment***

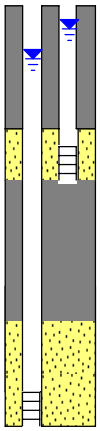
Job No.: ***6031G1***

Location: ***2999 Road 163a, Municipality of West Perth, Ontario***

Drill Date: ***November 11, 2005***

Depth (m)	Description	Symbol	Elevation (m)	Sample Number	Sample Type	N-Value
	Ground Elevation		98.22			
0.00	***TOPSOIL:*** dark brown to black clayey silt, moist					
1.00	***SILT TILL:*** loose brown silt, some sand, trace clay and gravel, moist to wet		97.00	1	SS	13
2.00	***SILT:*** compact brown silt, trace fine sand, wet		96.00	2	SS	22
3.00	***SILT TILL:*** compact brown sandy silt, trace clay and gravel, moist to wet grey		95.00	3	SS	12
4.00	Borehole terminated at 3.66 m		94.00	4	SS	14
5.00			93.00			
6.00			92.00			
7.00			91.00			
8.00			90.00			
9.00			89.00			
10.00			88.00			

Dynamic Cone: 20 40 60 80
Standard Penetration: 20 40 60 80
Shear Strength (PP) kPa: 50 100 150 200
Shear Strength (FV) kPa: 50 100 150 200
Water Content (%): WP WL; 10 20 30



At drilling completion, dry cave at 3.66 m

Nov. 28, 2005 water level in upper standpipe at 0.20 m (Elev. 98.00 m)

Nov. 28, 2005 water level in lower standpipe at 0.46 m (Elev. 97.76 m)

Reviewed by: ***CF***

Field Tech.: ***RM***

Drill Method: ***Solid Stem Auger***

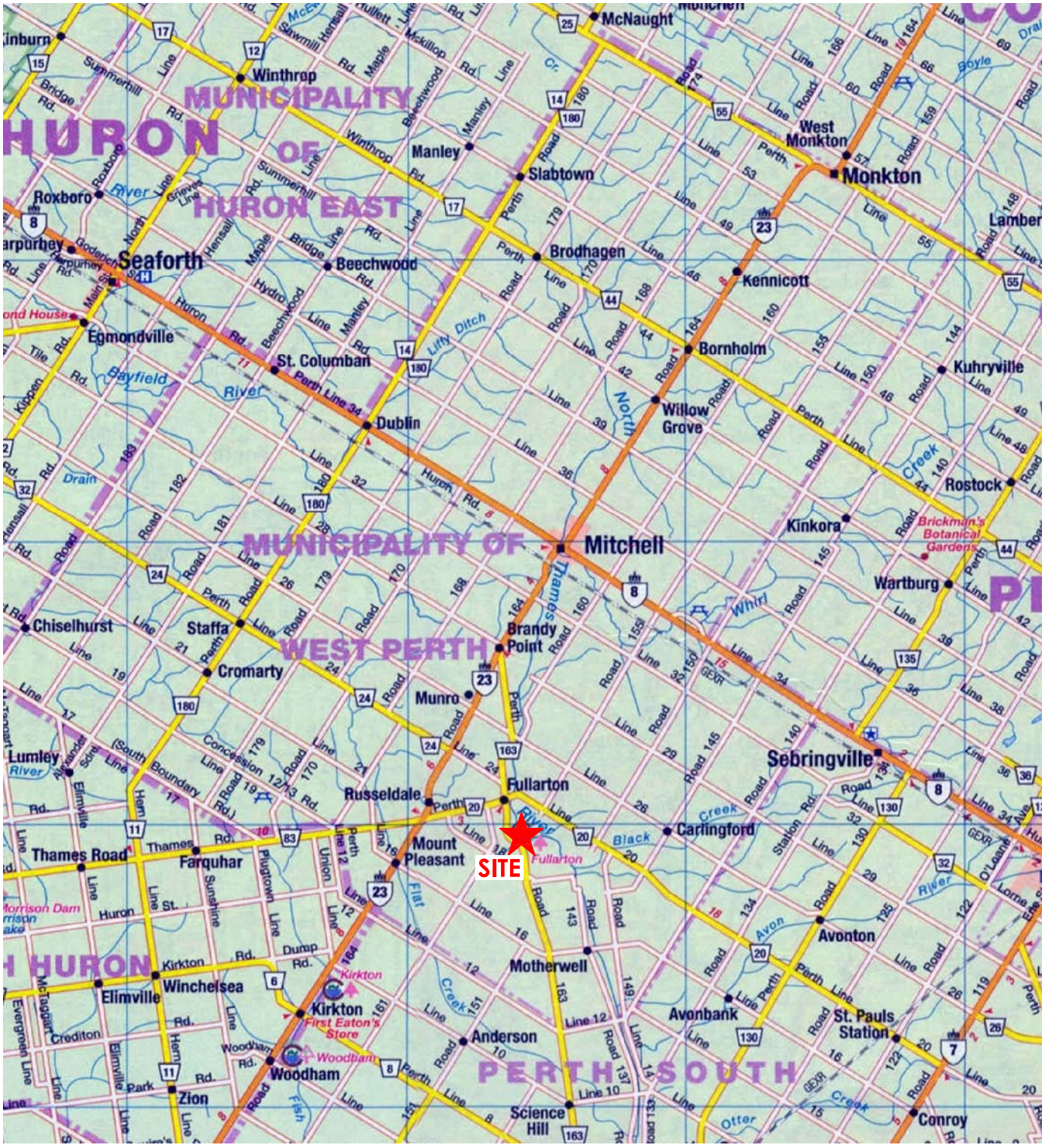
Sheet: ***1 of 1***

Notes:

Drafted by: ***DC (01a)***

No.	Revisions	Date
0	**Report Issued**	**Feb. 2006**
1		
2		
3		

NORTH



Drawing Reference: Base drawing from page 21 of MapArt's Ontario Road Atlas (2006).

Fullarton Dam Embankment Stability Assessment

2999 Road 163a

Municipality of West Perth, Ontario

Naylor Engineering Associates Ltd.
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LOCATION PLAN

Date	Scale	Job No.	Drawing No.
Feb. 2006	**1:200000**	**6031G1**	**1**

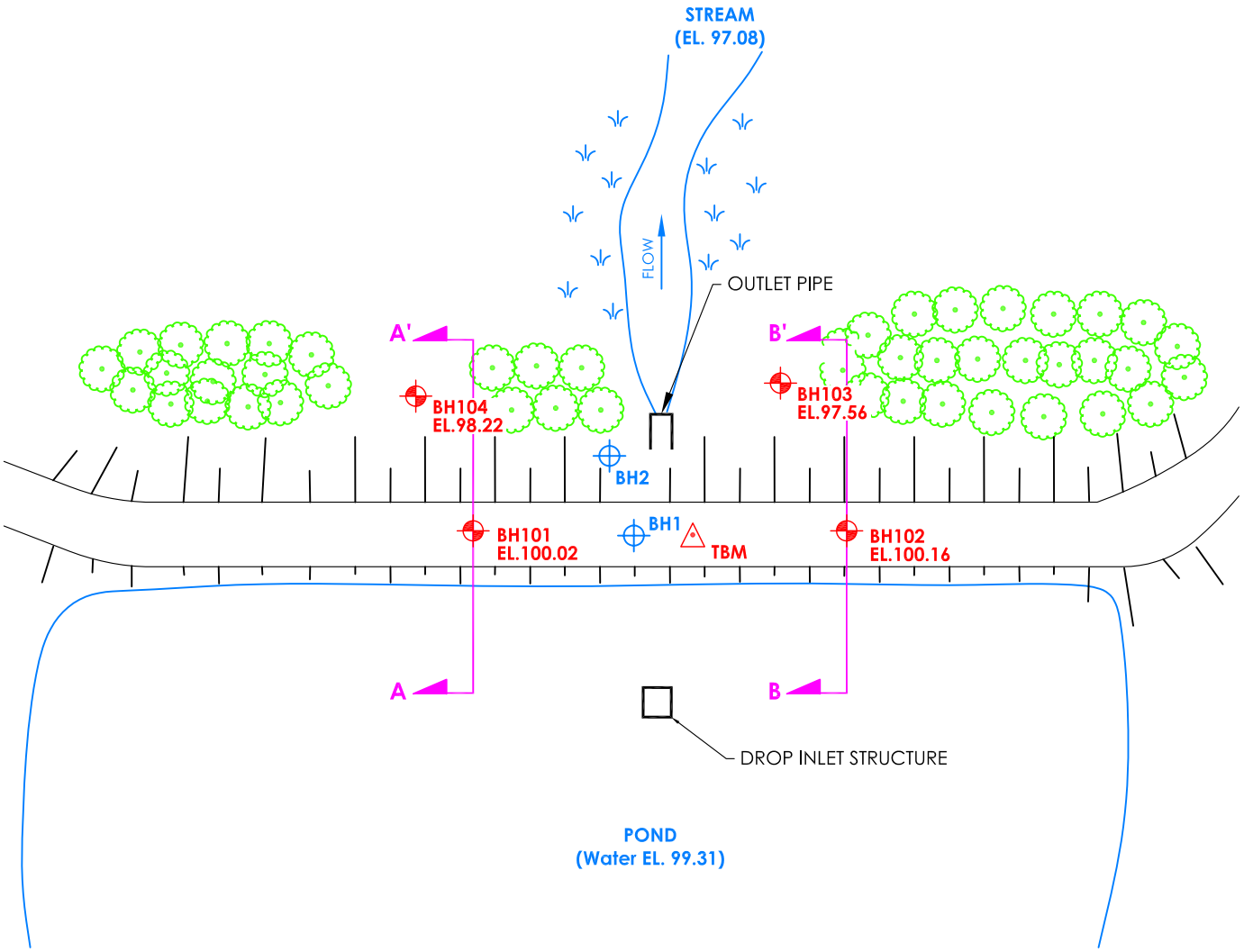
F:\6031\6031G1_01.dwg (dc)
November 15, 2005

No.	Revisions	Date
0	**Report Issued**	**Feb. 2006**
1		
2		
3		

NORTH

Legend

- Borehole Location (NEA Investigation)
- Borehole Location (Acres International)
- EL.100.02 — Ground Surface Elevation (m)
- Temporary Benchmark
  Top of Steel Baseplate of Swing Gate on Dam.
  Elev. 100.00 m (Assumed Local Datum).
- A — A' — Cross-Section Line (See Dwg. 3)



Drawing Reference: Base drawing provided by on-site measurements.

Fullarton Dam Embankment Stability Assessment

2999 Road 163a

Municipality of West Perth, Ontario

Naylor Engineering Associates Ltd.
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SITE PLAN

Date	Scale	Job No.	Drawing No.
Feb. 2006	**1:750**	**6031G1**	**2**

F:\6031\6031G1\6031G1_02.dwg
November 15, 2005 (dc)

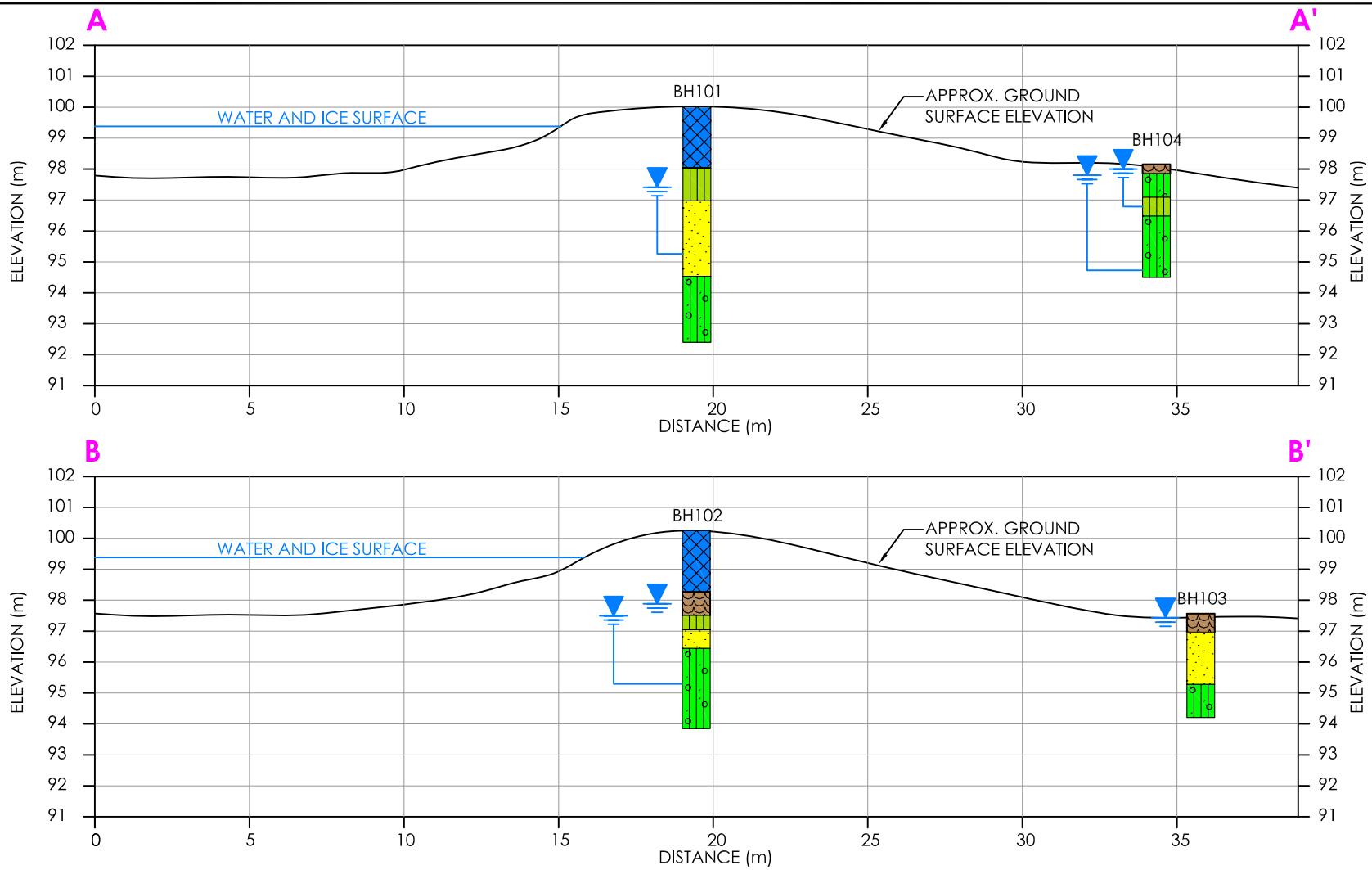
F:\6031\6031G1\6031G1_03.dwg
Novemver 30, 2005 (dc)

Profile Legend

Fill
Topsoil
Silt
Sand
Silt Till
Water Level
November 28, 2005

Notes:

Groundwater measurements taken on November 28, 2005. 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.



No.	Revisions	Date
0	**Report Issued**	**Feb. 2006**
1		
2		
3		

Fullarton Dam Embankment Stability Assessment

2999 Road 163a

Municipality of West Perth, Ontario

Naylor Engineering Associates Ltd.
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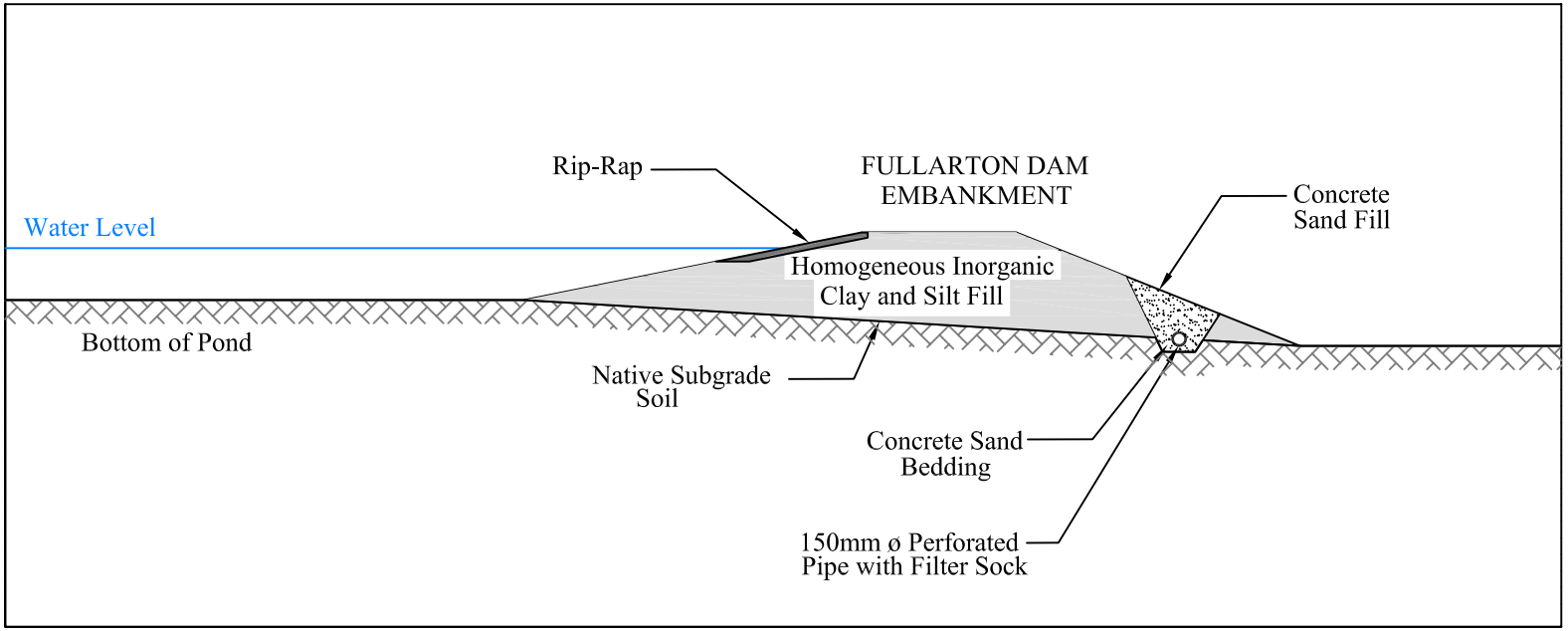
CROSS SECTIONS A-A' & B-B'

Date	Scale	Job No.	Drawing No.
Feb. 2006	**1:200**	**6031G1**	**3**



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 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 1.5 m should consist of a corrugated galvanized steel pipe with a rodent gate.

4. Bedding and backfill material shall be concrete sand meeting the gradation requirements of OPSS 1002 (Fine Aggregate for Concrete).

5. The upstream ends of pipes should be capped.

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Typical Detail for Earth Dam Toe Drain

Date	Scale	Job No.	Drawing No.
Feb. 2006	NTS	6031G1	4

Photo 1: Looking west along the top of the dam.

Photo 2: Overflow spillway located southeast of the dam.

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F:\603\603G\603G1\603G1_photo1-2.dwg
December 20, 2005 (GRL)

Photo 3: Looking south towards the pond and the drop inlet structure.

Photo 4: Outlet pipe on the north side of the dam.

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F:\603\603\G1\603\G1_photo3-4.dwg
December 20, 2005 (GRL)

Photo 5: Looking north towards the dam.

Photo 6: Creek north of the dam.