



**FOUNDATION INVESTIGATION AND DESIGN REPORT
for
WING WALL INSTALLATION
LOWER PRINCESS FALLS (UPPER CASCADES) OUTFALL
HIGHWAY 403
GWP 2054-14-00
TASK NO. 2054-14-00-001
HAMILTON, ONTARIO**

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PML Ref.: 16TF023A-2
Index No.: 031FIR and 032FDR
GEOCRES No.: 30M5-325
March 20, 2017



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FOUNDATION INVESTIGATION REPORT
for
Wing Wall Installation
Lower Princess Falls (Upper Cascades) Outfall
Highway 403, GWP 2054-14-00
Hamilton, Ontario

1. INTRODUCTION

This report summarises the results of a foundation investigation carried out for installation of a wing wall at the inlet structure for the Lower Princess Falls (Upper Cascades) Outfall in Hamilton, Ontario. The study was conducted for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The report provides subsurface information pertaining to the new wing wall installation at the inlet structure for the Lower Princess Falls (Upper Cascades) Outfall.

2. SITE DESCRIPTION AND GEOLOGY

The site of the Lower Princess Falls (Upper Cascades) Outfall is situated some 2.2 km west of Aberdeen Avenue in the City of Hamilton. It is located on the south side of Highway 403 at Station 10+010, Highway 403 chainage (ref. Contract Drawings 'Highway 403 – Longwood Channel and Lower Princess Falls (Upper Cascade) Outfall'). Highway 403 runs approximately in the west-east direction at the site.

Lang's Creek, a tributary of Chedoke Creek, flows northerly over the Niagara Escarpment and traverses under Highway 403 via a drainage conduit at the Lower Princess Falls (Upper Cascades) Outfall. Princess Falls is a cascade waterfall experiencing considerable flow after rain and the winter snow melt. Land use of the upstream drainage area has been changed from the rural to urban. There are no storm water management facilities in the upstream catchment.

The existing inlet structure is a concrete box with an opening 2.1 m wide and 1.3 m high on the south side wall and serves as a conduit across the highway for flows received from the Niagara Escarpment. It is reported that flows overtopped Highway 403 on several occasions during major storm events since 2004. Significant deposits of debris and mud on the highway



resulted in temporary closures of Highway 403. Falling debris from the Niagara Escarpment has also been an issue that may result in blockage of the outfall inlet.

The study area lies in the physiographic region known as the Iroquois Plain and is characterised by glaciolacustrine sands and silts discontinuously underlain by glacial till deposits overlying shale bedrock of the Queenston Formation (L.J. Chapman and D.F. Putnam, *The Physiography of Southern Ontario*, 3rd Edition, 1984). There is very shallow overburden at this site due to the proximity of the Niagara Escarpment, with evidence of ongoing erosion.

3. INVESTIGATION PROCEDURES

Peto MacCallum Ltd. undertook a visit to the site of the Lower Princess Falls (Upper Cascades) Outfall on September 14, 2016 for access and site review.

The field work for this study was carried out on October 19, 2016 and comprised one borehole advanced to a depth of 13.7 m at the proposed wing wall for the inlet structure. The borehole location is shown on Drawing IW-1 in Appendix FIR-A.

The location of the borehole was established in the field by Peto MacCallum Ltd. The ground surface elevation at the borehole was provided by Callon Dietz.

The borehole for the current investigation was advanced using continuous flight hollow stem augers, powered by a truck-mounted D-50 drill rig, supplied and operated by a specialist drilling contractor, working under the full-time supervision of a member of our engineering staff.

Representative soil samples were recovered at frequent depth intervals using a conventional split spoon sampler during drilling. Standard penetration tests (SPT) were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata.

The groundwater conditions at the borehole location were assessed during drilling by visual examination of soil, the sampler and drill rods as the samples were retrieved. Upon completion of



drilling, the borehole was backfilled with bentonite/cement grout in accordance with the MTO guidelines and MOE Regulation 903 for borehole abandonment procedures.

Soils were identified in the field in accordance with the MTO Soil Classification procedures. Recovered soil samples were returned to our laboratory for detailed visual examination, classification and routine moisture content determination. Atterberg limits testing (2) and grain size distribution analyses (2) were conducted on selected soil samples. The laboratory test results are presented in Appendix FIR-B and on the corresponding log.

4. SUMMARISED SUBSURFACE CONDITIONS

Reference is made to the appended Record of Borehole sheet for details of the subsurface conditions including soil classifications, inferred stratigraphy, boundary elevations, standard penetration test data and groundwater observations. The results of laboratory Atterberg limits testing, grain size distribution analyses and natural moisture content determinations are also shown on the Record of Borehole sheet.

The borehole location is shown on Drawing IW-1. The boundaries between soil strata have been established at the borehole location only. Beyond the borehole, the boundaries are assumed and may vary.

The subsurface stratigraphy revealed in the borehole drilled at the site comprised asphalt over fill overlying a cohesive deposit of clayey silt underlain by weathered shale bedrock. No groundwater was present in borehole IW-1 during or upon completion of drilling.

The strata encountered are summarised below.

4.1 Pavement Fill

Pavement fill covered with 100 mm of asphalt was present surficially in borehole IW-1. The pavement fill was made up of sand and gravel and extended to a depth of 0.7 m (elevation 136.3 m).



4.2 Fill

Silty clay fill was identified below the pavement fill at 0.7 m depth (elevation 136.3 m). The fill was stiff to very stiff in consistency. The silty clay fill had a thickness of 1.5 m and was penetrated at a depth of 2.2 m (elevation 134.8 m).

4.3 Clayey Silt

Overlain by the fill at 2.2 m depth (elevation 134.8 m) in borehole IW-1 was a cohesive deposit of clayey silt. This deposit was hard becoming very stiff in consistency and 16 to 20% in moisture content. The clayey silt was 3.5 m thick and penetrated at a depth of 5.7 m (elevation 131.3 m).

The results of Atterberg limits testing and grain size distribution analyses conducted on two cohesive samples of the deposit are presented in respective Figures IW-PC-1 and IW-GS-1 (Appendix FIR-B). The clayey silt had liquid limits of 26 and 28, a plastic limit of 15, its plasticity index being 11 and 13.

4.4 Bedrock

Weathered shale bedrock underlay the clayey silt at 5.7 m depth (elevation 131.3 m). The shale was reddish brown and had a moisture content of 5 to 7%. Borehole IW-1 was terminated in the shale bedrock at a depth of 13.7 m (elevation 123.3 m).

4.5 Groundwater

No groundwater was present in borehole IW-1 during or upon completion of drilling. However, the groundwater should be expected to accumulate at the bedrock surface. The groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns.



5. CLOSURE

The field work was carried out under the supervision of Mr. M. Khorsand and direction of Mr. C.M.P. Nascimento, P.Eng., Project Manager. The laboratory testing of selected samples was carried out in the PML laboratory in Toronto.

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., Project Manager and MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



Carlos M.P. Nascimento, P.Eng.
Project Manager
MTO Designated Principal Contact



APPENDIX FIR-A

Explanation of Terms Used in Report

Record of Borehole Sheet

Drawing IW-1 – Borehole Location

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

COMPOSITION: SECONDARY SOIL COMPONENTS ARE DESCRIBED ON THE BASIS OF PERCENTAGE BY MASS OF THE WHOLE SAMPLE AS FOLLOWS:

PERCENT BY MASS	0 - 10	10 - 20	20 - 30	30 - 40	> 40
	TRACE	SOME	WITH	ADJECTIVE (SILTY)	AND (AND SILT)

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S SPLIT SPOON	T P THINWALL PISTON
W S WASH SAMPLE	O S OSTERBERG SAMPLE
S T SLOTTED TUBE SAMPLE	R C ROCK CORE
B S BLOCK SAMPLE	P H T W ADVANCED HYDRAULICALLY
C S CHUNK SAMPLE	P M T W ADVANCED MANUALLY
T W THINWALL OPEN	F S FOIL SAMPLE
F V FIELD VANE	

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
c_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{v0}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_i	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	n	1, %	POROSITY	e_{max}	1, %	VOID RATIO IN LOOSEST STATE
γ_s	kN/m ³	UNIT WEIGHT OF SOLID PARTICLES	w	1, %	WATER CONTENT	e_{min}	1, %	VOID RATIO IN DENSEST STATE
ρ_w	kg/m ³	DENSITY OF WATER	S_r	%	DEGREE OF SATURATION	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
γ_w	kN/m ³	UNIT WEIGHT OF WATER	w_L	%	LIQUID LIMIT	D	mm	GRAIN DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_p	%	PLASTIC LIMIT	D_n	mm	n PERCENT - DIAMETER
γ	kN/m ³	UNIT WEIGHT OF SOIL	w_s	%	SHRINKAGE LIMIT	C_u	1	UNIFORMITY COEFFICIENT
ρ_d	kg/m ³	DENSITY OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	h	m	HYDRAULIC HEAD OR POTENTIAL
γ_d	kN/m ³	UNIT WEIGHT OF DRY SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	q	m ³ /s	RATE OF DISCHARGE
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	v	m/s	DISCHARGE VELOCITY
γ_{sat}	kN/m ³	UNIT WEIGHT OF SATURATED SOIL	DTPL		DRIER THAN PLASTIC LIMIT	i	1	HYDRAULIC GRADIENT
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	APL		ABOUT PLASTIC LIMIT	k	m/s	HYDRAULIC CONDUCTIVITY
γ'	kN/m ³	UNIT WEIGHT OF SUBMERGED SOIL	WTP		WETTER THAN PLASTIC LIMIT	j	kN/m ³	SEEPAGE FORCE
e	1, %	VOID RATIO						

RECORD OF BOREHOLE No IW-1

1 of 1

METRIC

G.W.P.	2054-14-00	LOCATION	Co-ords: 4 789 716.1 N; 269 890.3 E	ORIGINATED BY	M.Kh.
--------	------------	----------	-------------------------------------	---------------	-------

DIST Central BOREHOLE TYPE Continuous Flight Hollow Stem Augers COMPILED BY G.D.

DATUM Geodetic HWY 403 DATE October 19, 2016 CHECKED BY C.N.

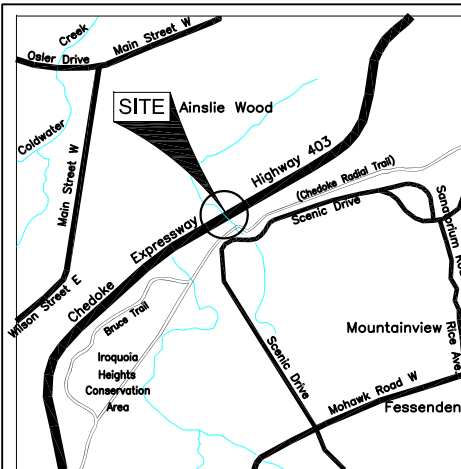
[illegible]

CONT No XXXX-XXX
GWP No 2054-14-00



WING WALL INSTALLATION
LOWER PRINCESS FALLS
(UPPER CASCADES) OUTFALL
BOREHOLE LOCATION PLAN

SHEET



KEY PLAN
250m 0 250m 500m 750m 1km

LEGEND

- Borehole
- Cone
- Borehole and Cone
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- CONE Blows/0.3m (60 Cone, 475 J/blow)
- WL at time of investigation July 2016
- WH Penetration due to weight of hammer and rod
- * Water level not established
- Head
- ARTESIAN WATER
- Encountered
- PIEZOMETER

BH No	ELEVATION	NORTHINGS	EASTINGS
IW-1	137.0	4 789 716.1	269 890.3

NOTE

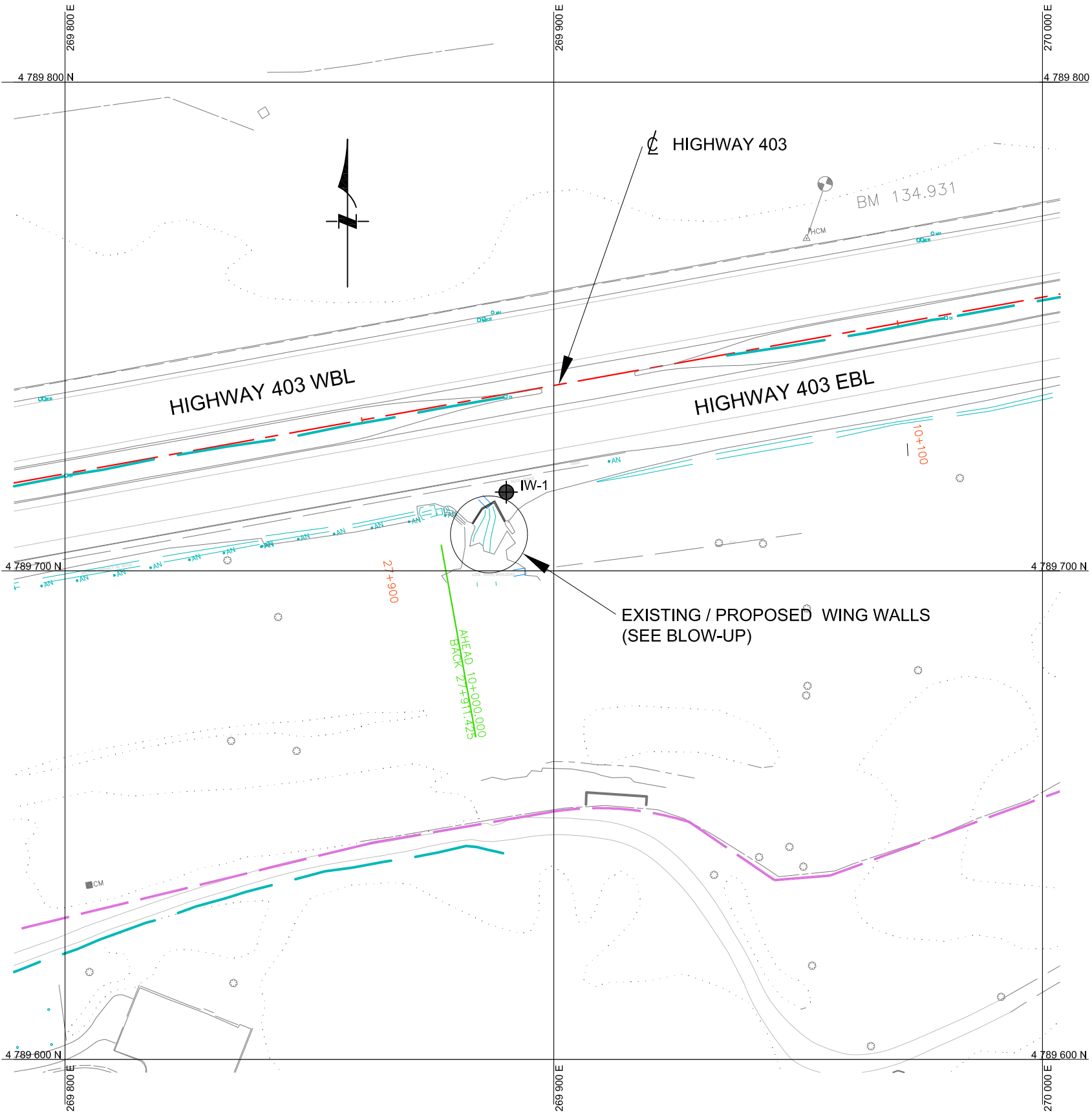
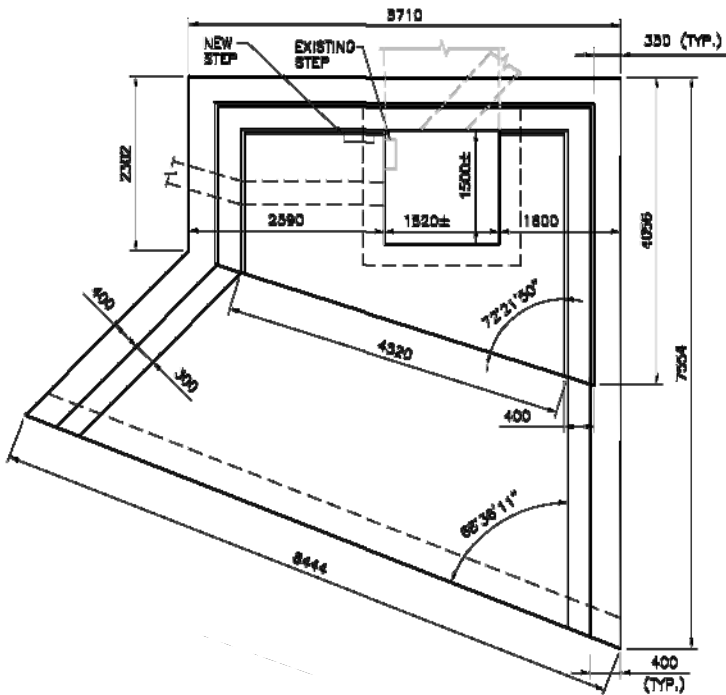
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

DATE	BY	DESCRIPTION

Geocres No. 30M5-325

HWY No	403	DIST CENTRAL
SUBM'D	NA	CHECKED GD
DATE	MAR. 20, 2017	SITE
DRAWN	NA	CHECKED MV
APPROVED	CN	DWG IW-1

PROPOSED WING WALLS
(BLOW-UP)
SCALE



PLAN
SCALE



NOTES:

- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE TEXT OF REPORT AND RECORD OF BOREHOLE LOGS.
- THIS DRAWING IS FOR SUBSURFACE INFORMATION ONLY. SURFACE DETAILS AND FEATURES ARE FOR CONCEPTUAL ILLUSTRATION.
- DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS ARE IN KILOMETRES AND METRES.

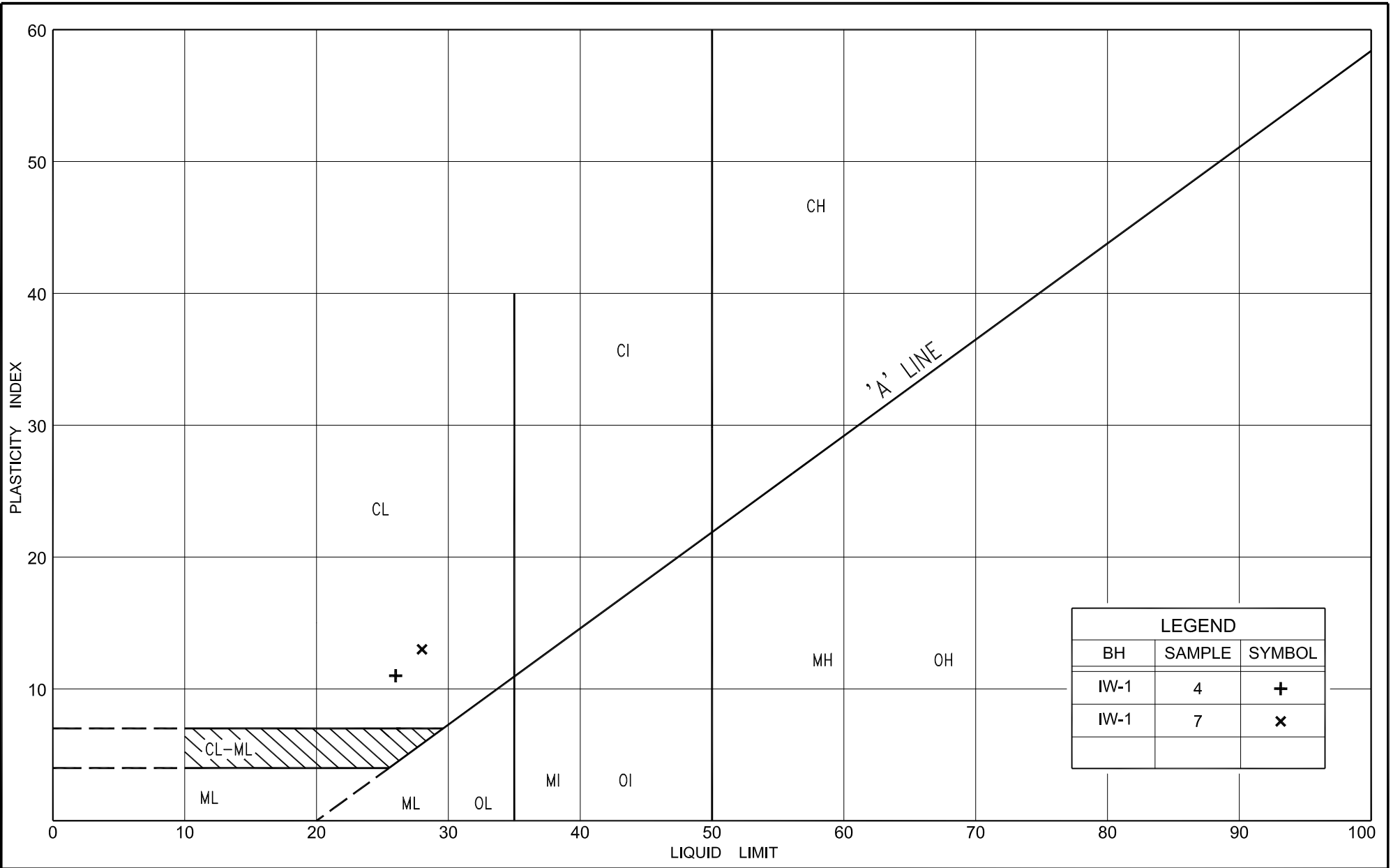


REF Drawing: 403 Longwood_alignment.dwg undated and Cascade Inlet General Arrangement - Sheet S 20 dated September 2016 in pdf format.



APPENDIX FIR-B

Plasticity Chart and Results of Grain Size Distribution Analyses



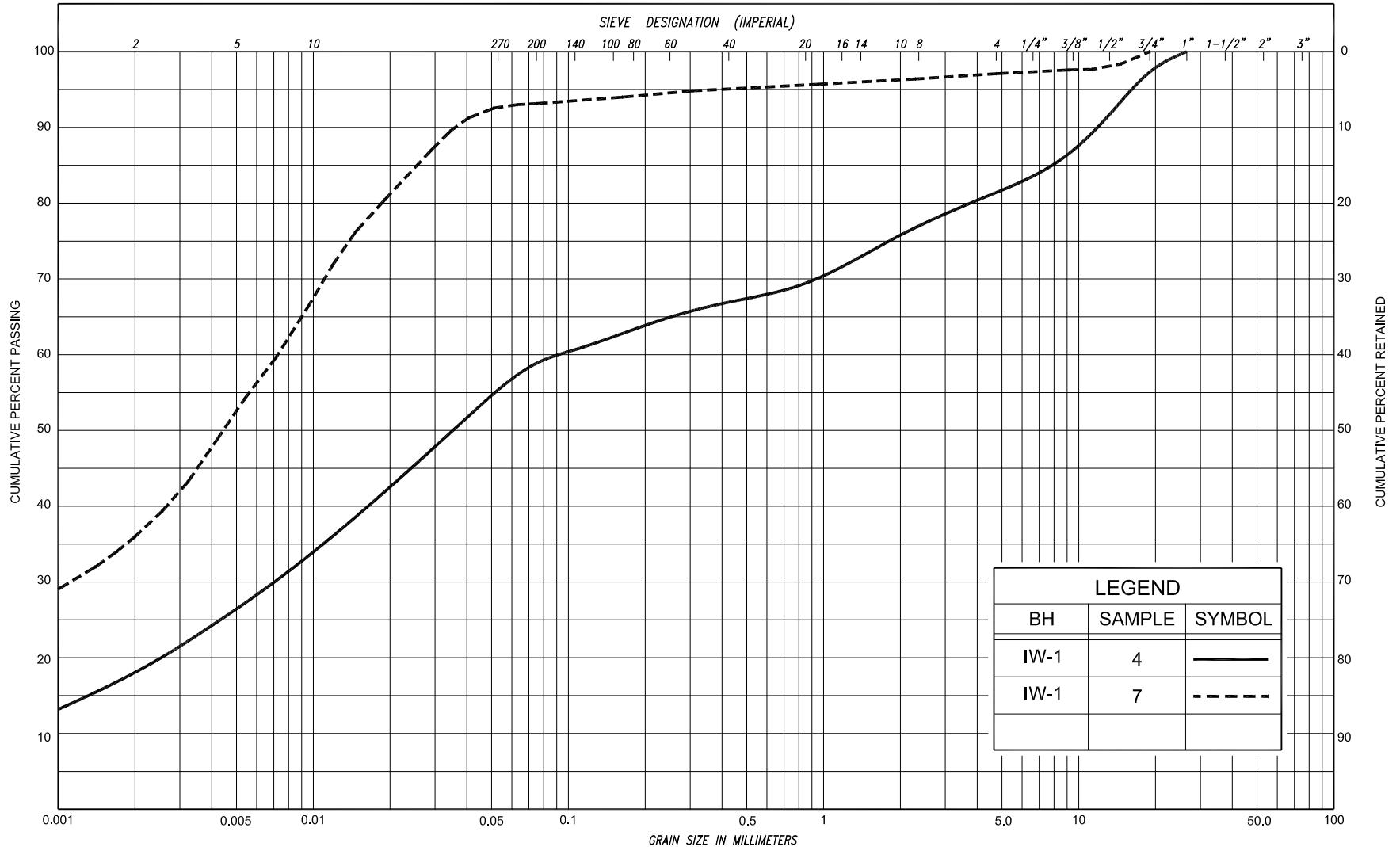
PLASTICITY CHART

CLAYEY SILT, with to trace sand, some to trace gravel (CL)

FIG No. IW-PC-1

HWY 403

G.W.P. 2054-14-00



LEGEND		
BH	SAMPLE	SYMBOL
IW-1	4	—
IW-1	7	- - -

SILT & CLAY					FINE		MEDIUM		COARSE	GRAVEL			COBBLES	UNIFIED			
					SAND												
CLAY	FINE		MEDIUM		COARSE		FINE		MEDIUM		COARSE		GRAVEL			COBBLES	M.I.T.
	SILT					SAND											
CLAY		SILT			V. FINE	FINE	MED.	COARSE		GRAVEL							U.S. BUREAU
					SAND												



GRAIN SIZE DISTRIBUTION CLAYEY SILT, with to trace sand, some to trace gravel (CL)

FIG No.	IW-GS-1
HWY	403
G.W.P.	2054-14-00



APPENDIX FIR-C

Site Photographs



Photograph 1: Looking northwest at the inlet structure of the drainage conduit under Highway 403 (September 14, 2016).



Photograph 2: Looking south at Lower Princess Falls (September 14, 2016).



Photograph 3: Looking south at the outfall chamber of Lower Princess Falls; huge boulders, cobbles and debris have accumulated as a result of erosion (September 14, 2016).



Photograph 4: Looking northeast at the inlet structure and debris accumulation area (September 14, 2016).



Photograph 5: Looking northeast at the east wing wall to be removed (September 14, 2016).



Photograph 6: Looking at the inlet structure and debris accumulated at the rack base (September 14, 2016).



Photograph 7: Looking down the chamber inside the inlet structure of the drainage conduit (September 14, 2016).



Photograph 8: Looking northeast at the inlet structure and access route along the fence (September 14, 2016).



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Appendix FDR-A – List of Standard Specifications and Special Provision Referenced in Report

FOUNDATION DESIGN REPORT
for
Wing Wall Installation
Lower Princess Falls (Upper Cascades) Outfall
Highway 403, GWP 2054-14-00
Hamilton, Ontario

6. INTRODUCTION

6.1 General

This report provides foundation engineering recommendations regarding design and comments for construction of new wing walls associated with the proposed reconfiguration of an inlet structure for the Lower Princess Falls (Upper Cascades) Outfall in Hamilton, Ontario. This report was prepared for AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation of Ontario (MTO).

The Lower Princess Falls (Upper Cascades) Outfall is located on the south side of Highway 403 at approximate Station 10+010, Highway 403 chainage (ref. Contract Drawings 'Highway 403 – Longwood Channel and Lower Princess Falls (Upper Cascade) Outfall'). The inlet structure is a concrete box with an opening 2.1 m wide and 1.3 m high on the south side wall. The inlet level of the structure is at approximate elevation 134.7.

It is intended to replace the inlet structure with a precast concrete structure to provide an opening about 4.5 m wide and 1.5 m high. Cast-in-place wing walls to direct the water to the opening will be installed at the southwest and southeast corners of the structure. The wing walls will be 3.5 m long and vary in height up to 2.65 m.

The scope of work does not include providing recommendations for installation of a retention fence at the upstream of the Upper Cascades Outfall to block medium and large rocks or for design of a new grate for the inlet structure to trap small flowing debris.



6.2 New Wing Walls

Several retaining schemes such as a cast-in-place reinforced concrete wall bearing on spread footings may be used for the project. Alternative retaining wall types at this site include an RSS wall and a soldier pile wall.

Taking into account the low retained height and that the existing wing walls have been constructed as cast-in-place concrete walls, it is considered that the most appropriate retaining scheme for the wing walls proposed at the southwest and southeast corner of the inlet structure is a cast-in-place reinforced concrete wall bearing on spread footings. The wing wall is likely to be founded at approximate elevation 133.5 m, about 1.2 m below existing grade in front of the wall.

7. FOUNDATIONS

7.1 General

The new wing walls should be designed and analysed for bearing capacity, sliding, overturning and overall stability in accordance with the methods outlined in the Canadian Highway Bridge Design Code (CHBDC) 2014 Edition.

7.2 Frost Protection

The foundation frost penetration depth for structure foundations at this site is 1.2 m according to OPSD 3090.101.

7.3 Seismic Design

The reference Peak Ground Acceleration (PGA_{ref}) is 0.180 for the City of Hamilton, Ontario (National Building Code of Canada, 2015). The soil at the project site for seismic design purposes is classified as Type C in accordance with clause 4.4.3.2 of the CHBDC, 2014.



Based on the SPT data, seismic-induced liquefaction of the foundation soils is not anticipated under the earthquake design.

7.4 Cast-in-Place Concrete Wall

The factored values of geotechnical bearing resistance of 300 kPa at ultimate limit states (ULS) and 200 kPa at serviceability limit states (SLS) are recommended for the wing wall foundations placed on the native clayey silt at or below approximate elevation 133.5 m. The factored geotechnical resistance at SLS considers 25 mm settlement. The above geotechnical resistance values are based on a maximum 2.5 m wide footing supported at a minimum depth of 1.2 m below the surface.

The geotechnical parameters employed to design the wing wall will be dependent upon the type of backfill and the soil adjacent to the retaining system that will govern global stability, overturning and/or sliding of the base. The following parameters for granular fill and the native clayey silt should be used for design of the new wing wall:

Table 7.4 – Geotechnical Parameters for Wing Wall

PARAMETERS	GRANULAR A / GRANULAR B TYPE II	VERY STIFF CLAYEY SILT
Friction Angle, degrees	35	0
Cohesion, kPa	0	150
Unit Weight, kN/m ³	22.8	20.0

Taking into account the retained height of about 2.5 m and the presence of competent founding soils at the site, it is considered that the global stability of the wing walls will be sufficient.

The horizontal force at the base of the wing wall will be resisted in part by the friction at the footing/subgrade interface or between the granular backfill and the founding soil. An unfactored friction coefficient of 0.6 is considered to be appropriate for both situations at this site.



The structural designer should use appropriate factors for the values of friction angle and cohesion when checking the sliding resistance.

8. LATERAL EARTH PRESSURE

The wing wall should be designed to resist the unbalanced lateral earth pressure imposed by the backfill adjacent to the wall. The lateral earth and water pressure, p (kPa) may be computed using the equivalent fluid pressure diagrams presented in Section 6.9 of the CHBDC or employing the following equation:

$$p = K (\gamma h_1 + \gamma' h_2 + q) + \gamma_w h_2 + C_p + C_s$$

where K = coefficient of lateral earth pressure (dimensionless)
 γ = unit weight of free-draining granular material above design water level, kN/m^3
 γ' = unit weight of submerged backfill material below design water level, kN/m^3
 $\gamma' = \gamma - \gamma_w$
 γ_w = unit weight of water
 $= 9.8 \text{ kN/m}^3$
 h_1 = depth below final grade, m, above design water level
 h_2 = depth below design water level, m
 q = surcharge load, kPa, if present
 C_p = compaction pressure, kPa (refer to clause 6.12.3 of CHBDC)
 C_s = earth pressure induced by seismic events, kPa (refer to clause 4.6.5 of CHBDC)
where ϕ = angle of internal friction of retained soil
 δ = angle of friction between the soil and wall

Free-draining granular material should be used as backfill behind the wall. The following parameters are recommended for design:

Table 8 – Geotechnical Parameters for Granular Backfill

PARAMETERS	GRANULAR A / GRANULAR B TYPE II
Internal Friction Angle, ϕ (degrees)	35
Unit weight, γ (kN/m^3)	22.8
Coefficient of Active Earth Pressure, K_a	0.27
Coefficient of Earth Pressure At Rest, K_o	0.43
Coefficient of Passive Earth Pressure, K_p	3.69



The coefficient of earth pressure at-rest should be used for design of rigid and unyielding walls, the active earth pressure coefficient for unrestrained structures. The earth pressure coefficients should be reviewed if the slope of the backfill exceeds 10° to the horizontal. Alternatively, the material above the top of the wall could be treated as a surcharge load (q in the preceding equation).

The magnitude of the passive resistance is dependent on the actual lateral movement of the structure toward the retained soil. We refer to Figure C6.16 of the CHBDC for this computation. The subsoil / backfill should be considered as medium dense sand for the project.

9. CONSTRUCTION CONSIDERATIONS

9.1 Excavation

All work should be carried out in accordance with the Occupational Health and Safety Act (Ontario Regulation 213/91) and with local/MTO regulations.

Excavation for construction of the new wing walls is expected to extend through the fill and native soils to depths of up to 4 m below existing grade.

The fill and native soils at the site are classified as Type 3 soils according to Occupational Health and Safety Act (Ontario Regulation 213/91) criteria. Temporary cut slopes in earth over the full depth of excavation should therefore be inclined at an angle of 45° to the horizontal.

The earth fill slopes and other exposed earth surfaces should be protected against surface erosion by sodding and suitable vegetation. Refer to OPSS 803 and OPSS.PROV 804 for time constraints and the type of seed and mulch required.



9.2 Roadway Protection System

Depending on the depth of excavation, a roadway protection system may be necessary along Highway 403. The roadway protection system is required where excavation geometry is steeper than 1H:1V.

The roadway protection system should be designed according to OPSS.PROV 539. It is recommended that a minimum performance level 2 be implemented to prevent excessive lateral movement of the adjacent embankment during construction.

The contractor should be responsible for the selection, detailed design and performance of the roadway protection scheme. OPSS.PROV 539 also calls for monitoring of the roadway protection system by the contractor to check the horizontal and vertical displacements of the roadway surface during construction.

9.3 Groundwater Control

No groundwater was present in borehole IW-1 during or upon completion of drilling.

It is considered that seepage from soil fissures or surface water run-off that enters the excavation should be handled by conventional sump pumping techniques. The groundwater level should be maintained a minimum of 0.5 m below the base of excavation. It is worth noting that groundwater levels at the site are subject to seasonal fluctuations and precipitation patterns, generally reflecting the water level in the outfall chamber.

10. BACKFILL AND DRAINAGE CONTROL

The backfill behind the cast-in-place concrete retaining wall should consist of suitable free draining granular materials such as Granular A or Granular B Type II conforming to the requirements of OPSS.PROV 1010. The backfill geometry should be in accordance with OPSD 3121.150.

Backfilling adjacent to retaining walls should be carried out in conformance to OPSS.PROV 501. Operation of compaction equipment at the retaining structures should be restricted to limit the



compaction pressure C_p noted in Table 8 of this report. Refer to OPSS.PROV 501 for additional information in this regard.

A subdrain system (OPSS 405) and weep holes (OPSD 3190.100) should be installed to minimise the build-up of hydrostatic pressure behind the cast-in-place concrete retaining walls. The subdrain tiles should be surrounded by a properly designed granular filter or non-woven Class II geotextile (with an FOS of 75-100 μm according to OPSS 1860) to prevent migration of fines into the system. The drainage pipes should be installed on a positive grade.

A Special Provision on dewatering structure excavations as an amendment to OPSS 902 included in Appendix FDR-A should be added to the Contract documentation. A designer should provide a design storm return period according to MTO Drainage Design Standard TW-1 as required in subsection 902.04.01.01 of the Special Provision.



11. CLOSURE

This report was prepared by Mr. G.O. Degil, PhD, P.Eng., Senior Foundation Engineer, and reviewed by Mr. C.M.P. Nascimento, P.Eng., MTO Designated Principal Contact.

Yours very truly,

Peto MacCallum Ltd.



Grigory O. Degil, PhD, P.Eng.
Senior Foundation Engineer



Carlos M.P. Nascimento, P.Eng.
Project Manager
MTO Designated Principal Contact

GD/CN:nk



APPENDIX FDR-A

List of Standard Specifications and Special Provision Referenced in Report



TABLE 1
LIST OF STANDARD SPECIFICATIONS REFERENCED IN REPORT

DOCUMENT	TITLE
OPSS.PROV 501	Construction Specification for Compacting
OPSS 803	Construction Specification for Sodding
OPSS 804	Construction Specification for Seed and Cover
OPSS 1860	Material Specification for Geotextiles
OPSS.PROV 501	Construction Specification for Compacting
SP 599S22	Requirements for The Design, Supply and Construction of Retaining Soil Systems (RSS)
SP 599S23	Requirements for Materials, Quality Control and Quality Assurance Testing and Acceptance Criteria for Precast Concrete Facing Elements Including Panels
OPSD 3090.101	Foundation Frost Depth for Southern Ontario
OPSD 3121.150	Minimum Granular Backfill Requirements – Retaining Walls
OPSD 3190.100	Retaining Wall and Abutment Wall Drain Detail

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision

Amendment to OPSS 902, November 2010

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 903.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means an electrical device that transfers power supply to a backup power source when there is an outage of the primary power source.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means a below grade wall that restricts groundwater flow and/or supports excavations, typically using soil-bentonite or cement-bentonite.

Design Storm Return Period means the average number of years based upon probability, between the occurrences of a storm event of a certain severity or greater.

Dewatering System means the components required to control water to permit construction work to proceed under specified conditions, and may include a groundwater control system, impermeable barriers, pumps, and/or equipment to carry out unwatering.

Groundwater Control System means sump pumps, oversized excavations with perimeter ditches, deep wells or well points or other systems used to lower the groundwater table.

Plug means an impervious, natural, or constructed drainage work that blocks water.

Sediment means soil particles detached from an earth surface by erosion.

Sediment Control Measure means a measure to remove sediment from water prior to discharge to the natural environment and sewer systems.

Temporary Flow Control means temporary flow control devices, channels, pipes, and other materials used to convey or divert water past an area under construction.

Unwatering means the removal of ponded or flowing surface water.

Vegetated Discharge Area means a sloped, open area of land with existing vegetation suitable to prevent erosion.

Waterbody means as any permanent or intermittent, natural or constructed body of water including lakes, ponds, wetlands and watercourses, but does not include sewage works as defined in the Ontario Water Resources Act.

Watercourse means a stream, creek, river, or channel including ditches, in which the flow of water is permanent, intermittent, or temporary.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

Subsections 902.04.01 and 902.04.02 of OPSS 902 are deleted in their entirety and replaced with the following:

902.04.01 Design Requirements

902.04.01.01 Dewatering

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work. The design of the system shall be sufficient to permit the work to be carried out as specified in the Contract Documents.

The design shall meet the requirements of the Contract Documents, and where a waterbody is present, shall include channel and inlet and outlet protection measures as required to protect the environment in the event of system failure or the design flow rate being exceeded.

The design shall not include the use of embankments and/or structures in public use, either existing or to be constructed as part of the Work, to control or stop water flow, unless approved by the Contract Administrator.

The design shall not result in displacement or damage to property, buildings, structures, utilities and other facilities adjacent to the Working Area, including from drawdown related settlement or other groundwater related effects.

The system shall be designed to prevent soil loss or erosion where water is removed, pumped, or discharged. The system shall be designed to prevent basal heave or instability.

Where the system involves the taking of water from a waterbody, the design shall maintain the flow of water and the natural functions of the waterbody upstream and downstream of the work area, and shall not interfere with other uses of the water.

When the system includes temporary flow control, the temporary flow control shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

Temporary flow control shall include provision for fish passage during low flows.

902.04.02

Submission Requirements

902.04.02.01

Working Drawings

Three (3) sets of Working Drawings for the dewatering system shall be submitted to the Contract Administrator at least 7 Days prior to commencement of the dewatering system installation, for information purposes only. Prior to submission of Working Drawings, the seals and signatures of a design Engineer and a design-checking Engineer shall be affixed on the Working Drawings verifying that the drawings are consistent with the Contract Documents.

One person shall not perform both the design Engineer and design-checking Engineer roles for a system.

Where multi-discipline engineering work is depicted on the same Working Drawing and the design or design-checking Engineer or both are unable to seal and sign the Working Drawing for all aspects of the work, the drawing shall be sealed and signed by as many additional design and design-checking Engineers as necessary.

The following information and details shall be shown on the Working Drawings, where applicable:

a) Plans, Elevations, and Details

- i. Type of system(s).
- ii. Design calculations demonstrating adequacy of the system and equipment.
- iii. Design flow rate(s).
- iv. Plan location, description, and dimensions of system components, including dams, cofferdams, cut-off walls, temporary channels, pipes, culverts, sewers, groundwater control systems employing wells and/or well points, sedimentation basins, tanks, pumps, power supply, and standby equipment.
- v. Method of management of pumped water and plan location of all dewatering discharge points.
- vi. Profile drawings shall extend through and immediately beyond the limits of the system.
- vii. Water elevations upstream and downstream of the system at design flow rate.
- viii. Dam height or crest elevation, cofferdam depth and tip elevation, cutoff wall depth or base elevation, pipe invert elevations, depths of wells and wellpoints, pump intake elevation, and sedimentation basin depth or base elevation.
- ix. Plan location, elevation, and dimensions of environmental protection measures.
- x. Pipe type, size, and length, pump capacity, and tank capacity.
- xi. Material and construction standards to be used for the work.
- xii. Method for establishing and monitoring construction site groundwater levels.
- xiii. Criteria and method of removal of the system.

b) Procedures for the system construction, operation, and maintenance, including daily start-up sequence where applicable, and operation shut down.

c) Procedures for the removal of the system, including the removal sequence, and well decommissioning.

d) Stand-by power or pumping system requirements and the use of automatic transfer switching, when required to protect the environment and the Work.

e) A copy of the Permit to Take Water issued by the Ministry of the Environment and Climate Change or confirmation of registration of water taking for construction dewatering, if a permit or registration is required by provincial regulation.

f) When applicable, a copy of the water taking report and discharge plan required by provincial regulation.

- g) A copy of any necessary permits for the discharge of water to a sanitary sewer, or stormwater sewer system, stormwater pond, or other facility.

902.04.02.02 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of twice the depth of excavation or tunnelling from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.03 Milestone Inspections

The Quality Verification Engineer shall witness the following Interim Inspections of the work:

- a) Dewatering of excavation for structure.
- b) Completion of excavation for foundation.
- c) Excavation for backfill and frost tapers.
- d) Backfilling.

A copy of the written permission to proceed shall be submitted to the Contract Administrator prior to commencement of the successive operation.

902.07 CONSTRUCTION

Subsection 902.07.04 of OPSS 902 is deleted in its entirety and replaced with the following:

902.07.04 Dewatering Structure Excavation

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation of temporary flow control, if applicable, shall be as specified in the Contract Documents.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When temporary flow control is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the temporary flow control during the seasonal shutdown period.

Temporary erosion and sediment control measures, including to control the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow control shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

Water from dewatering and unwatering operations shall be directed to a sediment control measure and/or a vegetated discharge area 30 m away from waterbodies or as far away as practicable from the top of the bank of any waterbody, prior to discharge to the natural environment.

Equipment and materials shall not be used or stored in vegetated discharge areas.

The discharge of water to the natural environment shall not be directed across pavements, sidewalks, curb and gutter or similar hard surfaces except through appurtenances as specified in the Contract Documents.

902.07.04.03 Monitoring

The Contract Administrator shall be notified of any complaints and any action taken or proposed to be taken in response to complaints.

Daily external visual monitoring of the surrounding area and property and structures on the preconstruction survey, if applicable, for impacts such as settlement and erosion shall be completed. Any observed impacts shall be immediately reported to the Contract Administrator. When public safety, the environment, or property is impacted or potentially impacted, the design Engineer shall, without delay, make a full assessment and direct changes to the system to eliminate impacts or potential impacts. Any changes shall be documented according to the System Amendments subsection.

When a groundwater control system is observed to negatively impact water supplies obtained from any adequate sources that were in use prior to groundwater control system operation, then water shall be supplied to the affected water users. The water shall be equivalent in quantity and quality to the normal water takings of the users. Supply shall continue until the negative impacts on the water supplies are removed, or until Contract Completion, whichever occurs first.

902.07.04.04 System Amendments

When displacement or damage to embankments and/or structures, or property adjacent to the Working Area, occurs due to the operation of the system, or soil loss or erosion occurs where water is removed, pumped, or discharged, the dewatering system or temporary flow control shall be amended to stop the displacement, damage, soil loss, or erosion.

Amendments shall be submitted to the Contract Administrator within two Business Days of the system being amended, on revised Working Drawings bearing the seal and signature of the design Engineer and design-checking Engineer.

902.07.04.05 Removal

Dewatering system and temporary flow control components shall be removed when no longer required. Removal of system components shall be according to the procedures specified on the Working Drawings, where applicable, and as specified in the Contract Documents.

Deactivation of temporary flow control shall be as specified in the Contract Documents.

Removal of temporary drainage work shall be according to OPSS 510.

Environmental protection measures and cut-off walls shall be removed, unless approved otherwise by the Contract Administrator.

Sedimentation basins and other excavations shall be backfilled with the original soil excavated, unless approved otherwise by the Contract Administrator. All disturbed areas shall be restored to an equivalent or better condition than existed prior to the commencement of construction.

NOTES TO DESIGNER:

Designer Fill-Ins

- * Fill in the design storm return period according to MTO Drainage Design Standard TW-1.

WARRANT: Include with this item **only** on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.