December 7, 2016

PAVEMENT DESIGN REPORT

Pavement Investigation and Design for Proposed Reconstruction and Rehabilitation Pukaskwa National Park Heron Bay, Ontario

Submitted to:
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REPORT

Report Number: 1545167

Distribution:

2 Copies - PARSONS Corp.
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1 Copy - Golder Associates Ltd.

Golder Associates

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1.0 INTRODUCTION

This report presents the results of a pavement investigation carried out for the proposed improvements at the Pukaskwa National Park, near Heron Bay, Ontario. The pavement engineering components of the project include the reconstruction or rehabilitation of approximately 3.1 km of paved access roads and 2 km of gravel roads. In addition, there are two parking areas which require rehabilitation and one parking area proposed for expansion. The location of the site is shown on the Borehole Location Plans attached as Figures 1 to 3.

The purpose of the pavement investigation was to evaluate the existing pavement structure and the existing subsurface soil and shallow groundwater conditions at the site by advancing 30 shallow boreholes, and provide pavement design recommendations for the reconstruction or rehabilitation of the access roads and existing parking areas, as well as the expansion of one parking area.

The project scope also includes replacement and rehabilitation of the sewer infrastructure which is addressed in a separate report.

Golder Associated Ltd. (Golder) submitted the scope of work and cost estimate for this investigation to Parsons Corporation (Parsons) in a proposal dated November 17, 2015 (P1545167). Authorization to proceed with this investigation was provided by Mr. Jan Wieczorek of Parsons, in an email dated December 22, 2015, and in the signed agreement dated February 1, 2016.

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location or elevation, or if the project is not initiated within eighteen (18) months of the date of the report, Golder should be given an opportunity to confirm that the recommendations are still valid. In addition, this report should be read in conjunction with the attached "Important Information and Limitations of This Report" included in Appendix A. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 SITE DESCRIPTION

The following tables summarize the pavement design components in the study area:

EXISTING ROADS

Section	Road	Starting Station	Ending Station	Approximate Length (km)
Primary Access Road	Pukaskwa Entrance Road	18+000	20+000	**2.0**
Circulation Roads	Administration Building Access Road	6+000	6+621	0.6
	Pukaskwa Entrance Road	17+664	18+000	0.3
	Visitor's Centre Access Road	5+000	5+244	0.2
	Total Circulation Roads			**1.1**

EXISTING ROADS				
Section	**Road**	**Starting Station**	**Ending Station**	**Approximate Length (km)**
Area Roads	North Campground Loop	1+000	1+669	0.7
	South Campground Loop - South	3+000	3+298	0.3
	South Campground Loop - East	4+000	4+297	0.3
	South Campground Loop – West	2+000	2+325	0.3
	Lagoon Access Road	10+000	10+437	0.4
	Total Area Roads			**2.0**

The two existing parking lots that require rehabilitation are as follows:

EXISTING PARKING LOTS	
Location	**Approximate Area (sq.m)**
Visitor Reception Centre	910
Administration Centre	1720
Total	**2630**

We understand that the parking lot adjacent to the Registration Kiosk at the entrance to the campground will be expanded to include seven additional parking spaces. The Beach Trail parking lot will include 4 spaces.

3.0 DESIGN CRITERIA

The following design standards are from the Design Criteria dated February 26, 2016.

PRIMARY ACCESS ROAD, Pukaskwa Entrance Road			
	Present Conditions	**Design Standards**	**Proposed Standards**
Functional Highway Classification	RU60	RU60	RU60
Min Stopping Sight Distance	n/a	85	85
Equivalent Minimum “K” Factor	Crest: 5	Crest: 15	Crest: 15
	Sag: 7	Sag: 18	Sag: 18
Grades Maximum (%)	8.9	12	8.9
Radius Minimum	160	130	160
Pavement Width (m)	6.0-7.0 (2 lanes)	6.0	6.5
Shoulder Width	1.0	1.0	1.0
Shoulder Rounding	n/a	0.5	0.5
Posted Speed	50	40	40
Design Vehicle	P, PT, B12, SU	P, PT, B12, SU	P, PT, B12, SU

CIRCULATION ROADS, Pukaskwa Entrance Road, Administration Building Access Road, Visitor's Centre Access Road			
	Present Conditions	**Design Standards**	**Proposed Standards**
Functional Highway Classification	RU30	RU30	RU30
Min Stopping Sight Distance	n/a	45	45
Equivalent Minimum "K" Factor	Crest: 3	Crest: 4	Crest: 4
	Sag: 3	Sag: 8	Sag: 8
Grades Maximum (%)	3.3	12	3.3
Radius Minimum	24	55	55
Pavement Width (m)	6.5-7.0 (2 lanes)	5.5	6.5
Shoulder Width	none	1.0	1.0
Shoulder Rounding	n/a	0.5	0.5
Posted Speed	30	30	30
Design Vehicle	P, PT, B12, SU	P, PT, B12, SU	P, PT, B12, SU

AREA ROADS, North Campground Loop, South Campground Loop, Lagoon Access Road			
	Present Conditions	**Design Standards**	**Proposed Standards**
Functional Highway Classification	RU20	RU20	RU20
Min Stopping Sight Distance	n/a	20	20
Equivalent Minimum "K" Factor	Crest: 1.5	Crest: 1	Crest: 1.5
	Sag: 2	Sag: 3	Sag: 3
Grades Maximum (%)	6.9	12	6.9
Radius Minimum	20	14	14
Pavement Width (m)	2.5 -3.75 (1 lane)	3.6	3.75
Shoulder Width	none	0.0 – 0.3	0.0
Shoulder Rounding	-	-	0.5
Posted Speed	15	15	15
Design Vehicle	P, PT, SU	P, PT, SU	P, PT, SU

4.0 SOIL CONDITIONS

The Ontario Geologic Society's 1979 Northern Ontario Engineering Geology Terrain Study 60 for the Heron Bay Area (NTS 42D/NE) indicates that Pukaskwa Road and the various campground access roads lie within two different surficial geologic areas within the District of Thunder Bay.

According to the study, the northern portion of the site consisting of Pukaskwa Road near Pic River is within a glaciolacustrine plain, primarily consisting of sandy material, and some silty material. The glaciolacustrine plain has low relief and is characterized as dissected and gullied with mixed drainage conditions (both wet and dry).

The southern portion of the site, consisting of Pukaskwa Road approximately 800 to 900 m south of Pic River and the campground access roads, is within a surficial geologic area characterized with rock knobs consisting of either exposed bedrock or bedrock overlain by a thin veneer of glacial till. The area has higher relief and is characterized as jagged, rugged and cliffed.

5.0 GEOLOGY

Based on the Ontario Geologic Society's digital data set for the Bedrock Geology of Ontario (MRD 126 – Revision 1), the bedrock at the site generally consists of felsic to intermediate metavolcanic rocks including tuffs and breccias with minor metasedimentary and intrusive rock.

6.0 FIELD INVESTIGATION

6.1 Geotechnical Drilling Investigation

The fieldwork for the investigation was carried out the week of January 19, 2016, during which time 30 boreholes (BH1 through BH30) were advanced to practical refusal or to a maximum depth of 2.2 m below ground surface (bgs) at the locations shown on the Borehole Location Plans attached as Figures 1 to 3.

Prior to commencing the investigation a private locator was retained and the borehole locations were cleared of underground infrastructure.

All the boreholes were drilled using a truck-mounted drill rig supplied and operated by KC Drilling Ltd. The fieldwork was carried out under the supervision of members of our engineering staff who directed the drilling operations, logged the boreholes, and obtained samples for further examination and testing. The shallow groundwater conditions were monitored in the open boreholes during drilling. All of the boreholes in the paved areas were backfilled and sealed with cold-mix asphalt at the surface, whereas the boreholes in the unpaved areas were backfilled with auger cuttings upon completion of drilling.

The borehole locations were marked out in the field based on stationing provided by a survey sub-consultant retained by PARSONS. Geodetic elevations of the borehole locations were provided by the survey sub-consultant. The locations of the boreholes as shown on the Borehole Location Plan should be considered as approximate.

All of the granular and soil samples obtained during this investigation were brought to our Whitby laboratory for further visual examination, and natural water content and classification testing on selected samples.

7.0 SUBSURFACE CONDITIONS

The existing pavement structures, subgrade soil and shallow groundwater conditions encountered in the boreholes, as well as the results of the field and the geotechnical laboratory testing, are shown in detail on the Record of Pavement Borehole sheets (Table 1) and on Figures 4 through 7 following the text of this report. The Method of Soil Classification and Symbols and Terms Used on the Records of Pavement Boreholes sheets are provided to assist in the interpretation of the logs.

It should be noted that the boundaries between the strata on the borehole logs have been inferred from drilling observations and non-continuous samples. They generally represent a transition from one soil type to another and should not be inferred to represent an exact plane of geological change. Further, conditions will vary between and beyond the boreholes. The following is a summarized account of the subsurface conditions encountered in the boreholes drilled at the site, followed by more detailed descriptions of the existing pavement structures, major subgrade soil strata and shallow groundwater conditions.

Underlying the pavement structure, the subsurface soil conditions generally consists of sand or silty sand with occasional cobbles, boulders and bedrock. A layer of clayey silt was encountered in Borehole 9.

7.1 Pavement Structure and Subgrade Conditions

The pavement structure encountered at the borehole locations drilled along existing roads is summarized as follows:

LOCATION		THICKNESS OF PAVEMENT LAYERS AND SUBGRADE TYPE Average (Min-Max)			
Road Classification	**Borehole Numbers**	**Asphalt (mm)**	**Base (mm)**	**Subbase (mm)**	**Subgrade Type**
Primary Access Road	6 – 13	65 (50-175)	280 (150-450)	790* (0-1880)	• Sand, Silty • Sand, • Boulders and Bedrock • Localized Clayey Silt
Circulation Roads	5, 15, 16 17, 26	55 (50-75)	200 (110-280)	1350 (370-2020)	• Sand • Boulders
Area Roads	1, 2, 18 – 23, 25	-	150 (50-340)	-	• Sand
Existing Parking Lot Visitor Reception Centre	27 - 30	50 (50-55)	250 (160-300)	-	• Sand
Existing Parking Lot – Administration Center	3, 4	70 (60-75)	180 (160-200)	-	• Sand
Proposed Parking Expansion - Campground Entrance Registration Kiosk	14		200	-	• Bedrock

*An existing subbase thickness of 300 mm has been assumed for design.

The base material generally consists of a brown silty crushed gravelly sand and the subbase material consists of brown fine to coarse sand, trace to some silt, trace cobbles. The results of the gradation testing carried out on two granular base samples indicate that the material generally does not meet the OPSS 1010 specification for Granular A (too fine on multiple sieves and too silty). The gradations of the granular base samples tested are provided on Figure 4.

Two of the four granular subbase samples tested did not meet the OPSS 1010 specification for Granular B, Type I due to excessive fines. The results of the gradation testing carried out on the granular subbase samples are provided on Figure 5. In many of the boreholes, the subbase material and subgrade material were similar and the layer boundary between the two layers could not be delineated.

The subgrade and subbase materials encountered generally have low frost susceptibility. A localized deposit of highly frost susceptible clayey silt was encountered in Borehole 9 at a depth of 1.9 m; however, based on the pavement condition, it does not appear to be impacting pavement performance. The results of the particle size distribution tests carried out on selected subgrade soil samples are provided on Figures 6 and 7.

7.2 Groundwater Conditions

The groundwater conditions observed during our January 2016 investigations were as follows:

Observed Groundwater Conditions

Area	Borehole Number	Water Level (m)
Pukaskwa Road	7	1.2
	9	0.85
North Campground gravel road (North Loop)	19	1.3
	20	1.5
South Campground gravel roads (South Loop)	21	1.2
	22	0.56
	23	1.5
	24	1.4
	25	1.3
Visitors Centre Parking Area	28	1.7

It should be noted that the groundwater levels are expected to fluctuate seasonally. Higher groundwater levels are expected during wet periods of the year, such as spring.

Rock was encountered in a number of boreholes. Details regarding depth to rock and potential impact on trenching for storm sewer/forecemain will be presented in the Supplemental Geotechnical Report.

8.0 DISCUSSION

This section of the report provides engineering information for the geotechnical and pavement design aspects of the project, based on our interpretation of the borehole data and on our understanding of the project requirements. The information in this portion of the report is provided for the guidance of the design engineers and technicians. Where comments are made on construction, they are provided only in order to highlight aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

9.0 PAVEMENT DESIGN CONSIDERATIONS

The AASHTO 93 method has been used for the design of the pavement structure.

Traffic within the Park's road network is limited to visitors and park staff and there is no through traffic. The park's entrance is located at the end of Highway 627. The vehicle types that utilize the road network include passenger cars, recreational vehicles and trailers, buses and single unit trucks (maintenance vehicles). Large commercial trucks are not anticipated within the park.

The number of visitors for the 2015 to 2017 period and the number of recreational vehicles, buses and light trucks are as follows:

Visitor and Traffic Information

Vehicle Type	Year	Number of Trips/Year	Average Truck Factor
Passenger Cars	2015	4950	0
	2016	5050	0
	2017	5150	0
Recreational Vehicles	-	2205	1.1
Buses	-	15	1.1
Light Trucks	-	3650 (10 trips/day)	0.8 (FHWA Class 6)

For pavement design purposes, it is assumed that two visitors arrive in each vehicle. The traffic volume growth rate is approximately 2%.

Based on the above traffic information, the site conditions and material properties outlined in Section 7.0 of the report, the following design parameters are selected.

Design Consideration	Parameter Selected
Pukaskwa Primary Access Road 18 Year ESALs	140,000
Initial Serviceability	4.2
Terminal Serviceability	2.0
Reliability Level (%)	85
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus (MPa)	40
Structural Coefficient of New Asphalt	0.42
Structural Coefficient of New Granular Base	0.14
Structural Coefficient of Existing Granular Base	0.11
Drainage Coefficient of Existing Granular Base	0.9
Structural Coefficient of New Granular Subbase	0.09
Structural Coefficient of Existing Granular Subbase	0.07
Drainage Coefficient of Existing Granular Subbase	0.9
Required Structural Number	**67**

The AASHTO design sheets are attached in Appendix B.

10.0 PAVEMENT DESIGN CONSIDERATIONS

Parsons has provided a list of four Options (Options A to D) considering varying levels of serviceability levels and design lives. The four options from a pavement engineering perspective are as follows:

- Option A – Full Depth Reconstruction (18 Year Design Life)
- Option B and C – Major Rehabilitation (15 Year Design Life)

- Option D – Minor Rehabilitation/Preservation/Holding Strategy (3-5 Year Design Life)

Based on the design analysis using AASHTO 93, the following pavement designs are recommended for the various project components. The selection of a reconstruction or rehabilitation strategy will be dependent on the location of the sewer/forcemain replacement locations. If the excavations for sewer/forcemain do not extend into the existing roadway, then a rehabilitation strategy should be selected.

Option A – Primary Access Roads, Circulation Roads and Existing/Proposed Parking Lots – Reconstruction/Expansion

- Excavate to a depth of 360 mm and place:
- 60 mm Superpave 12.5 or HL-3
- 300 mm Granular A

The backfill material placed in trenches for sewer/forcemain replacement should be compacted to 100% of the backfill material's Standard Proctor Density within 1 m of the bottom of the pavement. Specifications for backfill material will be provided in the supplemental report.

Options B and C - Primary Access Roads and Circulation Roads and Existing Parking Lots – Rehabilitation

- In-place process to a depth of 150 mm starting 15 m from Highway 627
- Pave with 60 mm of Superpave 12.5 or HL-3

Alternately, the asphalt can be removed full depth, the exposed granular materials re-graded and the grade brought to 60 mm below finished pavement grade using new Granular A base material prior to placing 60 mm of new asphalt. This option is recommended by Golder for Primary Access Roads, Circulation Roads and Existing Parking Lots and was selected by Parks Canada as the preferred strategy.

Option A - Area Roads – Reconstruction

Excavate to provide for:

- 300 mm Granular A

Options B, C and D – Area Roads – Rehabilitation

Add 200 mm of Granular A. This option is recommended by Golder for the Area Roads and was selected by Parks Canada as the preferred strategy.

Option D – Primary Access Roads and Circulation Roads and Existing Parking Lots – Minor Rehabilitation/Preservation/Holding Strategy

Micro-surfacing is a lower cost pavement preservation strategy that will extend the pavement service life by three to five years. The micro-surfacing mixture consists of a polymer modified asphalt emulsion, fine-medium graded high quality aggregate, filler, additives and water. A 10 mm lift of the material is applied to the existing asphalt surface. Micro-surfacing work should be completed in accordance with OPSS 336.

10.1 Asphalt Mix Type and Performance Graded Asphalt Cement

The SP12.5 surface course asphalt mix should be designed for Category B or higher. Performance graded PG 52-34 cement should be used on this project.

10.2 Pavement Distress Areas

A number of Pavement Distress Areas with moderate rutting were identified along Pukaskwa Road, from Sta. 18+900 to Sta. 19+000 and from Sta. 19+500 to Sta. 19+550. The following treatments should be completed depending on the Option selected.

- Option A – Full Depth Reconstruction – Raise grade by 200 mm by increasing the Granular A thickness to 500 mm
- Option B and C – Major Rehabilitation – Add 200 mm of Granular A after completion of IPP.
- Option D – Extend micro-surfacing through the distress area limits. Additional rutting is anticipated to form after the first spring-thaw if this option is selected.

10.3 Paved Shoulders or Bike Lanes

Option A – Full Depth Reconstruction

Paved shoulder and bike lanes should be constructed using the same pavement structure recommended for the main lanes in Section 10. Bike lanes are proposed along Pukaskwa Road from Sta. 17+880 to Sta. 20+000, along the Visitor Centre Road from Sta. 0+000 to the existing parking lot, and along the Administrative Centre Road from Sta. 0+000 to Sta. 0+300.

10.4 Compaction Requirements

Adequate compaction of all granular and earth fill materials is essential to ensure an acceptable level of pavement performance. Compaction of all materials should be carried out in conformance with the procedures outlined in OPSS.PROV 501, dated November 2014.

10.5 Conversion Factors

For estimating purposes, the following granular and hot mix asphalt conversion factors may be used to convert from volume (m^3) to mass (tonne):

- Granular A – 2.4 t/m^3.
- Granular B, Type I – 2.0 t/m^3
- Superpave 12.5 or HL-3 – 2.46 t/m^3
- Existing Hot Mix Asphalt for Removals – 2.46 t/m^3.

10.6 Pavement Transitions

The recommended pavement transition for the tie-in to existing Highway 627 is as follows:

Existing and Future Roadway, Tie-in Station and Proposed Asphalt Thickness	Existing Pavement Thickness (mm)	Recommended Pavement Transition Treatment
Highway 627 – Pukaskwa Road	175 mm HMA	– A transverse step joint 60 mm deep and 5 m long to key in the surface course of new pavement into the existing pavement on Highway 627.

10.7 Frost Penetration Depth

The depth of frost penetration for this project should be taken as 2.2 m. This depth should be used when designing frost tapers in accordance with the OPSD 803 series.

11.0 MONITORING AND TESTING

The geotechnical and pavement aspects of the final design drawings and specifications should be reviewed by this office prior to tendering and construction, to confirm that the intent of this report has been met. During construction, sufficient in-situ materials testing should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes and to monitor conformance to the pertinent project specifications. Testing of the asphalt mixes and granular base materials should be carried out in a CCIL certified laboratory.

12.0 CLOSURE

We trust that this report provides sufficient geotechnical and pavement engineering information to facilitate the design of this project. If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Report Signature Page

GOLDER ASSOCIATES LTD.

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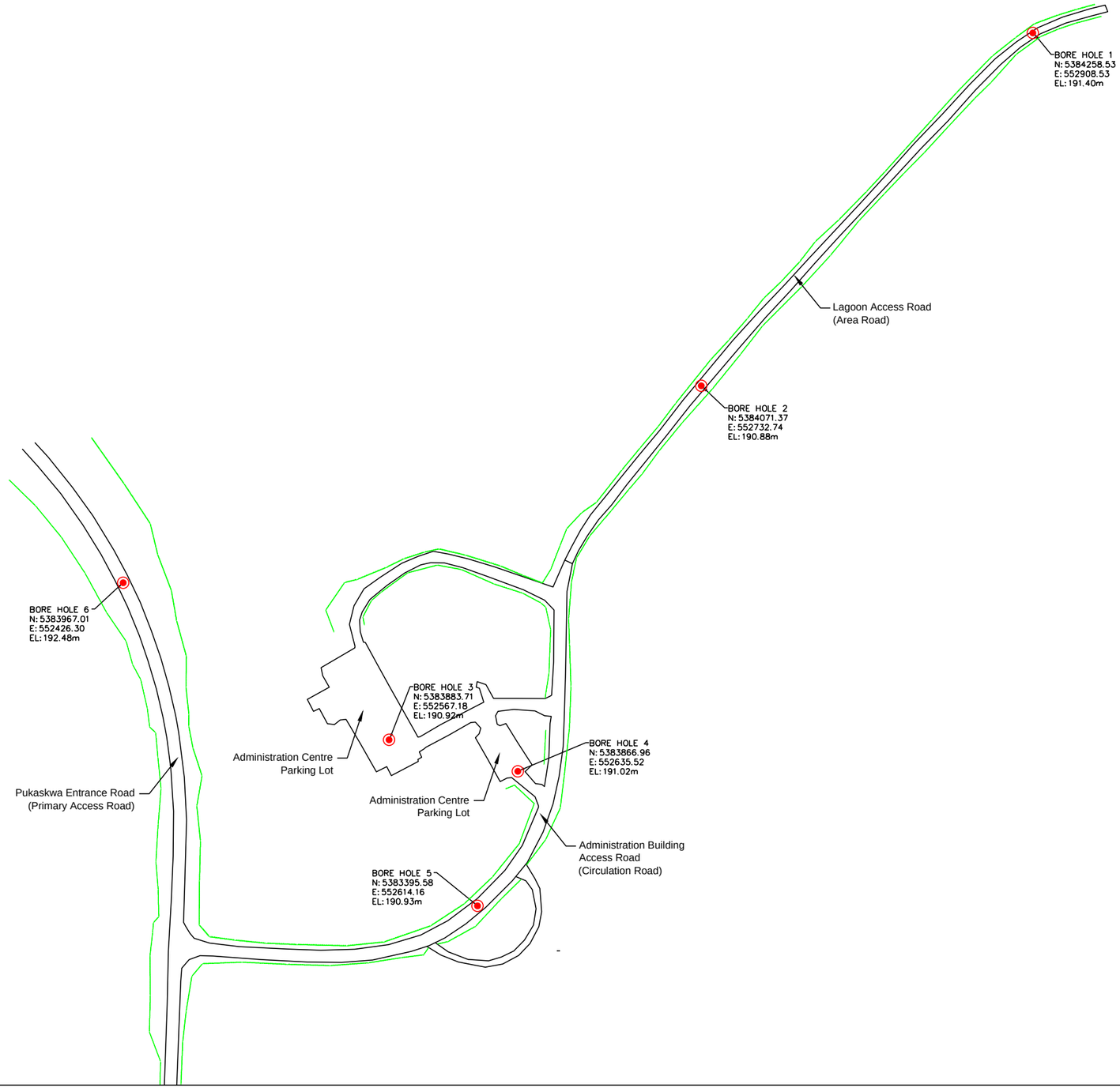
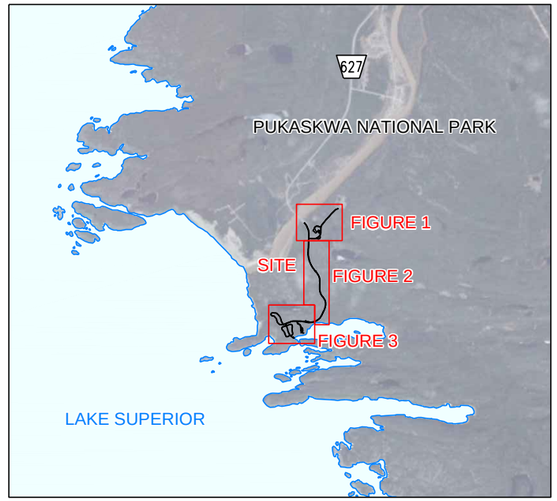
ATTACHMENTS

Figures 1 to 7
Record of Borehole Logs





REGIONAL LOCATION 1:100000 m

LEGEND

- BOREHOLE LOCATION

NOTES

1. DATUM UTM NAD 83 ZONE 16
2. MAPPING BASED ON CALLON DIETZ INC. ONTARIO LAND SURVEYORS (DRAWING NO. 16-20450 SHEET 1-3)

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CLIENT

PARKS CANADA

PROJECT

ROAD RECONSTRUCTION
PUKASKWA NATIONAL PARK
HERON BAY, ONTARIO

TITLE

BOREHOLE LOCATION PLAN

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-05-09
PREPARED	STB
DESIGN	
REVIEW	JBH
APPROVED	ALB

PROJECT No.	Phase	Rev.	Figure
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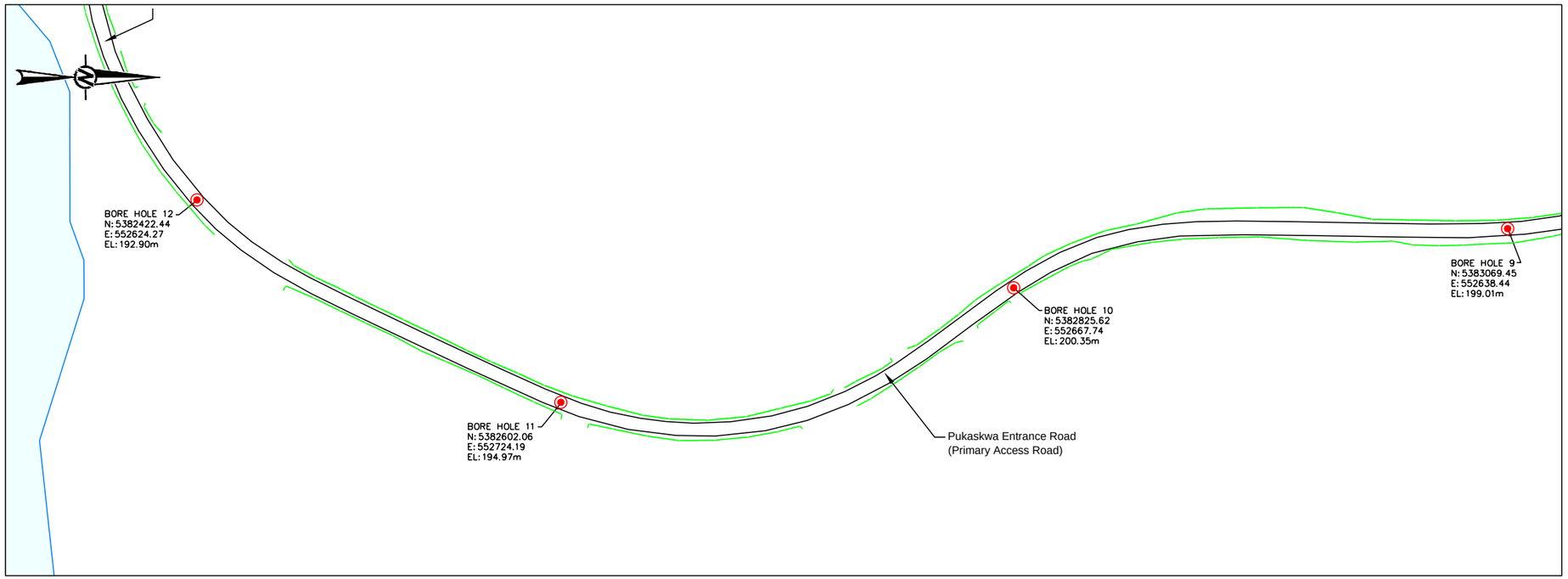

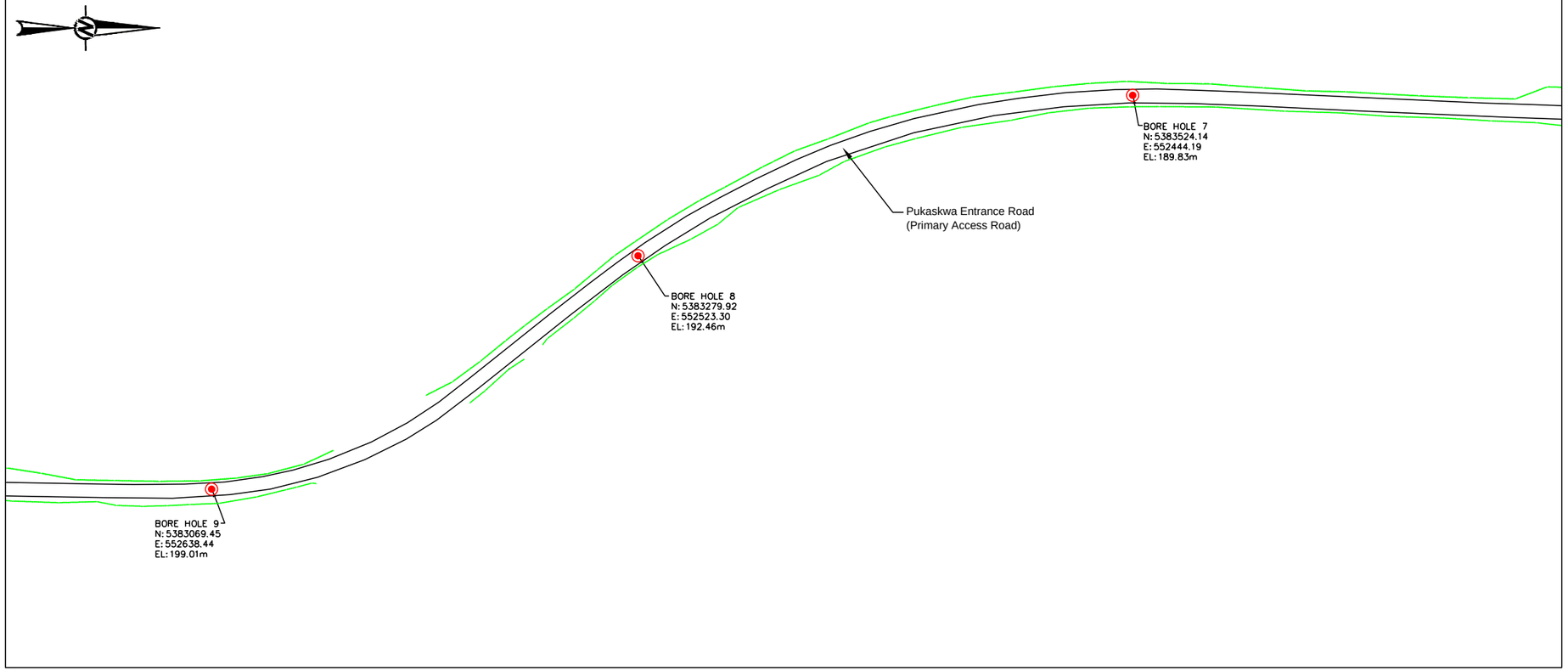

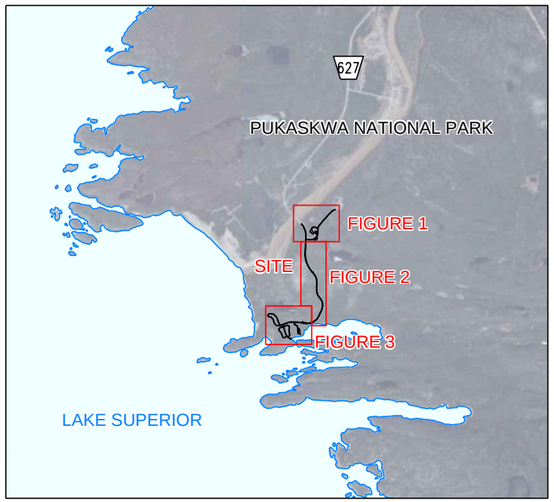

REGIONAL LOCATION 1:100000 m

LEGEND

- BOREHOLE LOCATION

NOTES

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2. MAPPING BASED ON CALLON DIETZ INC. ONTARIO LAND SURVEYORS (DRAWING NO. 16-20450 SHEET 1-3)

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PROJECT
ROAD RECONSTRUCTION
PUKASKWA NATIONAL PARK
HERON BAY, ONTARIO

TITLE
BOREHOLE LOCATION PLAN

CONSULTANT
Golder Associates

YYYY-MM-DD	2016-05-09
PREPARED	STB
DESIGN	
REVIEW	JBH
APPROVED	ALB

PROJECT No.	Phase	Rev.	Figure
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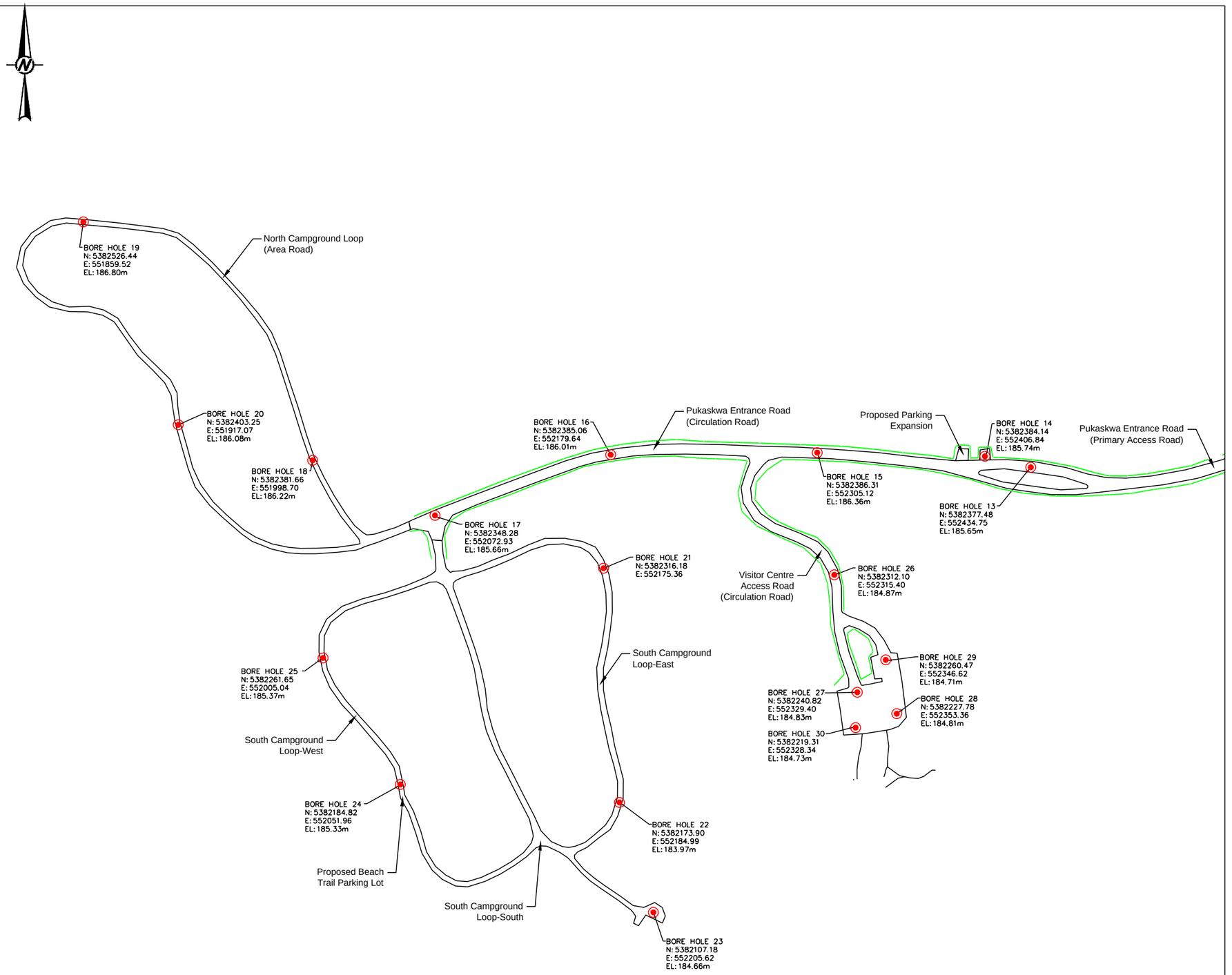

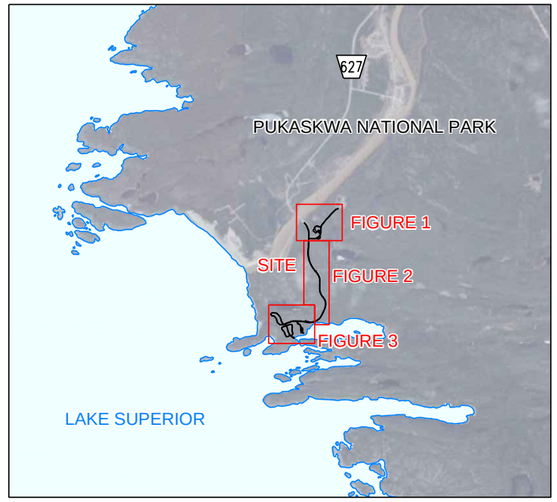

REGIONAL LOCATION 1:100000 m

LEGEND

- BOREHOLE LOCATION

NOTES

1. DATUM UTM NAD 83 ZONE 16
2. MAPPING BASED ON CALLON DIETZ INC. ONTARIO LAND SURVEYORS (DRAWING NO. 16-20450 SHEET 1-3)

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CLIENT
PARKS CANADA

PROJECT
ROAD RECONSTRUCTION
PUKASKWA NATIONAL PARK
HERON BAY, ONTARIO

TITLE
BOREHOLE LOCATION PLAN

CONSULTANT

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YYYY-MM-DD	2016-05-09
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REVIEW	JBH
APPROVED	ALB

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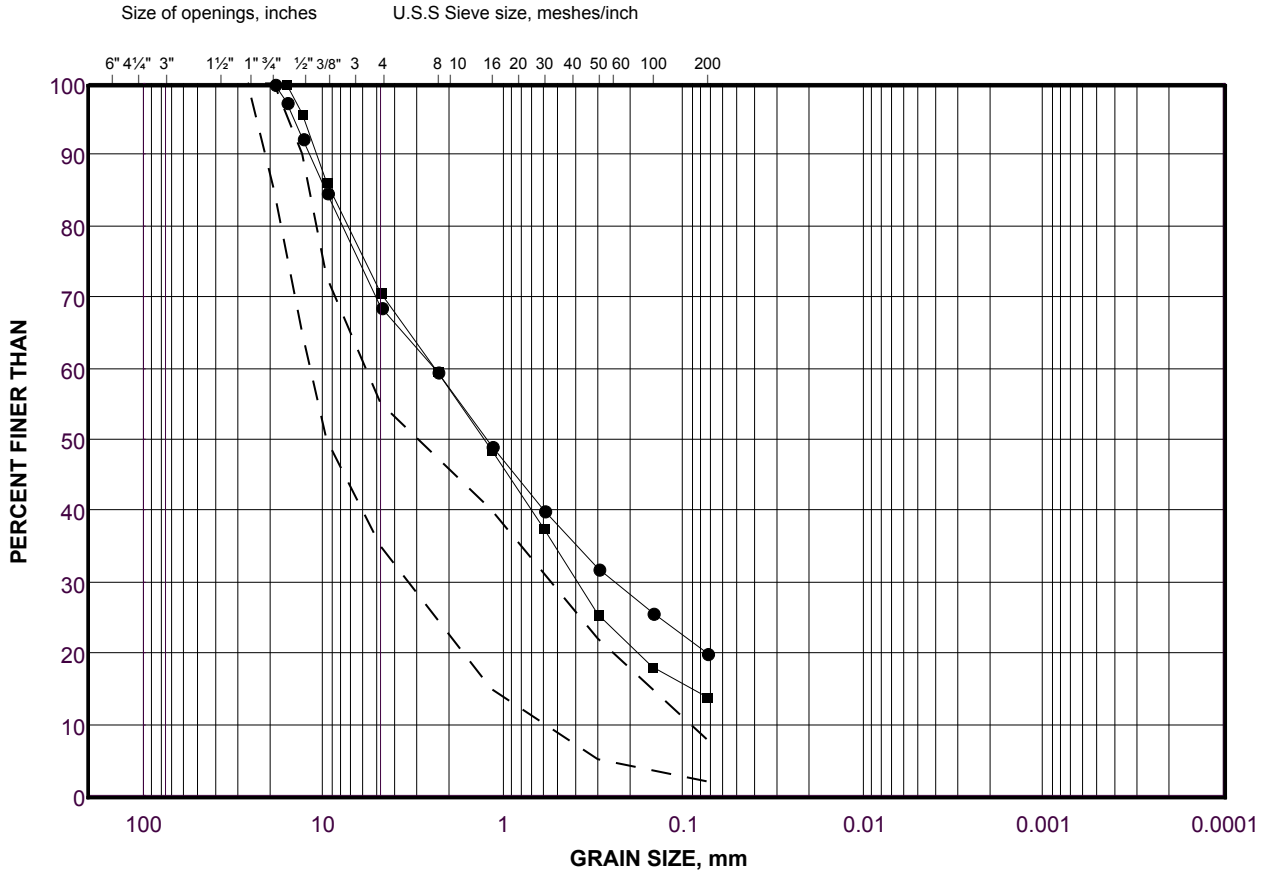
GRAIN SIZE DISTRIBUTION

Granular A

FIGURE 4



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	12	10	50.0 - 370.0
■	19	2	0.0 - 300.0

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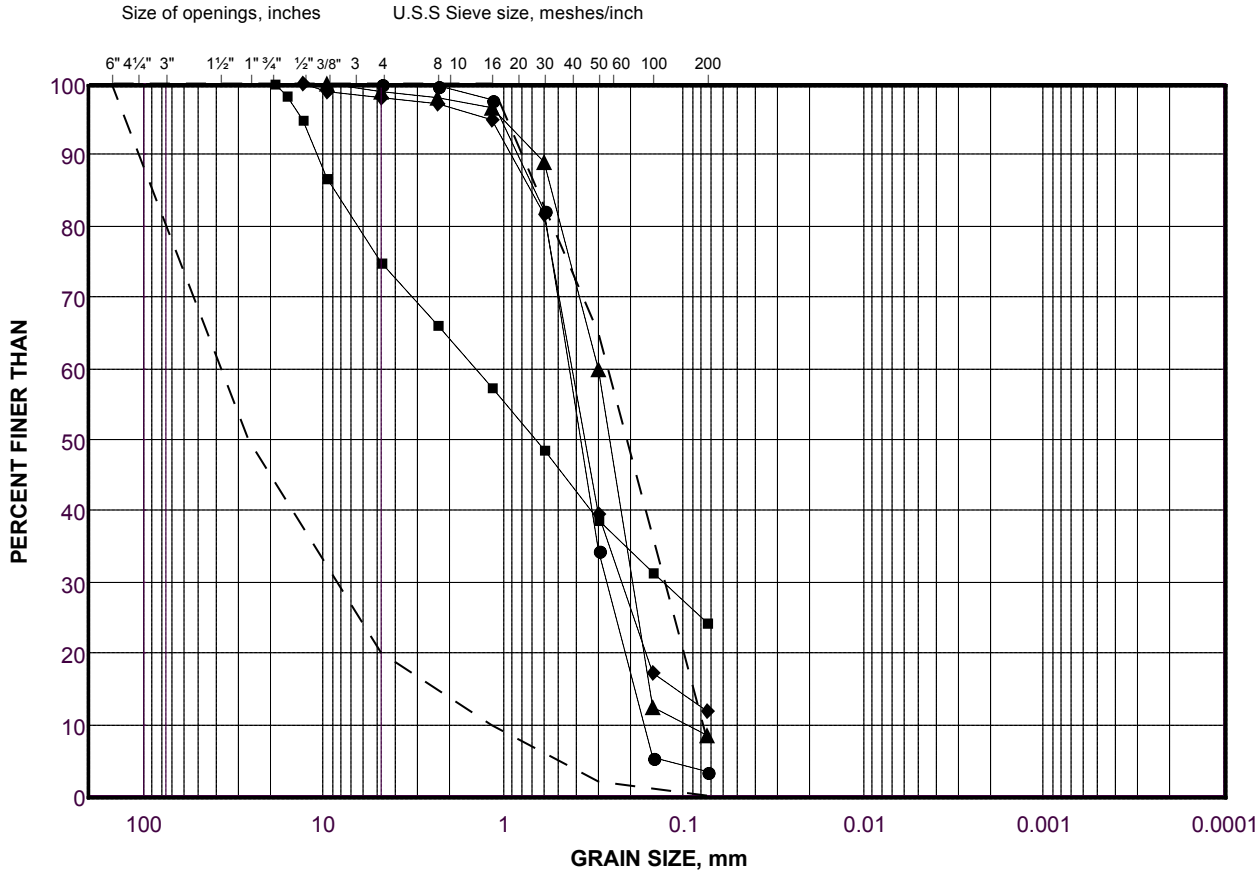
Date: 23-Feb-16

GRAIN SIZE DISTRIBUTION

Granular B Type 1

FIGURE 5



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	18	1	1.80 - 2.10
■	8	13	300.0 - 600.0
◆	23	4	500.0 - 800.0
▲	27	8	1.50 - 1.80

Project Number: 15-45167

Checked By: _____

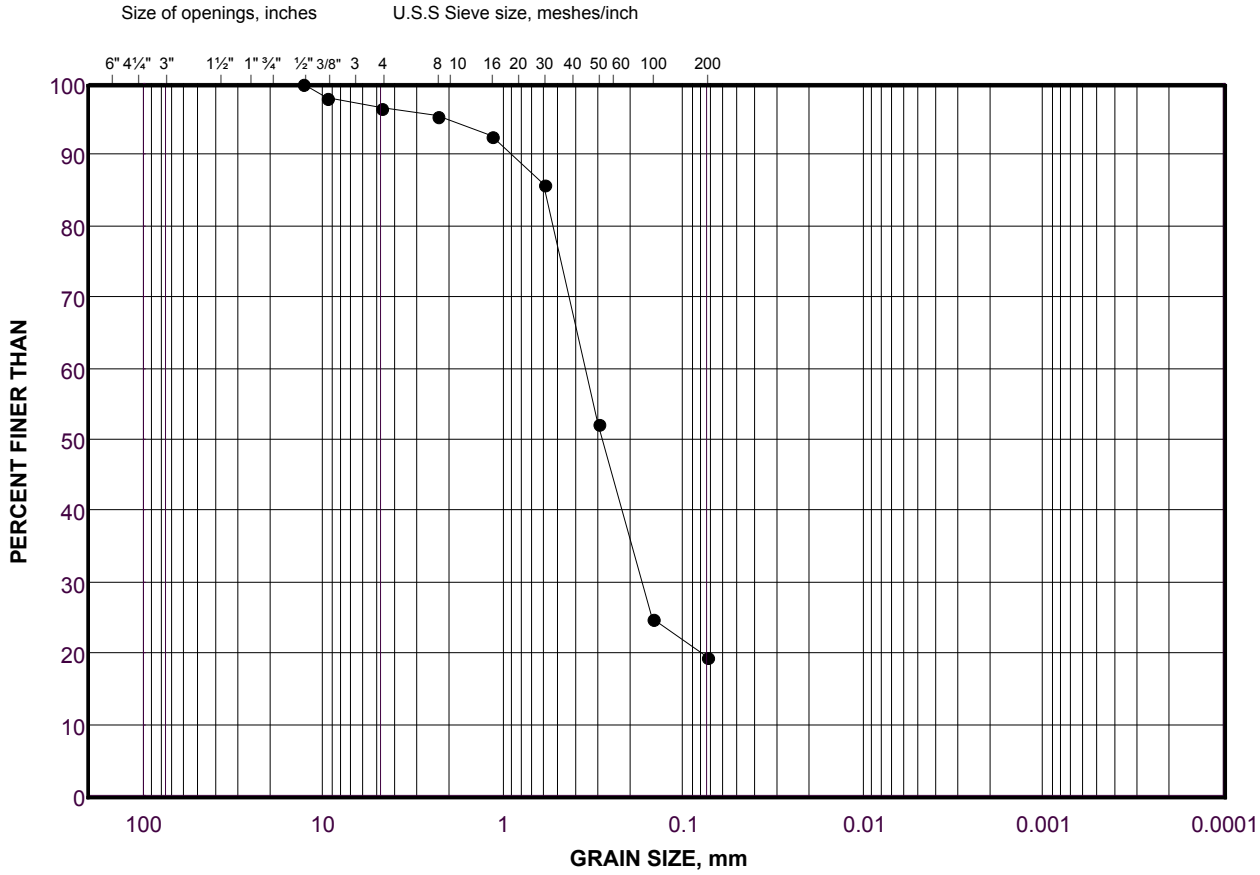
Golder Associates

Date: 23-Feb-16

GRAIN SIZE DISTRIBUTION

Silty Sand

FIGURE 6



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	9	12	700.0 - 1.0

Project Number: 15-45167

Checked By: _____

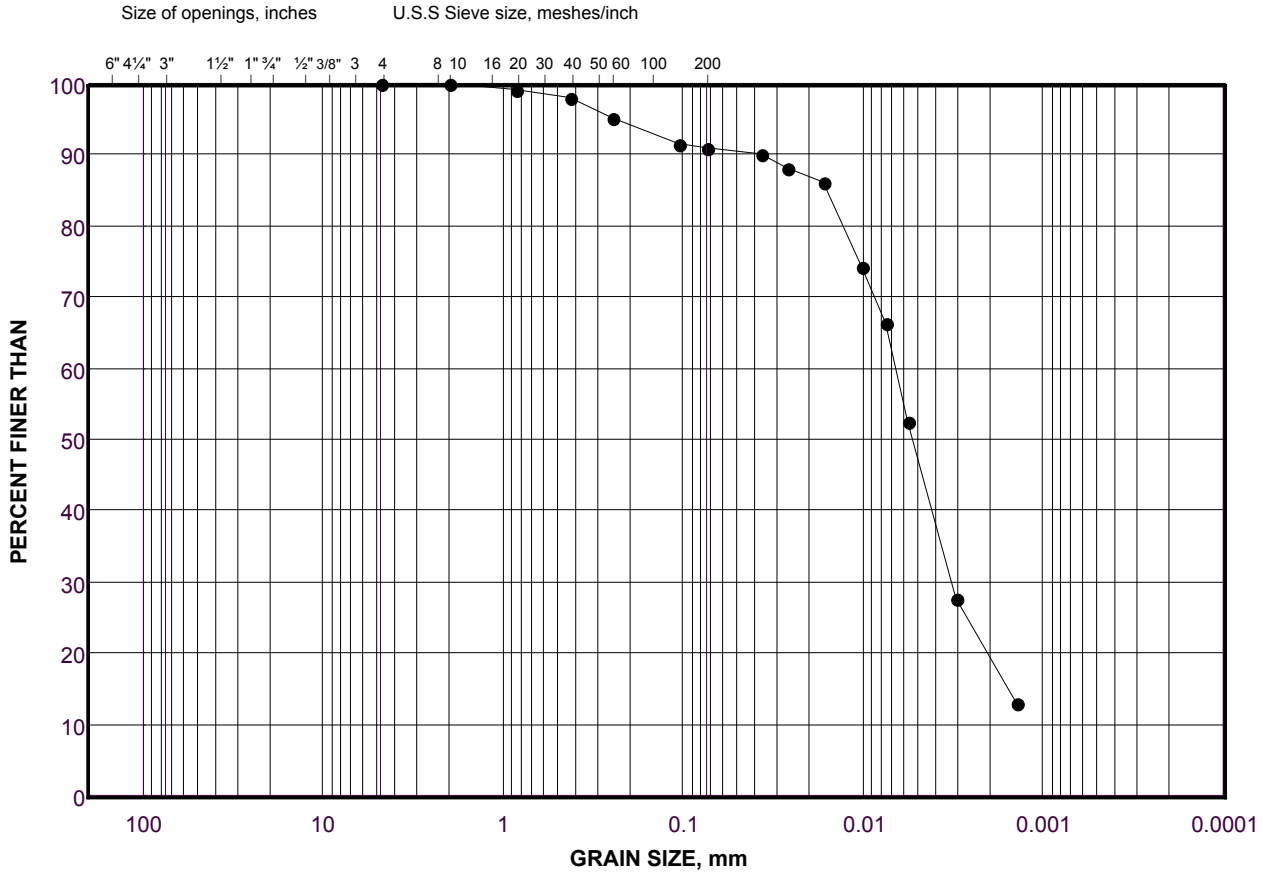
Golder Associates

Date: 23-Feb-16

GRAIN SIZE DISTRIBUTION

Clayey Silt

FIGURE 7



LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	9	18	1.90 - 2.20

Project Number: 15-45167

Checked By: _____

Golder Associates

Date: 23-Feb-16

TABLE 1
RECORD OF PAVEMENT BOREHOLES

Borehole No.	BOREHOLE LOG			Frost Susceptibility	K Factor (Erodability)	LABORATORY TESTING	
	Depth (mm/m)		Sample Depth (mm)			Water Content (%)	Gradation
Location	See borehole plan						
BH1	0 - 50	Brown crushed GRAVELLY SAND					
	50 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, compact					
Location	See borehole plan						
BH2	0 - 80	Brown crushed GRAVELLY SAND					
	80 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, compact					
Location	See borehole plan						
BH3	0 - 60	Asphalt					
	60 - 220	Brown crushed GRAVELLY SAND					
	220 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, compact					
Location	See borehole plan						
BH4	0 - 75	Asphalt					
	75 - 270	Brown crushed GRAVELLY SAND					
	270 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, compact					
Location	See borehole plan						
BH5	0 - 55	Asphalt					
	55 - 240	Brown crushed GRAVELLY SAND					
	240 - 760	Brown SAND with gravel, with silt, moist, compact					
	760 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, wet @ 1.5 m, compact					
Location	See borehole plan						
BH6	0 - 175	Asphalt					
	175 - 330	Brown crushed GRAVELLY SAND					
	330 - 2.2	Brown SAND trace gravel, trace silt, moist, compact					
Location	See borehole plan						
BH7	0 - 50	Asphalt					
	50 - 320	Brown crushed GRAVELLY SAND					
	320 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, free water @ 1.2 m, saturated, compact					
Location	See borehole plan						
BH8	0 - 50	Asphalt					
	50 - 280	Brown Crushed GRAVELLY SAND					
	280 - 1.1	Brown gravelly SILTY SAND, trace cobbles, moist, compact	300 -' 600	LSFH	0.05	5	Figure 5, Unacceptable Granular B Type I, too silty
	- 1.1	NFP Boulders					
Location	See borehole plan						
BH9	0 - 50	Asphalt					
	50 - 300	Brown Crushed GRAVELLY SAND					
	300 690	Brown SAND, trace gravel, trace silt, trace cobbles, moist, compact					
	690 1.9	Brown SILTY SAND, trace gravel, wet, free water @ 850 mm, saturated, compact	700 - 1.0	LSFH	0.1	13	Figure 6
	1.9 - 2.2	Grey CLAYEY SILT, some sand, wet, firm	1.9 - 2.2	HSFH	0.35	23	Figure 7
Location	See borehole plan						
BH10	0 - 50	Asphalt					
	50 - 350	Brown crushed GRAVELLY SAND					
	350 - 1.7	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, compact					
	- 1.7	NFP Boulders					

TABLE 1
RECORD OF PAVEMENT BOREHOLES

	BOREHOLE LOG					LABORATORY TESTING	
Borehole No.	Depth (mm/m)		Sample Depth (mm)	Frost Susceptibility	K Factor (Erodability)	Water Content (%)	Gradation
Location	See borehole plan						
BH11	0 - 50 50 - 500 - 500	Asphalt Brown crushed GRAVELLY SAND NFP Shattered Rock over Bedrock					
Location	See borehole plan						
BH12	0 - 50 50 - 370 - 370	Asphalt Brown crushed silty GRAVELLY SAND NFP Bedrock	50 370	LSFH	0.04	4.5	Figure 4, Unacceptable Granular A, too fine on multiple sieves & too silty
Location	See borehole plan						
BH13	0 - 60 0 - 60 60 - 400 - 400	Asphalt Asphalt Brown GRAVELLY SAND NFP Bedrock					
Location	See borehole plan						
BH14	0 - 200 - 200	Brown crushed GRAVELLY SAND NFP Bedrock					
Location	See borehole plan						
BH15	0 - 50 50 - 230 230 - 600 - 600	Asphalt Brown crushed GRAVELLY SAND Brown fine to coarse SAND with gravel, trace silt, trace cobbles, moist, compact NFP Probable Bedrock					
Location	See borehole plan						
BH16	0 - 50 50 - 310 310 - 2.2	Asphalt Brown crushed GRAVELLY SAND Brown fine to coarse SAND, trace gravel, trace silt, moist, compact					
Location	See borehole plan						
BH17	0 - 70 70 - 180 180 - 2.2	Asphalt Brown crushed GRAVELLY SAND Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, wet @ 1.7 m, compact					
Location	See borehole plan						
BH18	0 - 170	Brown crushed GRAVELLY SAND					
	170 - 2.2	Brown fine to coarse SAND, trace silt, moist, wet @ 1.8 m, compact	1.8 - 2.1	LSFH	0.05	18	Figure 5, Acceptable Granular B Type I
BH19	0 - 340	Brown crushed silty GRAVELLY SAND	0 - 300	LSFH	0.05	9	Figure 4, Unacceptable Granular A, too fine on multiple sieves & too silty
	340 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, free water @ 1.3 m, saturated, compact					
Location	See borehole plan						
BH20	0 - 50 50 - 2.2	Brown crushed GRAVELLY SAND Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, free water @ 1.5 m, saturated, compact					

TABLE 1
RECORD OF PAVEMENT BOREHOLES

	BOREHOLE LOG					LABORATORY TESTING	
Borehole No.	Depth (mm/m)		Sample Depth (mm)	Frost Susceptibility	K Factor (Erodability)	Water Content (%)	Gradation
Location	See borehole plan						
BH21	0 - 120	Brown crushed GRAVELLY SAND					
	120 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, free water @ 1.2 m, saturated, compact					
Location	See borehole plan						
BH22	0 - 150	Brown crushed GRAVELLY SAND					
	150 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, wet, free water @ 560 mm, saturated, compact					
Location	See borehole plan						
BH23	0 - 250	Brown crushed GRAVELLY SAND					
	250 - 2.2	Brown fine to coarse SAND, some silt, moist, free water @ 1.5 m, saturated, compact	500 - 800	LSFH	0.05	10	Figure 5, Unacceptable Granular B Type I, too silty
Location	See borehole plan						
BH24	0 - 160	Brown crushed GRAVELLY SAND					
	160 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, free water @ 1.4 m, saturated, compact					
Location	See borehole plan						
BH25	0 - 140	Brown crushed GRAVELLY SAND					
	140 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, free water @ 1.3 m, saturated, compact					
Location	See borehole plan						
BH26	0 - 55	Asphalt					
	55 - 330	Brown crushed GRAVELLY SAND					
	330 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, compact					
Location	See borehole plan						
BH27	0 - 50	Asphalt					
	50 - 350	Brown crushed GRAVELLY SAND					
	350 - 2.2	Brown fine to coarse SAND, some silt, trace cobbles, moist, wet @ 1.5 m, compact	1.5 - 1.8	LSFH	0.05	17	Figure 5, Acceptable Granular B Type I
Location	See borehole plan						
BH28	0 - 50	Asphalt					
	50 - 210	Brown crushed GRAVELLY SAND					
	210 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, free water @ 1.7 m, saturated, compact					
Location	See borehole plan						
BH29	0 - 55	Asphalt					
	55 - 310	Brown crushed GRAVELLY SAND					
	310 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, moist, wet @ 1.8 m, compact					
Location	See borehole plan						
BH30	0 - 50	Asphalt					
	50 - 330	Brown crushed GRAVELLY SAND					
	330 - 2.2	Brown fine to coarse SAND, trace gravel, trace silt, trace cobbles, moist, wet @ 1.6 m, compact					

APPENDIX A

Important Information and Limitations of This Report

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use o f the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder can not be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

APPENDIX B

Pavement Design Analysis

Table B1
PAVEMENT DESIGN AND ANALYSIS - FLEXIBLE STRUCTURAL DESIGN MODULE

PUKASKWA ROAD RECONSTRUCTION PROJECT
Option A - 18 YEAR DESIGN FOR RECONSTRUCTION OF PUKASKWA ACCESS ROAD

Flexible Structural Design

80-kN ESALs Over Initial Performance Period	140,000
Initial Serviceability	4.0
Terminal Serviceability	2.0
Reliability Level (%)	85
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	40,000 kPa
Stage Construction	1.0
Calculated Design Structural Number	67

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di) (mm)	Required Thickness (mm)	Calculated SN (mm)
1	New Hot Mix Asphalt	0.42	1.00	60	60	25
2	New Granular A Base	0.14	1.00	300	300	42
Total	-	-	-	360	360	67

Layered Thickness Design

Thickness precision

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Actual Spec Thickness (Di) (mm)	Actual Min Thickness (Di) (mm)	Elastic Modulus (kPa)	Calculated Thickness (mm)	Calculated SN (mm)
1	New Hot Mix Asphalt	0.42	1.00	-	-	2,750,000	84	35
2	New Granular A Base	0.14	1.00	-	-	210,000	231	32
Total	-	-	-	-	-	-	314	67

-

Table B2
PAVEMENT DESIGN AND ANALYSIS - FLEXIBLE STRUCTURAL DESIGN MODULE

PUKASKWA ROAD RECONSTRUCTION PROJECT
Option B and C - 18 YEAR DESIGN FOR REHABILITATION OF PUKASKWA ACCESS ROAD

Flexible Structural Design

80-kN ESALs Over Initial Performance Period	140,000
Initial Serviceability	4.0
Terminal Serviceability	2.0
Reliability Level (%)	85
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	40,000 kPa
Stage Construction	1.0
Calculated Design Structural Number	67

Specified Layer Design

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Thickness (Di) (mm)	Required Thickness (mm)	Calculated SN (mm)
1	New Hot Mix Asphalt	0.42	1.00	60	60	25
2	Pulverized Base	0.13	1.00	150	150	20
3	Existing Granular Base	0.11	0.90	195	195	19
4	Existing Granuar Subbase	0.07	0.90	300	300	19
Total	-	-	-	705	705	83

Layered Thickness Design

Thickness precision

Layer	Material Description	Struct Coef. (Ai)	Drain Coef. (Mi)	Actual Spec Thickness (Di) (mm)	Actual Min Thickness (Di) (mm)	Elastic Modulus (kPa)	Calculated Thickness (mm)	Calculated SN (mm)
1	New Hot Mix Asphalt	0.42	1.00	-	-	2,750,000	84	35
2	Pulverized Base	0.13	1.00	-	-	210,000	0	0
3	Existing Granular Base	0.11	0.90	-	-	210,000	117	12
4	Existing Granuar Subbase	0.07	0.90	-	-	105,000	328	21
Total	-	-	-	-	-	-	529	68

-

As a global, employee-owned organisation with over 50 years of experience, Golder Associates is driven by our purpose to engineer earth's development while preserving earth's integrity. We deliver solutions that help our clients achieve their sustainable development goals by providing a wide range of independent consulting, design and construction services in our specialist areas of earth, environment and energy.

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