REPORT N^{O} 1, REV. 0

HORSESHOE DAM REHABILITATION

GEOTECHNICAL DRILLING REPORT

SEPTEMBER 2015

WSP

HORSESHOE DAM REHABILITATION

GEOTECHNICAL DRILLING REPORT

Parks Canada Agency

Report 1, Rev. 0

Project No: 121-15275-51
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APPENDICES

1 INTRODUCTION

1.1 PROJECT DESCRIPTION

The objective of the Horseshoe Dam Rehabilitation Project is to provide professional engineering services to develop drawings and specifications and to provide construction contract administration support in connection with the rehabilitation of the dam. The project will address structural stability issues and improve operational safety aspects of the dam as identified in the recent Dam Safety Review completed by GENIVAR (now WSP Canada Inc.) in 2014.

WSP Canada Inc. (WSP) was retained by Parks Canada Agency (PCA), as part of the Horseshoe Dam Rehabilitation Project, to perform a concrete and rock drilling investigation of the Horseshoe Dam and foundation (bedrock) conditions. The purpose of this investigation was to assess the general quality of the concrete in both the deck and apron areas of the dam, as well as to determine the geology, lithology, rock quality, rock structure, bedrock location and rock strength of the bedrock immediately below the existing dam. The factual observations, site conditions and lab results from this investigation will be utilized as input data to deliver three rehabilitation options for the Horseshoe Dam to PCA.

1.2 BACKGROUND INFORMATION

The present Horseshoe Dam was originally constructed in 1909 with subsequent alterations in 1948 and is located in Minden Hills, Ontario on the Gull River. The dam is one of 21 PCA water control structures located in the Gull River Waterway and one of the 40 in the Haliburton Sector of the Trent Severn Waterway (TSW) National Historic Site of Canada.

The Dam is a 4 (four) bay stop log sluice water control structure that is 59 m long and 9.1 m in height. At normal operating water level the dam retains 7.4 m of head. The purpose of the dam is to control the water level in Horseshoe Lake upstream. Horseshoe Lake sits at the northernmost end of the TSW and serves as one of a number of reservoir lakes that collect run-off during the non-navigation season and subsequently feed the water system to support navigation during the operational season.

The physical condition of the existing concrete dam and its appurtenant wing walls have deteriorated to a level that required immediate rehabilitation. More specifically, there is a need for general concrete rehabilitation and anchorage of the dam to satisfy dam safety requirements.

1.3 PROJECT SCOPE OF WORK

In order to support the determination of possible rehabilitation options for the Horseshoe Dam, a geotechnical drilling program and subsequent core logging and laboratory testing to determine in situ parameters of both the structural concrete and the foundation bedrock was to be completed. This report summarizes the geotechnical drilling program, bedrock geology, core logging and observations and the factual laboratory results.

2 SITE DESCRIPTION

Horseshoe Lake Dam is located in the Gull River watershed, approximately 7 km north-east of the Town of Minden. The site area has all weather access via County Road 20, and is just south of the intersection of County Road 20 and Bethel Road. Access to the dam may be gained via either the left or right abutments. A private property is located at the south or left dam abutment. The area upstream of the dam includes cottages, private homes, the Bethel Road Bridge. Downstream of the dam, a white water canoe and kayaking course is present. The Minden Generation Station dam and headpond are also located downstream of the Horseshoe Lake Dam.

2.1 GEOLOGICAL SETTING

The Horseshoe Lake Dam is located on the edge of the Algonquin Highlands Physiographic Region, in an area characterized by shallows soils overlying metamorphosed intrusive igneous rocks of the Precambrian basement. The regional rock is from the Denna Lake Structural Complex, comprised of various units including gneisses and metamorphic tectonic breccia.

A thrust fault, of unknown age, and interpreted to be an upright thrust, parallels the Gull River to the immediate west of the dam. Similarly, a second thrust fault, of unknown age and also an upright thrust fault, has been mapped to the near east of the dam.

Local bedrock outcrops were identified only at the base of the Gull Riverbed, downstream of the dam structure. Glacial erratics and glacial overburden were noted on the steep left and right bank of the river.

2.2 EXISTING INFRASTRUCTURE

The Horseshoe Lake Dam is a concrete gravity structure 4.27 metres in height above the sill. It consists of four (4) stoplog operated sluiceways. The dam is comprised of 5 concrete gravity piers and a sill slab that extends for the length of the entire control structure. The deck is reported to be comprised of reinforced concrete and is 2.7 m wide and 33.6 m long. The dam is 45.27 m long and has a 17.23 m wingwall sections that is angled upstream of the dam on the right side.

The rock foundation level varies as per a historical drawing provided by PCA and as such the thickness of the concrete below the sill level varies in depth. This is detailed in Figure 2 within Appendix A.

3 SITE INVESTIGATION

3.1 GENERAL

A geotechnical site investigation was designed to determine concrete quality and strength within the dam. Drill holes were laid out through the piers, as well as in all four downstream sluice apron locations.

3.2 HISTORIC INVESTIGATIONS

GENIVAR Inc. (now WSP) was retained by Public Works and Government Services Canada to perform a concrete coring investigation of the Horseshoe Lake Dam to assess the general quality of the concrete as input to a Dam Safety Review (DSR). The coring program was undertaken on March 11, 2012 and advanced three (3) vertical core holes designated as CH12-1 through CH12-3 to depths of up to 7.1 m (23 feet) below the deck surface. The locations of these historic holes are identified in the Geotechnical Drilling Plan included in Appendix A.

The investigation determined, based on inspections and tests, that the concrete within the dam had variable poor quality and low compressive strength, with an average of 14.2 MPa. One sample broke during preparation and it was presumed that it had a compressive strength of less than 5 MPa. Oversize aggregate was present throughout the concrete and no rebar was observed. Bedrock was encountered in a single hole at a depth of 6.5 m. The bedrock was core sampled for a further 0.6 m to borehole termination. The bedrock was found to be primarily a sound granitic gneiss with a foliation perpendicular to the core axis.

3.3 2015 SITE INVESTIGATION

The concrete coring investigation of the Horseshoe Dam was completed by WSP as part of this study. The coring program included 8 (eight) vertical holes advanced in various locations on the dam, including through the piers and through the lower sluice apron area. Three holes were planned to be drilled through the concrete and 6 (six) metres into the rock to establish rock quality. All other holes were designed to drill through the concrete/rock interface and 0.5 m into the rock for verification of rock lithology. In order to ensure that the core was not an oversize piece of aggregate within the concrete and that bedrock had been cored, a minimum core length of 0.5 m into the rock was established. The drilling plan is included as Appendix A.

Drilling was completed by Walker Drilling Ltd., of Utopia, Ontario using a Winkie Percussion Drill. The core holes were advanced using a 30 mm inside diameter (ID) diamond impregnated coring pit, with river water used for drilling lubrication. Sampling intervals were continuous from the deck surface to termination depth.

Both concrete and rock samples were logged both in the field (for DH15-1, DH15-2) and indoors for DH15-3, DH15-5 and DH15-8.

At the site, core samples were placed into labelled boxes for transport.

All boxes were later reviewed, core recovery was measured, and core samples were placed into labelled sampling bags for transport. In addition, core was photographed, and the rock was geotechnically logged, detailing Rock Quality Designation (RQD), lithological, structural and rock strength details.

Core samples of both the concrete and rock were selected and submitted to strength testing, by point load testing, to determine compressive strength.

Concrete slurry and spoils from the rock coring operation were contained and removed from site. Drilling slurry was transferred into barrels, and the material was removed by Walker Drilling and transported to a registered waste facility.

Upon completion of the drilling, the core holes were backfilled using sand concrete mix and ½ inch gravel to the hole collar by the drilling contractor.

Selected samples of various locations, heights and rock lithologies were inspected, and sections selected and submitted for laboratory analysis. Point load tests, both axial and diametral, were completed on both concrete and bedrock samples at WSP's Peterborough laboratory. Results are summarized in the laboratory testing section following.

Not all holes were drilled as planned, due to time and access constraints. Drillholes DH15-4 and DH15-6 and DH15-7 were not completed as planned and DH15-3 was shortened due to drill issues.

Drillhole collar locations were measured, using a hand tape from two (2) known reference points. The following table details the planned and actual drillhole plan.

Table 1: Planned Versus Actual Drilling Plan

Hole ID	Easting (m)	Northing (m)	Planned Drilling (m)			Actual Drilling (m)			Measured Distance from Collar to hole bottom prior to grouting
			Estimated Depth to Top of Bedrock (A)	Depth of Drilling in Bedrock (B)	Depth of Hole (A + B)	Depth to Top of Bedrock (A)	Depth of Drilling in Bedrock (B)	Depth of Hole (A + B)	
DH15-1	682719.09	4981963.78	5.7	6.0	11.7	5.7	6.0	11.70	6.80*
DH15-2	682712.17	4981966.15	8.3	6.0	14.3	6.0	7.9	13.93	8.10*
DH15-3	682697.39	4981973.59	6.1	0.5	6.6	6.1	0.0	6.10	6.10
DH15-4	682691.03	4981977.27	4.8	6.0	10.8	0.0	0.0	-	-
DH15-5	682713.95	4981977.27	3.5	0.5	4.0	0.7	0.8	1.53	1.53
DH15-6	682707.47	4981966.21	2.8	0.5	3.3	0.0	0.0	-	-
DH15-7	682700.33	4981969.65	1.8	0.5	2.3	0.0	0.0	-	-
DH15-8	682692.87	4981971.76	1.3	0.5	1.8	1.1	1.5	2.56	2.56
				Total	54.8		Total	35.82	

*For DH15-1 and DH15-2, an obstruction was noted at the recorded distance from the collar prior to grouting.

The following is a summary of the observations noted for each of the drillholes.

3.3.1 DH15-1

This drillhole was drilled in the leftmost pier looking downstream and collared at the deck elevation.

Concrete was encountered from hole collar to 5.7 m in depth. The concrete consisted of a grey to buff coloured matrix with angular aggregate material ranging in size from centimetres to tens of centimeters. The aggregate is granitic type rock. Generally, the core recovery was poor and the core was very fragmented and broken.
A horizontal cold joint was noted at 1.19 m from the hole collar. More persistent weathering was noted at the collar as well as at the concrete/bedrock interface. Mechanical breakage was common at the concrete/aggregate interface.

The bedrock encountered within the drill hole was a feldspathic and amphibolite rich layered gneiss varying in colour from pink to dark grey. The rock is generally medium to coarse grained and exhibited localized iron and chloritic weathering. Gneissic layering and rock foliation are defined by biotite and chlorite mineralization oriented at approximately 45 degrees to perpendicular to the vertical core axis. The foliation varied from centimeters to tens of centimetres in spacing. Possible brittle fault zones with angular gouge were encountered at 6.29 m, 7.37 m and 8.97 m from the hole collar.

3.3.2 DH15-2

This drillhole was drilled in the second pier from the left hand side looking downstream and collared at the deck elevation. Concrete was cored from the collar elevation to 6.0 m down the hole. The concrete consisted of angular particles and some boulder sized aggregated pieces of granitic type material up to 35 cm in size contained within a porous and friable concrete matrix. The concrete core was found to break from a light hammer blow. The matrix can also be scratched with light knife pressure. The typical core length retrieved was between 10 and 15 cm in length. Weathered sections were noted at 1.4 m, 3.1 m and from 5 to 6 m from the hole collar.

Rock was drilled from the concrete/bedrock interface at 6.0 from hole collar to 13.93 m (hole termination). In general the rock can be described as layered gneiss, with colour varying from pink to light grey to dark grey. Some chloritic alteration was observed and joints were noted to be oriented at approximately 45 degrees to the vertical core axis. Joint spacing varied from centimetres to tens of centimetres. Possible fault zones, with gouge material, decreased rock quality and poor recovery, were encountered at 6.0 m, 7.5 m, 8.1 m, 8.6 m, 9.8 m, 10.7 m, 12.0 m and 12.9 m from the hole collar. Nearing the end of the hole, the foliation was oriented perpendicular to the core axis.

3.3.3 DH15-3

Drillhole DH15-3 is located on the fourth pier from the left side looking downstream. This hole was only drilled in concrete due to drill issues. The hole was terminated on the concrete/bedrock interface at 6.1 m from the hole collar.

The concrete was described as small to medium grained concrete with iron staining and localized weathering. Aggregate ranged from centimetres to tens of centimetres in size and varied in shape from subrounded to angular for large size aggregate and subrounded to rounded for smaller aggregates. The Matrix was buff to grey to weathered. Very poor core recovery was recorded in this hole due to a combination of poor quality concrete and drilling issues. A heavily weathered section was recorded form 0.5 m to 0.65 m from the hole collar. Localized pitting of the concrete was recorded.

3.3.4 DH15-4

This drillhole was not drilled due to time constraints.

3.3.5 DH15-5

Drillhole DH15-5 was collared on the dam apron, below the control structure, on the leftmost sluice (looking downstream). Concrete was encountered from collar to 0.68 m. The aggregate was rounded to angular with sizing up to 10 cm in size. The matrix was grey to buff coloured and could be scratched with a knife. All recorded breaks were mechanical. The concrete core recovered was of extremely poor quality and only a single small sample could be selected for further testing.

Rock was encountered from 0.68 m to 1.5 m (hole termination). The bedrock is described as grey banded gneiss, with some light coloured layers (dirty white to grey) with poorly developed banding and foliation at approximately 45 degrees to the core axis. No significant weathering was visible on joint or foliation discontinuities.

3.3.6 DH15-6

This drillhole was not completed due lack of access to the apron area for water control purposes.

3.3.7 DH15-7

This drillhole was not completed due lack of access to the apron area for water control purposes.

3.3.8 DH15-8

Drillhole DH15-8 was collared on the right most apron (looking downstream). Concrete was encountered from hole collar to 1.07 m down the hole. A cold joint was measured at 0.51 m from the collar. The concrete is described as containing a fine grained aggregate with grey to buff coloured matrix and aggregate particles from centimetres to tens of centimetres in size varying in shape from rounded to angular. All core breaks were accessed as mechanical breaks.

Bedrock was intersected from 1.07 m from hole collar to 2.6 m (hole termination). Bedrock at the concrete/bedrock contact is described as a light grey to medium grey diorite that is fine grained and without any preferred mineral orientation. Muscovite and biotite seams were present. A fault with angular gouge was identified at 1.51 to 1.79 m from collar. Below the identified fault/gouge zone, the rock is a banded anorthsite described as having a gneissic texture with well-developed banding consisting of light to dark grey and pink layers with minor chloritic alteration. Banding and joints and subperpendicular to the core axis with an average spacing of 5 cm

3.4 LAB TESTING RESULTS

Point load tests were completed on selected samples to determine rock and concrete strength indexes. The Point Load Test (PLT) is an accepted rock mechanic testing procedure used to calculate the rock strength index. Point load tests were completed at the WSP laboratory in Peterborough. Point load tests can be used to estimate uniaxial compressive strength with the use of index-to-strength and shape conversion factors.

The point load tests involved the compression of a rock or concrete sample between conical steel platens until failure occurs. Both diametral (loading on the side of the core) and axial (loading along the core axis) tests were completed.

3.4.1 CONCRETE TESTING RESULTS

Concrete samples were selected of various holes and at varying heights within the dam structure. The calculated unconfined compressive results from the PLT are detailed in the following table.

Table 2: Point Load Test Results of Concrete

Borehole #	Sample #	Sample Depth Start (m)	Sample Depth End (m)	Approximate UCS (MPa) (Diametral)	Approximate UCS (psi) (Diametral)	Approximate UCS (MPa) (Axial)	Approximate UCS (psi) (Axial)
DH15-1	15-1-1	1.78	1.92	12	1,740	28	4,061
DH15-1	15-1-2	4.60	4.76	27	3,916	36	5,221
DH15-2	15-2-1	1.62	1.83	16	2,321	59	8,557
DH15-2	15-2-2	2.20	2.35	33	4,786	16	2,321
DH15-3	15-3-1	0.83	0.95	31	4,496	30	4,351
DH15-3	15-3-2	2.43	2.53	7	1,015	31	4,496
DH15-3	15-3-3	2.90	3.03	9	1,305	26	3,771
DH15-5	15-5-1	0.25	0.30	12	1,740	-	-
DH15-8	15-8-1	0.16	0.32	15	2,176	32	4,641
DH15-8	15-8-2	0.38	0.50	13	1,885	38	5,511
Average				18	2,538	33	4,770

Note: Sample DH15-5 could not be tested axially due to insufficient sample size.

Figure 3 in Appendix D shows a cross sectional view of the dam with the concrete strength sampled locations and strength results.

The dam has variable poor quality concrete with low compressive strength that ranged from 7 MPa to 59 MPa, with an average of 18 MPa for diametral and 33 MPa for axial PLT at the sampled conditions. The concrete, as in the 2012 campaign, was found to be relatively porous without any steel reinforcement. Horizontal cold joints within the concrete were located within two drillholes.

Consistent with the previous geotechnical campaign, aggregates of varying size (from mm to tens of centimetres in size) and shape (rounded to subrounded to angular) were present throughout the concrete in all sampled intervals. This oversized aggregate material is typical for dams of this vintage as it was cheaper to use large stone aggregate and less cement due to the relatively high cost of cement and the low cost of labour when the dam was constructed.

As a cautionary note, the PLT test results and the resultant unconfined compressive strengths are estimated to be on the high side of the in situ strength of the concrete for several reasons. First, a required minimum sample size is required for testing purposes. Poorer quality concrete was not able to be selected as it did not meet sample size requirements, or was not recovered in the drilling program as it disintegrated during the drilling process. The maximum aggregate size and the small core size may have played a considerable role in affecting the strength results of the concrete. The aggregate, consisting generally of gneissic rock, is much stronger than the concrete matrix. Some selected samples had large size aggregate which may have resulted in stronger than expected PLT results. For these reasons, it is suggested that the PLT completed in this study overestimate the strength of the concrete.

The axial PLT have a larger sample size required to complete the testing. Samples for the axial point load test should have a minimum ratio of length to diameter of 3. The diametral test has a length to diameter minimum ratio of 1.5. For this reason, the strengthening effects of the aggregate and the aggregate size may result in a higher axial PLT result.

3.4.2 BEDROCK TESTING RESULTS

Bedrock samples were selected of various holes and at varying heights within the dam structure. The calculated unconfined compressive results from the PLT are detailed in the following table.

Table 3: Point Load Test Results for Bedrock

Borehole #	Sample #	Sample Depth Start (m)	Sample Depth End (m)	Approximate UCS (MPa) (Diametral)	Approximate UCS (psi) (Diametral)	Approximate UCS (MPa) (Axial)	Approximate UCS (psi) (Axial)	Sample Type
DH15-1	15-1-3	7.55	7.70	58	8,412	107	15,519	Banded Anorthsite
DH15-1	15-1-4	7.90	8.22	145	21,030	214	31,038	Banded Anorthsite
DH15-1	15-1-5	10.95	11.21	30	4,351	107	15,519	Banded Anorthsite
DH15-2	15-2-3	7.25	7.46	21	3,046	16	2,321	Banded Anorthsite
DH15-2	15-2-4	9.70	9.8	24	3,481	20	2,901	Banded Anorthsite
DH15-2	15-2-5	12.20	12.3	108	15,664	76	11,023	Banded Anorthsite
DH15-5	15-5-2	0.68	0.93	128	18,565	108	15,664	Banded Gneiss
DH15-8	15-8-3	1.21	1.31	29	4,206	50	7,252	Diorite
DH15-8	15-8-4	1.98	2.11	18	2,611	14	2,031	Banded Anorthsite
Average				62	9,041	79	11,474	

An average unconfined compressive strength of 62 MPa for diametral and 79 MPa for axial tests was assessed. This corresponds to a medium strength rock (Bieniawski, 1984).

The results obtained in the testing program correlate well with the visual observations and field testing of the bedrock observed at the riverbed downstream of the dam. The rock was assessed as R3 or R4 rock (moderately strong to strong rock), after Robertson, 1987.

3.5 ROCK QUALITY DESIGNATION

Rock Quality Designation (RQD) is a rough measure of the degree of joint or fracture in a rock mass, measured as a percentage of the drill core in lengths of 10 cm or more and was developed in 1964 by D.U. Deere. RQD is defined as the quotient:

$$RQD = \frac{Sum\ of\ lengths\ of\ core\ longer\ than\ 10\ cm\ measured\ along\ the\ core\ axis}{Total\ length\ of\ core\ measured}\ x\ 100\%$$

The following table details the core recovery and the RQD for each of the holes:

Table 4: Rock Quality Designation of Bedrock for Horseshoe Lake Dam Drill Program

Hole ID	% Recovery	Rock Quality Designation (RQD)	RQD Classification
DH15-1	67	56	Fair quality rock
DH15-2	50	31	Poor quality rock
DH15-3*	-	-	
DH15-4**	-	-	
DH15-5	100	67	Fair quality rock
DH15-6**	-	-	
DH15-7**	-	-	
DH15-8	95	38	Poor quality rock

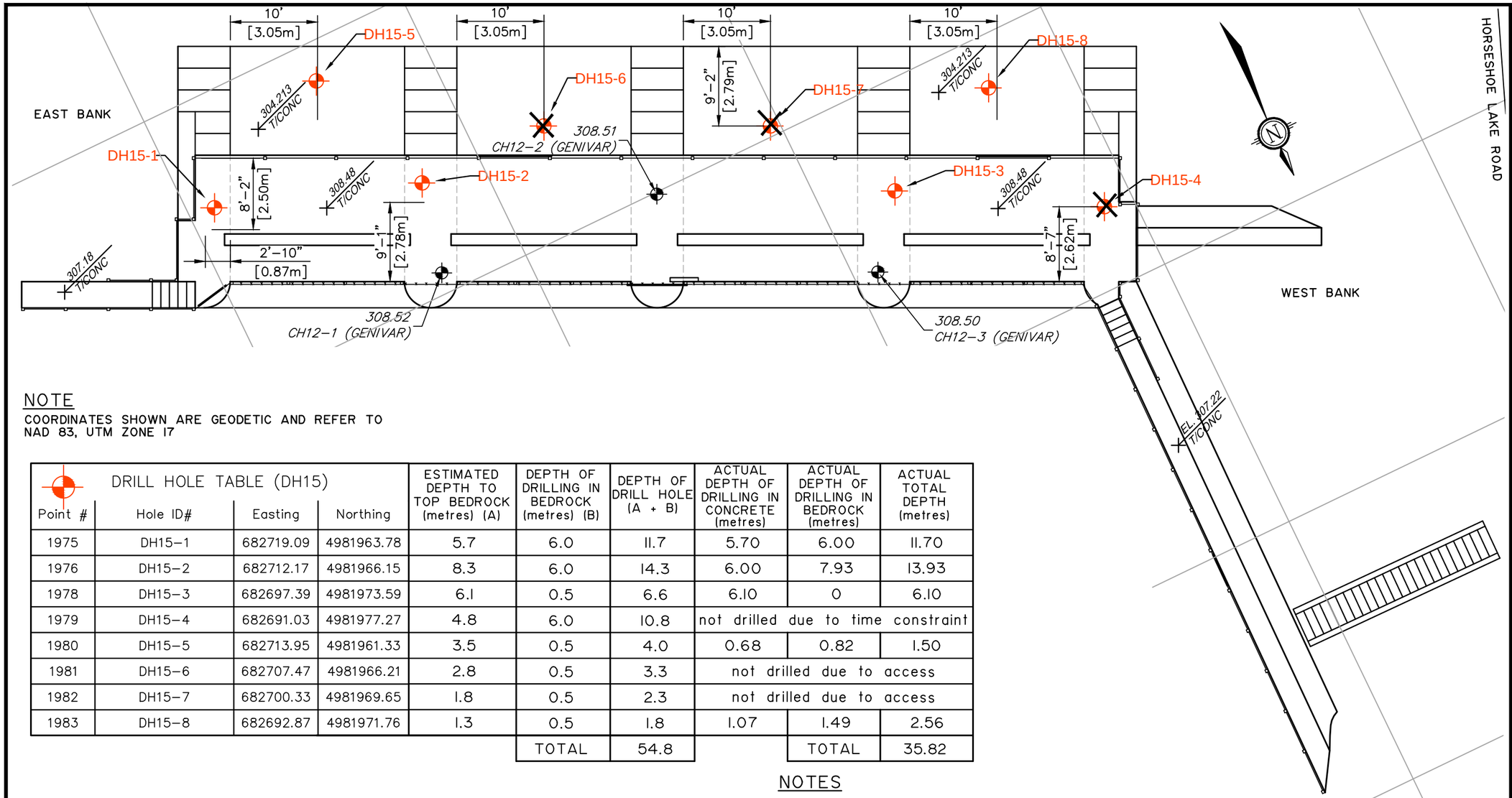
*bedrock was not drilled for hole DH15-3 due to drill issues
**DH15-4, DH15-6 and DH15-7 were not drilled due to access and time constraints

3.6 BEDROCK ELEVATIONS

The bedrock/concrete elevations intersected in drillholes are plotted on Figure 2 included in Appendix A. With the exception of DH15-5, the bedrock/concrete interface was at or near the 1909 historical plot. For hole DH15-5, the bedrock was interpreted to have been intersected at 0.7 m from the hole collar. Drilling was extended a further 0.82 m within rock, without any concrete matrix intercepts. It may be possible that this was a very large boulder that was placed and concrete formed around it to form the apron, or alternately, may be solid bedrock.

Appendix A

DRILL PLAN LOCATION



NOTE

COORDINATES SHOWN ARE GEODETIC AND REFER TO NAD 83, UTM ZONE 17

DRILL HOLE TABLE (DH15)

Point #	Hole ID#	Easting	Northing	ESTIMATED DEPTH TO TOP BEDROCK (metres) (A)	DEPTH OF DRILLING IN BEDROCK (metres) (B)	DEPTH OF DRILL HOLE (A + B)	ACTUAL DEPTH OF DRILLING IN CONCRETE (metres)	ACTUAL DEPTH OF DRILLING IN BEDROCK (metres)	ACTUAL TOTAL DEPTH (metres)
1975	DH15-1	682719.09	4981963.78	5.7	6.0	11.7	5.70	6.00	11.70
1976	DH15-2	682712.17	4981966.15	8.3	6.0	14.3	6.00	7.93	13.93
1978	DH15-3	682697.39	4981973.59	6.1	0.5	6.6	6.10	0	6.10
1979	DH15-4	682691.03	4981977.27	4.8	6.0	10.8	not drilled due to time constraint		
1980	DH15-5	682713.95	4981961.33	3.5	0.5	4.0	0.68	0.82	1.50
1981	DH15-6	682707.47	4981966.21	2.8	0.5	3.3	not drilled due to access		
1982	DH15-7	682700.33	4981969.65	1.8	0.5	2.3	not drilled due to access		
1983	DH15-8	682692.87	4981971.76	1.3	0.5	1.8	1.07	1.49	2.56
					TOTAL	54.8		TOTAL	35.82

2012 DRILL HOLES BY GENIVAR

Point No.	HOLE ID No.	Easting	Northing	DEPTH OF DRILLING IN CONCRETE (metres) (A)	DEPTH OF DRILLING IN BEDROCK (metres) (B)	DEPTH OF DRILL HOLE (A + B)
10070	CH12-1 (GENIVAR)	682712.92	4981969.28	0.69	N/A	0.69
10071	CH12-2 (GENIVAR)	682704.95	4981970.07	0.84	N/A	0.84
10072	CH12-3 (GENIVAR)	682699.16	4981975.89	6.5	0.5	7.0

NOTES

1. GROUTING - HOLES CHECKED FOR OPENNESS AND MEASURED PRIOR TO GROUTING. DRILL HOLE MEASUREMENTS FROM COLLAR,
   DHI5-1 OBSTRUCTION MEASURED AT 6.83m,
   DHI5-2 OBSTRUCTION MEASURED AT 8.12m.
2. HYDRAULIC PATCH INSTALLED ON SLUICE HOLES AT COLLAR. SANDBAG INSTALLED AT COLLAR TO ALLOW FOR CURING.

LEGEND

	DENOTES DRILL HOLE 2015
	DENOTES CORE HOLE GENIVAR 2012
	DENOTES ELEVATION AND DESCRIPTION
T/CONC	DENOTES TOP OF CONCRETE
CHI2-1,2,3	DENOTES 2012 DRILL HOLE BY GENIVAR

Public Works and Government Services Canada
Travaux publics et Services gouvernementaux Canada

Heritage Canals and Engineering Works
Ontario Region
Canaux historiques et travaux d'ingénierie
Région de l'Ontario

Canada

0 1 2 3 4 5 metres

WSP
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PROJECT:
HORSESHOE DAM REHABILITATION

TITLE:
GEOTECHNICAL PROGRAM PLAN

PROJECT NO: 121-15275-51

SCALE: 1 : 150 (WHEN PRINTED TO 11 X 17)

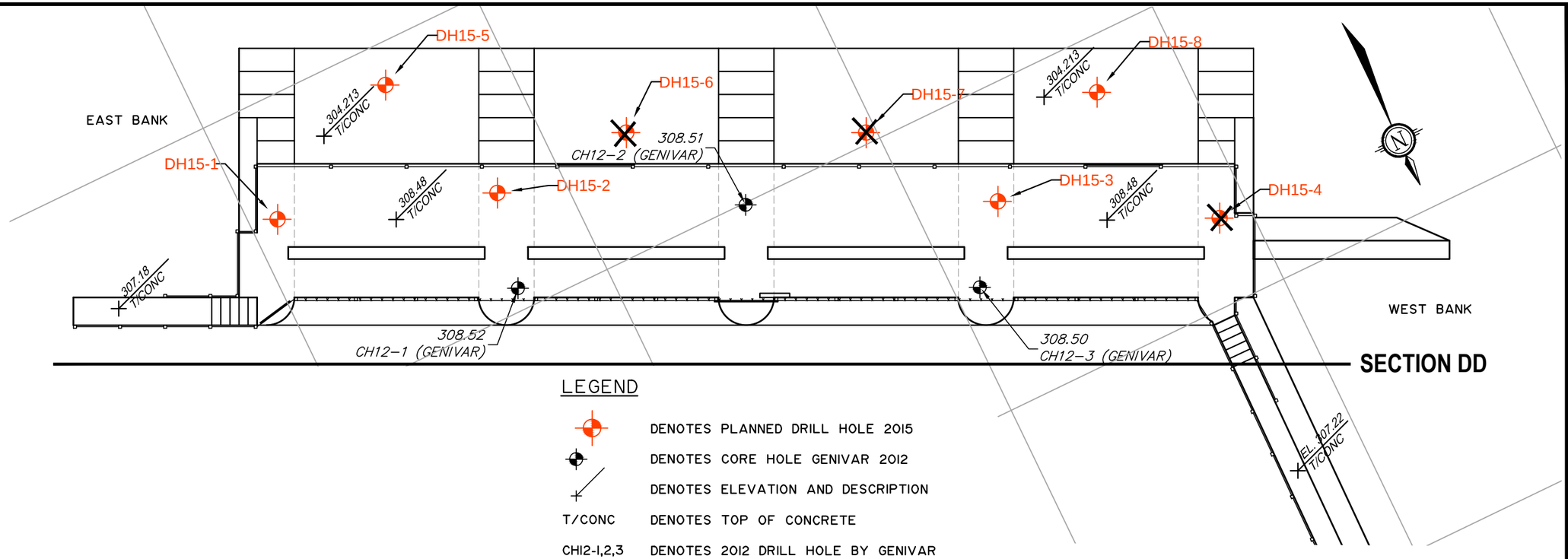
DRAWN BY: G. HOOGWERF

CHECKED BY: D. NELSON

ISSUE/REVISION: AS DRILLED ON SITE | 3

ISSUE DATE: AUG. 21, 2015

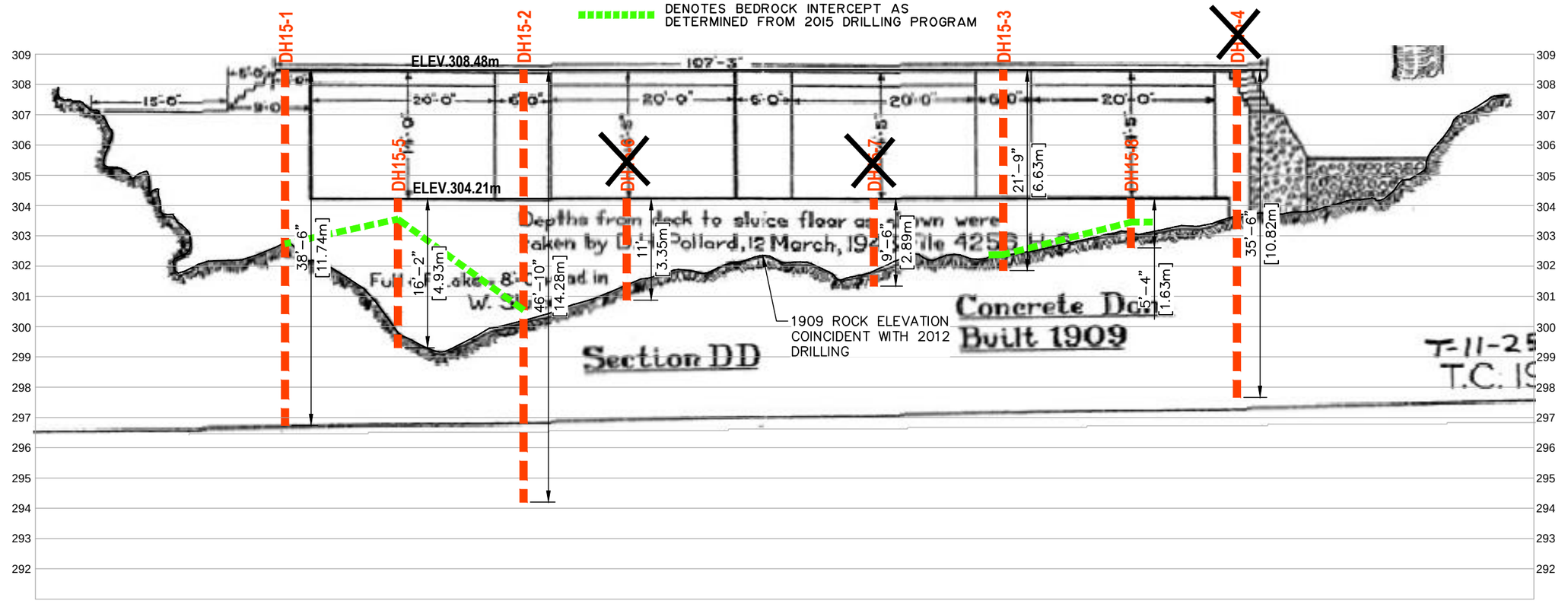
FIGURE NO: FIGURE 1



SECTION DD

LEGEND

- DENOTES PLANNED DRILL HOLE 2015
- DENOTES CORE HOLE GENIVAR 2012
- DENOTES ELEVATION AND DESCRIPTION
- T/CONC — DENOTES TOP OF CONCRETE
- CH12-1,2,3 — DENOTES 2012 DRILL HOLE BY GENIVAR
- DENOTES BEDROCK INTERCEPT AS DETERMINED FROM 2015 DRILLING PROGRAM



Public Works and Government Services Canada
Travaux publics et Services gouvernementaux Canada

Heritage Canals and Engineering Works
Ontario Region
Canaux historiques et travaux d'ingénierie
Région de l'Ontario

Canada

0 1 2 3 4 5 metres

PROJECT:
HORSESHOE DAM REHABILITATION

TITLE:
DRILL HOLE LOCATION PLAN

WSP
600 COCHRANE DRIVE, FLOOR 5,
MARKHAM (ONTARIO)
CANADA L3R 5K3
TEL.: 905 475-7270 | FAX: 905 475-5994
WWW.WSPGROUP.COM

PROJECT NO: 121–15275–51

SCALE: 1 : 150 (WHEN PRINTED TO 11 X 17)

DRAWN BY: G. HOOGWERF

CHECKED BY: D. NELSON

ISSUE/REVISION: AS DRILLED ON SITE | 3

ISSUE DATE: AUG. 21, 2015

FIGURE NO: FIGURE 2

Appendix B

SITE PHOTOS

Winkie Drill set up on DH15-1 looking downstream.

Set up on DH15-5 on July 3, 2015.

WSP
4502 Hanna Drive
Brockville (Elizabethtown), ON
K6T 1A9
613 342-8300
www.wspgroup.com

Horseshoe Dam Rehabilitation
Geotechnical Logging Photos

Project No.: 141-15777-00

Site Visit(s): June 9th – July 3rd 2015

Parks Canada Parcs Canada

Parks Canada Agency
Kingston, ON

Detail of set up and drilling on DH15-5 on July 3, 2015.

DH15-1 Box 1 of 2.
Concrete core of 30 mm size. Void at bottom of hole for last 30 cm (no core retrieved).

DH15-1 Box 2 of 2 showing rock core from 5.7 m to 11.7 m.
Feldspathic rich layered intrusive of moderate metamorphism with gneissic texture at 45 degrees to core axis. Medium to coarse grained with poorly defined foliation.

DH15-1 Box 2 of 2.
Detail of core showing medium to coarse grained units. Both dark banding and pink feldspathic banding are shown.

DH15-1 Box 2 of 2 showing detail of biotite seam

DH15-2 Box 1 of 2:
Showing concrete from hole collar to 8.3 m.
First 71 cm of core no retrieval due to highly weathered concrete.

DH15-2 Box 2 of 2:
Mostly dark banded rock units with some pink to buff coloured feldspathic units.

DH15-2 Box 1 of 2:
Detail of concrete with rounded to angular particles and granitic type aggregate material.

DH15-2 Box 1 of 2:
Detail of aggregate material and concrete.

DH15-2 Box 2 of 2:
Detail of gouge zone in rock. Rounded to angular rock fragments of small size.

DH15-2 Box 2 of 2.
Detail of large biotite crystals with no preferred orientation.

DH15-3 Box 1 of 1.
Concrete core showing poor recovery of core.

DH15-3 detail showing very friable concrete and poor recovery sections.

DH15-3 Box 1 Detail showing iron weathering within concrete core.

DH15-3 detail showing poor recovery.

DH15-5 Box 1 of 1:
concrete core at the top left and bedrock on the right of box.

DH15-4 detail showing poor concrete and small sample size of sample 15-5-1.

DH15-5 Box 1 of 1:
detail of bedrock section of very good rock quality. Sample 15-5-2.

DH15-8 Box 1 of 1.

DH15-8 detail showing concrete cold joint within concrete core at 0.51 m from collar.

DH15-8 detail showing biotite foliation at 1.21 from hole collar

DH15-8 detail showing large chlorite crystals and chlorite foliation/alteration.

Appendix C

SITE INVESTIGATION LOGS

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

CORE LOG Sheet 1 of 3

Hole ID:	DH15-1	Location:	Horseshoe Dam, Minden Hills, Parks Canada Agency
Drill Date:	June 22-24, 2015	Drill Method:	Percussion, Winkie Drill
Drill Crew:	Walker Drilling, Mark Byrne (Lead)	Hole Diameter:	30 mm ID
		Hole Depth:	11.7 m
		Hole Orient:	Vertical

Logged by: Darlene Nelson Date: Thursday, June 25, 2015

	Easting	Northing	Elevation
Survey Coordinates: (m)	682719.09	4981963.78	Dam Deck

Comments:

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
1	0 m - 5.7 m	80%	n/a	n/a	Concrete with angular and rounded aggregates varying in diameter from centimetres to tens of centimetres. Maximum size of aggregate is 20 centimetres. Aggregate is granitic type rock. Some sections of core very broken up and rounded fragments. Last 25 cm of concrete core was not recovered due to poor quality of concrete. For the top 90 cm of hole, there was no recovery of core due to poor quality concrete. Matrix is grey to buff. Core breaks with light hammer blow. Matrix scratches with light knife pressure. Very intensely to intensely fractured/broken. Horizontal cold joint identified at 1.19 m from hole collar. More persistent weathering at surface and structure/bedrock interface. Mechanical breaks commmon at aggregate/matrix interface. Very intensely to intensely fractured/broken.	Samples: **15-1-1** (1.78 m from hole collar, 13.5 cm in length) UCS_a = 28 Mpa UCS_d = 12 Mpa **15-1-2** (4.60 m from hole collar, 16 cm in length) UCS_a = 36 Mpa UCS_d = 27 Mpa

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

Hole ID:	DH15-1	CORE LOG			Sheet	2 of 3
Logged by:	Darlene Nelson				Date:	Thursday, June 25, 2015

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
2	5.7 m- 6.29 m	100%	85	Banded Anorthsite	Feldspathic rich layered intrusive of moderate metamorphism with gneissic texture. Alternating dark grey and pink layers with poorly defined biotite foliation. Medium to coarse grained with localized chloritic weathering. Foliation and predominant joint set at 45 degrees to core axis.	Alkaline Metatuff
3	6.29 m - 6.47 m	50%	0	Banded Anorthsite	Very fragmented rock for 10 cm - possible brittle gouge zone. Angular particles of rock	Fault Zone
4	6.47 m - 7.37 m	100%	44	Banded Anorthsite	As before, fewer amounts of biotite and no dark banding. Well developed foliation with biotite localized in areas. Foliation spacing less than 10 cm. Some foliation or jointing subparallel to drill access.	
5	7.37 m - 7.52 m	70%	0	Banded Anorthsite	Possible brittle fault gouge zone. Gouge with angular particles.	Possible fault zone

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

Hole ID:	DH15-1	CORE LOG			Sheet 3 of 3	
Logged by:	Darlene Nelson				Date:	Thursday, June 25, 2015
Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
6	7.52 m - 8.97 m	100% 100%	68	Banded Anorthsite	From 8.2 m to 8.4 m, intense chloritic weathering and pervasive foliation perpendicular to core axis. As before, feldspathic medium to coarse grain layered intrusive with localized dark fine grained banding. Foliation is more stronger developed in grey layers. Some chloritic weathering and biotite foliation.	Samples: **15-1-3** (7.55 from hole collar, dark band, 15 cm sample) UCS_a = 107 Mpa UCS_d = 58 Mpa **15-1-4** (7.9 m from hole collar, pink band, 32 cm sample) UCS_a = 214 Mpa UCS_d = 145 Mpa
7	8.97 m - 9.37 m	10%	0	Banded Anorthsite	As before with gouge zone. Very angular frangments less than 5 cm in size.	Fault Zone
8	9.37 m - 11.7 m EOH	100%	63	Banded Anorthsite	As before, fewer amounts of biotite and no dark banding. Well developed foliation with biotite localized in areas. Foliation spacing less than 10 cm. Biotite seams at 10.6 m, 10.7 m (horizontal to core axis), 10.82 m, 11.04 (horizontal to core axis).	Samples: **15-1-5** (10.95 m from hole collar, 26 cm sample) UCS_a = 107 Mpa UCS_d = 30 Mpa

Project No:. 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

CORE LOG Sheet 1 of 4

Hole ID:	DH15-2	Location:	Horseshoe Dam, Minden Hills, Parks Canada Agency
Drill Date:	June 24-26, 2015	Drill Method:	Percussion, Winkie Drill
Drill Crew:	Walker Drilling, Mark Byrne (Lead)	Hole Diameter:	30 mm ID
		Hole Depth:	13.93 m
		Hole Orient:	Vertical

Logged by: Darlene Nelson Date: Thursday, June 25, 2015

	Easting	Northing	Elevation
Survey Coordinates: (m)	682712.17	4981966.15	Collared on deck of dam

Comments: Hole on deck of dam in between Sluice 3 and 4 looking downstream

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
1	0 m - 6.0 m	100%	n/a	n/a	Concrete with angular particles and some boulder sized aggregate pieces of granitic type material up to 35 cm in size with friable concrete. Core is easily broken, often along aggregate boundaries. No long pieces of core were retrieved. First 28" of core there was not any core retrieval due to weathering for several other sections there was not any core retrieval in concrete due to weak concrete. Some aggregate pieces have foliation and joints. Core breaks with light hammer. Matrix scratches with light knife pressure. Aggregate has varied strength, some can be scratched with knife and some biotite seams and inclusions, some aggregate cannot be scratched with knife. Typical core size is 4-6" in length. Concrete appears porous. Weathered sections at 1.4, 3.1 and from 5-6 m.	Samples: **15-2-1** (1.62 m from hole collar, 21.0 cm in length) UCS_a = 59 MPa UCS_d = 16 MPa **15-2-2** (2.2 m from hole collar, 15.0 cm in length) UCS_a = 16 MPa UCS_d = 33 MPa

Project No:. 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

Hole ID:	DH15-2		CORE LOG		Sheet	2 of 4
Logged by:	Darlene Nelson			Date:		Thursday, June 25, 2015
Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
2	6.0 m - 6.8 m	50%	0%	Banded Anorthsite	Fault gouge with weathered rock with well developed foliation and chloritic weathering. Fine grained grey to black coloured.	Possible Fault gouge zone
3	6.8 m - 7.5 m	100%	60	Banded Anorthsite	Black to grey foliated banded anorthsite with light grey banding. Some chloritic alteration. Joints are at 45 degrees to core axis. Joint spacing is cm to tens of cm.	Sample: **15-2-3** (7.25 m from hole collar, dark band, 21 cm sample) UCS_a = 16 MPa UCS_d = 21 MPa
4	7.5 m - 7.7 m	10%	0	Banded Anorthsite	Fault zone with low recovery. Well developed biotite foliation and some chloritic weathering	Possible fault zone
5	7.7 m - 8.1 m	50%	0	Banded Anorthsite	White and pink feldspathic layer of banding with biotite micro crystals of no preferred orientation. Fine to medium grained with minor amounts of mafic minerals and pyrite mineralization. Biotite seam at 8.07 m. Poorer quality rock.	
6	8.1 m - 8.5 m	5%	0	Banded Anorthsite	Gouge material, fault like Poor core retrieval. Rounded and angular fragments from brittle fault area. Calcite vein.	Fault gouge

Project No:. 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

Hole ID:	DH15-2	CORE LOG	Sheet	3 of 4
Logged by:	Darlene Nelson	Date:	Thursday, June 25, 2015	

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
8	8.5 m-8.62 m	100%	100	Banded Anorthsite	Light coloured calcitic/quartz layer with medium sized crystals and plagioclase rich matrix.	
9	8.62 m - 9.3 m	5%	0	Banded Anorthsite	Fault gouge. Light and dark coloured angular framgents with muscovite and biotite. Little weathering.	Fault Gouge
10	9.3 m - 9.6 m	100%	0	Banded Anorthsite	Biotite seams within light coloured matrix with subhorizontal orientation Closely spaced joint spacing.	
11	9.65 m - 9.8 m	100%	40	Banded Anorthsite	White layer within rock with medium defined foliation of muscovite and some biotite. Medium sized quartz/calcite/plagioclase crystals. Foliation is subhorizontal with spacing varying from 1 to 10 cm	Sample: **15-2-4** (9.7 m from hole collar, dark band, 10 cm in length) UCS_a = 20 MPa UCS_d = 24 MPa
12	9.8 m - 10.1 m	0%	0	Banded Anorthsite	Fault gouge. Angular fragments.	Fault zone
13	10.1 m - 10.7 m	100%	70	Banded Anorthsite	Grey layered banded anorthsite with minor amounts of muscovite/biotite and minor weathering. Banding is subhorizontal.	

Project No:. 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

Hole ID:	DH15-2	CORE LOG		Sheet	4 of 4	
Logged by:	Darlene Nelson			Date:	Thursday, June 25, 2015	
Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
14	10.7 m - 11.0 m	50%	0	Banded Anorthsite	Fault gouge. Poor recovery	Fault zone.
15	11.0 m - 12.0 m	100%	82	Banded Anorthsite	Foliation/banding at approximately 45 degrees to core axis. Light grey with dark grey banding. Some biotite/muscovite. Some minor rust weathering on joint surfaces.	
16	12.0 m - 12.4 m	30%	0	Banded Anorthsite	Fault gouge. Poor recovery with some iron weathering.	Fault zone.
17	12.4 m - 12.9 m	100%	34	Banded Anorthsite	Pink and black layers of anorthsite. All layering is subhorizontal to the core axis	
18	12.9 m - 13.2 m	25%	0	Banded Anorthsite	Fault gouge with iron weathering on surfaces.	Fault zone.
19	13.2 m - 13.93 m **(EOH)**	100%	73	Banded Anorthsite	Pyrite inclusions and subhorizontal foliation/banding. Weathering present (iron) on surfaces. Pink and grey to dark coloured bandings. Joints are perpendicular to core axis.	Sample 15-2-5 (12.2 m from hole collar, 10 cm length) UCS_a = 76 MPa UCS_d = 108 MPa

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

CORE LOG Sheet 1 of 1

Hole ID:	DH15-3	Location:	Horseshoe Dam, Minden Hills, Parks Canada Agency
Drill Date:	25-Jun-15	Drill Method:	Percussion, Winkie Drill
Drill Crew:	Walker Drilling, Mark Byrne (Lead)	Hole Diameter:	30 mm ID
		Hole Depth:	6.0 m
		Hole Orient:	Vertical

Logged by: Darlene Nelson Date: Tuesday, July 28, 2015

	Easting	Northing	Elevation
Survey Coordinates: (m)	682697.39	4981973.59	Collared on deck of dam

Comments: Hole on deck in between Spillway #3 and #4 (from left to right) looking downstream

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
1	0 m - 6.1 m	40%	n/a	n/a	Small to medium grained concrete. Aggregate is weathering in some locations. Pitting in concrete. Large size metamorphic gnessic aggregate from cm to tens of cm in size. Rounded to subrounded to angular for larger sized particules. Matrix is buff to grey to weathered. Can be scraped with knife. Rock aggregate cannot be scraped with knife. Very poor recovery may be due to drill issues. Heavily weathered to dark buff at 0.5m to 0.65 m. Poor recovery in the following sections: 0.9 m to 2.1 m, 2.6 m to 3 m, 4.3 m to 4.5 m and 5.7 m to 5.9 m.	Samples: **15-3-1** (0.83 m from hole collar, 12 cm in length) UCS_a = 30 MPa UCS_d = 31 MPa **15-3-2** (2.43 m from hole collar, 10 cm in length) UCS_a = 31 MPa UCS_d = 7 MPa **15-3-3** (2.90 m from hole collar, 13.5 cm in length) UCS_a = 26 MPa UCS_d = 9 MPa

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

CORE LOG Sheet 1 of 1

Hole ID:	DH15-5	Location:	Horseshoe Dam, Minden Hills, Parks Canada Agency
Drill Date:	29-Jun-15	Drill Method:	Percussion, Winkie Drill
Drill Crew:	Walker Drilling, Mark Byrne (Lead)	Hole Diameter:	30 mm ID
		Hole Depth:	1.5 m
		Hole Orient:	Vertical

Logged by: Darlene Nelson Date: Tuesday, July 28, 2015

	Easting	Northing	Elevation
Survey Coordinates: (m)	682713.95	4981961.33	Collared on furthest left apron

Comments: Apron #4 on left side looking downstream

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
1	0 m - 0.68 m	75%	n/a	n/a	Concrete with aggregate (rounded to angular) with a particle size up to 10 cm. 100% mechanical breaks with core up to 4 cm in length. Matrix is grey to buff coloured and can be scratched with knife. Aggregate cannot be scratched with knife. Poor recovery of core. Sample taken may not be of sufficient length and quality to get results from point load testing.	Samples: **15-5-1** (0.25 m from hole collar, 5 cm in length) UCS_a = 12 MPa UCS_d = not done due to sample length
2	0.68 m - 1.50 m	100%	67	Banded Gneiss	Grey banded gneiss with poorly developed banding/foliation at approximately 45 degrees to the core axis. Some light coloured banding (dirty white to grey). Fine grained. No significant weathering visible on joint/foliation surfaces.	Samples: **15-5-2** (0.68 m from hole collar, 25 cm in length) UCS_a = 108 MPa UCS_d = 128 Mpa

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

CORE LOG Sheet 1 of 2

Hole ID:	DH15-8	Location:	Horseshoe Dam, Minden Hills, Parks Canada Agency
Drill Date:	3-Jul-15	Drill Method:	Percussion, Winkie Drill
Drill Crew:	Walker Drilling, Mark Byrne (Lead)	Hole Diameter:	30 mm ID
		Hole Depth:	1.5 m
		Hole Orient:	Vertical

Logged by: Darlene Nelson Date: Tuesday, July 28, 2015

	Northing	Easting	Elevation
Survey Coordinates: (Ft)	682692.87	4981971.76	Collared on right apron

Comments: Apron #1 on right side looking downstream

Run #	Depth	% Recovered	RQD	Profile (Rock Type)	Description	Remarks
1	0 m - 1.07 m	80%	n/a	n/a	Fine to coarse grained aggregate with grey to buff coloured matrix. Aggregate size cm to 10 cm. Rounded to angular particles. Matrix can be scraped with a knife. 100% mechanical breaks. Aggregate cannot be scraped with a knife. Cold joint at 0.51 m from hole collar.	Samples: **15-8-1** (0.16 m from hole collar, 16 cm in length) UCS_a = 32 Mpa UCS_d = 15 Mpa **15-8-2** (0.38 m from hole collar, 12 cm in length) UCS_a = 39 Mpa UCS_d = 13 Mpa

Project No.: 121-15275-51
Project Title: Horeshoe Dam Rehabilitation

Hole ID:	DH15-8		CORE LOG		Sheet 2 of 2	
Logged by:	Darlene Nelson			Date:	Tuesday, July 28, 2015	
2	1.07 m to 1.51 m	100%	52	Diorite	Light grey to medium grey diorite. Fine grained massive with no visual crystals or preferred orientation. Muscovite and biotite seams. Foliation very poorly developed. Joints are defined by poorly developed foliation with spacing around 5 cm.	Samples: **15-8-3** (1.21 m from hole collar, 10 cm in length) UCS_a = 50 Mpa UCS_d = 29 Mpa
3	1.51 to 1.79 m	70%	0	Diorite	Possible fault gouge area with iron staining and angular particles	Possible fault gouge.
4	1.79 m - 2.6 m	100%	34	Banded Anorthsite	Gneiss with well developed banding of light to dark grey and pink layers and chloritic alteration. Banding joints are subperpendicular to drill axis. Joints/foliation has a spacing on average of 5 cm. Some iron staining at 2.1 m. Some larger size chlorite crystals in both grey and pink layers.	Samples: **15-8-4** (1.98 m from hole collar, 13 cm in length) UCS_a = 14 Mpa UCS_d = 18 Mpa

Appendix D

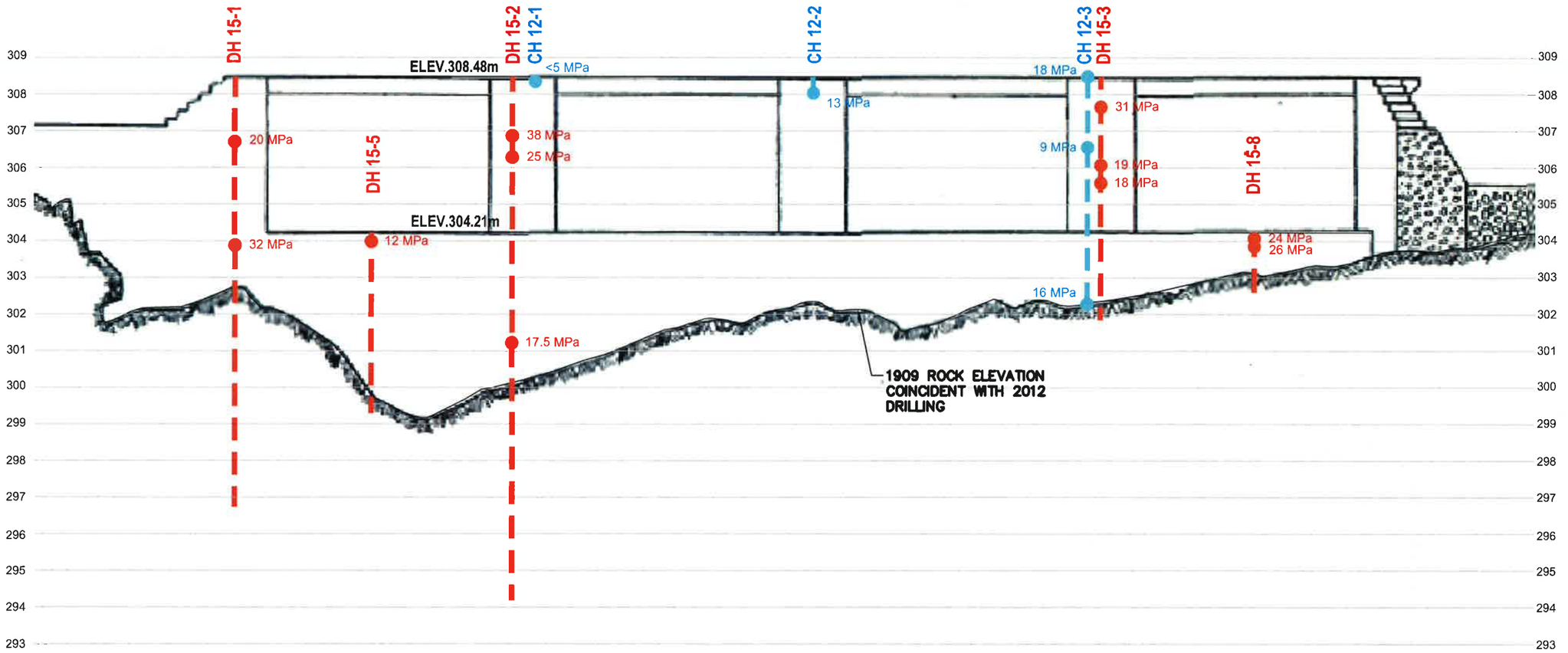
TESTING RESULTS

LEGEND

CH 12-1,2,3 DENOTES 2012 DRILL HOLE BY GENIVAR

DH 15-1,2,3,5,8 DENOTES 2012 DRILL HOLE BY GENIVAR

38 MPa DENOTES AVERAGE UNCONFINED COMPRESSIVE STRENGTH FROM POINT LOAD TESTING



Public Works and Government Services Canada
Travaux publics et Services gouvernementaux Canada

Heritage Canals and Engineering Works
Ontario Region
Canaux historiques et travaux d'ingénierie
Région de l'Ontario

Canada

0 1 2 3 4 5 metres

PROJECT:
HORSESHOE DAM REHABILITATION

TITLE:
CONCRETE TESTING RESULTS

WSP
600 COCHRANE DRIVE, FLOOR 5,
MARKHAM (ONTARIO)
CANADA L3R 5K3
TEL.: 905 475-7270 | FAX: 905 475-5994
WWW.WSPGROUP.COM

PROJECT NO: 121-15275-51

SCALE: 1 : 150
(WHEN PRINTED TO 11 X 17)

DRAWN BY: G. HOOGWERF

CHECKED BY: D. NELSON

ISSUE/REVISION: FOR REVIEW | 4

ISSUE DATE: SEPT. 16, 2015

FIGURE NO: FIGURE 3

Point Load Test Data ASTM D5731-08

Project: Horseshoe Dam Rehabilitation
Project No.: 121-15275-51
Tested By: LEK
Test Device: RocTest PIL-7
A_s of piston m^2: 0.000948
Date: 6/30/2015
Calibrated: 7/16/2014

Sample Details: Air Dried - tested in Laboratory

Sample ID				Data			Calculation						
Borehole Number	BH Depth Start (m)	BH Depth End (m)	Test Type (See Note)	Core Length, *(mm)*	Diameter (D' at failure) *(mm)*	Max Pressure (kPa)	Load (P) (kN)	D_e^2 (m^2)	D_e *(mm)*	I_s *(MPa)*	$F=(D_e/.05)^{0.45}$	$I_{s(50)}$ *(MPa)*	Approximate UCS (MPa) Table 1
DH15-1-1	1.78	1.91	d	135	30	740	0.702	0.90	30	0.78	0.795	0.62	12
DH15-1-2	4.60	4.76	d	160	30	1680	1.593	0.90	30	1.77	0.795	1.41	27
DH15-2-1	1.62	1.83	d	210	30	980	0.929	0.90	30	1.03	0.795	0.82	16
DH15-2-2	2.20	2.35	d	150	30	2080	1.972	0.90	30	2.19	0.795	1.74	33
DH15-3-1	0.83	0.95	d	120	30	1920	1.820	0.90	30	2.02	0.795	1.61	31
DH15-3-2	2.43	2.53	d	100	30	440	0.417	0.90	30	0.46	0.795	0.37	7
DH15-3-3	2.90	3.04	d	135	30	580	0.550	0.90	30	0.61	0.795	0.49	9

Notes:
d= diametral
a= axial
b= block
i= irregular

Statistics		
Mean Is(50)	Diametral	1.01

Point Load Test Data ASTM D5731-08

Project: Horseshoe Dam Rehabilitation
Project No.: 121-15275-51
Tested By: LEK
Test Device: RocTest PIL-7
A_c of piston m^2: 0.000948
Date: 6/30/2015
Calibrated: 7/16/2014

Sample Details: Air Dried - tested in Laboratory

Sample ID				Data			Calculation						
Borehole Number	BH Depth Start (m)	BH Depth End (m)	Test Type (See Note)	Core Length, *(mm)*	Diameter (D' at failure) *(mm)*	Max Pressure (kPa)	Load (P) (kN)	D_e^2 (m^2)	D_e *(mm)*	I_s *(MPa)*	$F=(D_e/.05)^{0.45}$	$I_{s(50)}$ *(MPa)*	Approximate UCS (MPa) Table 1
DH15-1-1	1.78	1.81	a	35	24	2040	1.93	1069.52	32.70	1.81	0.826	1.49	28
DH15-1-2	4.60	4.62	a	30	22	2140	2.03	840.34	28.99	2.41	0.782	1.89	36
DH15-2-1	1.62	1.64	a	27	22	3240	3.07	756.30	27.50	4.06	0.764	3.10	59
DH15-2-2	2.33	2.35	a	25	22.5	820	0.78	716.20	26.76	1.09	0.755	0.82	16
DH15-3-1	0.83	0.85	a	30	19	1620	1.54	725.75	26.94	2.12	0.757	1.60	30
DH15-3-2	2.43	2.45	a	25	17	1300	1.23	541.13	23.26	2.28	0.709	1.61	31
DH15-3-3	2.90	2.93	a	30	25	1720	1.63	954.93	30.90	1.71	0.805	1.38	26

Notes:
d= diametral
a= axial
b= block
i= irregular

Statistics		
Mean Is(50)	Axial	1.70

Axial, Block, Irregular samples $D_e^2=4(WD)/3.14$

Point Load Test Data ASTM D5731-08

Project: Horseshoe Dam Rehabilitation
Project No.: 121-15275-51
Tested By: KLC
Test Device: RocTest PIL-7
A_c of piston m^2: 0.000948
Date: 7/31/2015
Calibrated: 7/16/2014

Sample Details: Air Dried - tested in Laboratory

Sample ID				Data			Calculation						
Borehole Number	BH Depth Start (m)	BH Depth End (m)	Test Type (See Note)	Core Length, *(mm)*	Diameter (D' at failure) *(mm)*	Max Pressure (kPa)	Load (P) (kN)	D_e^2 (m^2)	D_e *(mm)*	I_s *(MPa)*	$F=(D_e/.05)^{0.45}$	$I_{s(50)}$ *(MPa)*	Approximate UCS (MPa) Table 1
15-1-3	7.55	7.73	d	175	30	3640	3.451	0.90	30	3.83	0.795	3.05	58
15-1-4	7.90	8.18	d	275	30	9140	8.665	0.90	30	9.63	0.795	7.65	145
15-1-5	10.95	11.21	d	149.16	30	1880	1.782	0.90	30	1.98	0.795	1.57	30
15-2-3	7.25	7.48	d	230	30	1240	1.176	0.90	30	1.31	0.795	1.04	20
15-2-4	9.70	9.75	d	51.11	31	1600	1.517	0.96	31	1.58	0.806	1.27	24
15-2-5	12.20	12.3	d	101.49	30	6820	6.465	0.90	30	7.18	0.795	5.71	108
15-5-2	0.68	0.93	d	250	30.5	8280	7.849	0.93	30.5	8.44	0.801	6.76	128
15-8-1	0.16	0.26	d	110.68	30	960	0.910	0.90	30	1.01	0.795	0.80	15
15-8-2	0.38	0.50	d	124.88	30	820	0.777	0.90	30	0.86	0.795	0.69	13
15-8-3	1.21	1.31	d	102.46	30	1820	1.725	0.90	30	1.92	0.795	1.52	29
15-8-4	1.98	2.12	d	134.57	30	1140	1.081	0.90	30	1.20	0.795	0.95	18

Notes:
d= diametral
a= axial
b= block
i= irregular

Statistics		
Mean Is(50)	Diametral	2.82

Point Load Test Data ASTM D5731-08

Project: Horseshoe Dam Rehabilitation
Project No.: 121-15275-51
Tested By: KLC
Test Device: RocTest PIL-7
A_c of piston m^2: 0.000948
Date: 7/31/2015
Calibrated: 7/16/2014

Sample Details: Air Dried - tested in Laboratory

Sample ID				Data			Calculation						
Borehole Number	BH Depth Start (m)	BH Depth End (m)	Test Type (See Note)	Core Length, *(mm)*	Diameter (D' at failure) *(mm)*	Max Pressure (kPa)	Load (P) (kN)	D_e^2 (m^2)	D_e *(mm)*	I_s *(MPa)*	F= $(D_e/.05)^{0.45}$	$I_{s(50)}$ *(MPa)*	Approximate UCS (MPa) Table 1
15-1-3	7.55	7.58	a	34.78	30	9140	8.66	1328.50	36.45	6.52	0.867	5.66	107
15-1-4	7.90	7.93	a	34.76	24	15280	14.49	1062.19	32.59	13.64	0.825	11.25	214
15-1-5	10.95	10.98	a	34.78	27	8420	7.98	1195.65	34.58	6.68	0.847	5.66	107
15-2-3	7.25	7.27	a	34.44	20	1320	1.25	877.01	29.61	1.43	0.790	1.13	21
15-2-4	9.70	9.72	a	34.43	22.6	1340	1.27	990.73	31.48	1.28	0.812	1.04	20
15-2-5	13.20	13.22	a	34.67	27.5	6060	5.74	1213.94	34.84	4.73	0.850	4.02	76
15-5-1	0.24	0.28	a	34.63	40	1220	1.16	1763.69	42.00	0.66	0.925	0.61	12
15-5-2	0.68	0.71	a	34.62	27	8460	8.02	1190.15	34.50	6.74	0.846	5.70	108
15-8-1	0.16	0.18	a	34.65	23.5	2220	2.10	1036.77	32.20	2.03	0.820	1.67	32
15-8-2	0.38	0.40	a	34.63	17	2140	2.03	749.57	27.38	2.71	0.763	2.06	39
15-8-3	0.93	0.96	a	34.63	27	3920	3.72	1190.49	34.50	3.12	0.846	2.64	50
15-8-4	1.98	2.01	a	34.57	30	1180	1.12	1320.48	36.34	0.85	0.866	0.73	14

Notes:
d= diametral
a= axial
b= block
i= irregular

Statistics		
Mean Is(50)	Axial	3.51

Axial, Block, Irregular samples $D_e^2=4(WD)/3.14$