



**THURBER** ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
DEAD HORSE CREEK CONCRETE ARCH REHABILITATION  
HIGHWAY 17, WALSH TOWNSHIP  
DISTRICT OF THUNDER BAY, ONTARIO  
LATITUDE: 48.817896°, LONGITUDE: -86.686889°**

**G.W.P. No. 6811-14-00, SITE No. 48E-21/C**

**GEOCRES Number: 42D-51**

**Report**

**to**

**HATCH**

Date: August 31, 2018  
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**PART 1: FACTUAL INFORMATION**

**1. INTRODUCTION**

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) for the proposed rehabilitation of Dead Horse Creek concrete arch culvert on Highway 17, located in the Walsh Township, District of Thunder Bay, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the concrete arch culvert site and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber was retained by Hatch to carry out this foundation investigation under the Ministry of Transportation Ontario (MTO) Agreement Number 6016-E-0008.

**2. SITE DESCRIPTION**

The site is located on Highway 17, approximately 42 km east of Terrace Bay, Ontario. The key plan showing the general location of the culvert site is presented on the Borehole Location and Soil Strata Drawings in Appendix D.

Highway 17 runs in an east-west direction in the general area along the northern shoreline of Lake Superior. The culvert is oriented at a slight skew (about 9°) to the centreline of the highway. The culvert carries Dead Horse Creek flow in an southerly direction towards Lake Superior.

The historical culvert drawings dated March 1953 and Ontario Structural Inspection Manual (OSIM) prepared by MTO for a site inspection conducted on July 17, 2013, indicate that the existing structure is a 37.8 m long, 9.8 m wide and 4.6 m high single span concrete arch culvert



founded on strip footings. The clear span between two strip footings is approximately 9.1 m. The grade level of Highway 17 at the existing culvert is at an approximate Elevation of 237.6 m. The upstream and downstream water levels in the creek were measured at Elevation 229.31 m and 228.31 m, respectively, in October 2015, as shown on the preliminary structural GA drawings provided by Hatch.

The lands surrounding the Dead Horse Creek Culvert site predominantly consist of heavily forested areas with occasional lakes. Local topography is generally of medium to high relief with jagged, rugged, cliffed and knobby terrains. Photographs of the culvert and surrounding area are presented in Appendix C.

Based on the published geological information, the subsurface soils at the site generally consist of exposed bedrock or a thin veneer of till overlying bedrock. Bedrock geology map of the area shows that the bedrock consists of mafic to intermediate metavolcanics rocks.

### **3. INVESTIGATION PROCEDURES**

The borehole investigation and field testing program for this project was carried out between August 18 and August 28, 2017 and consisted of drilling and sampling six (6) boreholes, designated as Boreholes 17-28 to 17-33. Boreholes 17-28 was drilled at the inlet of the culvert at the streambed elevation and extended to a depth of 4.9 m (Elevation 223.7). Boreholes 17-29 to 17-33 were drilled on the roadway surface or from the embankment side slope and extended to depths between 3.0 m and 4.9 m (Elevations 231.9 and 234.8). Bedrock was proved by NQ or HQ coring in Boreholes 17-28, 17-29, 17-30, and 17-33.

Boreholes 17-31 to 17-33 were drilled through the asphalt pavement, to the east of the existing culvert, at approximately 10 m, 20 m and 30 m distance, respectively. These three boreholes were advanced to investigate the extent of and assess the need for frost taper leading to the culvert.

Utility clearances were obtained prior to the start of drilling. The ground surface elevations for the boreholes were derived from cross-sections and topographic drawings provided by Hatch. The coordinate system MTM NAD 83, Zone 14 was used for the approximate locations of the boreholes shown on the Borehole Locations and Soil Strata Drawing included in Appendix D.

All boreholes except 17-28 were drilled using a rubber track mounted drill rig equipped with continuous flight hollow and solid stem augers. Borehole 17-28 was advanced by coring using a portable electric powered Hilti coring machine. Soil samples were obtained from the boreholes at



selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). A Dynamic Cone Penetration Test (DCPT) was conducted in Borehole 17-31 starting at a depth of 3.0 m and extending to cone tip refusal at a depth of 3.7 m (Elevation 234.1).

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The supervisor logged the boreholes and processed the recovered soil and rock samples for transport to Thurber's laboratory for further examination and testing.

All rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined on site and further inspected and confirmed in the laboratory.

Upon completion of drilling operations, the boreholes were backfilled in general accordance with Ontario Regulation 903 as amended by Regulation 128/03. Completion details of the boreholes are summarized in Table 3.1.

**Table 3.1 – Borehole Completion Details**

<b>Borehole Number</b>	<b>Borehole Depth / Base Elevation (m)</b>	<b>Completion Details</b>
17-28	4.9 / 223.7	Borehole backfilled with bentonite holeplug to surface.
17-29	4.9 / 232.8	Borehole backfilled with bentonite holeplug and cuttings to 0.9 m, concrete to 0.2 m, then asphalt patch to surface.
17-30	4.0 / 231.9	Borehole backfilled with bentonite holeplug and cuttings to surface.
17-31	3.7 / 234.1	Borehole backfilled with cuttings to 0.6 m, concrete to 0.2 m, then asphalt patch to surface.
17-32	3.7 / 234.1	Borehole backfilled with bentonite holeplug and cuttings to 0.6 m, concrete to 0.2 m, then asphalt patch to surface
17-33	3.0 / 234.8	Borehole backfilled with bentonite holeplug and cuttings to 0.6 m, concrete to 0.1 m, then asphalt patch to surface

#### **4. LABORATORY TESTING**

All recovered soil samples were subjected to visual identification (VI) and to natural moisture content determination. Selected samples were also subjected to grain size distribution analyses



(sieve and/or hydrometer). The results of this laboratory testing program are shown on the Record of Borehole sheets included in Appendix A and on the figures included in Appendix B.

Point load tests were carried out on selected samples of intact rock cores in the laboratory to assist in evaluation of the unconfined compressive strength of the bedrock. Results of the point load tests are included in Appendix B and on the Record of Borehole sheets in Appendix A.

In order to assess the potential for sulphate attack on concrete foundations, as well as the potential for corrosion associated with the structural members, a surface water sample was collected from the creek upstream of the culvert. The samples were submitted to SGS Canada Inc., a CALA accredited analytical laboratory in Lakefield, Ontario, for analytical testing of corrosivity parameters and sulphate content. The results of the analytical testing are summarized in this report and are presented in Appendix B.

## **5. DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets included in Appendix A. A general description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and should be used for interpretation of site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.

In general, the subsurface conditions encountered below the existing embankment fill typically consisted of cobbles and boulders, or sandy silt overlying bedrock at a shallow depth. Bedrock outcrops are visible in the surrounding area. Descriptions of the individual strata are presented below.

### **5.1 Asphalt**

Approximately 100 to 175 mm thick asphalt was encountered in Boreholes 17-29, 17-31, 17-32 and 17-33.

### **5.2 Embankment Fill**

Embankment fill consisting of sandy gravel to gravelly sand with trace to some silt and clay and occasional cobbles, was encountered below the asphalt in Boreholes 17-29, 17-31, 17-32 and 17-33 and from the ground surface in Borehole 17-30. The thickness of the embankment fill, where fully penetrated, ranged from 0.9 m to 2.8 m and extended to depths of 0.9 m to 3.0 (Elevations 234.8 to 235.7).



SPT 'N' values recorded in the fill ranged from 3 to 102 blows for 0.3 m penetration, indicating a very loose to very dense relative density. Measured moisture contents ranged from 1 to 19 percent.

The results of grain size distribution analyses conducted on samples of the fill are presented on the Record of Borehole sheets included in Appendix A and are summarized in the following table. The results are also presented on Figure B1 in Appendix B.

Soil Particle	Percentage (%)
Gravel	19 to 59
Sand	30 to 73
Silt & Clay	7 to 11

### 5.3 Silt

A layer of silt, containing some sand, trace clay and gravel, was encountered at a depth of 3.0 m (Elevation 234.8) in Borehole 17-32. Borehole 17-32 was terminated in the silt layer at a depth of 3.7 m (Elevation 234.1).

One SPT 'N' value recorded in the silt was 67 blows for 0.3 m penetration, indicating a very dense relative density. The measured moisture content in the silt was 18 percent.

The results of a grain size distribution analysis conducted on the sample of the silt is presented on the Record of Borehole sheets included in Appendix A and is summarized in the following table. The results are also presented on Figure B2 in Appendix B.

Soil Particle	Percentage (%)
Gravel	4
Sand	15
Silt	75
Clay	6

### 5.4 Cobbles and Boulders

Cobbles and boulders were encountered in Borehole 17-28 from the ground surface. The layer of cobbles and boulders extended to the bedrock surface at a depth of 1.8 m (Elevation 226.8).





Samples of the cobbles and boulders were obtained through coring.

## 5.5 Bedrock

Schist bedrock was encountered and cored in Boreholes 17-28, 17-29, 17-30 and 17-33. The bedrock was grey to black in colour with vertical to steeply dipping foliation. Occasional mechanical breaks were noted throughout the bedrock cores. The bedrock is generally described as slightly to moderately weathered. The table below summarizes depths and elevations to the top of bedrock.

**Table 5.1 – Depths and Elevations of Top of Bedrock**

Borehole	Top of Bedrock	
	Depth (m)	Elevation (m)
17-28	1.8	226.8
17-29	2.0	235.7
17-30	0.9	235.0
17-33	2.1	235.7

Total Core Recovery (TCR) in the bedrock ranged from 55% to 100% with Solid Core Recovery (SCR) typically ranging from 0% to 100%. The Rock Quality Designation (RQD) determined from the recovered cores generally ranged from 0% to 100%, indicating very poor to excellent rock quality. The lower bound values of RQD were typically recorded near the bedrock surface.

Average unconfined compressive strengths (UCS) of the intact rock cores typically ranged between 72 MPa and 153 MPa, indicating strong to very strong strength. The UCS values are correlated from the point load tests (PLT) results presented in Appendix B. UCS values correlated from tests performed normal to the foliations are typically much higher than those correlated from tests performed parallel or subparallel to the foliations.

## 5.6 Groundwater Conditions

When possible, groundwater conditions were observed during drilling operations and groundwater levels were measured in the open boreholes upon completion of drilling. However, water was used in Boreholes 17-29, 17-30, and 17-33 for the coring operations and thus the actual groundwater levels could not be observed. Borehole 17-28 was drilled within the creek from the streambed. The groundwater levels measured in the open boreholes are summarized in the table below.



**Table 5.2 – Groundwater Measurements**

Borehole	Date	Water Level (m)		Remark
		Depth	Elevation	
17-28	August 28, 2017	-	228.8	Creek level at time of drilling
17-29	August 19, 2017	-	-	Water added to borehole for coring
17-30	August 18, 2017	-	-	Water added to borehole for coring
17-31	August 19, 2017	Dry	-	Open borehole
17-32	August 19, 2017	Dry	-	Open borehole
17-33	August 18, 2017	-	-	Water added to borehole for coring

The upstream and downstream water levels of Dead Horse Creek were measured at Elevation 229.31 m and 228.31 m, respectively, in October 2015, as shown on drawings provided by Hatch.

The above groundwater levels are short-term readings and seasonal fluctuations of the groundwater levels are to be expected. The groundwater levels may be at a higher elevation after periods of significant or prolonged precipitation.

## **6. CORROSIVITY AND SULPHATE TEST RESULTS**

A sample of the creek water was submitted for analytical testing of corrosivity parameters and sulphate. The results of the analytical tests are shown in the table below. The laboratory certificates of analysis are presented in Appendix B.



**Table 6.1 – Analytical Test Results**

<b>Parameter</b>	<b>Units (Water)</b>	<b>Creek Water (Upstream)</b>
Sulphide	mg/L	<0.006
Chloride	mg/L	0.91
Sulphate	mg/L	1.7
pH	No unit	7.50
Electrical Conductivity	µS/cm	81
Resistivity	Ohms.cm	12300
Redox Potential	mV	182

## **7. MISCELLANEOUS**

Thurber obtained subsurface utility clearances prior to drilling. Thurber obtained the northing and easting coordinates and ground surface elevations from measurements taken in the field relative to the topographic plans provided by Hatch.

RPM Drilling Inc. of Thunder Bay and OGS Inc of Almonte, Ontario supplied and operated the drilling, sampling and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Mr. John Zoldy of Thurber. Overall supervision of the field program was provided by Mr. Cory Zanatta, B.A.Sc. of Thurber.

Geotechnical laboratory testing was carried out at Thurber's geotechnical laboratory. Analytical laboratory testing was carried out by SGS Canada Inc.

Interpretation of the field data and preparation of this report was carried out by Mr. Cory Zanatta, EIT and Mr. Keli Shi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.



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**PART 2: ENGINEERING DISCUSSION AND RECOMMENDATIONS**

**8. GENERAL**

This report provides an interpretation of the geotechnical data in the factual report, and presents foundation recommendations for the rehabilitation of Dead Horse Creek concrete arch culvert located on Highway 17 in Walsh Township, District of Thunder Bay, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only to highlight those aspects, which could affect the design of the project. Contractors must make their own interpretation of the information provided as it may affect equipment selection, proposed construction methods and scheduling.

Information on the existing culvert site was obtained from the MTO Terms of Reference and the Ontario Structure Inspection Manual (Inspection Form) prepared by McCormick Rankin on January 23, 2014, based on an inspection conducted on July 17, 2013. The existing structure is a single span open footing concrete arch culvert. The culvert span is approximately 9.8 m between centrelines of the two 37.8 m long strip footings. The existing road grade above the culvert is at approximately Elev. 237.6 m, which indicates approximately 2.0 m of fill above the top of culvert at Elev. 235.6 m.

Preliminary discussions with HATCH and MTO indicate that rehabilitation of the concrete arch structure with a corrugated steel lining on the inside of the culvert barrel is being considered. It is understood that the liner will apply an additional load of about 60 kPa to the existing strip footings. The upper part of the existing footings will need to be widened to accommodate placement of the



liner, and it is anticipated that the space between the existing culvert and steel liner will be grouted.

## **9. FOUNDATION REHABILITATION**

### **9.1 Assessment of Existing Foundations**

Drawing number TWP#868-21-1-A, the Plan, Footing Elevations, and Details for the original construction of the existing arch structure, dated March 12, 1953, was provided to Thurber by HATCH. The drawing shows the original rock profile along both footing alignments and indicates that the stepped footings were to be dowelled into rock near the inlet/outlet or recessed into rock along the middle sections to largely follow the natural rock surface contours.

The water level within the creek was described as shallow during the current investigation. Numerous cobbles and boulders with rounded or angular edges dotted the creek channel and formed the uneven streambed. The cobbles and boulders were present in the creek channel upstream and downstream of the culvert.

Visual observations during field investigation suggest that the east footing is founded on exposed bedrock in the middle section. Embedment of the east footing below the creek bed near the inlet and outlet could not be visually confirmed but is likely shallow given the nearby outcrops. Borehole 17-28 drilled near the north end of the east footing encountered bedrock at a depth of 1.8 m overlain by cobbles and boulders. Voids are visible between the underside of footing and the exposed bedrock at several locations along the footing. Photos 5 and 6 of Appendix C show examples of voids at the north end and south end of the east footing wall, respectively. exposed bedrock is slightly to moderately weathered and locally split or fractured along foliations.

The underside of the west footing was not visible and likely extended below the creek bed, with the exception of the north end (inlet) where the footing base was observed to be resting on fractured/jointed rock with soil infilling. Boreholes drilled from the top of embankment or on the side slope approximately 10 to 20 m west of the west footing encountered bedrock at Elevations 235.0 and 235.7 m, which are approximately 9 to 10 m higher than the base of the west footing.

The Ontario Structure Inspection Manual (Inspection Form) indicates that the arch structure was in an overall fair condition during the time of inspection. No severe structural distress was observed in the concrete arch and both footings except where multiple vertical to sub-vertical cracks were visible in the sloped portion of the arch above the south end (outlet) of the east footing. Deterioration (spalling, cracking, honeycombing, etc.) of the footing concrete immediately below the cracks was also visible. The OSIM Inspection Form attributed these damages to localized weathering of rock under the east footing near south end and localized scour/voids



under west footing near north end. Small movement of the east footing near the outlet possibly due to scour/erosion of the footing base can not be precluded.

Based on the historical drawings and visual observations of the arch structure foundation and boreholes drilled on the roadway, the bases of both strip footings of the concrete arch culvert are mostly founded on bedrock.

## **9.2 Foundation Considerations for Rehabilitation**

Based on the existing conditions of the concrete arch culvert footings and the founding bedrock, the addition of a corrugated steel liner and associated load increase on the existing footings are considered a feasible rehabilitation alternative.

It is understood that the load on each footing will be increased by approximately 60 kPa due to the steel liner installation. To accommodate the metal arch inside the existing concrete arch, both footings will require widening on top by approximately 400 mm as shown on the preliminary GA drawing. The structural designer must verify that the concrete strength and structural integrity of the existing footings is adequate to carry the increased foundation loads. To help develop a thorough rehabilitation plan, a precondition survey of the existing footings is recommended. All visible structural distress should be repaired before adding steel liner. It is recommended that the following be considered from a foundation perspective prior to footing widening:

- 1) If rock excavation is needed for footing widening, extreme care should be taken to not damage the existing footing. Blasting should not be permitted for any rock excavation. Any loose rock pieces or rock debris should be removed from the founding surface. Any visible fractures, joints or unfavorably oriented foliations should be doweled or grouted to improve rock mass integrity in resisting the footing load.
- 2) The entire length of the footing should be inspected to assess the contact between the rock and footing concrete. Any gap or void between footing base and founding bedrock, if detected, must be filled with flowable concrete to re-establish the founding stratum and avoid stress concentration in the footings. Temporary formwork could be erected in front of the footings and flowable concrete could be pumped in as a possible method of filling the voids or gaps beneath the footings. Any voids or gaps that are exposed during any rock excavation should also be grouted.

All works related to rock excavation, treatment and/or grouting below the existing footing bases must not damage, destabilize or undermine the existing footings. Local area dewatering may be



required to allow works to be carried out in the dry.

For a concrete footing founded on the bedrock at this site, a factored geotechnical resistance at Ultimate Limit State (ULS) of 2,000 kPa is recommended for design of the new liner and associated rehabilitation work. The SLS condition will not govern for footings founded on the bedrock.

The lateral resistance of the footings may be computed using an unfactored friction coefficient of 0.70 for mass concrete on clean sound bedrock. Based on the historical drawing, the existing footings are either dowelled into bedrock or recessed/socketed in bedrock. Dowelling and socketing will significantly increase the footing resistance against sliding.

The design depth of frost penetration at this site is 2.2 m. Footings on bedrock at this site do not require frost protection.

### **9.3 Widening of Existing Footings**

The existing footings will be widened on top on the creek side by approximately 400 mm to allow for installation of the new liner. Any footing extension or base widening, if required, should be placed on the underlying bedrock. All loose/soft fluvial deposits, sand, gravel, cobbles/boulders, organic materials and rock fragments should be removed and a clean rock bearing surface exposed where footing concrete will be placed.

The bedrock surface is uneven and jointed where exposed along the middle section of the east footing and the north end (inlet) of the west footing. It may be necessary to remove a certain quantity of bedrock and the contract documents must alert the contractor to this possibility and must contain provisional items to pay for rock excavation. Care should be taken not to damage or destabilize the existing footings during rock excavation and removal. Blasting should not be permitted for any rock excavation.

Dowelling of the widening to the existing footing may be required to ensure structural integrity of the widened footing. Footing widening and addition of the new liner will result in load eccentricity on the existing footings. Effects of the eccentric footing loads on the overall structure should be assessed by the structural designer.

### **9.4 Frost Cover**

The depth of frost penetration at this site is approximately 2.2 m, as per OPSD 3090.100. Footings on bedrock at this site do not require frost protection.





The frost taper investigation conducted in Boreholes 17-31 to 17-33 indicated the presence of 2.1 to 3.0 m of sandy gravel to gravelly sand fill overlying bedrock or a silt deposit to approximately 30 m east of the centreline of the existing culvert.

The sandy gravel to gravelly sand fill and the bedrock is not frost susceptible. The silt underlying the fill in Borehole 17-32 is frost susceptible, however it is covered by 3.0 m of sand and gravel fill. Therefore, a new frost taper is not required in the culvert approaches.

## **10. SCOUR AND EROSION CONTROL**

Erosion protection should be provided at the culvert inlet and outlet. Design of the erosion protection measures should consider hydrologic and hydraulic factors and should be carried out by specialists in this field. Grouting of any voids at the base of the footing should be completed.

Typically, rock protection should be provided over all surfaces with which creek water is likely to be in contact. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion, in general accordance with OPSS 804.

## **11. EXCAVATION AND CREEK WATER CONTROL**

All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the embankment fill, silt, and sand and gravel at this site are classed as Type 3 soils above the water level and Type 4 soils below the water level.

Any Excavation and backfilling at the creek level should be carried out in accordance with OPSS 902. Based on the preliminary GA drawing, footing widening will be mostly carried out above the normal creek level. If rehabilitation of the existing footings extends below the creek water level, it may be necessary to construct a localized cofferdam and to employ active dewatering inside the cofferdam to depress the water level along the culvert footings. Dewatering operations should be carried out in accordance with OPSS 517.

Design of an effective dewatering system, if required, is the responsibility of the Contractor. The Contract Documents must alert him to this responsibility and the need to engage a dewatering specialist. Dewatering must remain operational and effective until culvert rehabilitation is completed. Suggesting wording for an NSSP in this regard is included in Appendix F.



## **12. CORROSION AND SULPHATE ATTACK POTENTIAL**

The results of the corrosivity and sulphate analytical tests conducted on the creek water from the current investigation indicates the following conditions at the location tested:

- The potential for corrosion or sulphate attack on concrete foundations from the surrounding surface water is considered to be negligible due to the low concentration of sulphate and chloride in the sample tested.
- The potential for surface water corrosion on metal is considered to be mild.

Appropriate protection measures commensurate with the above are recommended if metal structural elements are used.

## **13. CONSTRUCTION CONCERNS**

Potential construction concerns include, but are not necessarily limited to:

- Rock excavation may be required. The Contractor should be prepared to have appropriate equipment for excavation, handling, and removal. Care should be taken not to damage or destabilize the existing footings during rock any rock excavation. Blasting should not be used for any rock excavation.
- An effective dewatering/unwatering system must be employed, if required, to enable footing widening construction in the dry.
- The water level in the creek may fluctuate and be at higher elevation at the time of construction than indicated in the report.
- Grouting of any existing voids beneath the existing culvert footings must be completed before footing widening is undertaken and the new liner is installed.



#### 14. CLOSURE

Engineering analysis and preparation of this report was carried out by Mr. Cory Zanatta, EIT, and Mr. Keli Shi, P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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## **Appendix A**

### **Record of Borehole Sheets**

## SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

### 1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

### 2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

### 3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT <sup>(1)</sup> 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer



### 4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

### 5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


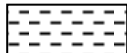



 Water Level  
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value      Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT      Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

# UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS $W_L < 50\%$	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. ( $W_L < 30\%$ ).
		CI	Inorganic clays of medium plasticity, silty clays. ( $30\% < W_L < 50\%$ ).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

## EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
<b>Fresh (FR)</b>	No visible signs of weathering.		
<b>Fresh Jointed (FJ)</b>	Weathering limited to the surface of major discontinuities.		CLAYSTONE
<b>Slightly Weathered (SW)</b>	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
<b>Moderately Weathered (MW)</b>	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
<b>Highly Weathered (HW)</b>	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
<b>Completely Weathered (CW)</b>	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength		Field Estimation of Hardness*
			(MPa)	(psi)	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

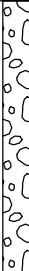
<u>TERMS</u>		Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.				
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.				
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.				
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail

# RECORD OF BOREHOLE No 17-28

1 OF 1

METRIC

W.P. 6806-14-01 LOCATION Dead Horse Concrete Arch N 5 408 893.0 E 327 819.0 ORIGINATED BY JZ  
 HWY 17 BOREHOLE TYPE Coring COMPILED BY AN  
 DATUM Geodetic DATE 2017.08.28 - 2017.08.28 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT  W <sub>P</sub>	NATURAL MOISTURE CONTENT  W	LIQUID LIMIT  W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL											
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE																			
228.6	GROUND SURFACE		1	GS			228																				
0.0	<b>COBBLES</b> and <b>BOULDERS</b> some sand and gravel		1	RUN													227										
226.8																											
1.8	<b>BEDROCK (SCHIST)</b> , moderately to slightly weathered, vertical foliation, grey Vertical fracture (25mm) at 1.8m, 2.2m, 2.4m and 2.9m  Horizontal fracture (25mm) at 1.9m, 2.2m, 2.3m and 2.7m  Horizontal fracture (25mm) at 2.9m, 3.5m, 4.2m, 4.5m and 4.6m	2	RUN		225										RUN #3 TCR=94% SCR=94% RQD=94% UCS=123MPa (Average)												
		3	RUN													224										RUN #4 TCR=100% SCR=100% RQD=100% UCS=110MPa (Average)	
		4	RUN																								
223.7																											
4.9	END OF BOREHOLE AT 4.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO SURFACE.																										

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE





# RECORD OF BOREHOLE No 17-29

1 OF 1

METRIC

W.P. 6806-14-01 LOCATION Dead Horse Concrete Arch N 5 408 877.6 E 327 797.3 ORIGINATED BY TY  
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2017.08.19 - 2017.08.19 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT				UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL      × LAB VANE				WATER CONTENT (%) w <sub>P</sub> w      w <sub>L</sub>										
237.7	GROUND SURFACE							20	40	60	80	100						GR	SA	SI	CL	
0.0	ASPHALT: (150mm)																					
0.2	SAND and GRAVEL, some silt and clay Very Dense Brown Moist (FILL)		1	SS	102																40   49   11 (SI+CL)	
					2	SS	73															
235.7	Occasional cobbles																				RUN #1 TCR=100% SCR=0% RQD=0%	
2.0	BEDROCK (SCHIST) , slightly to moderately weathered, vertical foliation, grey		1	RUN																		
																						RUN #2 TCR=100% SCR=27% RQD=7% UCS=128MPa (Average)
					2	RUN																
																					RUN #3 TCR=100% SCR=89% RQD=89% UCS=72MPa (Average)	
			3	RUN																		
232.8																						
4.9	END OF BOREHOLE AT 4.9m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.9m, CONCRETE TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.																					

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 0 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-30

1 OF 1

METRIC

W.P. 6806-14-01 LOCATION Dead Horse Concrete Arch N 5 408 864.5 E 327 786.0 ORIGINATED BY TY  
 HWY 17 BOREHOLE TYPE Solid Stem Augers/NQ Coring COMPILED BY AN  
 DATUM Geodetic DATE 2017.08.18 - 2017.08.18 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
235.9	GROUND SURFACE													
0.0	Sandy <b>GRAVEL</b> , some silt and clay Compact Moist (FILL)		1	SS	14									59 30 11 (SI+CL)
235.0							235							RUN #1 TCR=100% SCR=0% RQD=0% UCS=153MPa (Average)
0.9	<b>BEDROCK (SCHIST)</b> , slightly weathered, vertical foliation, grey to black		1	RUN										RUN #2 TCR=100% SCR=37% RQD=39% UCS=9MPa (Average)
			2	RUN			234							RUN #3 TCR=100% SCR=50% RQD=50%
			3	RUN										RUN #4 TCR=75% SCR=62% RQD=20% UCS=148MPa (Average)
			4	RUN			233							
231.9							232							
4.0	END OF BOREHOLE AT 4.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity 20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-31

1 OF 1

METRIC

W.P. 6806-14-01 LOCATION Dead Horse Concrete Arch N 5 408 874.7 E 327 826.5 ORIGINATED BY TY  
 HWY 17 BOREHOLE TYPE Solid Stem Augers/Dynamic Cone Penetration Test COMPILED BY AN  
 DATUM Geodetic DATE 2017.08.19 - 2017.08.19 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE									
237.8	GROUND SURFACE																
0.0	ASPHALT: (150mm)																
0.2	Gravelly SAND, some silt and clay Brown Moist (FILL)  Occasional cobbles		1	GS												33 56 11 (SI+CL)	
			2	GS													
			1	SS	3												
234.8	End of sampling and start DCPT																
3.0																	
234.1	END OF BOREHOLE AT 3.7m UPON DCPT REFUSAL. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT PATCH TO SURFACE.																
3.7																	

# RECORD OF BOREHOLE No 17-32

1 OF 1

METRIC

W.P. 6806-14-01 LOCATION Dead Horse Concrete Arch N 5 408 873.5 E 327 836.4 ORIGINATED BY TY  
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.08.19 - 2017.08.19 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  <b>γ</b>  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
237.8	GROUND SURFACE							<div>20406080100</div> <div>○ UNCONFINED + FIELD VANE</div> <div>● QUICK TRIAXIAL × LAB VANE</div>						
0.0	ASPHALT: (175mm)							<div>20406080100</div> <div>PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT</div> <div>W<sub>P</sub> W W<sub>L</sub></div> <div>WATER CONTENT (%)</div>						
0.2	SAND and GRAVEL, trace silt and clay		1	GS										19 73 8 (SI+CL)
237.2	Brown						237							
0.6	Moist (FILL)													
	Gravelly SAND, trace to some silt and clay		2	GS										
	Brown						236							
	Moist (FILL)													
234.8							235							
3.0	SILT, some sand, trace gravel and clay		1	SS	67									4 15 75 6
234.1	Very Dense													
3.7	Brown													
	Wet													
	END OF BOREHOLE AT 3.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.2m, THEN ASPHALT COLD PATCH TO SURFACE.													

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 17-33

1 OF 1

METRIC

W.P. 6806-14-01 LOCATION Dead Horse Concrete Arch N 5 408 872.1 E 327 846.3 ORIGINATED BY TY  
 HWY 17 BOREHOLE TYPE Solid Stem Augers COMPILED BY AN  
 DATUM Geodetic DATE 2017.08.18 - 2017.08.18 CHECKED BY CZ

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
							20	40	60	80	100	W <sub>p</sub>	W	W <sub>L</sub>			
237.8	GROUND SURFACE																
0.0	ASPHALT: (100mm)																
0.1	SAND and GRAVEL, trace silt and clay Brown Moist (FILL)		1	GS												38 55 7 (SI+CL)	
			2	GS													
235.7																	
2.1	BEDROCK (SCHIST), moderately weathered, vertical foliation, grey		1	RUN												RUN #1 TCR=55% SCR=17% RQD=0% UCS=99MPa (Average)	
234.8																	
3.0	END OF BOREHOLE AT 3.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.6m, CONCRETE TO 0.1m, THEN ASPHALT COLD PATCH TO SURFACE.																



## **Appendix B**

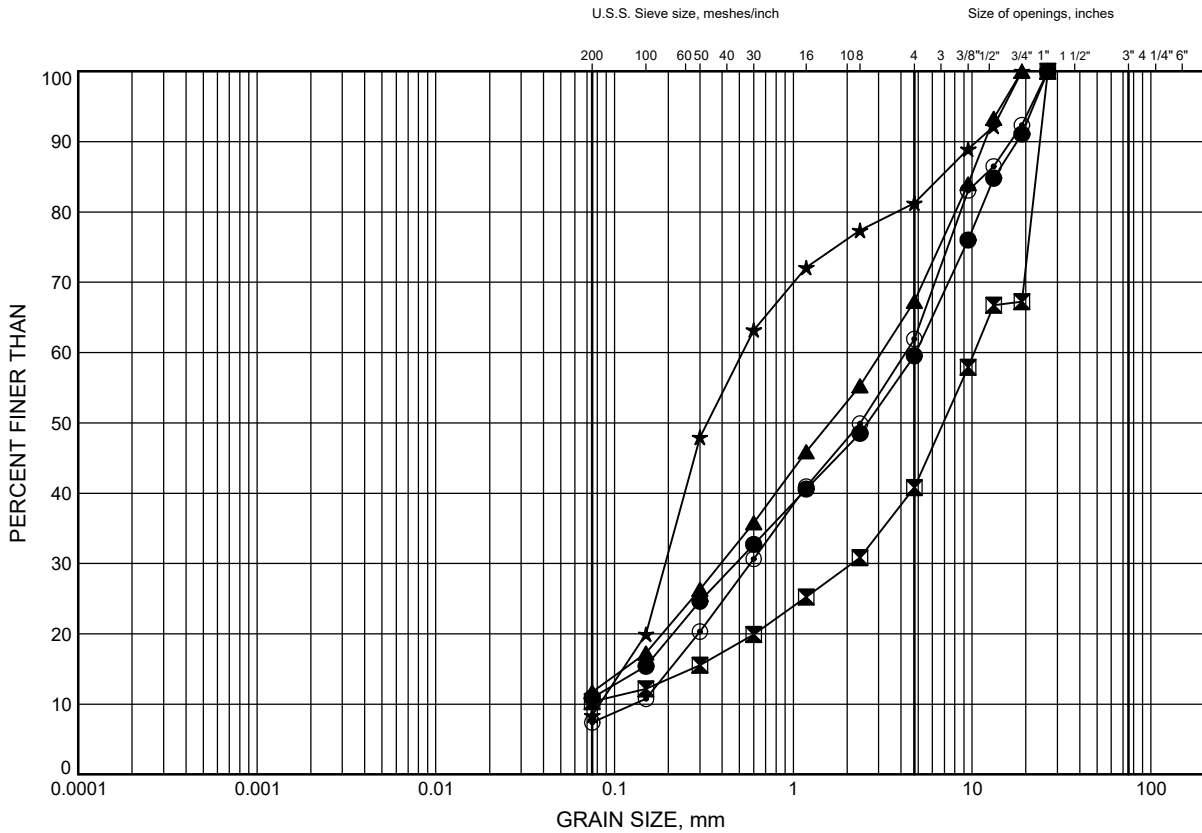
### **Geotechnical and Analytical Laboratory Test Results**

# Dead Horse Concrete Arch

## GRAIN SIZE DISTRIBUTION

FIGURE B1

### Sandy GRAVEL to Gravelly SAND FILL



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-29	0.3	237.4
⊠	17-30	0.3	235.6
▲	17-31	0.3	237.5
★	17-32	1.1	236.7
⊙	17-33	0.3	237.5

Date December 2017  
W.P. 6806-14-01

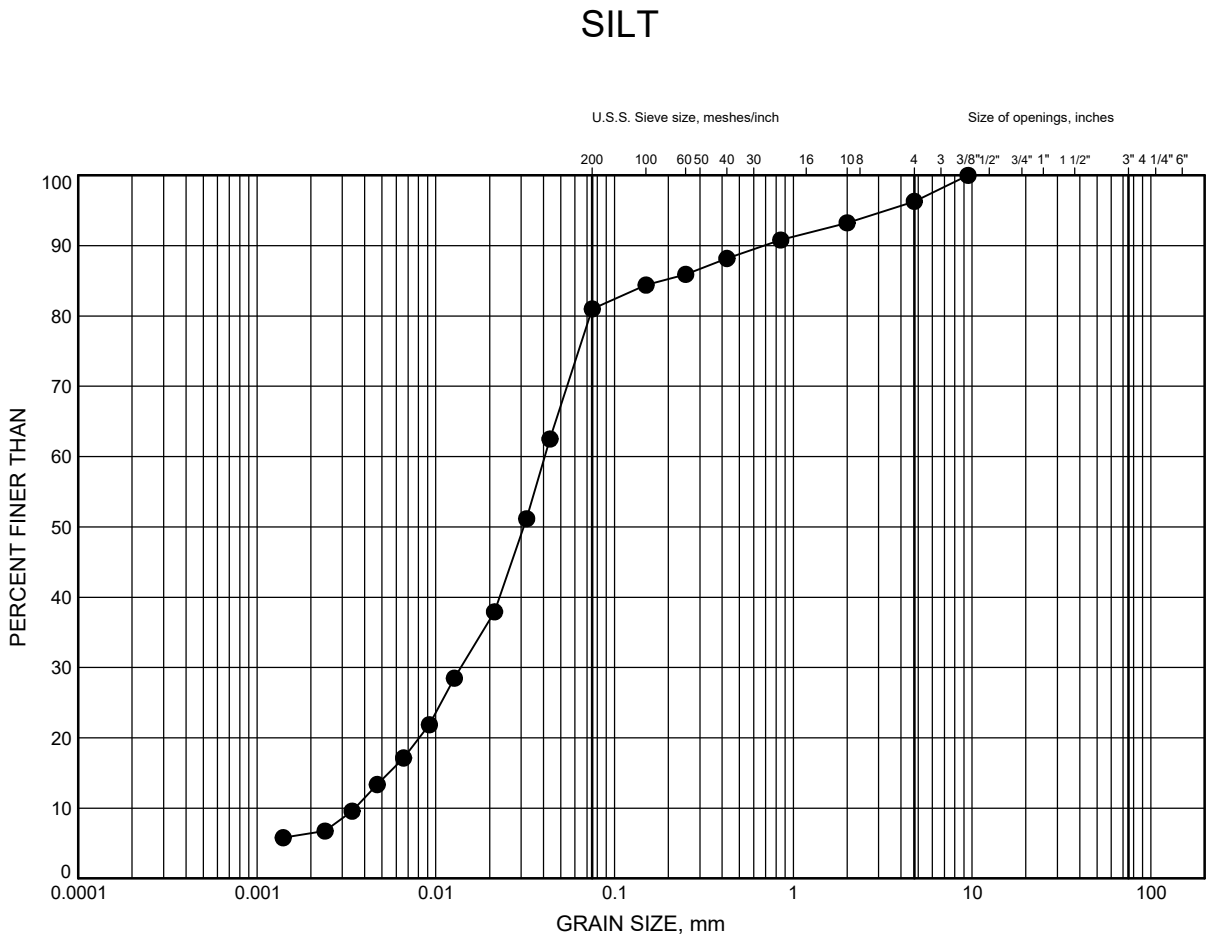


Prep'd AN  
Chkd. CZ

# Dead Horse Concrete Arch

## GRAIN SIZE DISTRIBUTION

FIGURE B2



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	17-32	3.4	234.4

Date December 2017  
W.P. 6806-14-01



Prep'd AN  
Chkd. CZ





## FINAL REPORT

CA12892-JUL17 R

Prepared for

**Thurber Engineering Ltd.**

## First Page

### CLIENT DETAILS

Client Thurber Engineering Ltd.

Address 103, 2010 Winston Park Drive  
Oakville, ON  
L6H 5R7.

Contact Mark Farrant

Telephone 905-829-8666 x 228

Facsimile

Email mfarrant@thurber.ca

Project

Order Number

Samples Water (2)

### LABORATORY DETAILS

Project Specialist Deanna Edwards, B.Sc, C.Chem

Laboratory SGS Canada Inc.

Address 185 Concession St., Lakefield ON, K0L 2H0

Telephone 705-652-2000

Facsimile 705-652-6365

Email deanna.edwards@sgs.com

SGS Reference CA12892-JUL17

Received 07/28/2017

Approved 01/23/2018

Report Number CA12892-JUL17 R

Date Reported 01/23/2018

### COMMENTS

Temperature of Sample upon Receipt: 23 degrees C

Cooling Agent Present: Yes

Custody Seal Present: Yes

### SIGNATORIES

Deanna Edwards, B.Sc, C.Chem





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# FINAL REPORT

CA12892-JUL17 R

**Client:** Thurber Engineering Ltd.

**Project:**

**Project Manager:** Mark Farrant

**Samplers:** John Zoldy

## PACKAGE: REG153 - 1.3 Other (ORP) (WATER)

**Sample Number** 7  
**Sample Name** 15545 Dead  
Horse Creek  
**Sample Matrix** Water  
**Sample Date** 26/07/2017

Parameter	Units	RL	Result
<b>1.3 Other (ORP)</b>			
pH	units	0.05	7.50

## PACKAGE: REG153 - Corrosivity Index (WATER)

**Sample Number** 7  
**Sample Name** 15545 Dead  
Horse Creek  
**Sample Matrix** Water  
**Sample Date** 26/07/2017

Parameter	Units	RL	Result
<b>Corrosivity Index</b>			
Resistivity (calculated)	ohms.cm	-9999	12300

## PACKAGE: REG153 - Metals and Inorganics (WATER)

**Sample Number** 7  
**Sample Name** 15545 Dead  
Horse Creek  
**Sample Matrix** Water  
**Sample Date** 26/07/2017

Parameter	Units	RL	Result
<b>Metals and Inorganics</b>			
Conductivity	µS/cm	2	81
Chloride	mg/L	0.04	0.91
Sulphate	mg/L	0.04	1.7



FINAL REPORT

CA12892-JUL17 R

Client: Thurber Engineering Ltd.

Project:

Project Manager: Mark Farrant

Samplers: John Zoldy

PACKAGE: REG153 - UNDEFINED (WATER)

Sample Number 7  
Sample Name 15545 Dead Horse Creek  
Sample Matrix Water  
Sample Date 26/07/2017

Parameter	Units	RL	Result
UNDEFINED			
Redox Potential	mV	-	182
Sulphide	mg/L	0.006	< 0.006



FINAL REPORT

CA12892-JUL17 R

QC SUMMARY

Anions by IC  
Method: EPA300/MA300-Ions1.3 | Internal ref.: ME-CA-IENVIIC-LAK-AN-001

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Chloride	DIO0425-JUL17	mg/L	0.04	<0.04	11	20	97	80	120	99	75	125
Sulphate	DIO0425-JUL17	mg/L	0.04	<0.04	0	20	99	80	120	98	75	125
Chloride	DIO0438-JUL17	mg/L	0.04	<0.04	1	20	99	80	120	111	75	125
Sulphate	DIO0438-JUL17	mg/L	0.04	<0.04	1	20	94	80	120	103	75	125

Conductivity  
Method: SM 2510 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Conductivity	EWL0430-JUL17	µS/cm	2	< 2	0	10	100	90	110	NA		



FINAL REPORT

CA12892-JUL17 R

QC SUMMARY

pH  
Method: SM 4500 | Internal ref.: ME-CA-IENVIEWL-LAK-AN-006

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
pH	EWL0431-JUL17	no unit	0.05	NA	0		100			NA		

Redox Potential  
Method: SM 2580 |

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Redox Potential	EWL0428-JUL17	mV	no	NA	5	20	109	80	120	NA		

Sulphide by SFA  
Method: SM 4500 | Internal ref.: ME-CA-IENVISFA-LAK-AN-008

Parameter	QC batch Reference	Units	RL	Method Blank	Duplicate		LCS/Spike Blank			Matrix Spike / Ref.		
					RPD	AC (%)	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
								Low	High		Low	High
Sulphide	SKA0007-AUG17	mg/L	0.006	<0.006	ND	20	98	80	120	102	75	125

## QC SUMMARY

---

**Method Blank:** a blank matrix that is carried through the entire analytical procedure. Used to assess laboratory contamination.

**Duplicate:** Paired analysis of a separate portion of the same sample that is carried through the entire analytical procedure. Used to evaluate measurement precision.

**LCS/Spike Blank:** Laboratory control sample or spike blank refer to a blank matrix to which a known amount of analyte has been added. Used to evaluate analyte recovery and laboratory accuracy without sample matrix effects.

**Matrix Spike:** A sample to which a known amount of the analyte of interest has been added. Used to evaluate laboratory accuracy with sample matrix effects.

**Reference Material:** a material or substance matrix matched to the samples that contains a known amount of the analyte of interest. A reference material may be used in place of a matrix spike.

**RL:** Reporting limit

**RPD:** Relative percent difference

**AC:** Acceptance criteria

**Multielement Scan Qualifier:** as the number of analytes in a scan increases, so does the chance of a limit exceedance by random chance as opposed to a real method problem. Thus, in multielement scans, for the LCS and matrix spike, up to 10% of the analytes may exceed the quoted limits by up to 10% absolute and the spike is considered acceptable.

**Duplicate Qualifier:** for duplicates as the measured result approaches the RL, the uncertainty associated with the value increases dramatically, thus duplicate acceptance limits apply only where the average of the two duplicates is greater than five times the RL.

**Matrix Spike Qualifier:** for matrix spikes, as the concentration of the native analyte increases, the uncertainty of the matrix spike recovery increases. Thus, the matrix spike acceptance limits apply only when the concentration of the matrix spike is greater than or equal to the concentration of the native analyte.



## LEGEND

## FOOTNOTES

**NSS** Insufficient sample for analysis.

**RL** Reporting Limit.

↑ Reporting limit raised.

↓ Reporting limit lowered.

**NA** The sample was not analysed for this analyte

**ND** Non Detect

Samples analysed as received. Solid samples expressed on a dry weight basis. "Temperature Upon Receipt" is representative of the whole shipment and may not reflect the temperature of individual samples.

SGS provides criteria information (such as regulatory or guideline limits and summary of limit exceedances) as a service. Every attempt is made to ensure the criteria information in this report is accurate and current, however, it is not guaranteed. Comparison to the most current criteria is the responsibility of the client and SGS assumes no responsibility for the accuracy of the criteria levels indicated. This document is issued, on the Client's behalf, by the Company under its General Conditions of Service available on request and accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). The Client's attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any other holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

This report must not be reproduced, except in full. This report supersedes all previous versions.

-- End of Analytical Report --



## ASTM D5731-08

Date Drilled:	Aug 28/17
Date Tested:	Sep 6/17
Tester:	JZ
Reviewed by:	WM

[illegible]



**THURBER ENGINEERING LTD.**

## POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 15595  
 Client: HATCH  
 Project Name: Replace 9 Culverts  
 Core Size: NQ BH No : 17-29

Date Drilled: Aug 18-19/17  
 Date Tested: Sep 8/17  
 Tester: JZ  
 Reviewed by: WM

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I <sub>s(50)</sub> (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	2	2.7	D	22.5	47.0	243.0	9.4	225.8	Schist	Very Strong
2	2	2.8	A	4.7	47.0	66.2	1.2	29.8	Schist	Medium Strong
3	3	4.4	A	4.9	47.0	66.7	1.3	31.2	Schist	Medium Strong
4	3	4.8	D	11.2	47.0	256.0	4.7	112.6	Schist	Very Strong
5										
6										
7					RUN #2 AVERAGE =			127.8		Very Strong
8					RUN #3 AVERAGE =			71.9		Strong
9										
10										
11										
12										
13										
14										
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34										

- \* It is ideal to perform axial test on core specimens with D/L ratio of  $1.1 \pm 0.1$   
 Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- \* Diametral Test should have  $0.7 \times D$  on either side of test point.
- \* Correlation factor to obtain UCS values is 24.



**THURBER ENGINEERING LTD.**

# POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 15595  
 Client: HATCH  
 Project Name: Replace 9 Culverts  
 Core Size: NQ BH No : 17-30

Date Drilled: Aug 18/17  
 Date Tested: Sep 6/17  
 Tester: JZ  
 Reviewed by: WM

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I <sub>s(50)</sub> (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	1.3	D	15.3	47.0	164.0	6.4	152.9	Schist	Very Strong
2	2	2.0	D	1.5	47.0	134.0	0.6	15.2	Schist	Weak
3	2	2.3	A	0.4	47.0	54.3	0.1	2.8	Schist	Very Weak
4	4	2.9	A	17.9	47.0	63.5	4.9	117.9	Schist	Very Strong
5	4	3.4	D	17.8	47.0	120.0	7.4	178.1	Schist	Very Strong
6										
7										
8					RUN#1 AVERAGE =			152.9		Very Strong
9					RUN#2 AVERAGE =			9.0		Weak
10					RUN#4 AVERAGE =			148.0		Very Strong
11										
12										
13										
14										
15										
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- \* It is ideal to perform axial test on core specimens with D/L ratio of  $1.1 \pm 0.1$   
 Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- \* Diametral Test should have  $0.7 \times D$  on either side of test point.
- \* Correlation factor to obtain UCS values is 24.



THURBER ENGINEERING LTD.

## POINT LOAD TEST SHEET

ASTM D5731-08

Job No: 15595  
Client: HATCH  
Project Name: Replace 9 Culverts  
Core Size: NQ BH No : 17-33

Date Drilled: Aug 18-19/17  
Date Tested: Sep 8/17  
Tester: JZ  
Reviewed by: WM

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I <sub>s(50)</sub> (MPa)	UCS (MPa)	Rock Type	Rock Strength (after Hoek & Brown, 1997)
1	1	2.3	D	9.9	47.0	93.3	4.1	98.8	Schist	Strong
2										
3										
4										
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34										

- \* It is ideal to perform axial test on core specimens with D/L ratio of  $1.1 \pm 0.1$   
Long pieces of core can be tested diametrically to produce suitable lengths for axial testing
- \* Diametral Test should have  $0.7 \times D$  on either side of test point.
- \* Correlation factor to obtain UCS values is 24.



## **Appendix C**

### **Selected Site Photographs**





**Photo 1: Highway 17 at Dead Horse Creek Culvert looking west (Taken: June 27, 2017)**



**Photo 2: Highway 17 at Dead Horse Creek Culvert looking east (Taken: June 27, 2017)**





**Photo 3: Dead Horse Creek Culvert inlet (Taken: August 27, 2017)**



**Photo 4: Dead Horse Creek Culvert outlet (Taken: August 27, 2017)**





**Photo 5: Voids beneath east footing near north end (Taken: August 27, 2017)**



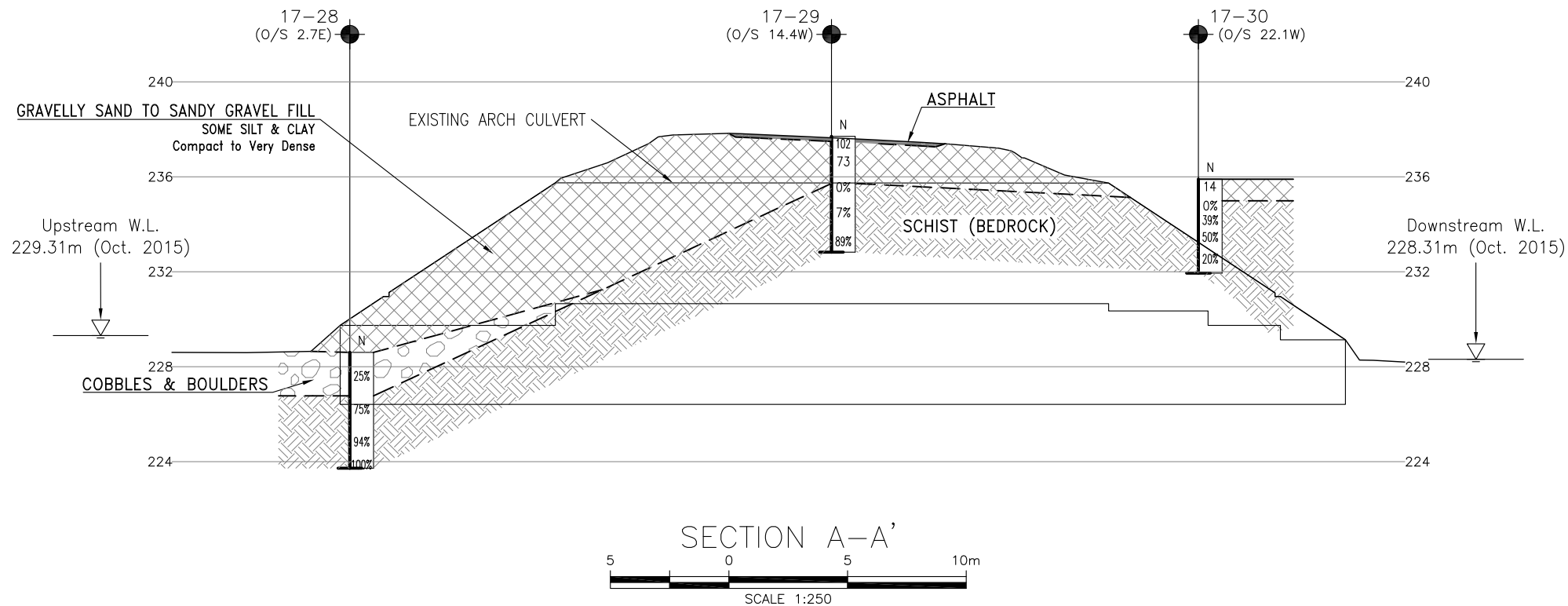
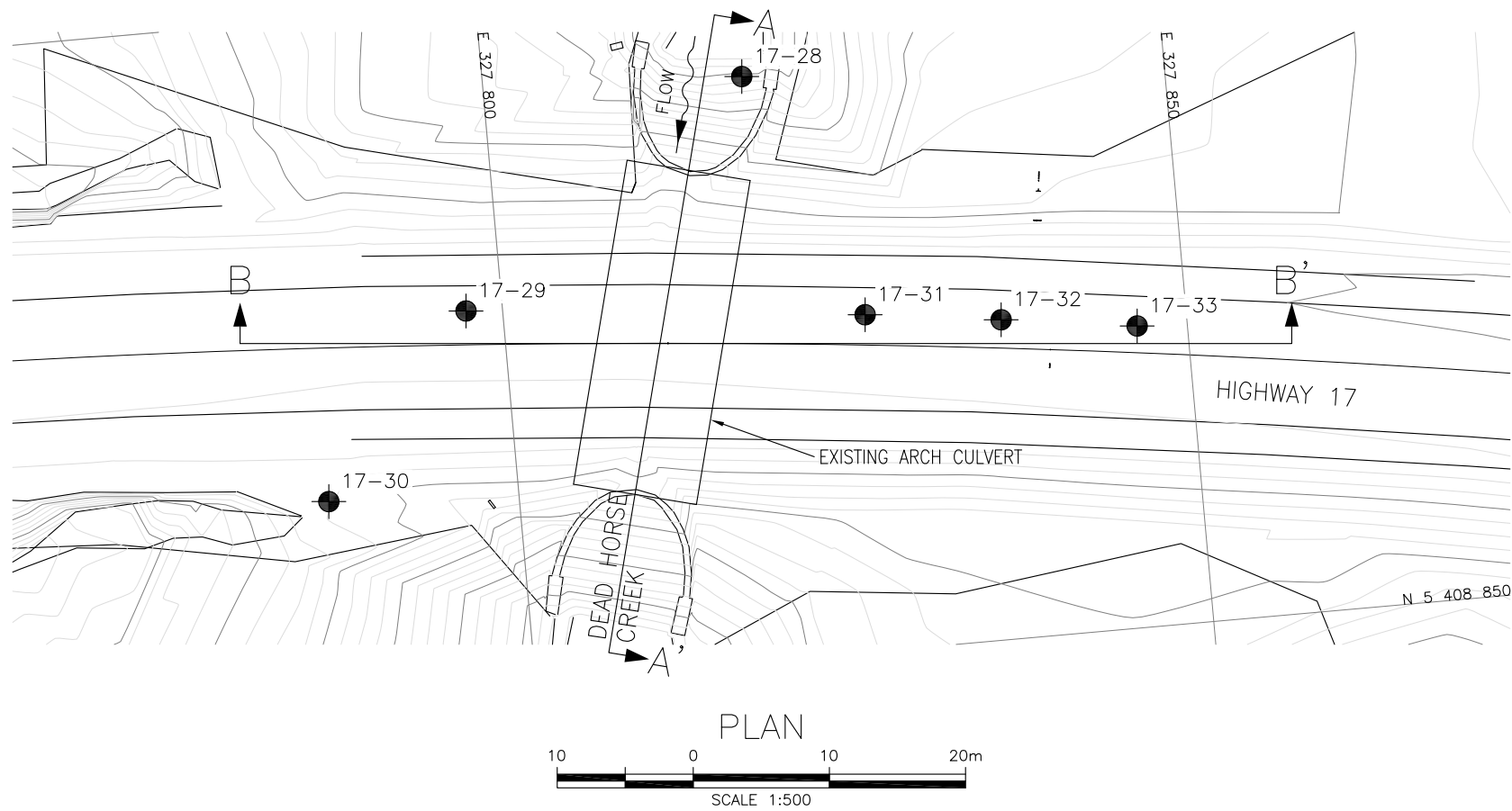
**Photo 6: Voids beneath east footing near south end (Taken: August 27, 2017)**



## **Appendix D**

### **Borehole Locations and Soil Strata Drawings**





METRIC  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN



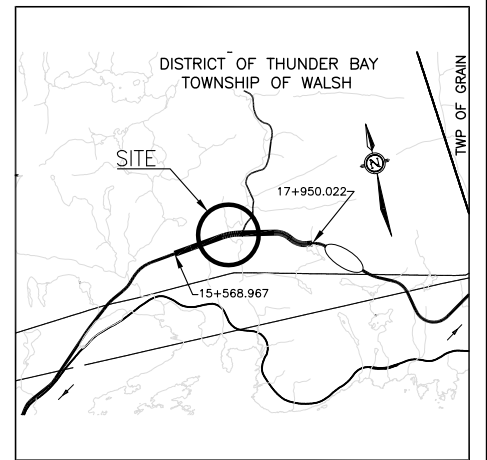
CONT No 6016-E-0012  
WP No 6806-14-01

HIGHWAY 17  
DEAD HORSE CREEK  
CULVERT  
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET  
4

**HATCH**



KEYPLAN

LEGEND

●	Borehole
⊙	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
▽	Water Level
⊥	Head Artesian Water
⊥	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-28	228.6	5 408 893.0	327 819.0
17-29	237.7	5 408 877.6	327 797.3
17-30	235.9	5 408 864.5	327 786.0
17-31	237.8	5 408 874.7	327 826.5
17-32	237.8	5 408 873.5	327 836.4
17-33	237.8	5 408 872.1	327 846.3

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42D-51

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	CZ	CHK PKC	CODE
DRAWN	MFA	CHK CZ	SITE 48E-21/C/STRUCT
			LOAD
			DATE
			AUG 2018
			DWG 2



CONT No 6016-E-0012  
WP No 6806-14-01

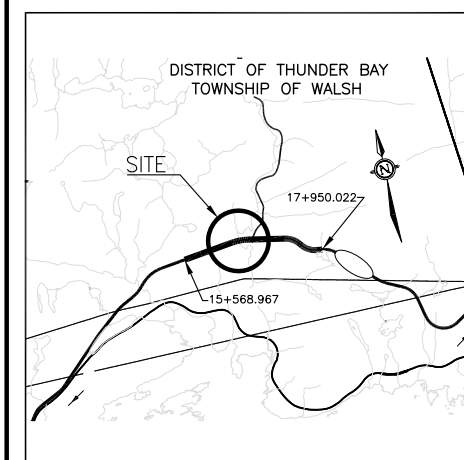
HIGHWAY 17  
DEAD HORSE CREEK  
CULVERT  
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET  
5

# HATCH








**THURBER** ENGINEERING LTD.



## KEYPLAN

## LEGEND

	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
17-28	228.6	5 408 893.0	327 819.0
17-29	237.7	5 408 877.6	327 797.3
17-30	235.9	5 408 864.5	327 786.0
17-31	237.8	5 408 874.7	327 826.5
17-32	237.8	5 408 873.5	327 836.4
17-33	237.8	5 408 872.1	327 846.3

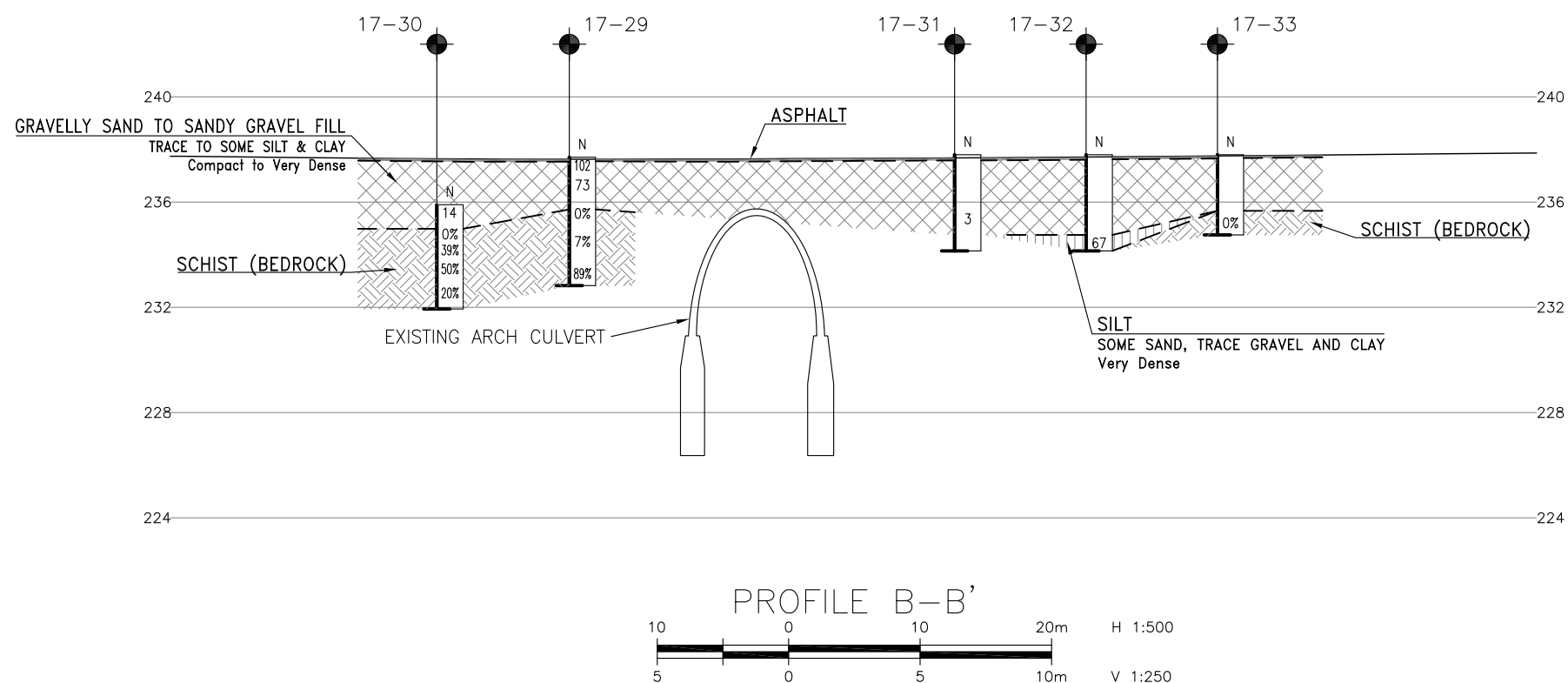
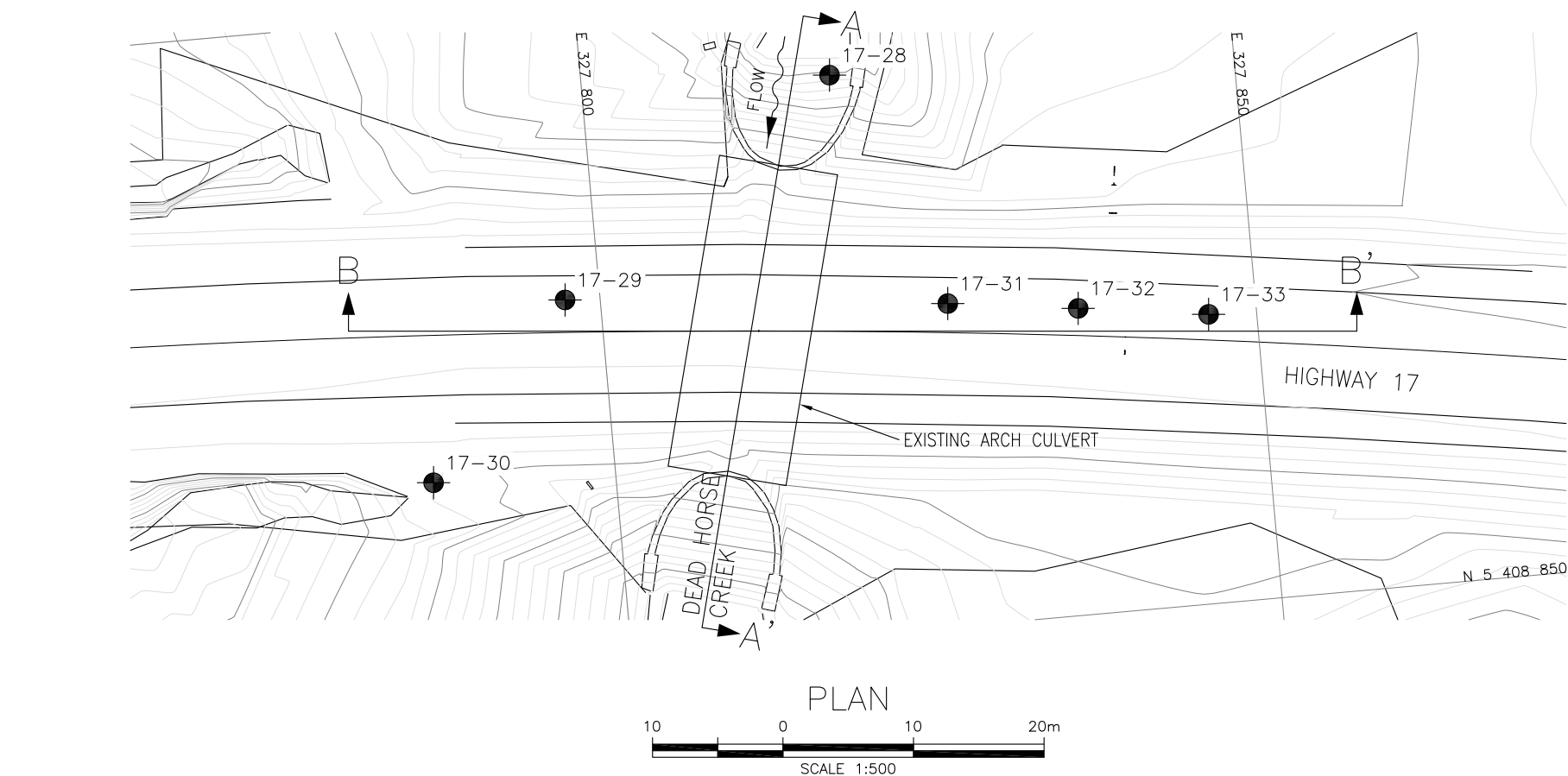
-NOTES-

- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.

GEOCRES No. 42D-51

[illegible]

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DATE: 8/31/2018 11:50 AM



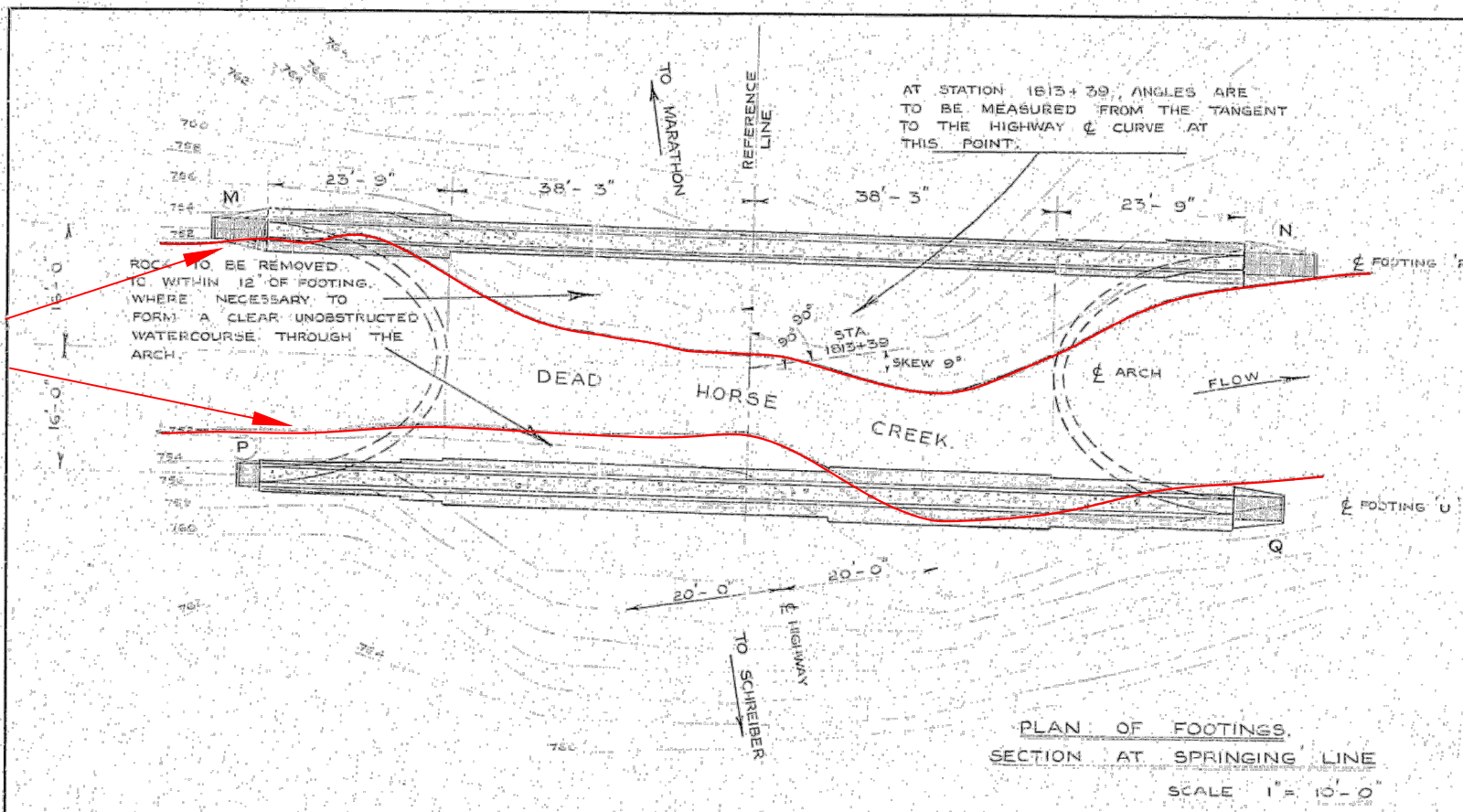


## **Appendix E**

### **Historical Structural Drawings**

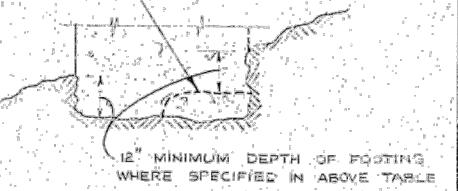
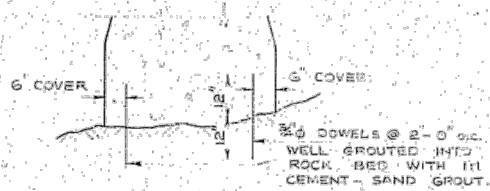


Presumed Rock Profile



FOOTG	SECTION	SECTION LENGTH	BASE WIDTH 'w'	DEPTH 'd'	REMARKS
R	WING WALL M	6'-0"	5'-0" ADJACENT TO SECTION R1	4'-0" ADJACENT TO SECTION R1	TO BE DOWELLED TO ROCK SURFACE AS INDICATED BELOW
	R1	23'-9"	5'-6"	4'-0"	
	R2	7'-0"	4'-0"	1'-0"	TO BE RECESSED INTO ROCK TO A MINIMUM DEPTH OF 12 INCHES
	R3	69'-6"	4'-0"	1'-0"	
	R4	13'-9"	4'-6"	2'-0"	
U	R5	10'-0"	5'-6"	4'-0"	
	WING WALL N	9'-0"	6'-6" ADJACENT TO SECTION R5	6'-0" ADJACENT TO SECTION R5	TO BE DOWELLED TO ROCK SURFACE AS INDICATED BELOW
	WING WALL P	3'-0"	4'-6" ADJACENT TO SECTION U1	2'-0" ADJACENT TO SECTION U1	
	U1	18'-0"	4'-0"	1'-0"	
	U2	5'-9"	3'-0"	3'-0"	
	U3	48'-0"	6'-0"	5'-0"	TO BE RECESSED INTO ROCK TO A MINIMUM DEPTH OF 12 INCHES
	U4	28'-6"	7'-0"	7'-0"	
	U5	11'-0"	6'-6"	6'-0"	
	U6	12'-9"	6'-0"	5'-0"	TO BE DOWELLED TO ROCK SURFACE AS INDICATED BELOW
	WING WALL Q	6'-0"	5'-6" ADJACENT TO SECTION U6	4'-0" ADJACENT TO SECTION U6	

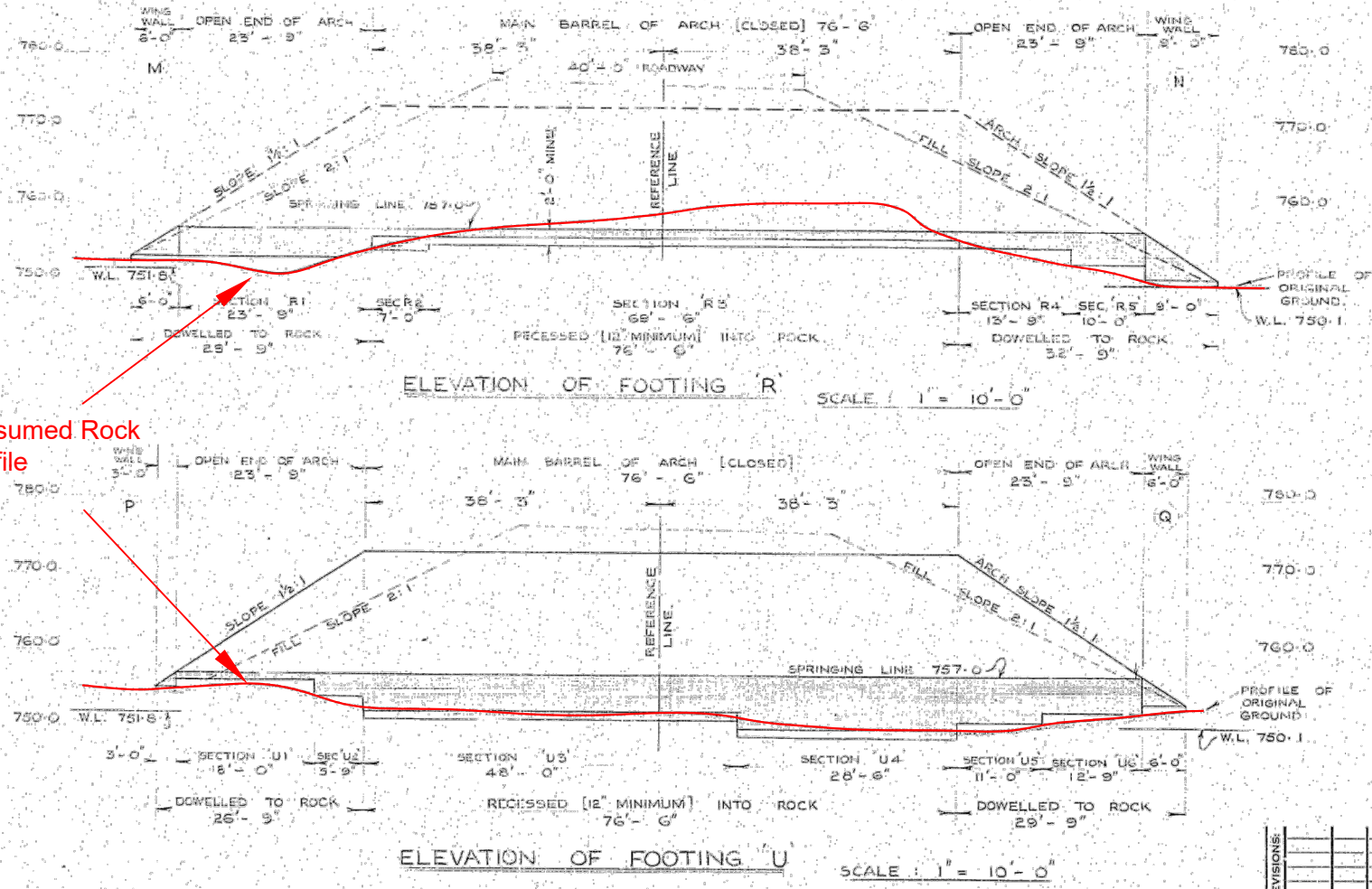
IN THE CASE OF WIDE FOOTING BASES, (EITHER DOWELLED OR RECESSED) WHERE THE NATURAL SLOPE OF THE ROCK ACROSS THE FOOTING IS GREAT, THE BEARING SURFACE OF THE ROCK UNDER THE FOOTING MAY BE STEPPED AS INDICATED BY THE DOTTED LINE BELOW. A ROUGHLY LEVEL BEARING SURFACE SHOULD BE MAINTAINED ACROSS THE FOOTING BASE TO REDUCE TENDENCY OF SIDESLIP.



NOTES:  
ALL EXPOSED CORNERS TO BE CHAMFERED 1/2" TO 25' BUILT IN ACCORDANCE WITH D.H.O. GENERAL SPECIFICATIONS FOR HIGHWAY BRIDGES 1935  
ALL LOOSE, EXTRANEUS AND ORGANIC MATERIALS TO BE REMOVED AND A CLEAN, PREFERABLY RUSH ROCK BEARING SURFACE EXPOSED BEFORE ANY FOOTING CONCRETE IS PLACED. NO CONCRETE IS TO BE PLACED FOR ANY FOOTING UNTIL CHARACTER AND PROFILE OF FOUNDATION HAVE BEEN APPROVED BY THE DIVISION ENGINEER.  
PROFILES OF FOOTING BASES ARE DESIGNED TO CONFORM TO CONTOURS INDICATED ON DRS. NO. E2742-1 AND, AFTER BLASTING AND REMOVAL OF ROCK AND OTHER LOOSE MATERIAL, THE PROFILES MAY DIFFER FROM THOSE INDICATED. IN SUCH CASES FOOTINGS MAY BE DEEPENED & WIDENED SUBJECT TO THE APPROVAL OF THE DIVISION ENGINEER.  
BACKFILL TO BE PLACED ON BOTH SIDES OF ARCH SIMULTANEOUSLY CONCRETE MIX - 1:2:4 WITH 1/4 LB. POZZOLITH PER BAG OF CEMENT. GROUT - 1 CEMENT:1 SAND.

BOTH ELEVATIONS OF THE FOOTINGS ARE VIEWED IN DIRECTION OF MARATHON FROM SCHREIBER.

Presumed Rock Profile



PRINT RECORD		
NO.	FOR	DATE
7	4-9-24	4-9-23

REVISIONS		
NO.	DATE	DESCRIPTION

DEPARTMENT OF HIGHWAYS-ONTARIO BRIDGE OFFICE-TORONTO	
30' ARCH CONCRETE BRIDGE OVER DEAD HORSE CREEK SKEW-9°	
THE KING'S HIGHWAY No. 17	DIV. No. 19
GO. DISTRICT OF THUNDER BAY	STA. 1813+39
TWP. N2 80	LOT CON.
PLAN, FOOTING ELEVATIONS & DETAILS	
APPROVED	
CHIEF BRIDGE ENGINEER CHIEF ENGINEER	
DESIGN D.H.R. CHECK T.T.	CONTRACT NUMBER 50-221
DRAWING D.H.R. CHECK T.T.	LOADING
TRACING	DRAWING NUMBER D-3370-1
DATE MARCH 12th 1953	H.20.

TWP # 868-21-1-A



## **Appendix F**

### **List of Specifications and Suggested Wording for NSSP**



**1. List of OPSS and OPSD Documents Relevant to this Project**

- OPSS.PROV 501
- OPSS 517
- OPSS.PROV 804
- OPSS 902
- OPSS.PROV 1010
- OPSD 3090.100

**2. Suggested Wording for NSSP on Dewatering**

The Contractor shall be prepared to design and provide a dewatering system during footing rehabilitation/widening and liner installation to allow the work to proceed in the dry. The dewatering system must be effective to maintain the water level at or below the creek bed throughout construction. The dewatering system must remain operational and effective until the culvert rehabilitation is completed.