THURBER ENGINEERING LTD.

To: Dale Wiersema, P.Eng.
HATCH Corporation

Date: March 17, 2021

From: Alireza Hejazi, Ph.D., P.Eng.
David Hill, P.Eng., P.Geo.
P.K. Chatterji, P.Eng.

File: 29076

PRELIMINARY DEWATERING ESTIMATE MEMORANDUM
HIGHWAY 599 – CRYSTAL RIVER BRIDGE REPLACEMENT
ASSIGNMENT NO. 6019-E-0009-011, SITE NO. 41S-098
DISTRICT OF KENORA, ONTARIO

1. INTRODUCTION AND SCOPE

Thurber Engineering Ltd. (Thurber) was retained by HATCH to complete a geotechnical investigation for the Highway 599 – Crystal River Bridge including construction of two abutments. The geotechnical investigation included drilling of boreholes, installation of a piezometer, measurement of groundwater levels and geotechnical laboratory testing. Temporary excavation for construction of the abutments will be below the groundwater table. HATCH authorized Thurber to prepare a preliminary estimate of the dewatering rate based on existing information. A complete Hydrogeological Investigation, including an impact assessment, was not included in the scope of work.

Groundwater taking for construction dewatering is governed by the Ontario Water Resources Act (OWRA), Environmental Protection Act (EPA) including Ontario Regulation 63/16 and the Water Taking and Transfer Regulation 387/04, a regulation under the OWRA.

If the water taking rate will be greater than 50,000 L/day and less than 400,000 L/day then registration on the Environmental Activity and Sector Registry (EASR) will be required. If the water taking rate will be greater than 400,000 L/day, then a Category 3 Permit To Take Water (PTTW) will be required. A preliminary assessment of the need for water taking permitting is provided herein.

2. PRELIMINARY DEWATERING ESTIMATE

Based on a review of the structure designs and drawings prepared by MTO, and on subsequent discussions, current construction plans call for construction of two bridge abutments where a portion of the temporary excavations will be below the groundwater table. Dewatering will be required to maintain a dry, stable base.

The following approach was used to estimate the budgeted peak water taking rate:

- A base groundwater extraction flow rate was estimated, and a factor of safety of three was applied to this flow rate to provide an allowance for removal of water from soil storage, variation in hydraulic conductivity, actual excavation dimensions and geometry, and ground water levels due to seasonality or other factors.

- An allowance for removal of rainfall directly into the temporary excavation was included, assuming 24 hours are used to remove 50 mm of rainfall, and
- Lowering of groundwater to 0.5 m below the base of the temporary excavation.

The water taking will be temporary in nature for the purpose of construction dewatering for the abutments. Dewatering rates were estimated using the Dupuit analytical solution. The radius of influence was calculated using the Sichardt equation. The calculation details including all the parameters used are presented in Attachment 1.

The geologic units that will need to be dewatered include boulder and cobble fill, sandy silt to silty sand, peat and sand and these layers will behave as unconfined aquifer. It is assumed that the predominant unit controlling flow to the excavations will be the sand due to its extent and permeability. No single well response tests were completed at the site. The hydraulic conductivity of the sand was estimated to be 6.8×10^{-5} m/s using the Kozeny-Carman empirical relationship based on a D10 grain size of 0.15 mm as estimated from the grain size distribution curve for sand at BH19-01. To provide some sensitivity analysis, hydraulic conductivity values of 50% greater and 50% smaller than this value were also evaluated.

The estimated dimension of each of the abutment excavations below the water table are summarized in Table 1. It is anticipated that the excavation and dewatering methods that will be used in the field will be determined by the Contractor.

Table 1: Assumed Temporary Excavation Dimensions and Ground Conditions.

Structure	Assumed Excavation Footprint (m)	Lowest Assumed Elevation of Excavation (m)	Highest Recorded Groundwater Elevation (m)	Geologic Units to Dewater
Each Abutment	10 x 5	418.3	419.2[1]	Sand

Note 1. Measured in open borehole at BH19-09.

The estimated maximum construction dewatering pump rates and radii of influence for the analyzed scenarios are summarized in Table 2.

Table 2: Summary of Construction Dewatering Estimates and Radii of Influence.

Scenario	Base Groundwater Flow (L/day)	Groundwater Flow with Safety Factor of 3 (L/day)	50 mm Rainfall Removal (L/day)	Estimated Peak Flow Rate (L/day)	Approx. Radius of Influence (m)
Preliminary Estimate for One Abutment	87,000	261,000	3,000	264,000	35
Preliminary Estimate for One Abutment – 1.5 Times Less Permeable	64,000	192,000	3,000	195,000	28
Preliminary Estimate for One Abutment – 1.5 Times More Permeable	119,000	357,000	3,000	360,000	42

With a safety factor of three on groundwater flow and a rainfall removal allowance of 50 mm in 24 hours, the estimated peak flow rate was estimated to range between 195,000 and 360,000 litres per day for the assessed single abutment scenarios. The maximum estimated radius of influence from the edge of the temporary excavations was estimated to be approximately 42 m.

To stay below the EASR maximum limit of 400,000 litres per day, temporary excavation dewatering may need to be carried out one abutment at a time, depending on actual volumes observed. It is the Contractor’s responsibility to remain below the EASR limit under normal operation, which does not include extreme weather events.

3. CLOSURE

Given that the peak water taking rate for one abutment at a time is estimated to be greater than 50,000 litres per day but less than 400,000 litres per day, registration on the EASR in accordance with the EPA, Ontario Regulation 63/16 under the EPA, the OWRA, and Ontario Regulation 387/04 under the OWRA is anticipated to be required.

We trust this memorandum provides the information required and is considered complete. However, should you have any questions regarding this memorandum, please feel free to contact the undersigned.

Respectfully Submitted,
Thurber Engineering Ltd.

Alireza Hejazi, Ph.D., P.Eng.
Senior Hydrogeologist and Environmental Engineer

LICENSED PROFESSIONAL ENGINEER
D. D. HILL
90550443
2021-03-17
PROVINCE OF ONTARIO

David Hill, M.A.Sc., MBA, P.Eng., P.Geo.
Associate | Senior Hydrogeological Engineer

THURBER

LICENSED PROFESSIONAL ENGINEER
P. K. CHATTERJI
March 17/2021
PROVINCE OF ONTARIO

P.K. Chatterji, P.Eng.
Review Principal

<u>Attachments:</u>

Statement of Limitation and Conditions

Attachment 1 Preliminary Dewatering Estimate Calculations

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STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.

b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.

c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.

d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.

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ATTACHMENT 1

Preliminary Dewatering Estimate Calculations

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Preliminary Dewatering Calculations for Unconfined Scenarios for Crystal River Culvert Abutment

Parameter	Units	Preliminary Estimate for One Abutment	Preliminary Estimate for One Abutment 1.5 Times Less Permeable	Preliminary Estimate for One Abutment 1.5 Times More Permeable
Geologic Unit to Dewater		Sand	Sand	Sand
10% diameter (D10)	mm	0.15	0.15	0.15
Input Hydraulic Conductivity in m/s (K)	m/s	6.8E-05	4.5E-05	1.0E-04
Hydraulic Conductivity converted to m/day	m/day	5.8	3.9	8.8
Input height of groundwater pressure (H)	m	4.4	4.4	4.4
Input dewatering height (h)	m	3.0	3.0	3.0
Input length of excavation (x, a)	m	8.5	8.5	8.5
Input width of excavation (b)	m	4.7	4.7	4.7
Input/calculate radius of trench (r_w or r_s)	m	2.4	2.4	2.4
Length to width ratio	unitless	1.8	1.8	1.8
Net water table lowering	m	1.40	1.40	1.40
Equation Type		Trench	Trench	Trench
Apply reduction for partial aquifer penetration?	yes/no	no	no	no
Vertical length actively dewatered	m	3	3	3
Radius of a single extraction well	m	0.075	0.075	0.075
Radii of Influence				
Sichardt Equation (Ro based on K, H, h)	m	35	28	42
Ro = Sichardt + (rw or rs)	**m**	**37**	**31**	**45**
Calculated Flow Rate				
Base groundwater flow	**L/day**	**83,000**	**61,000**	**114,000**
Partial Penetration Factor	unitless	1.00	1.00	1.00
Safety factor on groundwater flow	unitless	3	3	3
Groundwater flow with safety factor	L/day	249,000	183,000	342,000
Rainfall entering excavation	mm	50	50	50
Duration to remove rainfall	hours	24	24	24
Flow rate to remove rainfall	L/day	2,000	2,000	2,000
Budgeted peak flow rate	**L/day**	**251,000**	**185,000**	**344,000**
=	L/s	2.9	2.1	4.0
=	gal/min	38	28	53

Flow rate estimates rounded to nearest 1,000 L/day.

Theory and Formulae

Trench flow in unconfined aquifer

Use this equation when a/b > 1.5.

Equation 4.0

$$Q=\frac{\pi K\left(H^2-h^2\right)}{\ln R_0/r_w}+2\left[\frac{xK\left(H^2-h^2\right)}{2L}\right]$$

Equation 4.1 (Rectangular)

$$r_w=\frac{a+b}{\pi}$$

Trench flow in confined Aquifer

$$Q=\frac{2\pi KB(H-h)}{\ln(R_0/r_s)}+2\left[\frac{xKB(H-h)}{L}\right]$$

OR

Equation 4.1 (Circular)

$$r_s=\sqrt{\frac{a\times b}{\pi}}$$

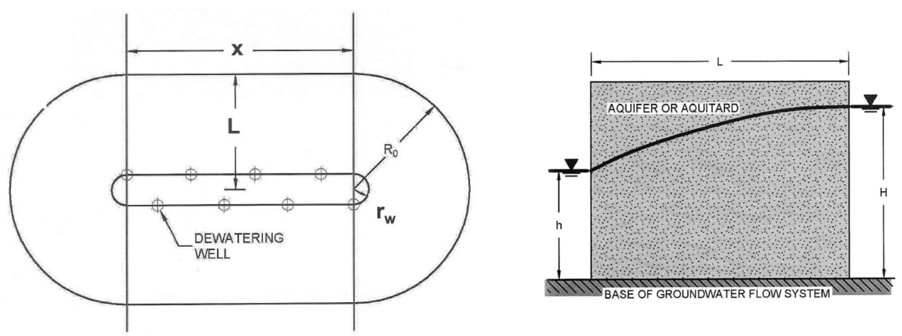

Figure 4.2 (Driscoll, 1986)

Note: L and Ro are the same distance

*Note: H, h measurements are relative to base of active groundwater

rw can be calculated (Eqn 4.1) or input = 1/2 the width of the trench.

For trench eqn estimate better if value is input as 1/2 the width of trench,

Rw must be smaller than Ro.

Rs for trench can be distance from centre line of trench to line of dewatering points.

Radial flow to well in unconfined aquifer (Dupuit Equation):

$$Q=\frac{\pi K\left(H^2-h^2\right)}{\ln R_0/r_w}$$

Steady-state flow in confined aquifer

Flow per well Q = 2.73 K b (H - h)/log(R/r)

Source: Driscoll, Fletcher G. (1986). *Groundwater and Wells* (2nd ed). St. Paul, Minnesota: Johnson Filtration Systems Inc.

Radius of Influece

Ro is determined by the Sichardt Equation:

Ro = 3000(H-hw)K^0.5 when K is in m/s

Alternative equation by Bear (Bear, J., 1979. **Hydraulics of Groundwater**, McGraw-Hill, New York, 569p) $R_0=1.5(Tt/S)^{0.5}$ where **T** is transmissivity in **m²/day**, **t** is pumping duration in **days.** $\mathbf{R_o}$ will be in **metres.**

Ro equals sichardt equation plus rw

add rw to Ro calculated from Sichardt's equation

rw as indicated in formulae

Hydraulic Conductivity and Grain Size

K = D10^2 , Hazen, where D10 = grain size diameter for 10% passing (smallest 10%) in mm and K in cm/s

OR

$$K=\left(\frac{\rho g}{\mu}\right)\left[\frac{n^3}{(1-n)^2}\right]\left(\frac{d_{10}^2}{180}\right)$$

Kozeny Carman equation

Image from groundwatersoftware.com

Partial Penetration Factor (F) Kozeny 1933

F = L/b*(1+cos(PI*L/(2b))*sqrt(r/2L))

where:

L = Vertical length from which water is being extracted

r = single well radius

b = saturated aquifer thickness

L/r must be > 30 L/b must be < 0.5

Assumption made that same factor may be applied to equivalent well and trench equations.

Sy to calculate the Radius of Influence of Unconfined aquifer using Bear 1979

The following table shows representative values of specific yield for various geologic materials (from Morris and Johnson 1967):

Material	Specific Yield (%)
Gravel, coarse	21
Gravel, medium	24
Gravel, fine	28
Sand, coarse	30
Sand, medium	32
Sand, fine	33
Silt	20
Clay	6
Sandstone, fine grained	21
Sandstone, medium grained	27
Limestone	14
Dune sand	38
Loess	18
Peat	44
Schist	26
Siltstone	12
Till, predominantly silt	6
Till, predominantly sand	16
Till, predominantly gravel	16
Tuff	21

Ss to calculate the Radius of Influence of Confined aquifer using Bear 1979

The following table provides representative values of specific storage for various geologic materials (Domenico and Mifflin [1965] as reported in Batu [1998]):

Material	S_s (ft^{-1})
Plastic clay	7.8×10^{-4} to 6.2×10^{-3}
Stiff clay	3.9×10^{-4} to 7.8×10^{-4}
Medium hard clay	2.8×10^{-4} to 3.9×10^{-4}
Loose sand	1.5×10^{-4} to 3.1×10^{-4}
Dense sand	3.9×10^{-5} to 6.2×10^{-5}
Dense sandy gravel	1.5×10^{-5} to 3.1×10^{-5}
Rock, fissured	1×10^{-6} to 2.1×10^{-5}
Rock, sound	$< 1\times10^{-6}$

To Convert	Divide By	To Obtain
ft^{-1}	0.3048	m^{-1}

Reference: Powers, J. P., Corwin, A. B., Schmall, Paul C. and Kaeck, W. E. 2007. Construction Dewatering and Groundwater Control: New Methods and Applications, Third Edition, New York, New York: John Wiley & Sons.