MORRISON HERSHFIELD

Seine River Bridge at Creek Bend Road Hydrotechnical Study

Winnipeg, Manitoba

Presented to:

City of Winnipeg

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1. STUDY OBJECTIVE

Morrison Hershfield (MH) has been retained by the City of Winnipeg to conduct a hydrotechnical study to support design of the new bridge replacement over the Seine River in Winnipeg at Creek Bend Road. The main objectives of this study are to review and determine hydrotechnical design parameters for the new structure, which includes:

- Design water levels for the new bridge (normal and flood conditions)
- Ice conditions on the structure
- Scour/erosion potential and armouring requirements for the structure

This report summarizes the hydrological and hydraulic analysis that were completed, as well as recommended design parameters.

2. AVAILABLE STUDIES AND DATA

2.1 Background Information

The following documents, drawings and data were reviewed to provide an understanding of the site conditions:

- Seine River at Fermor Avenue Bridge Crossing Replacement – Hydrologic and Hydraulic Assessment (May 2016) and HEC-RAS model
- Topographical Survey at Bridge and River Cross-Section, MH (November 4, 2022)
- Preliminary Design of the Aimes Road Crossing on Seine River Hydraulic Design – Draft (March 2020)
- Seine River Syphon Leakage Remediation (March 1999) by Acres International Limited
- Existing Bridge Records – 1987 Bridge Maintenance P.D. No. 774-87 (City Drawing No. B149-83-0, B149-87-01, B149-93-01)
- Daily temperature data collected by Government of Alberta at Winnipeg Airport Climate Station 5023227 & 502S001, published on Environment Canada website.
- Site photographs of the bridge and river.

2.2 Topographical and Bathymetric Data

A bathymetric and topographic survey of the Seine River in the vicinity of the bridge at Creek Bend Road was conducted by Morrison Hershfield Limited (MH) on November 4, 2022. Water levels were low at the time of the survey and allowed for bathymetric and topographic data on the riverbanks to be collected. The water level on day of survey was roughly at an elevation of 228.697 m, approximately a 1.4 m depth (Thalweg elevation= 227.3 m). The study area covered a reach of the Seine River approximately 80 m long, 40 m upstream and 40 m downstream of the bridge.

3. DESIGN CRITERIA

The hydraulic design criteria that were used in this project were consistent with the provincial Water Control & Structures Design Manual provided by Manitoba Infrastructure and Transportation (MIT) dated February 18, 2011.

The following criteria were used in this analysis:

1. A minimum clearance of 300 mm is required from the underside of girders to the design flood water level.
2. Ice thickness, pan size and depth of ice flow shall be considered when assessing the minimum clearance requirements.
3. Headloss shall not exceed 0.2m.
4. Navigable clearances as required by Transport Canada shall be provided as follows:
   a. Minimum vertical clearance of 1.5 m from the underside of girder to the water surface corresponding to the 50% (2 Year) discharge; and
   b. Minimum horizontal width of 3 m within the bridge opening at the water surface corresponding to the 50% (2 Year) discharge.
5. Average channel velocities through the bridge opening shall not exceed 1.5 m/s; and
6. Adequate erosion protection shall be provided to prevent erosion.
7. Adhere to the Manitoba Stream Crossing Guidelines with respect to fish passage. Bridge crossing shall not restrict upstream fish passage during a spawning migration period for flows up to a specified fish discharge (3DQ10). There is no velocity requirement for bridges in this guideline but culverts typically require a maximum velocity of 0.8 to 1.0 m/s to allow for fish passage.

The design flood discharge selected for the bridge crossing is the 1% (100 year) flood. The governing condition will depend on the following boundary conditions:

1. Low Red River water levels with no backwater. Low water levels normally run in the summer at 223.0 m (4.0 ft James Avenue Pumping Station Datum [JAPSD]).
2. Red River water levels at the Flood Protection Level (FPL) of 229.38 m at the Red River and Siene River Confluence (25.8 ft JAPSD) resulting in a backwater condition.

4. HYDROLOGY

4.1 Flood Hydrology

The Seine River is a tributary of the Red River that runs through southeastern Manitoba. The headwaters of the river originate in Sandilands Provincial Forest and pass by or through the communities of Marchand, La Broquerie, Ste. Anne, and Lorette before reaching the City of Winnipeg. The river is diverted just upstream of Ste. Anne and flows are monitored by hydrometric station 05OH009 just downstream of Ste. Anne before the floodway. Before running through Winnipeg, the river is conveyed under the Red River Floodway through a siphon at a maximum flow rate of 4.2 m^3/s. Any additional flows are diverted into the Floodway. At the Creek Bend Road, the river has a drainage area estimated at 439.8 km^2 (431.8 km^2 upstream of floodway and 8.0 km^2 downstream of floodway).

Hydrology for the Seine River was obtained from the following source:

- Hydrologic and Hydraulic Assessment – Seine River at Fermor Avenue Bridge Crossing Replacement (Including HEC-RAS Hydraulic Model), dated May 2016 by Bruce Harding Consulting Ltd.
- Seine River Hydrology Study by Acres Consulting Services, dated 1978
- Preliminary Design of the Aimes Road Crossing on the Seine River – Hydraulic Design by KGS Group Consulting Engineers (KGS), dated March 9, 2020.

The design flood estimates in the Hydrologic and Hydraulic Assessment at Fermor Avenue bridge were compared with the flood estimates in the Aimes Road Hydraulic Design Report by KGS. The design flood estimates in the Fermor Avenue Report were slightly higher for the 100-year event and conservative, therefore, they were used in this hydraulic analysis.

Table 5-1 below shows the Flood Estimates along Seine River in the hydraulic analysis.

Table 4-1: Flood Estimates

Location	2 Year (50% Q)	10 Year (10% Q)	100 Year (1% Q)
	(m^3/s)	(m^3/s)	(m^3/s)
Seine River Siphon	4.2	4.2	4.2
At Prairie Grove Rd	6.8	8.5	12
Creek Bend Rd	**7.4**	**9.3**	**15.6**
South Glen Boulevard	7.9	9.9	17
Navin Drain	10.8	13.6	21.2
Bibeau Drain	13.6	17	24.1

4.2 Downstream Backwater Conditions

The downstream backwater effects due to the Red River would cause the water levels at Creek Bend Bridge to rise. During the 1997 flood, backwater effects extended all the way upstream to the Perimeter Highway (Seine River at Fermor Avenue Bridge Crossing Replacement - Hydrological and Hydraulic Assessment, May 2016); therefore, the Seine River will be assessed due to normal summer levels of 4.0 ft JAPSD (223.0 m at Red River Confluence) and the Flood Protection Level of 25.8 ft JAPSD (229.38 m at Red River Confluence).

5. HYDRAULIC ANALYSIS

5.1 Hydraulic parameters

The Seine River is a fairly wide river channel with a depth of approximately 2.5 m. The hydraulic capacity of the channel is quite large before it overtops the banks. Channel geometry parameters were estimated using survey data collected on November 4th, 2022. Key channel parameters from the hydraulic model are provided in Table 5-1. Elevations of the lowest point of the existing and new bridge, and the minimum bed elevation (thalweg) at the bridge are provided for reference.

Table 5-1: Channel and Bridge Parameters

Design Parameter	At Bridge Location
Bed width, b (m)	<1m
Slope over study reach, S (m/m)	0.0015
Channel thalweg at bridge (m)	227.3
Bottom of existing bridge soffit (m)	230.2
Bottom of new bridge soffit (m)	230.5

5.2 Hydraulic Modelling

The one-dimensional HEC-RAS software developed by the US Army Corps of Engineers was used to model hydraulic conditions on the Seine River from the Floodway to the Red River confluence. HEC-RAS uses transverse cross-sections along the river channel to calculate various parameters based on a given flow condition (water levels, flow velocities, shear stresses, etc.). For this assessment, water levels, flow velocities, and shear stresses were studied. The HEC-RAS model provided by the City of Winnipeg, which was completed for the Fermor Avenue Bridge at Seine River by Bruce Harding Consulting Ltd. (May 2016), was used in this analysis.

Two cross-sections were inserted 40 m upstream of the existing bridge, and two were inserted 40 m downstream of the bridge based on the latest bathymetric survey. Any original cross-sections 40 m upstream and downstream of the bridge were removed from the model. The model reach is approximately 26 km long, extending 5 km upstream of the bridge and 21 km downstream. The existing bridge centerline is located approximately 21km upstream of the Red River confluence.

As per the model provided, a Manning's coefficient of 0.04 was used for the main channel and the banks along the entire reach have an assigned value of 0.1.

5.2.1 Calibration

Calibration of the HEC-RAS model was not completed. From past documents reviewed, it is understood that, in 2014, KGS Group subsequently completed an updated calibration of the original model with more recent observed data as part of a 3-year monitoring program of the Seine River between 2011 and 2013 for Manitoba Floodway and East Side Road Authority. Therefore, it is assumed that additional calibration is not needed at this time.

5.2.2 Boundary Conditions

The hydraulic analyses were run under subcritical flow conditions for the entire study reach. An assumed water level for each flow condition at the downstream-most cross section was used as the boundary condition for the HEC-RAS model. The table below shows the boundary conditions used for each flow condition.

Table 5-2: Hydraulic Conditions at Creek Bend Bridge

Boundary Condition	Design Discharge	Boundary Condition Water Level of Red River at Seine River Confluence (m)
No Backwater - Normal Summer Water Level (4.0 ft @ JAPSD)	50% Discharge (2 Year)	223.0
	10% Discharge (10 Year)	
	1% Discharge (100 Year)	
Backwater - Assumes Flood Protection Level (25.8 ft @ JAPSD)	50% Discharge (2 Year)	229.38
	1% Discharge (100 Year)	

5.3 Hydraulic Results at the New Bridge

Hydraulic conditions at the existing and new bridge alignments are very similar. The bridge parameters were entered in the HEC-RAS model assuming a three (3) - 8 m span (24 m total length) bridge. Bridge piers for the new bridge are assumed to have a width of 310 mm based on information provided to date. Simulated hydraulic parameters for a range of flow conditions at the bridge location are summarized in Table 5-3.

Table 5-3: Hydraulic Conditions at the New Creek Bend Bridge

Boundary Condition	**Design Flood**	**Flow at Creek Bend**	**Water Level**		**Headloss**	**Avg. Depth**	**Max. Velocity**
			U/S of Bridge	D/S of Bridge		(Thalweg = 227.3m)	Under Bridge
		(m^3/s)	(m)	(m)	(m)	(m)	(m/s)
No Backwater - Normal Summer Water Level (4 ft @ JAPSD)	50% Discharge (2 Year)	7.4	229.29	229.28	0.01	2.0	0.35
	10% Discharge (10 Year)	9.3	229.48	229.48	0.00	2.2	0.37
	1% Discharge (100 Year)	15.6	229.98	229.97	0.01	2.7	0.43
Backwater - Assumes Flood Protection Level (25.8 ft @ JAPSD)	50% Discharge (2 Year)	7.4	229.7	229.7	0.00	2.4	0.24
	1% Discharge (100 Year)	15.6	230.2	230.2	0.00	2.9	0.37

The bottom of the soffit of the existing bridge is at an elevation of approximately 230.18 m, which is the lowest elevation under the bridge deck. The bottom of the soffit of the new bridge is at a slightly higher elevation of 230.5 m. The new bridge provides a clearance of 300 mm for the 1 in 100-year water level during open water conditions. This clearance provides a high level of safety and extra freeboard in an unforeseen event such as debris blockage during a flood. As shown in the table, velocities are also less than the maximum allowed of 1.5 m/s, therefore should not affect fish passage. The bridge main channel works will be disturbed below the low water levels and therefore has minimal effect on fish swimming across.

The Seine River is at an approximately 10° skew to the existing roadway alignment. With the proposed roadway realignment, the new bridge would be constructed by aligning the abutments and piers with the flow direction to reduce potential for scour and to limit flow disturbances.

6. ICE ANALYSIS

Elevated water levels due to ice can occur during ice formation and at break-up. Ice affected water levels are not always dependent on flow, with no consistent stage-discharge relationship between water level and flow, as the hydraulic characteristics of the ice cover can be highly variable. A high-level evaluation of the severity of ice affected water levels during these periods was completed to determine their importance in overall bridge design and construction planning.

Based on consultation with the City, there is no ice record along Seine River and no historical ice issue flagged.

6.1 Spring Break-up Ice Process

Limited aerial imagery from Google Earth Pro shows ice break-up occurring in April 2015 and some ice floes moving. Based on monthly temperature records at the Winnipeg Airport Climate Station starting from year 1996 to 2007, the average minimum and maximum temperature are shown in Table 6-1 below. Temperatures can be seen transition from freezing to melting in the month of April.

Table 6-1: Monthly Average Minimum and Maximum Temperatures from 1996 to 2007

Month	Average Min Temp	Average Max Temp
January	-22.0	-11.8
February	-18.9	-8.2
March	-11.9	-1.3
April	-2.4	10.7
May	3.5	17.2
June	10.1	22.4
July	13.0	26.2
August	11.9	25.4
September	6.6	19.7
October	-1.0	10.2
November	-9.4	0.0
December	-15.6	-6.2

Available aerial imagery and daily temperature data in the month of April from 2019 to 2022 indicate that the river was consistently ice-free by mid-April as shown below. As a conservative estimate, the river can be reasonably assumed to be ice free by early May every year.

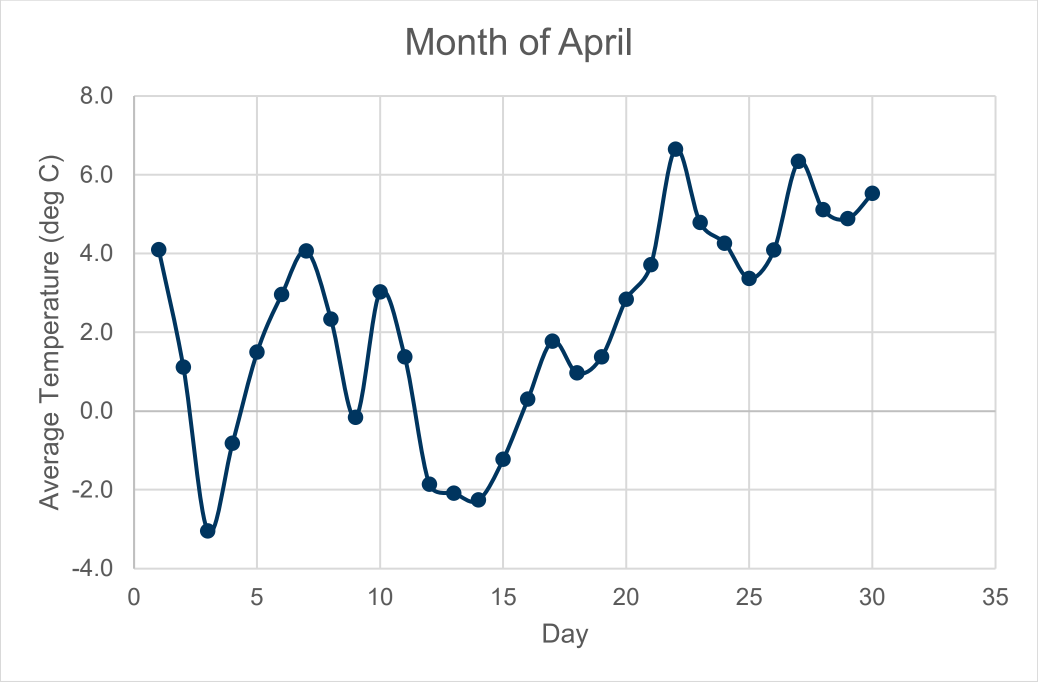

Figure 6-1: Average Temperature for Month of April

6.2 Ice Loadings

Ice impact loadings arise from ice floes impacting substructure elements or, if water levels are high enough, impacting the girders. Historical ice records during break-up periods are not available at this site. Ice interaction on the piers may include:

- Dynamic forces due to moving floes of ice being carried by river currents
- Static pressure due to thermal expansion movements of the ice cover

The most conservative parameters were selected for evaluating the static and dynamic ice conditions and elevations.

Section 3.12 of the Canadian Highway Bridge Design Code (CHBDC) is related to ice loading and should be referenced to develop ice loading forces for the design of piers. A brief discussion of ice forces for dynamic and static ice conditions is presented below.

6.2.1 Dynamic Ice Conditions

Dynamic ice forces occur when floating ice floes moving downstream impact a bridge pier. A review of limited historical ice conditions indicates that ice break-up is predominately thermally driven, and downstream movement of large ice sheets has not been observed in historical data. A brief discussion of ice design parameters is provided below to quantify the general magnitude of dynamic ice forces if they were to occur.

Forces imposed by the ice floe on a pier are dependent on the size of the ice floes (thickness, width and length), the internal strength of the ice and the geometry of the pier nose. Section 3.12.2.1 of the CHBDC provides guidelines for estimating the effective crushing strength of the ice cover (noted as '*p*' in the Code) which is then used in the calculation of ice crushing and bending force equations of Section 3.12.2.2.2 to determine the dynamic loading. Effective ice strength is dependent on air temperature and ice cover integrity. These conditions are not known at the bridge crossing, but expected possible values of 'p' from the CHBDC based ice breakup conditions are:

a) Ice breaks up at a melting temperature and is substantially disintegrated: 400 kPa

b) Ice breaks up at melting temperature and is somewhat disintegrated: 700 kPa

c) Ice breaks up or ice movement occurs at melting temperature and is internally sound and moving in large pieces: 1100 kPa

Based on the understanding of ice breakup and melting process from the gauge stations, aerial imageries and previous studies on Seine River, the eeffective ice strength of 700 kPa is recommended for the dynamic loading calculation.

The CHBDC provides equations for the estimation of horizontal ice impact forces for piers parallel to the flow and recommends that the governing ice force be taken as the minimum, of either the crushing or bending failure mode as the ice will fail once it reaches the magnitude of the smaller force. The governing dynamic ice forces should be applied at an elevation corresponding to the water levels anticipated during spring break-up, when dynamic ice forces would be the greatest.

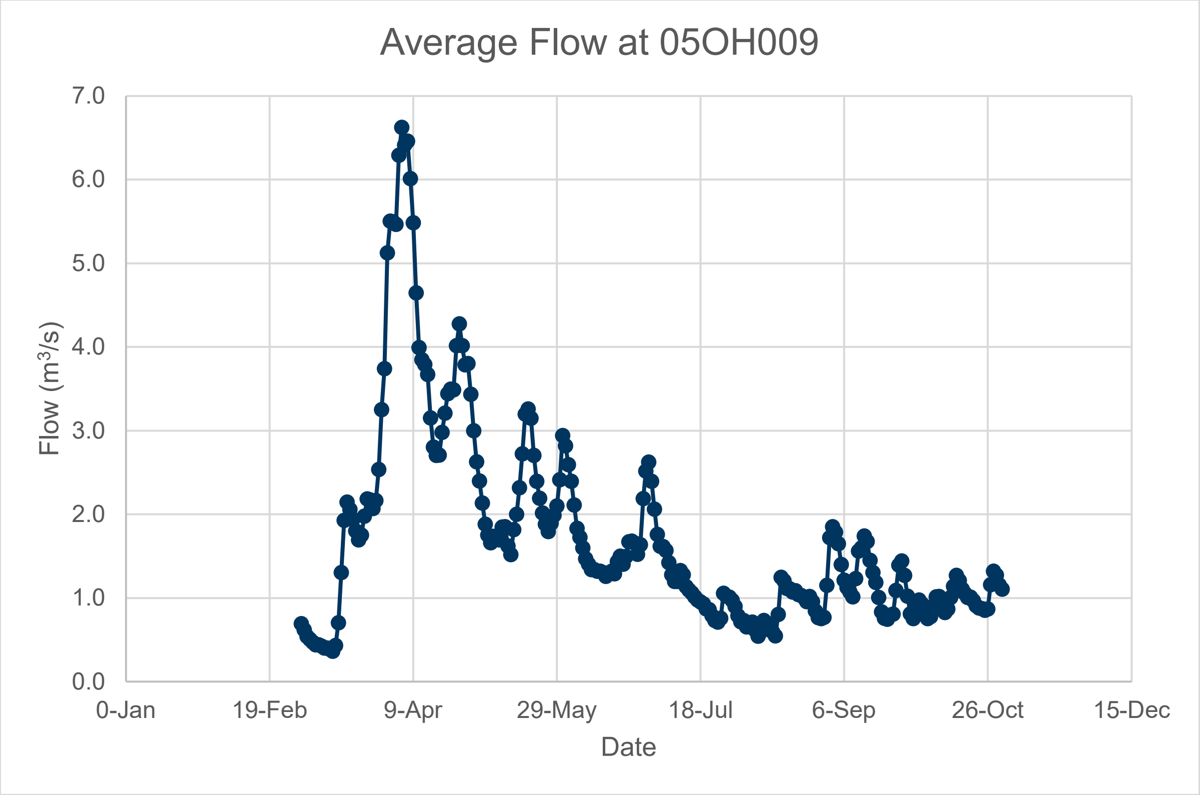

Figure 6-2: Average Flow at Hydrometric Station 05OH009 for a period of record of 34 years.

The total drainage area at this hydrometric station is 302 km^2 and the total drainage area at Creek Bend Road is 439.8 km^2. The highest average flow at the hydrometric station happens in April and it exceeds the maximum siphon capacity. Since flows are not monitored downstream of the siphon, it is difficult to estimate the dynamic ice elevation. Therefore, to be conservative, the estimated dynamic ice elevation was assumed to be between the 2-Year and 100-year elevation of 229.3 to 230.0 m with an upper limit average ice thickness of 30 inches (762 mm) as per March Flood Outlook Report for Manitoba by MTI Hydrological Forecast Centre dated March 17, 2022.

6.2.2 Static Ice Conditions

Static ice forces occur due to thermal expansion of an ice cover and can induce loading on piers if the loading is unbalanced or occurs high on the piers. Generally thermal expansion is of greater concern within lake environments where ice is constrained on one shoreline and expands laterally from the shore. Static ice conditions at the bridge have not been well quantified but are expected to be minor. It is assumed that static forces at the bridge are not large enough to generate static ice force that would result in imbalanced forces and therefore the static forces were not considered in design.

6.2.3 Ice Conditions Summary

Table 6-2 summarizes the static and dynamic ice conditions estimated at the Creek Bend Bridge. Those parameters were derived based on conservative methods recommended by

CHBDC. There is limited information available, but it appears unlikely that severe adverse ice conditions could develop at the bridge. The values presented below are believed to be conservative and well above expected ice levels for most years.

Table 6-2: Recommended Ice Design Parameters at Creek Bend Bridge

Category	Classification
Ice thickness (m) – Red River Measurement	30 inches (762 mm)
Estimated Ice Elevation – Dynamic (m)	229.3 to 230.0
Effective Crushing Strength – Dynamic (kPa)	700

7. EROSION & SCOUR ANALYSIS

The hydraulic conditions estimated using the HEC-RAS model were used to analyze potential erosion and scour conditions at the Seine River bridge crossing. The following analysis uses widely accepted empirical methods to estimate the potential erosion and scour and to determine appropriate sizing of erosion protection works.

7.1 Erosion Potential

Erosion protection measures are required to protect the bridge abutments and piers from erosion and undermining. The discussion below provides erosion protection requirements using riprap, if a local source is identified.

The Isbash equation has been used to determine the appropriate size of riprap required to resist estimated flow velocities. The Isbash equation is widely used in engineering applications and relates the median diameter of riprap (D_{50} in mm, where 50% of the material by weight must be larger than this value) required to resist a given flow velocity as shown in the following equation:

$$D_{50} = \frac{V^2}{2g\, C^2 \left(\frac{\gamma_r - \gamma_e}{\gamma_e}\right) \cos\alpha}$$

Where D_{50} (mm) is defined as riprap where 50% of its material by weight has to be larger than this value and where:

V = the flow velocity in m/s;
g = the gravitational constant of 9.81 m/s²;
C = the Isbash turbulence coefficient (0.86 for high turbulence, up to 1.20 for low turbulence);
γ_r= the specific weight of rock, approximately equal to 2.65 x 9,810 N/m³;
γ_e= the specific weight of water, approximately equal to 1 x 9,810 N/m³;
α = the angle of repose of riprap (based on side slope of channel).

Figure 7-1 presents curves for different turbulence coefficients for given flow velocities.

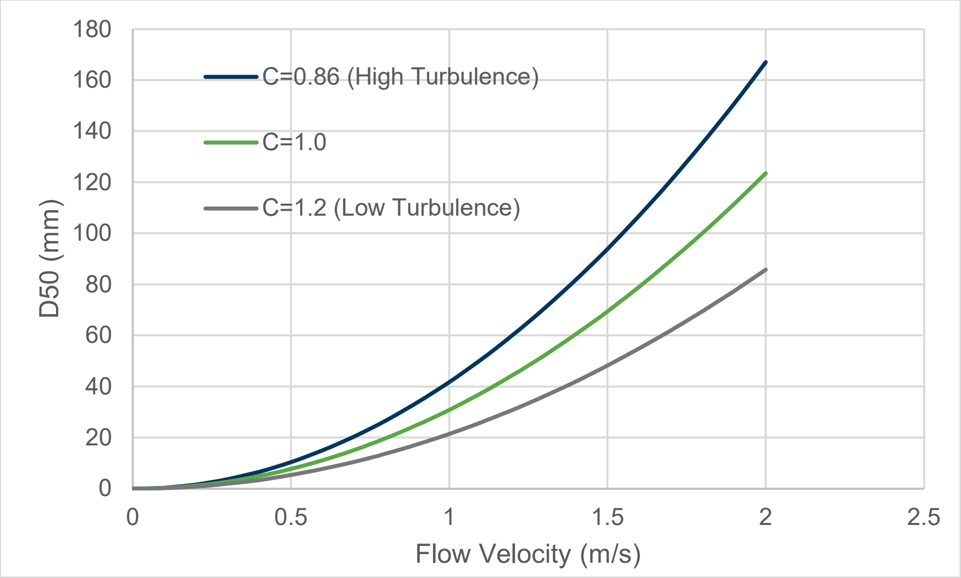

Figure 7-1: Required Riprap D50 to Resist a Given Flow Velocity.

Based on hydraulic conditions simulated for the new bridge, a maximum channel flow velocity of 0.43 m/s is estimated during the 1 in 100-year design flood. The velocity at this location is not high; as such, the requirements for the rock armouring within the bridge opening are not excessive. The existing slope against abutments are protected by grouted riprap. It is recommended that the grouted riprap be removed and replaced. Based on those observations, the following is recommended for erosion protection:

- Environment friendly measures (such as erosion control blanket) for any disturbance outside the bridge footprint.
- Class 350 (D50=200 mm) field stone on the disturbed slopes within the bridge footprint.

7.2 Scour Potential

Based on the geotechnical report and boreholes adjacent to the channel, the channel is sitting in a silty clay soil layer. The silt clay consists of a significant percentage of clay and has intermediate to high plasticity. It is assumed that the stream bed material is cohesive.

According to Design Chart in MTO Drainage Manual, the competent velocity of the stream bed material is around 1 m/s, therefore, the general scour should be negligeable.

The anticipated local scour at abutment should be minor as well, as channel cross-section will not be changed in geometry and there is no significant contraction from the abutments. The proposed riprap should provide scour protection.

The calculation based on Colorado State University Method and RTAC method shows around 0.5 m -1 m local scour depth around piers. To limit in-water works, local scour protection around the piers is not recommended. Instead, the local scour depth was considered into foundation design.

8. SUMMARY AND RECOMMENDATIONS

Hydrological and hydraulic analyses were completed to support the design of the new bridge crossing the Creek Bend Road in Winnipeg. Hydraulic conditions were analyzed using a HEC-RAS model to determine design water levels, maximum flow velocities, and erosion and scour protection needs.

A 1 in 100-year design flood was selected for the new bridge crossing, corresponding to an estimated peak flow of 15.6 m^3/s and a maximum water level of 230.2 m was estimated for the design flood, which would provide 300 mm of freeboard below the proposed underside of the bridge soffit (elevation 230.5 m). A flow velocity of less than 0.5 m/s was estimated at the bridge for this scenario. For comparison purposes, the average yearly flood (1 in 2-year event estimated at 7.4 m^3/s) would lead to a maximum water level of 229.3 m and a flow velocity also less than 0.5 m/s.

For erosion protection, velocities were low; as such, the requirements for the rock armouring within the bridge opening are not excessive. It is however possible that higher flow velocities will be experienced near the base of the bridge piers. Based on those observations, the following is recommended for erosion protection:

- Environment friendly measures (such as erosion control blanket) for any disturbance outside the bridge footprint.
- Class 350 (D50=200 mm) field stone on the disturbed slopes within the bridge footprint.

Ice breakup is generally thermally driven with ice melting in place, rather than dynamic breakup. Conservative maximum ice levels were estimated. For the new bridge, pier ice force magnitudes and application elevations were estimated as follows:

- **Dynamic Ice Force:** shall be equal to the minimum force associated with the ice crushing and bending failure modes calculated using the equations listed in CHBDC, Section 3.12.2.2.2. For those equations, the effective ice crushing strength should be taken as p = 700 kPa assuming ice breaks up at melting temperature and is somewhat disintegrated. The force should be applied at a pier elevation range between 229.3 to 230.0 m.
- **Static Ice Force:** expected to be minor and act on the lower portion of the piers. It is assumed that static forces at the bridge are not large enough to generate static ice force that would result in imbalanced forces, therefore, the impact from static forces was not considered in design.

These force application elevations are recommended for detailed design calculations as stipulated in the CHBDC to estimate ice loadings on piers. A history of ice jams and ice adhesion on piers has not been noted at the bridge and, as such, have not been evaluated.

9. CLOSURE

Thank you for engaging Morrison Hershfield to provide engineering services for the hydraulic and ice survey, analyses and recommendations associated with the replacement of the bridge crossing in the Seine River at Creek Bend Road, Winnipeg.

If you have any questions, please contact the undersigned.

Sincerely,
Morrison Hershfield Limited

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10. REFERENCES

Canadian Highway Bridge Design Code. (2014). CAN/CSA-S6-14.

Ministry of Transportation of Ontario (1997) Drainage Management Manual