Memorandum

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Subject: Hamlet Swing and Fixed Bridges – Hydrology and Hydraulic Study – DRAFT

INTRODUCTION

Parsons Inc. has been retained by Public Works and Government Services Canada (PWGSC) to prepare the detailed design for the replacement of the Hamlet Swing and Fixed Bridges. The Hamlet Swing and Fixed Bridges, owned and operated by Parks Canada Agency (PCA), carries Peninsula Point Road over the Trent-Severn Waterway in Hamlet, Ontario. The crossing consists of a 60 m equal arm swing span to the west and a 32 m fixed span to the east.

This project consists of replacement of the east pier that supports both the swing bridge and the fixed bridge, rehabilitation of the swing bridge pivot pier and replacement of both abutments. The proposed profile of the bridge will also be raised by 600 mm due to the need of raising the pivot pier to avoid flooding the mechanical equipment. Cofferdams will be used around the substructure to provide dry working conditions for these construction works. Because there are a number of recreational properties along the shore of the Severn River, and historically these properties have seen high water levels, the impact of restricting the channel to perform the aforementioned construction project was assessed. This memorandum has been prepared to document the hydrology and hydraulic analysis undertaken in support of the design and construction of the Hamlet Swing and Fixed Bridges Replacement Project. The following tasks were completed to determine impact of the construction works:

- The criteria for temporary works during construction was determined based on Ministry of Transportation Ontario (MTO) Highway Drainage Design Standards.
- A bathymetric and land survey was conducted by Callon Dietz along the Severn Waterway, which was used to define the river's channel and bank cross-sections.
- The Severn River's hydrology was assessed to establish standard return-period flows.
- Historical water levels at the outlet of the Severn River at Sparrow Lake were reviewed to determined appropriate boundary conditions.
- A 1-D hydraulic model was developed in HEC-RAS to represent the existing and construction conditions.
- Modeled water surface levels for the two conditions were compared to determine the acceptability of the construction works.

The following sections provide details about the hydrology and hydraulic assessment.

BACKGROUND INFORMATION

Exiting bridge

The Hamlet Bridges consist of the Swing Bridge (Bridge #57) and the Fixed Bridge (Bridge #58). The Swing Bridge was constructed in 1922, and the Fixed Bridge was originally built in 1905 for use at another location, and was later moved to the current location in 1915. The Swing and Fixed Bridges span 93 m over the Severn River. The Severn River flows from Wasdall Falls, through Hamlet Bridges #57 and #58, then into Sparrow Lake, which discharges through a regulated structure, Lock 43, at Swift Rapids.

The crossing is at a 15-degree skew angle compared to the river and has a concrete abutment on each shore. On the west side, a 7.3 m wide pivot pier supports the bearings on which the swing bridge pivots. The pivot pier is flanked by two 4.9m-wide rectangular rest piers extending 30.5m both upstream and downstream from the base. The east pier supports both the swing bridge when it is in a closed position and one end of the fixed bridge. This pier measures approximately 10 m long and has semi-circular ends, with a 5.1 m diameter on the upstream end and a 3.5 m diameter on the downstream end.

Proposed bridge and construction

The proposed bridge will be similar to the existing bridge except that deck will be approximately 600 mm higher. The entire west pivot pier will be resurfaced, raising its top elevation by approximately 300 mm and increasing its width by roughly 500 mm on each side. The east pier and both abutments will be replaced.

Temporary cofferdams will be placed around the east pier and abutments during construction to provide a dry working space. The cofferdams will be placed between 1 and 2 m from the footing's base, thus increasing the pier and abutment width by this amount on either side, and therefore decreasing the river's flow area accordingly. The west pier will use a permanent sheet piling system for resurfacing, which is only intended on increasing its width by roughly 500mm on either side. However, for the purpose of providing conservative results in this hydraulic study, an increase of 1m on either side was assumed during construction.

Construction criteria

The Ministry of Transportation (MTO) Highway Drainage Design Standards TW-1 provides guidelines for the minimum return period to use in the assessment of the consequences of capacity exceedance during temporary drainage works, broken down by the duration of construction and the consequences of capacity exceedances, as shown in Table 1.

Table 1: Minimum Return Period for temporary drainage works, as reported in the Ministry of Transportation Highway Drainage Design Standards

Minimum Minor Return Period for Temporary Drainage Works			
Duration of Construction	Return Period (Years)		
	Consequence:		
	Low	Medium	High
Less than 2 months	2	2	2
Up to 4 months	2	5	5
Up to 8 months	5	5	10
Up to 12 months	5	5	20
Up to 18 months	5	10	25
Greater than 18 months	10	10	25

The in-water construction works are expected to take 4-8 months. The consequence of exceeding the upstream water levels while using cofferdams would be an increase in flooding to the residences along the Severn River. Because the severity of the additional flooding is unknown, the consequence of failure is categorized as high. The guideline recommends assessing the impacts of the 10-year return period for this duration of construction and consequence rating.

HYDROLOGY AND WATER LEVEL ASSESSMENT

Streamflow and Water Level Data

Water Survey of Canada has historical data for ten gauging stations located on the Severn River and tributaries upstream of Hamlet Swing Bridge. Nine of these gauging stations have minimal data and have been discontinued. The current active station – 02EC014 Severn River above Wasdell Falls - is located approximately 10 km upstream of Hamlet Swing Bridge as shown on Figure 2. While the station has been in operation since 1978 continuous flow data is only available for 1978 and 1992 to 2004 – a total of 14 years - with continuous level data being recorded from 1979 to 1989 and 2005 to present.

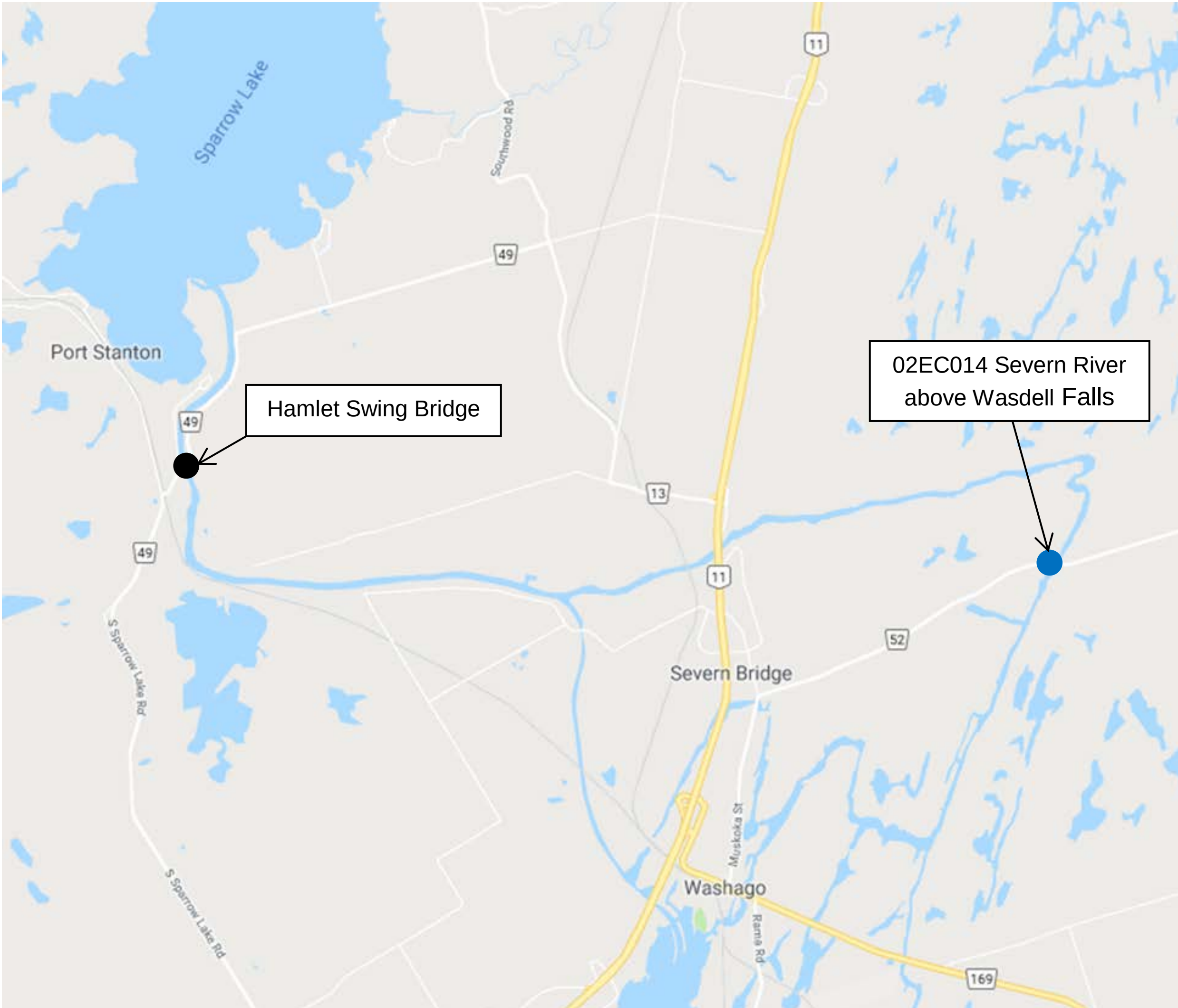

Figure 1: Streamflow Gauging Station Location

Daily streamflow data was provided by Parks Canada Agency for the Severn River at Hamlet Swing Bridge for the 11-year period 2007 to 2017.

Daily water level data for Sparrow Lake was provided by Parks Canada Agency for the 28-year period 1988 to 2015. The actual water level elevation is obtained by adding 200m to the reported data. Also included in this data set is the annual maximum water level for each year from 1918 to 1988 for a combined total record length of 98 years.

Flood Frequency Analysis – Severn River at Hamlet Swing Bridge

Flood frequency analysis was used to determine the return period flows for the hydraulic analysis of the existing conditions and potential impacts during construction of the proposed works. The data for Severn River above Wasdell Falls and at Hamlet Swing Bridge were combined to provide 25 years of daily streamflow.

The statistical program HEC-SSP was used to analyse the data and perform the frequency analysis. While the Severn River flow is regulated, the initial data checks indicated that the data, after the removal of a 3 outliers, was suitable for frequency analysis. The frequency analysis was carried out using the Log Pearson Type III distribution which is commonly used for the analysis of streamflow data. The maximum daily return period discharges are summarized in Table 2.

Table 2: Flood Frequency Analysis – Maximum Daily Discharge

Return Period	Discharge
Years	m^3/s
2	157.0
5	183.8
10	198.9
25	215.8
50	227.2
100	237.7

Water Level Analysis – Sparrow Lake

Sparrow Lake is located downstream of Hamlet Swing Bridge and will be used as the downstream boundary condition for the hydraulic river channel model of the Severn River form the outfall at Sparrow Lake to approximately 3 km upstream of Hamlet Swing Bridge. The maximum, average and minimum daily water levels for the 28-year period 1988 to 2015 are shown in **Figure 3**. The maximum water levels generally occur from late March to early May with a maximum water level during this period of 213.9 m on April 11, 2008. During this same period the maximum average water level was 212.9 m and also occurred during the late March to early May spring flow period.

Based on the overall historical data from the 98-year period 1918 to 2015 the maximum water level was 214.3 m on two occasions -1928 and 1947. Since 1954 the maximum water level has always been below 214.0 m.

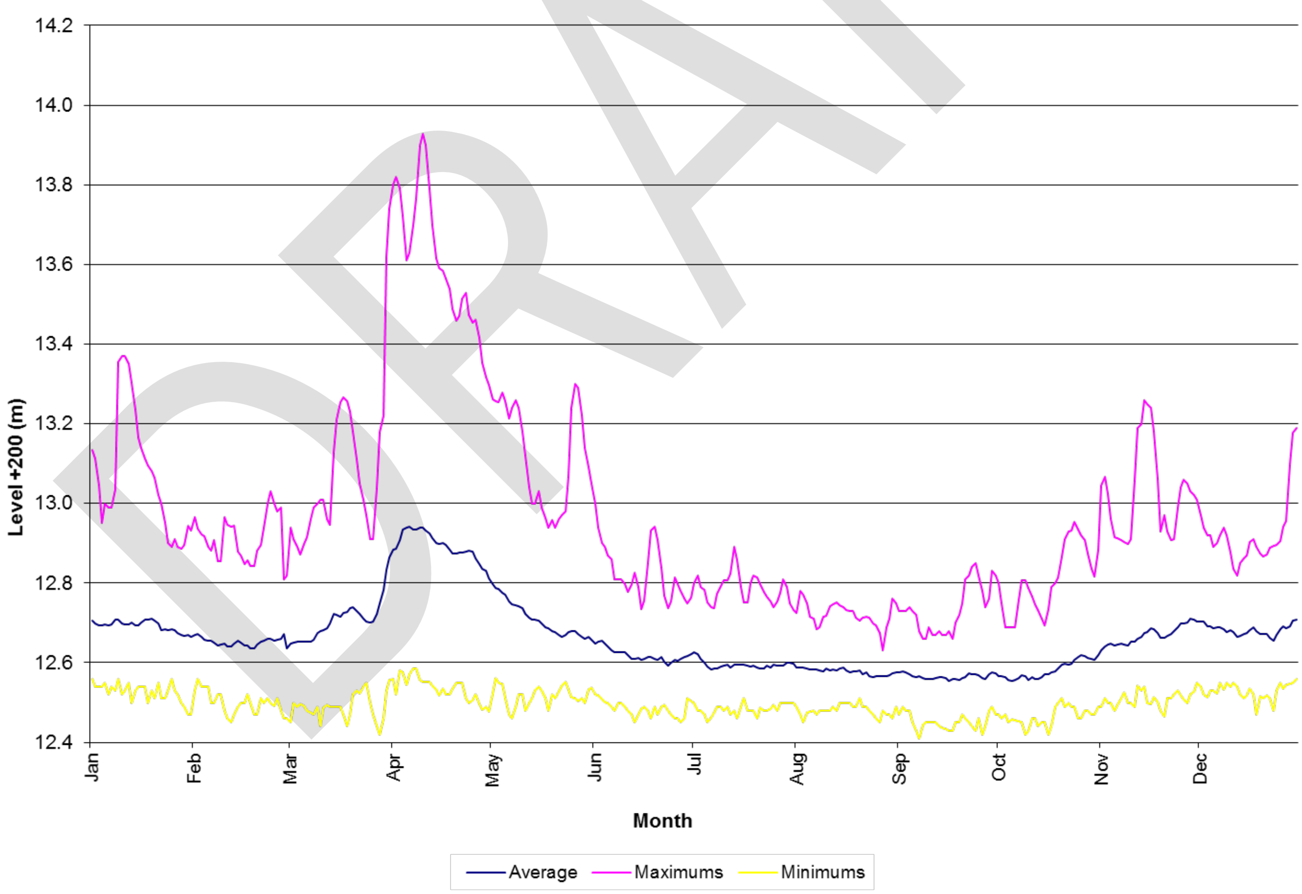

Figure 2: Sparrow Lake water levels

HYDRAULIC MODEL

HEC-RAS hydraulic model parameters

A hydraulic analysis of the Severn River was undertaken to assess the impact of the construction works on the risk of flooding. HEC-RAS was used to build the hydraulic model. HEC-RAS is a 1D modelling software used for computing water surface profiles in open channel flow. The model prepared for this analysis cover the 5-km portion of the Severn River upstream of Sparrow Lake. The only bridge along this portion of the channel is the bridge for which construction is proposed.

Cross-sections were extracted from surveyed data. Callon Dietz was retained to perform the bathymetric survey along the Severn Waterway from the outlet at Sparrow Lake to approximately 3km upstream of Hamlet Swing Bridge. Measurements of the edge of water, along the top and bottom of banks, and of the river bottom were taken every 200m. This data was used to define the channel cross-section used in the HEC-RAS model. Because the Digital Terrain Model provided by PSPC of the riverbed near and under the bridge was incorrect, these cross-sections near the bridge were estimated using existing design drawings.

The channel's bank and riverbed roughness coefficients were estimated based on field observation and standard published values. Standard expansions and contraction coefficients were used along the entire channel, including at the bridge cross-sections. Because the bridge abutments do not seem to contract the flow under the bridge higher and more restrictive coefficients were not required. The existing and proposed bridge decks were extracted from design drawings. Standard drag coefficients were used for the east pier, which is considered as an elongated pier with semi-circular ends. The western pivot pier was represented in the model by modifying the channel cross-section over the 63m length, according to the design drawings. For the construction scenario, the widths of the piers and abutments were increased to represent the cofferdam. Two-meter width were used around the east pier and abutments and 1m width was used around the west pier, as conservative estimate of the reduction in the bridge's opening.

Based on meeting the MTO's guidelines, the impact of the 10-year event was assessed. The 100-year flows were also used to test the difference in the water levels during extreme events. Two boundary conditions were used at the downstream end of the model to compare the difference in water levels based on varying boundary conditions. The following specific levels were tested:

- 213.9 m: the peak maximum level over the year;
- 212.9 m: the peak average level.

Because the highest water level tends to occur during the spring freshette (late Mar to early May), as seen in **Figure 3**, using a peak level of 213.9 m is conservative if these months are avoided during construction.

Scenarios

The results of the hydraulic analysis are summarized in **Table 3** for existing and construction conditions.

Table 3: Severn River Water Levels

Return period (years)	Water level at Sparrow Lake (m)	Existing conditions		Construction scenario	
		Downstream of Bridge (m)	Upstream of Bridge (m)	Downstream of Bridge (m)	Upstream of Bridge (m)
100	213.90	214.03	214.08	214.03	214.10
10		213.99	214.04	213.99	214.06
100	212.90	213.16	213.21	213.16	213.23
10		213.09	213.14	213.09	213.15

Under existing conditions, the water levels through the bridge increase by 5 cm irrespective of the starting water level at Sparrow Lake or the return period flow rate. This minor change in water level through the bridge confirms the minimal impact of the bridge piers and abutments on the flow in the Severn River. Similarly, under construction conditions the water levels through the bridge will increase by 7cm; 2 cm higher than existing conditions. This is a negligible increase in depth and would not be expected to increase the flood risk during the construction period.

The construction conditions will reduce the flow area under the bridge. However, an increase in channel velocity through the bridge minimizes the increase in water level upstream of the bridge.

Conclusions

The existing bridge has only a minor impact on the Severn River water levels because the bridge abutments barely constrict the river's opening and the piers do not cause any significant losses. As such, the main influence on the river water level near the bridge is the downstream water level at Sparrow Lake. During both 100-year and 10-year flow events, and using historical high water levels at Sparrow Lake ranging from 212.9 m to 213.9 m, the water level through the bridge only increases by 5 cm in existing conditions. Although the temporary cofferdams used during construction and the permanent sheet piling system will widen the piers and abutments by roughly 1 and 2 m on either side, this reduction in flow area will only cause an increase in the water level upstream of the bridge by approximately 2cm relative to the existing conditions. This increase is considered negligible and will not have a negative impact on potential flooding of upstream properties.

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