OCTOBER 2018
JACQUES CARTIER AND CHAMPLAIN BRIDGES INCORPORATED (JCCBI)

CHAMPLAIN BRIDGE

IMPACTS DUE TO POSSIBLE DELAYS OF NEW BRIDGE OPENING - UPDATE

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EXECUTIVE SUMMARY

On July 26th, 2017, Jacques Cartier and Champlain Bridges Incorporated (JCCBI) was informed by Infrastructure Canada that the replacement of the existing Champlain Bridge could be behind schedule. At the time, Infrastructure Canada asked JCCBI to investigate the consequences of two delay scenarios of 12 and 24 months beyond the original planned date of December 1, 2018 for decommissioning the existing Champlain Bridge. In September of 2017, COWI produced a report entitled "Champlain Bridge - Impacts Due to Possible Delays of New Bridge Opening" that summarized the risks to the bridge and included a recommended risk mitigation plan to address potential delay scenarios to the planned decommissioning date. In the Fall of 2018, Infrastructure Canada provided an updated estimate of the delays to the new Champlain Bridge, and based on this, JCCBI asked COWI to update its 2017 September report assuming that the decommissioning of the existing Champlain Bridge will be delayed by 6 to 12 months (i.e., sometime between 2019 June 1 and 2019 December 1).

JCCBI has been successfully mitigating the risk associated with the bridge for many years, and regularly encounters new issues due to the uncertainties in the nature of the deterioration. However, **the design details and concrete material characteristics built into the original bridge do not allow for elimination of the problems, and rehabilitation measures are designed, at best, to reduce the risk.** This report presents an updated risk mitigation plan with the objective of extending the service life of the existing Champlain bridge to 2019 December 1 in order to address a potential delay of 6 to 12 months. The recommended risk mitigation measures consider the continued deterioration of the structure, as well as the rehabilitation projects and inspections that were completed in the last year.

The existing Champlain Bridge has many different components, some of which are more deteriorated than others. In 2013, JCCBI implemented a five-year risk mitigation plan in order to deal with the increasing levels of deterioration, and to maintain an acceptable level of structural safety until the bridge's planned decommissioning in 2018. In the last 5 years, this plan has been updated regularly and implemented effectively, and even dealt with a girder failure that occurred in 2013 resulting in a partial closure of the bridge for several weeks. In

September 2017, an updated mitigation plan was recommended due to a potential delay of 12 or 24 to the new bridge. **JCCBI implemented and completed all of the mitigation measures recommended in 2017 which reduced some risks and controlled others**. However, due to continued deterioration of the bridge, **a revised risk mitigation plan is required, and additional measures must now be implemented in order to maintain an acceptable level of structural safety for the next 6 to 12 months beyond December 2018 until the new bridge is open**.

Following the 2018 additional mitigation plan is essential to manage the risk and maintain an acceptable level of public safety, however it cannot eliminate the possibility of a structural failure. Therefore, even with the continued rehabilitation, **substantial risks will remain including the risk of lane closures, the risk of long term full bridge closures, and even the possibility of a collapse of a portion of the bridge. These risks will increase with time due to continued deterioration.** Closing the bridge would have a devastating impact on both the travelling public and the economy of the Montreal region.

It is very difficult to estimate the amount of funding that will be required to maintain an acceptable level of public safety through rehabilitation, monitoring and inspection due to the uncertainties of its current condition and the progression of deterioration until the new bridge opens to traffic. However, COWI recommends that JCCBI have available funding of $20 million if the new bridge is delayed by up to 12 months. The most significant area of potential uncertainty is the condition of the pier foundations where a coring program is being carried out in conjunction with rehabilitation work in order to better define the risks with these components. It is noted that the findings of the underwater coring program could have a significant impact on the amount of budget required to secure the bridge.

COWI is of the opinion that JCCBI must continue to be vigilant in inspecting, monitoring, evaluating, and wherever necessary, strengthening the bridge.

CONTENTS

APPENDICES

1 Purpose

On July 26th, 2017, Jacques Cartier and Champlain Bridges Incorporated (JCCBI) was informed by Infrastructure Canada that the replacement of the existing Champlain Bridge could be behind schedule. At the time, Infrastructure Canada asked JCCBI to investigate the consequences of two delay scenarios of 12 and 24 months beyond the original planned date of December 1, 2018 for decommissioning the existing Champlain Bridge.

Since 1991, COWI has performed many engineering tasks on the Champlain Bridge for JCCBI. In the last 5 years, COWI has been mandated by JCCBI to assess the structure, be responsible for the overall coordination of JCCBI's risk mitigation program, and along with Stantec, be the engineer of record for the rehabilitation measures aimed at keeping the bridge safe for the public.

In September of 2017, COWI produced a report entitled "Champlain Bridge - Impacts Due to Possible Delays of New Bridge Opening" (Our ref: 2038-RPT-GEN-011, dated 2017 September 14) that summarized the risks to the bridge, and included a recommended risk mitigation plan to address potential delay scenarios to the planned decommissioning date.

In the Fall of 2018, Infrastructure Canada provided an updated estimate of the delays to the new Champlain Bridge, and based on this, JCCBI asked COWI to update its 2017 September 14 report[1] assuming that the decommissioning of the existing Champlain Bridge will be delayed by 6 to 12 months (i.e. sometime between 2019 June 1 and 2019 December 1).

This report summarizes the status of JCCBI's risk mitigation plan following the 2017 recommendations and provides COWI's recommended mitigation measures to address a potential delay of 6 to 12 months.

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[1] Champlain Bridge - Impacts Due to Possible Delays of New Bridge Opening, dated 2017 September 14

2 Description of Structure

The existing Champlain Bridge was opened to traffic in 1962. It is a 3.4 km long structure comprising seven steel truss spans (collectively referred to as Section 6), and 50 concrete girder spans (Sections 5 and 7). The bridge accommodates six lanes of traffic, three in each direction. See Figure 1 for an overview of the entire bridge. Appendix A includes a more detailed description of the bridge.

Figure 1 General View of Champlain Bridge

3 Risks with the Bridge

COWI has reviewed their assessment of the risk level for each major component of the bridge presented in the 2017 COWI Report[2] considering the risk mitigation measures completed by JCCBI to date, and how the risks change under 6 and 12 month delay scenarios. This portion of the report is separated into sections that relate to each major component of the bridge. COWI has included an assessment of the risk level for each major component of the bridge and how those risks could change under different delay scenarios in an attempt to give the reader an indication of the severity of each risk.

3.1 Section 6 – Steel Truss Spans

Based on information obtained from the annual inspection of Section 6, the steel truss spans are considered to be in good condition. The trusses have little corrosion, the deck was replaced in the early 1990s and continues to perform well, and the piers were recently repaired and show no major signs of deterioration or distress.

Additional inspections have been undertaken to assess the condition of Section 6 and these inspections are ongoing. In addition, a full load evaluation that incorporated the effects of corrosion identified during the 2017 inspections has been completed by COWI and established that there are no major structural issues with the steel truss spans.

Therefore, COWI believes that the risk associated with the performance of any component of Section 6 of the bridge is low. This level of risk is not expected to change if there is a 6 or 12 month delay to the new bridge.

3.2 Sections 5 & 7 – Concrete Spans

Severe deterioration has occurred in Sections 5 and 7 of the bridge. JCCBI has been aggressively repairing and retrofitting these sections of the bridge for many years. In 2013, COWI studied the overall condition of the concrete span edge girders of the Champlain Bridge. At the time, COWI recommended and JCCBI implemented a strategic action plan in order to address the condition of the bridge and maintain an acceptable level of risk to the structure until the bridge is decommissioned. This action plan included:

- Emergency strengthening measures to be completed by the end of September 2013;
- Short-term actions to be completed by the end of 2014;
- A five-year plan to be completed by the end of 2018.

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[2] Champlain Bridge - Impacts Due to Possible Delays of New Bridge Opening, dated 2017 September 14

In the last 5 years, the action plan developed in 2013 has been continuously updated and additional measures have been required, due to the exponentially accelerating deterioration in the girders and piers. Figure 2 shows the number of girder interventions per year as well as the total expenditures on the overall repairs to the Champlain Bridge per year since the first interventions in 1986. This figure shows the increase in interventions over time for the girders of the Champlain Bridge that have been required to maintain user safety and keep the bridge open to traffic. This also shows JCCBI's significant investment in rehabilitating the bridge since the failure of one of the edge girders in 2013 due to continued corrosion and deterioration of the structure.

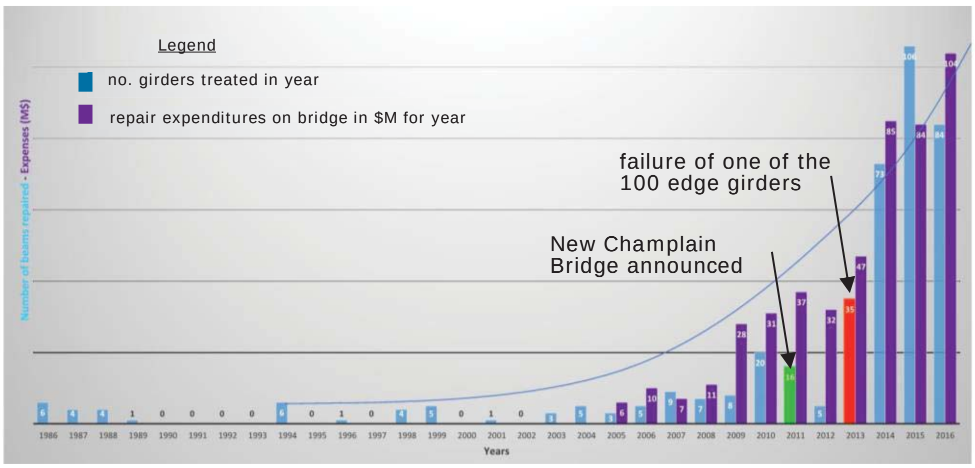

Figure 2 History of Girder Repairs for the Champlain Bridge between 1986 and 2016

3.3 Sections 5 & 7 – Roadway Deck Slab

The roadway deck slab of the concrete spans is the original post-tensioned concrete deck. It exhibits signs of significant deterioration and given the structural details, there is little that can be done to implement a permanent repair to the severely corroded locations. As such, JCCBI continues to repair the deck locally when signs of deterioration present itself.

Figure 3 shows typical observed signs of deterioration on the soffit of deck infill strips. At some locations, there is evidence of corrosion of the transverse post-tensioning tendons in the deck and these tendons are essential to ensure the transverse integrity of the deck slab.

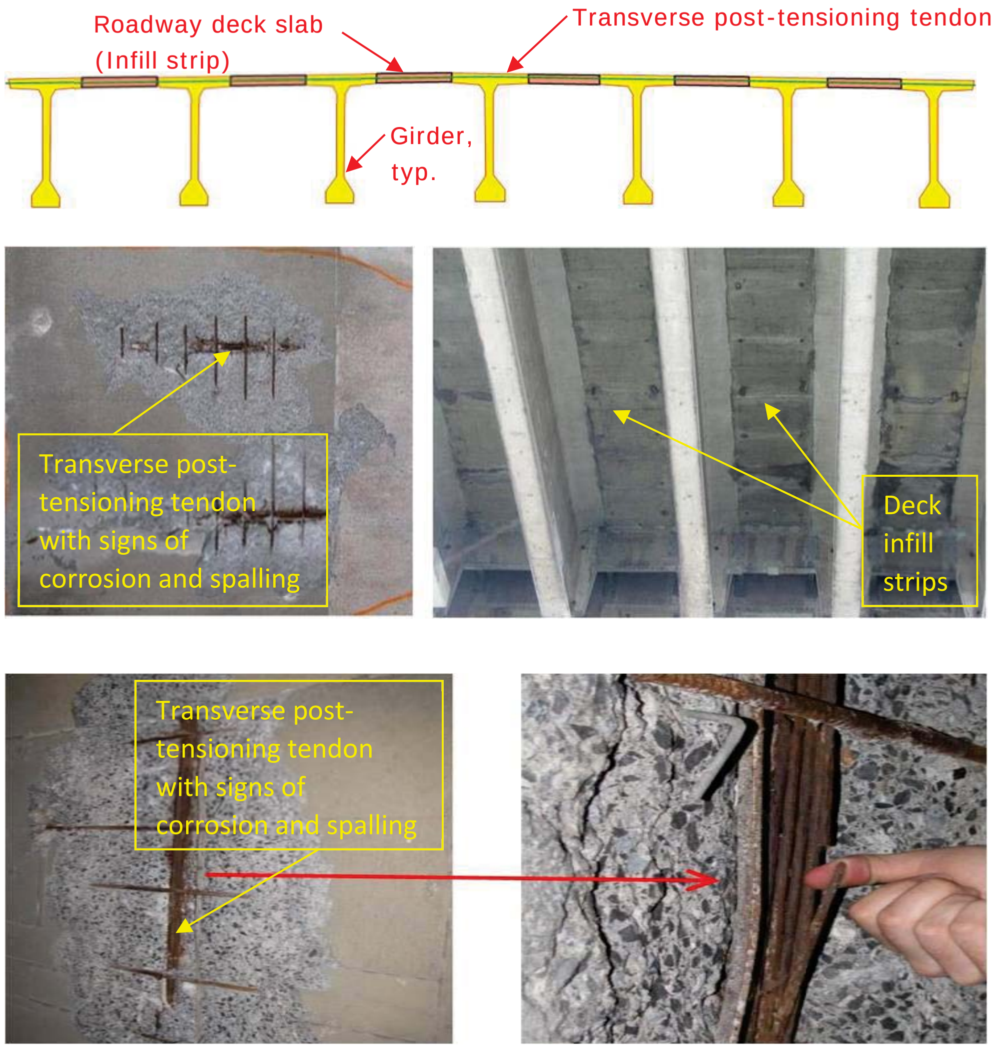

Figure 3 Observed Signs of Deterioration on Soffit of Deck Slab

COWI anticipates that the number of localized deck repairs required per year will continue to increase as time passes.

The risk associated with the deck if a serious problem is not identified by JCCBI's inspection team is a local failure in the deck. The most likely result of a local deck failure would be a short-term closure of one or two lanes of traffic (depending on the extent of the local failure).

Inspections are ongoing for the deck to help manage the risks. COWI believes that the risk of localized failure is low, and is expected to remain low under both 6 and 12 month delay scenarios, however the number of local failures needing repair will increase the longer the new bridge is delayed.

3.4 Sections 5 & 7 – Concrete Girders

There are 350 concrete girders that make up the 50 spans in Sections 5 and 7, and they are among the most seriously deteriorated components of the bridge.

The use of de-icing salts, the lack of proper deck drainage in the first 30 years of service and the absence of a waterproofing membrane, created an environment where salt laden water penetrated into the concrete girders from the deck, or by free drainage over the side of the bridge deck onto the concrete edge girders. The most significant corrosion is in the post-tensioning (PT) inside the girders, which has resulted in severe degradation of the girder concrete and significant loss of strength: in fact in 2013, one of the concrete girders failed and an emergency repair was required to secure the structure.

The initial signs of concrete deterioration and PT corrosion were first observed in the 1980s and over the last 30 years increasing signs of deterioration have been observed, mostly in the edge girders. Figure 7 and Figure 8 show typical signs of girder deterioration observed on many of the 50 concrete spans. Figure 4 shows the severe cracks observed on the surface of the girders that were caused by corrosion of the post-tensioning tendons. Figure 5 shows signs of severe deterioration and spalling on the girder soffit, near mid span. Severe deterioration and failure of some of the PT was also observed through exploratory openings in the concrete girders that were carried out to assess the condition of the PT tendons.

Establishing the amount of PT section loss in a girder is very difficult since only localized openings or surface observations are possible. Although attempts have been made to use non-destructive testing to determine corrosion levels, there is still uncertainty about the actual condition and section loss of the PT tendon and as a result the strength of the girders.

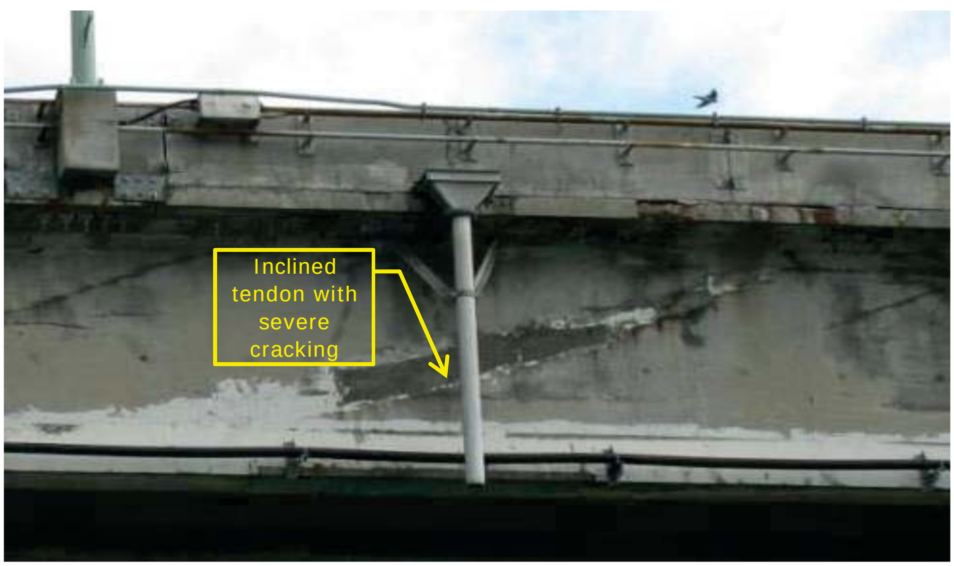

Figure 4 Severe Cracking as Sign of Deterioration of Girder Internal PT

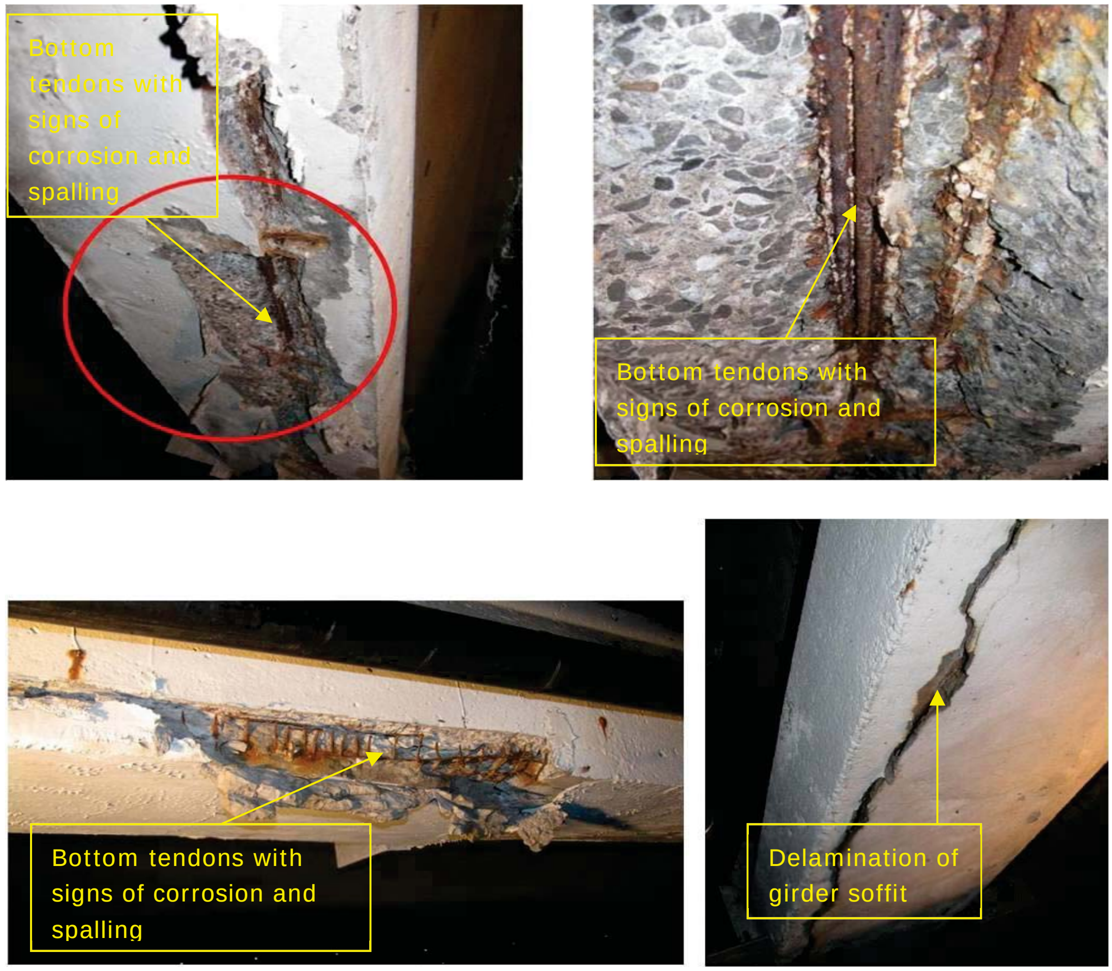

Figure 5 Observed Signs of Deterioration of Edge Girders

3.4.1 100 Concrete Edge Girders

In 2013 a very alarming structural failure occurred to one of the 100 edge girders. Fortunately, as part of JCCBI's proactive approach to managing the deterioration of the bridge, a steel support girder ("Superbeam") had been fabricated in 2009 and stored near the bridge, ready to be used in the event of such a failure. Following this girder failure, JCCBI updated its risk mitigation program and launched a major girder strengthening campaign to ensure structural integrity of all 100 edge girders.

Between 2013 and 2017, support trusses (see Figure 6) were placed under all concrete edge girders except for four spans where other strengthening systems were more suitable or cost-effective and these trusses were designed to carry the entire load that would result from an edge girder failure. Since truss installation was completed on all spans in March 2017, the risk of an edge girder failure has been effectively dealt with, and is considered to be very low (and is expected to remain very low under both the 6 and 12 month delay scenarios). However COWI continues to monitor the behaviour of all 100 concrete edge girders on a daily basis using sensors and a sophisticated monitoring system to assess any changes to the girder deformations.

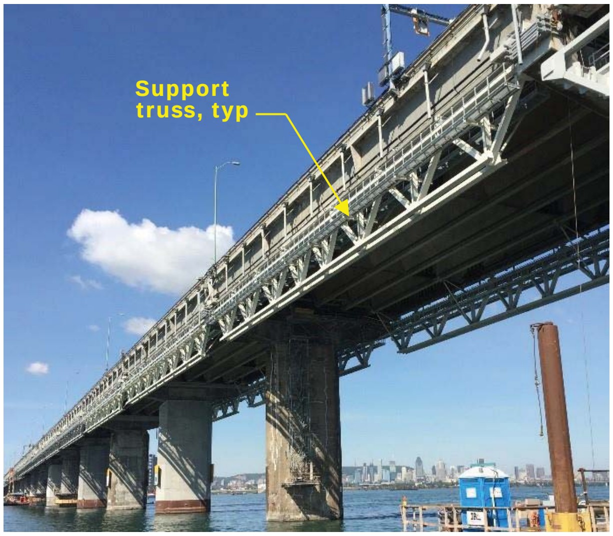

Figure 6 Support Trusses Installed under Concrete Edge Girders

3.4.2 250 Concrete Interior Girders

There are 250 interior concrete girders in Sections 5 and 7. Some interior girders show signs of significant deterioration, and therefore the risk with these girders has to be managed. Additional strengthening measures were designed and installed in 2018 to rehabilitate the most critical interior girders. JCCBI has instrumented 44 of the most deteriorated interior girders with strain gauges, and consultants to JCCBI continue to inspect and closely monitor these girders. COWI considers that there is a medium risk of failure of an interior girder, and that this risk will remain medium under the 6 and 12 month delay scenarios if the 2018 mitigation plan outlined in Section 4.2 is followed (i.e., ensuring that 30 most critical interior girders are equipped with sensors and increasing inspection frequency to every 4 months).

In the unlikely event of a major distress in one of the interior girders, JCCBI has fabricated 3 above deck support "Superbeams" and 1 universal modular truss (UMT). These components are available to be deployed to secure and support a distressed concrete girder.

The use of an above deck Superbeam to secure an interior girder would have a significant impact on traffic resulting in the closure of 2 or 3 traffic lanes. In addition, during the time that the Superbeam is on the bridge deck, it is likely that trucks would be banned from the bridge, and that the dedicated bus lane would be unavailable for use. This is acceptable as a temporary strengthening solution, but a permanent below-deck truss (UMT) would need to be installed under the failed girder to allow the removal of the Superbeam in order to restore traffic. The UMT is designed to fit beneath an interior girder in almost any span.

3.5 Sections 5 & 7 – Concrete Diaphragms

Many of the 1272 concrete diaphragms between the girders in Sections 5 and 7 are in poor condition and show signs of significant deterioration (see Figure 7). At some locations, corrosion of reinforcement, concrete spalling and cracking have been observed. The concrete diaphragms provide load sharing between girders under traffic, and deterioration to these components increase the girder demands and, in turn, the risk. In the last 5 years, many of the diaphragms have been strengthened.

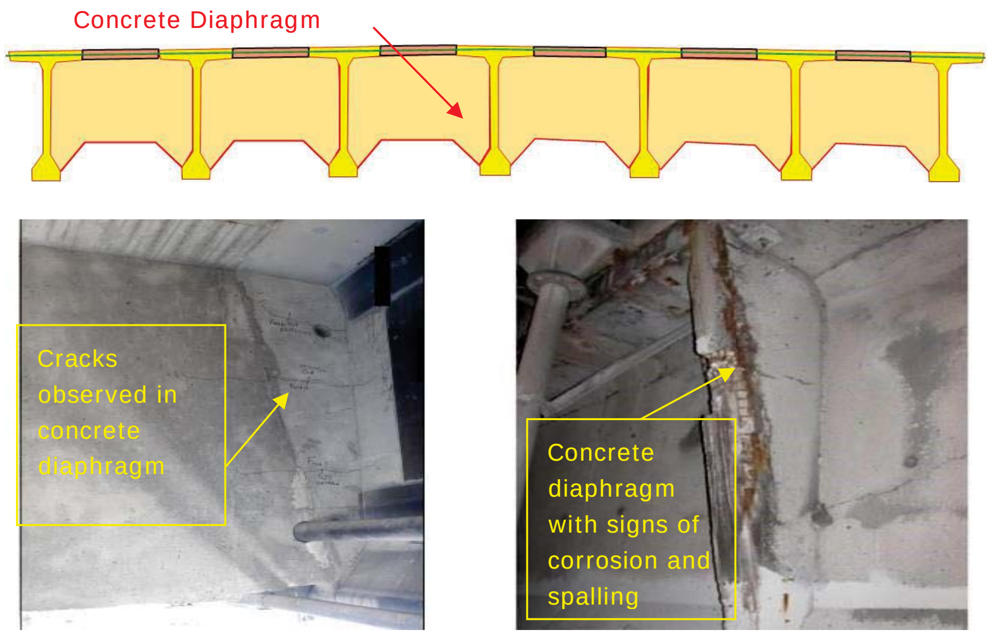

Figure 7 Observed Signs of Deterioration on Concrete Diaphragms

The consequence of a failed concrete diaphragm may require a lane closure on the bridge until it is rehabilitated. JCCBI continues to carry out frequent inspections to closely monitor for signs of distress in the diaphragms. In 2018, COWI developed a concept for strengthening a distressed concrete diaphragm, called the "Super Diaphragm", to provide relief to the distressed diaphragm and the rest of the superstructure. A Super Diaphragm has been fabricated and is currently available for deployment as it is stored in JCCBI's maintenance yard. As part of the 2018 mitigation plan outlined in Section 4.2, JCCBI plans to issue and award a contract for an "emergency" installation (if required) such that a Contractor will be capable of quickly installing the Super Diaphragm should diaphragm distress occur.

COWI considers that there is a medium risk of failure of a concrete diaphragm. This risk will remain medium under the 6 and 12 month delay scenarios due to the mitigation measures completed by and recommended to JCCBI in 2017 and 2018 (fabrication of a Super Diaphragm, the award of a contract for an "emergency" installation if needed, and increased inspection frequency to every 4 months).

3.6 Sections 5 & 7 – Pier Caps

The pier caps of the concrete spans have been retrofitted many times over the years – the most significant interventions were carried out between 2002 and 2013. At the time, significant deterioration of the pier caps, including structural cracking, was observed. Inspections of the pier caps completed in 2016 and early 2017 identified cracks that could be a sign of structural distress (see Figure 8).

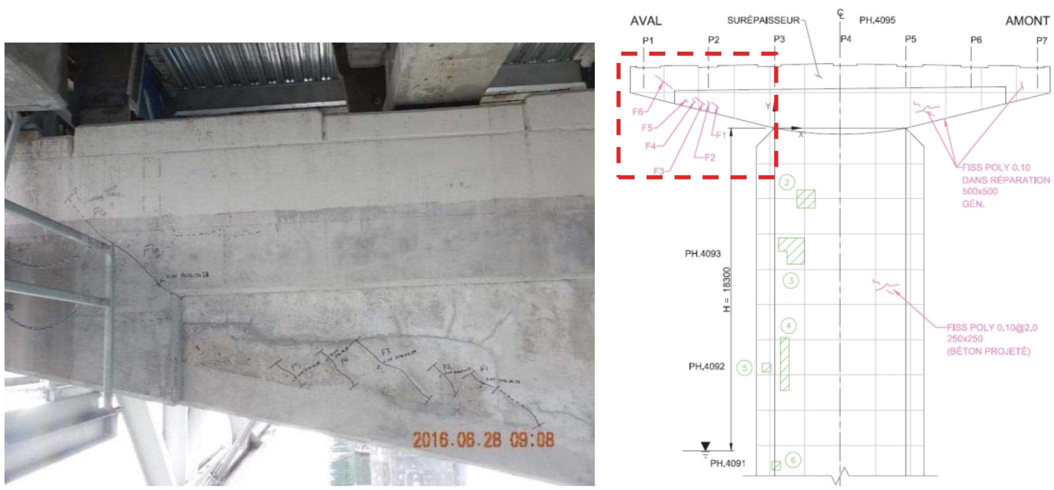

Figure 8 Observed Signs of Deterioration on Pier Caps (Pier 18W shown)

Even with the retrofits and strengthening systems that were added to the pier caps between 2002 and 2013, they are very highly stressed. In addition, due to the ongoing deterioration there is a possibility that unseen defects exist within the pier caps that would potentially affect their load carrying capacity. Since the pier caps have no redundancy, severe distress of a pier cap would result in a complete closure of the bridge, and a complete failure of a pier cap would result in the collapse of two spans of the bridge.

In September 2017, as a result of the communicated possible delays of up to 24 months beyond the original commissioning date of the new bridge, JCCBI made a preemptive decision to implement the additional mitigation measures for the pier caps, irrespective of whether the delays to the new bridge materialize since the risk is so high and the delays could not be quantified at the time. These mitigation measures included:

- Installing sensors on all pier caps to monitor their behavior
- Designing, fabricating and installing retrofit measures to strengthen the pier caps
- Increasing inspection frequency of the pier caps to once every 3 months until retrofit measures can be installed.

In 2017, COWI developed a concept for a strengthening system that will relieve the high stresses exhibited by the pier caps in the zones of concern. The aim of the concept is to relieve the high compressive forces in the zones of concern, and to allow for rapid installation in the event that an urgent situation needs to be addressed. This strengthening system is called the "Super Post" and is shown in Figure 9. In September 2017, COWI considered the risk associated with the pier caps to be medium which would change to high with either a 12 or 24 month delay to the new bridge. Therefore, due to the possible delays of up to 24 months beyond the original commissioning date of the new bridge, JCCBI elected to fabricate and install a Super Post System on 39 of the most critical pier caps in order to reduce the demands on these components. Super Post Systems are not required for the remaining 9 pier caps given their current condition and a maximum anticipated delay of 12 months.

Figure 9 Pier Cap with Super-post System

The installation of 39 Super Post systems implemented as part of the 2017 mitigation measures was completed at the end of August 2018 and reduced the risk to medium for the pier caps.

The additional measures recommended in the 2018 Risk Mitigation Plan, namely monitoring the behavior of all pier caps on a daily basis using sensors and a sophisticated monitoring system to assess any changes, and inspecting the pier caps without Super Post systems on an increased frequency of every 4 months will reduce the risk to low as of the end of October 2018.

3.7 Sections 5 & 7 – Pier Columns

The above-water portion of the piers (the pier-columns) have shown some deterioration over the years, and have generally been repaired. However, since the majority of the load on the columns is vertical, corrosion of the reinforcing in the pier columns is not a major concern.

COWI believe the risk associated with the failure of the pier columns is medium, and is expected to remain medium following completion of the ice breaker repairs in the event of a 6 or 12 month delay to the new bridge. It is noted that this risk level is subject to findings of future inspections.

3.8 Sections 5 & 7 – Pier Bases and Foundations

The underwater portion of the pier (the pier base) and the foundations of the piers are difficult to inspect, and are therefore inspected on a 5 year cycle. JCCBI has completed additional underwater inspections of 14 of the piers and their foundations since the fall of 2017 to ensure that all foundation units have been inspected within the last 5 years. The inspections completed in the Spring of 2018 increased the risk level for these components from low to high due to the extent of deterioration identified and therefore, rehabilitation is required at one pier base and 5 foundations to ensure the structural integrity of these components. The pier base and foundation rehabilitation work is currently ongoing and is expected to be completed before the end of December 2018.

Based on the latest inspection information, COWI believes that the risk associated with the pier base and foundation is high and will become low once the planned rehabilitation work is completed. Assuming that the current coring program included with the rehabilitation work does not identify any issues, the risk will remain low under both 6 and 12 month delay scenarios. It is noted that this risk level could change significantly subject to findings of the current footing coring program and additional pier and foundation rehabilitation work could be required.

4 Risk Mitigation Measures

JCCBI has been successfully mitigating the risk associated with the bridge for many years, and regularly encounters new issues due to the uncertainties in the nature of the deterioration. However, the design details and concrete material characteristics built into the original bridge do not allow for elimination of the problems, and rehabilitation measures are designed, at best, to reduce the risk. Keeping the bridge open beyond the original planned commissioning of the new bridge will be a challenge and will require additional mitigation measures that are summarized in this report.

The current strategic risk mitigation program is the product of a close cooperation between JCCBI and the consultants responsible for the assessment work (primarily COWI and Stantec) that has permitted a coordinated and proactive approach to maintaining the bridge. The strategic risk mitigation program has been critical to successfully ensuring an acceptable level of public safety and allowing the bridge to remain open to traffic.

This section presents the status of JCCBI's risk mitigation plan following the Sept 2017 recommended mitigation measures and provides COWI's 2018 additional recommended risk mitigation plan to address a potential delay of 6 to 12 months for completion of the new bridge.

4.1 Sept 2017 Recommended Mitigation Measures

In September 2017, due to the a possible delay of 12 or 24 months to the opening of the new bridge, COWI recommended additional mitigation measures to maximize the possibility of keeping the bridge open to traffic until the new bridge is open to traffic. The mitigation measures recommended in 2017 and their status are summarized in Table 1. At the time of writing, JCCBI has completed or implemented all of the risk mitigation measures presented in the 2017 COWI Report.

Table 1: Status of 2017 Recommended Risk Mitigation Plan

No	2017 Recommended Mitigation Measure	Status
1	Increase inspection frequency of the most deteriorated interior girders in Section 5 and 7 to twice per year	Implemented and ongoing Most critical interior girders (49/250) inspected twice per year in 2017
2	Increase the inspection frequency of the pier caps in Section 5 and 7 to once every 3 months until retrofit measures can be installed	Inspection frequency increased until retrofit measures installed Completed

3	Immediately design retrofit measures for all of the pier caps in Sections 5 and 7 (target design completion by mid-October 2017)	Completed Oct 2017
4	Install the retrofit measures for all of the pier caps in Sections 5 and 7 (target completion by the end of 2018)	Completed Aug 2018
5	As soon as possible, fabricate a set of retrofit measures that can serve as an emergency repair for the pier caps in Section 5 and 7 in the event that a sudden failure needs to be addressed. Target completion of design by mid-October 2017, and fabrication by end of February 2018.	Pier cap strengthening initiated and completed at 39 of 45 piers instead, therefore this item is no longer required.
6	Design and install retrofit measures for the underwater portions of the piers if issues are discovered during the inspections or engineering calculations show a need for repair.	Inspections completed in 2018 identified 5 piers/foundation units that required rehabilitation work. Construction underway. Planned completion Dec 2018
7	As time passes and deterioration accelerates, it may become necessary to install additional measurement devices on more interior girders in Sections 5 and 7 identified by COWI (anticipate to be a total of 50 girders, 31 of which already have instrumentation). Target completion of installation by the end of December 2017.	Additional sensors installed on 13 girders in 2017 for a total of 44
8	Install instrumentation measurement devices on some of the pier caps in Sections 5 and 7 (target completion of installation by the end of December 2017).	All pier caps were instrumented by end of Dec 2017 Completed.
9	Design and fabricate by summer 2018 an emergency standby truss to be installed between piers under an interior girder, if the need arises.	Design and fabrication completed
10	Design and fabricate an emergency replacement diaphragm to be installed on a distressed diaphragm, if the need arises	Design and fabrication completed

4.2 2018 Additional Recommended Risk Mitigation Plan

Due to the ongoing deterioration and the possible delay of 6 or 12 months to the opening of the new bridge, additional mitigation measures are recommended to maximize the possibility of keeping the bridge open to traffic until the new bridge is completed. These recommended mitigation measures are listed following:

1 Have a Contractor under contract and on standby to install a Superbeam to support any girder in Sections 5 and 7, should the need arise. Have contract in place by Oct 2018.

2 Have a Contractor under contract and on standby to install a universal modular truss under an interior girder and/or install a super diaphragm in Sections 5 and 7, should the need arise. Have contract in place by Dec 2018.

3 Increase the inspection frequency of the most deteriorated interior girders, diaphragms and pier caps in Section 5 and 7 from every 6 months to every 4 months, effective immediately. Plan next inspection for Nov 2018.

4 Ensure 30 most critical interior girders are equipped with sensors. As time passes and deterioration accelerates, since girder ranking changes, it may become necessary to install additional measurement devices on more interior girders in Sections 5 and 7 identified by COWI based on inspections (anticipate to be a total of 50 girders, 44 of which already have instrumentation). At the time of writing, 2 additional sensors are required on the interior girders. Target completion of new installations by the end of October 2018. Reassess the need to equip more girders with sensors following each inspection.

5 Design and install retrofit measures for additional underwater portions of the piers if ongoing foundation work shows condition is worse than assumed from visual underwater inspections. Target developing additional requirements by Dec 2018.

As experienced in 2013 with the unexpected failure of an edge girder, the strength of the bridge can change very quickly. Rehabilitation, frequent inspections and monitoring of the bridge are essential to manage the risk and maintain an acceptable level of public safety, however they cannot eliminate the possibility of a structural failure. Therefore, even with the continued rehabilitation, substantial risks will remain including the risk of lane closures, the risk of long term full bridge closures, and even the possibility of a collapse of a portion of the bridge. These risks will increase with time due to continued deterioration.

5 Conclusions

The existing Champlain Bridge was opened to traffic in 1962. Given its relatively young age, it is reasonable to expect that the bridge would be in much better condition than it is. Unfortunately, this is not the case due to design details and concrete material characteristics that have led to premature deterioration – the initial signs of which showed up 25 years after the bridge was opened which is much earlier than expected.

JCCBI has been successfully mitigating the risk associated with the bridge for many years, and regularly encounters new issues due to the uncertainties in the nature of the deterioration. However, the design details and concrete material characteristics built into the original bridge do not allow for elimination of the problems, and rehabilitation measures are designed, at best, to reduce the risk. Keeping the bridge open until the original planned commissioning of the new bridge is already a challenge. Extending the life of the bridge past December 2018 will require additional mitigation measures that are summarized in this report.

In 2013, JCCBI implemented a five-year risk mitigation plan in order to deal with the increasing levels of deterioration, and to maintain an acceptable level of structural safety until the bridge's planned decommissioning in 2018. In the last 5 years, this plan has been updated regularly and implemented effectively, and even dealt with a girder failure that occurred in 2013 resulting in a partial closure of the bridge for several weeks. In September 2017, an updated mitigation plan was recommended due to a potential delay of 12 or 24 to the new bridge. JCCBI implemented and completed all of the mitigation measures recommended in 2017 which reduced some risks and controlled others. However, due to continued deterioration of the bridge, a revised risk mitigation plan is required, and additional measures must now be implemented in order to maintain an acceptable level of structural safety for the next 6 to 12 months beyond December 2018 until the new bridge is open.

The existing Champlain Bridge has many different components, some of which are more deteriorated than others. The table below summarizes COWI's assessment of the risk level for each major component of the bridge, and how those risks could change under different delay scenarios and different mitigation plans. The "2017 mitigation measures" are those that were planned and implemented by JCCBI before September 2018, whereas the "2018 Mitigation Plan" is the updated plan required to keep the existing bridge open due to the potential 6 to 12 month delay to the new bridge.

Bridge Component	Risk Level (See note 1)			
	Sept 2018	Dec 2018	Jun 2019 6 month delay	Dec 2019 12 month delay
Section 6 - All components (truss spans)				
2017 mitigation measures	Low	Low	Low	Low
2018 mitigation plan	Low	Low	Low	Low
Section 5&7 - Roadway Deck Slab				
2017 mitigation measures	Low	Low	Low	Low
2018 mitigation plan	Low	Low	Low	Low
Section 5&7 – 100 Edge Girders (See note 2)				
2017 mitigation measures	Very Low	Very Low	Very Low	Very Low
2018 mitigation plan	Very Low	Very Low	Very Low	Very Low
Section 5&7 – 250 Interior Girders				
2017 mitigation measures	Medium	Medium	Medium	Medium
2018 mitigation plan	Medium	Medium (3)	Medium (3)	Medium (3)
Section 5&7 – 1,272 Diaphragms				
2017 mitigation measures	Medium	Medium	High	High
2018 mitigation plan	Medium	Medium (3)	Medium (3)	Medium (3)
Section 5&7 - Pier Caps				
2017 mitigation measures	Medium	Medium	Medium	Medium
2018 mitigation plan	Medium	Low (4)	Low (4)	Low (4)
Section 5&7 - Pier Columns				
2017 mitigation measures	Medium	Medium	Medium	Medium
2018 mitigation plan	Medium	Medium (5)	Medium (5)	Medium (5)
Section 5&7 - Pier Bases and Foundations				
2017 mitigation measures	High	Low	Low	Low
2018 mitigation plan	High	Low (6)	Low (6)	Low (6)

Notes:

1. Estimates for future risk levels are uncertain as it is not possible to accurately predict the effects of continued deterioration.

2. Risk has been effectively dealt with since truss installation was completed on all spans in March 2017.

3. Risk level remains medium for 2018 mitigation plan since JCCBI will have tools to secure components in the event of distress to reduce risk beyond Dec 2018. Furthermore, the frequency of inspection of the most critical interior girders and diaphragms has been increased to every 4 months from every 6 months and sensors will be installed on 2 additional interior girders before Dec 2018 to control the risk.

4. Risk level will be reduced to low as of October 2018 since Super Post Systems have been installed to strengthen the most critical pier caps, the behavior of all pier caps is monitored on a daily basis using sensors and a sophisticated monitoring system to assess any changes, and the pier caps without Super Post systems are inspected every 4 months.

5. Risk level subject to findings of future inspections.

6. The pier bases and foundations are currently considered to be high risk level due to the extent of deterioration identified in inspections completed in the Fall 2017 and early 2018. Ongoing pier base and foundation rehabilitation work will be completed before the end of December 2018 to reduce the risks with these components. Assuming that the coring program included with the current rehabilitation work does not identify any issues, the risk will remain low under both 6 and 12 month delay scenarios. It is noted that this risk level could change significantly subject to findings of current underwater coring program.

COWI is of the view that each of the above risks are currently at an acceptable level for JCCBI to keep the bridge open to traffic. Mitigation measures recommended in this report must be implemented to control the risks and maintain the integrity of the structure. Should any inspections or monitoring reveal any new structural defects or material deterioration, it may become necessary to close certain lanes or perhaps even the entire bridge for an undetermined period of time.

It is very difficult to estimate the amount of funding that will be required to maintain an acceptable level of public safety through rehabilitation, monitoring and inspection due to the uncertainties of its current condition and the progression of deterioration until the new bridge opens to traffic. However, COWI recommends that JCCBI have available funding of $20 million if the new bridge is delayed by up to 12 months. The most significant area of potential uncertainty is the condition of the pier foundations where a coring program is being carried out in conjunction with rehabilitation work in order to better define the risks with these components. It is noted that the findings of the underwater coring program could have a significant impact on the amount of budget required to secure the bridge.

Following the mitigation plan is essential to manage the risk and maintain an acceptable level of public safety, however it cannot eliminate the possibility of a structural failure. Therefore, even with the continued rehabilitation, substantial risks will remain including the risk of lane closures, the risk of long term full bridge closures, and even the possibility of a collapse of a portion of the bridge. These risks will increase with time due to continued deterioration. Closing the bridge would have a devastating impact on both the travelling public and the economy of the Montreal region.

In summary, COWI is of the opinion that that JCCBI must continue to be vigilant in inspecting, monitoring, evaluating, and wherever necessary, strengthening the bridge.

Appendix A Description of the Existing Bridge

A.1 Description of Structure

The existing Champlain Bridge was opened to traffic in 1962. It is a 3.4 km long structure comprising a cantilever steel truss main span over the Seaway, flanked by two truss spans on each side (collectively referred to as Section 6), and 50 concrete spans (Sections 5 and 7). The bridge accommodates six lanes of traffic, three in each direction. See Figure A10 for an overview of the entire bridge.

Figure A10 General View of Champlain Bridge

A.2 Section 6 - Steel Truss Spans

Figure A11 shows the general arrangement of Section 6, which consists of four under deck truss spans and a three-span truss main bridge. These seven spans are supported by eight concrete piers (4W to 4E).

[redacted]

Figure A11 General Arrangement of the Steel Truss Spans in Section 6

Each of the four under deck truss spans (78.0 m for spans 4W-3W, 3E-4E; and 78.5 m for spans 3W-2W, 2E-3E – see Figure A11) consists of four simply supported steel trusses topped by an orthotropic deck that supports the roadway traffic.

The main span bridge consists of three cantilever-type steel trusses, spanning over three spans. Each truss is composed of five separate portions: two [redacted] (117.5 m), [redacted] (48.9 m), and a [redacted] (117.5 m), as shown in Figure A11. The traffic is supported by an orthotropic deck, which is situated near the bottom chord of the trusses.

A.3 Sections 5 and 7– Concrete Spans

Each of the 50 concrete spans in Sections 5 and 7 is a simply supported system and has a cross-section of seven precast post-tensioned (PT) girders (see Figure A12). The deck slab between the top flanges of the girders at deck level is made up of cast-in-place infill strips. There are diaphragms between the girders, both at the bearing locations and within the span. The deck is post-tensioned in the transverse direction in the slab and the diaphragms. The top flanges of the girders together with the cast-in-place infill strips constitute the deck over which an asphalt riding surface is installed. This results in a structure that is highly integrated in both the longitudinal and transverse directions.

Figure A12 Typical Concrete Span in Section 5 & 7

The concrete spans range in length from 51.4 m to 53.7 m. A typical concrete girder is reinforced with 24 internal post-tensioning (PT) tendons. The tendons have a parabolic profile, with 14 tendons anchored on the girder ends and up to 10 tendons anchored on the girder top. Figure A13 shows the bridge deck typical section and an elevation of the girder PT tendon layout.

[redacted]

Figure A13 Typical Section 5 and 7 Concrete Span Deck Cross-Section and Elevation of Girder Internal Post-Tensioning System