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Attention: Mr. Byron Madrid, P. Eng.
Manager Asset Management, Major Pipelines
Enbridge Gas Distribution Inc.
101 Honda Blvd.
Markham, ON L6C 0M6

Reference: Amendment to the April 6, 2016 Update to Structural Condition Assessment, Don River Utility Bridge, Toronto

Dear Byron,

Stantec Consulting Ltd. (Stantec) was retained by Enbridge Gas Distribution Inc. (EGD) to conduct an assessment of the updated hydraulic modeling of the Lower Don River and prepare an update of the structural assessment of the Don River Utility Bridge.

This submission includes:

1. Bridge Survey (**Attachment 1**)
2. Hydraulic Report (**Attachment 2**)
3. Structural Report (**Attachment 3**)
4. Erosion Assessment (**Attachment 4**)
5. Geophysical Interpretation Report **(Attachment 5**)
6. 3D Model of the Bridge (**Attachment 6**)
7. Photos of the Bridge (**Attachment 7**)
8. ACB Mat Selection (**Attachment 8**)

1 BACKGROUND

The Don River Utility Bridge was built in 1929. It is owned and operated by EGD. The bridge has a 40 m span and a 5.25 m wide deck. It is located on the Don River close to the intersection of Eastern Ave and Bayview Ave in Toronto. The bridge is a reinforced concrete bowstring (tied arch) structure that sits on massive concrete abutments and spans east-west over the Don River. The bridge currently carries an NPS 30" steel EGD natural gas pipeline, an abandoned NPS 36" cast iron EGD natural gas pipeline and an abandoned NPS 12" water main. The bridge also has telecommunications fibre-optic cables which are affixed to the outside of the bridge on the north side. The bridge has withstood numerous flooding events through its life, including Hurricane Hazel in October 1954. Hurricane Hazel was later defined as the Regulatory flood for the Toronto Region and Southwest Ontario.

Photos of the bridge deck as well as both abutments are presented in **Attachment 6**.

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2 BRIDGE SURVEY

A Stantec survey team led by a professional Ontario Land Surveyor (OLS) equipped with a Trimble robotic 2" total station, Global Positioning System (GPS) and Faro 3D LiDAR scanning capabilities conducted the survey of the Don River Utility Bridge in September of 2015. A laser scanner was used to capture both the exterior and interior parts of the bridge.

A 2 (two) dimensional plan view of the bridge was prepared in Civil 3D (**Attachment 1**). Also, a 3 (three) dimensional model from the point cloud scan was prepared. The 3D model includes the exterior concrete outline of the bridge, location of the interior walls, pipes and deck (**Attachment 6**).

3 EROSION ASSESSMENT

Stantec conducted the erosion assessment (**Attachment 4**) using a boat and underwater camera on September 16, 2015. The objective was to characterize scour and erosion at the utility bridge abutments. The erosion assessment was conducted from a 14 ft aluminum boat using an underwater video camera (Shark Marine DV laptop with low light black and white lens) and a waterproof still image camera (Nikon Coolpix AW120). The images and video were georeferenced and were used to assist in characterizing existing conditions with respect to scour and erosion in the vicinity of the bridge abutments.

The survey identified erosion on both banks, upstream and downstream of the bridge abutments. Observations and imagery in the vicinity of the abutments indicate that substrate is primarily comprised of silt and that there is some degree of undercutting (0.1 m to 0.2 m) at the base of the abutments on both banks.

Remnants of wooden piles were completely submerged in front of the west concrete abutment. Remnants of wooden piles were visible above the water in front of the east concrete abutment. The wood piles vary in height up to approximately 1.5 m above the water surface.

The west abutment shows substantial deterioration of its upstream face. Signs of erosion and soil loss are extensive. Though both bridge abutments require stabilization to avoid further deterioration, the west abutment should be a priority.

4 HYDRAULIC ASSESSMENT

The hydraulic assessment report (**Attachment 2**) includes the results of hydraulic modeling, stream flow pressure calculations, ice pressure force estimates and probability of selected flood scenarios.

Hydraulic modeling was performed by TRCA using the Delft model for the Lower Don River. The model was built as a part of the Environmental Assessment for the Don Mouth Naturalization and Port Lands Flood Protection project. Recently constructed flood relief structures of the Lower Don River were incorporated into the model.

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Hydraulic loads were estimated based on the pressure acting on the utility bridge as a function of submerged depth and water velocity. Both average and maximum pressures were estimated, however, maximum pressures are used for the design loading and structural assessments. The dynamic force of floating ice sheets and floes striking the structure were also calculated.

Three flood scenarios were accessed in the hydraulic report:

1. 200 year flow with ice-free conditions. The bridge low chord is submerged by 0.1 m, average flow velocity is 3.8 m/s and maximum stream flow pressure is 5.51 kPa. The return period of this event is 200 years and probability is 0.005.

2. Regulatory flood with ice free conditions. The bridge low chord is submerged by 0.31 m, average flow velocity is 5.0 m/s and maximum stream flow pressure is 7.25 kPa. The return period of the Regulatory flood varies, based on various estimations, between 750 and 10000 years. For the purpose of this report, a conservative return period of 750 year was assigned to the Regulatory flood. Probability of this event is 0.00133.

3. 200 year flow with ice jams between January and April. The bridge low chord is submerged by 0.1 m and additional 0.3 m of ice was added. Average flow velocity is 3.8 m/s and maximum stream flow pressure is 5.51 kPa. Dynamic horizontal ice forces are 19,236 kN. The return period of a runoff event of the 200 year storm magnitude during the January – April period with modeled ice floe conditions is estimated at 4,000 years. Probability of this event is 0.00025.

It was noted that current conditions of the abutments are not adequate. A significant amount of embankment fill has washed away over the years. The west embankment is substantially deteriorated. It is recommended that the abutments should be protected to prevent further erosion and potential destabilization of the bridge. It is estimated that one large 100 year event or several smaller events can potentially cause critical embankment erosion, pipe exposure or bridge deck destabilization.

5 GEOPHYSICAL INTERPRETATION REPORT

MultiView Locates Inc. carried out a detailed Ground Penetrating Radar (GPR) analysis of the utility bridge (**Attachment 5**). The Non-Destructive Testing (NDT) Assessment Report summarizes the GPR data collection logistics and methodology, processing results and multi-parameter data interpretation associated with the bridge structural analysis. Potential deteriorated areas in several portions of the bridge were identified.

6 STRUCTURAL ASSESSMENT

In the original bridge design the abutments were protected from erosion by embankment fill. For the last 88 years the fill has been completely washed away and apparent signs of abutment deterioration (especially west embankment) were observed. The west bridge abutment is in a failure mode. The failure was defined as any risk to the pipeline. The pipeline is currently exposed below the concrete deck slab. The abutments should be protected to prevent further erosion and potential destabilization of the bridge. Sheet piles or Articulated Concrete Blocks (ACB) can be used for bank stabilization.

Stantec conducted a structural assessment of the bridge (**Attachment 3**) based on assumption that the abutments are protected from further erosion.

The utility bridge under normal loading is satisfactory, based on the results of our analysis for Ontario Building Code (OBC) combinations of dead, live, wind and snow loads. This result is consistent with the observed condition of the bridge.

Hydraulic modeling indicates that 0.1 m of the bottom chord of the bridge will be submerged during the 200 year flood event. When there is no ice loading on the superstructure, the loads are not significant and the stress levels of the structural components are relatively low. Therefore, considering our assumptions, based on the latest OBC, the bridge structure is adequate to carry the loads.

If the 200 year flooding event occurred simultaneously with ice loading the bottom chords and some members (such as bottom chords and hangers) will experience significant stress. Through the design process based on the CSA A23.3-04, hangers in particular, required significant amount of reinforcement which we assume it is not the case. Therefore, considering our assumptions, based on the latest OBC, the bridge structure is not adequate to withstand this condition.

The bridge deck will be submerged by 2.1 m during the Regulatory flood. Similarly to the 200 year flood, if there is no ice loading on the superstructure, the loads on the members are not significant and the stress levels of the structural components are relatively low. Therefore, considering our assumptions, based on the latest OBC, the bridge structure is adequate to withstand the loads.

If, during the Regulatory flooding event the ice loads come into account, there will be ice impact loads striking the wall panels and hangers. The probability of wall panels' failing and subsequently the hangers' failure will be extremely high. As a result, the likelihood of the bridge superstructure damage will also be much higher than during the 200-year flood event. Therefore, considering our assumptions, based on the latest OBC, the bridge structure is not adequate to withstand this condition.

Presently the pipeline is not attached to the bridge and the Regional storm can cause buoyancy of the pipe. Straps on the pipe are recommended to counter the buoyancy forces.

7 EROSION PROTECTION

Bank erosion upstream of the west abutment can be mitigated by installing metal sheet piles or articulated concrete blocks (ACB) mats. The sheet piles option was considered but not recommended because of two 762 mm cast iron bell and spigot sanitary sewers which cross the Don River about 2 m upstream from the proposed sheet piles. Sewer pipe drawings obtained from Toronto Water indicated the cast iron pipes were over 106 years old (1911) and placed about 4 m

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below river bed. Vibration or driving impact seismicity during sheet pile installation may cause failure of the underground cast iron sewer pipes.

The ACB mats are the preferred alternative mitigation for the west bridge abutment. The ACB mats are connected by cables allowing each individual block to be flexible and follow the terrain of the ground. The mats are clamped together to form a single strong unit. 7 oz non-woven geotextile is attached to the base of the concrete mat during manufacturing. International Erosion Control System Inc. (IECS) as a manufacturer of ACB run a model for site specific conditions and recommended to use CC-45 blocks (**Appendix 8**). The blocks have 292.1 mm square top faces and 393.7 mm square bottoms interlocked by 4 mm integrally woven stainless steel cables, which are poured within each block.

For mat stability on the steep slope, the arrowhead earth anchors will be used. The anchors are 1.2 m long and are placed every two blocks.

The total ACB area is about 18 m^2 with one row of blocks to be used for toe-in and one row of blocks to be used for key-in.

8 CONCLUSIONS

Current conditions of the west abutment are not adequate. Comparison of original bridge design drawings with the current survey indicates that a significant amount of embankment fill has washed away over the last 88 years along with the retaining walls that supported the fill. The west embankment is substantially deteriorated. The abutments should be protected to prevent further erosion and potential destabilization of the bridge.

It is estimated that one large 100-year event (water velocities at the bridge 3.5 m/s and water elevation of 77.7 m) or several smaller events (e.g. four 25 year events) can potentially cause critical embankment erosion, pipe exposure or bridge deck destabilization. Probability calculations of bridge failure for the existing conditions due to erosion are presented in **Table 1**. Bridge failure was defined as any bridge movement or disintegration which can potentially lead to pipe damage or erosion of embankments which can lead to pipe exposure.

Probability of failure calculations in *n* years was conducted using the following equation:

$$r = 1 - (1 - 1/T)^n$$

Where:

r = probability of an event being equaled or exceeded at least once in *n* years
T = return period, years
n = design life, years

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Table 1. Probability of Failure Calculations due to Erosion (Existing Conditions)

Design Life or Risk of Failure(n)	Return Period (T), years	Probability of Event (P)	Probability of Failure in *n* years (r)
1 year	100	0.01	0.01
5 years	100	0.01	0.05
25 years	100	0.01	0.22
50 years	100	0.01	0.39
100 years	100	0.01	0.63

It is recommended that the west abutment is protected to prevent further erosion and potential destabilization of the bridge. As described in Section 7 the ACB mats are the preferred alternative for erosion protection, however, at high water levels the deterioration of the west abutment may continue. The area of concern is the end of the bridge deck where the approach slab is located. Currently, there is a large cavity under the approach slab. The cavity is proposed to be filled with 50 mm diameter clear stone and "capped" the exposed areas in direct contact with flow with a larger rip-rap (i.e. R50). One 200-year event or several 100 year events may cause further erosion. At the 200-year flow, the bridge low chord is submerged by 0.1 m, average flow velocity is 3.8 m/s and maximum stream flow pressure is 5.51 kPa. Probability calculations of bridge failure after the ACB mats are installed are presented in **Table 2.**

Table 2. Probability of Failure Calculations due to Erosion (West Bank Protected with ACB)

Design Life or Risk of Failure(n)	Return Period (T), years	Probability of Event (P)	Probability of Failure in *n* years (r)
1 year	200	0.005	0.005
5 years	200	0.005	0.0247
25 years	200	0.005	0.1178
50 years	200	0.005	0.2217
100 years	200	0.005	0.3942

Another existing concern with the bridge is related to pipe buoyancy. Presently the pipes are not attached to the bridge and the Regional Storm can cause them to float. Probability of the Regional Storm was conservatively assumed 750 years for the purposes of this study.

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Pipe failure due to buoyancy forces has a predicted probability of 1 in 750 years. Buoyancy forces can be counteracted by installing pipe straps and connecting the pipes to the bridge deck. Predicted probability of pipe failure due to buoyancy after installation of pipe straps will be negligible. In terms of thermal loads on pipes, since concrete and steel expand at similar rates, and the overall length of the concrete structure is less than 50 m, the related forces imparted onto the pipes are negligible. Probability calculations of pipe failure due to buoyancy are presented in **Table 3**.

Table 3. Probability of Failure Calculations due to Pipe Buoyancy (Existing Conditions)

Design Life or Risk of Failure(n)	Return Period (T), years	Probability of Event (P)	Probability of Failure in n years (r)
1 year	750	0.0013	0.0013
5 years	750	0.0013	0.0066
25 years	750	0.0013	0.0328
50 years	750	0.0013	0.0645
100 years	750	0.0013	0.1249

Three additional scenarios were considered based on assumptions that abutments are protected, pipe is attached to the bridge with the straps and embankments are stabilized from further erosion by using ACB mats, sheet piles or other alternative protection:

1. 200-year flow with ice-free conditions;
2. Regulatory flood with ice-free conditions; and
3. 200-year flow with ice jams in January – April.

The Regulatory flood (tropical depression storm) with ice conditions was not evaluated as these two events are improbable to occur simultaneously due to differing seasonality of occurrence. Return periods, probabilities, and bridge integrity for three evaluated scenarios are presented in **Table 4**. Based on assumptions described in the Hydraulic and Structural reports, the bridge structure can withstand hydraulic loading from the 200-year flow and the Regulatory flood. However, a simultaneous combination of the 200-year flood in January-April and additional ice load of 0.3 m can cause bridge deformation/deflection which may lead to pipe movement, rupture and/or failure.

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Table 4. Return Period and Probability of Different Scenarios

Scenario		Return Period (T), years	Probability of Event (P)	Bridge Structure
1	200-yr flow & ice-free conditions	200	0.00500	Adequate
2	Regulatory Flood & ice-free conditions	750	0.00133	Adequate
3	200-yr flow & 5 yr ice conditions (January – April)	4,000	0.00025	Potential Failure

Scenarios 1 and 2 do not have the probability of failure as the structure is adequate to withstand these events.

Results of probability of failure calculations for Scenario 3 (i.e. 200-year flow & 5-year ice conditions) are presented in **Table 5**. Pipe failure due to a 200-year flow and 5 year ice cover has a predicted probability of 1 in 4,000 years. The removal of concrete walls within the bridge arches was considered as a mitigation measure, however, it was not recommended as it can increase probability of failure due to ice impact. Currently, the panels shield the pipeline from direct ice impact. The probability of failure of the bridge for Scenario 3 in one year is 0.00025 and in 5 years is 0.0012. The bridge failure was defined as any bridge movement or deterioration which can lead to pipe damage.

Table 5. Probability Calculations for 200-year Flow & 5-year Ice

Design Life or Risk of Failure(n)	Return Period (T), years	Probability of Event (P)	Probability of Failure in n years (r)
1 year	4,000	0.00025	0.00025
5 years	4,000	0.00025	0.0012
25 years	4,000	0.00025	0.0062
50 years	4,000	0.00025	0.0124
100 years	4,000	0.00025	0.0247

Probability of failure calculations for all potential scenarios are summarized in **Table 6**. Each of these scenarios can cause bridge deformation/deflection/movement which may lead to pipe damage, rupture and failure.

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Table 6. Summary of Probability Calculations

Scenarios	Return Period (T), years	Probability of Event (P)	Probability of Failure in 5 years
Failure due to Erosion (Existing Conditions)	100	0.01	0.049
Failure due to Erosion with Installed ACB	200	0.005	0.0247
Failure due to Pipe Buoyancy	750	0.0013	0.0066
Failure due to 200 yr Flow & 5 yr Ice	4,000	0.00025	0.0012

9 PROPOSED REMEDIAL MEASURES

The following remedial measures are recommended to increase structural stability of the bridge:

- Current conditions of the west abutment are not adequate. The abutment should be protected to prevent further erosion and potential destabilization of the bridge. Sheet piles are not recommended due to proximity of two older large cast iron sanitary sewer trunks. The ACB mats are recommended as a bank stabilization and protection measure.
- It is important to address the deteriorated shape of the west embankment as soon as possible.
- Straps on the pipe to counter the buoyancy forces are recommended as a long-term solution. The pipe is scheduled to be decommissioned within next 5 years. Probability of pipe failure due to buoyancy in the next 5 years is low. As such, there is no need for straps on the pipe as part of the short-term west bridge abutment remediation plan.
- ACB mats will protect the bank and bridge abutment from erosion. Probability of pipe failure after the ACB installation within 5 years is 0.024, which is low.

Reference: Amendment to the April 6, 2016 Update to Structural Condition Assessment, Don River Utility Bridge, Toronto

We trust this information is suitable for the purpose of this study. Please do not hesitate to contact the undersigned should you have any questions or require additional information regarding this Project.

Regards,

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Attachments: **Attachment 1 -** Bridge Survey
Attachment 2 - Hydraulic Report
Attachment 3 - Structural Report
Attachment 4 - Erosion Assessment
Attachment 5 - Geophysical Interpretation Report
Attachment 6 - 3D Model of the Bridge
Attachment 7 - Photos of the Bridge
Attachment 8 - ACB Mat Selection