Integrity Assessment of Lateral movement Risk for Line 5 at Straits of Mackinac Including Biota Effect

This document presents the results of an assessment carried out internally by Enbridge to assess the integrity of Line 5 at the Straits of Mackinac with respect to lateral movement threat. PRCI Guidelines PR-170-9520 (Integrity Assessment of Exposed/Unburied Pipe in River) was used to evaluate the hydrodynamic drag forces and ASME B31.4-2016 was used to determine the allowable stresses for the integrity assessment. DNV/GL-RP-F114 (Pipe-soil Interaction for Submarine Pipelines) was used to characterize the lateral resistance of the lake bottom to pipe movement.

The effect of biota (i.e. marine growth on the pipeline) was studied using the preliminary data from samples taken from the pipeline and tested in the lab. The biota mass per unit length of pipe ranged from 0.71 to 18.4 lb/ft, with an average of 5.40 lb/ft. A biota mass per unit pipe length of 18.5 lb/ft was conservatively assumed in the assessment. The final results from the Biota study will be reviewed to evaluate the need to update this assessment.

Table 1 below shows the input parameters and their values used in the assessment:

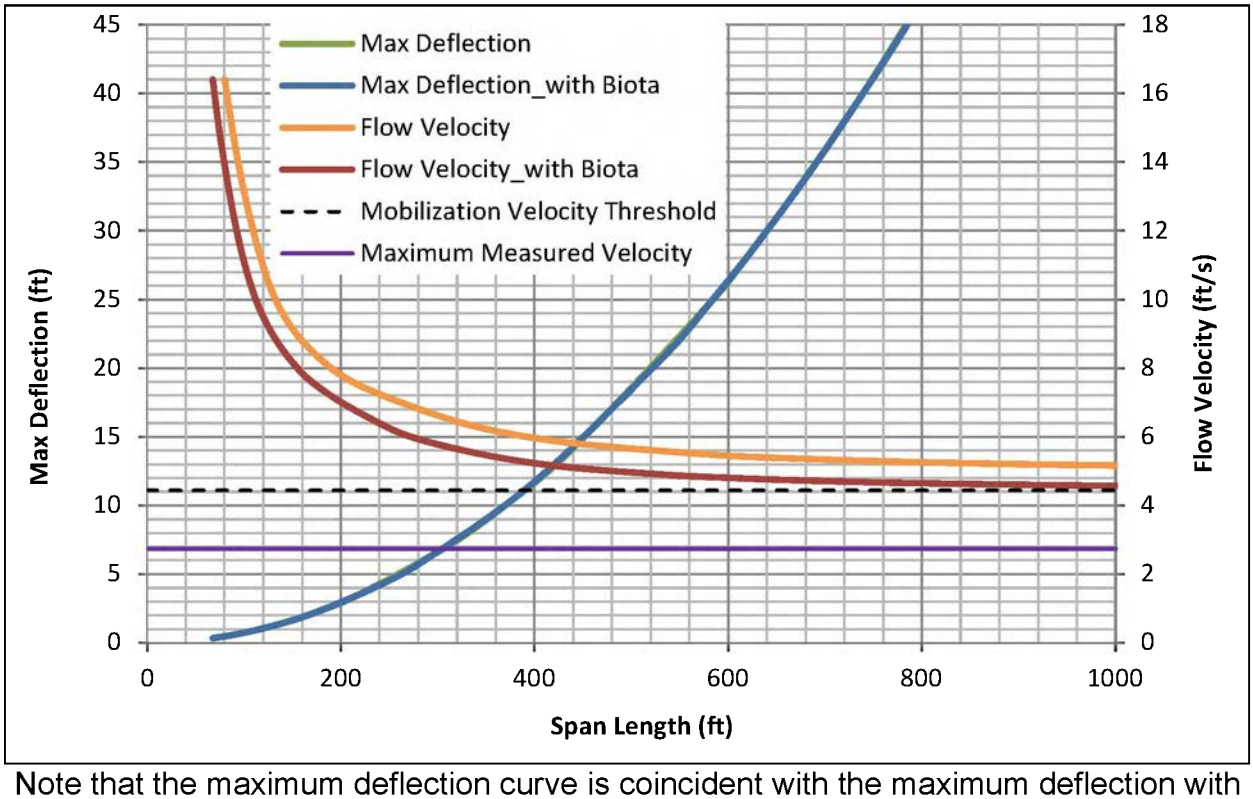
Table 1 – Input Parameters

Input Parameter	Value	Unit	Source
Pressure	600	psi	MOP – conservative value as pressure is always kept under 400 psi in normal operation
OD	20	in	Nominal value consistent with ILI measurements
WT	0.813	in	Nominal value consistent with ILI measurements (0.813 in)
Yield Strength	30	ksi	Minimum of the range given by the pipe specs (30 to 37 ksi)
Temperature Change	36	°F	Conservative value based on pipe temperature during operation
Penetration Ratio (Z/D)	0.1		The minimum limit for partial burial of pipeline into the lake bottom
Biota Mass	18.5	lb/f	Upper bound for all testing samples as described in the paragraph above
Product (crude) Specific Gravity	0.9		Conservative value based on the past and future operational projections
Drag Coefficient – no biota	1.05		PRCI Guidelines PR-170-9520
Drag Coefficient – with biota	1.4		PRCI Guidelines PR-170-9520
Drag Coefficient Reduction Factor	0.9		PRCI Guidelines PR-170-9520 (corresponding penetration ratio of 0.1)
Lift Coefficient – no biota	0.85		PRCI Guidelines PR-170-9520
Lift Coefficient – with biota	0.825		PRCI Guidelines PR-170-9520
Lift Coefficient Reduction Factor	0.96		PRCI Guidelines PR-170-9520 (corresponding penetration ratio of 0.1)

Figure 1 shows the pipe deflection response at the maximum allowable stress limit (as governed by the 0.9SMYS combined stress limit) for a range of assumed length of partially buried pipe (10% buried all along the span but otherwise supported at the ends by complete burial or anchors) and the water flow velocities that are required to induce such deflections that bring the pipe stress levels to the allowable limit. The maximum deflection and velocity responses are given in the plot for both with and without biota cases to illustrate the effect of biota. The plot also shows the mobilization velocity threshold (dashed line, which corresponds to 4.44 ft/s velocity) below which, the flow is not capable of moving the pipeline laterally due to the resistance of the lake bottom to pipe lateral movement. Finally, the plot also shows the maximum velocity measured at the lake bottom (2.74 ft/s shown by the purple line), which occurred at a localized area rather than a large portion of the crossing.

As an example of the usage of the plot, for a span of 240 ft, the maximum allowable stress limit is reached at a maximum deflection of 4.2 ft for both with and without biota cases (as expected, the maximum deflection response for both with and without biota cases are identical), and a flow velocity of 6.4 ft/s and 7.2 ft/s across the entire 240-ft span is required respectively for the with and without biota cases to give rise to such deflection (i.e. 4.2 ft).

Figure 1 – Deflection & Flow Velocity vs Span Length at Maximum Allowable Stress Limit



Note that the maximum deflection curve is coincident with the maximum deflection with biota curve in the figure as both curves are virtually the same.

Although the maximum span length (with partial burial) is 753 ft, a flow velocity across the whole span of 4.6 ft/s and 5.3 ft/s is required respectively for with and without biota cases

to move the pipe sufficiently to reach the maximum allowable stress. It can be argued that these critical velocities (i.e. 4.6 ft/s and 5.3 ft/s) are highly conservative because they were calculated assuming a 10% burial (corresponding to Enbridge's operational limit) whereas in reality, as the latest survey results indicate, there is a minimum of 30% burial anywhere beyond the free (unsupported) spans. Furthermore, the minimum velocity required to initiate pipe lateral movement (assuming a 10% burial) is 4.44 ft/s, far exceeding 2.74 ft/s, which is the maximum velocity ever measured at the lake bottom. Note that typically the current velocity at the bottom of a body of flowing water is significantly lower than those away from the bottom. The measured current velocity from other sources such as National Oceanic and Atmospheric Administration (NOAA) Great Lakes environmental research laboratory and the buoy deployed by Michigan Technological University is consistent with the 2.74 ft/s maximum as measured by the current profilers deployed by Enbridge in 2002 – 2004 time frame. In other words, the 2.74 ft/s water velocity as measured near the lake bottom would be the more realistic maximum of the current. Given the above facts, it can be concluded that Line 5 at the Straits of Mackinac has adequate safety margin with respect to the lateral movement threat.