FLOW
FOR LOVE OF WATER

Protecting the Common Waters of the Great Lakes Basin
Through Public Trust Solutions

November 12, 2019

Director Dan Eichinger
Michigan Department of Natural Resources
("DNR")
Executive Division
P.O. Box 30028
Lansing, MI 48909

Director Liesl Clark
Michigan Department of Environment, Great
Lakes, and Energy ("EGLE")
Constitution Hall
525 West Allegan
P.O. Box 30473
Lansing, Michigan 48909

VIA ELECTRONIC SUBMISSION
FLOW (FOR LOVE OF WATER) LEGAL COMMENTS ON ENBRIDGE'S VIOLATIONS OF THE 1953 EASEMENT FOR THE LINE 5 OIL PIPELINES IN THE STRAITS OF MACKINAC AND LAKE MICHIGAN

Dear DNR Director Eichinger and EGLE Director Clark:

On June 27, 2019, Governor Gretchen Whitmer directed the Michigan Department of Natural Resources ("DNR") to "begin a comprehensive review of Enbridge's compliance with the 1953 Easement and other factors affecting its validity." The extensive record makes it clear that Enbridge has violated, and continues to violate, many vital covenants and conditions set forth in the 1953 Easement. It is also clear that there are major "other factors affecting the validity" of the 1953 Easement and Enbridge's continued use and operation of the Line 5 dual oil pipelines in the open waters and on the bottomlands of the Great Lakes in the Straits of Mackinac.

In response to the Governor's directive, and in an effort to assist the DNR in its comprehensive review of the 1953 Easement, FLOW submits the following accounting of the formal, including current and ongoing, easement violations. In support of these comments, we also submit, by incorporation into the record of your review, the multiple reports and extensive comments that FLOW and others have previously submitted to the DNR, DEQ (now EGLE), the Attorney General's office, and Governor's office over the past six years.[1]

1 To date, excluding these Comments, FLOW has submitted ten public comments challenging Enbridge's continued drumbeat request to install more and more anchors on the lakebed floors. See Public Comments on the Joint Application of Enbridge Energy for Anchor Screws for Line 5 Pipelines in the Straits of Mackinac July 19, 2018; Public Comments on Enbridge's Studies Required by the November 2017 Agreement July 15, 2018; Public Comments on the Joint Application of Enbridge Energy for 48 New Anchor Screws for Line 5 Pipelines in the Straits of Mackinac May 11, 2018; Letter to MPSC and DEQ on New or Altered Structures of Line 5 April 11, 2018; Supplemental Comments on 2017 Anchor Permit Application February 9, 2018; FLOW Supplemental Comments on Enbridge Anchor Permit Application October 12, 2017; Supplemental Comments on the Joint Application of Enbridge Energy to Occupy Great Lakes Bottomlands for Anchoring Supports August 4, 2017; Comments on the Joint Application of Enbridge Energy to Occupy Great Lakes Bottomlands for Anchoring

Based on our legal analysis as reflected in these comments, it is our conclusion that you, as Director of the DNR, and your executive team, as trustees of the Great Lakes and soils beneath them, have the authority and duty to invalidate, direct compliance with, terminate, and/or revoke the 1953 Easement. This conclusion is based on the serious non-curable violations of the Easement and major "other factors" set forth below, including the failure of Enbridge to obtain from previous directors of the DNR (and its predecessor Department of Conservation) the authorizations required by the common law of public trust and/or the Great Lakes Submerged Lands Act, Part 325, NREPA, MCL 324.32501 et seq. ("GLSLA").

Recent compelling evidence only further supports the urgent need for affirmative state action to address Enbridge's violations and other serious matters affecting the 66-year-old Easement and its validity. First, according to a report recently released by a globally recognized expert on insurance and financing of environmental risks and damages, the Enbridge parent company did not sign, and therefore is not be liable under, the agreements made with the State of Michigan during the Snyder administration to pay damages in the event of a release from Line 5 in the Straits. Furthermore, the risk report concludes that the subsidiaries that signed the agreements lack the financial resources to address the consequences of a Line 5 rupture.[2] Second, the three miles of elevated dual pipelines in the Straits segment of Line 5 constitutes a new or substantially changed design with seriously increased risks has never been evaluated or authorized by the DNR or EGLE under the GLSLA and public trust law that apply to Great Lakes waters and bottomlands.[3]

We conclude and urge the DNR to take the following actions:

1. Revoke the 1953 Easement based on serious and multiple non-curable violations; shut down Line 5 in the Straits in a prompt and orderly manner, subject to specific protective conditions that reduce the flow volume of the crude oil, prohibit oil transport in the Straits during winter, ice cover, and/or storm, wave height, and strong current conditions, and require filing of a bond, insurance, and affidavit, signed by Enbridge, Inc., parent company and Michigan subsidiary, to cover damages of any nature up to $6.3 billion.

2. Simultaneously, send a notification and letter to Enbridge that should it desire an opportunity to continue using and operating the Straits segment, it may submit an application to the EGLE for authorization for a conveyance document or agreement pursuant to the Great Lakes Submerged Lands Act, Part 21, Section 2129, and the standards and required determinations under these laws, regulations under the public trust doctrine in Michigan. If Enbridge applies for such authorization, impose emergency conditions described in Action 1 above on its operation of the Straits segment of Line 5 pending completion and final decision by the EGLE.

3. If Enbridge chooses not to apply within 90 days in response to the notification for the authorization described in Action 2 above, then direct Enbridge to shut down the Line 5 Straits segment in a prompt and orderly fashion, imposing appropriate conditions and limitations described in Action 1 above.

Supports June 29, 2017(Appendices Table of Contents: Appendix A, Appendix B, Appendix C, Appendix D, Appendix E); Supplemental Comments on 2017 Anchor Permit Application February 9, 2018.

2 See Section II.A.4, *infra*.

3 See Section III.B.5, *infra*. see attached Affidavit of Dr. Edwin R. Timm in support of Petitioners' Combined Response to Respondent EGLE's and Intervenor Enbridge's Motions for Summary Disposition, Consolidated Contested Case Proceedings, dated Oct. 21, 2019, *In re Petitions for Contested Case, In Re City of Mackinac Island, Grand Traverse Band of Ottawa and Chippewa Indians, Straights of Mackinac Alliance* (Consolidated Contested Cases, Michigan DEQ (EGLE) Administrative Law Tribunal, Permit No. WRP014208 et al.), n. 44, *supra*.

Upon termination, nullification, and/or revocation of the Easement, it will be Enbridge's decision to determine whether to apply for GLSLA authorization of all, or any part, of its occupancy, use, and operations of the Line 5 dual oil pipelines in the Straits. In effect, you will be exercising your authority and fulfilling your duty, under the unique and compelling conditions and circumstances in 2019, to direct Enbridge to comply with the rule of law, including, if necessary, the shutdown of its use and operation of the Line 5 dual pipelines on the public trust bottomlands and in public trust waters, and decommission this Line 5 Straits segment. Your paramount interest and obligation is to protect the public trust in the Great Lakes; the DNR must direct Enbridge, like all private applicants, to satisfy the inalienable and mandatory requirements of public trust law and the GLSLA.

I. STATE OF MICHIGAN HAS CLEAR AND COMPELLING EVIDENCE TO TERMINATE AND/OR REVOKE THE 1953 PUBLIC TRUST EASEMENT WITH ENBRIDGE BASED ON KNOWN AND ONGOING VIOLATIONS

Since 2013, FLOW, along with the Oil & Water Don't Mix Coalition (representing over 26 organizations and federally recognized tribes), have continued to submit legal and technical reports documenting the eight direct violations of the express terms of the 1953 Easement between the State of Michigan and Enbridge.[4] They include the following on-going violations:

1. Standard of Care of Reasonably Prudent Person (Easement, Section A)
2. State Public Trust Law and Great Lakes Submerged Lands Act[5]) (Section A)
3. Federal Law (Federal Emergency Oil Spill Response Plan) (Section A)
4. Indemnity Provision (Section J)
5. Pipeline Wall Thickness Provision (Section A (11))
6. Pipeline Exterior Slats and Coating Requirements (Section A (9))
7. Minimum Curvature Requirement (Section A (4))
8. Maximum Unsupported Span Provision (Section A (10))

Enbridge is currently operating its Line 5 pipelines in the Straits contrary to the easement's covenants and the 13 specific design, material specifications, construction, and operation requirements. FLOW's numerous reports, letters, testimony and other matters of public record have well documented and established the evidentiary nature, scope, and risk of Enbridge's ongoing violations and its continued oil pipeline operations in public trust waters and bottomlands of the Great Lakes. Despite these and other public efforts, in December 2018, the Snyder Administration entered into three agreements with Enbridge that ignored and willfully refused to enforce the express terms of the 1953 Easement and the required authorization standards under the GLSLA, Act 10, and public trust law for continued use and occupancy of the existing Line 5 dual pipelines in the Straits.[6]

4 The following Line 5 easement violation letters and related reports are incorporated by reference and can be accessed via hyperlink. Letter from the Oil & Water Don't Mix Campaign to Governor Snyder re: 1953 Easement Violations (2014); FLOW & Oil & Water Don't Mix Sign-On Letter to the State, (April 13, 2016); Final Letter to State of Michigan re: Enbridge Corrosion Violations (March 9, 2017); Letter on State of Michigan's Authority on Line 5 (May 24, 2018). Report on the Inadequacy of Enbridge Financial Assurances to the State of Michigan (January 29, 2019); Oil Spill Economics: Estimates of the Economic Damages of an Oil Spill in the Straits of Mackinac in Michigan (May 2, 2018).

5 Part 325, NREPA, MCL 324.32501 et seq.; *Illinois Central R Rd v Illinois*, 146 US 397 (1892); *Obrecht v National Gypsum Co*., 361 Mich 399 (1960); MCL 324.32501 et seq.

6 The Administration also willfully failed to obtain authorization for the tunnel agreement, third agreement, and DNR easement, and the assignment of the easement to Enbridge to occupy and use the waters and soils beneath them for a new tunnel and tunnel pipeline in the Straits of Mackinac. FLOW Letter/Public Comments on Public Act

A comprehensive review of the eight easement violations set forth in Section II below demonstrates, convincingly, that Enbridge has committed and continues to commit through its conduct and omissions non-curable breaches and violations of the 1953 Easement.[7] In addition, a review of Enbridge's recent actions and agreements with the Snyder Administration reveals several major "other factors affecting the validity" of the easement. For these reason, the DNR should immediately terminate, nullify, or revoke the 1953 Easement, and simultaneously direct Enbridge to obtain the required authorizations under the GLSLA, Act 10 (now MCL 324.2129), and public trust law to continue its occupancy and use of the waters and soils of the Straits for the Line 5 dual pipelines. If Enbridge refuses to apply for such authorization, the DNR should direct Enbridge to cease using the 1953 Easement and shut down Line 5 in the Straits of Mackinac. Alternatively, or at the same time, the DNR can advise the Governor and EGLE of the invalidity of the 1953 Easement, and request EGLE to direct Enbridge to comply with the GLSLA and/or public trust law determinations, or stop its use of the Line 5 pipelines in the Straits.

II. SUMMARY OF 1953 PUBLIC TRUST EASEMENT VIOLATIONS TRIGGERING TERMINATION OR REVOCATION BY MICHIGAN DNR

A. Eight Primary Non-Curable Violations

This section summarizes eight primary non-curable violations of the 1953 Easement that give rise to immediate termination, nullification, or revocation by the Michigan DNR. For your reference, we have included direct links to all of our work and requested actions by the state and its officials since 2014.

1. Violation of the Covenant of the Standard of Care as a Reasonably Prudent Person

Section (A) of the Easement states that the grantee[8] "…*at all times shall exercise the due care of a reasonably prudent person for the safety and welfare of all persons and of all public and private property*…" This "due care" obligation extends to "public property," which includes public trust waters, the soils or bottomlands beneath them, fish, fish and aquatic habitat, ecosystem resources, and public trust uses of citizens, tribal property in the fish and fishing. And, the obligation extends to private riparian properties, residences and businesses, and to riparian communities, such as the City of Mackinac Island, St Ignace, Mackinac City, and Cheboygan.

The *Merriam-Webster* dictionary defines prudence as: "careful good judgment that allows someone to avoid danger or risks."[9] In the 2015 task force report, the State of Michigan expressly recognized that

359 and Line 5 Agreements December 18, 2018; FLOW Letter/Public Comments on Record On Line 5 Tunnel and Pipelines in Straits of Mackinac, July 12, 2018; See Section III, these Comments, *infra*. So, the DNR and/or DEQ (now EGLE) have the authority and duty to take the same course of action on the 2018 Tunnel Agreement, Third Agreement, and the 2018 DNR Easement to the Mackinac Straits Corridor Authority and its Assignment of the DNR Easement to Enbridge. None of these agreements were authorized as required by public trust law and/or the Great Lakes Submerged Lands Act. See State Defendants (DNR and DEQ) Brief in Support of Motion for Summary Disposition, June 27, 2019, at 47-49; FLOW Amicus Curiae Brief in Support of Defendants' Motion for Summary Disposition, Sept. 10, 2019, *passim*, *Enbridge v State of Michigan et al.* (Mich Ct of Claims No. 19-000090-MZ).

7 These violations, collectively, affect the entire validity and legal status of the 1953 Easement and cannot be remedied within the easement's specified 90-day period.7 Because Enbridge is not in compliance with law, Enbridge is breaching its express easement covenant to exercise prudence at all times. E.g. see Section A, 1953 Easement.

8 Enbridge is successor to 1953 grantee Lakehead Pipe Line Company.

9 https://www.merriam-webster.com/dictionary/prudence.

Enbridge's position with respect to operation of Line 5 is not reasonable.[10] Enbridge nevertheless claimed that "the existing 61-year-old Straits Pipelines [now 66-years-old] can be operated indefinitely and that it neither has, nor needs to consider, a plan to replace them."[11]

Since then, significant and damaging evidence has emerged about the risk Line 5 poses to our public waters, including grave questions about the structural integrity of the aging pipeline infrastructure, the lack of state review of risks associated with more than 200 anchor screws that constitute a major change in engineering design with 3 miles of pipelines elevated off the lakebed floor, an actual anchor strike that dented the pipelines in 2018, Enbridge's multi-billion-dollar liability for potential economic and natural resources damages, the lack of emergency response capability in the event of an oil spill, and much more. Continued operations of Line 5 in the Straits constitute an unacceptable high risk given the magnitude of potential harm to the Great Lakes, the drinking water systems, the tribal fishing rights, public and private property, natural resource damages, and tourism and economy. Enbridge's high-risk operations have been extensively documented in numerous reports, including the November 2017 Dynamic Risk Report, July 2015 Task Force Report, FLOW's 2018 Oil Spill Economic Report, the National Wildlife Federation's London Economics International Report on propane alternatives, and the University of Michigan's 2016 computer modeling study. The 2016 University of Michigan study, for example, demonstrated that more than 700 miles of shoreline in Lakes Huron and Michigan are potentially vulnerable to an oil spill, threatening drinking supplies for hundreds of thousands of citizens.

Given the severity of these substantial risks, Enbridge's actions and omissions clearly violate the "reasonably prudent person" standard to prevent harm to public property, private property, and the health and safety. Enbridge has further exacerbated and violated its duty of care by:

- withholding critical information essential to evaluating the risks of continued operation of Line 5 and to avoiding danger and unacceptable risk.

- misrepresenting information about the condition of these aging pipelines (ranging from "excellent"[12] to sections that are corroded up to 26 percent of wall thickness).

- downplaying the operation and the high risk and magnitude of harm of a pipeline break in the middle of the Great Lakes as illustrated in April 2018 when a tugboat anchor struck, dented, and gouged Line 5 in three locations; Enbridge's technology failed that test when, despite the damage to Line 5, no warnings were triggered and it was three weeks before underwater vehicles contracted by Enbridge could safely navigate the turbulent Straits to put eyes on the damage.

- mispresenting in 2017 that missing protective coatings along the Straits pipeline were a mere "hypothetical" possibility, while in fact at that same time a video in their possession showed areas of missing coatings and the company knew of approximately 80 bare spots the size of dinner plates since 2014.

- falsely claiming about Line 5 safety when it knew that since 2003 numerous bottom support anchors were missing and failed to disclose it until 2017, nine months after a report documented

10 Michigan Petroleum Pipeline Task Force Report (July 2015) at 47 [hereinafter "Task Force Report."] http://www.michigan.gov/documents/deq/M_Petroleum_Pipeline_Report_2015- 10_reducedsize_494297_7.pdf
11 *Id.*
12 Task Force Report (July 2015) at 43 "Enbridge has sought to reassure the public and the State that the Straits Pipelines are in 'excellent' condition, present minimal risks, and can reasonably be expected to safely function *indefinitely*." (emphasis added).

that pipeline spans of up to 286 feet had no anchor support making the pipelines vulnerable to bending and rupturing.

- operating with vastly insufficient liability coverage (see section 4 below).

- failing to comply with the express "minimum [design] specification, conditions, and requirements" of the Easement as detailed in section (2) through (8) below.

2. Violation of Covenant to Comply with State Law (Section A)

Section (A) of the 1953 Easement expressly requires that Enbridge "shall comply with all laws of the State of Michigan and of the Federal Government." Enbridge has never complied with the Great Lakes Submerged Lands Act ("GLSLA"), the standards under public trust law, and the incorporation of those standards in Act 10 of 1953.

As demonstrated in Section III, B, below, Enbridge has never obtained authorization or otherwise complied with the GLSLA, MCL 324.32501 et seq. and the public trust standards incorporated into the Act in 1955.[13] Further, Enbridge has never obtained authorization for the 1953 Easement that complies with the mandatory standards imposed under the common law of public trust, both in the exercise of authority under Act 10 of 1953 and the applicable standards under public trust law.[14]

3. Violation of the Federal Water Pollution Standard or Restriction under the Oil Pollution Act/Clean Water Act (Section A)

Enbridge is in violation of the federal Oil Pollution Act ("OPA") because the company is transporting oil through Line 5 in the Straits without the legally required oil spill response plan approved by the Secretary of the U.S. Department of Transportation ("the Secretary"). Enbridge cannot prevent a termination because Enbridge itself cannot correct this breach or take remedial action to correct it. The breach can be corrected only by the Secretary, because only he or she has the authority to approve a spill response plan for a pipeline crossing under navigable waters. The State may therefore invoke its authority under the Easement to terminate the conveyance by giving written notice to Enbridge of this breach or termination.

In the aftermath of the *Exxon Valdez* oil spill, Congress enacted the OPA in 1990 to amend §311(j) of the CWA and to ensure an effective and immediate response to future oil spills. On February 22, 2016, the National Wildlife Federation ("NWF") filed a 60-day notice of intent to sue Pipeline and Hazardous Materials Safety Administration ("PHMSA") for violations of the Oil Pollution Act, National Environmental Policy Act, and Endangered Species Act in connection with that agency's unauthorized approval of Enbridge's facility response plans ("FRP") for the segments of Line 5 that cross navigable waters.

In 2017, NWF filed a lawsuit against the Secretary based on her failure to comply with the OPA by reviewing and, if appropriate, approving spill response plans for Line 5. The Secretary's authority for oil pipeline facilities, including segments of pipelines that cross inland waters, has been delegated to PHMSA. PHMSA approved Enbridge's response plan for the Great Lakes Region Response Zone on June 7, 2017 (the "2017 Great Lakes Plan"), which covers all of Line 5 located in Michigan, including the

13 Section III.B.4, *infra;* See also Plaintiff's (State of Michigan) Motion Brief for Partial Summary Disposition, Sept. 16, 2019, Argument: "The 1953 Easement Violated the Public Trust Doctrine and Is Void from its Inception," pp. 7-12. See also arguments based on same principles set forth in State Defendants (DNR and DEQ) Brief in Support of Motion for Summary Disposition, n. 6, *supra.*

14 Section III.B.1, 2, and 3, *infra.* See also, Verified Complaint, *Attorney General ex rel. People of Michigan*

segments running under the Straits of Mackinac. But in March 2019, the U.S. District Court for the Eastern District of Michigan held that PHMSA's approval of the 2017 Great Lakes Plan was unlawful.[15] Consequently, Enbridge has been operating Line 5 to transport oil through the Straits contrary to OPA's prohibition against oil transport without a duly approved oil spill response plan. Enbridge does not have the power either to correct the breach of the requirement that it comply with federal law within 90 days of written notice from the State, or to take remedial action to correct the breach within 90 days of such notice because only the Secretary has the authority to approve a spill response plan for the Straits section of Line 5. The State may therefore invoke its authority under the Easement to terminate the conveyance by giving written notice to Enbridge of this breach.

4. Violation of the Mandatory Indemnity, Bond, or Surety Provision (Section J)

Section J (1) of the Easement requires Enbridge to indemnify and hold harmless the State of Michigan "for all damage caused by loss to property (including property belonging to or held in trust by the State of Michigan." To assure the full coverage and satisfaction of this obligation, Section J (1) requires the grantee (now Enbridge) to "maintain … during the life of the easement … a Comprehensive Bodily Injury and Property Damage Liability policy, bond, or surety, in form and substance acceptable to the Grantor in the sum of *at least* One Million Dollars ($1,000,000)." Section J (1) clearly states that the amount of insurance, bond, or surety is for the purpose of "covering the liability herein imposed upon the grantee." Section J (1) set the floor or minimum for the insurance or other instrument at $1,000,000 based on the circumstances in 1953. It did not set the amount based on circumstances thereafter, and clearly not 2001, 2010, 2014, 2015, and certainly not 2019.

In July 2015, the State of Michigan confirmed that Enbridge was in violation of Section J (1) of the Easement in its Michigan Petroleum Pipeline Task Force Report. "To date, Enbridge has not documented that it is in compliance with this requirement."[16] Remarkably, from 2010-2018 under the Snyder Administration, the State of Michigan never conducted a risk management and insurance review of any kind on Line 5 to evaluate whether the financial assurances Enbridge has offered would protect the State of Michigan's natural resources as well as coastal communities, citizens, tribes, property owners, fisheries, and businesses.

Even in the wake of University of Michigan's 2016 study that concluded over 700 miles of coastline were vulnerable to a Line 5 oil spill, the economic impact of an oil spill in the Straits was not analyzed. As a result, prior to 2018, liability estimates were largely speculative but roughly compared to Enbridge's Line 6B $1.2 billion tar sands pipeline spill along 40 miles of the Kalamazoo River.

In 2018, FLOW commissioned the first economic impact study concluding that a spill from Line 5 at the Straits of Mackinac could deliver a blow of over $6 billion in impacts and natural resource damages to Michigan's economy. Conducted by nationally respected ecological economist Dr. Robert Richardson of Michigan State University, the study for the first time added up potential costs of a Line 5 spill into the Straits of Mackinac and adjoining waters under a realistic – but not worst-case – scenario. The study estimated $697.5 million in costs for natural resource damages and restoration and more than $5.6 billion in total economic impacts, including:

- $4.8 billion in economic impacts to the tourism economy;
- $61 million in economic impacts to commercial fishing;
- $233 million in economic impacts to municipal water systems;
- Over $485 million in economic impacts to coastal property values.

15 *National Wildlife Federation v. Department of Transportation*, No. 17-10031, (S.D. Mich. March 29, 2019).
16 Task Force Report at 46.

A second related study concluded that a major oil spill in the Great Lakes could cause $45 billion in losses in gross national product in just 15 days from disrupting commercial shipping and steel production. By contrast, a 2018 study commissioned by the State of Michigan capped liability from a Line 5 oil spill at $1.878 billion dollars, failing to calculate and include damages beyond the first year of the disaster.

In a report to the Whitmer Administration in January 2019, FLOW demonstrated that Enbridge's Line 5 liability[17] was substantial, and that the Snyder Administration agreement with Enbridge on October 3, 2018 ("Second Agreement") failed to comply with Section J(1) of the 1953 Easement. The dollar amounts of financial assurances (e.g. cash, credit facilities, other resources available, general liability insurance, surety bonds, parent affiliate guarantees, other) were *left blank*. A review of Enbridge's financial assurances demonstrated serious inadequacies in Enbridge's compliance with the Section J (1) and its commitment under the "Second Agreement."

Under any estimate or risk of damage analysis or estimate, whether $1.8 billion to $6.3 billion, Enbridge has not complied with Section J (1) of the indemnity and hold harmless insurance, bond, or surety requirement of the Easement. The egregious nature of Enbridge's non-compliance was confirmed last week by a risk report commissioned by the Attorney, DNR, and EGLE, which concluded the following:

- The Enbridge subsidiaries who signed the agreements with the Snyder administration **do not have** the financial wherewithal to address the consequences of a Line 5 rupture.
- Enbridge, Inc., a Canadian corporation, is not a signatory to any of the agreements made with the Snyder Administration.
- Enbridge, Inc. is not contractually obligated to stand behind the indemnity agreements its subsidiaries.
- Enbridge, Inc. is not a legal successor to Lakehead Pipeline Company, the company that obtained the easement from the State of Michigan in 1953.
- Lakehead's legal successor, Enbridge Energy Partners, L.P., was acquired by another unnamed Enbridge subsidiary shortly after Enbridge Energy Partners signed the agreements with the Snyder administration in late 2018.
- Enbridge Inc. has 275 subsidiaries, including the subsidiaries who actually signed the agreements under Governor Snyder's administration. These subsidiaries may shield the parent company, Enbridge, Inc. from financial liability in the event of a Line 5 failure.
- Enbridge, Inc.'s Chief Financial Officer, Chris Johnson, testified in a legal proceeding in Minnesota last year, that Enbridge, Inc. could not be bound to any financial commitments made by its subsidiaries.
- The analysis also found that the global insurance marketplace for genuine environmental insurance does not have $1.878 billion in capacity. The insurance marketplace for genuine Environmental Impairment Liability insurance has a global market capacity of just over $400,000,000 in potential limits of liability.
- Enbridge, Inc., the Canadian parent corporation, faces a number of future market risks as its primary business is focused on transporting oil derived from Canadian tar sands, which are expensive to produce and have a higher environmental impact.
- The $1.878 billion liability estimate is likely inadequate.

In sum, Enbridge's insurance, bond, or surety for existing Line 5 operations do not satisfy or comply with Section J (1) of the 1953 Easement to cover the magnitude of harm and high risk to the state's public trust waters, bottomlands, fisheries, fish habitat, public trust, and private riparian protected uses and interests.

17 Report on the Inadequacy of Enbridge Financial Assurances to the State of Michigan, January 29, 2019.

This violation alone should trigger immediate decommissioning of Line 5. In the event of a catastrophic oil pipeline spill in the Straits of Mackinac, the economic costs to private and public property, drinking water sources, tourism, natural resource damages and more will be unprecedented. And the people of the State of Michigan will foot the bill for cleaning up Enbridge's Line 5 disaster.

5. Violation of Wall Thickness Provision (Section A (11))

Section A (11) of the Easement states: "The pipe weight shall be not less than one hundred sixty (160) pounds per lineal foot." The weight of the pipeline was designed to lie on the bottom of the Straits. By incorporating the 1953 Michigan Public Service Commission ("MPSC") Order by reference, this specification translates into 0.812 pipeline wall thickness or schedule 60 seamless pipe.

This engineering covenant is critical because failure of corrosion and materials, welds, and equipment are the top causes for pipeline ruptures.[18] In 2014, Enbridge's first publicly available document on Line 5, the Operational Reliability Plan ("ORP"), claimed that the Line 5 Straits of Mackinac section of the pipeline had "No observed corrosion growth."[19] The ORP, however, did acknowledge annual levels of corrosion for the rest of the 640 miles of Line 5. In February 2016, Enbridge released new data from 2013 inspection reports (predating Enbridge's claims of no corrosion) indicating that the "East Straits" segment of Line 5 on-shore is corroded in nine areas and in one seven-inch-long spot had lost 26 percent of its wall thickness to corrosion.

This fact alone constitutes a per se violation of the pipeline wall thickness requirement of 0.812 inches. Enbridge also reported two dents on the East Straits pipeline, the largest dent with a width of eight inches and a length of eighteen inches, and 35 circumferential cracks at the locations where pipe segments are welded together – the girth welds. Despite the metal loss, dents, and cracks, Enbridge concluded: "Our engineering analysis of the pipelines under the Straits of Mackinac tells us these pipes are in excellent condition, almost as new as when they were built and installed."[20]

In addition, Enbridge admitted on its website to mill anomalies that suggest the pipelines were never constructed according to the "minimum [design] specification, conditions, and requirements" in Section A of the 1953 Easement.

> In the case of Line 5, which consists of specially manufactured seamless piping for extra strength and safety, some variations in wall thickness result from (and are expected from) the manufacturing process itself.
>
> … The peak depth of mill anomalies on the East and West pipelines was 37 and 41 percent of the wall thickness, respectively. Table 1 below shows the distribution of features for both Straits pipelines, where there were 141 and 294 features identified by the MFL inspections of the East and West pipelines, respectively.[21]

18 According to PHMSA; See http://smartpig.pstrust.org/tag/incidents/.
19 Enbridge Pipeline Limited Partners, "Operational Reliability Plan: Line 5 and line 5 Straits of Mackinac Crossing," 2014. [hereinafter "Enbridge 2014 ORP"] https://www.enbridgepartners.com/~/media/7FDCBAC7A8FE4705A2729F3D1B51B6B3.ashx
20 Enbridge website: http://www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-cracking.aspx
21 Enbridge website: http://www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-metal-loss-corrosion.aspx [emphases added]. As reported by Michigan Radio: "In addition to corrosion, the company says certain parts of the pipelines are not as thick as .812 inches. It says those are places where the pipe thickness varies because the way it was originally manufactured. The depth of these variations in wall thickness are found in both pipelines. On the

Enbridge's disclosures show that Line 5 in the Mackinac Straits was built at less than a half-inch thick in places, far short of the required specification in the Easement. Enbridge simultaneously disclosed that "nearly one-inch-thick walls of Line 5's steel pipe travelling under the Straits."[22]

In sum, Enbridge's admission that the pipe used to construct the Straits sections of Line 5 may not have met the specifications set forth in the 1953 Easement and 1953 MPSC Order violates the Easement. Other requirements in both API 5L and API 1104 may have also been violated and thus must be investigated. In addition, Enbridge has never disclosed any publicly available pipeline integrity studies following the 2018 anchor strike that dented the pipeline in three known locations. As for a remedy, Enbridge cannot cure this defect in the Easement's allocated 90-day period or even in an extended period. This significant and incurable violation must be addressed immediately before Michigan faces another aging infrastructure crisis threatening drinking water supply for hundreds of thousands of citizens who rely on Lake Michigan and Lake Huron.

6. Violation of Exterior Slats and Coating Requirements (Section A (9))

Section A (9) of the Easement requires: "All pipe shall be protected by asphalt primer coat, by inner wrap and outer wrap composed of glass fiber fabric material and one inch by four inch (1" x 4") slats prior to installation." The Engineering and Construction Considerations provides more detail and specifically requires that the pipe be entirely wrapped with 1" x 4" wooden slats: " . . . and after attaching 1" x 4" wood slats to the full circumference of the pipe, it will be lowered into a previously prepared 'bed' on the floor of the Straits."[23]

The wooden slats wrapped around the Straits sections of Line 5, or "circumferential lagging" as they are called in the industry, fulfilled two important structural functions: (1) protection against abrasion where the pipes rested on the gravel support bed; and (2) protection from excessive stresses if the pipelines encountered a sharp edge such as a large rock or other miscellaneous stresses. Appendix 3's Section 19 labeled Miscellaneous Stresses explains: "Other conditions of load and support have been considered and found to be unimportant. For example, the possibility of concentrated load acting on the pipe is excluded due to the slats and wrapping."17 In other words, Appendix 3 demonstrates that the circumferential wooden slats wrapped around the circumference of the Straits sections of Line 5 were not a temporary measure to aid the pipe laying operation. Rather they are an integral part of the structure and are intended to be in place throughout the pipelines' entire service life.

Underwater photographic surveys also show that the circumferential bands used to secure the slats around the circumference of the pipeline have rusted away; so, the slats in those areas are missing. Without this protection, the water barrier coating that protects the steel pipe from external erosion and corrosion will not fully satisfy its function, resulting in an increased risk of excessive erosion and corrosion on the

eastern pipeline, wall thickness reaches .512 inches in some places (or 37% less than the original wall thickness). **And on the western pipeline, wall thickness reaches .479 inches in some places (or 41% less than the original wall thickness**). Mark Brush, "Recently released Enbridge report shows areas of corrosion along Line 5," Michigan Radio, Feb. 5, 2016 http://michiganradio.org/post/recently-released-enbridge-report-shows-areas-corrosion-along-line-5#stream/0 [emphasis added].

22 Enbridge website: http://www.enbridge.com/Projects-and-Infrastructure/Public-Awareness/Line-5-Michigan/Safeguarding-the-Great-Lakes/Inspections/Inline-inspection-results/Results-metal-loss-corrosion.aspx

23 "Engineering and Construction Considerations for the Mackinac Pipeline Company's Crossing of the Straits of Mackinac" and "Report on the Structural Analysis of the Subaqueous Crossing of the Mackinac Straits," by Dr. Mario G. Salvadori, P. E., Department of Civil Engineering, Columbia University, New York 27, NY, (January 19, 1953) submitted by Mackinac Pipeline Company/Lakehead Pipeline Company to the Michigan Department of Conservation, January, 1953." http://www.michigan.gov/documents/deq/Appendix_A.2_493980_7.pdf

bottom of the pipe, with the increased hazardous risk of rupture. Accordingly, the failure to maintain this wooden protective coating layer is a clear violation of the conditions of the Easement, and requires immediate action.

As for the easement's pipeline coating requirements, visual images from the ROV inspections show a rusty pipeline encrusted in mussels and other biota. These invasive species, in turn, have made it impossible for Enbridge or anyone to conduct an external inspection to evaluate the integrity of the pipeline coating. In addition, Line 5's pipeline coating has been compromised in at least 80 locations due to Enbridge's reengineering efforts to stabilize the aging infrastructure. Similar to Enbridge's five year delay in notifying the NTSB prior to the Line 6B spill that the Applicant knew of cracks in the section of Line 6B that eventually ruptured, Enbridge knew in 2014 yet failed to disclose to the State and federal officials for 3 years (until November 2017) the fact that the corporation was aware that its newly implemented anchor design (with saddle supports, as suggested for implementation in this instance) was actually causing damage to the Line 5 pipeline coating and to the overall integrity of the pipelines themselves.

7. Violation of Minimum Curvature Requirement (Section A (4))

Section A (4) of the Easement states: "The minimum curvature of any section of pipe shall be no less than two thousand and fifty (2,050) feet radius." This stipulation, which applies to both the pipe laying operation and the pipe as it rests on the bottom, was intended to make sure the pipe was not plastically deformed during the pipe laying operation. When the bending stress applied to a pipe exceeds the steel's yield strength, the pipe is permanently bent, resulting in plastic deformation. Plastic deformation (bending) of the pipe results in residual or "locked in" stresses in the pipe that increase local stress in the pipe beyond what is calculated in the design basis. This is particularly true as it applies to the girth welds used to join the numerous sections of seamless pipe. Residual stresses can cause unpredictable cracking at bending stresses far less than those intended in the original design. The 2,050-foot radius of curvature requirement limits bending stress to 34 percent of yield strength.

This violation is critically important to the pipeline's integrity. Plastic deformation of a weld seam not only makes it more likely to crack at stresses much lower than those that would crack the base metal but also makes the weld more susceptible to corrosion of the deformed areas. This engineering violation is also non-curable and also triggers the Easement's termination provision.

8. Violation of Maximum Unsupported Span Provision (Section A (10))

Section A (10) of the Easement provides that: "The maximum span or length of pipe unsupported shall not exceed 75 feet." The Easement authorized Lakehead to "lay, construct, maintain, and use and operate two (2) pipelines… each to consist of twenty-inch (20") O.D. pipe, together with anchors and other appurtenant structures and fixtures." [24] The Easement was based on the specific original and "as built" design of the Straits segment Line 5 dual pipelines. The heavy steel lines were assembled in sections, and then dragged, literally, across the 4.5 mile segment to lay on the bottomlands. Because of the irregularity of the bottomlands and concern for undue movement and failure, the 75-foot span requirement was incorporated into the Easement. In order to meet this requirement and address currents in the Straits, sections of the pipelines were "anchored" to the bottomland with rip-rap, cover, and later grout bags. Engineering documents accompanying the original 1953 Easement make it clear that the Bechtel engineers intended for the Line 5 underwater pipelines to "lie on the bottom with no cover," and soil would allow "the pipe to settle into position and probably bury itself, eliminating any possibility of

[24] Easement, p. 1.

movement."[25] The express terms of the 1953 Easement provided for a strict 75-foot maximum span requirement for the placement of the heavy steel pipelines on the lakebed floor, not a completely different design for multiple spans exposed to currents above the lakebed floor.

In 2001 Enbridge, in what it characterized as an "emergency,"[26] applied for joint DEQ and U.S. Army Corps of Engineers permits under the GLSLA and the federal River and Harbors Act "to provide support underneath our pipelines in sections where the pipeline shows spans unsupported over too great a distance." Since then, Enbridge has continued to apply for and obtain joint inspection and maintenance permits under the GLSLA and CWA to install more anchor structures on the public bottomlands of the Straits.[27] It has done so by labeling the additional supports as "repairs" or "maintenance," and persuading the DEQ (now EGLE) of this, even though they clearly constitute a near total or substantial change in the Straits segment dual pipelines.[28] As a result, the agency arbitrarily narrowed its review and evaluation to the potential impacts in a 50-foot diameter around supports where each is screwed into the bottomlands.[29]

Documentation not previously disclosed by Enbridge to the DEQ and MPSC turned over to the State in 2016 revealed that a 2003 Enbridge report confirmed 16 sections of the pipelines spanning bottomlands for distances of 140, 224, and 286 feet. In the 2014 report, Enbridge admitted[30] that it was still violating this critical easement provision. In 2014, it filed its first request for adding an extensive number of supports, seeking a joint permit from the State under the GLSLA and the U.S. Army Corps of Engineers under the Clean Water Act. The joint application sought permits to "fill" bottomlands of the Straits to install 42 additional saddle supports under the lines that were then "anchored" by legs that screwed into the bottomlands. After completing the installation of the several elevated sections of the lines on November 19, 2014, Enbridge claimed that it had cured the maximum span requirement for both of its twin pipelines: "As you can see, no span length exceeds the seventy-five (75) feet."[31] In fact, Enbridge

25 For a more lengthy understanding of the original pipeline design on the lakebed floor, see *Consolidated Contested Cases, In Re City of Mackinac Island et al., infra,* n. 44, on the permits issues to Enbridge Pipelines (Lakehead), LLC (consolidated Cases), Brief in Support of Petitioners' Motion for Summary Disposition regarding Respondent Department's Failure to Properly Apply the Requirements of the Great Lakes Submerged Lands Act (Sept. 27, 2019).

26 Enbridge Letter (Adam Erickson) to MDEQ (John Arevalo), Enbridge Joint Permit Application for Repair Work to be Completed on Crude Oil Transmission Pipelines Located in the Straits of Mackinac: September 14, 2001.

27 Email from Enbridge Jacob Jorgenson to Scott Rasmussen (DEQ) and Gina Nathan (ACE), Nov. 18, 2010. In 2010 after receiving a permit from the DEQ under the GLSLA for additional anchoring structures to support the pipeline, Enbridge notified DEQ that "we do not have the future structure locations determined at this point," "nor the scope of the projects to come…"

28See *Consolidated Contested Cases, In Re City of Mackinac Island et al., infra,* n. 44.

29GLSLA rules prohibit authorizations and permits for structures as "fill" or "other materials" of public trust bottomlands unless the applicant demonstrates (1) through an environmental impact statement that there will be no impairment or adverse impacts to the public trust, and (2) that there exist no other feasible and prudent alternatives to the proposed use or activity. R 322.1015. The DEQ ("EGLE") narrowed the scope of this review to exclude the risks of the pipeline itself and the consideration of alternatives to the change in design. See *In Re City of Mackinac Island et al., Consolidated Contested Cases*, n. 44, *infra*.

30 Enbridge's June 27, 2014 letter to the State of Michigan http://www.michigan.gov/documents/deq/Appendix_B.2_493988_7.pdf State of Michigan's July 24, 2014 letter to Enbridge, "Enbridge's Response acknowledges that at least some portions of the pipelines do not currently meet the Easement's support spacing requirement." "[P]lease consider this letter formal written notice on behalf of the State of Michigan, and pursuant to Condition C. of the Easement, that to date, Enbridge has not fully complied with the 75-foot support spacing requirement contained in Condition A.(1) of the Easement."

31 Enbridge's November 19, 2014 Letter and Attachment to Attorney General Schuette and DEQ Director Wyant re: Joint July 24, 2104 State Letter on Easement Violation of Maximum Unsupported Span. http://www.michigan.gov/documents/deq/Appendix_B.4_493991_7.pdf; and Dr. Ed Timm's chart: Unsupported Span Data from Enbridge's November 19, 2014 Letter.

changed the design of the lines. The spans were caused by the failed cover and other attempts to secure or "anchor" the heavy lines to the lakebed and the strong currents not accounted for in the original design and construction in 1953. The currents have been measured to equal more than 10 times the volumetric flow of the Niagara River.

As of 2019, including the 22 more supports added in 2014, 150 saddle supports have been anchored to the bottomland, and elevated approximately two miles of pipelines two to four feet above the bottomlands. The DEQ (now EGLE) issued permits for another 48, and then up to four more saddle supports; if and when installed the total number of supports will exceed 200, elevating more than 3 miles of the dual lines above the bottomlands. The continuing forces of currents, scouring, and destabilizing the lines and supports will require more and more supports. The Task Force Report commented on this very troubling issue: "Given Enbridge's failure to maintain the legally required intervals for pipeline supports during an apparently extended period of time, and the very significant underwater currents at the Straits, there is a need to analyze the resulting stresses on the pipelines and potential impacts to their integrity."[32]
As described in Section III, B., 5, *infra,* the elevation of the dual heavy pipelines that were designed to be placed on the bottom by supports constitutes a total or substantial change in design of the pipeline itself, the change, risk, and alternatives of which have never been reviewed, evaluated, or authorized as required by the GLSLA and public trust law.[33] The Affidavit of Dr. Edwin Timm filed in the consolidated contested cases demonstrates seriously increased risks, a total lack of review of applicable risk standards for elevated multiple-span pipelines, and new or substantially changed pipeline that has not been assessed.[34]

Enbridge incredulously still asserts the continuous addition of saddle supports is only a "repair" or "maintenance" under the 1953 Easement, so as to qualify for permits to fill or add "other materials"[35] to the bottomlands of the Straits. In fact, the saddles screwed to the bottomlands are not a "repair," but a new change in engineering design that elevates more than 3 miles, of the dual pipelines in the water column and above and off the bottomlands of the Straits. They are now more exposed to anchor strikes, with a greater risk of rupture or release, and the constant force of currents around the entire circumference of pipeline surface. It is little wonder that the Attorney General and legal staff state in their complaint filed on June 27, 2019, paras. 18 and 19, that near-shore pipelines remain exposed in water because of loss of cover and protective shielding, and that a large portion of the pipelines are now "elevated several feet above the lakebed."[36]

In summary, over the past 66 years, the underwater Line 5 pipelines have continued to "washout" bottomlands due to strong and unpredictable currents that exceed the original design assumption of 2.26 mph. Because of this documented failure in design, and the existence of spans beneath a pipeline designed to be placed along the bottom, year after year, Enbridge has repeatedly violated the Easement 75-foot maximum span pipeline requirement. In the 1960s through 1990s, Enbridge attempted to address this engineering design flaw by installing grout bags and clay pillars. By 2001, the situation of Line 5 was dire. It was so bad that Enbridge employees stated in a letter to DEQ that it was an "emergency" situation. This crisis led Enbridge to fundamentally change the design of Line 5 so that it now more closely approximates an underwater suspension bridge with nearly 200 elevating three miles of pipeline

32 Task Force Report at 44.
33 See Section III.B, *infra.*
34 See the attached Affidavit of Dr. Edwin R. Timm, n. 3, *supra*.
35 "Other materials" are defined by GLSLA Rule to mean "any man-made structures," Rule 1001(k), R322.1001(k), interpreting the permit requirement for filling… or "placing spoils or other materials on bottomlands." R1008(1); R322.1008(1). Satisfying the anchor support permit requirement for the Straits pipelines to "place other materials on bottomlands" do not satisfy the requirement and authorization for an occupancy and use of bottomlands agreement for the change to over 3 miles of elevated pipeline under Sections 32502 and 32503, MCL 32432503, 33503 et seq.
36 See Section II.A.8, *supra*, Section III.B.5, i*nfra*.

with anchor support structures.[37] Most alarming is that Enbridge's new engineering design for the entire infrastructure – never legally authorized under the Great Lakes Submerged Lands Act – creates a greater risk of anchor strikes similar to the one that struck Line 5 on April 1, 2018. Ironically, just six months before in October 2017, the Dynamic Report commissioned by the state estimated the chance of a rupture of the Straits pipelines in the next 35 years to be not one in a million but a stunning one in sixty. Finally, the uniquely vulnerable location of these exposed pipelines under multiple shipping lanes for domestic and international trade is at complete odds with the State of Michigan's duty to protect public trust uses of the Lakes for fishing, navigation, commerce, and recreation from potential harm, impairment, or pollution from an oil spill.

To date, we are not aware of any comprehensive engineering analysis for this total change in underwater infrastructure.[38] It was designed as a dual pipelines on the bottom of the Straits, but the risks and stresses related to the powerful underwater currents and other factors have not been analyzed for the elevated multiple plan change in design of the dual lines, or for the coating loss (over 80 dinner plate size locations), and increased risk of anchor strikes from this elevated change in the dual pipelines.

Clearly, Enbridge's elevated pipelines with over 200 anchor support structures do not constitute a mere "repair" or "maintenance" within the existing built and used design or Easement. Thus, Enbridge's permit applications for new anchor supports constitute a substantial modification of the original pipeline design as engineered in 1953. As such, the Easement's 75-foot maximum span requirement is a non-curable breach, triggering termination. The fact is that the failure of the original design has not and cannot be cured by the addition of several hundred anchor supports. Moreover, as described in Section II.A.2 and Section III.B.5, apart from the "permits" for "other materials" or structures, Enbridge has never complied with the requirement under the GLSLA and public trust law for authorization for an occupancy or other conveyance instrument to occupy the bottomlands of the Straits.

B. Termination or Revocation by DNR Based on Substantial Non-Curable Violations of the Easement

Section C provides for termination of the Easement as follows:

"If, after being notified in writing by Grantor of any specified breach of the terms and conditions of this easement, Grantee shall fail to correct said breach within ninety (90) days, or, having commenced remedial actions within such ninety (90) day period, such later time as it is reasonably possible for the Grantee to correct said breach by appropriate action and the exercise of due diligence in the correction thereof."

Enbridge has not been and is not complying with at least eight express terms of the Easement, as described above. The State may therefore invoke its authority under the Easement to terminate the conveyance by giving written notice to Enbridge of these breaches. Furthermore, Enbridge cannot prevent a termination because Enbridge itself cannot correct these breaches within the 90-day period or take remedial action to correct the breaches. Even if the State were to extend the deadline, Enbridge also cannot correct these breaches because they are material and incurable defects relating to the integrity and current operation of this aging infrastructure that threatens the public trust resources of the Great Lakes.

[37] It is critical to remember that the Bechtel engineering calculations on pipeline stress and fracturing were based on the critical assumption that the infrastructure would be fully supported by the lakebed itself.
[38] The high risks of this total or substantial change in design and failure to obtain authorization for this new or major change in the pipeline is underscored by the Affidavit of Dr. Edwin R. Timm, n. 3, *supra*.

Accordingly, the DNR and EGLE, with the Attorney General's Office, as trustees, should take immediate action to enforce the Easement and to eliminate the risk to these public trust waters, bottomlands, ecosystem, public uses, private property and businesses, and communities and persons in the Straits and northern Lake Michigan and Lake Huron area. The enforcement and other actions described above remain urgent and critical. The violations listed in the above sections (1) through (8) call for immediate state action.

Since its construction in 1953, Enbridge has increased the flow through Line 5 from its design capacity of 300,000 barrels per day to 540,000 barrels per day — an increase of 80%. This increase has occurred: (a) without any environmental assessment as to the potential impacts of such expansion and continued activities, (b) outside of the requirements of the public trust doctrine (c) outside of the requirements of the GLSLA, and (d) without any affirmative findings or demonstration by the State of Michigan or Enbridge concluding that any risks or potential adverse effects to the environment, public trust, and riparian interests from those expansion activities would be minimal and that no feasible and prudent alternative to the operation of Line 5 in this manner exists.

III. THERE ARE SIGNIFICANT "OTHER FACTORS AFFECTING THE VALIDITY" OF THE 1953 EASEMENT, INCLUDING THE COMPLETE LACK OF COMPLIANCE WITH THE AUTHORIZATION AND STANDARDS REQUIRED BY THE PUBLIC TRUST DOCTRINE AND THE GREAT LAKES SUBMERGED LANDS ACT, PART 325, NREPA.

A. Background and Overview

The conveyance of an easement or other interest of the waters or soils and bottomlands beneath the Great Lakes cannot be authorized without due determinations by the EGLE that Enbridge has applied for and satisfied the standards of public trust law and the GLSLA, MCL 324.32502, 32503 et seq. In any event, the conveyance of the 1953 Easement under Act 10 did not contain the required determinations under public trust law. Act 10 is flawed because it does not contain the required standards to satisfy public trust law, and, in any event, the Department of Conservation 1953 did not determine that the Easement complied with the required public trust law standards. In short, the 1953 Easement is invalid, because it was never authorized under the requirements and narrow standards of public trust law.[39]

In response to the Attorney General's advice, in 1953, the legislature enacted Public Act 10.[40] Act 10 authorized the Department of Conservation to grant easements to public utilities for an easement over, in, or under state lands, including the bottomlands of the Great Lakes "held in trust."[41] Lakehead applied for an easement under Act 10, and it was granted. But Act 10 does not contain the required narrow standards for complying with public trust law; and, in any event, the Department of Conservation never made the required findings that the easement fell within the narrow exceptions under Michigan's public trust law. Accordingly, the 1953 Easement is invalid, and Enbridge should be directed to apply for and obtain authorization for a new easement or agreement under public trust law and the GLSLA. If Enbridge refuses to apply for such authorization, the DNR should direct Enbridge to cease using the 1953 Easement and shut down Line 5 in the Straits of Mackinac. Alternatively, or at the same time, the DNR can advise the Governor and EGLE of the invalidity of the 1953 Easement, and request the EGLE to Direct Enbridge to comply with the GLSLA and/or public trust law determinations, or stop its use of Line 5 in the Straits.

39 See Section II.B, *infra*.
40 Act 10 (now NREPA, MCL 324.2129) ("Easements for Public Utilities— "The department may grant easements… for pipelines… over, through, under, and upon … the unpatented… *lake bottomlands* belonging to *or held in trust* by this state.").
41 *Id*.

The 1953 Easement contained covenants that the easement and the dual pipelines in the Straits were subject to compliance with all state and federal laws, and that all due care would be exercised at all times to prevent injury to public and private property and safety.[42] The Easement authorized and incorporated a specific legal description, location, design and engineering requirements, limitations, and conditions. On its face, while Act 10 states an easement is subject to bottomlands "held in trust" by the state, Act 10 did not contain standards the satisfaction of which would also satisfy the public trust doctrine under the common law, and, in any event as noted above, the Department never made the findings required by public trust law.

In 1955, the GLSLA (aka "Act 247") was enacted[43] to conform Michigan law to the mandatory standards under the public trust doctrine that apply to waters and soils under the Great Lakes. Public trust law requires a statute to provide express authority for deeds, leases, other dispositions, such as easements, or agreements for occupancy and use of waters and bottomlands and soils under the Great Lakes. The GLSLA incorporated those standards (improvement of public trust, public purpose, and no interference or impairment) into law. The GLSLA did not exempt Act 10, nor would it have done so, because the standards added to the GLSLA were absolutely necessary for the validity of past and future easements or other dispositions under public trust law.[44]

B. The 1953 Easement Is Invalid Because It Violates the Requirements of the Michigan Common Law Public Trust Doctrine.

1. Equal Footing Doctrine and State's Trust Title in the Soils under Navigable Waters

When Michigan joined the United States in 1837, the State of Michigan took title, absolutely, as sovereign for its citizens under the "equal footing" doctrine to all of the navigable waters in its territory, including the Great Lakes, and "all of the soils under them" below the natural ordinary high mark.[45]

> The people of each State, based on principles of sovereignty, "hold the absolute right to all their navigable *waters and the soils under them*," subject only to rights surrendered and powers granted by the Constitution to the Federal Government.[46]
>
> * * *
>
> The law seems to be well settled in the different states that the title to and dominion over lands covered by tide waters within the boundaries of the several states belong to each state wherein they are located. The state holds the fee in trust for the public. The doctrine established in regard to lands covered by tide waters has also been held applicable to lands bounded by fresh water on our large lakes.[47]

42 1953 Easement, para A.

43 1955 PA 247; now NREPA, MCL 324.32501 et seq.

44 In addition, as described in Section II, the total or substantial design and increased risks by Enbridge's addition of over 200 anchor supports to elevate the failing condition of the pipelines has never been authorized in compliance with public trust law and is contrary to law. See *Petitions for Contested Case, In Re City of Mackinac Island, Grand Traverse Band of Ottawa and Chippewa Indians, Straights of Mackinac Alliance* (Consolidated Contested Cases, Michigan DEQ (EGLE) Administrative Law Tribunal, Permit No. WRP014208 et al.)

45 *Shively v Bowlby,* 152 U.S. 33, 14 S. Ct. 548 (1894); *Illinois Central R Rd v Illinois,* 146 U.S. 387 (1892); *State v Venice of America Land Company*, 160 Mich 680 (1910); *Glass v Goeckle*, 473 Mich 667 (2005).

46 *Martin v. Lessee of Waddell*, 16 Pet. 367, 410; 10 L. Ed. 997 (1842); *Phillips Petroleum Co. v. Mississippi,* 484 U.S. 469; 108 S. Ct. 791 (1988).

47 *Id*. at 593-594.

The title to these navigable waters and the lakebed, bottomlands, or soils beneath them is held by the state as sovereign and protected by a public trust; the public trust inheres and applies to the entire bottomlands, soils and water held in trust by the State.[48]

> The states did not take an unqualified title to these lands. They were taken by them *in trust for a public use* for the people of the states...[49]
>
> * * *
>
> It will be noted in cases involving this question that the expression 'easement of navigation' is frequently used. This term should not be confused. When applied to the unorganized public, *the individual member of the public, it unquestionably correctly describes his right. He has the right of passage, an easement*. *But when considering the organized public as represented by the government, it does not measure or correctly describe its rights.* The government … *the paramount dominant right,* superior to that of the riparian owner, and in the enforcement of that right it may take, control and regulate in the interest of navigation the navigable waters of the nation and the submerged lands over which they flow.[50]

2. The Public Trust Doctrine Requirements and Standards

The public trust doctrine is of ancient origin. Its roots trace to Roman civil law and its principles can be found in the English common law on public navigation and fishing rights over tidal lands and in the state laws of this country. Today, those rights and protected public trust uses include fishing, navigation, swimming, boating, bathing, beach walking below the ordinary, natural high water mark, and sustenance (such as drinking water).[51]

The quintessential public trust case is the U.S. Supreme Court's decision in *Illinois Central R. Rd. v Illinois* in 1892.[52] The question before the Court was whether the State of Illinois had the authority to convey by legislative grant a square mile of the waters and bottomlands of Lake Michigan to a private railroad company for expansion of its industrial operations. Despite the economic and job benefits, the Court ruled that the conveyance was beyond the authority of the state legislature. This was because the title to all of the waters and soils beneath them vested in the states on admission to statehood, and that these waters and bottomlands were held in trust for navigation, fishing, and other public uses and purposes. The Court reasoned that under the state's title in these public trust bottomlands or soils could not be alienated to or controlled by private parties for primarily private purposes or where the use, occupancy, or alteration of these public trust waters and soils would be impaired.[53]

The public trust doctrine means that the state holds these waters and soils beneath them in trust for the public for the protection of preferred or dedicated public trust uses of navigation, fishing, boating,

48 *Id*.; *Illinois Central Rail Road v Illinois*, 146 U.S. 387; 13 S Ct 110, 36 L Ed 1018 (1892); see also *Obrecht v National Gypsum*, 361 Mich 299 (1961).
49 *State v Lake St. Clair Fishing & Shooting Club*, 127 Mich 580, 594;87 N.W. 117 (1901); *Venice of America Land Company*, 160 Mich 680, 702.
50 *McMorran Milling Co*, 201 Mich at 313, 315.
51 MCL 324.32502; *Glass v Goeckle*, 473 Mich 673, 703 NW 2d 58 (2005*); Obrecht v National Gypsum Co.*, 360 Mich 399 (1961); *Collins v Gerhardt*, 237 Mich 38, 211 NW 115 (1926); *Nedtweg v Wallace*, 237 Mich 14, 208 NW 51 (1926); The word "sustenance" is included in the first major reported public trust case in American jurisprudence. *Arnold v Mundy*, 6 N.J. 1, 12 (1821). *Arnold v Mundy* was recognized by the US Supreme Court in *Illinois Central*, *infra*, n. 52, which was in turn adopted by *Obrecht*, *supra*.
52 *Illinois Central R Rd, supra*, 146 U.S. at 436-437, 459.
53 *Id*., 146 U.S. at 436-437.

swimming, bathing, drinking water, and other recreation.[54] As a general rule, there can be no disposition, transfer, conveyance, occupancy or use of any kind of these public trust waters and the soils beneath them; the state can never divest itself of the trust title in the waters and soils beneath them.[55] Subject to the rule against divestiture of the trust interest, the state can only authorize the use, occupancy, or a disposition of public trust bottomlands and soils if there is a statute that expressly authorizes such action. Moreover, the statute must contain the following standards that are determined to be met in particular circumstances:[56]

(1) The proposed disposition, occupancy, or action predominantly serves or enhances a public trust interest (such as navigation, fishing, etc.), not a private one; and
(2) The proposed disposition, occupancy, or action will not interfere with or impair the public trust waters, soils, habitat, wildlife like fish and waterfowl, or one or more of the public-trust uses.[57]

3. Act 10 of 1952 (currently, MCL 324.2129)

Act 10 authorized the state to grant public utility easements over state lands, including "over, through, under, and upon" lake bottomlands "belonging to or held in trust by the state." It does not authorize any lease, deed, or other disposition or form of conveyance. Act 10 was re-codified in 1994:

> Sec.2129. The department may grant easements, upon terms and conditions the department determines just and reasonable, for state and county roads and for the purpose of constructing, erecting, laying, maintaining, and operating pipelines … over, through, under, and upon any and all of the unpatented overflowed lands, made lands, and lake bottomlands belonging to or held in trust by this state.[58]

Act 10 or Section 2129 does not contain any public trust standards as required by *Illinois Central R Rd.*, *Obrecht v National Gypsum*, and public trust law.[59] *Obrecht* adopts and requires authorizations for public trust lands and waters to comply with the narrow standards in *Illinois Central*.[60] *Illinois Central* and *Obrecht* provide for only two narrow exceptions for grants, dispositions such as easements, leases, and agreements for occupancy and use of trust bottomlands and soils under the Great Lakes: these are: (1) primarily public purpose or improvement of public trust interest; (2) no substantial or material impairment or interference with bottomlands, waters, or protected public trust uses.[61] It is imperative that the state make due recorded determinations whether a proposed use complies with these exceptions based on the application and the proofs of factual circumstances. Because approval is in the nature of a grant, the state cannot be compelled to grant authority to occupy and use its bottomlands and waters (with the exception of those who are riparians and engaged in lawful riparian uses or activities).

In the case of Enbridge, the 1953 Easement states that it covers Great Lakes waters and the bottomlands beneath these waters, but there are no finding requirements in Act 10 based on the necessary standards to comply with public trust law; an easement based on a statute like Act 10 that does not contain public trust standards and/or is not based on findings or determinations that these standards have been considered and

54 *Id.; Glass v, Goeckle,* 473 Mich. at 673.
55 *Id*.
56 *Obrecht v National Gypsum*; *Illinois Central*, n. 51, *supra.*
57 *Id*.
58 1953 PA 10, MCL 324.2129.
59 *Superior Public Rights v Department of Natural Resources*, 80 Mich App 72; 263 NW2d 290 (1977).
60 *Obrecht* at 412-413; *Illinois Central R Rd v Illinois*, n. 51 *supra*.
61 *Id*.

met, is contrary to law and invalid. In any event, the Department of Conservation and its successors (now EGLE have never made the required determinations that the 1953 Easement falls within the narrow exceptions of public trust law; the Easement is, therefore, invalid.

4. The Great Lakes Submerged Lands Act ("GLSLA"), Part 325, NREPA, MCL 324.32501 et seq.

The GLSLA implements the state's duty to comply with the public trust in the Great Lakes and the soils beneath the lakes up to the "ordinary high-water mark." As noted above, Act 10 is limited to "easements" for public utilities. While the Act 10 clearly authorizes utility easements in or over public trust bottomlands, it does not contain the required standards under public trust law.[62] Two years later, in 1955, the GLSLA was enacted to make sure past and future dispositions or the filling of the waters and lands of the Great Lakes complied with the standards and requirements of *Illinois Central R Rd v Illinois*.[63]

> Sec. 32502. This part shall be construed so as to preserve and protect the interests of the general public in the lands and waters described in this section, to provide for the sale, lease, exchange, *or other disposition* of unpatented lands and the private or public use of lands *whenever it is determined by the department that the private or public use of those lands and waters will not substantially affect the public use of those lands and waters for hunting, fishing, swimming, pleasure boating, or navigation or that the public trust in the state* or that the public trust in the state will not be impaired by those agreements for use, sales, lease or other disposition…The word "land" or "lands" as used in this part refers to the aforesaid described unpatented lake bottomlands and unpatented made lands and patented lands in the Great Lakes….
>
> Sec. 32503. (1) Except as otherwise provided in this section, the department, *after finding that the public trust in the waters will not be impaired or substantially affected*, may enter into *agreements* pertaining to waters over and the filling in of submerged patented lands, or to lease or deed unpatented lands, *after approval of the state administrative board*. Quitclaim deeds, leases, or agreements... shall contain such terms, conditions, and requirements as the department determines… in conformance with the public trust.[64] …; (2) The

62 *Illinois Central R Rd v Illinois*, 146 U.S. 387 (1892).

63 See *Obrecht v National Gypsum Co*, 361 Mich 399 (1960), approving public trust standards in the GLSLA as consistent with the standards required for dispositions and uses of the bottomlands of the Great Lakes under *Illinois Central R Rd*, n. 51, *supra*. "[I]t will be found authoritatively that no part of the beds of the Great Lakes, belonging to Michigan and not coming within the purview of previous legislation such as the swamp land acts and the St. Clair Flats leasing acts (see *State v. Lake St. Clair Fishing & Shooting Club and Nedtweg v. Wallace*, *supra*), can be alienated or otherwise devoted to private use in the absence of due finding of one of two exceptional reasons for such alienation or devotion to non-public use. One exception exists where the State has, in due recorded form, determined that a given parcel of such submerged land may and should be conveyed 'in the improvement of the interest thus held' (referring to the public trust). The other is present where the State has, in similar form, determined that such disposition may be made 'without detriment to the public interest in the lands and waters remaining.'" *Obrecht*, 361 Mich. 399, 412, 413.

64 MCL 324.32503. It should also be noted that the GLSLA rules prohibit authorizations to use or occupy the public trust bottomlands and waters of the Great Lakes unless the applicant demonstrates (1) through an environmental impact statement that there will be no impairment or adverse impacts to the public trust, and (2) that there exist no other feasible and prudent alternatives to the proposed use or activity. R 322.1015.

department shall not enter into a deed or lease that allows drilling…*beneath the unpatented lands* for the exploration or production of oil or gas.[65]

5. DEQ (now EGLE) Has Never Authorized Enbridge's Major Engineering Design Change with the Construction of Its 200 Anchor Supports That Elevate Line 5 Off the Lakebed Floor Under the Rule of Law under the GLSLA and Public Trust Law.

As described in **Section II., 7**, and **Section III, A,** above, the 1953 Easement design, as built, incorporates two dual pipelines that were designed because of their weight to lay on the bottomlands of the Straits; the design requirement prohibited construction of the lines to leave more than a 75-foot span where a line did not touch the bottomlands. DEQ (now EGLE) has authorized anchor support permits to shore up a failed design in the pipelines, but the permit review and authorization is confined to the "foot" or individual anchor where it is screwed into the bottomlands. No cumulative review of the failing condition of the scoured pipelines, increased risk, potential impacts, or alternatives to this substantial change in design was required or conducted.

Again, Section A of the 1953 Easement explicitly requires prudence to protect the public trust in the Straits and private property and public safety, and it requires compliance with all state or federal laws. Enbridge has never applied for or obtained authorization under the GLSLA for the substantial change of the design and structure of the dual pipelines. Despite the near total change in design and increased risks associated with an elevated lakebed oil pipeline structure, the DEQ has never made a determination regarding the potential massive impairment and impacts or the existence of other alternatives under the GLSLA, the public trust, and laws of Michigan. Accordingly, Enbridge has never obtained authorization for the occupancy and use of the waters and bottomlands of the Straits for its major change in design from the original design to place the heavy pipelines on the bottom as described and authorized under the 1953 Easement, and therefore, Enbridge's reliance and use of its 1953 Easement for authorization to build more than 200 anchors supports as "repairs" is invalid and/or contrary to law.

IV. CONCLUSION AND REQUEST FOR ACTION

Based on the above reports and comments, other public comments, and the extensive record in this critical Great Lakes matter, FLOW submits that the unique facts, circumstances, and applicable laws compel the State of Michigan to take the following actions:

1. Terminate the 1953 Easement based on non-curable violations, and/or nullify or revoke the 1953 Easement based on its invalidity or substantial change in circumstances, and immediately halt the flow of oil in Line 5 in the Straits of Mackinac in a reasonably prompt manner;
2. Impose immediate emergency measures until Line 5 is shut down that reduce and limit the flow of oil to 300,000 bbl./day, with more stringent requirements for shutdown (including wave height no more than 3.3 feet and winter conditions), and adequate insurance, bond, surety and/or secured

[65] Sections 32502 and 32503 apply to all previous occupancies or conveyances of bottomlands and waters, because the 1955 GLSLA was enacted to bring Michigan into compliance with previously occupied bottomlands that violated the public trust doctrine requirements. Moreover, the statute involves the mandate and minimum requirements for any occupancy, use, structure on the bottomlands of the Great Lakes. Legal defenses of statute of limitations, adverse possession, estoppel, or prescription do not apply to public trust lands and waters. *Shively v Bowlby,* 152 U.S. 33, 14 S. Ct. 548 (1894); *Illinois Central R Rd v Illinois,* 146 U.S. 387 (1892); *State v Venice of America Land Company*, 160 Mich 680 (1910); *Glass v Goeckle*, 473 Mich 667 (2005). An easement or authorized use of public trust lands and waters is subject to the continuing, perpetual trust, and the State is never foreclosed from terminating or revoking an easement or occupancy where subsequent circumstances are discovered that violate the public trust standards and the state's affirmative duty to prevent impairment to the public trust. *Id*.

assets in the total amount of $5 billion, including Enbridge parent and Michigan subsidiary companies; and

3. Direct Enbridge to apply under public trust law, Section 2129, MCL 324.2129, and Sections 32502, 32503 et seq. of the GLSLA, to prove that its use and operation, including the substantial change in design with hundreds of elevated spans, together with significant other matters listed below, complies with, and is entitled to, authorization required by the rule of law.

Thank you for your serious consideration of our comments. Please advise if you have any questions or desire further information. In addition, we request a meeting with you to discuss this matter at your earliest convenience. Please contact us to set up a time that is suitable for you and your executive staff.

Sincerely yours,

James Olson
President

Elizabeth R. Kirkwood
Executive Director

For Love of Water (FLOW)
153 ½ E Front Street, Suite 203C
Traverse City, MI 49684

cc: Hon. Governor Gretchen Whitmer
Hon. Attorney General Dana Nessel

STATE OF MICHIGAN
OFFICE OF ADMINISTRATIVE HEARINGS & RULES

IN THE MATTER OF: Petition of Straits of Mackinac Alliance, Grand Traverse Band of Ottawa and Chippewa Indians, and the City of Mackinac Island on the permits issued to Enbridge Pipelines (Lakehead), LLC (consolidated cases)	Docket No. 18-010802 Agency No. WRP008225 v.1 WRP014208 v.1 WRP015016 v.1 Part(s): 325, Great Lakes Submerged Lands Agency: Department of Environment, Great Lakes & Energy Case Type: Water Resources Division

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Ross A. Hammersley (P70105)
Rebecca Millican (P80869)
OLSON, BZDOK & HOWARD, PC
Attorneys for Straits of Mackinac Alliance
420 East Front Street
Traverse City, MI 49686
Ph. (231) 946-0044
ross@envlaw.com
rebecca@envlaw.com

Daniel P. Bock (P71246)
Charles A. Cavanaugh (P79171)
ASSISTANT ATTORNEYS GENERAL
Attorneys for Michigan Dept. of Environment, Great Lakes & Energy
Environment, Natural Resources, and Agriculture Division
P.O. Box 30755
Lansing, MI 48909
Ph. (517) 373-7540
bockd@michigan.gov
cavanaughc2@michigan.gov

William Rastetter (P26170)
OLSON, BZDOK & HOWARD, PC
Attorney for Grand Traverse Band of Ottawa and Chippewa Indians
420 East Front Street
Traverse City, MI 49686
Ph. (231) 946-0044
bill@envlaw.com

Timothy A. Stoepker (P31297)
DICKINSON WRIGHT PLLC
Co-Counsel for Enbridge Pipelines (Lakehead), LLC
200 Ottawa, N.W., Ste. 1000
Grand Rapids, MI 49503
Ph. (616) 458-1300
tstoepker@dickinsonwright.com

Scott W. Howard (P52028)
Attorneys for City of Mackinac Island
OLSON, BZDOK & HOWARD, PC
420 East Front Street
Traverse City, MI 49686
Ph. (231) 946-0044
scott@envlaw.com

Phillip J. DeRosier (P55595)
DICKINSON WRIGHT PLLC
Co-Counsel for Enbridge Pipelines (Lakehead), LLC
500 Woodward Ave., Ste. 4000
Detroit, MI 48226
Ph. (313) 223-3866
pderosier@dickinsonwright.com

AFFIDAVIT OF DR. EDWARD E. TIMM IN SUPPORT OF PETITIONERS' COMBINED RESPONSE TO RESPONDENT EGLE AND INTERVENOR ENBRIDGE'S MOTIONS FOR SUMMARY DISPOSITION

Dr. Edward E. Timm, being sworn, states the following:

1. I am a licensed professional engineer in the state of Michigan (License No. 6201023829, expiring 10/31/2021). I hold bachelors, masters, and Ph.D. degrees in chemical engineering from the University of Michigan, Ann Arbor.

2. I spent my professional career at Dow Chemical Company, concentrating on research and development. During my last eight years at Dow, I served as a Senior Scientist and Consultant to the company's Environmental Operations Business. In that role, I became the technical leader of Dow's efforts to reduce dioxin emissions globally from all of Dow's process operations. In 2000, I received the Dow Responsible Care Award for my work related to the success of this effort. I retired in 2001. A copy of my curriculum vitae is attached hereto as **Exhibit A**.

3. Since 2015 I have studied Enbridge's Line 5, the 645-mile long pipeline that transports oil, natural gas liquids, and propane from Alberta, Canada, through Wisconsin and Michigan to Sarnia, Canada. I became interested in the history and technology of Line 5 in 2015. My lifelong interest and knowledge in the hydrodynamics of structures like Line 5 led me to believe that the flows around this unique submarine pipeline were not well understood and could be problematic. My early background in Engineering Mechanics made me understand the difficulty of the engineering analysis of the stresses on and failure modes of the pipe. My long career in the chemical industry allowed me to evaluate evidence of pipeline deformities and age (bending, cracking, denting, delamination, ovaling, corrosion, pitting and marine growth).

4. Although the focus is often on the line's underwater crossing through the Straits of Mackinac, I have also studied various aspects of the pipeline's siting and operations on land, such as stream crossings or the route along the north edge of Lake Michigan, where in some places the line is within 250 yards of the shoreline, posing potential risks to the lake even from an inland spill incident.

5. I have given over 20 presentations regarding Line 5 over the years to various citizens' and environmental groups, county and city boards, and to the public generally, at no charge.

6. In 2015, after hearing a lecture on the subject by Founder and President Jim Olson and Executive Director Liz Kirkwood, I volunteered to work with the water policy center, FLOW (For Love of Water), as a technical consultant on matters related to Enbridge's Line 5. In this capacity I have written eleven detailed technical reports and numerous letters which have been submitted to the Governor, Attorney General, the now-disbanded Pipeline Safety Advisory Board ("PSAB"), and various other state officials and agencies in connection with public comments prepared by FLOW.[1]

7. The opinions and statements made in this affidavit are based upon my education, professional experience, and ongoing review and study of all publicly-available Enbridge data, technical reports and analyses commissioned by the State of Michigan, Enbridge filings in the

[1] Among the most relevant of my reports are: a technical note dated August 2, 2017, "A Lower Bound Examination of the Monte Carlo Analysis for Spanning Risk in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5"; a technical note dated December 6, 2017, "Rebuttal of Revised Alternatives Attachment 6 and Related Sections of the Dynamic Risk Revised Alternatives Assessment"; and a technical letter dated July 18, 2018, "Comments Regarding the Enbridge Application for a Permit to Install 48 New Screw Anchor Supports under Line 5 in the Straits of Mackinac" All three reports are attached as **Exhibit B**.

federal litigation related to the Line 6B spill in 2010, this contested case, as well as a thorough review of the open engineering literature regarding pipeline integrity.

8. I have long contended, and continue to believe, that Line 5, as it exists today through the Straits, is a changed design from the original, as-built 1953 design, and this new design has not been subjected to a technically robust failure mode analysis.

9. To my knowledge, there is no existing structural engineering analysis of Line 5 in the Straits that addresses the safety and efficacy of the "as remediated"[2] design which supports the pipe off the lakebed using 200+ anchor support structures. If the underlying data necessary for such an analysis exists, I am unaware of it, or it has not been revealed by Enbridge.

10. More specifically, without such data and analysis, conclusions about the potential adverse environmental effects of, and any feasible and prudent alternatives to the installations of anchor supports (such as those at issue in this contested case), cannot be determined. Based on my review of the permit application materials, it does not appear any such data or analysis was provided by Enbridge to EGLE. EGLE's statements that it properly evaluated the effects and alternatives in the context of Enbridge's permit applications therefore cannot be considered technically robust, leaving the risk associated with the anchor supports and possibility of catastrophic failure unquantified.

11. Enbridge also seems to have failed to provide any real details concerning the screw anchors themselves, such as the strength and flexibility of the installed support assembly, its

[2] "As remediated" is language used in DNVGL and other guidelines and standards to describe a structure that has been modified from its original design because it had become structurally unstable and construction actions have been taken to stabilize the structure and extend its lifespan. The original design of Line 5 in the Straits had to be remediated by installing a multiplicity of screw support anchors because the original design failed structurally due to strong currents eroding the soil that was intended to support the pipe.

vibrational properties, and the effects of thermal expansion and contraction and the ultimate strength of the anchors in the various soil types found on the Straits lakebed.

12. To the extent Enbridge has claimed that the periodic installation of numerous screw anchor supports constitutes regular "maintenance" on the structure, I cannot agree. "Maintenance" activities do not transform a structure into something never contemplated in the original design, as has occurred here. No reasonable engineer would argue otherwise.

13. As a general proposition, to introduce changes to a structure, such as the Line 5 pipeline, without the requisite analysis is not acceptable engineering practice. On this point, forensic engineer Henry Petroski has lamented that changes not analyzed lead to unintended consequences.[3]

14. I understand it has been suggested that the original 1953 Easement's granting language, which includes "anchors and other necessary appurtenances and fixtures" should encompass the installation of the anchor supports that are the subject of this case. I believe that language must be put in the historic context in which it was written. No one had ever built a pipeline like Line 5 through the Straits before. The designers surely knew they might have to make changes to the plans as construction progressed. For example, the 1954 Notes of Clark Rankin, the Bechtel project manager, reference the possibility that concrete saddles could be used to add necessary extra weight to maintain the stability of the pipeline in the event currents in excess of 2 knots were encountered.[4] It is one thing for the designers of a structure to recommend changes to a recently-built structure, and this happens frequently. It is quite another to decide 65 years later

[3] "Miami Bridge Collapse," Petroski, H., American Scientist, v. 106, n. 4, July-August 2018, p. 206 (Attached **Exhibit C**). Petroski is the Alexander S. Vesic Professor of Civil Engineering and Professor of History at Duke University.

[4] See Attachment 3 to Petitioners' Motion for Summary Disposition, p. 20, ¶ 3.

that an entirely new design is warranted, and to implement that design without analysis, using "maintenance" as an excuse.

15. As evidence of the failed -- and now altered -- design of Line 5 in the Straits, I call the Tribunal's attention to a recently-filed document in the federal litigation addressing the rupture of Enbridge's Line 6B in Talmadge Creek near Kalamazoo in 2010.[5] Exhibit 5[6] to the Memorandum in Support of the Unopposed Motion for Entry of the Third Modification of the Consent Decree, entitled "Integrity Assessment of Lateral Movement Risk for Line 5 at Straits of Mackinac Including Biota Effect" references (to my knowledge, for the first time) "PRCI Guidelines PR-170-9520 (Integrity Assessment of Exposed/Unburied Pipe in River).

16. PRCI Guidelines PR-170-9520 is a proprietary industry guideline[7] intended to assure the stability of submarine pipelines in rivers with erodible soil leading to unsupported spans. Enbridge asserts that Line 5 in the Straits is a stable structure, but, based on the limited detail found in the recently submitted Exhibit 5 from the *US v Enbridge Energy* proceeding, it appears that this assertion is the result of a questionable analysis of the pipe resting on the lake bottom and not an analysis of the structure as it will exist when all of the screw anchor supports have turned the structure into a multi-span suspended structure. The original designers in 1953 had intended Line

[5] *United States v Enbridge Energy, Limited Partnership, et al.*, Case No. 16-cv-914 in the U.S. District Court for the Western District of Michigan. As I understand it, various aspects and requirements of Enbridge's operations of Line 5 have been memorialized within the consent decree that resolved that case between the U.S. government and the company.

[6] Attached hereto as **Exhibit D**.

[7] In this context, it is critical to distinguish the terms standard, guideline, and recommended practice. Technically speaking, a standard has been recognized by the government and carries the force of law. An example would be ASTM B 31.4 governing pipelines, which has been written into the Code of Federal Regulations. Guidelines and recommended practices may come from open sources like ASME (American Society of Mechanical Engineers) or proprietary sources like PRCI (Pipeline Research Council International). Typically, guidelines and recommended practices must be followed for insurance purposes, and may be used as a liability defense in case of an incident.

5 through the Straits to be a continuously supported structure (i.e., resting on the lakebed) to prevent plastic deformation of the pipe due to the effects of gravity and currents.

17. Before the State of Michigan consented to the construction of Line 5 in the Straits, the original design was reviewed in 1953 for over twenty different possible failure mechanisms by famed structural engineer Mario Salvadori.[8]

18. It is my professional opinion that the remediated design for Line 5 in the Straits has introduced failure modes that were not considered in the original design or by Dr. Salvadori and that must be considered and analyzed before any opinion regarding the recently-permitted anchor supports or the overall stability of this pipe can be considered valid.

19. The import of the Integrity Assessment (Ex. D) is twofold. First, the mere fact that PRCI-PR-170-9520 exists demonstrates that a pipeline constructed to mostly rest on the lakebed (the Line 5 as-built design) is something other than a free spanning pipeline (the as-remediated design). Second, it raises the question whether Enbridge has been applying guidelines and standards outside the intended scope of their application. It is my professional opinion that neither PRCI Guidelines PR-170-9520 nor DNVGL-RP-F105, Free Spanning Pipelines[9], which are cited in **Exhibit D**, directly applies to the remediated design of Line 5 in the Straits (although RP-F105 does outline a path for such a structure to be analyzed by knowledgeable experts).

20. Consistent with the guidance given in DNVGL-RP-F105, Line 5 in the Straits must now be considered a remediated multi-span structure. Regardless of the exact number of supports, whether 22 or 48 or 3 (the number of supports authorized by the three permits at issue in this case, respectively),any analysis that merely looks at the impacts from the screw anchors' footprints on

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[8] See Attachment 1 to Petitioners' September 27, 2019 Motion for Summary Disposition.

[9] DNVGL-RP-F105, Free Spanning Pipelines, DNVGL Recommended Practice, October 2017 Ed., DNVGL, Hovik, Norway.

the lakebed or treats Line 5 as non-interacting individual spans (instead of an interacting, multi-span structure as defined in DNVGL RP-F105), is woefully insufficient. Not to mention, that kind of cursory analysis ignores Line 5's long history of deferred maintenance and structural failure. In short, the apparent failure of both the Department and Enbridge to examine the aggregate changes and impacts resulting from the installations of screw anchor supports cannot be considered a valid determination of the risk this structure presents.

21. Line 5 in the Straits is not, in its "as remediated" condition, a case where DNVGL-RP-F105 is directly applicable, as shown in the following figure taken from this standard.

22. Figures 1-2, 1-3, and 1-4 below are reproduced from DNVGL RP-F105 to illustrate the types of free spans considered within the scope the recommended practice. As can be seen from these figures, the standard applies directly to pipelines where scouring of bottomland has created a small number of free spans in the pipeline but some of the pipe is still resting on the bottom. Application of this guideline to a structure comprising scores of free spans between support structures that were not part of the original design may be attempted utilizing the principles found in Section C 3.1 of RP-F105, but the practice cautions that this is a very complex task. Importantly, the description under Figure 1-4 notes that "[i]nteracting multi-spans cannot be assessed using only isolated single span approaches."

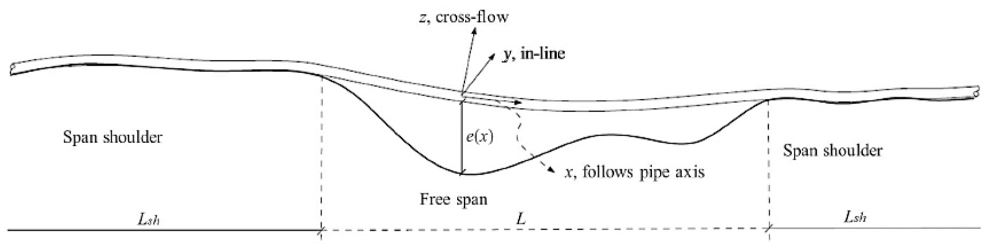

Figure 1-2 A typical isolated single span, with definition of axes, gap, span, and shoulder

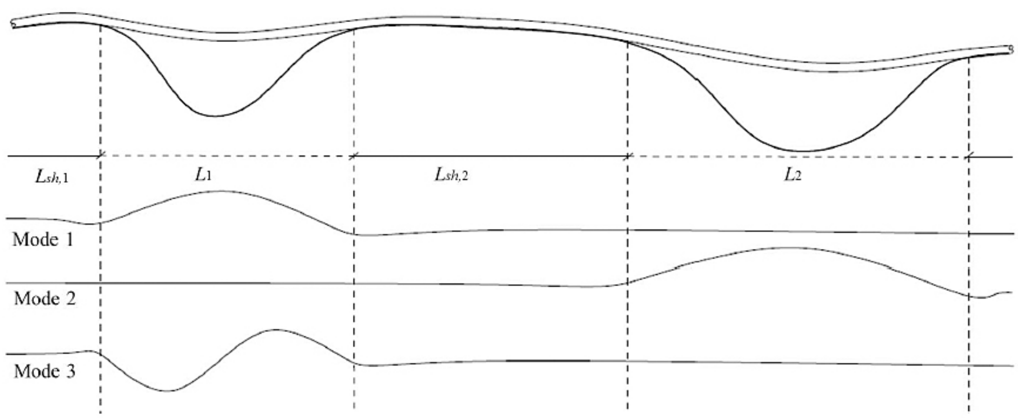

Figure 1-3 A typical scenario on a rough seabed where the free spans are still isolated single spans

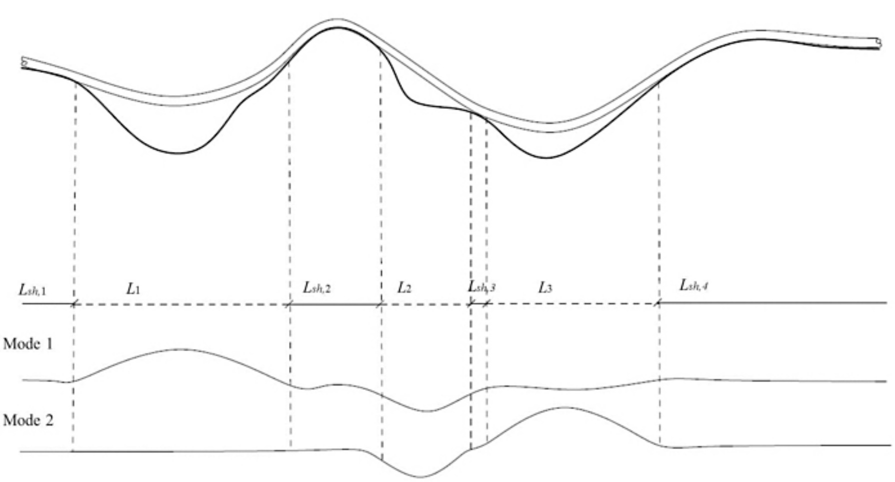

Figure 1-4 A typical interacting multi-span scenario

In Figure 1-4, three spans are in close proximity. The peak at the second shoulder influences the static configuration, particularly of the second span. Furthermore, if we assume that the two presented modes are among the active modes in the multi-span, the dynamic behaviour of each individual span is affected by the other spans as observed from the mode shapes. Hence, the multi-span in Figure 1-4 is an interacting multi-span.

Interacting multi-spans cannot be assessed using only isolated single span approaches. A precise mathematical formulation to distinguish between isolated single spans and interacting multi-spans is presented in [6.10].

23. DNVGL-RP-F105 does provide a path to valid analysis of a remediated multi-span structure under the guidance of section C.3, "VIV in other structural components," and other sections of this guideline.[10]

C.3 VIV in other structural components

C.3.1

Other subsea cylindrical structural components, such as braces, trusses, etc., can also be evaluated, using this RP at the designer's discretion and judgement. The following conditions should, however, be carefully evaluated:

— uniform current assumption
— frequencies and mode shapes should be based on detailed FE analysis
— L/D ratio should be within the RP's design range
— location of the structural element (relevance of wave induced VIV, which is not covered by this RP).

24. An analysis of Line 5 in the Straits requires consideration of <u>all the components</u> in a free span assessment under the guidance of DNVGL-RP-F105 as shown in the following figure taken from the recommended practice.

[10] "VIV," or vortex-induced vibrations, are described as "a fluid flow past a bluff body, such as a circular cylinder, [which] will result in the periodic shedding of vortices into the body's wake for all but the lowest flow speeds. This process gives rise to oscillatory lift and drag forces which, if the body is compliant or elastically supported, can result in Vortex-Induced Vibrations (VIV). VIV can in turn lead to fatigue damage in vibrating structures, which makes it an important issue in the design of bridges, chimney stacks and marine riser pipes." (http://www2.eng.ox.ac.uk/tidal/research/viv-cylinder).

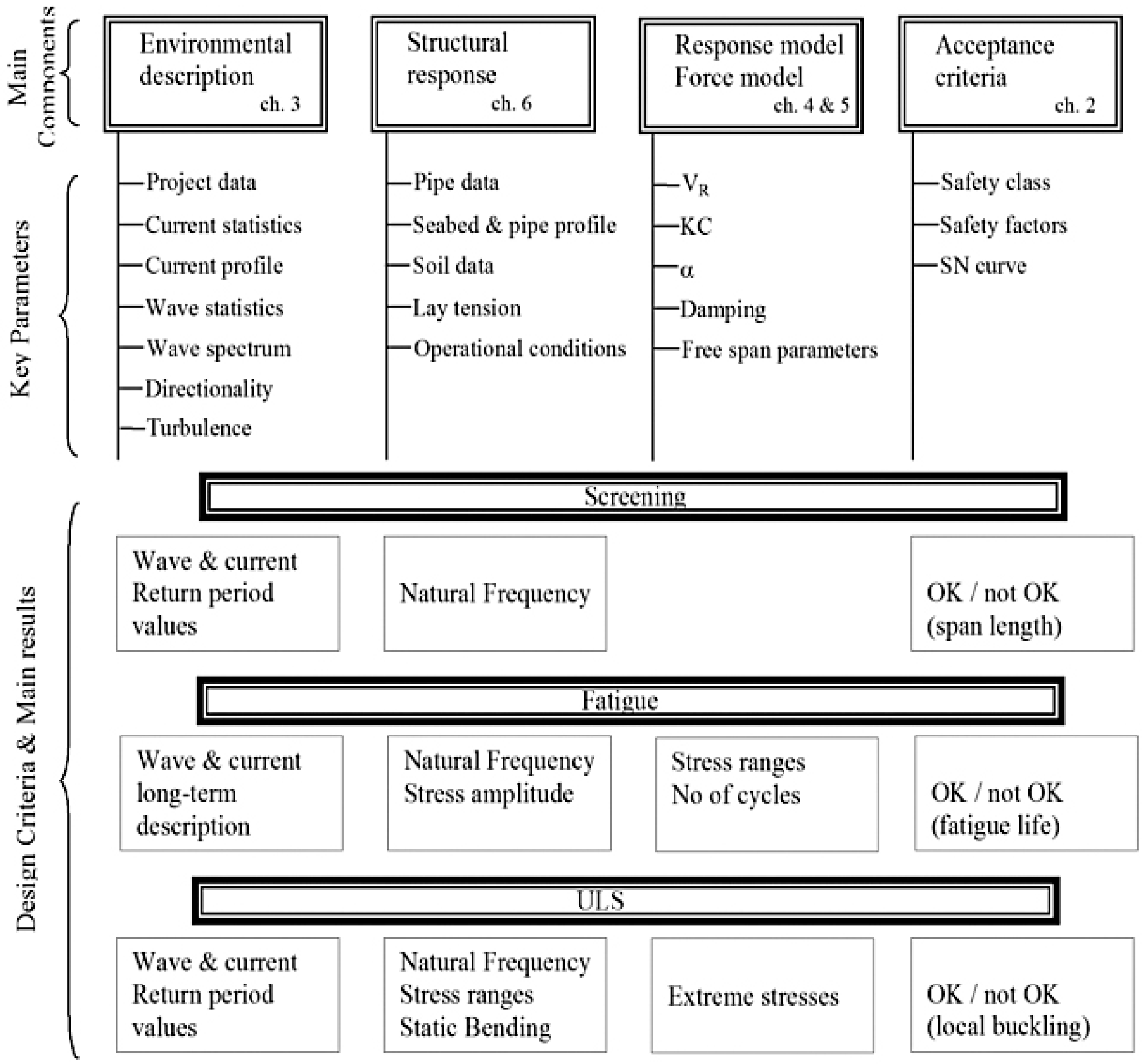

Figure 1-1 Overview of main components in a free span assessment

25. Figure 1-1 above illustrates the complexity involved in the rigorous analysis of a submarine structure that has developed free spans due to current-induced erosion of the supporting soil. ***Even if only one span has developed, DNVGL-RP-F105 requires a complete reanalysis of the structure.*** This rigorous analysis is required even if only one isolated span has developed (as shown in Figure 1-2, above).

26. For the case of the remediated design of Line 5 in the Straits, the addition of hundreds of support structures requires analysis of all possible failure modes that can occur in an interacting, multi-span structure. This analysis requires detailed knowledge of the profile and statistics of the currents impacting the structure, as well as a multiplicity of design information necessary to calculate all stresses and fatigue statistics due to static, dynamic, and vibratory deformation of the structure under the influence of currents and the shifting lakebed.

27. It is my professional opinion that, because of the issues raised in this affidavit, it is not possible to conclude that Line 5 in the Straits is in compliance with the engineering standards and guidelines cited by Enbridge. It is also my opinion that the information necessary to apply these standards and guidelines does not exist or has not been revealed by Enbridge and that, consequently, it is not possible to assess the risk of catastrophic failure of Line 5 in the Straits using these standards and guidelines or other methods, now that the structure (as remediated by the addition of a multiplicity of support structures) is a complete departure from the original design. The fitness for service of Line 5 in the Straits cannot be determined at this time with a sufficient level of confidence to proceed with remediating the structure (i.e., installing anchor supports) without complete re-analysis of the remediated structure.

This affidavit is made on my own personal knowledge. If called as a witness, I could competently testify to the facts herein.

Dated: 10/21/19

Edward E. Timm, P.E.

STATE OF MICHIGAN)
)ss
COUNTY OF GRAND TRAVERSE)

Acknowledged before me on this 21st day of October 2019, by Edward E. Timm.

Karla L. Gerds, Notary Public
Grand Traverse County, Michigan
Acting in Grand Traverse County
My commission expires: November 13, 2024

Exhibit A

Edward E. Timm
5785 Deer Run Trail
Harbor Springs MI 49740
231-526-7159
August 9, 2016

Expertise

Dr. Timm developed world class expertise during his 27 years of work experience in R&D at the Dow Chemical Company. During this time he became a recognized and published expert in numerous areas of Processing Technology. He is experienced in all phases of process development including invention, patenting, piloting, process development, plant design, plant construction management, plant startup, process optimization, troubleshooting and documentation.

During the last eight years of his career, Dr. Timm was a Senior Scientist and Consultant to Dow Chemicals Environmental Operations Business (EOB). He was a subject matter expert on Dioxin Formation and Transport in Chemical Process Systems and was leader in the company’s voluntary efforts to reduce the emission of this chemical compound.

As a Senior Scientist in EOB, he served as the senior technical professional developing process for gasification of chlorinated wastes as alternate to incineration.

He also served as a subject matter expert on development and evaluation of new chemical processes

He was a Senior Scientist for Liquid Separations Business including Ion Exchange and FilmTec Products. Film Tec is the low cost supplier of reverse osmosis membranes, commonly used in water treatment to concentrate dissolved solids, and produce high purity water.

Education

B.S. ChE - 1968, University of Michigan, Ann Arbor
M.S. ChE - 1970, University of Michigan, Ann Arbor
Ph.D ChE - 1974, University of Michigan, Ann Arbor

Registered Michigan Professional Engineer.

Awards

1978 Chemical Processing Magazine Vaaler Award
1979 A. O. Beckman Award
1982 Dow Central Research Inventor of the Year Award
1984 Saginaw Patent Law Association, Inventor of the Year Award
1984 Michigan R&D Scientists Award
1991 Spangenberg Ceramic Achievement Award

1993 Chemicals and Performance Products, Significant Inventor Award
1997 Liquid Separations Spectrum and Enterprise Awards
1998 Liquid Separations Enterprise Awards
2000 Dow Responsible Care Award
2005 Award for work on the Dow Dioxin Reduction Task Force

Work Experience

2004-Present Board Member and Vice Chair of the Harbor Springs Area Sewage Disposal Authority (Volunteer Position as elected by the harbor Springs City Council).

1998-2001 Senior Scientist, Dow Chemical, Midland MI - Engineering Science/Mrkt Development Lab

- Consultant to Dow Environmental Operations as a subject expert on Dioxin Formation and Transport
- Subject matter expert on development and evaluation of new chemical processes
- Consultant to Dow Patent and EH&S/Regulatory Departments

1997- 1998 Senior Scientist, Dow Chemical, Midland MI, Environmental Operation Business

- Senior technical professional developing process for gasification of chlorinated wastes
- Consultant to Dow Environmental Operations as a subject expert on Dioxin Formation and Transport

1994 - 1997 Senior Scientist, Dow Chemical, Midland MI

- Dow New Ventures Department Principal Investigator on Dow/Diochem Dioxin Inhibition Technology
- Consultant to Dow Environmental Operations as a subject expert on Dioxin Formation and Transport
- Senior Scientist for Liquid Separations Business including Ion Exchange and FilmTec Products

1991- 1994 Senior Associate Scientist, Dow Chemical, Midland, MI

- Technical Resource for Dow New Ventures activities
- Consultant to Dow Patent Department.
- Senior scientist for Dow Ceramics and Advanced Materials Laboratory.
- Chairman: Michigan R&D Scientists Organization 1992

1991 - 1989 Senior Associate Scientist, Dow ROC Development Center, Traverse City, MI

- Fundamental studies into the mechanisms and utility of the ROC production of cutting tools, wear parts, and ordinance articles - Design and ballistic testing of Dow proprietary ordinance articles.
- Development of high temperature technology for the production of Dow engineering ceramics.

1986 - 1989 Associate Scientist, Dow ROC Development Center

1984 - 1986 Associate Scientist, Dow Midland

- Fundamental studies into the mechanisms and utility of the ROC-Tec, Inc. isostatic forging process.
- Administration of a research contract between Dow and ROC-Tec, Inc. to study isostatic forging.

1981 - 1984 Senior Research Specialist, Dow Midland

- Scale-up and plant design for Dowex Monosphere* uniform size ion exchange resin.
- Fundamental research into the production of ultra low density, plastic foam.
- Invention of a process to produce uniform diameter, uniform pore size silica beads.

1979 - 1981 Research Specialist II, Dow Midland

Applied process research, development and scale-up of Monosphere* Process for ion exchange resin.

1978 - 1979 Research Specialist I, Dow Midland, Process Development

- Fundamental studies of suspension polymerization.
- Invention and development of Monosphere* Process for ion exchange resin.

1977 - 1978 Leave of Absence

1976 - 1977 Research Specialist I, Dow Midland, Process Development

- Mathematical modeling and computerized analysis of Accelerating Rate Calorimeter data.
- Invention and development of diesel incineration.
- Invention and development of solids calorimeter for thermal characterization of solids.
- Invention and development of continuous Dowicide G* Process.

1974 - 1976 Senior Research Engineer, Dow Midland, Process Development

- Continuous miniplant for Sym-TET hydrolysis kinetics.
- Continuous miniplant for Dursban* esterification kinetics.

*Registered Trademark of The Dow Chemical Company

Patents

US Patent 6,613,462
Method to form dense complex shaped articles, September 2003

US Patent 6,613,127
Quench apparatus and method for the reformation of organic materials, September 2003

US Patent 6,479,715
Process for the preparation of alkylene glycols, November 2002

US Patent 6,448,456

Process for the preparation of alkylene glycols, September 2002

WPI Acc No: 96-139420/199614
Spinal support system for seating which properly positions sacrum, pelvis, iliac crests, and musculo-skeletal system to produce total pelvic stability - has support member, brace member, and support device with fluid-filled hollow bladder foam padding member
(Not Assigned to Dow, Personal Work)

WPI Acc No: 95-060345/199508
Submicron composition of metallic carbide compounds, their solid solution or precursors - are prepared by carbothermic reaction whereby metal oxide is heated very rapidly with carbon source in inert atmosphere

WPI Acc No: 94-316860/199439
Wear-resistant complex multiphase sintered product - from partial reaction of metal boride(s), carbide(s), nitride(s) or silicide(s)

WPI Acc No: 93-350849/199344
High hardness and wear resistant material - is prepared by incomplete reaction of metal carbide nitride or silicide compounds, to form variable stoichiometry products e.g. tungsten carbide and molybdenum and chromium compounds

WPI Acc No: 93-288441/199336
Dense refractory composition for hand metals - comprises rhenium binder for carbide composities e.g. tungsten, titanium and hafnium carbide(s), for composites in cutting tools

WPI Acc No: 93-219593/199327
Cobalt-free wear-resistant material for shaped article - comprises reaction products from incomplete reaction between boron, carbon, nitrogen or silicon derivative of 1st metal, source of 2nd and opt. 3rd metals

WPI Acc No: 93-188527/199323
Hard, wear resistant ceramic material for nozzle, cutting tool etc. - prepared by incomplete reaction of metal boride, silicide or nitride with second metal carbide, where metals are e.g. titanium, vanadium, tungsten

WPI Acc No: 92-079448/199210
Hard or wear resistant material for water jet nozzles, etc. - comprises at least 1 product of incomplete reaction between metal and its carbide boride, nitride or silicide cpd.

WPI Acc No: 90-253560/199033
High wear resistance mixed carbide prod. - obtained by incomplete reaction

of carbide especially tungsten carbide with source of second metal esp. molybdenum

WPI Acc No: 90-093101/199013
High hardness, wear resistant materials - comprise partial reaction prods. between compounds of refractory metals and boron, carbon, silicon or nitrogen

WPI Acc No: 88-154870/198822
Mfr. of densified solid bodies - using die assembly comprising preform surrounded by fluid pressure medium contained in ceramic shell with open top

WPI Acc No: 88-030520/198805
Uniform size and porosity silica polymer bead produced by dispersing polymerisable silicon oxide and gelation agent as droplets in liquid medium then polymerizing

WPI Acc No: 87-157102/198722
Preperation of uniform size polymer beads - by dispersing polymerizable monomer droplets into immiscible continuous phase suspension liquid

WPI Acc No: 86-063354/198610
Preperation of uniform, fine, spherical polymer beads - by vibrating monomer jet to form droplets and polymerizing in gas phase or in dispersion

WPI Acc No: 84-120674/198419
Spheroidal polymer beads produced by jetting monomer into immiscible medium through vibrating jet to form droplets and polymerizing droplets without coalescence

WPI Acc No: 84-094525/198415
Measuring adiabatic exothermic chemical reaction rate - as function of time to determine thermal runaway characteristics of chemicals

WPI Acc No: 82-39610E/198220
Spheroidal polymer beads of uniform size for ion exchange - by jetting monomer into suspending medium with vibratory excitation

WPI Acc No: 80-G1156C/198028
Accelerating rate adiabatic calorimeter - has sample vessel positioned inside reaction chamber to measure adiabatic self-heat rate of exothermic chemical reactions

WPI Acc No: 79-21549B/197911
Reducing emission of halogenated hydrocarbon(s) - by oxidation in a

diesel engine

WPI Acc No: 79-H9338B/197937
Non-adiabatic reaction calorimetric technique - quantifies reaction kinetics of thermally unstable solids by determining thermal gradient across reaction sample

WPI Acc No: 78-23621A/197813
Adiabatic calorimeter - esp. for measuring time-to-explosion data for exothermically decomposing chemicals

DOW CRI Reports

Author of 23 Dow Confidential Technical Reports

Publications and Non-Dow Reports

Timm, E. E., Hammitt, F. G., "Cavitation Vibratory Damage Test Procedure Using Baffle Plate Configuration," ASME 1969 Cavitation Forum, Pub. ASME, New York.

Timm, E. E., Hammitt, F. G., "A Repeating Water Gun Device for Studying Erosion by Water Jet Impacts," U-M Cavitation and Multiphase Flow Lab Report #02643-1-PR, for U. S. Naval Air Development Center, April, 1969.

Timm, E. E., Hammitt, F. G., "On Modes of Operation of Automated Water Slug Gun," U-M Cavitation and Multiphase Flow Lab Report #02643-PR-3, for U. S. Naval Air Development Center, July, 1969.

Kling, C. L., Hammitt, F. G., Mitchell, T. M., Timm, E. E., "Bubble Collapse Near a Wall in a Flowing System," ASMW 1970 Cavitation Forum, Pub. ASME, New York.

Kling, C. L., Hammitt, F. G., Mitchell, T. M., Timm, E. E., Bubble Collapse Near a Wall in a Flowing System, a film available at the Engineering Societies Library, 345 East 47th Street, New York, New York.

Hammitt, F. G., Kling, C. L., Mitchell, T. M., Timm, E. E., "Assymmetric Cavitation Bubble Collapse Near Solid Objects," submitted for presentation at the International Union of Theoretical and Applied Mechanics Congress, Leningrad, Russia, May 1971.

Timm, E. E., A High Speed Photographic Study of Cavitation Bubble Collapse and Liquid Jet Impingement, PhD Thesis, University Of Michigan, Ann Arbor, Michigan, 1974, Available from University Microfilms, Ann Arbor, Michigan.

Timm, E. E., "The ROC Process: Densification of WC-Based Hard Materials with the Dow Isostatic Forging Process," Proc. Adv. Hard Materials Production. MPR Publishing Services Ltd., 1988.

Kelto, C. A., Timm, E. E., and Pyzik, A. J., Rapid Omindirectional Compaction of Powder, Ann. Rev. Mat. Sci., 19, 1989

Timm, E. E., “Hydrodynics of Droplet Formation in Agitated, Non-Coalescing Oil in Water Suspensions,” Presented at University of Chicago James Franck Institute, November 20, 1995.

Timm, E. E., and Nestrick, T. J., “Data Quality from field Sampling of a Municipal Incinerator,” Presented at 7th Annual Karasek Conference on Dioxin Formation and Transport, Mar 11, 1996, Phoenix, AZ.

Salinas, L, Bork, P, and Timm, E, “Gasification of Chlorinated Feeds,” Presented at Gasification Technology Conference, October 1999, San Francisco, CA.

Salinas, L, Bork, P, and Timm, E, “Environmental Benefits of Gasification of Chlorinated Feeds,” Presented at Gasification Technology Conference, October 2000, San Francisco, CA.

Timm, E. E., “Bimodal Modeling of Buried Pipeline External Pitting Corrosion,” Presented at NACE Corrosion Risk Management Conference, May 25, 2016, Houston, TX

Exhibit B

Technical Note

A Lower Bound Examination of the Monte Carlo Analysis for Spanning Risk in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5

Edward E. Timm, PhD, PE
5785 Deer Run Trail, Harbor Springs MI 49740
EdTimm@Gmail.com

The Dynamic Risk, Inc. Line 5 Alternatives Analysis[1], Option 5 makes use of a Monte Carlo probabilistic analysis to analyze the risk of failure due to the effects of gravity and currents on unsupported spans of pipe. The following description of this analysis is taken from the Alternatives Analysis:

"<u>Spanning Assessment</u>
The evaluation of threat attributes indicated that the Straits Crossing segments are potentially vulnerable to two separate failure mechanisms related to spanning:

i) fatigue caused by vortex-induced vibration (VIV) at span locations, resulting from near-lake-bottom water currents; and,
ii) over-strain caused by stresses due to unsupported span length (gravity and water current drag forces)

With respect to the threat of VIV, depending on pipeline design attributes and span lengths, even moderate currents can induce vortex shedding, at a rate determined by the velocity of water flowing around the pipe. Each time a vortex sheds, a force is generated, causing an oscillatory multi-mode vibration. Under some circumstances, this vortex-induced vibration can give rise to fatigue damage and failure of submarine pipeline spans. The threat of VIV was analyzed utilizing an amplitude response model in which input parameters of span length and upper-bound bottom-layer water currents along both the east and west Straits Crossing segments were represented as probability distributions. The span length distributions reflect observations that actual span lengths have exceeded (in some cases, by significant margins), the 75 ft. maximum stipulated in the Line 5 easement agreement. Using a total of 100,000,000 simulations in a Monte Carlo analysis, the probability that fatigue life would be exceeded for each of several future time periods was determined up to the year 2053.

As a separate analysis, a stress analysis was conducted that considered stresses arising from both gravity and drag forces in addition to those arising from operating pressure and temperature. As was done for the VIV analysis, input parameters of span length and upper-bound bottom-layer water currents along both the east and west Straits Crossing segments were represented as probability distributions. For the purposes of the spanning stress analysis, the probability of failure was defined as the fraction of simulations in which the maximum combined effective stress exceeded yield stress. Using a total of 100,000,000 simulations in a Monte Carlo analysis, the probability that the pipe's yield strength would be exceeded by the maximum combined effective stress would be exceeded was determined. Although there is ample strain capacity beyond yield (and therefore, failure does not occur when the maximum combined effective stress *reaches yield stress), yielding was selected as a failure criterion because it defines the onset of plasticity, which in a dynamic environment could give rise to high amplitude fatigue."*

The failure criterion and results of the Monte Carlo analysis for spanning risk due to the forces due to gravity and currents are reported as follows:

<u>"2.4.1.1.2.1.3.2 Probability of Failure</u>
Multiple stochastic simulations of the above stress calculations were performed in a Monte Carlo analysis, with each simulation using random variables of span length, water current velocity, and gap ratio derived from the probability density functions for those variables described in the preceding Section. In each simulation, the Von Mises maximum combined effective stress was compared against the yield stress of the material.
For the purposes of the analysis, the probability of failure was defined as the fraction of simulations in which the Von Mises maximum combined effective stress exceeded yield stress. This condition was selected as a failure criterion because although there is ample strain capacity beyond yield (and therefore, failure does not occur when the maximum combined effective stress reaches yield stress), it defines the onset of plasticity. In a dynamic environment, characterized by changing water currents, span lengths and gap ratios, there is potential for the maximum combined effective stress to vary with time in a repetitive manner, as the variables that control the stresses vary over time. Under such conditions, the potential for plasticity creates the potential for plastic fatigue, under which conditions, progression to failure can occur after relatively few cycles.
Because water depth and product density affects the biaxial stress state of a spanned pipeline, six different scenarios were evaluated for each crossing segment, corresponding with two different water depths (the minimum and maximum depths along the untrenched portion of the segment), and three different product density values, encompassing the full range of densities. For each of the six scenarios evaluated per segment, a total of 100,000,000 Monte Carlo simulations were conducted, providing a resolution of 1.0x10-08.
From this analysis, the failure probability was determined to be below the resolution of the analysis – i.e., <1.0x10-08."

This exceedingly low value for the risk of failure of the Straits sections of Line 5 due to the forces of gravity and currents on long unsupported spans invites examination. A value for the lower bound to this risk can be deterministically calculated by assuming that currents have no effect on the spans and the only force acting on the pipe is due to gravitational stress on the unsupported spans. Since stress due to currents can only increase the probability of failure, this zero current assumption results in a lower bound for the risk that is calculated by the Monte Carlo analysis that includes the effect of currents.

Calculations of the unsupported span length at which the pipe reaches its elastic limit have been done by Salvadori[2], Rosenfeld[3], and Timm[4]. These calculations all conclude that the pipe is very near its elastic limit at an unsupported span length of 140' and beyond the elastic limit at a 150' unsupported span with few exceptions. This knowledge makes it possible to estimate the probability of failure by simply determining the probability of a span greater in length than 150'.

A description of the span length probability distributions used in the Monte Carlo analysis for failure risk due to the forces of gravity and currents in the Alternatives Analysis follows:

<u>"Span Length Distribution</u>
Based on a review of information obtained from seven underwater inspections of the East and West segments spanning the years 2005 – 2016, it was observed that the lengths of individual spans change over time. [82] While the terms and conditions of the April 23, 1953 Straits of Mackinac Pipeline Easement limit allowable span length to 75 ft., and maintenance activities have been undertaken to maintain span lengths to less than that limit, span lengths have varied both below and above that limit over time. Therefore, for modeling purposes, it would be non-conservative to assume that span lengths will be limited to 75 ft. on a go-forward basis. Instead, the results of the seven inspections performed between 2005 – 2016 were used to generate separate span length distributions for each of the East and West segments. A total of 715 separate span length measurements were used to generate a span length distribution on the East segment, and 691 separate span length measurements were used to generate a span length distribution on the West segment. In both cases, Weibull distributions were found to provide the best fit to these data, as shown in the figures below."

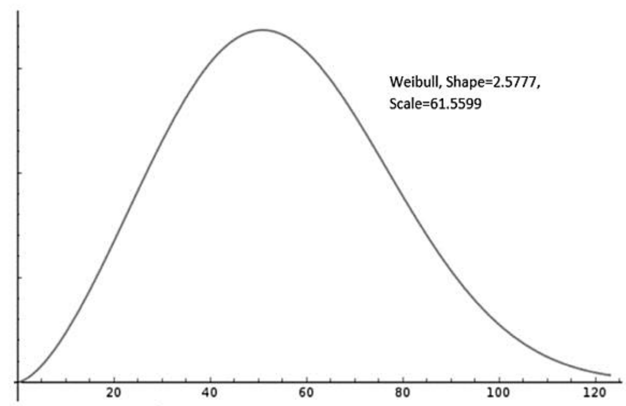

Figure 2-10: Span Length Distribution, East Segment

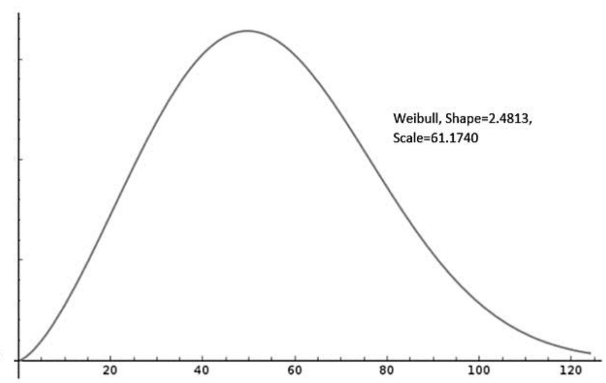

Figure 2-11: Span Length Distribution, West Segment

Based on the Weibull Distribution parameters shown above, the expected probability of spans exceeding 150' in length is shown in Table 1 as well as the expected number of failures in 10^8 samples from these distributions.

<u>Table 1. Expected Failures Due to Spanning Risk from Gravity and Current Forces</u>

Location	Shape Parameter	Scale Parameter	Probability of Span Greater Than 150'	Expected Failures in 10^8 Samples
East Leg	2.5777	61.5599	4.8594E-05	4859
West Leg	2.4813	61.1740	9.5326E-05	9533

The 4859 East Leg samples and the 9533 West Leg samples that meet the failure criterion of 150' or greater are a direct result of the span distribution Weibull functions used in the Alternatives Analysis. This result stands in stark contrast to the findings of the Alternatives Analysis where: "*From this analysis, the failure probability was determined to be below the* *resolution of the analysis – i.e., <1.0x10-08."* That the Monte Carlo analysis used in the Alternatives Analysis results in an estimate that is inconsistent with a simple calculation of the lower bound for spanning risk due to the force of gravity, implies that either a mathematical error or unstated assumption exists in this risk analysis. It may be that some assumption that caps the maximum unsupported span length to around 90' was used in the Monte Carlo calculation, but, if this is so, it surely should have been stated in the report. Many other errors and omissions in the Alternatives Analysis calculation of spanning risk are discussed in the Timm report[4]. In any case, a complete explanation for why the spanning risk calculated in the Alternatives Analysis is so completely inconsistent with the simple calculation for the lower bound for that number discussed here is required before even limited credibility can be given to Dynamic Risk's calculation of this risk.

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References

[1] "Alternatives Analysis for Petroleum Pipelines", https://mipetroleumpipelines.com/document/alternatives-analysis-straits-pipeline, July 6, 2017

[2] "Engineering and Construction Considerations for the Mackinac Pipeline Company's Crossing of the Straits of Mackinac" and "Report on the Structural Analysis of the Subaqueous Crossing of the Mackinac Straits," submitted by Mackinac Pipeline Company/Lakehead Pipeline Company to the Michigan Department of Conservation, January, 1953

[3] "Assessment of Span Exposures on the 20-inch Petroleum Pipelines Crossing the Straits of Mackinac", Rosenfeld, M., Kiefner and Associates, Columbus, OH, October 2016

[4] "Technical Report: An Investigation into the Effect of Near Bottom Currents on the Structural Stability of Enbridge Line 5 in the Straits of Mackinac", Timm, E. E., March 2017, http://blog.nwf.org/wp-content/blogs.dir/11/files/2017/03/2017-Edward-Timm-Currents-and-Stresses-Report.pdf

Technical Note
Rebuttal of Revised Alternatives Analysis Attachment 6 and Related Sections of the Dynamic Risk Revised Alternatives Assessment

Edward E. Timm, PhD, PE
5785 Deer Run Trail, Harbor Springs MI 49740
EdTimm@Gmail.com

Author's Preface

Enbridge's catastrophic Line 6b rupture near Kalamazoo, Michigan in 2010 made me aware that problems related to aging infrastructure affect more than just roads and bridges. Pipelines are a critical part of our national infrastructure and privately owned oil and gas pipelines are a key component of the energy infrastructure that provides access to fuel and feedstocks for downstream processing. As the investigation into the 6b rupture proceeded, much was revealed about the condition of the pipe and the causes for the rupture. This information indicates that Enbridge Energy Partners did not have sufficient knowledge and motivation to maintain and operate its Line 6b pipeline assets in a manner consistent with Michigan's unique location surrounded by water, including groundwater, drinking water, lakes, streams and the Great Lakes. This concern is supported by Enbridge's claim that its 64-year old Line 5 was in "like new condition" after the rupture of its 58-year old Line 6b into the Kalamazoo River and a tributary stream in 2010.

My years of experience in the petrochemical industry raised the level of my concerns because it is elementary that no structure made of carbon steel and exposed to the elements could possibly be in "like new condition" as stated by Enbridge. As a result, what initially started as an attempt on my part to examine a few basic questions about the true condition of Line 5 evolved into an engineering and scientific investigation, including an in-depth historical review of the circumstances, that uncovered information that demonstrated that Enbridge's claimed of "like new condition" was unsupportable. During this same time period, the Michigan Governor's Pipeline Task Force made recommendations that called for comprehensive and independent studies of the risks, magnitude of harm, and alternatives to the Line 5 twin pipelines in the Straits of Mackinac. These recommendations evolved into the Michigan Governor's Pipeline Safety Advisory Board which, in turn, resulted in the release of a great deal of documentation concerning Line 5 and its condition. This documentation has continued to grow and, the more it has grown, the more it has confirmed that Line 5, particularly the submerged portions in the Straits of Mackinac, is far from "like new condition" and instead presents serious and significant hazard to the waters, aquatic resources, economy and quality of life, and the ecology of the State and its citizens.

As my investigation, research, and analysis into the true condition of Line 5 progressed, I became aware of the multiplicity of laws, codes, standards and recommended practices that have been put in place over the past 50 years that attempt to assure pipeline safety. This regulatory framework, which is similar to the framework that regulates petrochemical facilities, appears robust but, in fact, serious incidents involving pipelines are commonplace while serious incidents involving petrochemical facilities are not. Figure 1 is taken from the PHMSA incident database[1] for oil and high volatility liquids. The incident count reflected in Figure 1 indicates that the current regulatory framework for oil and High Volatility Liquid (HVL) pipelines is more directed at the needs of pipeline operators than it is at assuring a level of safety or impairment of water and related aquatic resource resources, environment that is consistent with the public health, safety and welfare

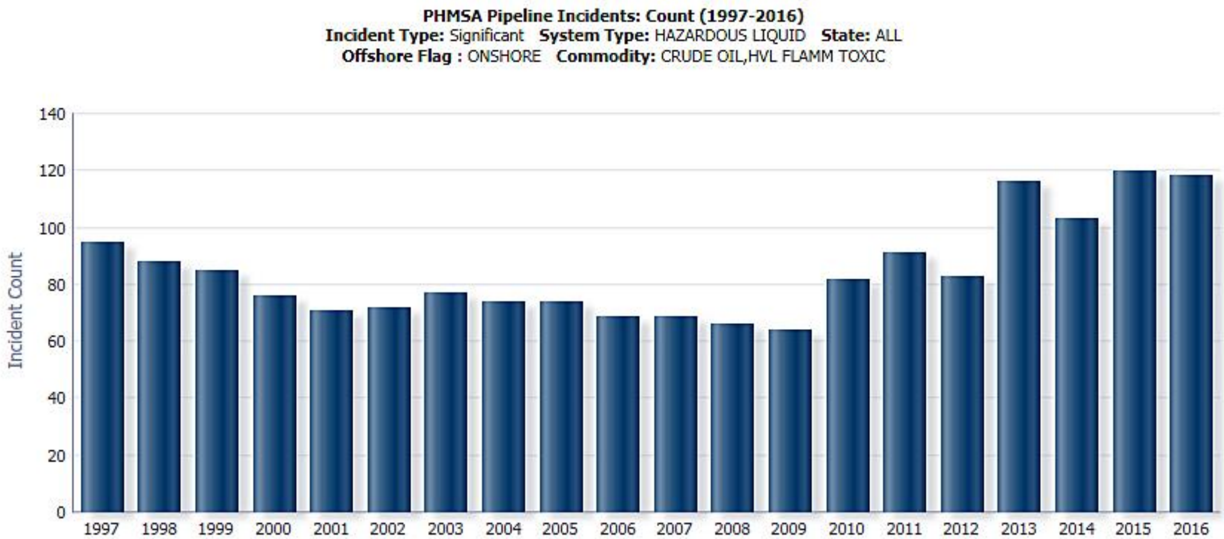


Figure 1. Incident Count for Oil and HVL Liquid Pipelines Over the Last 20 Years

Recent events have reinforced my serious concern that the pipeline industry operates in a flawed regulatory framework which adds to the risks or hazards of Line 5, including the Straits segment. For example, on November 16, 2017 a segment of the Keystone Pipeline operated by TransCanada ruptured for the third time since its construction in 2015 spilling an estimated 5000 barrels of oil. This pipeline was intended by TransCanada to be a showpiece for modern pipeline construction. PHMSA agreed to 57 special conditions regarding the materials, construction and operation of this pipeline including allowing operation at 80% of System Maximum Yield Strength (SMYS) instead of the ASME B 31.4 mandated maximum of 72%. However, this showpiece demonstration has not lived up to its design and intent. There have been three major leaks from this segment since it was put into operation, which is contrary to the pre-construction prediction, reported below[2].

"Before constructing the pipeline, TransCanada provided a spill risk assessment to regulators that estimated the chance of a leak of more than 50 barrels to be "not more than once every seven to 11 years over the entire length of the pipeline in the United States," according to its South Dakota operating permit.

For South Dakota alone, where the line has leaked twice, the estimate was for a "spill no more than once every 41 years."

The fact that this pipeline, which was designed, constructed and inspected to the highest standards, has not come close to meeting safety predictions confirms my suspicion that the current legal framework for regulating pipeline safety has serious flaws. It is possible that the pipeline industry along with their associated contractors and regulators have come to believe that by minimally meeting the letter of the relevant regulations, codes, standards and recommended practices that have been developed during the last 50 years they will automatically have a safety record acceptable to the public. The litany of recent failures in pipelines that have been operated under Integrity Management Systems (IMS) that thoroughly utilize state-of-the-art In Line Inspection (ILI) technologies suggests that the industry has fallen into an operational paradigm that encourages the profitable operation of unsafe pipes.

As I continued investigation and research into pipeline safety in general and Line 5 design, modifications and operational safety in particular, my efforts necessarily turned into an even more serious engineering project which included an understanding of the regulatory framework governing oil and HVL pipelines. This was accompanied by efforts to understand how Line 5 under the Straits was constructed and how it has been impacted by the passage of years since 1953 when it was laid. These efforts required sifting through enormous amounts of historical documentation as well as using classic engineering principles to analyze and calculate conditions affecting the pipe. To make this work accessible, I authored a number of reports as noted below and which are part of the record of the State regarding its review of risks and alternatives of Line 5 and the Straits segment. In doing this work, I was acutely aware that the engineering procedures and methods I employed, the procedures and methods that were used in the '50's and '60's to actually design Line 5 and others, had largely been replaced by commercially available numerical applications by pipeline operators and the engineering contractors that serve them. It was never my intention that my work should be thought of as equivalent to the precision of modern numerical methods but it is my belief that the methods and procedures I have employed are sufficiently scientifically precise and based on accepted methodology to support my work and the validity of my calculations and opinions. Moreover, the methods I have relied on raise serious concerns and questions regarding the conclusions of the Dynamic Risk report, which unlike my own investigation and analysis, are drawn by industry insiders using numerical packages whose workings are not infrequently poorly understood even by the firms that program them.

Accordingly, it is not surprising that Dynamic Risk ("DR") in its Final Alternatives Report on Line 5 report attacked my lack of inside-the -industry qualifications in an effort to undermine my work and conclusions. I fully expected my work and conclusions to be the subject of rigorous intellectual examination and debate as would be expected in academia or in the context of the conducting of the risk and alternative studies called for by the above-mentioned Task Force Report as facilitated by the Pipeline Safety Advisory Board. It is disturbing, not to me personally, but to the quality of the DR's own work and conclusions that DR would take on an adversarial role and attack me rather than assuring an unbiased independence. In effect, DR has become an advocate for the pipeline industry rather than seriously evaluating the risks and hazards and the full range of alternatives to avoid these risks and hazards as contemplated by its consulting contract with the State of Michigan.

I expected that the firm contracted by the State of Michigan, Dynamic Risk, to prepare the Alternatives Analysis for the Straits sections of Line 5, to be intellectually even handed and would examine the pros and cons of the subjects I presented without bias. Following is Attachment 6 of the Revised Alternatives Analysis which is devoted to exploring the validity of my work. I think it is rather obvious by the tone of the Introduction to Attachment 6, that Dynamic Risk has not chosen to use its extensive resources in an intellectually balanced and unbiased way as requested by the State of Michigan. Rather, Dynamic Risk has chosen to attack the messenger personally as well as refusing to consider ideas and calculations that challenge their own paradigm and approach to the study and response to the reports and comments filed by many organizations and persons in accordance with the procedures established by the State of Michigan in this matter.

In order to facilitate an orderly understanding for the reader of this Technical Note, I have provided below the full text of the Dynamic Risk Revised Alternatives Analysis. My technical response and comments are embedded in the DR text and are shown in black type and constitute my annotated comments regarding the DR Report and DR's critique of my work. My intent is to address the substance of the scientific and engineering questions that require review and understanding to enhance and assure a good basis for the decisions that may result from the full process of these reports, comments, and discussion that is required.

Attachment 06, Review of Timm Documents

October 11, 2017
Prepared for
State of Michigan
Prepared by
Dynamic Risk Assessment Systems, Inc.
Project number SOM-2017-01
Document number SOM-2017-01-RPT-001
Revision 0

Dynamic Risk
1110, 333 – 11 Avenue SW
Calgary, Alberta, Canada T2R 1L9
Phone: (403) 547-8638
www.dynamicrisk.net
Dynamic Risk
Waterway Plaza Two, Suite 250
10001 Woodloch Forest Drive
The Woodlands, TX 77380
Phone: (832) 482-0606

Introduction

As part of the public review process for the Line 5 Straits of Mackinac Alternatives Assessment, a number of documents were submitted by Dr. Edward E. Timm, who, according to the website of For Love of Water (FLOW), is a FLOW adviser and former Dow Chemical engineer. Within Dr. Timm's CV provided on the FLOW website, no mention is made of any background in fields that are related to pipeline design, operation, risk & reliability or stress analysis. That said, Dr. Timm has submitted a number of technical reports ('the Timm Reports') that relate to those fields as they pertain to the July 27 2017 Draft Report 'Alternatives Analysis for the Straits Pipeline' ("the July 27 Draft Report").
The number and nature of claims made within the Timm Reports warranted an in-depth review of those documents. This was particularly so, since, as was evidenced by some of the comments submitted by others during the course of the public review process, the Timm Reports were being perceived as the product of a particular subject matter expertise in fields related to pipeline reliability assessment.
As will be demonstrated later, the Timm Reports are characterized by an apparent lack of working knowledge of applicable codes and standards and pipeline stress analysis, the mischaracterization of data, and an apparent lack of familiarity on topics related to pipeline design, construction, operations, and inspection.

To date, the following documents have been submitted by Dr. Timm as part of the public review process (presented in chronological order):

- 8/20/2016 "Technical Note Regarding Enbridge Line 5 Non-Compliance with 1953 Easement Requirements A Mechanistic Analysis of Straits Pipeline Washout Phenomena" ("the Easement Non-Compliance document")
- 3/5/2017, "Technical Report An Investigation into the Effect of Near Bottom Currents on the Structural Stability of Enbridge Line 5 in the Straits of Mackinac" ("the Currents document")

6/27/2017, "June 18, 2017 Supplemental Addendum to Technical Note Regarding Enbridge Line

- 5 Non-Compliance with 1953 Easement Requirements A Mechanistic Analysis of Straits Pipeline Washout Phenomena" ("the Washout Phenomena document")
- 7/20/2017 "Technical Note An Analysis of Errors and Omissions in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5" ("the Errors and Omissions document")
- 8/2/2017 "Technical Note A Lower Bound Examination of the Monte Carlo Analysis for Spanning Risk in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5" ("the Examination of the Monte Carlo Analysis document")

A number of themes and associated claims have emerged from the above-referenced documents, relating to the following topic areas:

- Spanning Stresses
- Water Currents
- Fatigue Life
- Failure Probability
- Presence of Corrosion

Reviews of the commentary provided in the above-referenced documents as they pertain to each of the above topic areas are provided in the sections below.

Rather than engage is a discussion concerning credentials, my work has focused on technical discussion. Dynamic Risk's portrayal of a credentialed PhD, Professional Engineer with a long and successful career as incapable of understanding the mundane subject matter of pipeline technology is simply an attempt to avoid discussion of problems with their work. My well received recent publication of a paper on pipeline external pitting corrosion at the 2016 Houston National Association of Corrosion Engineers (NACE) Corrosion Risk Management Conference was intended to demonstrate my ability to contribute to the development of pipeline technology. This paper utilized advanced Monte Carlo simulation techniques similar to those utilized in the Dynamic Risk Alternatives Analysis, Option 5. Based on a literature search, it does not appear that any of the credited authors of the Alternatives Analysis have published material indicating expertise in Monte Carlo techniques. Moreover, from the DR comments, one would think my years of engineering and hydrodynamics expertise involving the pipeline systems of Dow's world scale petrochemical complexes is not applicable The miles of pipelines and related facilities in a petrochemical complex are equally significant to crude oil pipelines.

Throughout the history of technology, many critically important contributions have been made by educated professionals working out of their fields of formal training, but based on fundamental principles of their education, training and methodologies, and experience. (A CV was attached to my previous report, dated 8/9/2016, and is attached here as a convenience)

<u>Spanning Stresses</u>

Stress Analysis Methodology and Accuracy

One feature that all of the above-referenced documents have in common is the lack of detailed description showing the basis for any of the calculations performed. By convention, the authors of technical papers are expected to provide detailed descriptions of their analysis methodology (including equations, assumptions used, etc.) to facilitate the peer review process of their work. This convention was not adopted in any of the documents submitted, and in fact not one mathematical expression that was used as the basis for the calculations performed appears in any of the documents. It was therefore very challenging to perform quality control checks on the calculations (including the stress calculations) that serve as the underlying basis for the conclusions advanced, or to identify the sources of the numerous errors found.

My work contains extensive references to the sources of information used for my calculations. Since I have used classical methods from well recognized references like the Piping Handbook[3] and not proprietary numerical packages to perform my calculations. I would expect that Dynamic Risk could easily duplicate them since that ability would be expected from an undergraduate engineer.

If Dynamic Risk thinks it is "very challenging" to perform quality control checks on my work, the same criticism applies equally to their work underlying the Alternatives Analysis. This document contains many unstated or buried assumptions and unsubstantiated, the problems with which are described in a footnote.

Nevertheless, the text relating to Figure 31 of the Currents document provided sufficient information to facilitate an attempt to reproduce the results contained in that Figure. Stress values reported in Figure 31 were checked against values generated by the stress analysis software tool that served as the basis of the span analysis contained in the Alternatives Analysis1. Section 2.4.1.1.2.1.3 of the Alternatives Analysis report provides a detailed description of the approach, references, equations used, etc. in this software tool. This software tool was validated against the stress calculation approaches detailed in the references cited in Section 2.4.1.1.2.1.3 of the Alternatives Analysis report. In addition, the independent results reported by Rosenfeld2 were readily reproduced using this software tool, thereby providing further validation of that tool.

Using information found in the text relating to Figure 31 of the Currents document, it was not possible to reproduce the results shown in that Figure. The stress results reported in Figure 31 were found to be high on a consistent basis, relative to check values, with the stress values found in Figure 31 exceeding check values by as much as a factor of 1.73. In the absence of a detailed description of approach used, it is impossible to know the underlying basis for the considerable departures from the check values.

Since Dynamic Risk has not identified* what check value they are talking about, it is impossible for me to analyze this statement. Dynamic Risk has chosen not to include a version of Figure 31 that utilizes their own calculations. Until they are available the source of our disagreement cannot be determined. The stress values for zero current velocity shown in my Figure 31 indicate that the maximum combined stress reaches the yield strength of the pipeline steel (35,000 psi) at an unsupported span length of slightly over 160'. This value is totally consistent with values reported by Salvadori[4] and Kiefner[5]. Using the Von Mises method as expressed in ASME B31.4, my calculation gives a value of 174.3 feet. Applying the code mandated combined stress factor of 0.9 as required for offshore pipelines by B31.4, results in a calculated value for maximum allowable span of 165.2 feet. The following discussions will shed light on why the values

I report for stress are consistently higher than those reported by Dynamic Risk. Generally, my work reflects much more conservative assumptions about the condition of and the stresses affecting the pipe than Dynamic Risk chooses to use. Another reason for divergence between my numbers and those of Dynamic Risk involves assumptions about the mass of biota growing on the pipe, with my work using a significant biota mass loading and Dynamic Risk's work using mass loading values for an unfouled pipe. Dynamic Risk assumes no significant biota mass exists, when the fact of its presence has been identified and its mass estimated[6].

Furthermore, because the Straits pipelines are subject to longitudinal bending, axial, and hoop stresses, they operate in a multi-axial stress state. This fact has been ignored in the stress analysis found in the Currents document. As a result, within that document, material yield behavior is characterized as that which would occur only under uni-axial loading (a condition that is inconsistent with the conditions found in the Straits Crossing pipeline segments). While this simplification makes the analysis more accessible to practitioners not familiar with piping stress analysis, this aspect of the stress analysis represents a procedural error that violates basic stress analysis methodology, as well as the requirements for combining stresses as prescribed in ASME B31.4.

The apparent presence of very significant errors in the stress analysis methodologies found in the documents submitted by Dr. Timm are of some consequence to his conclusions regarding the potential for yielding to occur in spans, since these conclusions are predicated on the accuracy of the stress calculations that he performed.

The fact that pipelines operate in a multi-axial stress state is basic structural engineering. It appears that Dynamic Risk may not have or has not carefully read my "Currents and Stresses" paper carefully before making this comment. There are at least four recognized mathematical methods to collapse a multi-axial stress state into a maximum combined stress scalar for use in comparison to material yield properties. Ranked from least to the most complex, these methods are:

1. Vector Resolution
2. Tresca Resolution
3. Von Mises Resolution
4. Direct Numerical Computation using a Finite Element Model

Each of these methods has strengths and weaknesses but they all contain assumptions that make their results approximate. My work clearly states that I have chosen to use the *Vector Resolution* method of resolving axial, bending and hoop stress into a single number, the maximum combined stress, and I have chosen this method because of both simplicity and the fact that both the axial stress and the torque on this pipe are not known. While the ASME B31.4 codes mandate the Tresca or Von Mises methods they do not specify how to treat the condition where axial and torque stresses are uncertain. In my experience, simplicity is a virtue in the face of unknowns and, since all these methods are approximate, choosing the simplest is reasonable and often precludes the risks of a narrower approach. I estimate that this choice of stress resolution method will result in numbers that are 10-20% more conservative than Dynamic Risk's numbers, although this conclusion is qualified by the lack of documentation of how Dynamic Risk has chosen to resolve stress in the Alternatives Analysis. I submit that, if the fate of the Straits segments of Line 5 hinges on a 10-20% difference in approximate numbers, it is scientifically more prudent to use the more conservative number. There are no errors in the stress calculations in my work: There is only a difference of opinion between myself and Dynamic Risk about the use of conservative methods of calculation.

The statement by Dynamic Risk immediately following this paragraph saying the conclusions in my Examination of Monte Carlo Analysis document were affected by incorrect stress analysis is incorrect. The paper referred to by Dynamic Risk does not contain any stress analysis by me and its conclusions are based on the stress analyses performed by others including Dynamic Risk. The paper calculates the number of spans that exceed 150', a value used as a conservative estimate for the unsupported span length at which the elastic limit is exceeded, using the Weibull distributions for span length as reported in the Alternatives Assessment. Since the Dynamic Risk Monte Carlo analysis for spanning risk defines exceeding the elastic limit as its failure criteria, any span that exceeds 150' is defined as a failure. This is a simple check on the lowest number of failures that can be expected since the influence of current can only make the number of failures larger.

Among the conclusions so affected are those contained in the Examination of the Monte Carlo Analysis document, in which the following assertions are made:

"That the Monte Carlo analysis used in the Alternatives Analysis results in an estimate that is inconsistent with a simple calculation of the lower bound for spanning risk due to the force of gravity, implies that either a mathematical error or unstated assumption exists in this risk analysis.
and;

a complete explanation for why the spanning risk calculated in the Alternatives Analysis is so completely inconsistent with the simple calculation for the lower bound for that number discussed here is required before even limited credibility can be given to Dynamic Risk's calculation of this risk."

Quoting from my Lower Bound analysis paper:

"Table 1. Expected Failures Due to Spanning Risk from Gravity and Current Forces

Location	Shape Parameter	Scale Parameter	Probability of Span Greater Than 150'	Expected Failures in 10^8 Samples
East Leg	2.5777	61.5599	4.8594E-05	4859
West Leg	2.4813	61.1740	9.5326E-05	9533

The 4859 East Leg samples and the 9533 West Leg samples that meet the failure criterion of 150' or greater are a direct result of the span distribution Weibull functions used in the Alternatives Analysis. This result stands in stark contrast to the findings of the Alternatives Analysis where: "From this analysis, the failure probability was determined to be below the resolution of the analysis – i.e., <1.0x10-08." That the Monte Carlo analysis used in the Alternatives Analysis results in an estimate that is inconsistent with a simple calculation of the lower bound for spanning risk due to the force of gravity, implies that either a mathematical error or unstated assumption exists in this risk analysis. It may be that some assumption that caps the maximum unsupported span length to around 90' was used in the Monte Carlo calculation, but, if this is so, it surely should have been stated in the report. Many other errors and omissions in the DR Revised Alternatives Analysis calculation of spanning risk are discussed in the Timm "Errors and Omissions" report. In any case, a complete explanation for why the spanning risk calculated in the Alternatives Analysis is so completely inconsistent with the simple calculation for the lower bound for that number discussed here is required before even limited credibility can be given to Dynamic Risk's calculation of this risk."

Table 1a. Expected Failures Due to Spanning Risk from Gravity and Current Forces Recomputed for a Failure Criterion of 174' or Greater

Location	Shape Parameter	Scale Parameter	Probability of Span Greater Than 150'	Expected Failures in 10^8 Samples
East Leg	2.5777	61.5599	4.75E-07	47
West Leg	2.4813	61.1740	1.55E-06	155

Table 1a reflects the same computation of the expected number of failures except with the span length at which the elastic limit is exceeded set to the extreme value of 174 feet. Even using this extreme value for the onset of plasticity, a significant number of failures are found. Clearly, something is wrong in the implementation of Dynamic Risk's Monte Carlo analysis for spanning risk. There is also what appears to be a fatal mathematical error in the way Dynamic Risk has implemented this Monte Carlo analysis for spanning risk that will be discussed in the "Spanning Risk" section this document.

In pipeline stress analysis, a variable known as the 'drag coefficient' plays a significant role in determining drag forces on a pipeline associated with the flow of water around a pipe. This drag coefficient is a function of several variables, including pipe surface roughness, pipe diameter, current velocity, proximity of the pipe to the lakebed, and cross-flow vortex-induced vibration amplitude. On p. 24 of the Currents document, it was described that the drag coefficient that was used for the purposes of performing stress calculations was derived from a journal article published in 1981 (Achenbach and Heinecke). Specifically, the drag coefficient was obtained from a Figure from that journal article that depicts drag coefficient as a function of Reynolds number for cylinders having specific surface roughness values. It is important to note that this Figure does not address lakebed proximity or vortex induced vibration amplitude, which normally are significant factors in determining drag coefficients for spanned pipelines lying in proximity to lakebed.

Nevertheless, having selected a surface roughness value of 30x10-03 (corresponding to very rough pipe), and having established that the appropriate Reynolds number is in the range of 105 – 106, a drag coefficient was selected using the Figure published by Achenbach and Heinecke:

The Reynolds numbers calculated for velocities in the range of interest range from 105 to 106, a range where the Cd's determined from Figure 17 are reliable.

The Figure published by Achenbach and Heinecke clearly shows that the drag coefficient relationship for surface roughness values of 30x10-03 is valid only at Reynolds numbers below 105, and not for Reynolds numbers in the range of 105 - 106, as had been established to be the applicable range. It is not possible to know the magnitude of effect that this improper application of the drag coefficient variable has on drag forces and stresses that are calculated and used as the basis of the conclusions found in the documents submitted.

As noted above, Dynamic Risk has drawn an incorrect conclusion from the above language. The drag coefficients actually used in the stress analysis that is at the heart of my “Currents and Stresses” paper are the result of long experience in the field of “bluff body flow” and not directly taken from the Achenbach plot. The subject of bluff body flow has been studied by hydrodynamicists for over 100 years. Following is a review that addresses the difficulty of determining drag coefficient in the range $10^5<Re<10^6$ taken from the work of Allen and Henning[7] who are employed by Shell Global Solutions and are recognized experts on the subject.

> Numerous studies have been made of flow past a stationary circular cylinder, most of these with air as the flowing fluid[1-6]. These studies have covered Reynolds numbers well exceeding $1x10^7$. Figure 2 illustrates the general relationship that these studies have found between drag coefficient (defined as $C_d = F_d/(0.5*p*V^2*D*L)$ and Reynolds number for flow past a stationary cylinder. This figure shows that, at a Reynolds number of about $1x10^5$ (the ″critical″ Reynolds number range), the drag coefficient diminishes dramatically, a phenomenon known as the ″drag crisis″. This corresponds to a change in the boundary layers from laminar to turbulent. Since turbulent boundary layers produce flow reattachment (after separation) much more easily than laminar boundary layers, the pressure on the downstream side of the cylinder is reduced. For rough cylinders, the drag crisis is much less pronounced. With sufficient roughness the drag crisis can be eliminated.

As Allen and Henning make clear, the drag coefficient in the critical range is extremely sensitive to the surface roughness of the bluff body under study. Drag coefficient for flow around a cylinder in the critical range can vary from a value of ~0.2 to a value of ~1.3 depending on the surface roughness of the cylinder at a given Reynolds Number. Nowhere to be found in all of the DR Revised Alternatives Analysis is any discussion of this subject or the actual values of drag coefficient computed in the Dynamic Risk stress analysis. The failure to appreciate the importance of surface roughness is but one of three hydrodynamic considerations that are sources of error in Dynamic Risk’s stress analysis. DR’s failure to consider the implications of mesoscale turbulence in the Straits flow field and its indifference to the importance of averaging time when determining peak current velocities are also problematic.

The drag coefficient values used in the stress analysis in my “Currents and Stresses” paper are the result of long experience as a hydrodynamicist and proprietary unpublished work that lead to US Patent 4,444,961. The following three figures (Figures 2,3,4) show the drag coefficients actually used in my stress computations compared to the work of Achenbach, Allen and Henning, and Andres[8]. As can be seen from examination of Figures 2,3 and 4, the values for drag coefficients used in my work

are good representations of the data for very rough pipes in the critical Re range of 10^5<Re,10^6.
Since the data shown in Figure 4 is field data taken from an instrumented 8' diameter pipe in the ocean, as opposed to the other two studies which were done in subscale flow tunnels, this data should be given the highest weight when trying to determine appropriate drag coefficients for Line 5 under the Straits.

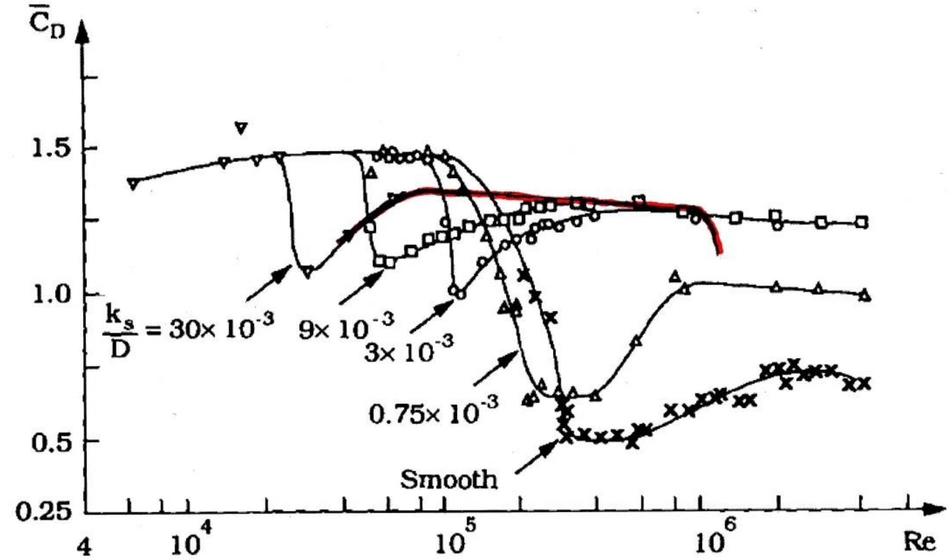


Figure 2. Drag Coefficient Data of Achenbach with Timm Values Overlaid (red line)

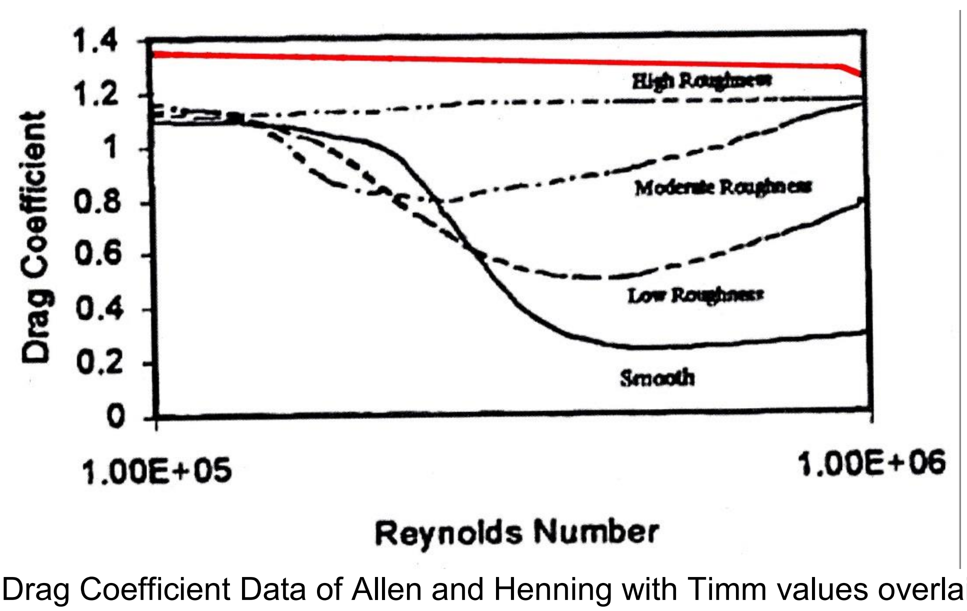


Figure 3. Drag Coefficient Data of Allen and Henning with Timm values overlaid (red line)

Dynamic Risk has made a point* about being unable to compare "check values" between their calculations and mine. One likely source of difference may be the way the drag on the pipe from currents is calculated. Comparing the experimentally based drag coefficient values used in my work with the calculated drag coefficients used by Dynamic Risk would be a valuable exercise to help understand the source of differences between calculations. Unfortunately, Dynamic Risk has not published either their drag coefficients or the surface roughness numbers they used to support their calculations or their work. This is an obvious missed opportunity by Dynamic Risk to improve understanding and their failure to do so is concerning, as this information would be expected by hydrodynamicists in any discussion of drag in bluff body flow. The failure of DR to fully disclose and explain the basis of this part of their work renders it unverifiable and should not be used to support their conclusions in this regard.

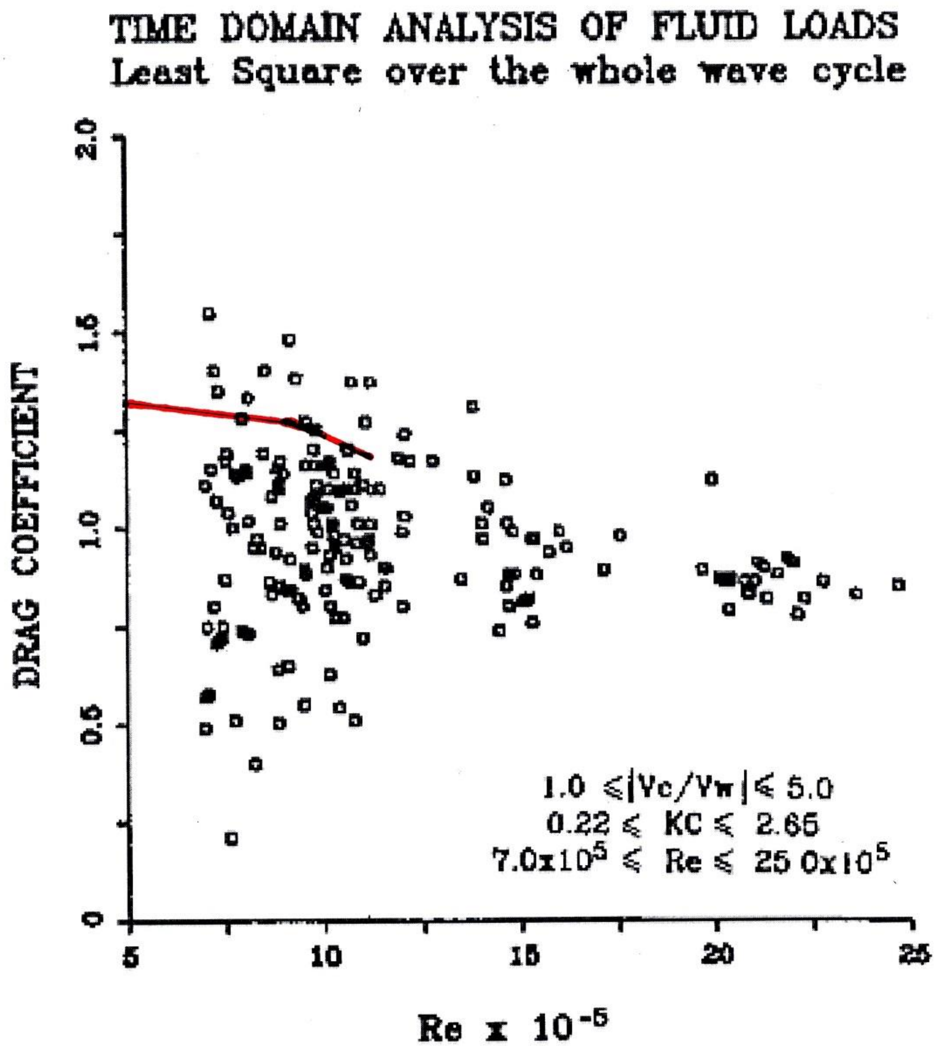


Figure 4. Drag Coefficient Data of Andres with Timm values overlaid (red line)

As with all fields of engineering, piping stress analysis is a field that requires some background and training, an understanding of best-practices, and a working knowledge of applicable codes and standards. With respect to the last point, on p. 36 of the Currents document, as part of a discussion pertaining to longitudinal stress due to axial and bending loads, an assertion is made that ASME B31.4 requires a maximum stress of 72% SMYS. This assertion regarding the requirements of ASME B31.4 is incorrect. In fact, the 72% SMYS stress limit prescribed within ASME B31.4 applies specifically to stresses arising from internal and external pressures. Other criteria exist for installation stresses, additive longitudinal stresses, combined longitudinal stresses from sustained and occasional loads, and equivalent combined stresses.

My undergraduate curriculum and studies in the Engineering Mechanics department at the University of Michigan included the basic mathematics of classic stress analysis While my primary expertise may not involve the details of engineering codes that set a minimum standard for pipeline construction and operation, this does not affect the application of my mathematical and engineering expertise and experience to assess the validity of DR's assumptions and interpretation of B31.4. In fact, DR's applicability of B31.4 to a pipeline that is not like new and has been used and in some instances was neglected for nearly 50 years and allowed to develop unsupported spans approaching 300 feet which resulted in plastic collapse of the structure in several places is not explained or clear. A review of ASME B31.4 however illustrates the hyperbole and misleading nature of the above statement by Dynamic Risk. Because its history includes plastic collapse events there are necessarily questions about both residual stress in the pipe wall and the overall axial stress state of the pipeline. The "other criteria" in B 31.4 that Dynamic Risk refers to are primarily found in the Section A402.3.5 "Strength Criteria During Operations" and this section says nothing about how to treat residual stress in a pipeline that has suffered plastic collapse resulting in unknown axial stress in the pipe.

As with all fields of engineering, hydrodynamics and Monte Carlo analysis are fields requiring extensive education and considerable experience to produce reliable results. It should be noted that neither of the principal authors of Attachment 6 have a public record of publication in these fields, except for author Mihell co-authoring one paper[9], and this paper does not cover the subject matter from either of these fields. Based on their apparent lack of knowledge concerning turbulent flow phenomena and their measurement as well as the mathematical error made in setting up the Monte Carlo analyses in the Revised Alternatives Analysis, the conclusions in the DR Alternatives Report that require expertise and knowledge in these fields are not reliable.

On p. 33 of the Currents document, a description is offered as to how a stress analysis was conducted by taking measurements from an off-perspective photo taken during installation in 1953:
By carefully scaling the photo, it is clear that the pipe was yielded during launch by bending to a radius of curvature of ~300 feet.

There is no reasonable means by which the scaling exercise described in the Currents document can be characterized as credible or accurate. Regardless, as those familiar with pipeline design and construction practices will know, the installation methods depicted in the Figure are not uncommon in modern pipe-laying practices (particularly in J-Lay and S-Lay offshore techniques), and installation stresses and strains are accommodated in the ASME B31.4.

To prevent plastic deformation of the pipe during pipelaying operations the Easement from the State of Michigan governing Line 5 in the Straits of Mackinac states "(4) The minimum curvature of any section of pipe shall be no less than two thousand and fifty

(2,050) foot radius." In his review of Bechtel's design calculations, Salvadori in 1953 commented: "The pipe should under no circumstances be bent to a radius of less than 1750 feet." During an interview with Bruce Trugen, a mechanical engineer that was employed as a surveyor during the construction of Line 5, I was told that the above restrictions were violated during the pipelaying process. As evidence of this I used geometric scaling from an old photo of the pipelaying operation using techniques used by draftsmen for hundreds of years to make an approximate estimate of the radius of curvature illustrated in the photo. This technique includes a correction for the perspective of the photo by estimating that the photo was taken from a position about 45 degrees from the axis of the pipe. My estimate of a radius of curvature of approximately 300' from the construction shown in Figure 5 is nearly half an order of magnitude less the above limits and, while approximate, is certainly reliable enough to conclude the above stipulations were violated.

Calculation of Radius of Curvature During Line 5 Straits Pipelaying Operation

Image, Bruce Trugen 000010370007.tif Taken summer, 1953

Figure 5. Estimation of Radius of Curvature During the Pipe Laying Operation in 1953

Dynamic Risk's criticism of this conclusion is typical of their criticism of much of my work. The statement "There is no reasonable means by which the scaling exercise described in the Currents document can be characterized as credible or accurate" is without support*. Further, Dynamic Risk does not attempt to make any effort to discover if my significantly relevant hypothesis, that the pipe was plastically deformed during the pipe laying operation is correct. DR merely dismiss the subject without consideration and invokes ASTM B31.4 to support their argument that if it happened it is not important even though it is in violation of the 1953 Easement and against the advice of a structural engineer[10], whose reputation eclipses that of anyone who worked on the DR Revised Alternatives Analysis. If anything, this shows that Dynamic Risk is not acting in good faith in providing the required independent and unbiased analysis called for by the protocol of its client, the State of Michigan.

Statements Regarding Lack of Conservativism

To better understand my discussion of the sections of Attachment 6 that follow below, certain engineering considerations should be kept in mind

First, Line 5 will not fail on a nice day. A fundamental difference between the Dynamic Risk assessment of Option 5 and the one I have conducted is that I have focused on trying to elucidate the probability of an extreme current event under the Straits and the effect this event would have on a structure that has been damaged by decades of neglect. If I had concluded that the existing water current velocity data base adequately described the entire spectrum of current velocity, my approach would have been to try and estimate what a 100 or 1000 year current storm under the Straits entailed and use this information to compute a meaningful risk of failure over the long term. Unfortunately, the existing data base is inadequate for this purpose due to several factors including:

1. Existing buoy data only covers a period of a few years,
2. Existing buoy data was taken in inappropriate locations,
3. Existing buoy data does not include data from the winter storm season,
4. Existing buoy data is not well documented, especially including critical experimental details like sample averaging time.
5. All existing buoy data is averaged over time periods ranging from ten minutes to three hours which obscures short term peak current events.

Second, both the Line 5 pipeline design as built and the pipeline under the Straits have already failed; it has been undermined by strong currents creating unsupported spans approaching 300’ in several locations as documented in the Kiefner Report from 2003. These long spans resulted in a slow plastic collapse of the structure until collapse was halted by contact with Straits bottomland. During the period of slow plastic collapse the pipe was repeatedly bent back and forth by strong currents raising the possibility of metal fatigue and increasing the probability of stress corrosion cracking due to large residual stresses from flexing and collapse. Because Dynamic Risk was not informed of the Kiefner or Biota reports before it released its original DR Alternatives Analysis, the report did not consider this information. Rather than attempt to include this information in their revised Revised Alternative Analysis, which would have required significant changes in methodology, Dynamic Risk made an assumption goes to the heart of the condition of the pipeline in the Straits and its design. In the Revised Alternatives Analysis, Dynamic Risk has assumed that because In Line Inspections using several sensing methodologies have not found evidence of any obvious problems they can ignore the documented history of the pipe and treat it as if it was newly constructed in ca. 2003 and project the 2003 condition of the pipe support system backwards to 1953 as if there were no intervening history. Rather than take a deeper look at the history of the pipeline and its condition from 1953 to the present, Dynamic Risk chose to insert the following language into the Revised Alternatives Analysis:

Impact of Historical Spans

The degree to which historical spans may have impacted the integrity of the existing pipeline segments may be evaluated through an assessment of recent in-line inspections for deformation and weld zone cracking. In this regard, the recent 2016 Baker Hughes Geopig Inspection, and the 2016 Oceaneering tethered PA/TOFD weld zone inspection are most relevant to a determination of historical span-related damage. Inspection reports from these in-line inspections were reviewed with a particular focus on the sections of pipeline that lie on top of lake bed, where historical spans might have resulted in deformations. The reporting thresholds for the 2016 Baker Hughes Geopig Inspection were:

• Dents and wrinkles greater than or equal to 2% of nominal outside diameter of the pipeline;
• Multi-apex geometric anomalies greater than or equal to 1% of outside diameter;
• Top side geometric anomalies greater than 0.5% of outside diameter and in close proximity to a dent or geometric anomalies greater than or equal to 1% of outside diameter;
• Bottom side geometric anomalies greater than 0.5% of outside diameter and in close proximity to a dent greater than or equal to 2% of outside diameter;
• Ovalities greater than 5% of outside diameter;
• Areas of pipeline movement with bending strain difference exceeding 0.1% and spanning more than 1 pipe joint

In addition to the above, bends greater than 1.5° were also reported. In the 2016 Baker Hughes Geopig inspection report for the East Straits Crossing segment, 20 bends were identified, ranging from less than 2 to 44°. None of these bends are located in the section of the pipeline that lies on top of lake bed. No other geometric anomalies that exceed the reporting thresholds were found within the section of pipeline that lies on top of lake bed. In the 2016 Baker Hughes Geopig inspection report for the West Straits Crossing segment 23 bends were identified, ranging from 3 to 52°. Five of these 23 bends, ranging from 3 to 9° were located on the section of pipeline that lies on top of lake bed. The bend radii associated with these five bends range from 24 x pipe diameter to 48 x pipe diameter, and so they have strains that are comparable with those associated with field bends for new pipelines, as allowed by ASME B31.4, which specifies minimum bend radii as low as 18 x outside diameter. Ovalities of 1.8 in. (4.6 cm) and 1.1 in.

Assessment Approach

Because there is no evidence of degradation of pipeline integrity, including fatigue damage attributed to historical spans, the approach adopted for spanning is based on the knowledge that the pipeline segments exist in a dynamic environment in which both span length and water currents can change over time. Under such circumstances, there is a potential for extreme values of both water current velocity and span length to co-exist. Failure is often associated with extreme (albeit rare) combinations of conditions or events.

An existing span length data set obtained from seven underwater inspections of the East and West segments, spanning the years 2005 – 2016, serves as a conservative basis for developing a span length distribution for future years. This is because this database includes span lengths that are in excess of 130 ft. (40 m), whereas the Consent Decree between the United States of America and Enbridge (dated

05/23/17) mandates that henceforth, Enbridge must at all times support and anchor the pipelines with a series of screw-anchor supports that are placed so that the maximum distance between adjacent screw anchors does not exceed 75 ft. (23 m). (1)
Also, as is illustrated in Figure 2-7, a review of the span data collected from 2005 – 2016 shows a general trend for individual span lengths to become shorter with time, and the development of random span length distributions derived from data from the 2005 –2016 inspections will not give credit for this trend. Instead, incorporated into the analysis is the underlying assumption that span lengths that are characteristic of the 2005 – 2016 time frame are indicative of the future.

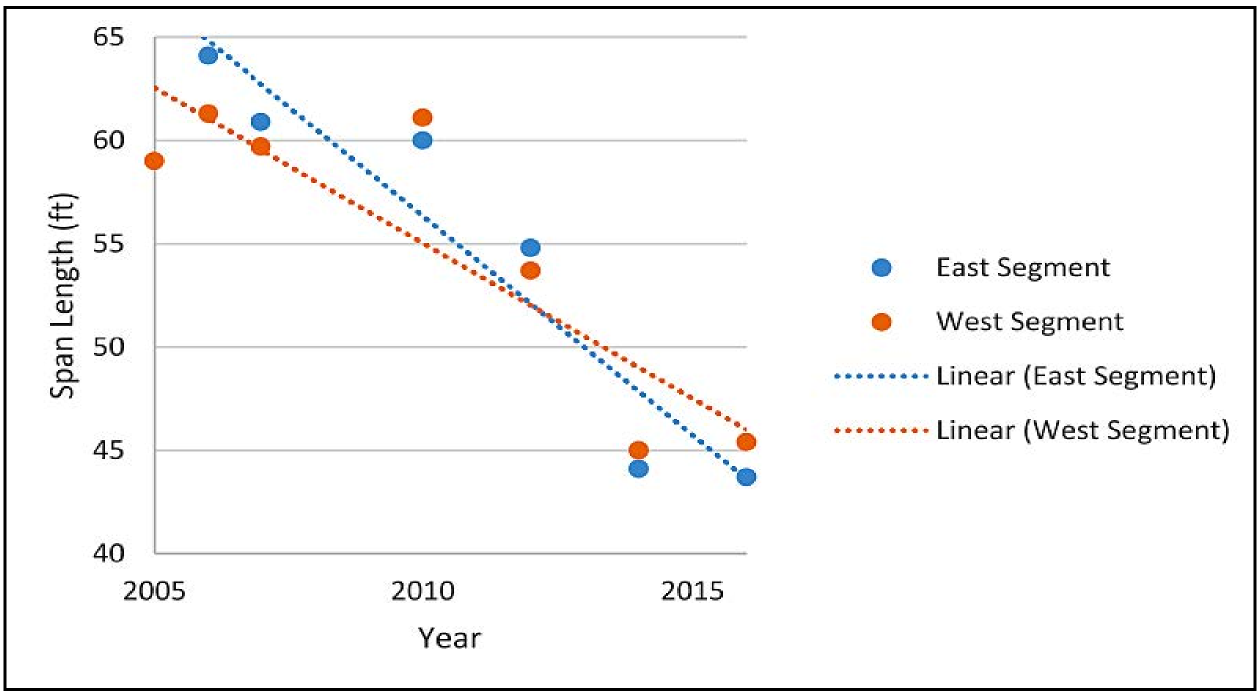
In short, Dynamic Risk assumes that because current ILI technology cannot find any evidence of damage from the failure of the original design for Line 5 under the Straits, there is none. While Dynamic Risk recognizes the fact that the pipeline may have been damaged, DR arbitrarily refused to address this fact or engineering certainty directly. They have completely ignored evidence of plastic collapse documented in both my work and the Kiefner report, even though DR admitted that the " historical spans might have resulted in deformations." Later in this text information will be presented that casts doubt on Dynamic Risk's gross assumption that ILI technology can assure fitness for a pipeline that has suffered known historical damage. I, for one, do not consider it prudent engineering practice to make this assumption without extensive review and consideration of all historical documentation that is relevant. Betting the future of the Straits waterway on unproven inspection technology is not conservative engineering practice as should be expected when so much is at risk.

With respect to the purported lack of conservativism in the stress analysis, the following statement is found on p. 13 of the Errors and Omissions document:

"These distributions are a very good fit to the span data revealed in Reference 21 but when used in a Monte Carlo analysis to estimate risk, the authors of the Alternatives Analysis appear to have made a serious mathematical error. The 715 East Leg span length measurements and the 691 West Leg span length measurements result from pooling data taken during inspections in 2005, 2006, 2007, 2010, 2012, 2014 and 2016. Each individual dataset contains a differing number of spans both because of new washouts and the addition of new supports. This means that while the distribution functions plotted above may be relatively time invariant over the period 2005-2016, the ensemble of spans existing during each time interval between inspections is different. Because a random selection of current velocity in the Monte Carlo impacts all the spans in an ensemble, each span in that ensemble must be tested for the failure criteria not just one randomly selected span. Because extreme current events are quite rare but each such event tests a large number of spans, multiple failures may occur for each random current velocity selection. This physical fact results in a much larger number of failures than the Monte Carlo implementation apparently done in the Alternatives Analysis and the estimates of risk derived from this analysis are erroneously underestimated by a large margin! This problem affects both the spanning risk Monte Carlo and the vortex induced vibration Monte Carlo analysis."

This is a critical point in my critique of the Monte Carlo methodology used by DR to estimate spanning and VIV risk. It appears that Dynamic Risk has insufficient knowledge of Monte Carlo fundamentals to understand what I have pointed out and believe, that DR Consultants have made a significant mathematical mistake in their approach to Monte Carlo analysis that; moreover, their approach has little to do with their critique that is quoted immediately below. In fact, the DR Revised Alternatives Analysis contains so little information about how Dynamic Risk has actually implemented their analysis*. It appears that Dynamic Risk has solved the wrong problem. Writing in non-technical terms, I believe Dynamic Risk has solved the problem of a pipe in a current *with only one span* and represented that solution as a solution to the problem of two a pipelines each of which has many spans currently affected by currents. It is not unlikely that a practitioner unskilled in the art of Monte Carlo analysis has used a packaged Monte Carlo analysis computer application to perform these calculations without acknowledging, accurately defining, or fully appreciating the the problem as posed.. No commercially available Monte Carlo package that I am aware of has the built in capability to correctly address this problem. To accomplish this, it is necessary to develop an application to the problem as it exists in fact and then perform the calculation as I have previously done. Accordingly, up to date information is required on the spans, currents and conditions of the pipes is required before any credence can be given to the Monte Carlo simulations presented in the Revised Alternatives Analysis.

Although nested within the above statement is the assertion that span length distributions are relatively invariant over the period 2005-2016, a review of the span data reveals that this is not so. Based on a review of the span data collected from 2005-2016, the Figure below illustrates a general trend for individual span lengths to get shorter with time (possibly, in part due to span management intervention activities).



This represents one of the conservative aspects of the span analysis contained in the Alternatives Analysis report, since no credit is given for the trend towards shorter span lengths on a go-forward basis. In respect of that analysis, the following factors collectively contribute to that conservativism:

Compared to numerous unsupported spans approaching up to 300' in length over a period of 50 years, it is reasonable to conclude that the span distributions and conditions that have existed invariantly well before Enbridge added the new anchor support or screw anchor design to shore up the original design as it was built. Given the cost of the extensive span remediation program started by Enbridge in 2001, I would certainly hope that the information given in the figure above shows progress. How could it not when Enbridge has drilled over 120 anchors into Straits bottomland to remediate the spans that are ignored in Dynamic Risk's analysis, and even some of those screw anchors have failed? The failure of Dynamic Risk to consider the whole 63 years of spanning history in their analysis renders their risk analysis suspect and far from prudent or conservative.

• Current velocity data were derived from modeled results corresponding with the location along both the East and West segments that is associated with the maximum current velocity for the entire pipe segment.
• Although this maximum current velocity is associated at only one point along the East and West pipe segments, it was taken to be representative of the entire un-trenched portions of each pipeline.

Numerous comments made to the Michigan PSAB have concerned the unrealistic current modeling results used by Dynamic Risk as a critical input to their stress analyses. Despite this information , there does not appear to be any change between the Alternatives Analysis and the Revised Alternatives Analysis concerning DR's input meteorological data used by the model to predict current velocities near the Straits bottom. Consider the following language:

4.1 Selection of Production Period

Following consultation with the project team, the 1 year time period of time extending from 1st of July 2014 to 30th of June 2015 was adopted for the model production runs. The following considerations were put forward when selecting this timeframe:

• Advantageous to start the model simulation in summer to allow a well-developed model solution (in terms of flow and water levels) prior to any ice effects influencing the model results
• Ice cover: the winter of 2014/2015 is a winter with fairly high ice coverage in Lakes Michigan and Huron; however, the period with significant ice cover is brief (not like in winter 2013/14, for example, with a prolonged period of ice cover)
• Wind conditions are fairly average compared to other years, without any particular high wind events or extreme situations.
• The selection of the simulation period has been based on the last 10 years, rather than further in the past

Later on, the simulation period was extended through to the 30th of September 2015 due to modeling considerations.

Dynamic Risk has used meteorological data as input to their Mike 3 current model where "Wind conditions are fairly average compared to other years, *without any particular high wind events or extreme situations*." By inputting meteorological data that comes from a particularly benign period of Michigan's weather history, Dynamic Risk has assured or designed their model so that it will not produce any of the extreme currents that are associated with truly extreme weather events. Instead of using their model to determine what the currents would be during an extreme storm, say a 100 or even a 1000 year storm, DR has chosen an average or nice weather set of data to conclude that the pipelines in the Straits are not at risk of rupture. Average nice weather cannot be relied on to calculate the credible range and actual maximum current velocities in the Straits.. These assumptions are unfounded and defy common sense to even those persons without expertise in the field of hydrodynamics and stress analysis.

• Although a trend of decreasing span length was noted for the time period from which the data was collected, this trend was not accounted for on a go-forward basis. The span distribution for the period 2005 – 2016 that is used for the purposes of the analysis includes span lengths that are in excess of 130 feet. As the span distributions that are fitted to the data are open-ended (i.e., they have no upper-bound limit), this enables Monte Carlo simulations to consider span lengths that are even longer than this largest span length encountered in the 2005 -2016 data set. Therefore, incorporated into the analysis is the underlying assumption that such span lengths will be experienced in the future, and no credit is given to the span management plans currently being implemented, which endeavor to limit span lengths to the 75-ft maximum limit. In particular, the Consent Decree between the United States of America and Enbridge (dated 05/23/17) mandates that henceforth, Enbridge must at all times support and anchor the pipelines with a series of screw-anchor supports that are placed so that the maximum distance between adjacent screw anchors does not exceed 75 feet.

As previously discussed, when the Weibull distributions used by Dynamic Risk are examined to determine how many spans are above the length necessary for plastic deformation to occur, a significant number of spans that exceed that figure are found. The lack of documentation* concerning the Monte Carlo method used in this work makes it impossible to determine why examination of the span length Weibull distributions shows a number of spans that are in the plastic range, while Dynamic Risk's Monte Carlo simulation that uses those span length distributions as input shows no spans have reached the stress level necessary for plastic deformation. Something is seriously wrong when a "check value" as found documented in my Lower Bound paper is inconsistent with Dynamic Risk's work. Since this comment was made to the PSAB before Dynamic Risk produced the Revised Alternatives Analysis, such a serious criticism should have been addressed, not ignored. This fits a pattern of practice where Dynamic Risk has chosen to ignore critical comments made to the PSAB rather than to address their substance. Moreover, the assumptions about the anchor support or screw-anchors used to support Line 5 in an attempt to minimize bending from long spans caused by the scouring of currents are not part of the 75-foot maximum span length in the 1953 Easement. If called for by consent decree, these are an attempted new design in connection with the initial design that from the documentation disclosed by Enbridge since June 2017, beginning with the Kiefner Report [5], has not worked well and is causing problems with exposing bare metal of pipe.

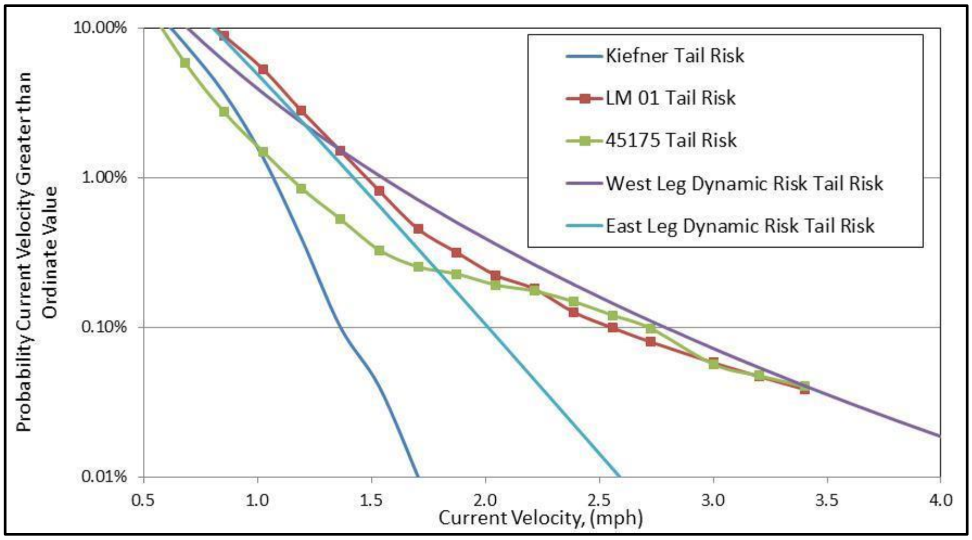
• In the vortex-induced vibration analysis, fatigue life values that fall within the time period of the analysis (prior to the year 2053) were dominated by extreme values of current velocity in conjunction with extreme values of span length. Although extreme values of current velocity are known to be transient (short-term) events, and although longer span lengths get remediated through the installation of screw anchors, it was assumed that these extreme values persisted for the time period of the evaluation. In other words, in simulations involving high currents and long span lengths, no span management intervention activities were assumed, and extreme current values were assumed to last indefinitely, resulting in fatigue loading conditions that reflect those extreme values of current velocity and span length that extend through time, uninterrupted until failure is predicted.

• The vortex-induced vibration analysis was modeled in such a way that fatigue damage was accumulated from the start of operation in 1953 and the fatigue analysis was run over a 100-year period from 1953 to 2053, with failure probability results being reported for the period 2018-2053. In reality, any failure occurring over the near term would be associated with near-critical fatigue cracks that would be detectable by non destructive inspection. Such non-destructive testing was recently undertaken on both the East and West segments using the Oceaneering tethered tool. This automated inspection system utilizes time of flight diffraction (TOFD) and phased array (PA) pulse-echo ultrasonic techniques that are configured to detect and size surface breaking defects such as fatigue cracks residing in girth welds and their associated heat affected zones, where the potential for fatigue cracking to initiate and propagate exists. In the analysis, no credit was given to the fact that these inspections showed no evidence of sub-critical fatigue damage or cracking of any kind.

As previously discussed, Dynamic Risk used a span length distribution in its Monte Carlo analysis for Vortex Induced Vibration (VIV) that represented the remediated span distributions for the period 2005-2015. Had they used the actual span distributions that were documented in the Kiefner report, their analysis would have failed because the excessively long spans approaching 300' that developed after 1978 collapsed to the bottom of the Straits. Dynamic Risk has justified the assumption that the pipe was not damaged during the nearly 50 year period of abuse by invoking the argument that because ILI scans show no obvious damage, there is none. ILI inspection for circumferential cracking is a developing technology as will be discussed in the Presence of Corrosion section that follows. In my professional opinion this is an error and puts the risks to the Straits which form the basis for the DR alternative study at greater risk based on unproven and uncertain inspection techniques.

<u>Water Currents</u>

In the Errors and Omissions document, a great deal of discussion was devoted to assertions that the current velocity distributions used in the Alternatives Analysis do not appropriately characterize actual values. Figure 4 of that report (reproduced below) was presented in order to support the contention that extreme values of the distributions used in the Alternatives Analysis do not adequately or accurately reflect extreme values recorded in ADCP buoy data.



With respect to the above Figure, the following statement is found on p. 7 of the Errors and Omissions document:

" Figure 4 is a cumulative probability plot of data taken from buoys 45175, LM 01 and the unreported measurements revealed in the Kiefner report with the current velocity fits resulting from the one year duration run of the MIKE 3 model. This figure shows that the tail risk for current velocity between data taken from Buoys 45175 and LM 01 is similar to the risk calculated from the MIKE 3 model for the West Leg of Line 5. The agreement between the buoy data and the MIKE 3 model for the East Leg as well as the Kiefner data is not nearly so impressive."

The basis for the above statement regarding the current velocity distribution derived from the MIKE 3 model (employed in the Alternatives Assessment) for the East Leg is that the modeled results do not reflect high current velocity data derived from ADCP buoys LM01 and 45175. This claim is demonstrated by the fact that at current velocity values above approximately 1.8 mph, the line on the above chart that represents the modeled current velocity distribution for the East segment (turquoise line) falls below the ADCP data (red and green lines).

Data for buoy 45175 is available on line at the Michigan Technological University's Great Lakes Research Centre website. For the lowest-bin (representing measurements obtained closest to lake bottom) the highest recorded East-West water velocity has a magnitude of 2.33 knots (2.68 mph), corresponding roughly with a modeled probability of occurrence on the East Leg of 0.01% in the above Figure (see turquoise line).

The Alternatives Analysis project team obtained ADCP current velocity data for buoy LM 01 from Dr. E.J. Anderson, of the National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory. These data indicate that for buoy LM 01, the lowest-bin (representing measurements obtained closest to lake bottom) maximum measured water velocity is 1.35 mph, having a maximum E-W velocity component of 1.33 mph.

These results call into question the validity of the data displayed in Figure 4 of the Errors and Omissions document which show velocity values attributed to buoys 45175 and LM01 that range in values of up to approximately 3.5 mph. Any calculations performed on the basis of those data, and the conclusions derived from those calculations are equally suspect.

Of note, the maximum near-lakebed velocities modeled by the MIKE 3 model at the locations of buoys

LM 01 and 45175 were 1.88 mph and 1.70 mph, respectively, reflecting a conservative result relative to measured data.
Also of note, as has been noted previously, for the purposes of performing the spanning analysis, current velocity values were derived from modeled results corresponding with the location along both the East and West segments associated with the maximum current velocity for the entire pipe segment. These locations are different from the buoy locations.

Once again, Dynamic Risk has not presented data to substantiate their argument*. They do not state when their supposed maximum current values were recorded by the buoys so it is not possible to determine the source of the disagreement or inconsistency between Dynamic Risk's assertion about maximum measured current velocity and the following Tables 2 and 3.

In addition, Dynamic Risk did not address the maximum current velocity values analysis that was presented in my Mechanism of Washout paper. Based on both calculations of the current velocities necessary to move bottomland soil particles and examination of the "swept clean" appearance of Straits bottomlands, it can be concluded that the maximum current velocities modelled by Dynamic Risk are not sufficient to cause the washout phenomena that have caused problems with Line 5 under the Straits**. If the extreme values of current velocity in the Straits were actually as low as predicted by Dynamic Risk, we would not be having this discussion because Line 5 would not have been undermined by extreme currents.**

Table 2. Top Ten Measured Current Velocity Data Sets from the Lowest Bin for Buoy 45175

Date & Time of Observation	Data Point Number	Current Velocity, (mph)
07/31/2016 19:50:00	21010	4.09
07/31/2016 21:30:00	21020	3.70
07/31/2016 19:40:00	21009	3.59
08/03/2016 23:40:00	21464	3.46
08/03/2016 00:50:00	21327	3.38
07/31/2016 20:40:00	21015	3.32
07/31/2016 23:00:00	21029	3.25
07/31/2016 22:40:00	21027	3.22
07/31/2016 18:50:00	21004	3.10
07/31/2016 20:00:00	21011	3.10

Table 3. Top Ten Measured Current Velocity Data Sets from the Lowest Bin for Buoy LM01

Data Point Number	Current Velocity (mph)
111996	3.71
111928	3.34
111962	3.27
95302	2.41
95268	2.32
95336	2.27
95370	2.25
95404	2.00
95438	1.95
112982	1.95

With respect to Dynamic Risk's modeled current velocity results Dynamic Risk maintains: "Of note, the maximum near-lakebed velocities modeled by the MIKE 3 model at the locations of buoys LM 01 and 45175 were 1.88 mph and 1.70 mph, respectively, reflecting a conservative result relative to measured data." The following comments taken from my currents and Stresses paper cast doubt on this statement:

"Figure 2 shows that while the MIKE 3 model predicts currents that generally correspond with the measured velocities, it fails to predict the critical peak current velocities necessary to predict maximum stresses on the pipe. Of the six current excursions depicted in Figure 2, one is correctly predicted, one is over-predicted by ~15%, three are under-predicted by ~20% and one is under-predicted by ~50%. The meteorological information shown on Figure 2 describes a period of generally moderate weather for October on the Great Lakes with high pressure and winds not exceeding 24 mph. Given that hydrodynamic forces on Line 5 generally scale with the square of current velocity, these predictions of peak current velocity are insufficiently robust to be the basis for examining the rupture risk of the single most critical oil pipeline in the Great Lakes Basin."

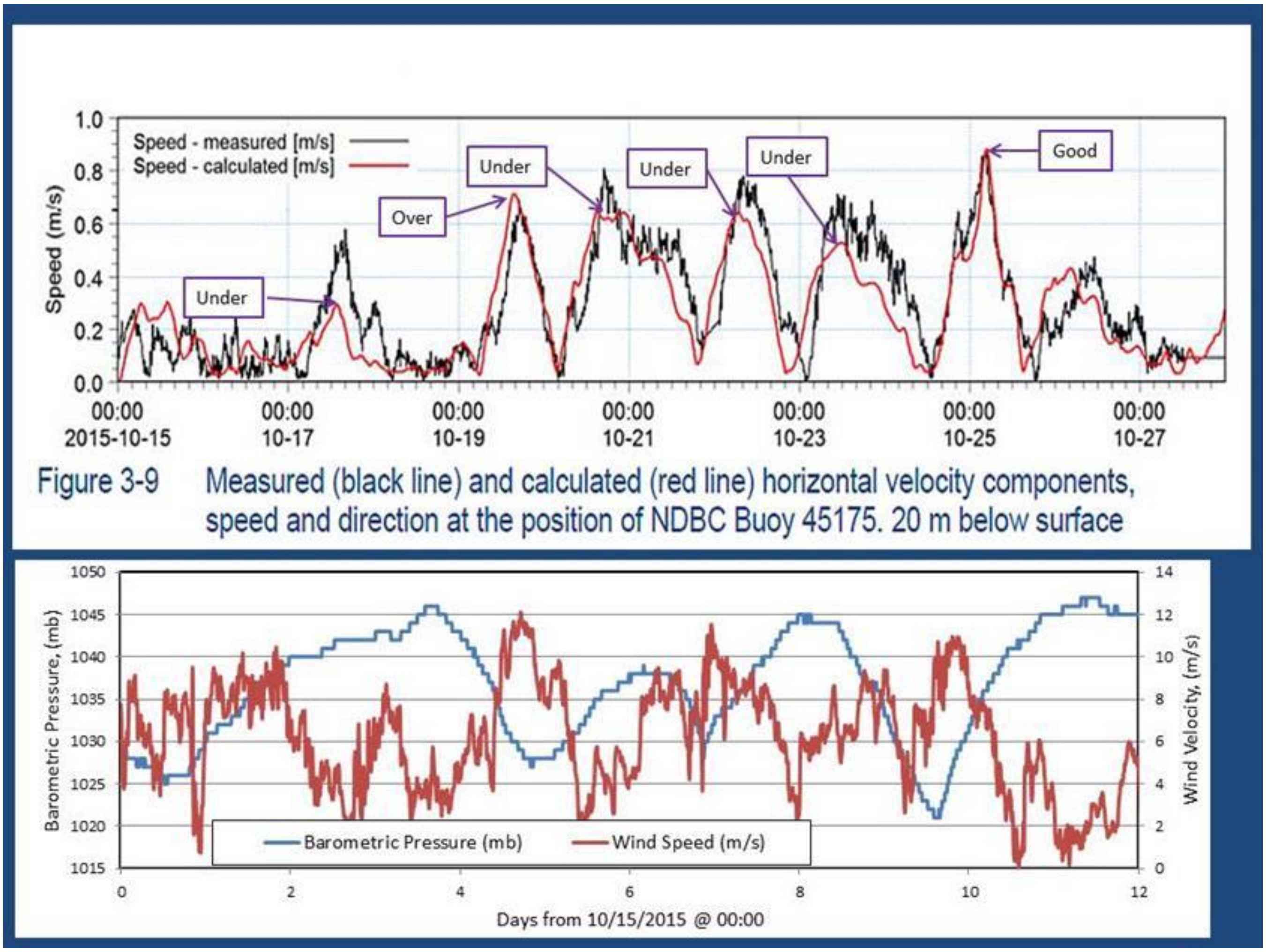


Figure 3-9 Measured (black line) and calculated (red line) horizontal velocity components, speed and direction at the position of NDBC Buoy 45175. 20 m below surface

Figure 2 from the Currents and Stresses Report

The Timm "Currents and Stresses" report (3/5/17) goes into great detail about the unique bi-directional flow in the Straits which is classified by hydrodynamicists as developing mesoscale turbulence. There is also discussion about the effect of measurement averaging time on obscuring peak flow velocities. As previously stated, a robust risk analysis for current induced forces must consider the extremes of current velocity since the structure will respond to fluid velocity on a millisecond time scale while available current velocity data and Dynamic Risk's Mike 3 model have a minimum time resolution of ten minutes. Just as a ten minute average wind speed measurement will contain a peak gust much stronger than the average wind speed, a ten minute or more average completely obscures the peak current velocity. In my currents and stresses paper I utilized the work of Thompson[11] to attempt to elucidate what peak currents may be found in averaged data. In the Revised Alternatives Analysis, Dynamic Risk has completely failed to address these subjects yet they claim their current velocity analysis is conservative. By using averaged data and ignoring turbulent flow phenomena in the open channel flow field of the Straits, Dynamic Risk has made a methodological error that reflects a fundamental lack of understanding of open channel flow phenomena. No stress analysis predicated on such a weak understanding of hydrodynamics can be considered conservative or even correct.

Fatigue Life

The following is reproduced from p. 14 of the Errors and Omissions document:

“Therefore, it is necessary to know the stress-strain history of the pipe in order to know if the pipe is close to its fatigue limit. A heavily fatigued pipe may well fail at a stress well below the elastic limit of virgin material so the failure criteria must take into account what has gone before. Similarly, the vortex induced vibration failure criteria is based on the number and severity of vibratory cycles. Again, the analysis must start from a time when the material in the pipe has zero fatigue cycles so that cycles can be accurately counted as the fatigue failure limit is approached.
From the preceding discussions, one problem with the Monte Carlo risk estimates in the Alternatives Analysis is that they don’t start from the pipeline’s construction in 1953. Instead, Dynamic Risk assumes the material making up the pipe is in virgin condition when they start their analysis in 2018 and use it to predict a risk of rupture extrapolated to 2053. In fact, the pipe has endured five different periods of spanning history with each adding its quanta of damage as the years pass. Essentially, Dynamic Risk has chosen to ignore the first 50 years of Line 5 under the Straits history, a history that includes little or no span maintenance with spans growing to at least 286’, and then begins its calculations starting in 2018 assuming virgin material properties. Any risk estimate based on this methodology is so erroneous an equally accurate estimate could be produced using black cat bones and fuzzy dice! A correct Monte Carlo risk estimate would require doing separate year by year analyses each featuring a realistic current velocity distribution, span length probability distribution and number of spans. This would result in over sixty different Monte Carlo risk estimates which could be added up starting in 1954 to the current date then projected forward to get a realistic estimate of risk for any year in the future.”

The assertion that the fatigue analysis didn’t start from the pipeline’s construction in 1953 is incorrect. In fact, in the analysis, fatigue damage was accumulated from the start of operation in 1953 and the fatigue analysis was run over a 100-year period from 1953 to 2053. Although the fatigue analysis was performed for this full time period, results were reported only for the years 2018 – 2053 for the simple reason that failure probability is known with 100% certainty for past years of operation. It would therefore be nonsensical to report predicted probability of failure for past years of operation.

Dynamic Risk has mischaracterized the point of the above statement. Of course I realize they started their fatigue analysis in 1953 but it is also a fact that they used a unsupported span distribution that it claims only began to occur starting in ca. 2005. I do agree that the failure probability for the past is known with 100% certainty, and furthermore I maintain that there is a 100% certainty that segments of Line 5 under the Straits failed by plastic collapse onto the Straits bottomland during that period. The Dynamic Risk Revised Alternatives Analysis turns a blind eye to this documented reality and then goes on to say this history can be ignored based on the ILI results that follows:

It should be pointed out that any failure occurring over the near term would be associated with near-critical fatigue cracks that would be detectable by non destructive inspection. Such non-destructive testing was recently undertaken on both the East and West segments using the Oceaneering tethered tool. This automated inspection system utilizes time of flight diffraction (TOFD) and phased array (PA) pulse-echo ultrasonic techniques that are configured to detect and size accuracy for surface breaking defects such as fatigue cracks residing in girth welds and their associated heat affected zones, where the potential for fatigue cracking to initiate and propagate exists. These inspections showed no evidence of sub-critical fatigue damage or cracking of any kind that has occurred as a result of past operations.

Author Mihell[8] is a published expert on the subject of fatigue damage in pipelines. In a section of Mihell's 2010 paper regarding classification of crack feature size he states:

"This process is not as simple when addressing crack features as current ILI capabilities do not provide discrete measurements for crack dimensions. For example, some ultrasonic crack detection tools report crack depths as ranges, such as < 1mm, 1mm to 2 mm, 2 mm to 3 mm, and > 3mm. Other processes apply a categorization based on indication signal strength. Any effort to improve the resolution in categorizing ILI anomalies can help reduce conservativeness by providing a more accurate representation of the size of those crack features on a pipeline."

Further comments regarding ILI and the detection of circumferential cracking are to be found a following section of this document, however, this author finds a strong disconnect between Mihell's language above where "as current ILI capabilities do not provide discrete measurements for crack dimensions" and Dynamic Risk's conclusion that a history including nearly fifty years of neglected operation or management leading to plastic collapse of the structure can be ignored based on these same ILI crack detection techniques, which failed to document this neglect leading to a compromised condition or collapse . Also noted, is author Mihell's emphasis on reducing conservatism in ILI data interpretation.

Failure Probability Estimation

As an alternative to the threat-based evaluation of failure probability described in the Alternatives Analysis, the following approach and corresponding results are offered on p. 14 of the Errors and Omissions document:

"A very simple risk estimate for the whole of the underwater section of Line 5 can be done based on the average failure rate for all DOT 195 pipelines from all causes. This risk is given as 0.89 failures/(1000 mi * yr)23. Using this figure, the risk of failure for the 8.15 miles of twinned lines under the Straits gives a failure rate of 7.25*10-3 per year. Adding up the failure probability on a yearly basis gives the 2017 failure probability at 46.4% and the 2053 failure probability at 72.5%. These figures are very different from the Alternatives Analysis estimate of 1.6% by 2053. This means that Line 5 under the Straits is 45 times safer than a typical buried DOT 195 pipeline, a conclusion that defies sense."

No mention was made of the exact dataset that was employed for the purposes of the above analysis.

The source of the data for accident rates used above was fully referenced as reference 23 in my Errors and Omissions paper. Furthermore, the values I used in my calculation are given. This comment is nonsensical!

Nevertheless, good practice dictates that when using industry incident data to estimate failure probability along specific infrastructure, the underlying incident database should replicate, as much as possible, the characteristics of the pipe segment being modeled. Nevertheless, as no mention was made of any attempt to ensure that this basic tenet of good practice was adhered to, it is likely that this analysis mixed failures that occurred in onshore environments with those that occurred in offshore environments. It is also likely that this analysis mixed failures that occurred within pipeline rights-of-way with failures that occurred within terminals, tank farms, offshore platforms, below-ground storage piping, etc., as the PHMSA Hazardous Liquids Incident Database contains data for all this infrastructure. Furthermore, equipment failure (defined as failures occurring within non-pipe components, such as seals, gaskets, instrument tubing, o-rings, etc.) represents the biggest single cause of failure within the PHMSA Hazardous Liquids Incident Database. There is no non-pipe equipment within the Straits Crossing segment. Therefore in the absence of any effort to ensure that the incident data reflect characteristics of the Straits Crossing segments, failure rates will be skewed by failures that occur in infrastructure that isn't represented within those pipe segments. Finally, this simplistic approach ignores specific threats that have been identified, and which may be applicable to the segments of interest (such as anchor interaction, geohazards, etc.), and conversely, the failure rates will reflect threats that have been shown to be not applicable to these segments (such as selective seam corrosion, landslides, etc.).

My calculation of accident rates for all DOT 195 pipelines was intended to frame the discussion of probable accident rates for Line 5 under the Straits and is, as stated, a very simplistic approach. No representation was made that it is anything but that. Dynamic Risk's preceding paragraph is entirely correct but misses the larger point that DR's failure probability estimate of 1.6% by 2053 is at odds with real world experience. If my numbers for failure risk are corrected to only cover accidents in cross country sections of pipe without valves and fittings, the risk estimate is still an order of magnitude greater than that calculated by Dynamic Risk. It is misleading and simply not credible in my professional opinion for MI-DNR to argue that Line 5 under the Straits of Mackinaw has a far lower risk of rupture than that of a modern buried cross country pipeline. Moreover, DR once more has chosen to argue, rather than assess my calculations and conclusions. DR has bypassed a chance to calculate a "check value" regarding their work by calculating risk using existing pipeline rupture databases and has thus missed a chance to enhance the credibility of their risk estimate calculated from flawed Monte Carlo analyses.

Presence of Corrosion

The following is reproduced from p. 20 of the Errors and Omissions document:

"Although numerous MFL inspections of the Straits sections of Line 5 have been conducted that show little metal loss corrosion it should be noted that MFL technology has a limit of detection for metal loss of about 10% of the wall thickness of the pipe. Because of the extremely thick walls of Line 5 (0.812"), this limitation means that corrosion damage of 0.080" is the detection threshold in this situation and significant metal loss and pitting could exist just below the detection threshold of MFL inspection technology. Further information will be available regarding corrosion and the condition of the coating on Line 5 under the Straits following the completion of the ongoing Biota report."

In fact, the minimum detection capabilities for general metal loss of the Magnescan tool that was deployed in 2013 is 5% of wall thickness at 90% probability of detection, and metal loss below that performance threshold is routinely reported in pipelines where such corrosion exists. Had external corrosion been an active and ongoing process in the 60 years of operation prior to that inspection, then evidence of it would be expected. As is documented in the Alternatives Analysis report, to date, no external corrosion features.

Opinions about the real world capabilities of various ILI techniques for assessing pipeline damage vary. For example, in a report[12] for MI Senator Peters by the USGAO, Neil G. Thompson, PhD, wrote an appendix[13] about corrosion control in gas and liquid pipelines. In this appendix he states the following conclusion about the reliability of ILI methods.

“The high-resolution ILI tools are readily capable of detecting and discriminating corrosion. Typically, the ability to detect corrosion anomalies with a diameter less than three times the wall thickness is more difficult. Once the corrosion exceeds these dimensions, the ILI tools are more capable of detecting and sizing corrosion anomalies. Typically, ILI tools (both MFL and UT) are capable of sizing corrosion within +10 percent of the pipe wall thickness with an 80 percent level of confidence.”

More specific to the type of threat posed to Line 5 under the Straits, circumferential cracking, a paper[14] entitled “A practical process for managing the threat of circumferential Stress Corrosion Cracking”, by Roland Palmer-Jones and Thomas Beuker, of ROSEN Group writes:

“In general, for cracks, the use of a sensor technology such as shear wave UT or EMAT is the preferred choice. These crack detection ILI tools can be reconfigured to inspect for circumferential cracking. The accuracy and reliability of these re-configured systems is not yet well understood due to the infrequent use. In theory the capabilities should be similar to the performance with axial cracks.”

In a document[15] prepared for the Pipeline Safety Trust that was submitted to PHMSA, noted pipeline expert Richard Kuprewicz concludes:

“There is also another form of cracking associated with poor girth welding during pipeline construction/installation that is causing pipeline rupture. In my opinion, no ILI inspection tool is currently capable of reliably ascertaining girth weld cracks despite many claims. This is one reason why some pipeline operators nondestructively inspect all girth welds during construction even though federal minimum pipeline safety regulation do not require such 100 % assessment. Because of the different hoop stresses imposed by pipeline pressure, hydrotesting of pipeline, even to 125 percent of MAOP as historically required in federal pipeline regulations, can leave very large cracks in girth welds. These cracks can survive through many years of pipeline operation only to fail when placed under different lateral stresses, such as surface loading or earth movement, or pipeline change in service such as reverse flow.”

In fact, there is a considerable disagreement about the actual capabilities of ILI tools. This is particularly true about recently developed tools to detect circumferential cracking and there is no definitive report about the actual field capabilities of tools that utilize ultrasonic technology to detect and characterize circumferential cracking. There are over 30 vendors of ILI technology, individual inspection reports are the intellectual property of pipeline operators, competition in the industry is fierce and no independent ILI standard setting body exists. In its assertions about the capabilities of ILI technology used to inspect Line 5 under the Straits, Dynamic Risk has most likely used manufacturer's claims as to the capabilities of their products and these claims are not verifiable. The Oceaneering tethered crack inspection tool has only been used once to inspect these critical lines and the reports from these inspections are not available. In the past, Enbridge has made assertions that by using the Baker Hughes CPCM tool they determined that there were no coating holidays on the pipe. This information turned out to be untrue. The willingness of Dynamic Risk to bet the future of the Great Lakes on a single inspection using an unproven circumferential crack detection tool is not reasonable or prudent and defies claims that Dynamic Risk has prepared an unbiased report for its client, the State of Michigan.

Recommendations

1. The State of Michigan should reject the Revised Alternatives Analysis as it is not an unbiased engineering assessment of the Straits segments of Line 5. It would be unreasonable and imprudent to rely on the DR Revised Alternative Analysis regarding any determination regarding alternatives to Line 5.

2. The agreement[16] between Enbridge and MI governor Snyder that includes language mandating shut in of Line 5 when waves in the Straits reach 8' height for a period of an hour should be renegotiated based on unbiased engineering input to utilize wind data to determine shutdown conditions rather than wave height data that cannot be measured during storm season. The use of wave height model predictions to accomplish this task may be unreliable because of lack of calibration data for the Great Lakes Environmental Research Lab (GLERL) NOWCAST wave height model. This whole agreement requires further study because of comments made in the following section.

3. A network of several (~5) bottom mounted, cabled Acoustic Doppler Current Profiler (ADCP) current meters should be placed between the pipelines to collect year-round critical current data necessary to insure pipeline integrity. These measurements could also provide a real time warning of extreme current events requiring a shut in of Line 5 for integrity reasons.

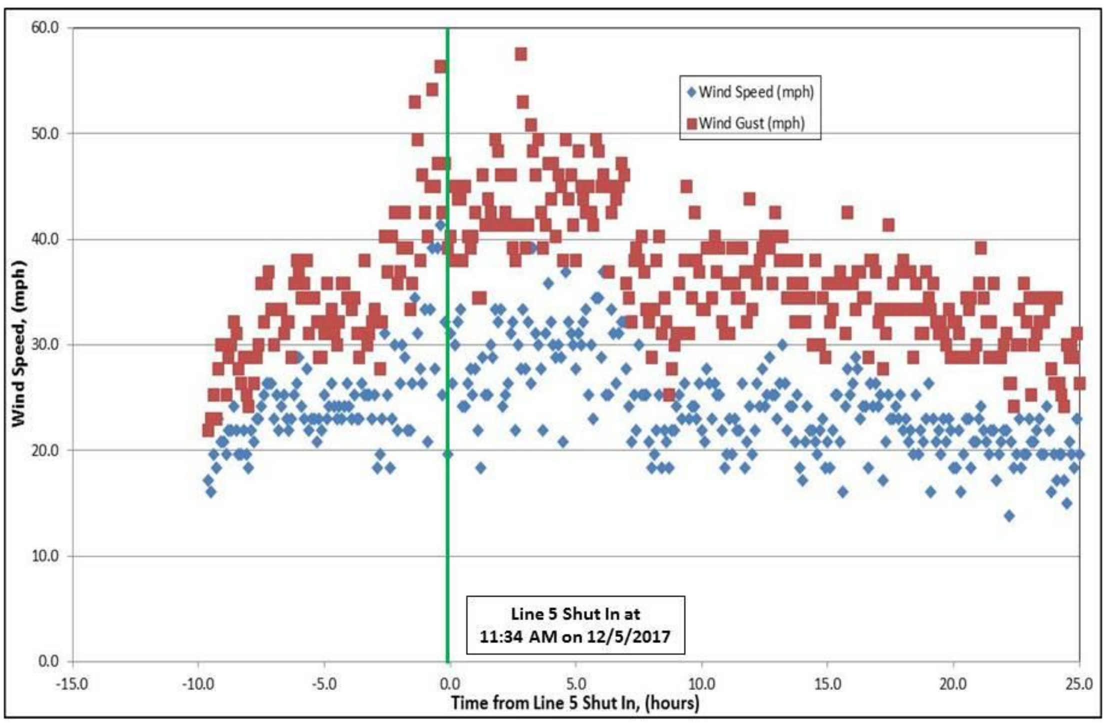
4. Concurrently with 3 above, initiate an effort to utilize existing 3D hydrodynamic models to determine the subsea current conditions that represent a once in 100 year storm under the Straits. Using a model to determine what meteorological conditions lead to a once in a 100 year extreme current event will provide useful guidance for future weather model based prediction of extreme current events.

5. A full engineering investigation by unbiased experts of the failure history of Line 5 under the Straits must be conducted to reveal critical facts about Line 5 that remain unrevealed. This investigation should particularly focus on revealing details of the

history of long unsupported spans and segments of the pipe where plastic deformation is suspected. . The recent disclosures by Enbridge concerning the continued failure of screw anchor supports and the overall bending or collapse of portions of the Straits segment of Line 5 without such full investigation in my opinion demonstrate an even greater risk of a rupture or leak from these pipeline segments.

<u>Additional Comment – Weather Related Shut-In of Line 5</u>

As this document was being edited, a strong winter storm system crossed into the Great Lakes Basin which resulted in weather initiated shut-in of Line 5 according to the complex procedures found in the shut-in agreement[15] between Enbridge and the State of Michigan. According to publically released information, Enbridge shut-in Line 5 at 11:34 AM on 12/5/2017 when the GRERL NOWCAST model predicted 8' seas in the Straits for a period of one hour. Following is a plot of wind speed and wind gust speed before and after this shut-in event



Wind Speed in Mackinaw City During Line 5 Shut In on 12/5/2017

This complex shutdown system dis respond to an extreme weather event but spill response would have been impossible as long as 10 hours before the line was shut in. Of significant concern is the fact that when the line is shut in, it cools and contracts ca. 4 feet in a relatively short period of time. This causes stress to redistribute throughout the length of the line which may not be what is the best course of action during a peak current event. This stress redistribution is the kind of event mentioned by Kuprewicz1[4] as potentially hazardous to structures susceptible to girth weld cracking.

Once a structure has been bastardized to “fix” things that went wrong with an original design, things get very complicated.

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[13] “APPENDIX E, GAS AND LIQUID TRANSMISSION PIPELINES”, NEIL G. THOMPSON, PH.D,

[14] “A practical process for managing the threat of circumferential Stress Corrosion Cracking”, Palmer-Jones, R. and Beuker, T, 11th Pipeline Technology Conference, May 2016, Berlin

[15] “A Review, Analysis and Comments on Engineering Critical Assessments as proposed in PHMSA’s Proposed Rule on Safety Of Gas Transmission and Gathering Pipelines”, Richard Kuprewicz, Accufacts Inc., 55/16/16

[16] https://mipetroleumpipelines.com/document/agreement-between-state-michigan-and-enbridge-energy-line-5-michigan

July 18, 2018 Technical Letter

Comments Regarding the Enbridge Application for a Permit to Install 48 New Screw Anchor Supports under Line 5 in the Straits of Mackinac

Edward E. Timm, PhD, PE
5785 Deer Run Trail, Harbor Springs MI 49740
EdTimm@Gmail.com

Before the State of Michigan granted the easement required to construct Enbridge Line 5 across the bottomlands of the Straits of Mackinac, the State carefully reviewed the design calculations made by Bechtel, Inc., the design and construction firm that had overall responsibility for building a safe and reliable structure. Most important of the documents submitted for the State's review was an outside review of Bechtel's calculations by famed Columbia University Professor Mario Salvadori, the father of forensic structural engineering.

In a summary document[1], Salvadori discusses the calculations necessary to insure the structural stability of the pipe and the results of these calculations regarding the exposed, submerged sections of Line 5. The foremost of these conclusions is shown in Figure 1 and it is this conclusion that led the State of Michigan to mandate that there should be no unsupported span greater than 75' anywhere along the exposed sections when granting the easement required for construction.

Figure 1 Main Conclusion of Salvadori Stability Analysis

> **Conclusions**
>
> The main recommendations arrived at on the basis of the evaluations outlined above are as follows:
>
> a. The pipe must not be allowed to span a valley of more than 140 feet.

As has been documented in numerous previous documents by Timm that have been submitted to both the MIDEQ and the MIPSAB, the original construction of the line did not comply with either the 1953 easement requirements or Salvadori's simple mandate for long term structural stability. While the full history of non-compliance has not been revealed, three documents[2,3,4] have shown the degree of non-compliance at two points in time, 1980 and 2003. Tables 1 and 2 tabulate data taken from these documents.

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[1] "Engineering and Construction Considerations for the Mackinac Pipeline Company's Crossing of the Straits of Mackinac" and "Report on the Structural Analysis of the Subaqueous Crossing of the Mackinac Straits," submitted by Mackinac Pipeline Company/Lakehead Pipeline Company to the Michigan Department of Conservation, January, 1953

[2] "East Leg Profile Drawing", Michigan Pipeline Task Force, AG Attachment B, Parts A-E, Section A2, Document 164-00-1_700-10483-01_523921_7.pdf

[3] "West Leg Profile Drawing", Michigan Pipeline Task Force, AG Attachment B, Parts A-E, Section A2, Document 164-00-1_700-10483-01_523922_7, 1979

Table 1 along with notes found on the reference drawings reveals that the pipeline did not meet the easement requirements for unsupported span length at the time of construction and, by 1980, had three spans that violated Salvadori's stability limit.

Table 1 Tabulation of Unsupported Spans in 1980

Summary of non-Compliant Unsupported Spans as of 1980

Location	Spans > 75 feet	Spans > 140 feet
West Leg	10	3
East Leg	7	0

Table 2 tabulates data taken from the Kiefner report. This report, commissioned by Enbridge and released to Enbridge in draft form in 2003 revealed that the unsupported spans had multiplied and grown very significantly over the time period from 1980 to 2003.

Table 2 Tabulation of Unsupported Spans in 2003

Summary of non-Compliant Unsupported Spans as of 2003

Location	Spans > 140 feet	Maximum Span, feet
West Leg	7	224
East Leg	9	286

Table 3 is an annotated table taken from Enbridge reports that details the results of underwater ROV inspections of Line 5 and the subsequent actions taken by Enbridge. The table provided to the SOM by Enbridge includes actions through the year 2012 and has been annotated by adding information about current and future support installations.

Table 3 reveals a pattern of neglect by Enbridge regarding the unsupported spans that developed under Line 5 because of bottomland erosion due to current action. Early efforts to support the line involved placing canvas bags under the pipe that were then filled with grout. These bags proved ineffective as supports and the failure of one of these supports led to the unstable 286' span shown in Table 2. It was not until 2001 that Enbridge started adding mechanical supports that supposedly ensure the stability of the line. From the time the line was constructed until 2001 Line 5 was essentially neglected and allowed to develop unstable spans. During this 48 year period of

[4] "Assessment of Span Exposures on the 20-inch Petroleum Pipelines Crossing the Straits of Mackinac", Rosenfeld, M., Kiefner and Associates, Columbus, OH, Released October 2016

deferred maintenance there is reason to believe[5] the pipe was damaged by gravitational, current and expansion induced stresses.

Table 3 History of ROV Inspections and Support Actions on Line 5

Year of ROV Inspection	Supports Installed	Total Supports	Type of Support
1963	None	0	
1972	None	0	
1975	3	3	Grout Bags
1979	None	3	
1982	None	3	
1987	7	10	Grout Bags
1989	None	10	
1990	None	10	
1992	6	16	Grout Bags
1997	None	16	
2001	8	24	Grout Bags and Mechanical Supports
2003	16	40	Mechanical Screw Anchors
2004	16	56	Mechanical Screw Anchors
2005	14	70	Mechanical Screw Anchors
2006	12	82	Mechanical Screw Anchors
2007	None	82	
2010	7	89	Mechanical Screw Anchors
2012	17	106	Mechanical Screw Anchors
2014	22	128	Mechanical Screw Anchors
2016	22	150	Mechanical Screw Anchors
2018	48	198	Mechanical Screw Anchors

Table 3 includes the 48 supports that are the subject of the permit request from Enbridge that is the subject of this document. If this permit request is approved, Line 5 under the Straits will be supported by 198 discrete support structures. The rationale for the permit to install these supports can be found in conditions attached to the Federal Consent Decree[6] that resulted from settlement with the Federal Government of the negligent rupture of Enbridge Line 6b in 2010. Apparently, the need for the additional 48 supports is discussed in an unreleased Enbridge document that bases this need on bottomland erosion predictions that show many spans will exceed the 75' unsupported span condition of the original easement with the State of Michigan in the near future.

[5] "Technical Note: Evidence of Damage to Line 5 under the Straits of Mackinac", an excerpt from "An Analysis of Errors and Omissions in the Dynamic Risk, Inc. Line 5 Alternatives Analysis, Option 5", E. E. Timm, 2017, Filed with the MIPSAB

[6] Federal Consent Decree, Case 1:16-cv-00914, ECF No. 3 filed 7/20/16, condition 68.

Assuming a 75’ spacing, 2.81 miles out of a total exposed length of 4.2 miles of the non-buried sections of Line 5 under the Straits will be supported off the bottom. This means about 67% of the pipe that was originally designed to be continuously supported will be transformed into a discretely supported structure through incremental maintenance. It appears the sole rationale for installing additional supports under Line 5 is to comply with the 75’ easement limitation even though this 75’ figure was the result of calculations that assume the pipeline is a continuously supported structure with a small number of unsupported spans. Line 5 has been transformed from a continuously supported structure to a discretely supported structure through incremental maintenance operations without any engineering stress analysis of the transformed structure.

As previously mentioned, Salvadori did an extensive engineering stress analysis of the proposed design for Line 5 under the Straits in 1953. Table 4 is a list, taken from Salvadori’s report, of the possible failure modes and analyses conducted to assure the structural stability of the continuously supported design for the pipe. Over nineteen different failure modes for the continuously supported pipe were analyzed resulting in recommendations that were incorporated into the 1953 easement.

To date, the record does not indicate that any similar holistic stability analysis has been conducted for the new, discretely supported structure that is the result of Enbridge’s incremental repairs. The stresses in a discretely supported pipeline are calculated using different mathematical approaches from those used for a continuously supported pipeline. Additionally, a discretely supported pipeline has failure modes not contemplated by Salvadori and is much more subject to vibrational issues due to the lack of damping compared to the very damp structure that results from continuous support. Vibrations excited by turbulent currents are much more likely in the supported structure because it is off the bottom and further into the current flow field with resultant increased current forces. Clearly, a supported structure is more vulnerable to being hooked by an errant anchor than a structure resting half buried on the bottom and is also far less able to withstand the forces caused by such an anchor hooking event compared to a continuously supported structure.

For the State of Michigan to grant a permit to transform Line 5 under the Straits from a continuously supported structure into a discretely supported structure without a complete analysis of the stability of the new structure cannot be justified as responsible engineering practice. There is a large body of engineering literature that documents how the transformation of a structure by maintenance without regard to the overall effect on the structure has resulted in disaster.

There are indications that the screw anchor supports being used by Enbridge to prop up Line 5 are either ill-conceived or inadequate for the job. Figures 2 and 3 are frames clipped from Enbridge underwater inspection videos that appear to show deformation of the supports caused by pipe movement. The cause of this deformation is not known but may involve either thermal expansion stresses or stresses caused by pipe motion due to currents and gravitational action. It is apparent that the screw anchor supports used by Enbridge may be inadequate to provide suitable support in the vertical, transverse and longitudinal directions.

Table 4 Salvadori Stability Calculations

The following conditions have been considered in detail in order to specify the limitations recommended at the end of this report and to set up specifications for the materials and the construction of the pipe.

1. Forces due to the Current

Under the action of a recorded current of 1.96 knots, the pipe bends laterally. It is assumed that the pipe will rest on the bottom of the river on two points and will span a valley. The pipe span is assumed simply supported to magnify the existing stresses. The maximum permissible span due to current stresses is thus determined.

2. Stresses due to Vertical Loads

Under the action of its own weight (negative buoyancy) the pipe will bend in the vertical direction when spanning a valley. The pipe is considered full of water or empty and the corresponding maximum valley span is determined under the assumption of simple supports. The favorable influence of continuity of spans is ignored.

3. Combination of Horizontal and Vertical Forces

The stresses due to the current and to the vertical loads are combined to obtain the maximum safe span under both forces, both when the pipe is empty and when it is full.

4. Stresses due to Pressure

The stresses (hoop and longitudinal) due to internal operating and testing pressure were investigated, assuming the pipe to be a thin cylinder and a thick cylinder. The longitudinal stresses were obtained under the assumption of a pipe closed at both ends.

5. Combination of Bending Stresses and Pressure Stresses

The stresses under (3) and (4) were combined in such a way as to obtain the worst possible condition of stress in both tension and compression. The maximum shear stress due to these principal stresses was also determined.

6. Longitudinal Temperature Stresses

A maximum temperature differential of 40° F. was assumed as the basis for the determination of longitudinal stresses due to the prevented expansion of the pipe. This type of stresses is relieved by extension of the pipe due to bending.

7. Critical Length for Thermal Buckling

A temperature increase of 30° F. was assumed to determine the buckling length of pipe under fixed ends and simply supported ends conditions. These spans are longer than the minimum recommended spans.

8. Friction Required to keep Pipe in place during Thermal Expansion

The available friction on the bottom of the river is not capable of preventing the lateral displacement of the pipe due to thermal buckling. Hence the pipe will be displaced laterally and thermal longitudinal stresses will be relieved.

9. Ring Thermal Stresses

The stresses due to a temperature differential at 30° F. between the oil and the water were investigated under the assumption of a thick pipe. The pipe being thin, these stresses will not be reached.

10. Temperature Increase in Curvature

The increase in curvature due to temperature differentials of the order considered were found negligible. Thus, the corresponding bending stresses may be neglected.

11. Limitations on Curvature

In order to limit the bending stresses in the pipe due to the curvature of the bottom of the river, the minimum allowable curvature is determined and recommended.

12. Collapse of Empty Pipe

Under the assumption of an abnormal condition (due to imposion) which will suddenly empty the pipe, the external pressure is found not to be capable of buckling the pipe. The pipe, hence, will not collapse, due to external pressure, even if empty.

13. Local Buckling Stress

The maximum longitudinal compressive stress is much smaller than the buckling compressive stress for the pipe. Hence, no danger of local buckling is present.

14. Torsional Stresses Due to Slanted Approaches

The pipe does not follow the line of maximum slope on the banks of the river. This condition produces torsional moments and torsional shear stresses. The determination of these stresses under wide conditions proves that they are far from dangerous.

15. Rolling Tendency

The pipe has a tendency to roll under the action of the current pressure and of the lateral component of its weight on the slanted banks of the river. The available friction is proved to be sufficient to prevent such motion.

16. Lateral Motion of Pipe

Available friction on the full pipe is proved sufficient to prevent the lateral motion of the pipe under the pressure of the current at the bottom of the river. The friction available on the empty pipe may possibly not be sufficient to prevent its lateral motion and a minimum additional negative buoyancy is recommended for the pipe.

17. Knife Edge Cradle Stresses

The possibility of the pipe resting on a sharp edge is considered and the stresses due to this condition, assimilated to a line pressure all around the perimeter of the pipe, are determined. The angle subtended by the knife edge support is varied between 30° and 180°.

18. Catenary Action

The reduction of lateral displacement due to catenary action, under the assumption that the ends of a pipe span be prevented to move one towards the other by friction or other obstacles, is found to be of the order of 20%.

19. Miscellaneous Stresses

Other conditions of load and support have been considered and found to be unimportant. For example, the possibility of a concentrated load acting on the pipe is excluded due to the slats and wrapping.

Figures 2 and 3 show screw anchor supports that are tilted substantially from plumb. Since the apparatus used to screw these supports into the bottomland assures their plumb vertical placement, it is likely that these supports have been bent sideways by the longitudinal motion of the pipeline to which they are clamped.

Figure 2 Frame Clipped from 2012 Enbridge West Leg Inspection Video

Figure 3 Frame Clipped from Enbridge 2016 West Leg Inspection Video

The support legs of the screw anchor supports are made from 5”, Schedule 40 pipe which may have adequate compressional strength to support the weight of the pipeline but is not adequate to accommodate the transverse and longitudinal forces imposed on them by a very rigid 20”, Schedule 60 pipeline.

In 2001, Table 3 shows that Enbridge began transitioning from using grout filled canvas bags in their attempts to shore up the seriously undermined and sagging pipe. Following the discontinuance of the use of grout filled bag supports, Table 3 describes the supports installed in 2001 as “Grout Bags and Mechanical Supports.” This is the first mention of mechanical supports and it is unclear exactly what kind of mechanical supports were installed in 2001. Concurrently, Enbridge contracted with the well-known offshore firm J. P. Kenny, to provide guidance on how best to support Line 5 under the Straits. Enbridge has not released whatever report(s) were produced by Kenny[7] but there is a reference to this subject in the Kiefner report. It is probable that the “mechanical” anchor(s) installed in 2001 derive their design from this report and differ from the “mechanical screw anchors” installed at later dates. Careful examination of Enbridge’s underwater inspection videos reveals a mechanical anchor structure that is unlike all the other mechanical anchors installed under Line 4. Figure 5 shows this unique anchor structure which is differentiated from later anchors by the heavy X-bracing that provides substantial additional transverse stiffness as compared to the design adopted for all supports installed in 2003 and later.

Figure 4 Frame Clipped from Enbridge 2012 East Leg Inspection Video

[7] “Analysis of Spans”’ J. P. Kenny Report, Released to Enbridge in 2003, Documented as Reference 12 in the Kiefner Report, Reference 4

It is not known why Enbridge chose to simplify the design of the mechanical supports that are used under Line 5 but the later design is obviously cheaper to manufacture, easier to install and less able to resist transverse forces. It is possible that Enbridge has conducted analyses that conclude transverse stiffness is not an issue for the supports used under Line 5 but, if that analysis has been conducted, it should be examined to assure the design change made to the mechanical support structures provides adequate transverse stiffness to resist current induced loadings.

It should be apparent from the preceding discussion that for the State of Michigan to allow Enbridge to convert Line 5 under the Straits into a discretely supported pipeline from a continuously supported pipeline under the guise of maintenance is unsound engineering practice. A qualified structural analysis consultant should be retained to provide a complete, Salvadori style analysis of the structural stability of Line 5 as a discretely supported structure. Furthermore, as has been shown with the issues surrounding the Revised Alternatives Analysis by Dynamic Risk, Inc., this consultant should not be one whose source of income is the oil and gas industry. Hiring a consultant from the Mechanical Engineering Department of a major university, as was done with Salvadori, provides assurance of freedom from conflict of interest.

It is also my professional opinion that there are three issues remaining from the past work of the MIDEQ and the MIPSAB regarding structural stability of Line 5 under the Straits. These issues should be resolved before attempting a new study.

1. There is near total disagreement between the works of Timm and the Revised Alternatives Analysis regarding the stresses and stability of Line 5. These disagreements are clearly outlined in the rebuttal of the Revised Alternatives Analysis by Timm[8]. A qualified, non-industry consultant should be hired to thoroughly investigate the sources of these differences and form an opinion regarding the technical robustness of the differing approaches.

2. Stresses on the pipeline from currents occur instantaneously while all of the data taken regarding current velocities is long term averaged data. Current velocities estimated from hydrodynamic models suffer both from the lack of adequate data to calibrate these models and the fact that the models cannot determine instantaneous peak velocity. From my early reports to the State of Michigan regarding the stability of Line 5, I have recommended that a multi-point, cable powered ADCP be installed in the vicinity of the pipeline. Current and past ADCP measurements have tended to miss the peak storm season when the highest current velocities could be expected because they have to be removed from the Straits before icing occurs. It is unacceptable engineering practice to base calculations regarding the stability of Line 5 on incomplete data that is not suited to the purpose of determining the peak stresses on the pipe.

3. Much of the content of the Kiefner[4] report is devoted to the subject of how best to remove stress from sagged sections of the pipeline when placing supports. This is a

[8] "Technical Note: Rebuttal of Revised Alternatives Analysis Attachment 6 and Related Sections of the Dynamic Risk Revised Alternatives Assessment", E. E. Timm, 12/6/2017

critical subject because merely placing a support without lifting the pipe into a lower stress condition merely stabilizes the pipe in its sagged, high stress state. The Kiefner report analyzes different strategies for destressing the pipe including filling it with low density NGL's, filling it with gas and lifting the pipe mechanically. All of these options have tradeoffs regarding their ability to destress a plastically deformed pipe and the impact of the destressing operation on the ability of the pipe to withstand thermal expansion. This is complicated subject matter but the first step in any stress analysis of this vintage, neglected, discretely supported pipeline is to understand its stress history and current stress state. Any changes to the stress state of the pipeline caused by Enbridge's destressing operations during support placement are material to the understanding of the current condition of the pipeline. Figure 5 is a frame clipped from Enbridge inspection video that appears to show a broken lifting strap around the pipe. It is not known when and why this strap was utilized and broken but, if this strap broke violently during a lifting operation, it is possible that the pipe was damaged by the event. An inquiry into this subject to reveal Enbridge's methods for destressing the pipe during support placement is necessary to understand the effectiveness of this critical operation.

Figure 5 Broken Lifting Strap around West Leg from 2012 Enbridge Inspection Video

In a recent publication[9], Henry Petroski[10] made the following comment about the structural failure of the newly constructed bridge on the campus of Florida International University on March 15, 2018: "Any time a structural design is altered, even in the seemingly smallest detail, the ways in which it can fail can be altered. That potential outcome is why it is essential for a modified design to be reanalyzed, with a complete set of new mathematical calculations. What may have been a perfectly safe structure can become a vulnerable one even when seemingly beneficial changes are introduced."

This advice applies completely to Enbridge's transformation of Line 5 under the Straits from a continuously supported structure to a discretely supported structure under the guise of beneficial maintenance. It would be the height of folly for the MIDEQ to grant further permits for Enbridge's unanalyzed transformation of Line 5 into a new structure in light of what is known about past negligence and ongoing "maintenance" of this structure which has the potential to inflict catastrophic losses on an entire region in the event of rupture.

[9] "Miami Bridge Collapse", Petroski, H., American Scientist, v. 106, n. 4, July-August 2018, p. 206
[10] Henry Petroski is the Alexander S. Vesic Professor of Civil Engineering and Professor of History at Duke University

Exhibit C

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Miami Bridge Collapse

As usual, a failed structure leaves behind more questions than answers.

Henry Petroski

When a yet-to-be-opened pedestrian bridge in Miami, Florida, collapsed in mid-March of this year, I received a number of inquiries from the media for comment on the fatal accident. Producers and reporters wanted to know: What did I think about it? What had caused the collapse to occur? Who was responsible? Did the so-called accelerated bridge construction method that was employed have anything to do with the failure? The inquirers were on a fishing expedition, hoping to get a scoop.

The now-collapsed bridge, as shown in this artist's rendering, was designed as a pedestrian walkway connecting the town of Sweetwater, Florida, with the Modesto A. Maidique campus of Florida International University.

All that I and, I suspect, other engineers not directly involved with the project knew in the days immediately following the incident was what we had read in the newspaper and on the internet or had seen on television. The structure had fallen, reportedly without warning, across a multilane thoroughfare. Vehicles stopped under the newly-erected span when the traffic light turned red were crushed, and five of their occupants were killed, along with a worker on the structure. Everyone wanted to know what had happened. There was a lot of cracked and crushed concrete and twisted steel where the bridge span had been. But what exactly was the cause of the failure? Nobody seemed to know for sure.

As an article in *Engineering News-Record* (the go-to trade journal of the construction industry for definitive reporting on structural failures) put it, most engineers did not wish to speculate "based on professional courtesy and lack of intimate knowledge of the design and construction." Engineers and contractors who might have been directly involved would generally not have been talking so soon after the event. Even they were likely to have been unsure of what had happened. And they would have been wary of saying something that might come back to haunt them in subsequent legal proceedings, which were sure to follow.

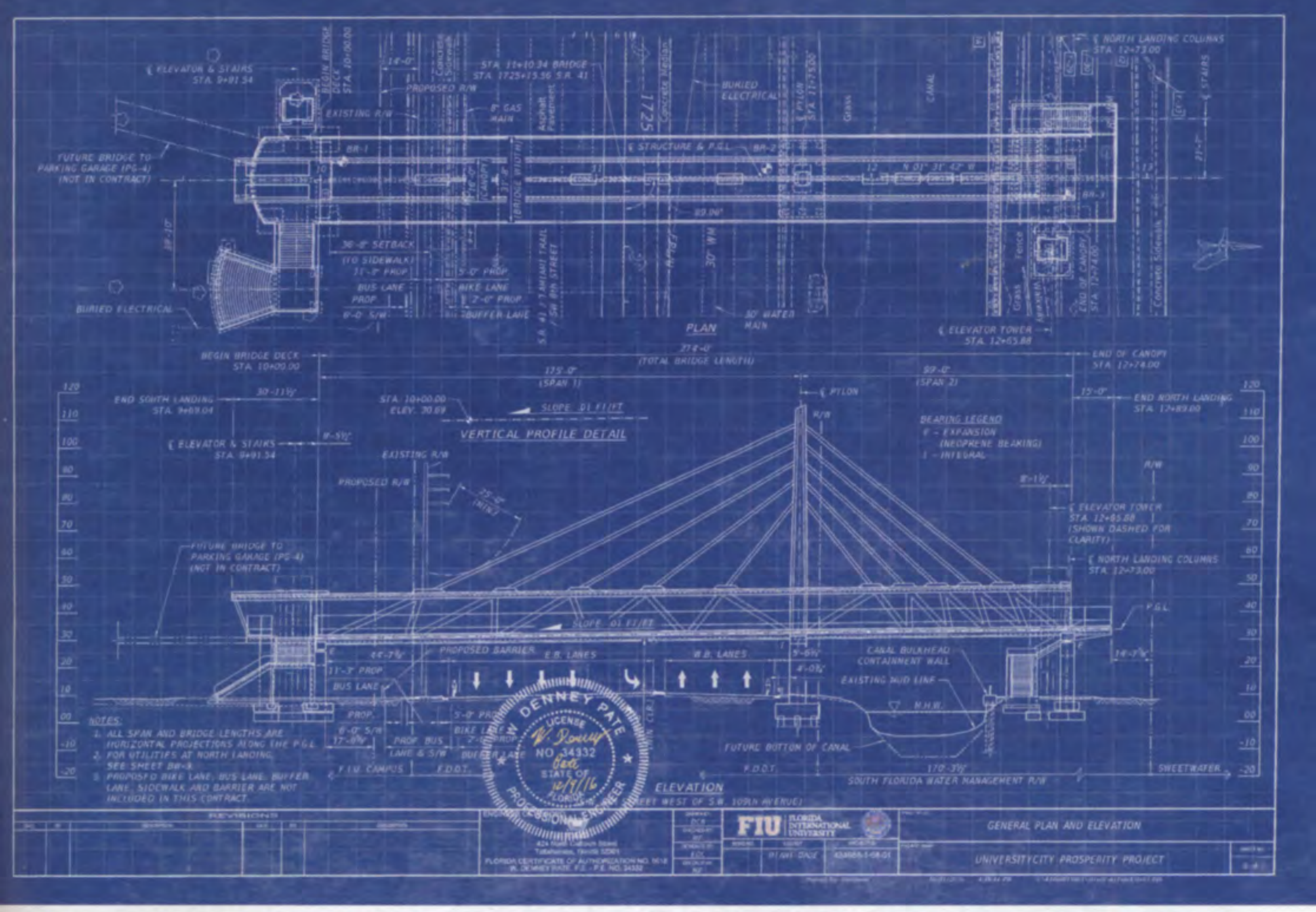
Henry Petroski is the Aleksandar S. Vesic Professor of Civil Engineering and a professor of history at Duke University. His most recent book is The Road Taken: The History and Future of America's Infrastructure. *Address: Box 90287, Durham, NC 27708.*

An Unusual Design

At least one engineer was willing to speculate for the record that the problem was not with the bridge design, for if that had been the case, the bridge would not have been able to support its own weight once the transporters used to move it into position and lower it into place on its pedestals were removed. "It would have fallen the same day, not five days later," one person said. "Something else happened" on the day of the failure. Among the speculations were that workmen on the bridge at the time it fell might have been tightening or loosening cables embedded in one or two of the diagonal members of the bridge truss. If something like that had occurred, there was not yet enough information to conclude what.

Regardless, it was easy to tell that this was a bridge of unusual design, and I understood that the method of construction involved moving a large part of it into place before the structure was completed. This operation was part of the accelerated bridge construction (ABC) process. It also was clear from early reports that the span's owner was Florida International University (FIU). The design and construction of the bridge were commissioned to carry pedestrians safely across the wide thoroughfare known as Tamiami Trail, which separates the campus proper from the town of Sweetwater, where many FIU students live.

As evidence of its being a serious research university, FIU is home to the



In a media briefing after the collapse, investigators from the National Transportation Safety Board shared this elevation and plan drawing to explain the structure of the bridge. The Florida Department of Transportation required that the bridge tower be moved three meters north.

Center for Accelerated Bridge Construction. The Center was established with seed money from the university in 2010, and within a couple of years a successful major proposal to the U.S. Department of Transportation from FIU, joined by initial partners Iowa State University and the University of Nevada, Reno, enabled it to be expanded into a federally funded center, known as the Accelerated Bridge Construction University Transportation Center (ABC-UTC). A second successful proposal, joined by the University of Washington and the University of Oklahoma, cemented FIU as the lead campus for research and education in ABC.

Accelerated Construction

According to the ABC-UTC website, the mission of the Center is "to reduce the societal costs of bridge construction by reducing the duration of work zones, focusing special attention on preservation, service life, construction costs, education of the profession, and development of a next-generation workforce fully equipped with ABC knowledge."

The 860-metric ton, 53-meter-long span across Tamiami Trail was to be a showcase for the ABC method. A sign showing a rendering of the completed bridge spanning the 10 or so lanes of traffic of the trail and an adjacent canal advertised it as "an innovative signature bridge to celebrate FIU." My first impression from this image of the bridge was that it was to be a true cable-stayed design, in which case it was indeed innovative in the sense that the deck was erected before the tower and cables were in place. That's opposite the way cable-stayed bridges are usually erected.

Nevertheless, the completed bridge was pictured to look like a cable-stayed bridge, though of a very unusual design. Instead of the cables issuing from a tower terminating in a sleek but typically hollow concrete roadway deck, whose strength and stiffness were provided by its boxy depth supplemented by the pull of the cables, the FIU bridge cables were to terminate in a pedestrian walkway that was in fact an open beam with a thinly disguised concrete truss exhibiting highly asymmetrical features, meaning that every other one of its diagonal members was to align with the cables. Whether this styling constitutes an aesthetically pleasing design depends on one's tastes and point of view. Still, it was the nature of the deck that presumably enabled it to behave like an enormous truss, and to span the road and canal even without the aid of the cables.

But the more I read, the more I realized that even when finished, the bridge, which one report called "a symbolic new portal to the university," was not to be a true cable-stayed structure at all, for what look like cables in the renderings were in fact just "pipes that would have the appearance of cables." These faux cables would run from a tower more than 30 meters tall—yet to be erected when the collapse occurred—to locations at which the pipes would align with diagonal members of the truss on the part of the bridge in place. In other words, the part of the bridge spanning the trail when it failed was in fact to be the full structural support.

The Miami bridge was designed to look like a cabled-stayed bridge but departed from the usual construction schedule of such structures by having its deck (the pedestrian walkway) hoisted and moved into place before the cables and towers were erected.

The reason for the pipes was apparently to make the completed structure look, but not function, like a cable-stayed bridge—the most fashionable kind of bridge being built today. David Billington, author of *The Tower and the Bridge*, railed against structures that do not express their true structural behavior, of which the Miami bridge's design would surely provide a stunning example.

Cables or Trusses?

Trusses are usually very repetitive and symmetric in the placement of their verticals and diagonals, and cable-stayed bridges also have a rather repetitive pattern. Seldom would these repetitions come together harmoniously, however. One of the biggest challenges in designing a cable-stayed bridge is deciding how to arrange the cables, but no matter how they're arranged they would not naturally align with trusswork diagonals. This setup is why, at least to me, the renderings of the FIU bridge looked so odd, and the arrangement of diagonals appeared forced.

The design-build team responsible for the bridge consisted of Miami-based Munilla Construction Management and Tallahassee-headquartered FIGG Bridge Group, which is named for the late bridge designer Eugene Figg and is known for its aesthetic structures—"purposeful works of art," according to its website. Because I did not know how MCM-FIGG rationalized its design, when initial media queries began coming in, I begged off responding to most requests. One Associated Press reporter, however, asked general questions that I felt comfortable answering. In particular, he was interested in historical precedent for the supposedly new construction method of ABC.

From repeated viewing of video footage of the deck of the Miami bridge being cast on land adjacent to the highway and then moved into place in a matter of hours, I had a clear picture of how the bridge was erected. It reminded me of the construction of the Britannia Tubular Bridge, the railroad structure that was installed across the Menai Strait in northwest Wales in the mid-19th century. Just one of the heavier and longer main spans of that bridge was made up of wrought-iron plates riveted together to form a 1,630-metric ton beam, 140 meters in length, and its method of erection was very similar to that the failed Miami bridge.

Beside one bank of the Menai Strait, the tubular beams were assembled and then floated on a tide to the resting place on the masonry towers that had been readied for them. The operation, although delicate and time-consuming, blocked water traffic for only a matter of days, while the tubes were jacked up into place. The bridge's engineer, Robert Stephenson, who realized that he was breaking new ground not only in structural design but also in method of construction, made the towers extra tall in the event that cables had to be added to provide additional support for the long hollow beam. When the tubes proved to have sufficient stiffness without suspension cables, the cables were left off and the too-tall towers became a point of discussion as to their aesthetic value and structural function. Billington did not like the bridge because of its seemingly too-tall towers.

In the case of the Miami bridge, its designers and constructors must have believed that its trussed pedestrian pathway—the part hoisted and moved into place on specialized wheeled carriers—was sufficiently strong without cables that it could safely be erected across the roadway, and the tower and faux cables could be added subsequently. That proved not to be the case, of course, and the truss bridge collapsed within about five days of being put in place. The partial bridge had been declared completed, according to some news reports. The declaration of completeness had confused me at first, but when I understood the design, the statement proved to be accurate, in the sense that the tower and faux cables would add nothing beyond decoration to the structure.

Photos of the collapsed bridge did not show the pattern of its trusswork very well because elements of the truss were broken in the bridge's fall onto the roadway. But day by day, as more photos and videos came to light, the design began to arise out of the ashes of the crushed concrete. The bridge span that was erected by ABC had a walkway that was somewhat wider than the canopy surmounting it. Between the walkway and the canopy was the truss of unusual design, thus making the bridge taken as a whole a beam with a larger bottom than upper flange. This arrangement is the way the main structural components of some early iron bridges were made, an acknowledgment that the material was stronger in compression than in tension, a property it shares with concrete.

In the Miami bridge design, the two flanges were separated by the open trusswork, perhaps in part to allow any cooling breezes to flow across the walkway, which was also intended to be a place for meeting, working, and relaxing. (Some design drawings showed tables surrounding truss members.) This usage reinforced for me the idea that the truss was probably given its unusual asymmetrical look in order to avoid any discordance between the angles of the truss diagonals and the cables. If the trussed part of the bridge had been lengthened, as some reports claimed, or if the tower had been repositioned, per Florida Department of Transportation (FDOT) requirements, reanalyses might not have been carried out as carefully as were the calculations that went into the initial design. After all, such changes are often considered minor, almost simply aesthetic.

Among the earliest electronic communications I received in the wake of the bridge collapse was one from an engineer whose knowledge of bridges is broad and deep. His first email called attention to the truss design as lacking shear strength, meaning that some photos suggested the absence of essential members, which would make the structure insufficiently strong along its length. Busy with other matters when his message came in, I could not confirm his claim immediately, and before I could study it and compare images, he sent a second message essentially saying, "Never mind." Subsequent images of the structure revealed that the truss, although unorthodox in its arrangement of members, may indeed have been properly designed—or at least it was not necessarily improperly designed.

Several days later, I received a message going into some detail about what happened to the bridge, but the writer repeatedly referred to the structure as a "suspension bridge," which it definitely was not. He based his whole argument on a false assumption. For one thing, a true suspension bridge, such as the Brooklyn or the Golden Gate, does not have its roadway put in place before its cables are complete. Indeed, the cable-stayed form evolved precisely to enable a different order of construction, and no expert confuses the two types.

Awaiting the Facts

Thus are the difficulties and pitfalls of performing a failure analysis without complete, correct, and informed input. And this complexity is why the National Transportation Safety Board (NTSB), which has jurisdiction over accidents such as the Miami bridge collapse, can seem to take an inordinate amount of time to issue a final report stating its view of what must have been the most probable cause of a failure.

Other early attempts to explain what happened likened the bridge collapse to the 1981 failure of the elevated walkways spanning the atrium of the Kansas City Hyatt Regency Hotel. In fact, that accident is not a good direct comparison for a variety of reasons. First, in the Hyatt case, the collapsed walkways (which might be thought of as steel bridges) left behind among the debris clear signs of how they were constructed and how they failed. Within days of the accident, photos in the *Kansas City Star* of the supporting steel rods that remained hanging from the roof clearly showed nuts and washers still in place, a clear indication that the box beams that supported the walkways proper had pulled off the hanging rods. Second, the deformed box beams showed how the nut and washer combination pulled through them, identifying the weak link in the structural system. Subsequent laboratory tests on prototypes confirmed the hypothesis that had been reached in a matter of days.

In the case of the Florida failure, the timeline has been very different. Two weeks out, *Engineering News-Record* published a story headlined "Theories Outrun Reliable Facts in Florida Bridge Collapse." This headline, mutatis mutandis, may still be viable for stories that will run in months to come. Because there is no immediately obvious cause that jumps out at the thousands of engineers scrutinizing press reports of the failure and its aftermath, it may only be through the efforts of the NTSB—which will study the failure fully—that the most probable cause will be determined.

In the meantime, theories will likely continue to outrun reliable facts. And there have been plenty of hypotheses, as the *Miami Herald* explained in a comprehensive article that appeared two weeks after the failure. Among the other categories of confusion, according to the *Herald* story, was the matter of "missing evidence." An article, titled "Miami bridge collapse still has experts baffled," stated that there were no "photographs of and the precise location of cracking reported by the FIGG engineer to FDOT two days before the collapse." Also missing were "construction plans showing precisely how the bridge was to be built, along with any mathematical calculations. Those early plans by FIGG almost certainly changed, engineers say."

Indeed, early plans for any structural design often do change. It was a change in the number and arrangement of the steel rods supporting the Hyatt Regency walkways that was found to be ultimate cause of their failure. Any time a structural design is altered, even in the seemingly smallest detail, the ways in which it can fail can be altered. That potential outcome is why it is essential for a modified design to be reanalyzed, with a complete set of new mathematical calculations. What may have been a perfectly safe structure can become a vulnerable one even when seemingly beneficial changes are introduced. Galileo Galilei made this clear in his 1638 treatise, *Dialogues Concerning Two New Sciences*, which he wrote when the Church forbade him from writing about otherworldly things.

There were changes made to the bridge across Tamiami Trail. According to repeated but disagreeing reports, FDOT required that the bridge on the drawing board or that its tower yet to be built be moved about three meters to the north. Given that the cables connecting the tower to the bridge deck were designed to align with alternating diagonal members of the truss, this would mean a new truss design with a new distribution of stresses and strains. This and other missing evidence—or an explanation of why it is missing—will no doubt be discussed in the NTSB final report, but good investigative reporting may uncover some of the information before then. In short, without the appropriate hypotheses, and given that some evidence about the failed bridge is still missing, it may be many months before we know with any degree of certainty what happened in Miami.

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Exhibit D

EXHIBIT 5

ENBRIDGE

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:

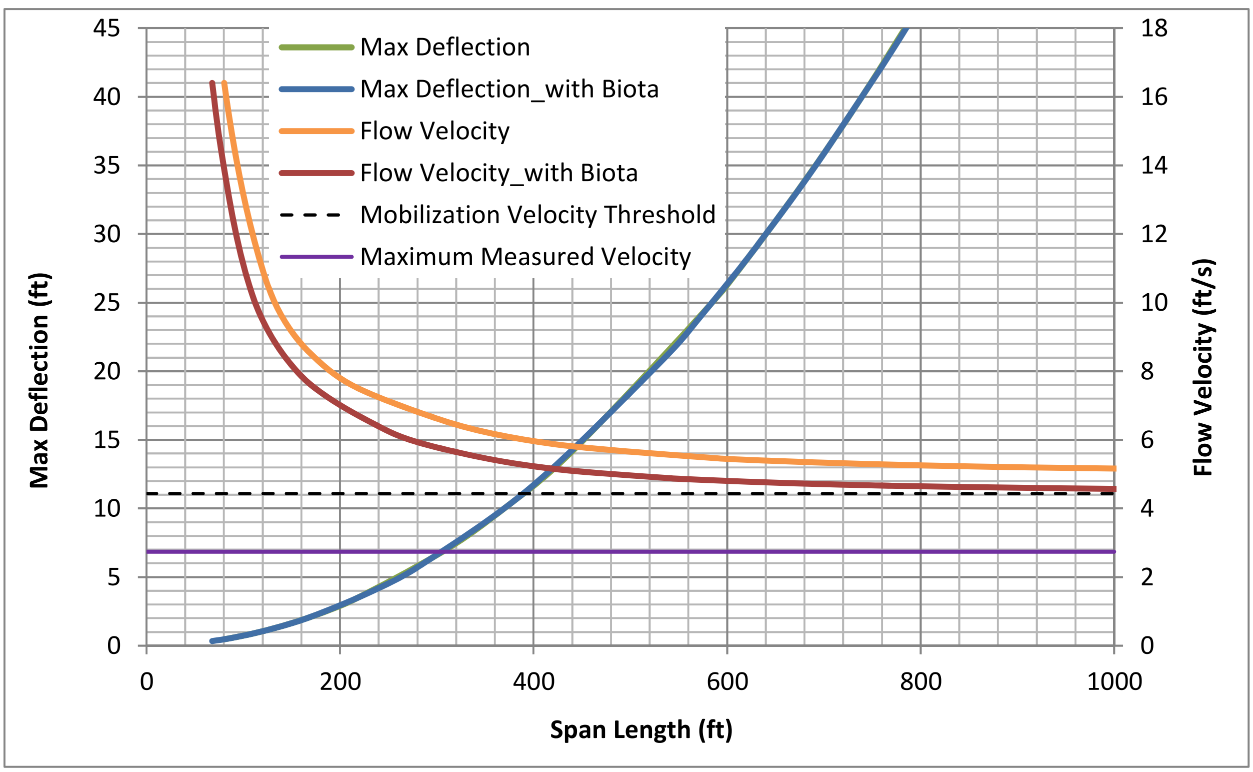
Table 1 – Input Parameters

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.