2.4.1.1.1.4.1.3 Incorrect Operations

As outlined in Section 2.4.1.1.1.3.10, since the Marshall incident in 2010, Enbridge has undertaken a review and upgrade of the management systems by which it controls its pipeline operations. Despite this, numerous pipeline investigation analyses have shown that regardless of the direct cause, some element of incorrect operations, such as procedural, process, implementation or training factors invariably plays a role in the root causes of pipeline failure. Furthermore, it is often impossible to foresee in advance what sequence of events and breakdown in management systems and operating practices might lead to failure. For this reason, failures that are related to incorrect operations cannot be discounted, and are considered a Principal Threat.

Failure Probability Estimation

The US DOT's Pipeline and Hazardous Materials Safety Administration's Hazardous Liquids Failure Incident Database was used to provide historical estimates of failure likelihood associated with incorrect operations in offshore transmission pipeline infrastructure in liquids service (e.g., crude oil and NGLs).

Failure Mechanism

Due to the range of conditions leading to a failure that are considered under this threat, the distribution of potential hole sizes is broad. For the purposes of associating failures attributed to incorrect operations with consequences in the determination of risk, a 3-in. (75 mm) diameter hole was determined through probability-weighting the distribution of hole sizes for offshore pipelines. [71, p. 40]

2.4.1.1.1.4.2 Secondary Threats

Secondary Threats, defined as those threats for which an evaluation of susceptibility attributes indicates a relatively insignificant vulnerability and that therefore have the potential to contribute only at a second-order level in terms of overall failure probability, include the following:

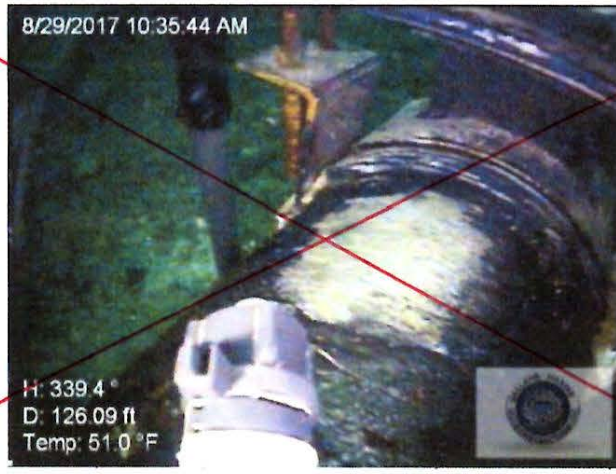
- external corrosion
- internal corrosion
- selective seam corrosion
- stress corrosion cracking (SCC)
- construction and fabrication defects
- manufacturing defects
- equipment failure (non-pipe pressure containing equipment)
- time-dependent failure due to resident mechanical damage
- activation of resident damage from pressure-cycle-induced fatigue.

East Seg. Loc. 3 (339.40 ft)	1.56	0.00	West Seg. Loc. 3 (330.68 ft)	1.63	0.00
East Seg. Loc. 4 (443.11 ft)	1.73	0.17	West Seg. Loc. 4 (454.72 ft)	2.10	0.47
East Seg. Loc. 5 (504.49 ft)	3.01	1.45	West Seg. Loc. 5 (506.17 ft)	3.17	1.54
East Seg. Loc. 6 (651.71 ft)	3.88	2.32	West Seg. Loc. 6 (651.15 ft)	3.88	2.25

A.2.4 Potential Causes of Failure

The possible causes of a maximum worst-case spill from Line 5 in the Straits include corrosion, construction and material defects (cracking and fatigue), natural hazards, third party damage (accidental or sabotage), and operational errors. The Alternatives Analysis identified third party damage and incorrect operations as the principal threats to the pipeline. In line with the understood definition of a worst-case scenario, potential causes were considered if they were plausible, even if very unlikely.

The following assessment includes both pinhole leak and full-bore rupture failure modes. A ~~pinhole~~ leak could plausibly be caused by ~~corrosion, defects~~, fatigue or third party damage, with fatigue being most likely. ~~In 2017, Enbridge provided an interim report of coating damage found during inspections (Figure A4). Coating gaps were confirmed at three locations with an inconclusive result reported for one additional location. Coating gaps were confirmed to cause bare pipe metal to be exposed to the environment. Even though no evidence of metal loss was found to date, the absence of coating increases the probability of corrosion and thus could plausibly contribute to future pinhole leakage.~~



Delete. Irrelevant for current report.

~~Figure A4: Coating damage found during a pipeline inspection~~

A rupture scenario could be caused by incorrect operation~~, such as accidental over-pressurization or improper closing or opening of valves~~; spanning-related stress such as fatigue caused by vortex-induced vibration or excessive unsupported span length; or mechanical damage (including accidental damage, such as anchor drag or damage during maintenance, and malicious third-party damage). The possibility of malicious damage was not addressed in the Alternatives Analysis, but pipeline systems are recognized as a physical target for terrorist groups and have been the focus of numerous plots intended to cause significant damage, as Dancy & Dancy recently summarized:

> *In 2005, a U.S. citizen sought to conspire with Al Qaeda to attack a major natural gas pipeline in the eastern region of the United States. In 2006, federal authorities discovered a posting on a website purportedly linked to Al Qaeda that encouraged attacks on U.S. pipelines using weapons or hidden explosives. In 2007, the U.S. Department of Justice arrested members of a terrorist group planning to attack jet fuel pipelines and storage tanks at the John F. Kennedy International Airport. In 2011, an individual planted a bomb, which did not detonate, along a natural gas pipeline in Oklahoma. In 2012, a man who reportedly had been corresponding with "Unabomber" Ted Kaczynski unsuccessfully attempted to bomb a natural gas pipeline in Plano, Texas. Canadian pipelines have also been targeted by physical attacks. Natural gas pipelines in British Columbia, Canada, were bombed six times between October 2008 and July 2009 by unknown perpetrators in acts classified by authorities as environmentally motivated "domestic terrorism.* (2016, p. 589)

Table A4 summarizes the possible threats considered in this assessment and the related potential failure modes of the pipeline.

Table A4: Primary Line 5 Threats and Associated Failure Modes.

Threats	Mode	Pipes Likely Affected
~~*Corrosion*~~	~~Pinhole leak~~	~~One 20"~~
Cracking (defects and fatigue)	Larger area hole	One 20"
Spanning-related stress	Guillotine rupture	One 20"
3rd Party damage	3" ~~Any~~ hole size	One or both 20"
Incorrect Operation ~~*(over-pressure/hammer shock)*~~	ANY SIZE HOLE TO Guillotine rupture	One or both 20"

Secondary Cause.

A.2.5 System Detection and Response Time

The total response time to an incident equals the spill detection time plus the time required to decide how to respond and to isolate the affected pipeline section, as shown below:

$$\text{Total Response Time} = \text{Spill/Leak Detection Time} + \text{Decision/Isolation Time} \quad (1)$$

A.2.5.1 Spill/Leak Detection Time

Based on real-time transient model sensitivity performance testing on Line 5 following API 1130 conducted in fall of 2017, the Computational Pipeline Monitoring (CPM) system can detect a rupture immediately, and a small leak in 30 minutes or less. Exact detection times are confidential but have been provided for this analysis.

A scenario where either the loss of containment is not detected by the CPM or a detected leak is ignored due to human error, leading to a longer than expected detection time, is also plausible. Leak detection systems complemented by a Supervisory Control and Data Acquisition (SCADA) and CPM, such as those in place at the Straits crossing, are used by the pipeline industry to reduce both the frequency and volume of liquid (oil and natural gas liquids) and gas spilled. In addition to aiding in leak detection, SCADA and CPM systems are capable of quickly closing valves and shutting down the pumps. Leak Detection (LD) and monitoring systems are essential tools for any pipeline operator. The primary purpose of an LD system is to detect and provide the approximate location of the leak. A system that is automated could provide for a timely warning and could prevent a major spill by closing valves and stopping the flow in a pipe.

There are two major categories of LD, internal and external; both of them use technologies such as sensors detecting hydrocarbons, acoustic, temperature variation, pressure drop and material balance. Operators install a combination (hybrid) of these systems because the pipeline is used to transport various products such as crude, refined and Natural Liquid Gas (NLG) using the same conduit according to seasonal needs. These detections systems are only accurate for steady-state operations. A pipeline under transient conditions (start-up and shut-down) produce additional background noise which results in inaccurate detection. It is critical for operators to have exact procedures to minimize the potential for error during start-up and shut-down.

5, upstream and downstream of the Straits. In addition, our practice is to dispatch staff to site to control any manual valves in the area, which would include closing the valves at the Straits. Such actions would take between 15 minutes to 2 hours depending on the time of day and location of existing personnel. (Shamla 2015, emphasis added):

This length of time seems appropriate given that, although there are Enbridge personnel based locally in the Straits area, in a worst case scenario with severe weather conditions, travel could be difficult and the Mackinac Bridge could be closed, significantly increasing the typical response time. Furthermore, we requested that Enbridge estimate the time that would be required to manually close the valves at the north side of the Straits only, thus interrupting the flow toward the underwater portions of Line 5. This time has been estimated by Enbridge to be approximately 1 hour. Therefore, we have also estimated the volume that would be released in a scenario where the northern end of the Straits pipelines is closed after one hour.

A.2.6 Tiers of Failure

As previously defined in Table A4, several failure types were considered based upon plausible threats. In Table A5 below, these threats are now grouped into five Tiers of failure in order of severity in creating plausible worst case scenarios.

Table A5. Primary Threats Induced Pipeline Manifestation

Threats	Manifestation	Pipes Likely Affected	Tier
Spanning stress	Guillotine rupture	One 20"	Tier 1 Rupture or Pin-hole in one 20" line with immediate response
Cracking (fatigue)	Larger area hole	One 20"	
~~*Corrosion*~~	~~Pinhole leak~~	~~One 20"~~	
Third-party damage	Any hole size	One 20"	Tier 2 Rupture or Pin-hole in one 20" line with maximum allowable response time
Incorrect Operation (~~over pressure/hammer shock~~)	~~Guillotine rupture~~ 3" HOLE	One or both 20"	Tier 3 ~~Rupture in~~ both 20" lines with primary valve failure
Third-party damage	Any hole size to rupture	One or both 20"	Tier 4 Rupture in one 20" line with manual valve closure Tier 5 Rupture in both 20" lines with manual valve closure