

# **Investigation of Disturbances to Line 5 in the Straits of Mackinac Discovered in May and June of 2020**

UPDATED August 21, 2020

## OVERVIEW AND EXECUTIVE SUMMARY

This Investigation Report (Report) reviews the disturbances recently discovered during planned maintenance and inspection activities on the Line 5 Dual Pipelines:

- On May 20, Enbridge's planned maintenance and inspection of the Dual Pipelines' crossing, utilizing a remotely operated vehicle (ROV), discovered an area of rubs and scraping on the East Line at a depth of approximately 235 feet. This area is denoted as **EAP-9** throughout this Report (based on the name of the pipeline support nearest to the identified area).
- On June 18, ongoing inspection and maintenance work on the East Line revealed a damaged pipeline support denoted as **EP-17-1**. The installed pipeline support had been moved off of its vertical axis and the support saddle bolts had been bent in a NNE to SSW direction. EP-17-1 is at a depth of approximately 235 feet.
- On June 19, an ROV inspection on West Line conducted as a result of the June 18 discovery led to the discovery of a small area of disturbed biota and calcareous deposit that came to be known as the West Line Feature of Interest. Drag marks subsequently found on the bottom of the Straits led to the conclusion that the West Line Feature of Interest was probably caused by the same source that caused a second Feature of Interest on the East Line, which also consists of a loss of biota and the formation of a calcareous deposit. These two locations are cumulatively denoted as the "**Features of Interest**" throughout this Report. The Features of Interest are at depths between 235 and 245 feet.

This Report summarizes the results of Enbridge's investigation into the causes and impacts associated with the areas identified above. This Report also provides Enbridge's views on whether such discoveries impact the integrity of the Dual Pipelines, the effectiveness of preventive measures existing as of June 2020, and a description of additional measures implemented or planned in light of the discoveries of the areas of damage or disturbance. These issues are addressed in the following sections of this Report:

- I. Background Map
- II. Analysis of Impact and Subsequent Repairs
- III. Investigation of Cause
- IV. Preventive Measures: Historical and Additional Measures

The evidence available supports a conclusion that a cable-like object (such as a mooring cable), most likely suspended from a surface vessel, caused the damage at both EAP-9 and EP-17-1. The evidence also supports a conclusion that the type of surface vessel involved was a small to moderately-sized vessel. It is possible that a surface vessel could have been anchored near the Line 5 Dual Pipelines and its cable became entangled around and pulled the pipeline support at EP-17-1. Some portion of that anchor cable, or another cable, perhaps with something attached to it, could have damaged the pipe coating at EAP-9. It is also clear from the evidence that the damage at these locations was not the result of a large vessel dragging its anchor through the shipping channel.

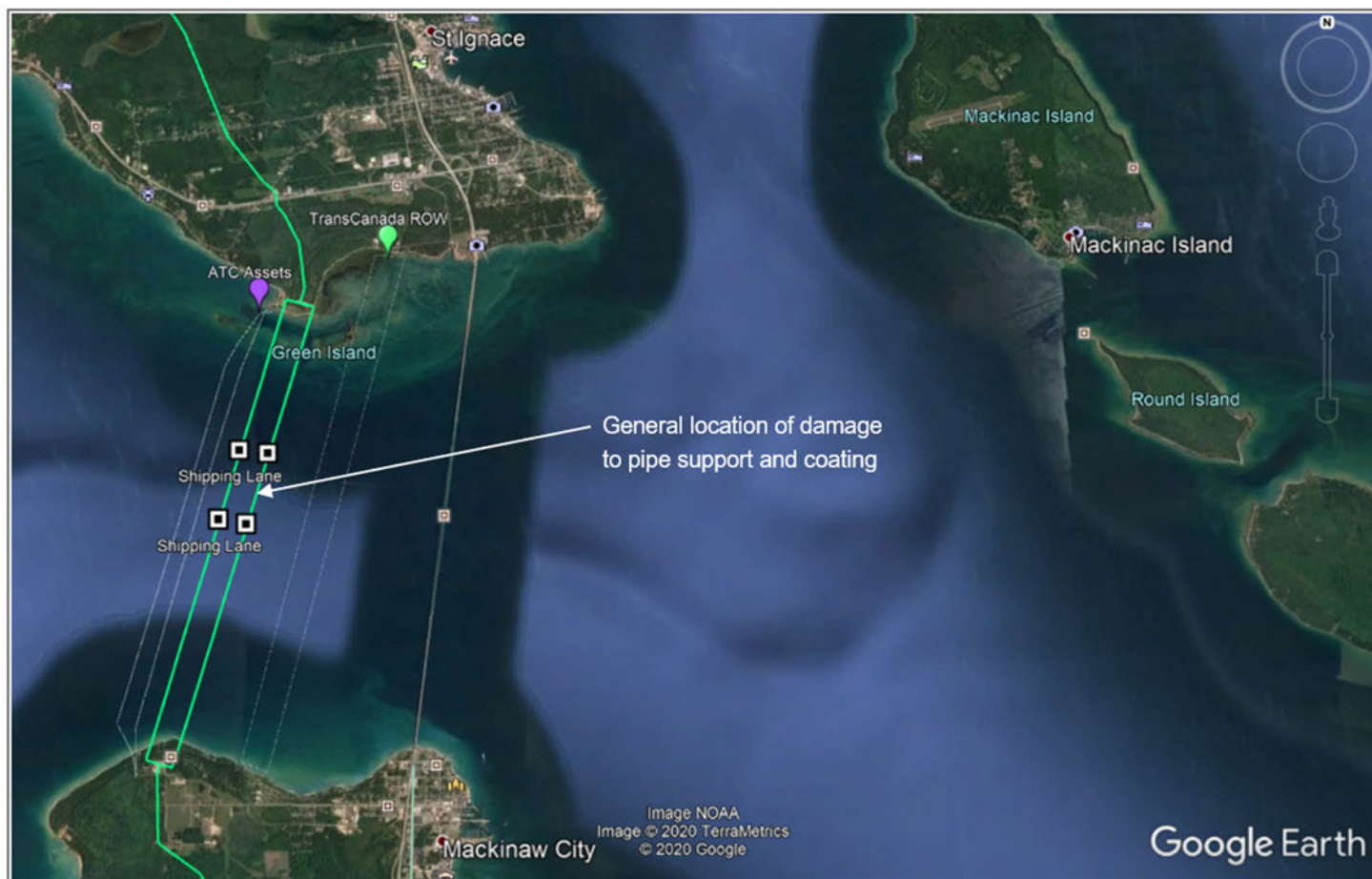
Enbridge has reviewed a number of sources in an attempt to identify a surface vessel that could have caused the damage described above. That review was informed by Enbridge's marine command center in Mackinaw City which has been tracking vessels with automatic identification system (AIS) data that identifies the GPS tracks of vessels operating in proximity to the Line 5 Dual Pipelines. Based on Enbridge's review of that data, Enbridge identified 13 small to moderately-sized vessels that travelled in proximity to the Line 5 Dual Pipelines. 5 of those vessels travelled in a manner consistent with the orientation of the damage at EAP-9 and EP-17-1.

The evidence available also supports a conclusion that the Features of Interest could have been caused by a vessel transiting the shipping channel. This is based on the east-to-west (or west-to-east) alignment of the disturbances, along with a light track in the lakebed that was observed extending in the same alignment away from the disturbances. Due to the minimal depth of the light track, along with the fact that only biota was removed from the pipelines, it is believed that the light mark in the lakebed was the result of a dangling cable or a small vessel anchor; a heavy ship anchor would have left a deeper impression in the clay lakebed.

A root cause analysis (RCA) of the incident was conducted to support the broader investigation and ensure the prevention of recurrence. Associated additional damage prevention mitigations identified through this effort are actively in development, and are being implemented or will be implemented, to more fully address similar threats in the future.

## I. BACKGROUND MAP

The image below reflects the general location of the damage to pipe support EP-17-1 and to coating in the vicinity of EAP-9.



## II. ANALYSIS OF IMPACT AND SUBSEQUENT REPAIRS

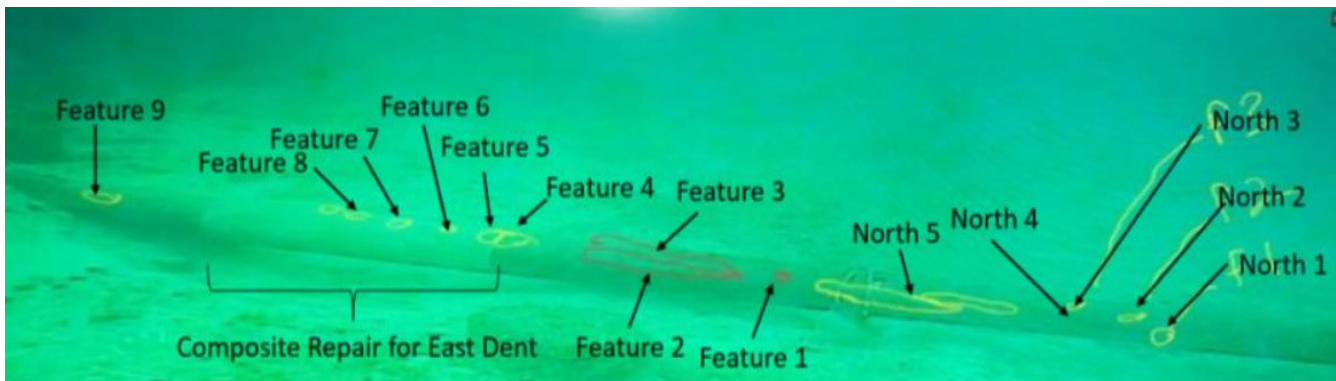
Integrity engineers analyzed the potential impact to pipeline safety resulting from each of the three areas at the time they were discovered. This section confirms the safety of the East and West Leg in light of the discovered areas.

### A. EAP-9

The coating disturbance and corresponding pipe features at EAP-9 were inspected through diver and ROV examinations (see figure 1).

Pipeline engineers analyzed the features and deemed them non-injurious to the pipeline as supported by a fitness for service assessment of the pipeline. Specifically, integrity engineers determined that no safety issue existed based on the assessment of the minor surface scratches, and that only minor coating repairs would be required to address the coating disturbance.<sup>1</sup>

Based on this analysis, Enbridge performed repairs to the features observed at EAP-9 from May 20 to June 7. This consisted of buffing of surface scratches and performing coating repairs where bare metal was found, pursuant to the work plans previously approved by the State of Michigan and the EPA. Repairs were completed on June 7, 2020. The exterior disturbances observed at EAP-9 no longer exist and the pipe is fully protected.



**Figure 1: Coating disturbances at EAP-9 location**

### B. EP-17-1

The coating disturbances and corresponding dislodged pipeline support at EP-17-1 were inspected through diver and ROV examinations.

Enbridge also completed an Engineering Assessment for the East Line following the discovery of the damaged pipeline support. That Engineering Assessment (attached hereto as Attachment 2) included detailed modelling and fitness for service assessments to confirm and demonstrate that the East Line is safe for continued operation. Through that Assessment, it was determined that approximately 2600 lbs of force was needed to move the pipeline support saddle out of position. This dragging force equates to less than 54psi or less than 0.18% specified minimum yield strength (SMYS) of the pipe material. The level of force needed to dislodge or bend the installed screw anchor support is thus much less than the level of force needed to damage the steel wall of the pipe.

The Engineering Assessment further determined that the lack of a pipeline support at the location of EP-17-1 does not impair the integrity of the pipeline or warrant the installation of a new pipeline support in proximity to that location before operations can resume. This is due to the fact that even following the damage to EP-17-1 and its subsequent removal, the pipe on either side of EP-17-1 was supported by nearby clay touchdown points that limited the length of unsupported pipe at this location to be 66 feet. Importantly, Enbridge has also recently installed an additional support (EAP-7) approximately 58 feet north of EP-17-1. Even though a pipeline support is not required at this location for purposes of safety or compliance with the 1953 Easement, Enbridge has submitted requests to

<sup>1</sup> See EAP-9 Coating Inspection (May 28, 2020) (copy attached as Attachment 1).

the US Army Corps of Engineers and Michigan Department of Environment, Great Lakes, and Energy (EGLE) to modify its existing permits to install a new pipeline support in proximity to EP-17-1.<sup>2</sup> EGLE has already granted the modification to the existing permit necessary to perform the installation; the Army Corps has determined that a nationwide permit may be used, but is also engaging in Tribal consultation on Enbridge's use of the permit. That pipeline support will be installed upon obtaining the necessary regulatory approvals.

An image of the damaged pipeline support at EP-17-1 is provided in Figure 2 below; an image of markings on the damaged pipeline support is provided in Figure 3 below.



**Figure 2: EP-17-1 pipe support**



**Figure 3: Cable marks on EP-17-1 pipe support**

#### **1. Enbridge's Response to PHMSA June 29, 2020 Letter Concerning EP-17-1**

As of July 15, 2020, Enbridge fully responded to the requests for information set forth in PHMSA's June 29, 2020 letter related to the bent pipeline support at EP-17-1. As part of Enbridge's response to PHMSA, Enbridge provided PHMSA with the letter report prepared by an independent third-party (DNV GL USA, Inc. ("DNV GL")) to confirm the conclusions set forth in Enbridge's Engineering Assessment for the East Line. DNV GL confirmed the methodologies used by Enbridge in the Engineering Assessment were appropriate and that no evidence exists to call into question the ability of the East Line to safely operate. DNV's letter report further confirmed that: (i) the damaged support at EP-17-1 did not put any undue stress/strain on the East Line; (ii) Enbridge appropriately calculated that the force necessary to remove EP-17-1 from position was approximately 2,600 lbs; and (iii) a new pipeline support need not be installed in proximity to EP-17-1 before the East Line may safely operate because the pipe at that location is already adequately supported by the existence of nearby touchdown points and a recently-installed pipeline support (EAP-7) installed 58-feet north of EP-17-1.

No further actions are necessary, and the East Line has been demonstrated to be safe to return to operational service. Post-restart of the East Line, Enbridge intends to conduct a combined MFL, Caliper, and IMU in-line inspection ("ILI"). That ILI will be completed to further verify the information contained in the Engineering Assessment; it is not needed to determine whether the East Line is safe to operate.

#### **C. Features of Interest**

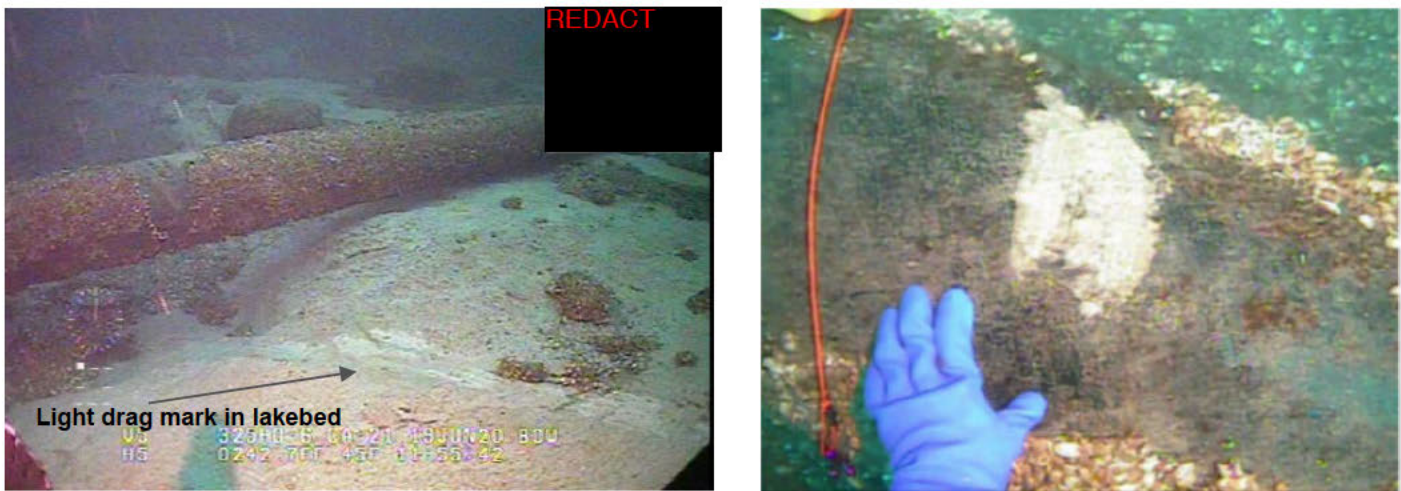
Enbridge completed integrity assessments of the East and West Line Features of Interest that concluded that identified disturbances at these locations do not present an integrity concern to the pipelines and do not interfere with their normal operations. This conclusion was based on the fact that the Features of Interest each consisted only of disturbed biota and calcareous deposits. No inline inspections

<sup>2</sup> The 1953 Easement has a maximum span limit of 75 feet. The Federal Consent Decree entered and modified in *United States v. Enbridge Energy, Limited Partnership, et al.*, Civ. No. 1:16-cv-0914 (W.D. Mich.), does require as a precautionary measure that spans greater than 65 feet, or where clay touchdowns are less than 10 feet in length, be controlled by the addition of supports as needed. As discussed in the text, Enbridge is preparing to replace EP-17-1, as provided in the Consent Decree.

(ILI) performed prior to the discovery of the Features of Interest revealed any anomalies in proximity to these locations. The result of the ILI conducted on July 1, 2020 on the West Line similarly confirmed that no metal loss or geometry anomalies exist in proximity to the West Leg Feature of Interest. The calcareous deposits are similar to other such deposits observed on the Line 5 Dual Pipelines. These are protective mineral deposits that are formed as a result of a properly functioning and effective cathodic protection system. None of these observations suggest any impairment of the safety of the lines.

PHMSA was provided with details regarding the West Line Feature of Interest, including a copy of the Integrity Assessment (copy attached hereto as Attachment 3) and ROV videos. In its June 29, 2020 letter to Enbridge, PHMSA indicated that with regard to the West Line, PHMSA “has not identified any safety concerns, and based on available information, has no technical or safety-related objection to the continued operation of that leg.”

Images of the West Line and East Line Features of Interest are provided in Figure 4 below, along with the light drag mark observed in the clay lakebed.



**Figure 4: West Line Feature of Interest and East Line Feature of Interest**

### III. INVESTIGATION INTO POSSIBLE CAUSE OF DISTURBANCES AT EAP-9, EP-17-1, AND FEATURES OF INTEREST

#### A. Investigation Methodology

Enbridge's investigation has entailed the initiation and completion of the following actions:

- (1) Conducting diver and ROV examinations to identify and/or collect visual evidence at EAP-9, EP-17-1, and the Features of Interest.
- (2) Completion of a new ILI on the West Line and review of that data, along with review of prior ILI data for the West and East Lines.
- (3) Reviewing acoustic monitoring results generated by Enbridge's *ThreatScan* system to identify any acoustic signatures that may be linked to EAP-9 or EP-17-1.
- (4) Obtaining and reviewing vessel AIS data to identify vessel operations occurring over the last year in proximity to EAP-9, EP-17-1.
- (5) Reviewing information obtained through Enbridge's Coordinated System for anchor strike mitigation that may be related to the damage/disturbances at EAP-9, EP-17-1, and the Features of Interest.
- (6) Interviewing crews of Enbridge-contracted vessels that have operated in proximity to the Dual Pipelines over the past year, including maritime expert review of the contractors' anchoring plans/procedures.
- (7) Removal and inspection of damaged pipeline support at EP-17-1.
- (8) Seeking from the U.S. Coast Guard all requests made by vessels to the Captain of the Port to obtain authorization to anchor in the Regulated Navigation Area for the Straits established under 33 C.F.R. § 165.944.
- (9) Detailed finite element modelling to determine directional forces and loads to result in the observed damage.
- (10) Notification of PHMSA, State of Michigan, US Coast Guard, EPA and utility companies in the area.
- (11) Removal of damaged EP-17-1 pipeline support and 3<sup>rd</sup> party laboratory analysis.

#### B. Evidence

The evidence available supports a conclusion that a steel cable (such as a mooring cable) most likely suspended from a surface vessel caused the damage/disturbances at both EAP-9 and EP-17-1. The evidence also supports a conclusion that the type of surface vessel involved was a small to moderately-sized vessel. The low force impact, directional orientation of the damage/disturbances, and lack of drag marks in the lakebed also indicates that it was not an East/West transiting freighter or other large vessel dragging an anchor through the shipping channel that caused the damage/disturbances at EAP-9 and EP-17-1 (such large vessels do not typically travel north-to-south in the Straits). The date range and direction of damage has allowed Enbridge to narrow the cause to 13 vessels that operated within 500ft of EAP-9 and EP-17-1. It is possible that one of the 13 vessels could have been anchored near the Line 5 Dual Pipelines and its cable became entangled around and pulled the pipeline support at EP-17-1. Some portion of that anchor cable, or another cable, perhaps with something attached to it, could have damaged the pipe coating at EAP-9. The specific vessel activities that are possible causes of the damage/disturbances at EAP-9 and EP-17-1 are identified in subsection (ii) below.

A summary of evidence gathered as a result of the investigation is provided in APPENDIX A.

##### i. Visual Observations

Following the discovery of the disturbances at EAP-9 and EP-17-1, Enbridge conducted a full visual inspection of the East and West Lines. Based on the existence of cable markings on the damaged pipeline support at EP-17-1 (as depicted in Figure 3 above) and lack of anchor marks on the pipeline support or in the surrounding clay lake bottom,<sup>3</sup> it is believed that a cable-like object suspended from a vessel at the surface became entangled around the pipeline support, pulling it in a NNE to SSW direction.

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<sup>3</sup> For example, the clamshell marks resulting from construction trenching activities conducted nearly 70 years ago to install the Line 5 Dual Pipelines are still evident in the clay lakebed today. If the disturbance at EP-17-1 was caused by an anchor of any size, that anchor would have left a notable trench or marking adjacent to the damage. This conclusion is reinforced by the fact that such a marking from the 2018 anchor strike can still be seen on the lakebed.

Inspection data is not conclusive but suggests that EAP-9 and EP-17-1 may have been caused by the same event. The direction of force of the EAP-9 coating damage is approximately aligned NNE to SSW. The EP-17-1 disturbance is similarly directionally oriented, with the pipeline support bent (having been pulled) NNE to SSW. Thus, the: (i) close proximity of the two locations; (ii) the similar orientation of the damage; and (iii) the estimated timeframe in which the disturbances occurred all suggest that the two events may have been caused by the same activity.

The coating disturbance at EAP-9 is also consistent with a cable-like object, potentially with something attached to it, dragging over the top of the pipe in a NNE to SSW direction. If a heavier object was involved, there would be an expectation of a more extensive disturbance on the lakebed and pipelines. While the end of a cable seems likely, the possibility of a small vessel anchor cannot be ruled out at this point in the investigation as a possible cause of the damage at EAP-9. The dimensions of the coating disturbances, for example, could be consistent with the type of anchor used for a small to moderately-sized vessel. A large anchor or object dangling from a vessel is unlikely given the lack of identifiable marks in the clay lakebed that would be observable (similar to those still observable in the lakebed resulting from the 2018 anchor strike event).

Adjacent to the West Line Feature of interest, a light track in the lakebed was identified through ROV inspection. The light track was found to extend between the East and West Lines, with similar evidence of removed biota and the formation of a calcareous deposit on the East Line (East Line Feature of Interest). The light track was found to extend in either direction, in an east-to-west (or west-to-east) alignment, consistent with vessels transiting the shipping channel. Due to the minimal depth of the light track, along with the fact that no damage to the East or West Line pipes occurred (i.e., the Features consist of only removed biota and some coating disturbance), it is believed that the light mark was the result of a dangling cable or a small vessel anchor; a heavy ship anchor would have left a deeper impression in the clay lakebed.

Based on its review of inspection data from 2018 and 2019, Enbridge estimates that the disturbances at EAP-9 and EP-17-1 occurred after the June 27, 2019 ROV inspection and before the inspection occurring on May 20, 2020. Similarly, Enbridge has confirmed that the Features of Interest were not present in September 2018 inspection data. This, combined with the calcareous deposits which are known to take several months to develop, Enbridge estimates that the disturbances at the Features of Interest occurred between September of 2018 and the Fall of 2019.

The conclusion that all of the disturbances were caused by a cable or small object is supported by the fact that Enbridge's *ThreatScan* acoustic strike detection system, which is part of the Line 5 Straits monitoring program, did not record in any acoustic signatures in excess of the reporting threshold. The type of disturbance occurring at EAP-9, EP-17-1, and the Features of Interest, if they would have been caused by a larger object (such as a large anchor), would be expected to result in acoustic signatures detectable by the *ThreatScan* system. The *ThreatScan* system, for example, detected signatures associated with the vessel anchor that resulted in the 2018 anchor strike event.<sup>4</sup>

## ii. Vessel Activity

Enbridge has identified vessel activity consistent with a possible cause of the observed disturbances at EAP-9 and EP-17-1.

In order to identify vessel activity occurring over this timeframe and in proximity to the damage/disturbances, Enbridge reviewed AIS data collected through its *Guardian:protect* system, which has been installed since December 6, 2017. Such AIS data allows Enbridge to review the precise GPS track of each vessel with an AIS system. The US Coast Guard specifically requires that certain vessels have AIS installed, including self-propelled vessels that are: greater than 65-feet in length engaged in commercial service; towing vessels greater than 26 feet or more than 600 horsepower; self-propelled vessels that carry more than 150 passengers; self-propelled vessels

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<sup>4</sup> The *ThreatScan* system is a prototype system under development. Accordingly, the system was not fully operational at all periods of time in 2019-2020. Specifically, Enbridge's investigation also identified the following three periods of time when the *ThreatScan* was not, due to technical issues, alarming or storing complete acoustic data: Aug 16, 2019 16:00 MST to Aug 20, 2019 07:00 MST; Nov 29, 2019 04:00 MST to Dec 09, 2019 08:00 MST; and Dec 14, 2019 11:53 MST to Feb 21, 2020 13:37 MST. Because it is possible that the *ThreatScan* system was not operational at the time of EAP-9 or EP-17-1, the lack of acoustic signatures is only supportive evidence and cannot be relied upon as conclusive evidence that there was no strong acoustic signature generated that would have met or exceeded the *ThreatScan* reporting threshold.

engaged in dredging operations; self-propelled vessels engaged in the movement of dangerous or flammable cargo; and fishing industry vessels. While all vessels are not required to have AIS systems, it is believed that most non-AIS vessels would not likely be capable of exerting the 2,600-pound force necessary to damage the pipeline support at EP-17-1; nor would such vessels be likely to carry cable of sufficient size and length (more than 200 ft) required to reach the depths and cause the observed damage/disturbances. However, non-AIS vessels cannot be fully ruled out at this point as a possible cause.

Enbridge narrowed down the AIS data to identify only those GPS tracks for vessels: (i) passing within 500 feet of EAP-9 and EP-17-1; (ii) since June 27, 2019; and (iii) with a course constraint of +/- 40 degrees of north/south movement. The course constraint was added to remove commercial vessels transiting the Straits in an east-to-west or west-to-east direction within the shipping channel, movement which is inconsistent with the NNE to SSW-aligned damage/disturbances at EAP-9 and EP-17-1. The AIS data includes the Maritime Mobile Service Identity ("MMSI") to allow Enbridge to review detailed information regarding each vessel, including its size.

Enbridge identified 13 vessels that meet the criteria identified above. Based on Enbridge's review of all 191 AIS vessel tracks associated with those 13 vessels, Enbridge, in conjunction with maritime experts, has identified 5 vessels as "possible" causes, including 4 vessels contracted by Enbridge. Any of the 5 vessels would have been capable of dragging a cable that became wrapped around the pipeline support, with the cable eventually slipping off the pipeline support as the vessel pulled the cable and the anchor possibly attached to it.

Further information on these vessels is provided in APPENDIX B.

### iii. Enbridge Has Interviewed Vessel Contractors

Enbridge has interviewed the operators of vessels contracted by it to perform maintenance activities associated with the Line 5 Dual Pipelines, and activities related to the geotechnical investigations being conducted to inform the design the Great Lakes Tunnel Project. Enbridge also obtained from such operators their vessel anchoring plans, procedures, and logs.

The operators were not aware of any instance in which their vessels may have caused the damage at EAP-9, EP-17-1, or the Features of Interest.

Maritime experts have reviewed the internal anchoring plans and procedures for these companies. The maritime experts will be identifying potential improvements to those plans and procedures, including standard requirements for their contents, to ensure that maintenance activities conducted by Enbridge contractors do not result in damage to the Line 5 Dual Pipelines.

## C. **Summary of Observations and Conclusions Related to Cause**

As a result of its investigation, Enbridge has identified the following key observations:

- EAP-9 and EP-17-1:
  - The features at EAP-9 and EP-17-1 are oriented in a NNE to SSW direction, suggesting that the damage was not caused by any large commercial vessels transiting the Straits in an east-to-west (or west-to-east) direction that could pose a safety threat to the Dual Pipelines.
  - No features in the lakebed or on the Pipelines have been observed to suggest that a large object capable of posing a threat to the safety of the Dual Pipelines caused the observed disturbances.
  - Diver and ROV evidence suggest that a cable-like object dangling from a small to moderate-sized vessel became entangled with the leg of the pipe support at EP-17-1 and may have caused the disturbance at EAP-9. However, a small anchor could have caused the disturbance at EAP-9.
  - Enbridge has identified the AIS vessel tracks of 13 vessels that travelled within 500 feet of the disturbance at EAP-9 and EP-17-1, and in a direction that could have caused the NNE to SSW-oriented damage. 5 of these vessels engaged in activities that are considered to be more likely to have caused the disturbance; 4 such vessels were contracted by Enbridge.
- Features of Interest:
  - The directional alignment of observed disturbances indicates that the vessel activity resulting in the disturbances was travelling directly along the middle of the shipping channel in an east-to-west (or west-to-east) direction. This activity could be associated with commercial vessels that regularly transit the Straits.

- The disturbances are superficial, and not resulting in any dent or other anomaly to the steel pipe that would be expected were the pipeline struck by an anchor of a larger commercial vessel utilizing the shipping channel.
- The light track and disturbances suggest that they were caused by a cable or chain, possibly with a lightweight appurtenance attached.

#### D. Additional Investigative Actions

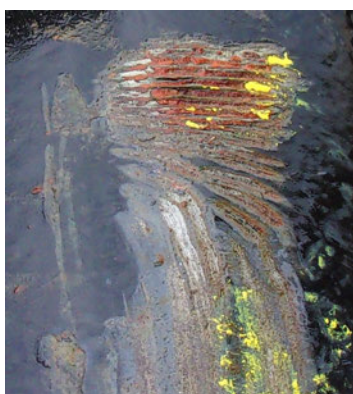
i. Enbridge Has Removed and Examined the Damaged Pipeline Support in an Effort to Inform the Investigation

Enbridge has removed the damaged pipeline support at EP-17-1. PHMSA and State of Michigan representatives were provided with the opportunity to inspect, and did inspect, the damaged pipeline support onshore. Enbridge retained a third-party expert, DNV GL, to conduct an inspection and examination of the damaged pipeline support post-removal. Specifically, the third-party expert has:

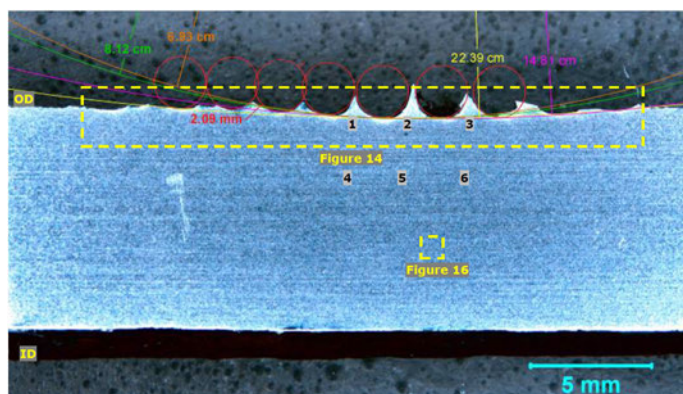
- Conducted a visual and nondestructive examination of the pipeline support;
- Taken physical measurements of the pipeline support, including documentation of any anomalies, markings, or deformations and mapping its thickness;
- Performed metallurgical analysis on the damage areas;
- Performed hardness testing to estimate the mechanical properties of the helical piles; mechanical properties are within the specifications for the materials used to fabricate the support anchor.

The results of the metallurgical analysis conducted by DNV GL are included in the report attached as APPENDIX C, and a summary of that report is provided below.

Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) were conducted on the surfaces of the cross-member of the support structure where evidence of gouging was found. Metallurgical cross sections were also taken from these same locations. Based on the visual examination and SEM results, the gouge marks are consistent with a steel cable. The wear morphology (determined by the SEM 10X to 500X magnification) indicates that the cable slid across the pipeline support in an East to West direction, consistent with a vessel pulling that cable at the water's surface in a NNE to SSW direction. Though sizing of the cable is not possible to ascertain from assessment of the cross sections alone, the gouge striations were determined to be roughly 2 mm in diameter. The gouge marks and striations sizes are consistent with either a 1-1/8" 6x26 IWRC or a 1-1/2" 6x36 steel cable, which are typical of what is used for marine mooring applications.



**Figure 5: Example of Gouged Area**



**Figure 6: Metallurgical Cross-Section of Gouged Area**

Energy Dispersive X-Ray Spectroscopy (EDS) was used to assess whether or not evidence of organic (i.e. paint) or inorganic (i.e. zinc) coating present in the gouged areas. No evidence of organic or inorganic coatings were detected, leading to the conclusion that the cable was a bare steel cable.

## ii. Enbridge is Seeking US Coast Guard Anchoring Data to Inform the Investigation

On July 2, 2020, Enbridge inquired with the Prevention Department Head at US Coast Guard Sector Sault Ste. Marie about obtaining information possessed by the US Coast Guard regarding vessels that have requested to anchor in the Straits RNA. Under 33 C.F.R. 165.944, all the following vessels must obtain the Captain of the Port's approval to deploy an anchor within the Straits RNA:

- Vessels 40 meters (131 feet) or more in length; towing vessels 20 meters (approximately 65 feet) or more in length;
- Vessels certificated to carry 50 or more passengers; and
- Each dredge or floating plant.

Enbridge was advised to submit a Freedom of Information Act (FOIA) request to the US Coast Guard to obtain this information. On July 10, 2020, Enbridge's FOIA request was submitted electronically to the US Coast Guard. Enbridge will review any information provided by the US Coast Guard to identify any vessels that requested to anchor in proximity to EAP-9, EP-17-1, and the Features of Interest. However, the recommendations identified in this report are intended to reduce the risk of similar occurrences regardless of the identity of the source vessel. Accordingly, it is not expected that any information that may be provided by the US Coast Guard will alter the recommendations in this report or require that this report be supplemented.

## E. Other findings

Enbridge notes that it discovered and recovered a small Danforth-style anchor, likely from a small vessel, lying on the lakebed of the Straits approximately one foot from the light track mentioned above and at a location approximately 1,500 feet West of the West Leg. The light track extends alongside and beyond the anchor location, suggesting that the anchor was not the cause of the Features of Interest. Based on visual inspection of the anchor (Figures 7 and 8 below), there is no definitive evidence to support a conclusion that the recovered anchor was the cause of the damage/disturbances at EAP-9, EP-17-1, or the Features of the Interest.



**Figure 7: Danforth-style Anchor as discovered on lakebed**



**Figure 8: Danforth-style Anchor as recovered**

## V. PREVENTIVE MEASURES: HISTORICAL MEASURES, ROOT CAUSE ANALYSIS, AND ADDITIONAL MEASURES

### A. Enbridge Prevention Measures

Enbridge has extensive and robust systems and procedures in place to prevent threats to the Line 5 Dual Pipelines and mitigate the consequences of any threats, should they occur. A review of all such systems and procedures determined that they were operating as intended and effective. Such systems/procedures include the following:

- Leak Detection: Enbridge employs a comprehensive, multi-layered approach to leak detection that operates continuously 24 hours per day, seven days per week. Enbridge is committed to the continuous improvement of its leak detection strategy. This strategy encompasses multiple computational leak detection methods, each with a different focus and featuring differing technology, resources and timing. Used together, these methods provide an overlapping and comprehensive leak detection capability under all operating scenarios to identify potential releases and generate alarms in the Enbridge Control Center and resulting in a shutdown, as well as the closure of automatic valves in response to a pressure drop below a specified level to

prevent ongoing operation of the pipeline. In the case of the recent damage, the leak detection system and operational procedures were not called into action, given that the damage to EAP-9, EP-17-1, and the Features of Interest did not result in any damage to the Pipelines that could cause a release.

- Routine Underwater Inspections: Enbridge periodically conducts underwater diver and ROV inspections of the Line 5 Dual Pipelines' crossing of the Straits. The inspections conducted in May-June 2020 identified the disturbances at EAP-9, EP-17-1, and the Features of Interest. The information generated/identified as a result of the inspections was conveyed to Enbridge's Operations personnel, who out of an abundance of caution, directed the closure of the West and East Legs pending further investigation.
- Annual ILI Inspections: Enbridge performs annual ILI inspections capable of detecting small changes in wall thickness or dents. Enbridge's review of historical ILI data confirmed that no metal loss or geometry anomalies above the reporting threshold were identified in proximity to EAP-9, EP-17-1, or the Features of Interest. The ILI conducted on the West Leg on July 1, 2020 confirmed that no metal loss or geometry anomalies exist in proximity to the West Leg Feature of interest. Enbridge's ILI program operated correctly and effectively, given that the damage/disturbances at issue in this Report would be considered minor and below detection thresholds. Any features caused by vessel activity that exceed reporting thresholds would be expected to be identified in historical or future ILIs, as occurred through the identification of dent anomalies following the completion of ILIs conducted after the 2018 anchor strike event.
- ThreatScan: Enbridge installed a *ThreatScan* system that is designed to acoustically detect significant impacts that might present a threat to the Pipelines and alert Enbridge personnel. Based on the vendor experience, the damage to EAP-9, EP-17-1, and the Features of Interest would not be expected to generate an acoustic signature that would exceed the *ThreatScan* system reporting/alarm threshold.
- Enbridge's Coordinated System: Enbridge has implemented a Coordinated System to reduce the risk of a vessel's anchor puncturing, dragging or otherwise damaging the Line 5 Dual Pipelines. The Coordinated System is operated 24 hours per day, seven days per week out of the land-based Enbridge Straits Maritime Operation Center (ESMOC) located in Mackinaw City. The Coordinated System reduces the risk and mitigates the consequences of a vessel's anchor puncturing, dragging or otherwise damaging the Line 5 Dual Pipelines through the following elements:
  - Visual Verification: The ESMOC utilizes an AIS and marine chart plotter to track and identify vessels with AIS that are transiting the Straits. For all vessels that are identified as intending to transit the Straits that meet the size criteria established by the US Coast Guard's RNA, the ESMOC will: (i) assign an Event Number to that vessel; (ii) continue to monitor that vessel as it transits through the Straits; and (iii) require that observations be conducted (either shore-based or on-water) to confirm that the vessel is operating safely and that an unsafe condition is not present that poses a risk to the Line 5 Dual Pipelines. An unsafe condition is any observed condition that poses a risk to the Dual Pipelines, which may include but is not limited to a deployed anchor or cable. Shore-based observations are conducted at appropriate shoreline locations utilizing high-resolution optics to identify any unsafe vessel conditions. On-water observations are conducted using a fleet of three patrol boats that identify any unsafe vessel conditions from on-water locations in proximity to transiting vessels.
  - Vessel Communication: For all vessels assigned an Event Number, the ESMOC communicates directly with vessels to inform them: of the location of the Line 5 Dual Pipelines; and to advise the vessel that the ESMOC will be conducting observations of the vessel. Each vessel with AIS that enters the US Coast Guard's RNA also receives an automated message issued via the *Guardian:protect* system that will indicate that the vessel is entering a federally-regulated navigational area and that no-anchoring is permitted. That *Guardian:protect* system also transmits four virtual aids to navigation that electronically depict the location of the Line 5 Dual Pipelines to vessels. Enbridge was required to obtain authorization from the US Coast Guard and Federal Communications Commission to operate the *Guardian:protect* system to broadcast these alerts to passing vessels.
  - Resolution of Unsafe Conditions: If an unsafe condition is identified as a result of observations, ESMOC personnel will hail the vessel captain via radio to attempt to resolve the condition. Resolution of an unsafe condition may include, but is not limited to, requesting that the vessel captain lift a deployed anchor or turn the vessel to avoid crossing the Line 5 Dual Pipelines.
  - Response to Unresolved Unsafe Condition / Consequence Mitigation: If an unsafe condition cannot be resolved, ESMOC personnel will contact the Enbridge Control Center Operations in Edmonton, Alberta to order the shutdown of

Line 5. All ESMOC personnel have been granted full authority by Enbridge to direct the shutdown of Line 5 when an unsafe condition is observed that poses a risk to the Dual Pipelines that cannot be resolved.

The Coordinated System has been fully operational since May 1, 2020, although certain components have been in place longer. For example, day-time visual observations were initiated on October 12, 2019, and 24-hour visual observations were initiated on November 19, 2019. Accordingly, it is possible that the damage to EAP-9, EP-17-1, and the Features of Interest could have occurred prior to the time that the Coordinated System, or its components, were implemented.

Even if the Coordinated System, or its components, were implemented when the damage/disturbances to EAP-9, EP-17-1, or the Features of Interest occurred, the System was not designed or intended to identify/observe vessel activity that could be at issue. As explained above, the Coordinated System is specifically designed to observe and monitor commercial vessels subject to the US Coast Guard's RNA regulation at 33 C.F.R. 165.944, which encompasses larger vessels that transit the Straits. Such vessels are observed/monitored because they can carry (and hence deploy) cables and anchors of sufficient size to cause damage to the Line 5 Dual Pipelines (e.g., a dent). Such damage did not occur at EAP-9, EP-17-1, or the Features of Interest; as explained above.<sup>5</sup>

## **B. Root Cause Analysis of Cable Contact**

A root cause analysis (RCA) was conducted by Enbridge, with the support of DNV GL, as an additional step to identify the gaps in Enbridge's existing measures to reduce the risk of a vessel anchor/cable striking the Dual Pipelines (referred to herein as "barrier gaps"). The purposes of the RCA was to also identify improvements to address any identified barrier gaps (referred to herein as "barrier improvements"). The RCA reached the same conclusions as the broader investigation.

The results of the RCA are summarized as follows:

- Direct Cause:
  1. Anchoring or cable drag by vessel contracted by Enbridge or a 3<sup>rd</sup> party vessel.
- Barrier Gaps:
  1. Current damage prevention measures identified in Section IV.A above are primarily designed to address the threat of anchor drag from large commercial vessels. They are not specifically designed to prevent or mitigate the risk of a small or moderately-sized vessel's anchor or cable from striking the Dual Pipelines when such vessel is intentionally conducting maintenance activities in proximity to the Dual Pipelines, including vessels contracted by Enbridge.
  2. Assessments by maritime experts are not completed to identify and mitigate all potential threats resulting from the deployment of an anchor or cable of a vessel that is conducting maintenance activities in proximity to the Dual Pipelines.

The results of the RCA were considered in establishing the barrier improvements described in the following section. Additional details regarding the RCA are provided in APPENDIX D.

## **C. Enhanced Measures to Further Reduce the Risk of Impacts on the Pipelines**

As a result of Enbridge's investigation into the disturbances at EAP-9, EP-17-1, and the Features of Interest, additional measures have been implemented that are designed to ensure that smaller vessels – which historically would not have been observed through Enbridge's Coordinated System – are monitored and observed going forward. On June 27, 2020, Enbridge revised its Coordinated

---

<sup>5</sup> Enbridge notes that the RNA established by the US Coast Guard under 33 C.F.R. 165.944 complements Enbridge's Coordinated System and further reduces the risk of a vessel anchor being deployed in proximity to the Line 5 Dual Pipelines. Any boats subject to the size limitations set forth in that regulation must obtain authorization from the Captain of the Port to anchor in the RNA. The activity that caused the damage at issue in this Report may have been caused by a vessel subject to the RNA that did not intentionally anchor (and thus never sought approval from the Captain of the Port), or was caused by a vessel that does not exceed the size thresholds for seeking anchoring approval. It is also possible that the damage at issue in this Report was caused by a vessel that obtained approval to anchor in the RNA, including an Enbridge-contracted vessel.

System protocols to require the ESMOC to maintain at least one on-water patrol boat 24 hours per day, 7 days a week above the Line 5 Dual Pipelines to monitor all commercial vessels for potential threats to the Line 5 Dual Pipelines, including deployed anchors or cables.

In addition, as of June 27, 2020, Enbridge enhanced its Coordinated System protocols to ensure that visually unobserved vessel activity does not pose a threat to the Line 5 Dual Pipelines. Specifically, when on-water or shore-based observations of a vessel transiting the Straits cannot be completed, that vessel will be hailed via radio to ask that it confirm to Enbridge that its anchors/cables are stowed prior to crossing over the Line 5 Dual Pipelines.

Further to the Coordinated System, Enbridge intends to commission two radar systems and six high resolution infrared cameras capable of identifying and observing all vessels transiting the Straits, even those not utilizing AIS. The radar system, working in conjunction with the cameras, will ensure a detailed account of all vessel activity operating in the Straits of Mackinac. Engineering design is already underway with an anticipated in-service date of late 2020 to early 2021.

Also, as mentioned above, Enbridge is completing an expert review and audit of its current contractors' anchoring plans and procedures. Any improvements to those anchoring plans and procedures that may be identified by maritime experts will be implemented by contractors when completing future maintenance activities in proximity to the Dual Pipelines. As a barrier improvement to reduce the risk of contractors' activities damaging the Line 5 Dual Pipelines, Enbridge, in conjunction with maritime experts, is also developing a standard protocol that establishes the contents of contractors' anchoring plans and procedures. That protocol will also facilitate the completion of a risk assessment to be conducted by a maritime expert of anchoring plans and procedures for vessels that are conducting work in proximity to the Dual Pipelines.

Finally, Enbridge is working to establish an industry network for identifying and coordinating all construction and maintenance activities in the Straits. Enbridge recognizes that it is not the only entity with submerged infrastructure in the Straits that conducts routine maintenance activities via vessel. Enbridge anticipates that close collaboration with other entities with infrastructure in the Straits will ensure better oversight and monitoring for all parties whose assets may be at risk of anchor/cable strike as a result of vessels conducting maintenance activities in the Straits.

**APPENDIX A**  
**SUMMARY OF EVIDENCE GATHERED THROUGH INVESTIGATION**

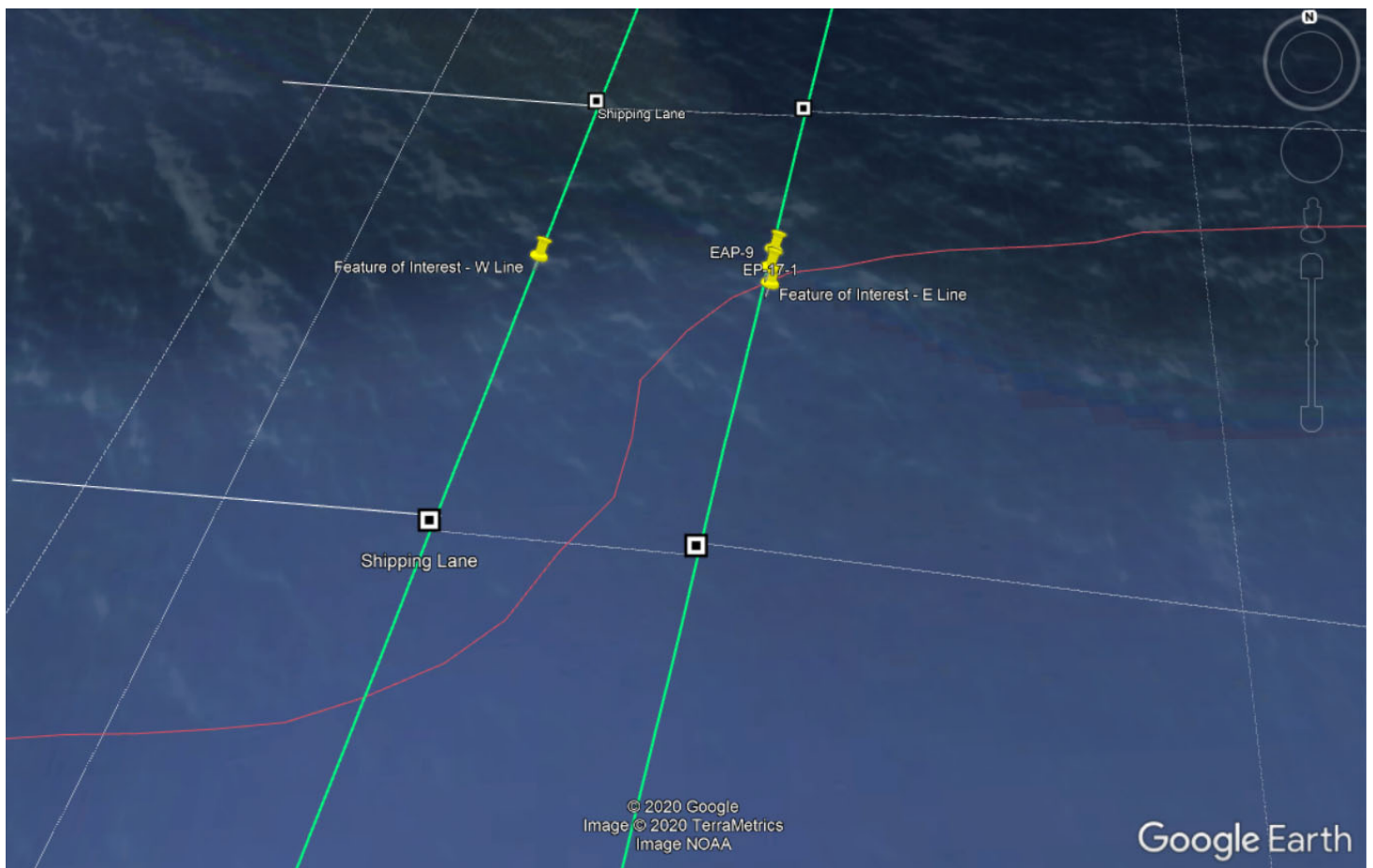
	<b>EAP-9</b> Coating damage with minor surface features	<b>EP-17-1</b> Pipeline support pulled to angle with abrasions on pipe support legs	<b>Features of Interest</b> Coating disturbance at 12 o'clock; no bare metal
<b>Travelling Direction of Source of Impact</b>	Vessel likely travelling NNE to SSW		East-West direction in shipping channel.
<b>Timing of Feature</b>	Post June 27, 2019.		Between Sep 2018 and Fall 2019.
<b>Lakebed Observations</b>	No tracks or other evidence.		Narrow track/disturbance on lakebed.
<b>Potential Cause of Feature</b>	Contact from cable possibly with attached appurtenance	Cable wrapped around pipe support and subsequently slipped-off	Cable drag possibly with attached appurtenance
<b>ILI Data</b>	No metal loss or geometry anomalies identified.		
<b>ThreatScan</b>	No acoustic signature reported/identified.		
<b>AIS Vessel Tracking Data</b>	13 vessels operated in area; 5 vessels are possible cause.		Typical vessel traffic operating in the shipping channel
<b>Coordinated System</b>	No information generated.		N/A – not in place at time of feature.
<b>Review of Enbridge Contractors</b>	No incident identified; expert review of anchoring plans/procedures ongoing.		
<b>Lab Assessments of Visual Observations</b>	N/A.	Supports the NNE to SSW direction	N/A.
<b>Coast Guard Anchoring Data</b>	Requested from Coast Guard; not yet obtained.		

## APPENDIX B

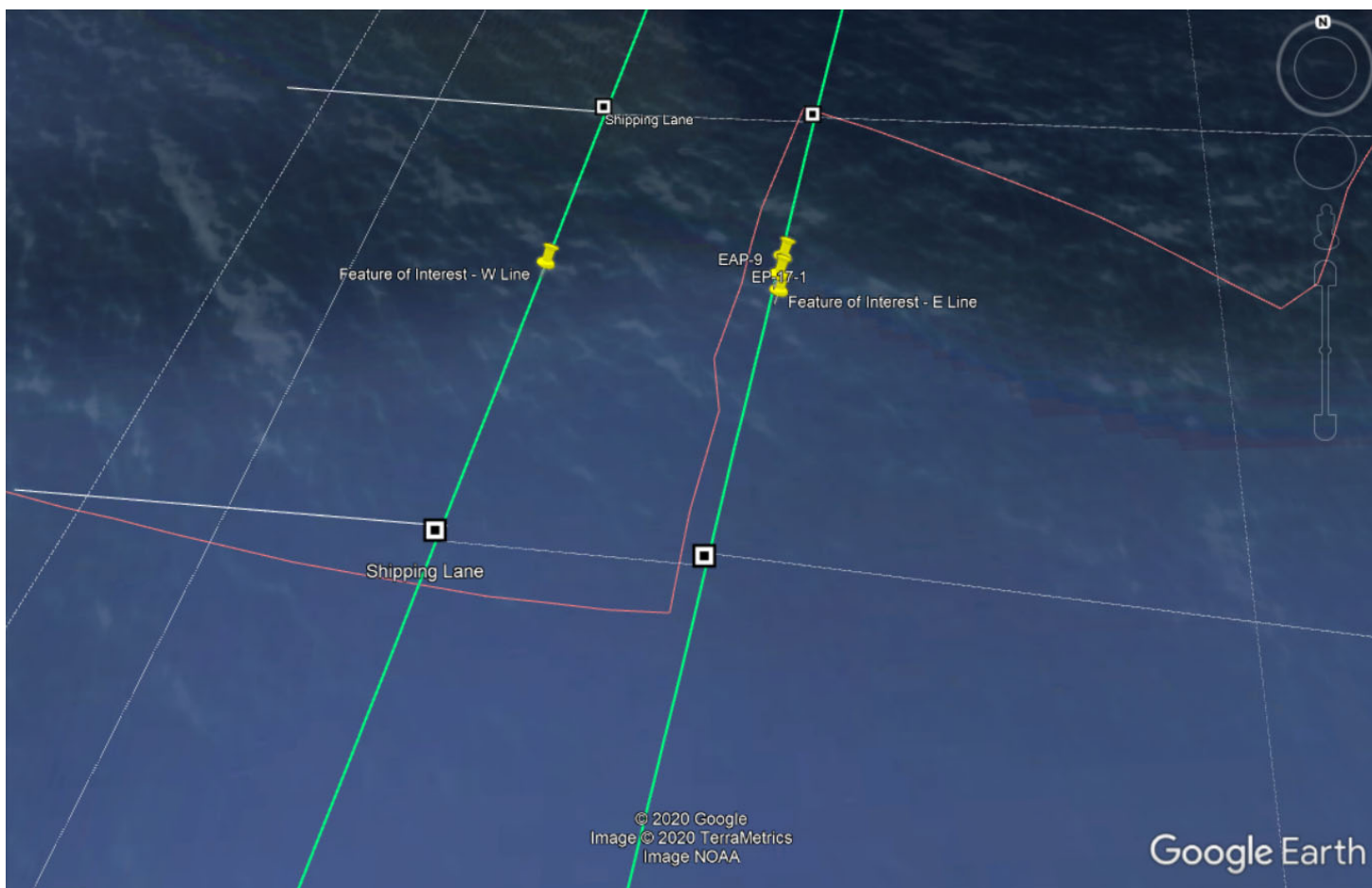
### Vessel AIS Track Summary and Tracks of Interest

Vessel #	Vessel Type	Length (m)	Vessel Name	Investigation Findings/Likelihood of Vessel Being Associated with the Incidents
1	Pleasure Craft	N/A	REDACT	Crossed the line opposite to the direction of damage & too small to be dragging >200ft of cable ( <b>UNLIKELY</b> )
2	Sailing	11		Crossed the line opposite to the direction of damage & too small to be dragging >200ft of cable ( <b>UNLIKELY</b> )
3	Towing	9		Crossed the line opposite to the direction of damage ( <b>UNLIKELY</b> )
4	Tug & Barge	18		Enbridge contract tug towing a barge for geotechnical investigation. Associated barge did anchor in the area – <b>POSSIBLE</b>
5	Tug & Barge (same barge as above)	23		Enbridge 2 <sup>nd</sup> contract tug for geotechnical investigation supporting the operation with the tug above – <b>POSSIBLE</b>
6	Sailing	12		Crossed the line perpendicular to the direction of damage, not directly over top of damage & too small to be dragging >200ft of cable – <b>UNLIKELY</b>
7	Sailing	11		Crossed the line in the opposite to direction of damage & too small to be dragging >200ft of cable – <b>UNLIKELY</b>
8	Drilling	72		Enbridge geotechnical drilling vessel. Crossed the line opposite to the direction of damage but did anchor in the area. Actual drilling operations were confirmed safe by cameras mounted at depth on drilling apparatus – <b>POSSIBLE</b>
9	Dredging	12		Crossed the line opposite to direction of damage but then partially circled the damaged pipe support. If dragging a very long cable, it could have become entangled with the pipeline support and caused the resulting damage – <b>POSSIBLE</b>
10	Law Enforcement	42		US Coast Guard, crossed perpendicular to the direction of damage – <b>UNLIKELY</b>
11	Search and Rescue	14		US Coast Guard, crossed perpendicular to the direction of damage – <b>UNLIKELY</b>
12	Tug & Barge	17		Enbridge contract maintenance tug with significant operations in the area. Barge anchored in the area for these operations – <b>POSSIBLE</b>
13	Sailing	12		Crossed near but not directly over top of damage & too small to be dragging >200ft of cable – <b>UNLIKELY</b>

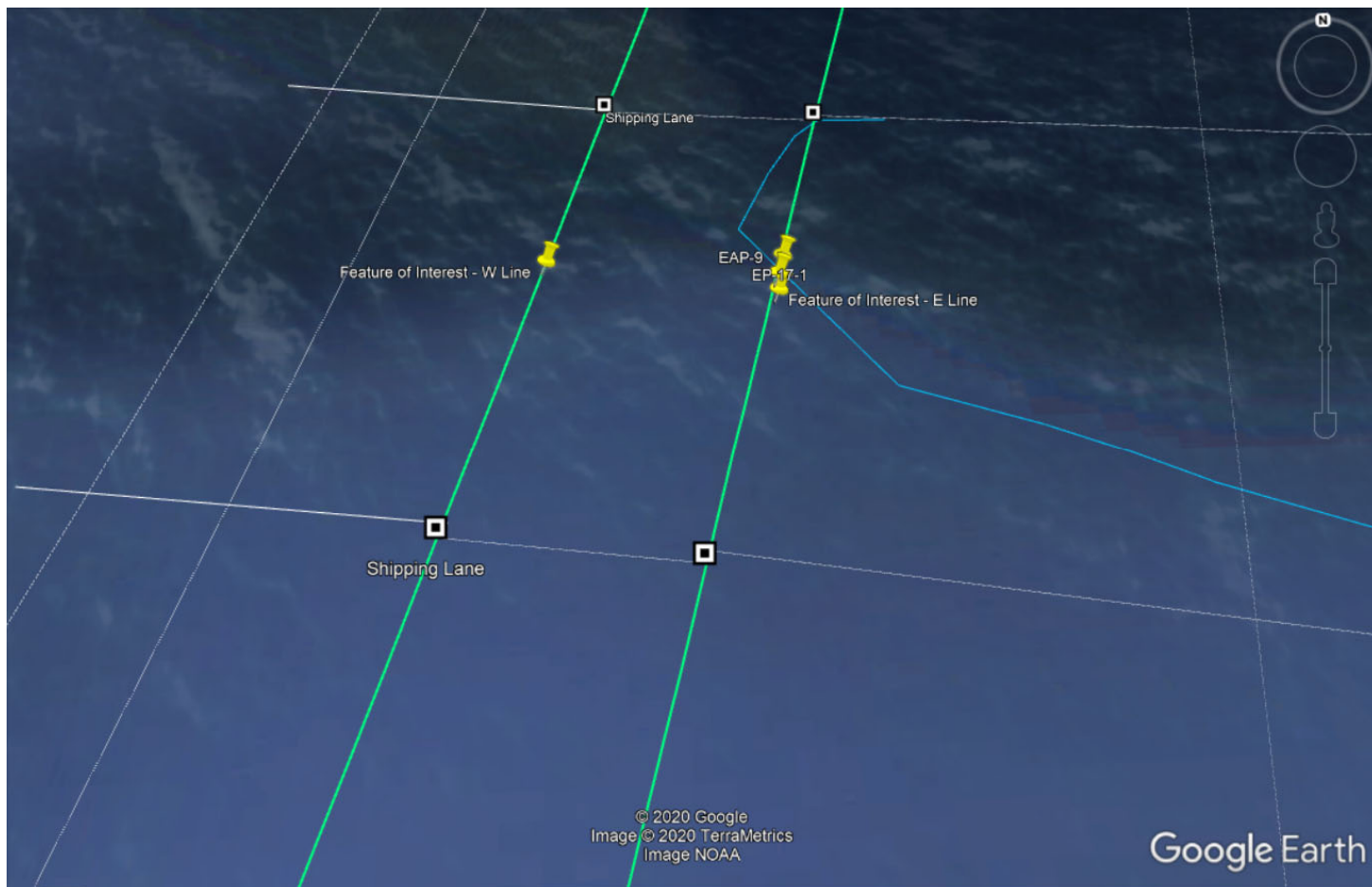
**Vessel 1 Track – August 11<sup>th</sup>, 2019**



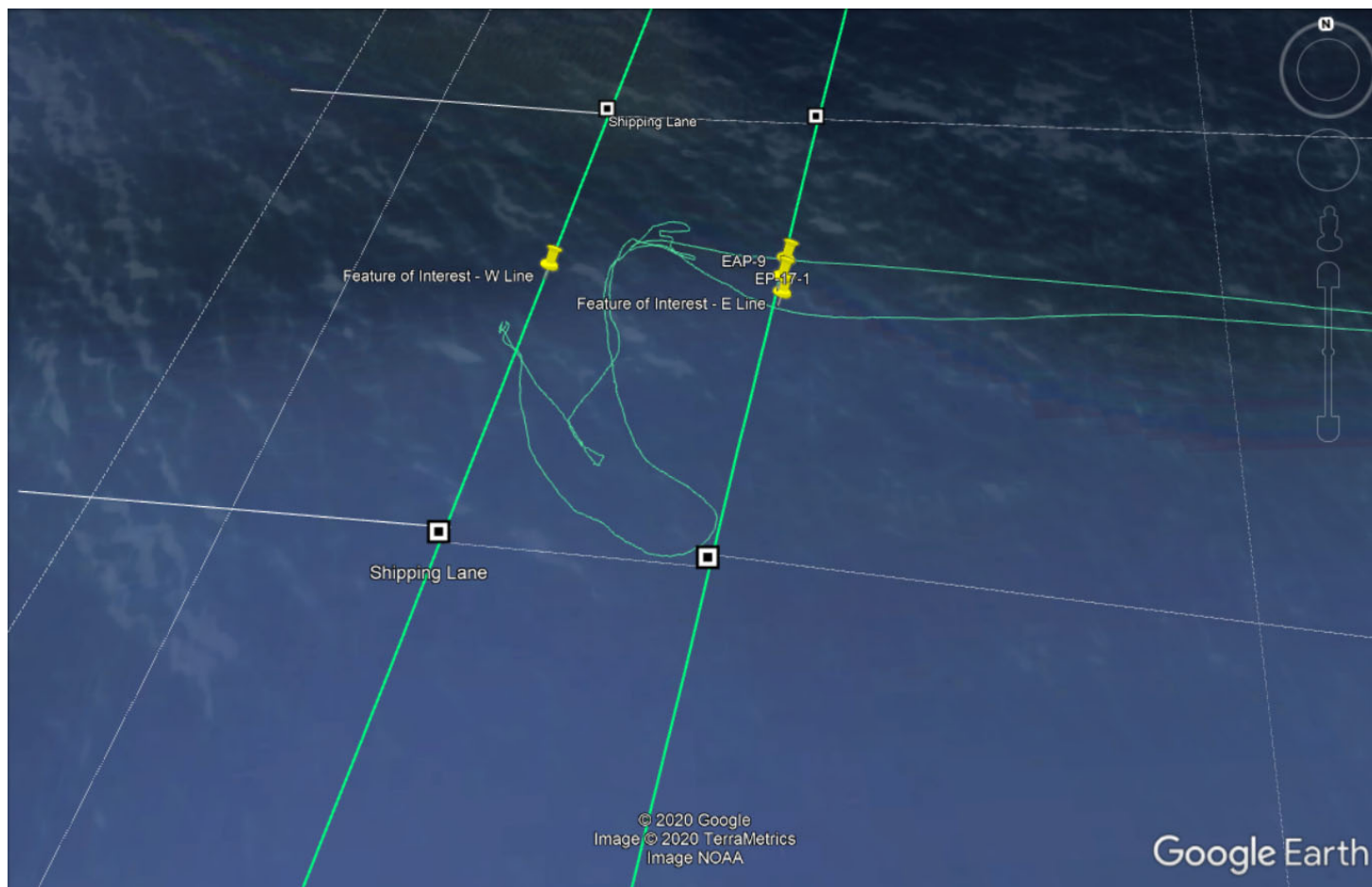
**Vessel 2 Track – August 16<sup>th</sup>, 2019**



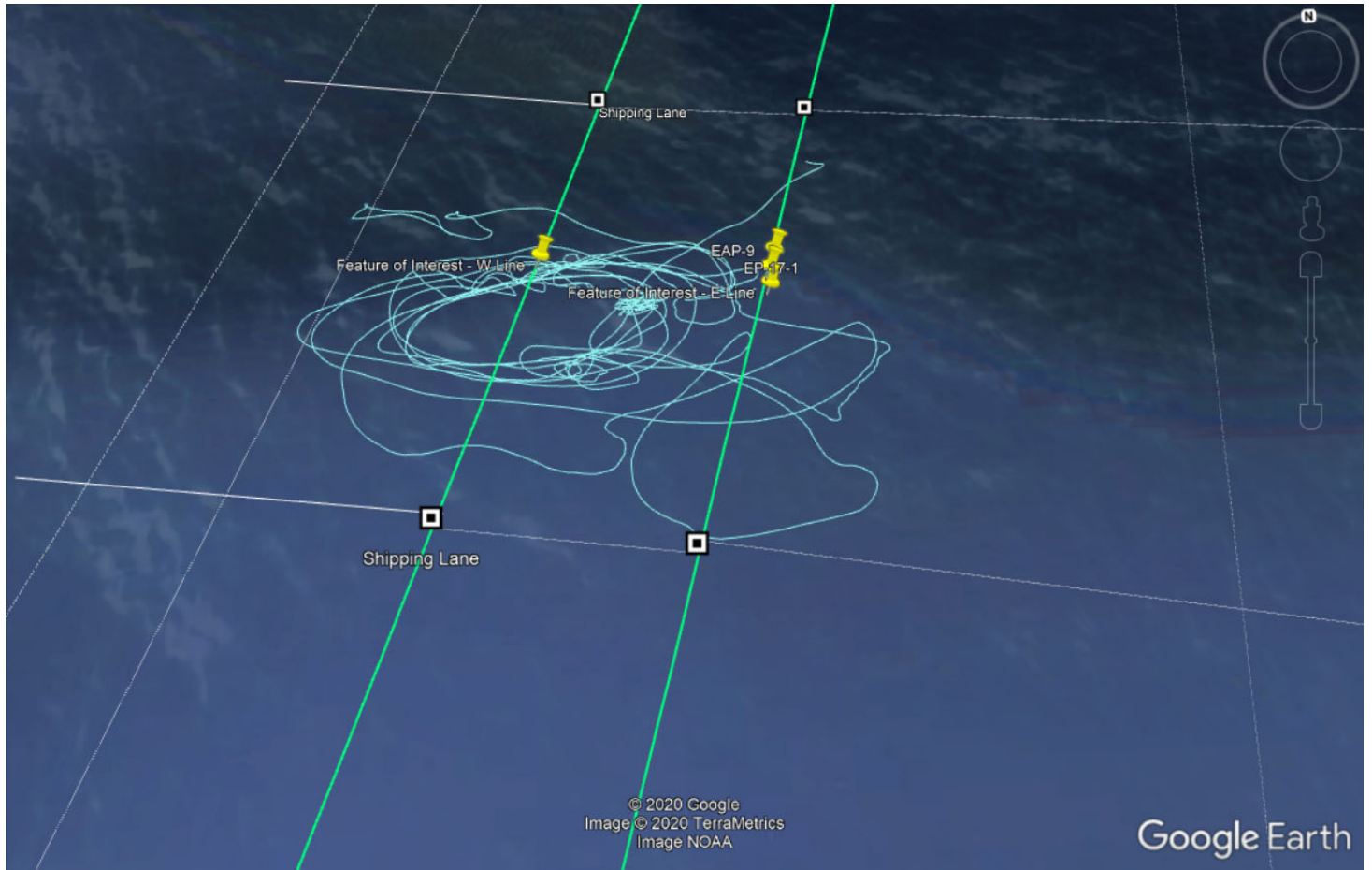
**Vessel 3 Track – May 8<sup>th</sup> and June 3<sup>rd</sup>, 2020**



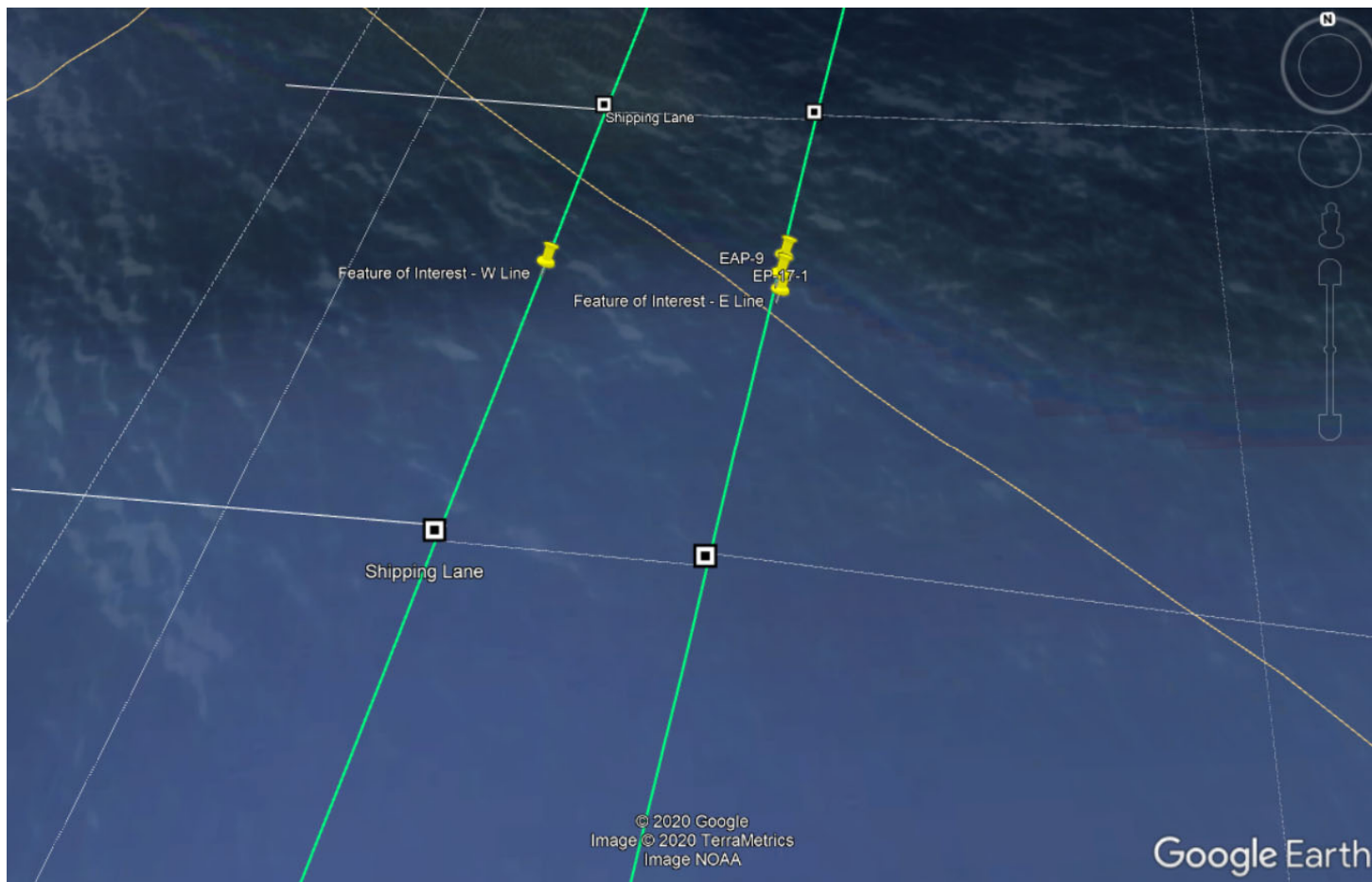
**Vessel 4 Track – December 22<sup>nd</sup> & 28<sup>th</sup>, 2019**



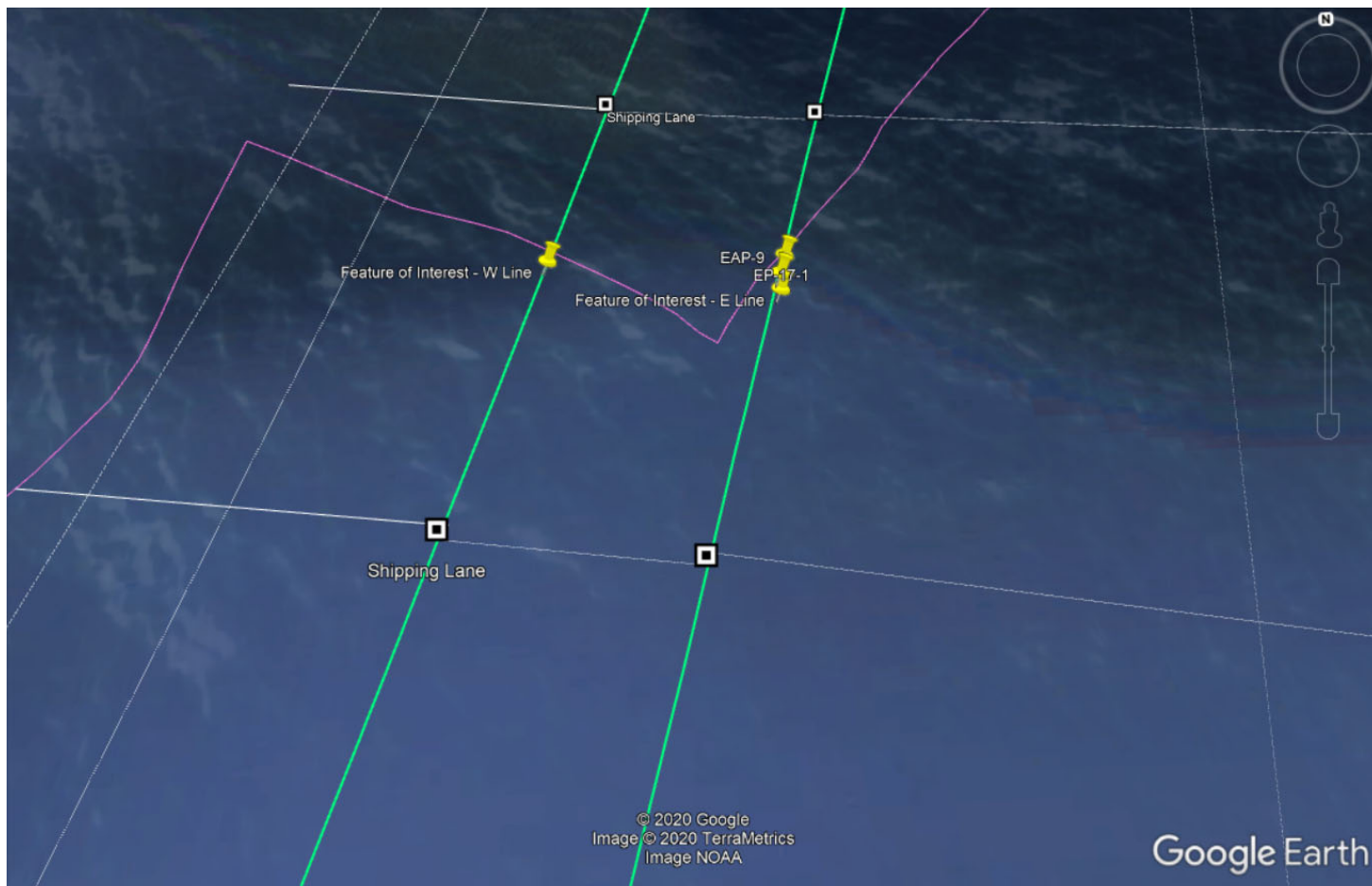
**Vessel 5 Track – December 21<sup>st</sup> & 22<sup>nd</sup>, 2019**



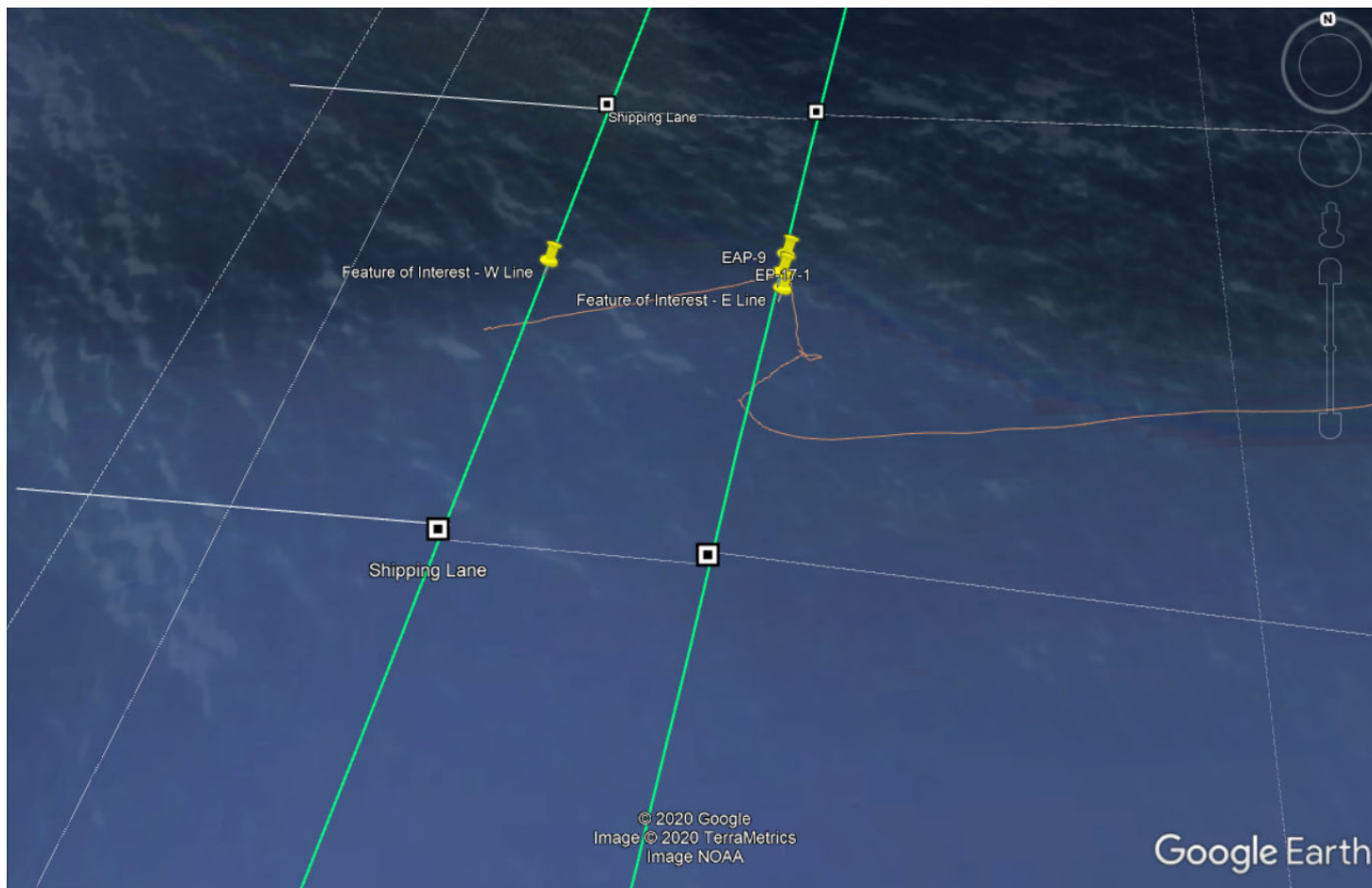
**Vessel 6 Track – June 24<sup>th</sup>, 2019**



**Vessel 7 Track – August 15<sup>th</sup>, 2019**



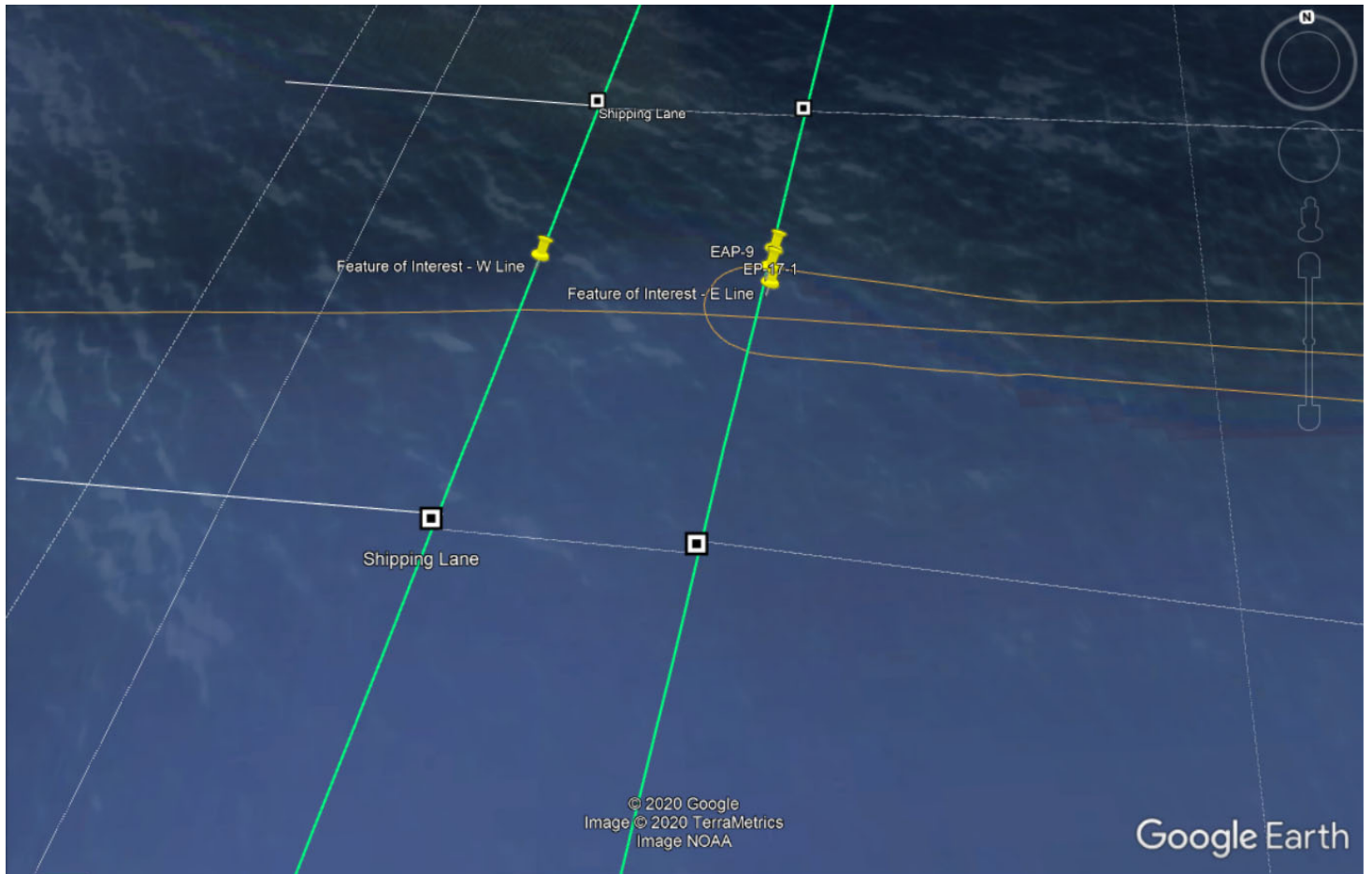
Vessel 8 Track – August 7<sup>th</sup>, 2019



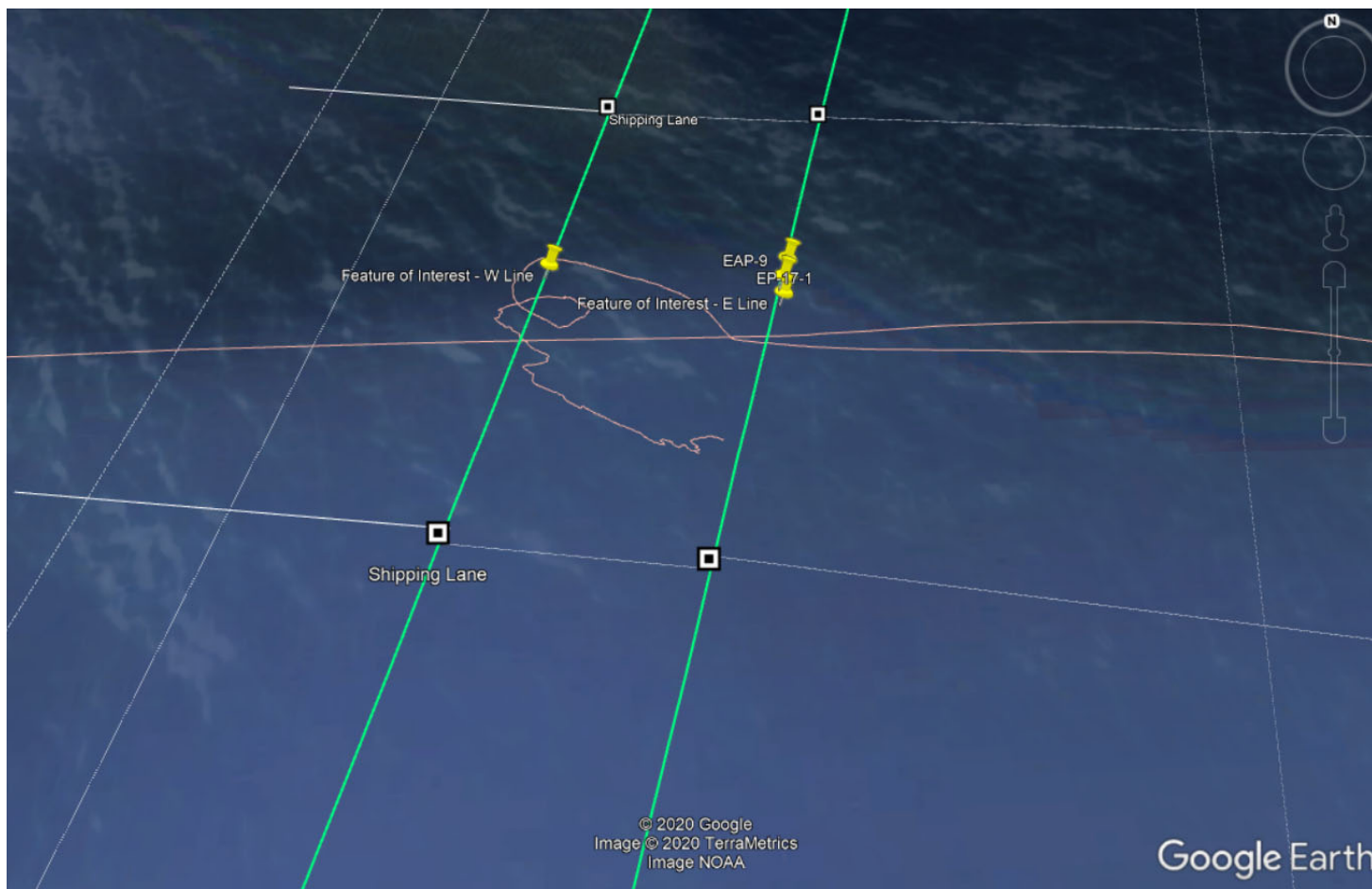
**Vessel 9 Track – September 11<sup>th</sup>, 2019**



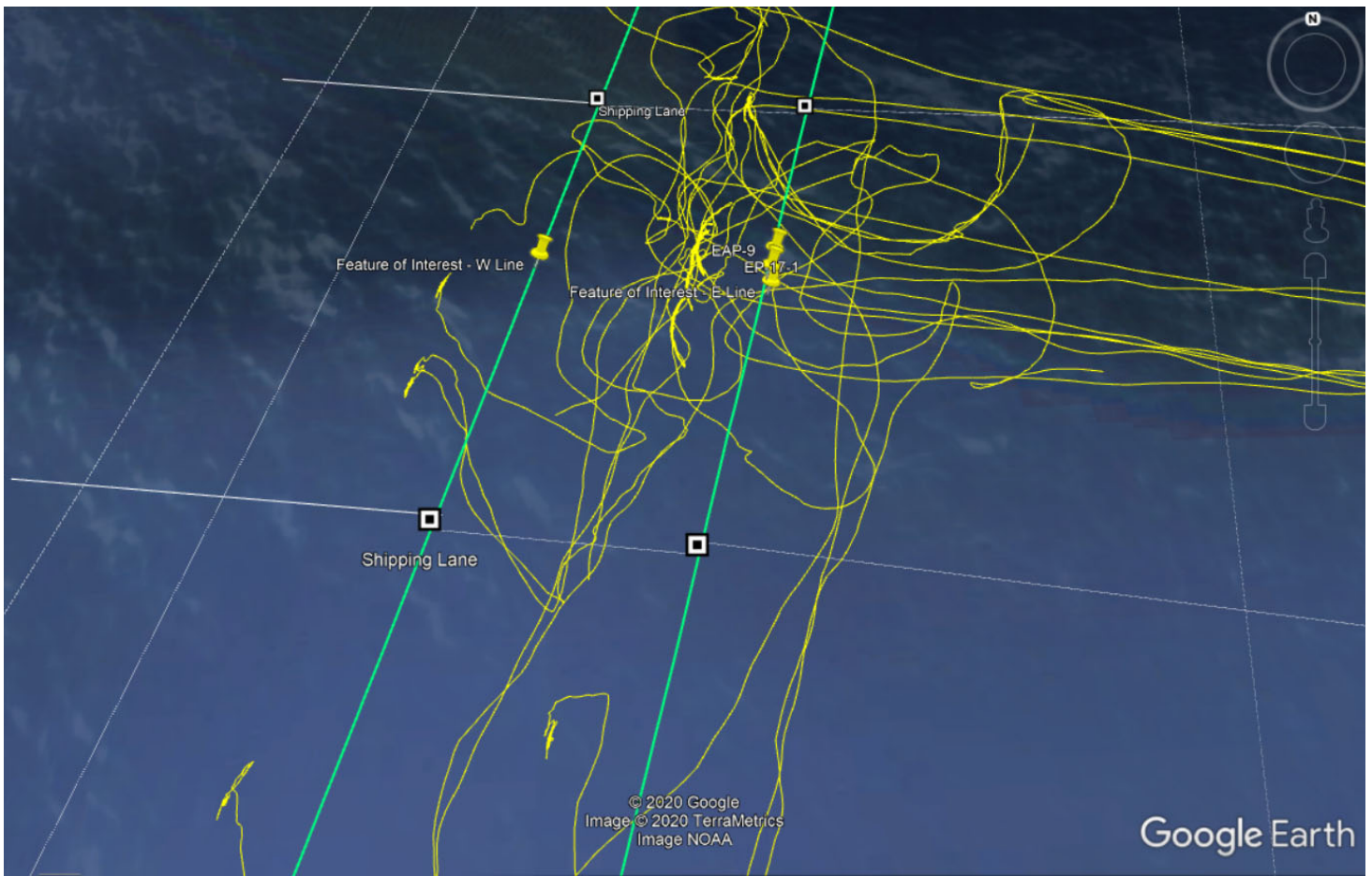
Vessel 10 Track – February 16, 2020



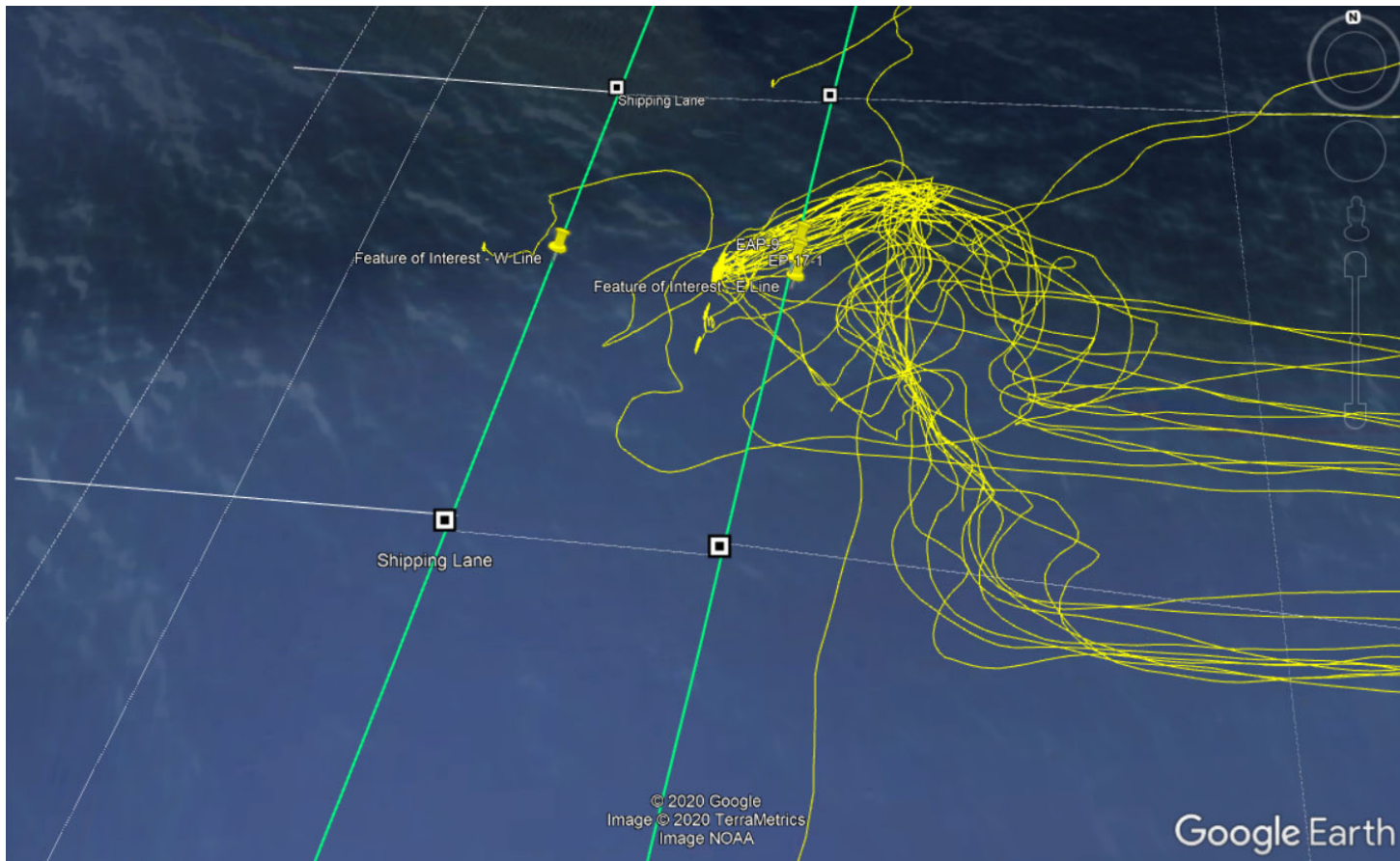
**Vessel 11 Track – August 15<sup>th</sup> & 23<sup>rd</sup> and September 19<sup>th</sup> & 27<sup>th</sup>, 2019**



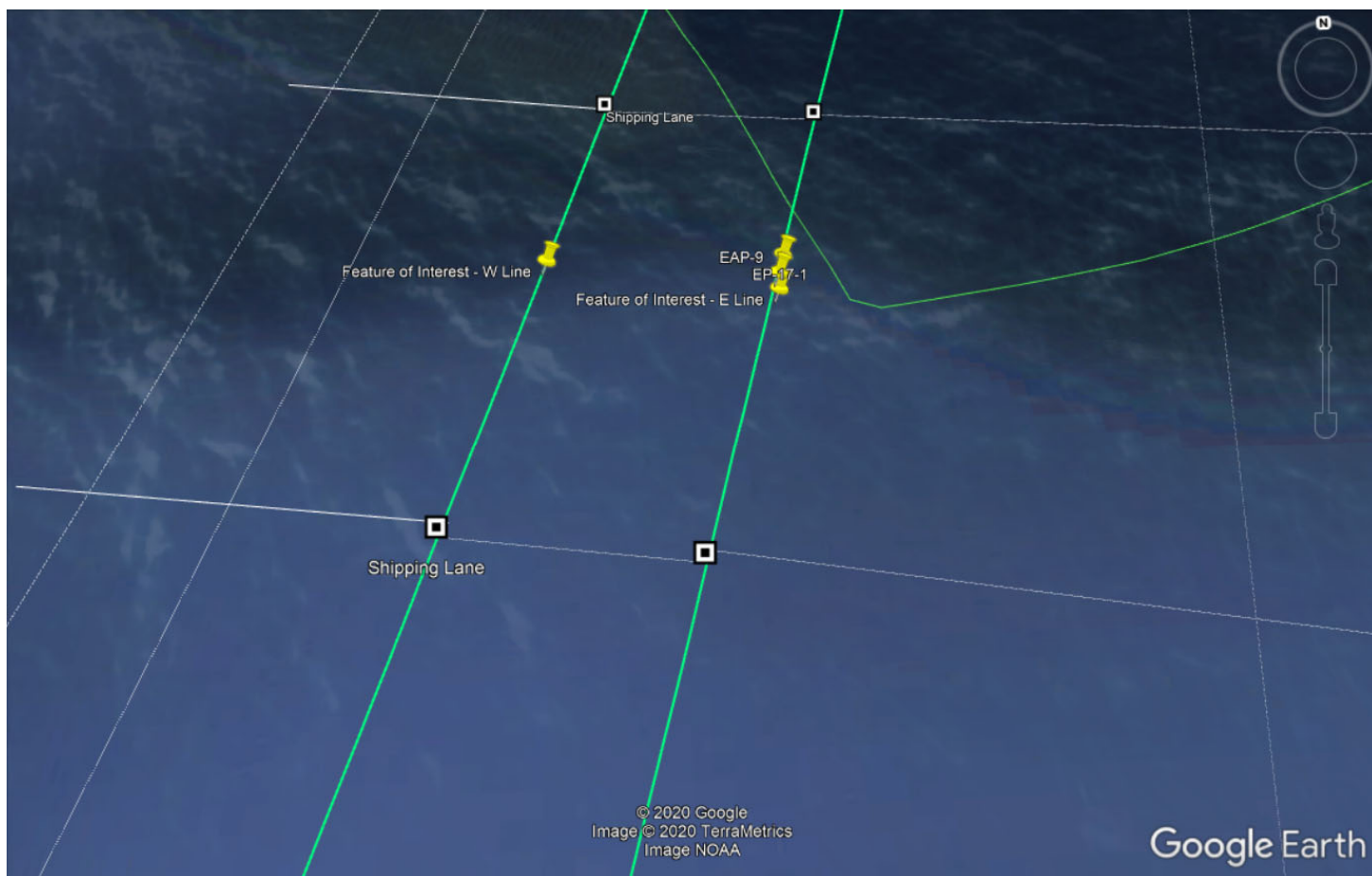
**Vessel 12 Track – Enbridge Maintenance Tug 2019 Operations**



**Vessel 12 Track – Enbridge Maintenance Tug 2020 Operations**



Vessel 13 Track – August 15<sup>th</sup>, 2019



## APPENDIX C

### Metallurgical Analysis Report – DNV-GL

**Final Report**

# **Metallurgical Analysis of Line 5 Straits Anchor**

**Enbridge**

Report No.: O-AP-FINV / RITC (10248951)  
August 14, 2020



Project Name: Metallurgical Analysis of Line 5 Straits Anchor  
Customer: Enbridge  
Contact Person: Sean Lepine  
Date of Issue: August 14, 2020  
Project No.: 10248951  
Organization Unit: Incident Investigation  
Report No.: O-AP-FINV / RITC

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Objective:

Please see Executive Summary.

Prepared by



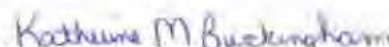
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0	2020-08-12	First Issue			
1	2020-08-14	Final Issue			



## Executive Summary

Enbridge retained DNV GL USA, Inc. (DNV GL) to perform a metallurgical analysis on an underwater anchor assembly from the East Leg of Line 5 in the Straits of Mackinac located near Mackinaw City, (Cheboygan County) Michigan. The anchor assembly consists of two helical screw anchors, a support beam and sleeve ring, spacer, saddle, and the associated nuts, bolts, washers and washer plates.

The assembly was removed from the lakebed and delivered to DNV GL for analysis. The objectives of the analysis were to document the geometry of the assembly and document any anomalies on the assembly.

***The results of the metallurgical analysis indicate that the anomalies consist of mechanical deformation from a wire rope comprised of wires with a diameter of approximately 2 mm.***

The results of the metallurgical analysis indicate that the anomalies on the assembly formed as a result of mechanical damage likely from a wire rope that contacted the assembly. The location of the anomalies, on the north to northeast side of the anchor, suggests that the loading direction of the cable was from the south to southwest direction. The surface of Anomaly 1 and Anomaly 2 contained macroscopic and microscopic deformation features/smear marks consistent with contact in the east to west direction. The anomalies consist of several parallel gouges and witness marks. Anomaly 2 consists of gouges with a relatively uniform diameter of 2.09 mm, consistent with a wire rope composed of wire of similar diameter.

Below is a summary of additional observations and conclusions:

- The deepest gouge was approximately 0.5 mm (6% of nominal wall thickness) and was located in Anomaly 2.
- The estimated wire rope diameter from measurements of Anomaly 2 range from 6.93 to 22.39 cm. The large distribution indicates that determination of the possible cable size was inconclusive.
- No foreign material was observed/detected at the surface of the anomalies.
- The composition of the sample removed from the sleeve ring meets requirements for ASTM A106 Grade B steel.
- The microstructure of the sleeve is consistent with cast steel.



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## 1.0 BACKGROUND

Enbridge retained DNV GL USA, Inc. (*DNV GL*) to perform a metallurgical analysis on an underwater anchor assembly from the East Leg of Line 5 in the Straits of Mackinac located near Mackinaw City, (Cheboygan County) Michigan. The anchor assembly consists of two helical screw anchors, a support beam and sleeve ring, spacer, saddle, and the associated nuts, bolts, washers and washer plates.

The assembly was removed from the lakebed and delivered to DNV GL for analysis. The objectives of the analysis were to document the geometry of the assembly and document any anomalies on the assembly.

## 2.0 TECHNICAL APPROACH


The procedures used in the analysis were in accordance with industry-accepted standards. Three of the general standards governing terminology, metallographic procedures, mechanical testing, and chemical analysis used are as follows:

- ASTM E7, "Standard Terminology Relating to Metallography."
- ASTM E3, "Standard Methods of Preparation of Metallographic Specimens."
- ASTM E8, "Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products."

The following steps were performed for the analysis. The as-received components of the assembly were visually inspected and photographed. Wall thicknesses, diameters, and circumferences were measured on the ends of the screw anchor extensions and sleeve ring where there was no measurable corrosion and no coating was present. The external surfaces of the components were cleaned with methanol in preparation for 3D laser scanning. 3D laser scanning was performed on the external surfaces of the assembly components, using FaroArm and Creaform HandySCAN 3D laser scanners to produce digital maps documenting the depth of the anomalies and the geometry of the components.

Three coupons were removed from anomalies on the support beam and sleeve ring component: one from the east sleeve ring, one from the west sleeve ring, and one from the support beam. Samples were removed from the coupons containing portions of the anomalies for examination in the scanning electron microscope (SEM). Energy dispersive spectroscopy (EDS) was performed on samples of deposits removed from the external surface of the anomalies to determine the elements present.

The two samples removed from the East Sleeve ring and West Sleeve ring were ultrasonically cleaned in ENPREP®214 and imaged in the SEM at high magnification to



document the morphology of the anomaly surfaces and to determine the direction of mechanical deformation.

Two transverse cross-sections were removed from the anomalies: one from the East Sleeve ring and one from the West Sleeve ring. The cross-sections were removed perpendicular to the witness marks associated with the anomalies. The cross-sections were mounted, polished, and etched. Light photomicrographs were taken to document the feature morphologies and steel microstructures. The cross-sections were examined in the SEM using EDS for elemental mapping to detect any foreign material present at the outside diameter (OD) surface of the anomalies. Chemical analysis was performed on a sample removed from the east sleeve ring to determine the chemical composition.


## **3.0 RESULTS**

### **3.1 Optical Examination**

The anchor assembly was received in a plywood shipping crate. The sleeves and support beam component (Item 3 and 4) were secured with a rope to a wooden pallet in the crate for shipping. Figure 1 is a photograph of the sleeves and support beam component (Item 3 and 4), and the east and west screw anchor extensions (Item 1a and 1b) after removal from the shipping crate and the removal of the rope. A majority of the external surface of the support beam and sleeve ring is covered in a black epoxy/paint type coating. The remaining areas of the external surface of the component where coating was not present corresponded to the locations of anomalies on the external surface. Three anomalies, Anomaly 1, Anomaly 2, and Anomaly 3 were identified and are discussed below. The surfaces of the anomalies are red to brown in appearance and consistent with a superficial oxide in the form of rust. No coating was present on the OD surfaces of the screw anchor extensions.

Figure 2 consists of photographs of the OD surface of the East Sleeve Ring showing Anomaly 1 that is located predominantly on the north side of the assembly. Anomaly 1 is located from the top of the assembly to approximately 1 m (3 feet) down from the top of the assembly. Anomaly 1 consists of mechanical damage in the form of gouges in the steel and several parallel witness marks in the paint of the sleeve ring. The morphology of the mechanical damage is consistent with an object such as a wire rope contacting the sleeve ring at a depth of approximately 1 m (3 feet) down from the top of the sleeve ring and moving to the top of the assembly.

Figure 3 is a close-up photograph of the OD surface of the West Sleeve Ring showing Anomaly 2 that is located on the north to northeast side of the assembly from approximately 64 to 84 cm down from the top of the assembly (2.10 to 2.75 feet).



Anomaly 2 is similar in morphology to that observed on the East Sleeve Ring in that the anomaly consists of mechanical damage in the form of gouges and parallel witness marks. The morphology of the anomaly is consistent with wire rope contacting the sleeve at a depth of 84 cm (2.10 feet) down from the top of the sleeve ring and moving towards the top of the assembly. Figure 4 is a close-up photograph of a portion of Anomaly 2. The figure shows several parallel witness marks on the OD surface of the sleeve. At this magnification the damaged surface is grey in appearance with regions that are red to brown in appearance located within the witness marks.

A photograph of Anomaly 3 located on the support beam of the assembly is shown in Appendix A in Figure A-1. The morphology of Anomaly 3 is similar to that of Anomaly 1 and 2, in that it consists of mechanical damage in the form of gouges and parallel witness marks.

### 3.2 Dimensional Measurements

Circumferences, diameters, and wall thicknesses were measured on the ends of the sleeve ring and screw anchor extensions (when feasible). Table 1 shows the results of the circumference and diameter measurements. The top and bottom diameters of the screw anchor extensions calculated from the circumference measurements were 90 mm. The diameters of the screw anchors were measured with a tape measure from the 3:00 to 9:00 and 12:00 to 6:00 orientations at the tops of the screw anchors. The measured diameters of the top and bottom ends were 89 mm. The diameters of the screw anchors are consistent with 3-inch nominal pipe size (NPS) with an outer diameter (OD) of 88.9 mm.<sup>1</sup> Note, the diameter of the bottoms of the screw anchors could not be measured due to the unevenness of the cut end. The top and bottom diameters of the sleeve rings calculated from the circumference measurements were 116 mm. The diameters of the sleeve rings were measured with a tape measure from the 3:00 to 9:00 and 12:00 to 6:00 orientations at the tops and bottoms of the sleeves. The measured diameters of the top and bottom of the sleeves were 114 mm. The diameters of the sleeves are consistent with 4-inch NPS with an OD of 114.3 mm.<sup>1</sup>

Wall thicknesses were measured at the 12:00, 3:00, 6:00, and 9:00 orientations (90 degrees apart) at the ends of the screw anchor extensions and sleeve rings using calipers; see Table 2 for details. The wall thickness values of the screw anchor extensions ranged between 7.04 and 7.29 mm. These measurements are within the tolerance specifications for 3 NPS Schedule 80 of 7.62 mm.<sup>2</sup> The wall thickness values of the sleeve rings ranged

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<sup>1</sup> ASTM A999/A999M – Standard Specifications for General Requirements for Alloy and Stainless Steel Pipe: tolerance on pipe OD is +0.40 mm, -0.79 mm

<sup>2</sup> ASTM A999/A999M – Standard Specifications for General Requirements for Alloy and Stainless Steel Pipe: tolerance on pipe thickness is -12.5% of nominal wall thickness.

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between 7.82 and 8.20 mm. These measurements are within the tolerance specifications for 4 NPS Schedule 80 of 8.56 mm.<sup>2</sup>

### 3.3 Scanning Electron Microscopy


Figure 5 is an SEM image of Sample S-1 showing the surface at the location of Anomaly 1 on the East Sleeve Ring. The figure shows witness marks/gouges on the surface of the sleeve. Figure 6 through Figure 8 are higher magnification SEM images of the surface of the anomaly showing deformation/smearing of the surface in the east to west direction.

Figure 9 is an SEM image of Sample S-2 showing the surface at the location of Anomaly 2 on the West Sleeve Ring. The figure shows gouges on the surface of the sleeve and that the gouges formed as a result of material that was deformed/smeared in the east to west direction. Figure 10 through Figure 12 are higher magnification SEM images of the surface of the anomaly showing smearing in the east to west direction. The morphology of the mechanical damage is consistent with contact of a wire rope with the external surface that occurred in the east to west direction.

### 3.4 Metallographic Examination

Figure 13 is a light photomicrograph of metallographic cross-section (Mount M-2) that was removed from the West Sleeve Ring, 0.67 m (2.20 feet) down from the top of the sleeve across the anomaly/mechanical damage. The figure shows the mechanical deformation of the metal on the OD surface of the sleeve ring. The figure shows multiple shallow gouges ranging in depth from approximately 0.1 to 0.5 mm (1 to 6% of wall thickness), on the OD surface of the sleeve ring. The gouges are separated by regions of extruded metal with heights ranging from approximately 0.1 to 1.5 mm (1 to 20% of wall thickness). The morphology of the gouges is consistent with mechanical deformation produced by contact of individual wires within a wire rope contacting the OD surface of the sleeve. The bottoms of the gouges are approximately circular in shape and consistent diameters. As indicated in the figure, the gouges exhibit a diameter of 2.09 mm as measured by fitting red circles to the shape of the bottom of the gouges. This indicates that the wire rope likely consisted of wires approximately 2 mm in diameter.

Circular/arc segments were fit to the bottoms of sets of 3 gouges to estimate the overall wire rope diameter. Four different combinations of gouges were used to produce arc segments ranging in diameter from 6.93 to 22.39 cm. The large distribution indicates that determination of the possible cable size was inconclusive. This may be a result of several factors including: (1) the wire rope may have deformed under the applied force creating an out of roundness condition, and (2) the wire rope may have rolled/rotated as it traversed



upwards along the length of the sleeve. Each would contribute to an overestimation of the wire rope diameter.

Figure 14 and Figure 15 are higher magnification light photomicrographs of the gouges located on the OD surface of the sleeve ring. The figures show elongated grains of the microstructure in the extruded material. No foreign material was observed in the gouged regions.

Figure 16 is a high magnification light photomicrograph showing the typical microstructure of the sleeve ring. The microstructure of the sleeve ring consists of ferrite (white regions), pearlite (dark lamellae regions), and inclusions (solid grey regions). The microstructure of the sleeve ring is consistent with a low carbon steel.

A light photomicrograph of Mount M-1 removed from across Anomaly 1 is shown in Appendix B in Figure B-1. The figure shows Anomaly 1 consists of several gouges on the OD surface of the sleeve. The gouges are shallower compared to Anomaly 2 and are somewhat smeared.

### 3.5 Energy Dispersive Spectroscopy

Elemental analyses using EDS was performed on deposits removed from the surfaces of Anomaly 1, 2, and 3 (EDS-1-1, EDS-2-1, and EDS-3, respectively) and on the OD surfaces of Mount M-1 and M-2 (EDS-1-2, and EDS-2-2, respectively) to determine the elements present at the surfaces of the anomalies. Table 3 shows the results of the EDS analyses. The results of the analyses indicate that the material present at the surface of the anomalies are primarily comprised of iron (Fe), oxygen (O), carbon (C), and calcium (Ca). The deposits removed from the external surface (EDS-1-1, EDS-2-1, and EDS-3) are comprised of trace (~1 wt % or less) of sodium (Na), magnesium (Mg), aluminum (Al), silicon (Si), potassium (K), and manganese (Mn). Carbon, Si, and Mn are alloying constituents of steel. The high amounts of iron and oxygen are consistent with iron oxide. The high amounts of Ca detected may be associated with calcareous deposits, which commonly form as a result of cathodic protection of structures in aqueous environments.

The deposits analyzed on the OD surface of Mount M-1 and M-2 (EDS-1-2 and EDS-2-2) are similar in composition to the deposits removed from the external surface, with the exception of the detection of greater amounts of Al and Si, as well as the presence of Ti in the deposits. The Al, Si, and Ti in the sample were detected at locations embedded beneath portions of folded material from the mechanical damage. The location and amounts of the elements are likely associated with the black epoxy coating on the anchor.

### 3.6 Hardness Testing

Vickers hardness testing was performed on Mount M-2 in the area of mechanical damage and in the base metal using a 10 kg load. Figure 13 is a light photomicrograph of Mount M-2 showing the indent locations. Table 4 summarizes the results of the testing. The hardness values were between 163 and 206 Vickers Hardness (HV) [84 and 95 Rockwell Hardness B {HRB}]. Overall, the hardness of the deformed region is slightly higher than the base metal, which is typical of strain hardening and other changes in the microstructure from the mechanical deformation.

### 3.7 Chemical Analysis

The results of the chemical analysis performed on a steel sample removed from the West Sleeve Ring are shown in Table 5. The results of the analysis indicate that the sample meets chemical composition requirements for ASTM A016 Grade B steel.

## 4.0 CONCLUSIONS

The results of the metallurgical analysis indicate that the anomalies on the assembly formed as a result of mechanical damage likely from a wire rope that contacted the assembly. The location of the anomalies, on the north to northeast side of the anchor, suggests that the loading direction of the cable was from the south to southwest direction. The surface of Anomaly 1 and Anomaly 2 contained macroscopic and microscopic deformation features/smear marks consistent with contact in the east to west direction. The anomalies consist of several parallel gouges and witness marks. Anomaly 2 consists of gouges with a relatively uniform diameter of 2.09 mm, consistent with a wire rope composed of wire of similar diameter.

Below is a summary of additional observations and conclusions:

- The deepest gouge was approximately 0.5 mm (6% of nominal wall thickness) and was located in Anomaly 2.
- The estimated wire rope diameter from measurements of Anomaly 2 range from 6.93 to 22.39 cm. The large distribution indicates that determination of the possible cable size was inconclusive.
- No foreign material was observed/detected at the surface of the anomalies.
- The composition of the sample removed from the sleeve ring meets requirements for ASTM A106 Grade B steel.
- The microstructure of the sleeve is consistent with cast steel.



Table 1. Results of circumference and diameter measurements performed at the top and bottom ends of the Screw Anchor Extension East (Item 1A), Screw Anchor Extension West (Item 1B), and the East Sleeve Ring and West Sleeve Rings (Item 4).

Item	Component Name	Location	Circumference (cm)	Diameter (mm)		
				From Circumference Measurements	12 to 6 o'clock	3 to 9 o'clock
1a	Screw Anchor Extension East	Top	28.3	90	89	89
		Bottom	28.3	90	_1	_1
1b	Screw Anchor Extension West	Top	28.3	90	89	89
		Bottom	28.3	90	_1	_1
4	East Sleeve Ring	Top	36.3	116	114	114
		Bottom	36.3	116	114	114
	West Sleeve Ring	Top	36.3	116	114	114
		Bottom	36.3	116	114	114

1 – Uneven cut end, diameter measurement not feasible.

Table 2. Results of wall thickness measurements performed at the top and bottom ends of the Screw Anchor Extension East (Item 1A), Screw Anchor Extension West (Item 1B), and the East Sleeve Ring and West Sleeve Rings (Item 4) using calipers.

Item	Component Name	O'clock Orientations	Wall Thickness (mm)	
			Top	Bottom
1a	Screw Anchor Extension East <sup>1</sup>	3:00	7.26	7.29
		6:00	7.11	7.16
		9:00	7.16	7.14
		12:00	7.11	7.16
		Average	7.16	7.19
1b	Screw Anchor Extension West <sup>1</sup>	3:00	7.24	7.04
		6:00	7.14	7.16
		9:00	7.11	7.24
		12:00	7.14	7.19
		Average	7.16	7.16
4	East Sleeve Ring <sup>2</sup>	3:00	8.00	7.92
		6:00	8.03	7.92
		9:00	8.08	8.00
		12:00	7.92	8.00
		Average	8.00	7.98
4	West Sleeve Ring <sup>2</sup>	3:00	8.08	7.82
		6:00	8.03	7.92
		9:00	8.20	8.10
		12:00	7.92	7.92
		Average	8.05	7.95

1 – Orientation directions could not be determined.

2 – 12:00 corresponds to north, 3:00 corresponds to east, 6:00 corresponds to south, and 9:00 corresponds to west.

Table 3. Results of elemental analyses, using energy dispersive spectroscopy (EDS), performed on deposits removed from the outside diameter (OD) surface of the anomalies on the East Sleeve Ring (EDS 1), West Sleeve Ring (EDS 2-1) and on the OD surface of Mount M-2 (EDS 2-2). Refer to Figure 2, Figure 4, Figure 14, Figure A-1 and Figure B-1 for the sampling locations.

Element	Composition (wt %)				
	EDS-1-1	EDS-1-2	EDS-2-1	EDS-2-2	EDS-3
C (Carbon)	29.7	16.9	26.0	31.8	50.0
O (Oxygen)	34.6	36.2	30.1	27.0	18.0
Na (Sodium)	0.1	0.3	0.1	0.6	0.5
Mg (Magnesium)	0.3	1.0	1.2	1.9	–
Al (Aluminum)	0.1	6.4	0.1	2.8	0.1
Si (Silicon)	0.3	13.5	0.4	12.7	0.2
P (Phosphorus)	–	<0.05	–	–	–
S (Sulfur)	–	–	–	0.1	–
Cl (Chlorine)	–	–	0.1	<0.05	–
K (Potassium)	<0.05	0.4	–	0.3	–
Ca (Calcium)	23.7	5.8	11.0	1.7	13.6
Ti (Titanium)	–	0.4	–	0.3	–
Mn (Manganese)	0.2	0.4	0.5	0.6	0.3
Fe (Iron)	11.1	18.6	30.7	25.6	17.3

Table 4. Results of hardness testing performed on Mount M-2. Mount location shown in Figure 3 and Figure 4. Hardness locations shown in Figure 13.

Hardness Location	Hardness (Vickers)	Rockwell Hardness B (HRB)	Equivalent UTS (MPa)
1	186	86	593
2	203	94	645
3	206	95	664
4	168	86	541
5	165	85	531
6	163	84	525

Table 5. Results of the chemical analysis, using optical emission spectroscopy (OES), of a sample removed from the West Sleeve Ring (Item 4), compared with chemical composition requirements for ASTM A106 Grade B Steel.

Element	Composition (Wt. %)	
	West Sleeve Ring	ASTM A106 Grade B <sup>1</sup>
C (Carbon)	0.219	0.30 (max)
Mn (Manganese)	0.805	0.29-1.06
P (Phosphorus)	0.012	0.035 (max)
S (Sulfur)	0.007	0.035 (max)
Si (Silicon)	0.012	0.10 (min)
Cu (Copper)	0.047	0.40 (max)
Sn (Tin)	0.005	–
Ni (Nickel)	0.017	0.40 (max)
Cr (Chromium)	0.057	0.40 (max)
Mo (Molybdenum)	0.005	0.15 (max)
Al (Aluminum)	0.048	–
V (Vanadium)	0.003	0.08 (max)
Nb (Niobium)	0.006	–
Zr (Zirconium)	0.001	–
Ti (Titanium)	0.001	–
B (Boron)	0.0002	–
Ca (Calcium)	0.0002	–
Co (Cobalt)	0.002	–
Fe (Iron)	Balance	Balance

1 – From ASTM A106, "Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service," (2011).

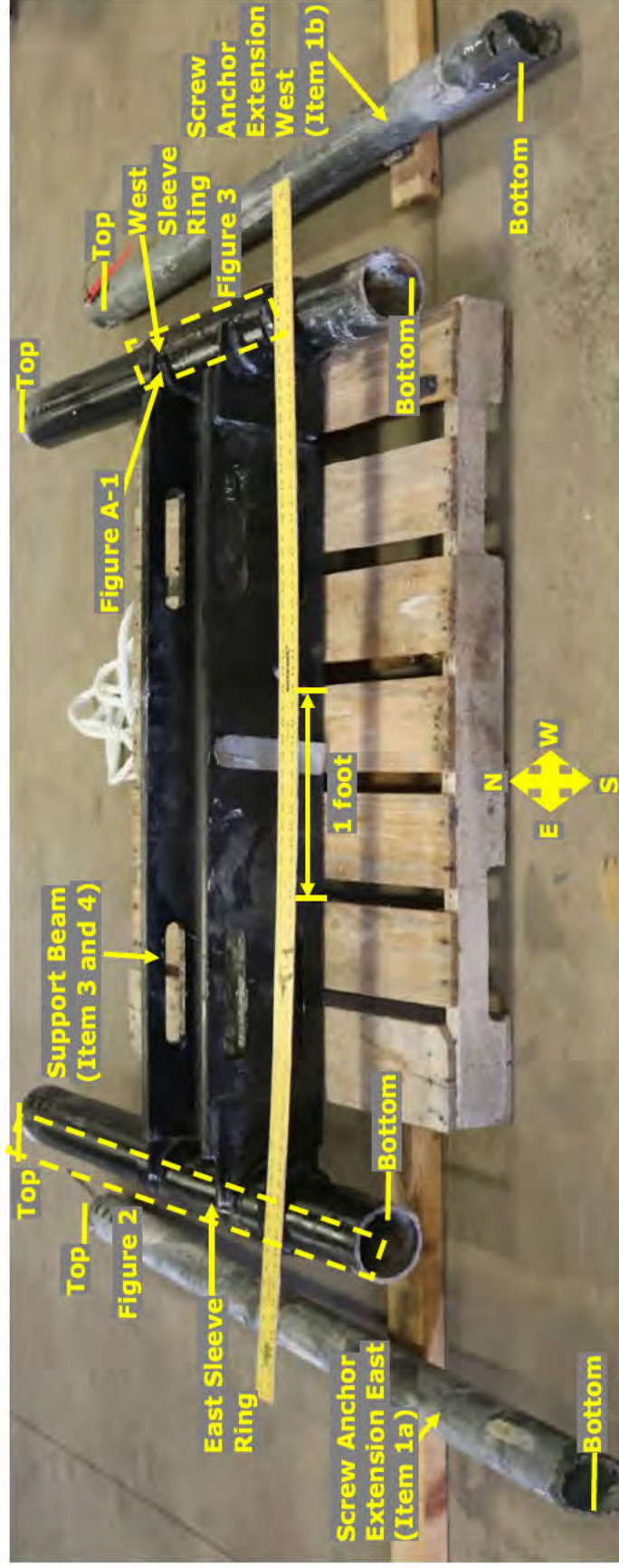


Figure 1. Photograph of the support beam and sleeve rings (Items 3 and 4) and the anchor screw extensions (Items 1a and 1b). Ruler is in inches.

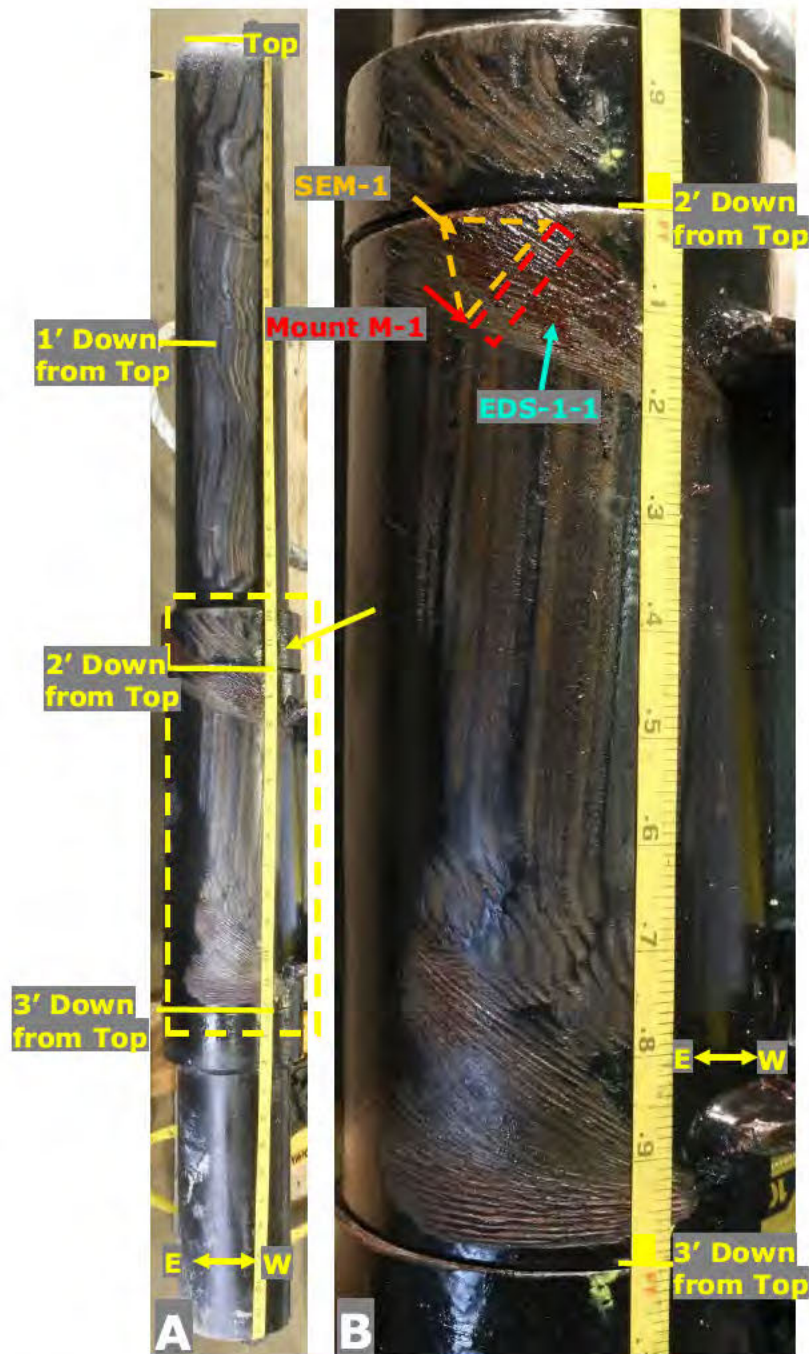


Figure 2. Photographs of Anomaly 1 located on the OD surface of the East Sleeve Ring (showing North side of assembly) and locations of Mount M-1, SEM-1 and EDS-1. (A) shows entire East Sleeve Ring, (B) shows close-up of anomaly. Location indicated in Figure 1. Tape measure indicates distance down from top of assembly in feet.

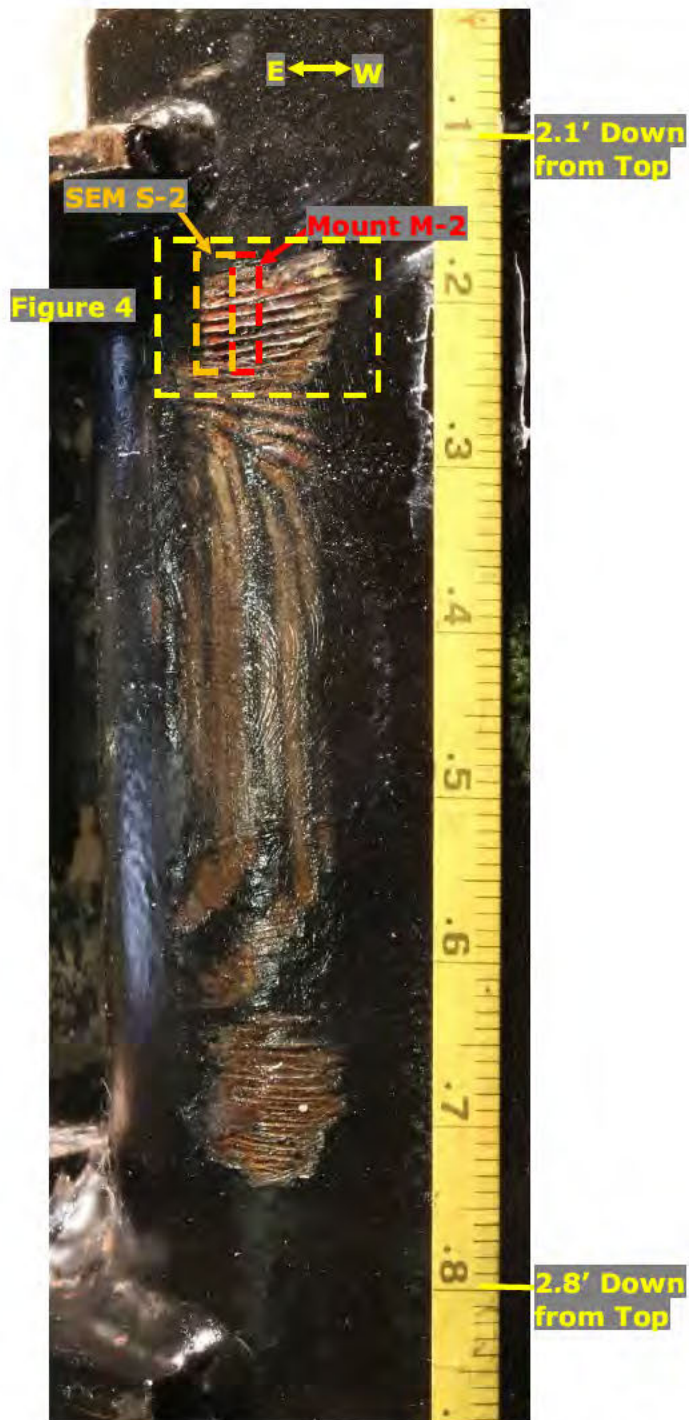


Figure 3. Photograph of Anomaly 2 located on OD surface of the West Sleeve Ring (North side of assembly), and locations of Mount M-2 and SEM-2. Location shown in Figure 1. Tape measure indicates distance down from top of assembly in feet.

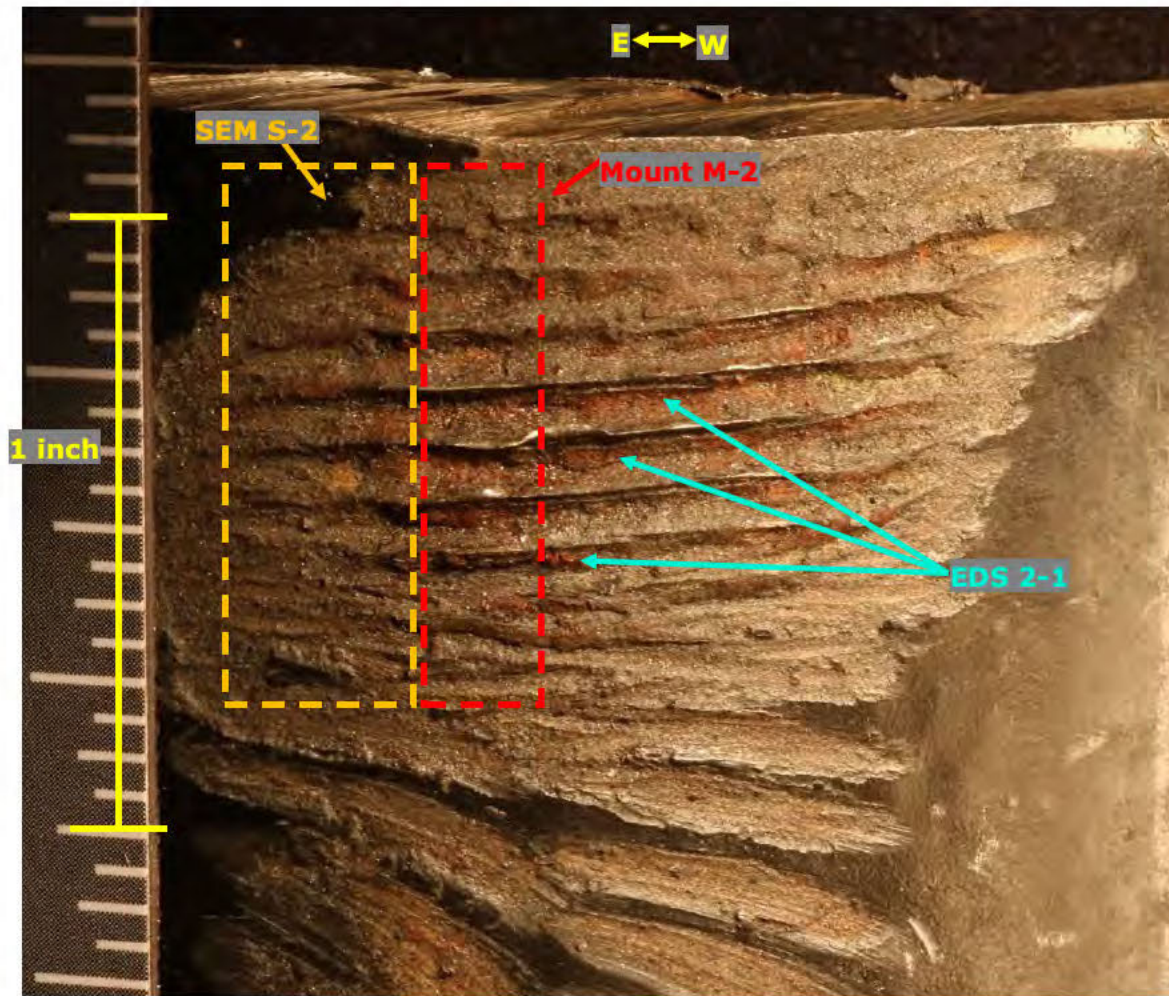


Figure 4. Close-up photograph of Anomaly 2 on OD surface of West Sleeve Ring (North side of assembly), and the locations of Mount M-2, EDS 2-1 and SEM-2. Location shown in Figure 3. Ruler for reference in inches.

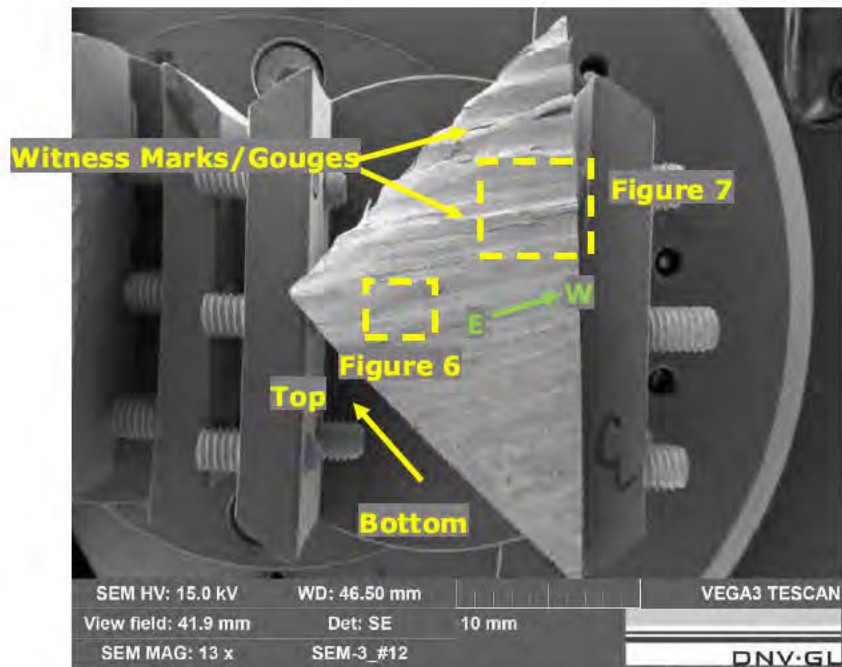


Figure 5. SEM image of the surface of SEM Sample S-1. Location where sample was removed is shown in Figure 2.



Figure 6. Higher magnification SEM image of the surface of West Sleeve Ring Anomaly; area indicated in Figure 5.

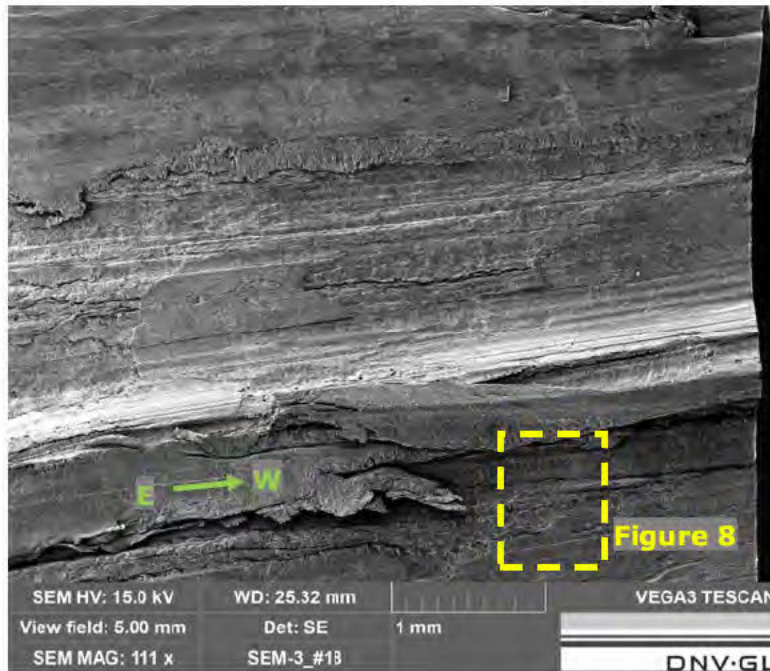


Figure 7. Intermediate magnification SEM image of the surface of West Sleeve Ring Anomaly; area indicated in Figure 5.

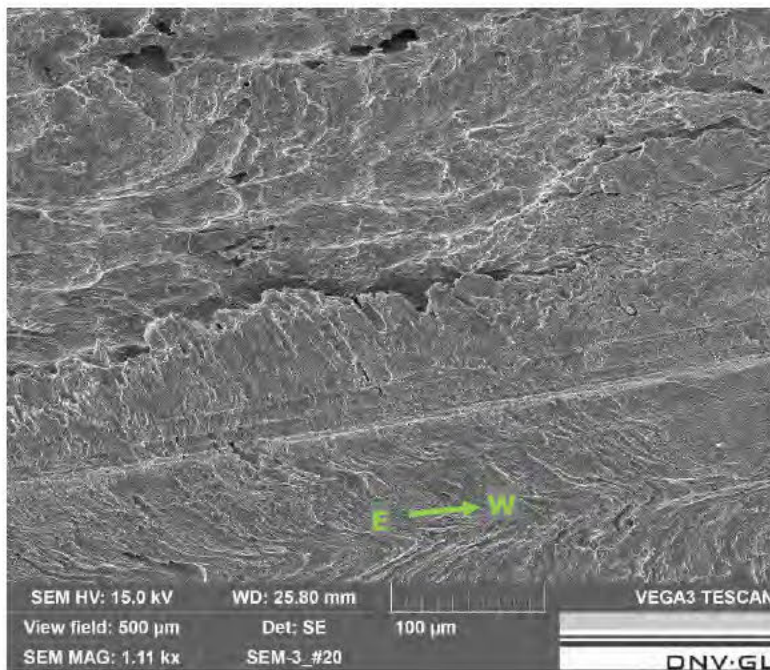


Figure 8. High magnification SEM image of the surface of West Sleeve Ring Anomaly; area indicated in Figure 7.

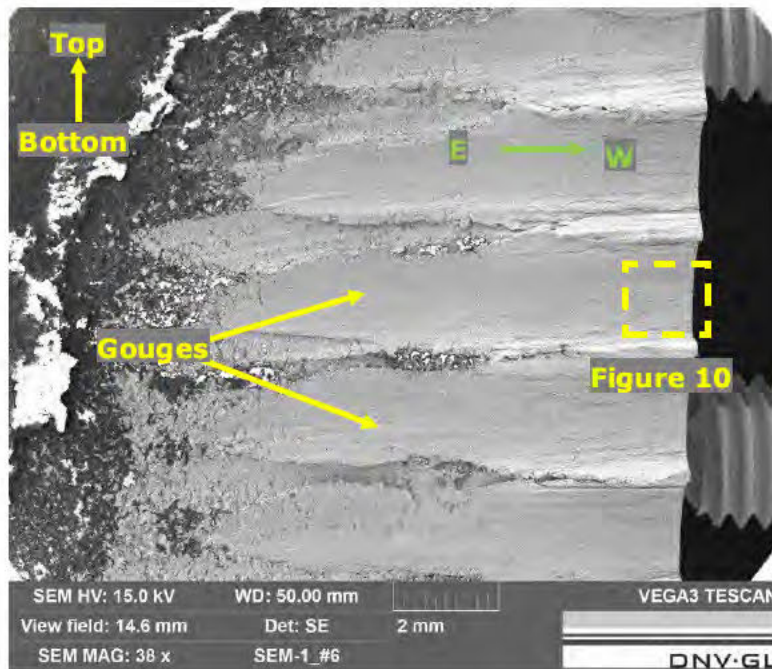


Figure 9. SEM image of the surface of SEM Sample S-2. Location of sample shown in Figure 3 and Figure 4.

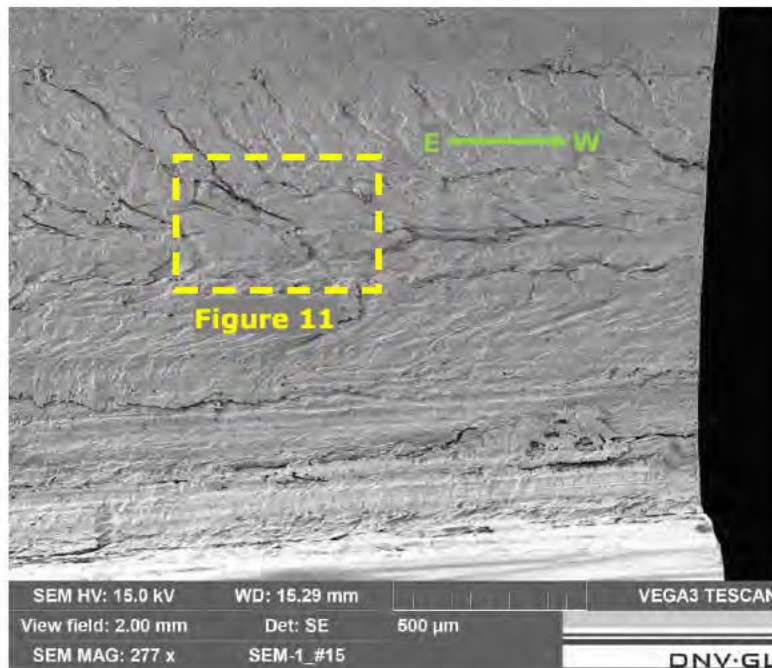


Figure 10. Intermediate magnification SEM image of the surface of East Sleeve Anomaly; area indicated in Figure 9.

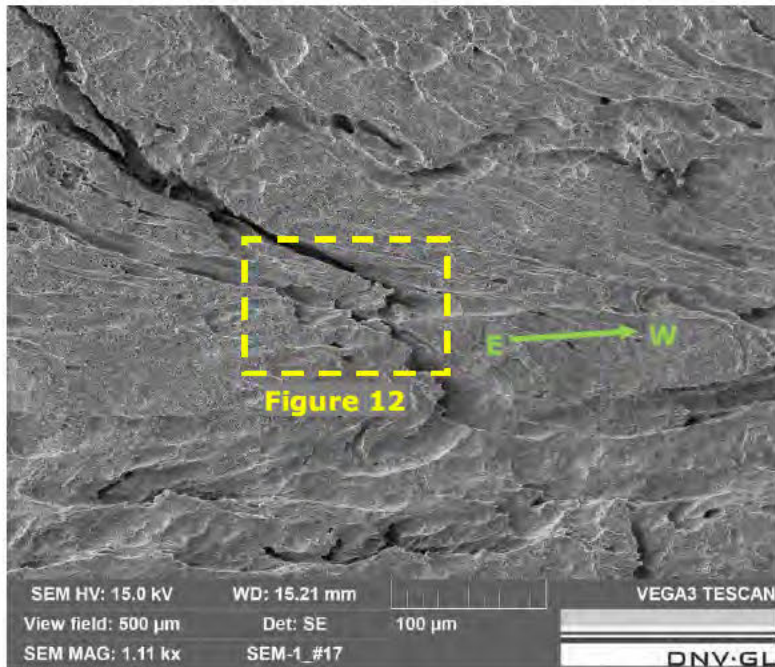


Figure 11. High magnification SEM image of the surface of East Sleeve Anomaly; area indicated in Figure 10.

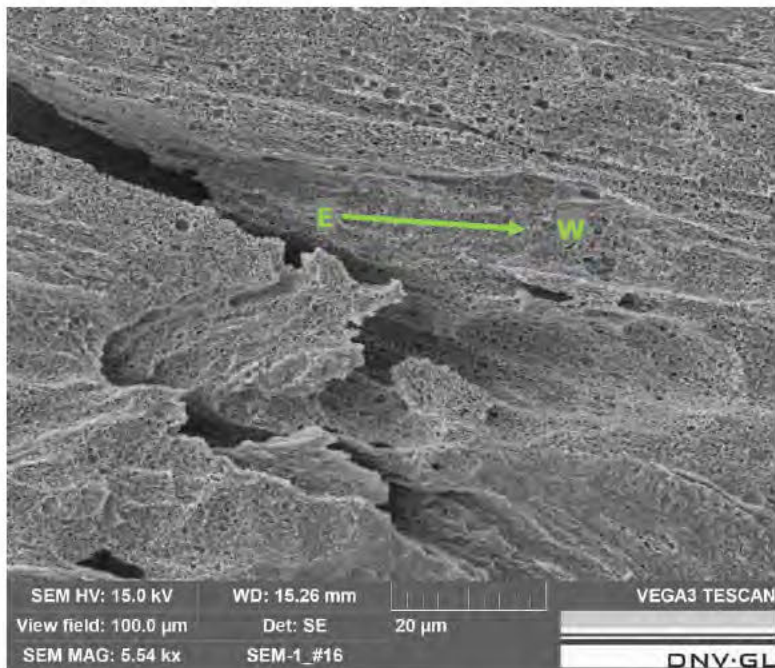
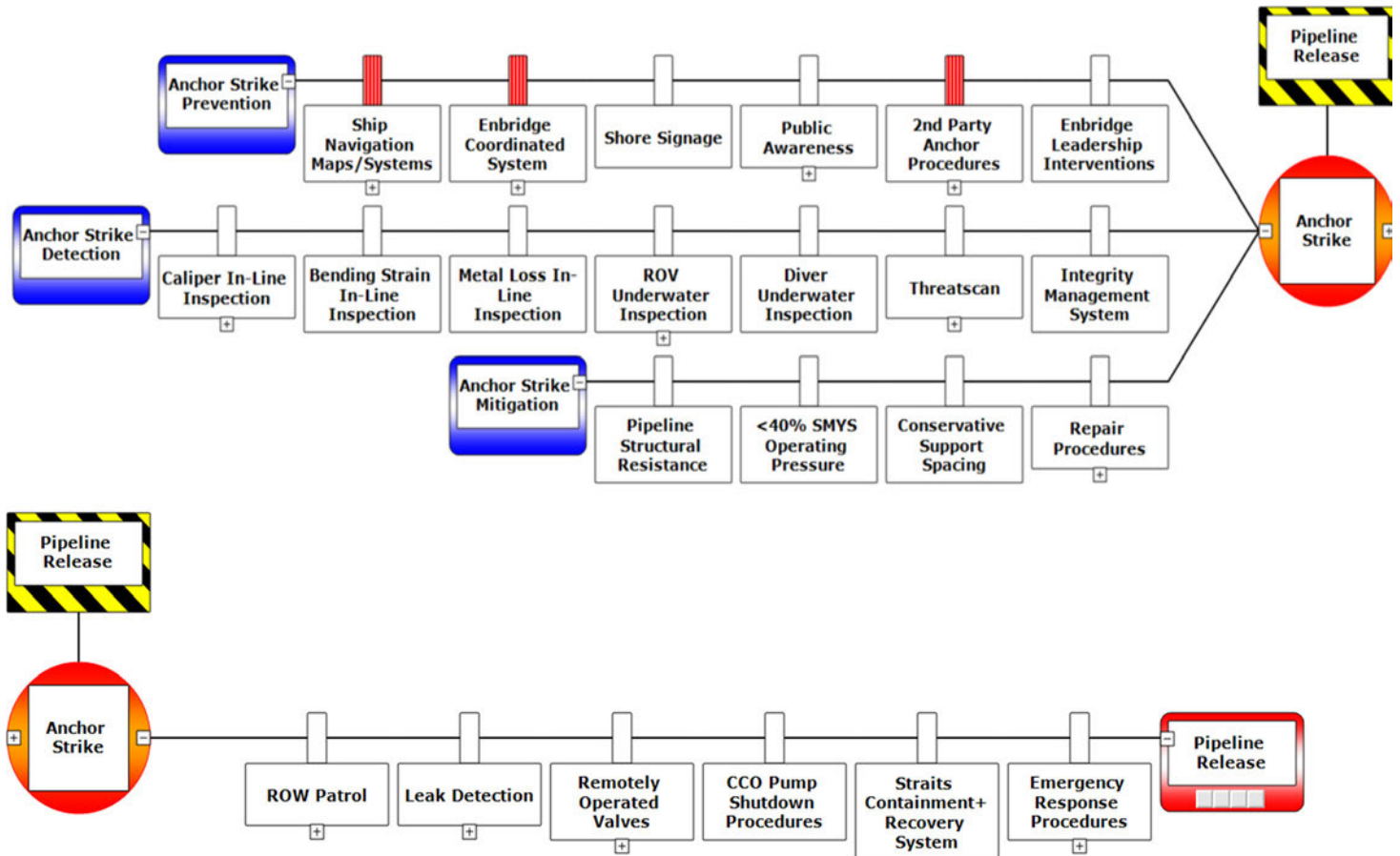


Figure 12. High magnification SEM image of the surface of East Sleeve Anomaly; area indicated in Figure 11.

## APPENDIX D

### Root Cause Analysis of Cable Contact

A BSCAT (barrier-based systematic cause analysis technique) analysis was conducted to support a root cause analysis of the incident. Within the BSCAT, barriers currently in place to prevent significant release due to a line strike were compiled (see below figure). Subsequently, the root cause of the incident (in this case the cable contact event) and barriers gaps leading to the incident were identified. Finally, recommendations for barrier improvements that would prevent incident recurrence were generated. It was demonstrated within this analysis that Enbridge currently has more than 20 barriers in place at the Straits to mitigate the threat of anchor strike with the Dual Pipelines.



### **BSCAT Analyses for Anchor Strike Threat & Consequence Mitigation**

The performance of the most important Straits crossing cable contact barriers, in relation to this incident, are summarized below:

#### Anchor Strike Prevention

- Identification of the right-of-way no anchor zone on ship navigation maps has historically provided the primary Straits crossing anchor strike prevention mitigation.
  - This barrier does not mitigate emergency or unintentional anchoring, or negligent anchor or cable deployments during planned and approved activities within the RNA.
- The Enbridge Coordinated System is intended to actively reinforce the navigation map barrier and observe/identify vessels of significant size that, through emergency, unintentional, or negligent anchor/cable deployments, may cause harm to the Dual

Pipelines. If any risk of harm is observed that cannot be resolved, the Coordinated System provides that the Dual Pipelines are to be shut down.

- Anchor plans and procedures are developed by qualified vessel contractors, however there is no detailed risk assessment of anchor plans/procedures.

#### Anchor Strike Monitoring

- Performed acceptably
  - The cable contact was identified during routine planned underwater maintenance and inspection.

#### Anchor Strike Mitigation

- Performed acceptably
  - Pipeline allowable span length was not exceeded.
  - Pipeline pressure containment capacity was not exceeded (no damage to the pipeline).

#### Release Response

- Not Applicable for this incident

The results of the root cause analysis are summarized as follows:

#### Direct Cause – Either of:

1. Negligent mooring or anchor cable deployment by small or moderately-sized vessel; or
2. Faulty mooring or anchor cable deployment by a vessel contracted by Enbridge to conduct maintenance work in proximity to the Dual Pipelines.

#### Barrier Gaps:

1. Current damage prevention measures are primarily designed to address the threat of anchor drag from large commercial vessels. They are not specifically designed to prevent or mitigate the risk of the anchor or cable from coming into contact with the Dual Pipelines where that anchor/cable is intentionally or negligently deployed by a vessel conducting work in proximity to the Dual Pipelines, including by vessels contracted by Enbridge.
2. External risk assessments are not completed to identify and mitigate all potential threats resulting from the deployment of an anchor or cable in proximity to the Dual Pipelines, including by vessels contracted by Enbridge.

As a result of the RCA, it was identified that the current damage prevention measures did not reduce the likelihood of a faulty or negligent mooring or anchor/cable deployment by small or moderately-sized vessel conducting work in proximity to the Dual Pipelines, including vessels contracted by Enbridge. Based on the BSCAT analysis, potential barrier improvements were identified.

#### Barrier Improvements:

1. A standard protocol should be developed that specifies the minimum requirements for anchoring plans and procedures for vessels conducting work in proximity to the Dual Pipelines. This protocol should include:
  - a. Requirement for a risk assessment of anchoring procedures, including associated mitigations, by a maritime expert.
    - i. Such review should be conducted for anchor plans/procedures for Enbridge contracted vessels, as well as third-party vessels conducting maintenance activities associated with other submerged infrastructure in proximity to the Dual Pipelines.

The RCA demonstrated that both the anchor strike monitoring and anchor strike mitigation barriers performed acceptably, while the release response barriers were not activated.

# **ATTACHMENT 1**

**LINE 5 – Straits of Mackinac**  
**EAP-9 Coating Inspection**  
**Overview**

28 May 2020 (Rev 1)

Enbridge began its seasonal maintenance work for Line 5 in the Straits at the beginning of May and has already made significant progress with several scheduled activities.

Crews have installed seven new steel screw anchors with 13 more to complete the current span management program.

As part of the pre-anchor installation work the week of May 18-22, crews using an ROV to inspect the coating at the location of proposed anchor install EAP-9 on the east pipe identified several areas of disturbance to the coating which required further evaluation. Using divers, it was determined that of the 15 areas inspected, there are four areas near the proposed EAP-9 installation that contain bare metal and require coating repairs. The areas with bare metal range from .07 to .43 square feet.

None of the disturbed areas effect the integrity of the pipeline.

Further, this install location is near where a ship anchor impacted the pipeline in 2018 and the inspection team also noticed that the outer sheath of the strike repair material has a slight scrape. While there is no impact to the integrity of the repaired area, the material also will be repaired.

Enbridge anticipates using the pre-approved coating repair work plan procedures to perform the necessary coating repairs before the installation of the anchor at EAP-9 and has been in communications with both the Michigan EGLE and the U.S. Army Corps of Engineers regarding any necessary modifications to existing permits, including for the excavation of a small amount of bottomlands to perform repairs at Feature 9. One area with bare metal appears also to have two scratches on the metal that will require buffing before the coating repairs can be performed. These scratches have no effect on the fitness of the pipeline. The coating repairs are anticipated to take 5-10 days.

It's not evident at this stage what caused the coating damage. Enbridge is looking at all the monitoring data, including our ROV and dive info from last year, January 2020 ILI's, vessel movement monitoring, and acoustic monitoring. Enbridge will continue to review information from this location and will provide updates as available.

The ongoing maintenance and inspections for Line 5 worked exactly as intended. In this case, Enbridge identified the coating issues and is moving quickly to make repairs per the State-approved coating repair work plan already in place. Again, we can confirm that there is no damage affecting pipeline integrity.

Summary Table of Features inspected near EAP-9. (as of 5/27/2020 at 1600 hours local)

Feature Number	Location/ Position	Measured Feature size (ft <sup>2</sup> )	Classification	Status and Actions
1	1' 9" South	0.004 (1.5" X 3/8")	Disturbed Area	Inspection complete No coating damage No further action required
2	2'5" – 5'6" South	0.51 (37" X 2")	Disturbed Area	
3	3'4" – 5'8" South	0.39 (28" X 2")	Disturbed Area	
4	7'5" – 7'9" South	0.03 (4" X 1")	Disturbed Area	
5	7'10" – 8'1" South	0.10 (3" X 5")	Dislodged Area	Inspection complete Previous repair (Viper Skin) outerwrap with minor damage, no integrity threat Minor trimming of overwrap may be required
6, 7, 8	8'2" – 9' South	0.02 (3" X 1")	Disturbed Area	Inspection complete No coating damage of Viper skin outerwrap No further action required
9	16'9 – 1" South	0.06 (3" x 3")	Holiday (bare metal)	Inspection complete Bare metal identified Repair required and excavation
North 1	8'6" – 9' North	0.13 (6" X 3")	Holiday (bare metal)	Inspection complete Bare metal identified. Repair required
North 2	7'6" – 8'1" North	0.18 (7" X 3.75")	Holiday (bare metal)	Inspection complete Bare metal identified, coating removed and two surface indications identified. NDE assessment and repair required
North 3	6'2" – 6'7" North	0.43 (5" X 1.25")	Holiday (bare metal)	Inspection complete Bare metal identified. Repair required
North 4	5'11" – 6'9" North	0.07 (10" X 1")	Disturbed Area	Inspection complete No coating damage No further action required
North 5	3'3" North – 12" South	1.42 (51" x 4")	Disturbed Area	Inspection complete No coating damage No further action required
A	34' 8,5" – 35'2" South	0.34 (5.5" X 9")	Deposit	Inspection complete Calcareous deposit found at location. No further action required

## **ATTACHMENT 2**

# **Line 5 Straits**

## **Engineering Assessment**

### **East Leg and Anchor EP-17-1**

PRIVILEGED AND CONFIDENTIAL

21 June 2020

## SUMMARY:

This Engineering Assessment (EA) was conducted following the discovery of a damaged support anchor identified as EP-17-1 on the East Leg of Line 5. Enbridge has completed detailed modelling and fitness for service assessments in order to confirm and demonstrate that the East Leg pipeline is safe for continued operation. The longitudinal loading experienced by the anchor and resulting stress transferred to the pipeline is between 60 – 77 times lower than engineering design limits of the pipeline critical strength. Further, direct field examination of the pipe shows only minor coating damage and no metal disturbance caused by the movement of the anchor. Additionally, this assessment demonstrates that the damage to the support did not create a pipeline span or support safety concern. Finally, a recent ROV inspection has confirmed that there is no mechanical damage to the other screw anchors and other portions of the pipe.

## PIPE CONDITION ASSESSMENT

ROV imagery as well as a diver survey was conducted at Span E-11 where anchor EP-17-1 is located. Photos of the condition of the anchor as found coupled with the diver assessment of the pipeline coating indicate very little load transfer between the screw anchor's saddle assembly and the pipeline. In addition, as the saddle of the anchor traversed towards the South, no coating holidays occurred due to contact in this area indicating that the shear stresses on the coating remained low throughout the event. The diver assessment indicates no visible deformations on the pipeline.

The maximum force on the support anchor would have been due to dragging it in the longitudinal direction (i.e. along the axis of the pipe). The limiting point on the anchor is the slip force of 2600 lbs friction load which occurs at the saddle component and is the interface between the anchor and the pipe. This dragging force equates to less than 0.054 ksi or less than 0.18% specified minimum yield strength (SMYS) of the pipe.

The support anchors are designed to provide stability to the pipeline where spans develop. By design, the anchor supports can de-couple or come apart at various connections in case unplanned forces act upon them. This de-coupling or de-connection occurs at forces far less than the force (700 – 900 kN or 157,366 – 202,328 lbs) needed to cause critical pipeline damage. The resultant movement and damage of the support anchor in this instance demonstrates this design behavior. In other words, an unplanned force that can displace or break apart the anchor is well below the force required to cause critical pipeline damage. For illustration purposes, the pipeline's resistance (represented as 180,000 lbs) to pulling force relative to the force imparted on the East Leg support is shown in Figure 1 below alongside some pulling force comparators. As shown, the design of the Straits crossing is highly resistant to this type of event.

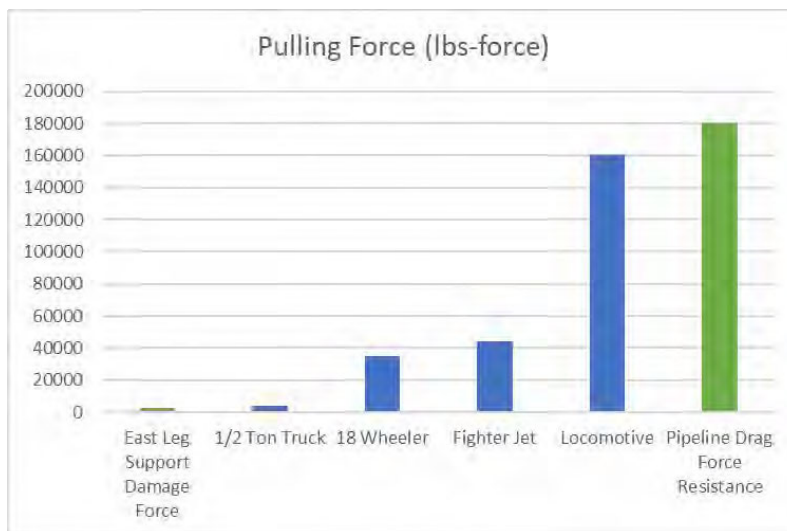


Figure 1: Comparison of Drag Force that Occurred at the Anchor to Sample Scenarios

## LINE 5 ANCHOR DESIGN

The primary purpose of the anchors is to manage forces associated with loads such as gravity, buoyancy and water current. These are “in-plane” lateral loads (perpendicular to pipe axis). The in-plane frame action of the anchor assembly with the high bending stiffness of the cross-beam provides higher stiffness and strength to support the pipe in lateral direction. In the out-of-plane direction (along the pipe axis), the anchor assembly deforms in a cantilever mode which provides much less stiffness and strength. In simpler terms, the anchor is designed to be stiffer or stronger when the forces are perpendicular to the pipe. When these forces are aligned to the pipe, the anchor will deflect easily as intended. Under out-of-plane loads applied to the cross-beam or one of the helical piles, the flexible bolted connection between the beam and the pipe limits the axial load transfer between them. The Neoprene pad between the pipe and saddle also limits the load transfer between the pipe and the anchor assembly in the longitudinal direction of the pipe.



Figure 2: Displaced Anchor looking West

## ANCHOR ASSEMBLY LOAD DETERMINATION

Two load case scenarios are analyzed to verify the safety of the line when the anchor assembly is loaded in the out-of-plane direction by an external source.

In the first loading scenario, under horizontal out-of-plane load applied to one anchor pile, the anchor and pipe system remain connected until such time as the static friction between the Neoprene pad and pipe coating is exceeded. The assembly of the anchor involves increasing torque on the threaded rod sections until there is approximately 3/16" worth of compression in the 1 1/2" thick 60 durometer Neoprene. This level of compression corresponds to just under 50 ft lbs of torque on each of the 4 threaded rod assemblies. The compressive force between the saddle assembly can then be calculated based on the 8" wide saddle as 13,000 lbs. The static friction coefficient is conservatively estimated at 0.2 based on wet contact face between the Neoprene and the coal tar coating. The resulting required axial force at the pipe to cause initial slip is then calculated to be approximately 11.6 kN or 2600 lbs. Once axial movement is initiated, all preload stored between the three 1/2" Neoprene pads is lost as the upper spacer separates from the cross-beam as shown in Figure 2 above.

Secondly, the same analysis was repeated with no restraint on the pipe saddle to calculate the maximum load that fails the anchor pile after the anchor assembly is completely detached from the pipe. The maximum applied horizontal load in this scenario is 6.5 kN or 1461 lbs as determined through Finite Element Analysis where loading was increased until pile failure initiation was observed. Once the

yield strength of the pile is reached, there is relatively little increase in load to continue deforming the anchor assembly. The loading condition shown in Figure 3 below has the loading of the cross-member where it meets the East helical screw pile. This loading condition matches the as found deformed shape of the assembly when viewed from above as shown in Figure 4 below. Also, the reduced stresses within the West helical screw pile in Figure 3 support this loading condition.

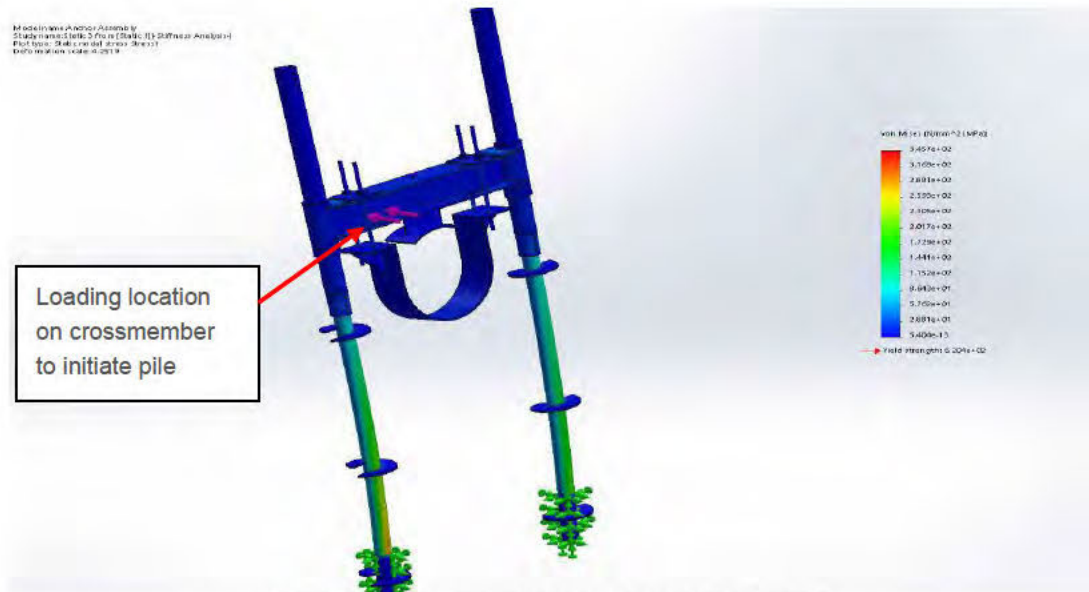


Figure 3: Required loading to yield the helical anchor



Figure 4: View from above showing the increased deflection within the East helical pile

### PIPE SPAN SUPPORT CONDITION

The pipe is currently sitting on clay material nearby the damaged support anchor as shown in Figure 4 above and Figure 5, below. The clay touchdown serves as a support point and is 66 ft from the next anchor. This new pipe span of 66 ft is shorter than the remediation target of 75 ft, as stipulated within the requirements of the Line 5 Straits Easement Agreement. The 75 ft target provides a 2x safety factor. The 3<sup>rd</sup> Consent Decree additionally stipulates that locations identified beyond 65 ft span will require assessment and determination for remediation. The damaged anchor is incapable of carrying any measurable pipeline load due to the damaged and mis-aligned 1-inch threaded rods, as well as the gap between the top cross member and the pipeline as shown in Figure 5 below. This indicates that the maximum vertical load that can be imparted to the pipe is limited to the bending load of the failed 1" threaded rods and that the existing damaged anchor does not provide sufficient span management. As such, in order to meet the requirements of the Consent Decree, a replacement anchor will be scheduled for install in the near term once the required permit modifications are approved by both USACE and EGLE.

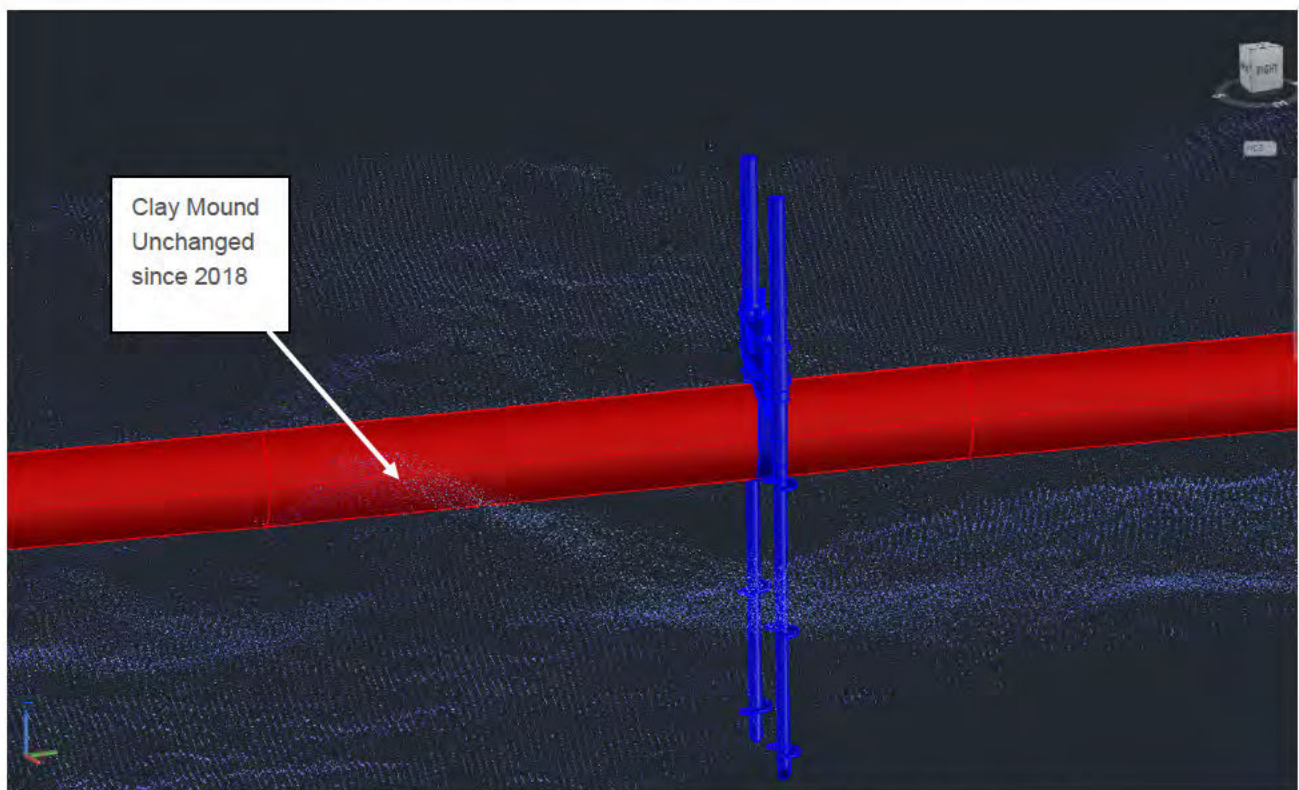


Figure 5: Multibeam bathymetry of EP-17-1 in relation to the adjacent clay mound.



Figure 6: Damaged Threaded Rod Assemblies and Pipeline Gap to Cross Member

#### ADDITIONAL INSPECTIONS

The East Pipeline through the Straits was inspected to detect metal loss using BHGE Magnescan MFL4CAL on January 14, 2020. This tool provides simultaneous collection of metal loss inspection data as well as geometric inspection data. Vendor specifications indicated that metal loss as low as 12% of wall thickness, and geometric anomalies as small as 0.6% of diameter can be discerned.

The metal loss inspection reported zero metal loss anomalies and zero geometry features in this general area.

In addition, an ROV assessment of the east leg has been recently completed, confirming that there is no mechanical damage to any of the other screw anchors, or to the east leg pipeline and its coating.

#### CONCLUSION

The design of the Line 5 helical screw piles is fit for purpose to assure unplanned loading does not damage the pipe. This assessment of the unplanned load acting on the anchor assembly at anchor EP-17-1 has demonstrated no mechanical damage was caused to the pipeline, and ROV inspection has confirmed that there is no mechanical damage to the other screw anchors and other portions of the pipe.

## **ATTACHMENT 3**

## **Integrity Assessment – West Leg – Line 5 Straits**

June 20, 2020 (issued)

June 21, 2020 (revised: first dive post ROV inspection results)

June 24, 2020 (revised: i) additional dive activity, ii) ROV flight path clarification, iii) follow-up dive data confirmation and iv) expanded historical ILI analysis)

### **Summary**

The West Leg of the Line 5 Straits was inspected and assessed on June 19, 2020, as a precautionary measure following mechanical damage being found on a pipe support anchor on the East Leg. Across the entire West Leg, no mechanical damage was observed on any support anchors. This inspection identified a visual anomaly (“feature of interest”) consisting of disturbed biota and a small light-colored patch. Review of previous inspection data (close interval survey, metal loss ILI and geometry ILI) revealed no anomalies in the vicinity near the feature of interest. The feature of interest is similar to calcareous deposits observed during all previous Line 5 Straits work. Calcareous deposits are a protective build up from minerals naturally occurring in the water and demonstrate effective corrosion protection using cathodic protection. Based on these examinations and the pipe nominal pipe wall thickness of 0.812”, this feature does not present an integrity concern to the pipeline and does not interfere with normal operations.

Follow-up dive examinations were completed on June 21 and June 22, 2020 and confirmed that there was no bare metal, no physical damage and that a coating repair was not required.

### **Assessment**

#### **Remote Operated Vehicle (ROV) and Diver Inspection:**

The Enbridge marine contractor conducted a full inspection of the West Leg of the Dual Pipelines using ROV equipped with video imaging. This inspection was completed following evidence of damage to a pipe support on the East Leg pipeline (EP-17-1). The inspection included a single ROV flight over the West Leg pipeline that allowed the top and sides of the pipe to be observed. The visual inspection confirmed that none of the pipe support anchors on the West Leg have experienced any damage. The inspection identified a single new feature of interest (see figures 1, 2 and 3, below).

The feature of interest identified by ROV on the West leg is comprised of an area of disturbed biota (quagga mussel encrustation is removed) with a small light-colored patch (approximately 50 square inches). The light-colored patch are calcareous deposits formed by the proper operation of the cathodic protection system. The images show there was no bare metal or mechanical damage and the pipe was protected by coating and cathodic protection. The follow up dives confirmed all ROV findings, and additional details were collected. The feature measurements from Diver was found to be slightly larger (~70 square inches) than the estimate previously provided based on ROV images. The feature of interest did not require repair.



Figure 1: Location (overview)



Figure 2: Location (close)



Figure 3: Feature of Interest (close)

### Close Interval Survey (CIS):

Enbridge conducted a comprehensive cathodic protection CIS across entire pipeline in 2018/2019. The results of the survey have been previously reported. No cathodic protection anomalies were reported on either of the Dual Pipelines, therefore indicating effective operation of the corrosion protection systems.

The area containing the feature of interest on the West pipeline was carefully examined for electrical variations to determine any signs of coating damage. No electrical anomalies were identified, indicating that there was insufficient exposed metal to alter local protection levels at the time of the CIS. Figure 4 presents the segment of survey containing the feature of interest, with the location of the feature highlighted.

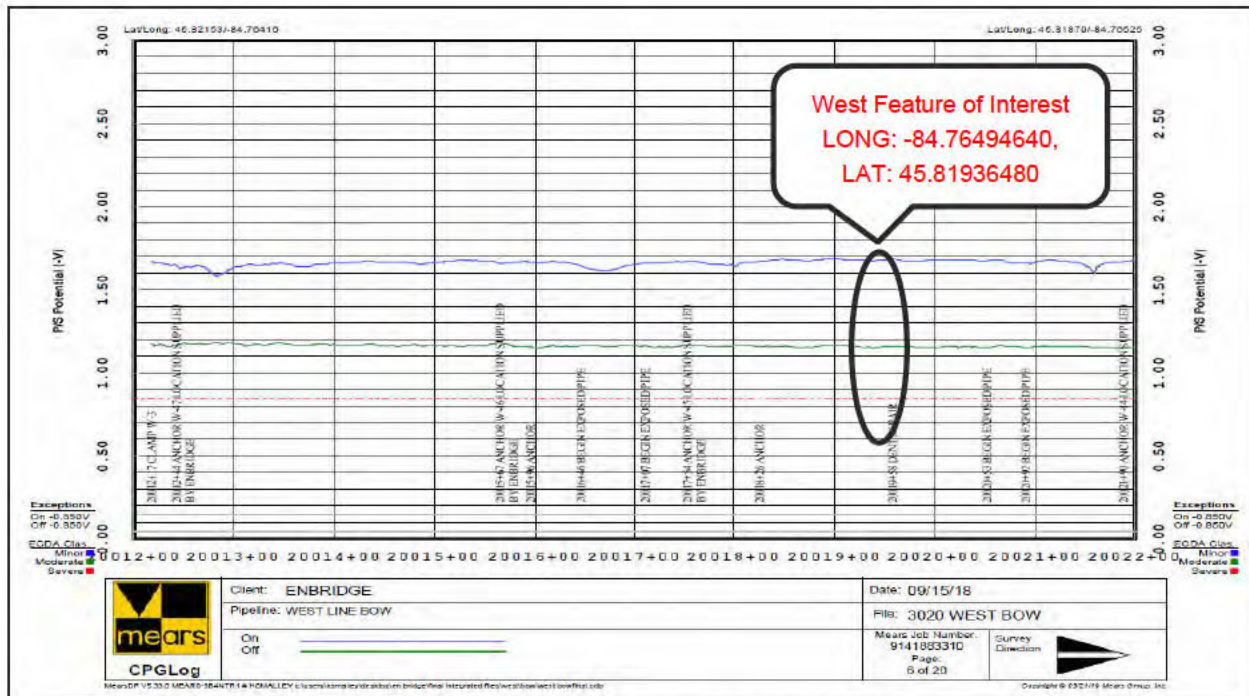


Figure 4: CIS of the Segment Containing Feature of Interest (Feature identified)

### Metal Loss and Geometry ILI:

The West Pipeline through the Straits was inspected to detect metal loss using BHGE Magnescan MFL4CAL on January 17, 2020, this tool provides simultaneous collection of metal loss inspection data as well as geometric inspection data. Additionally, Enbridge has inspected the West Pipeline through the Straits to detect metal loss and geometric features annually since 2017. Following this event all reports have been reviewed and there are no features that require repair on the entire West Leg pipeline.

### Conclusions:

Based on ROV and dive inspection data, with further support from the recent ILI inspection data and CIS, the feature of interest does not constitute an integrity concern to the pipeline and does not interfere with normal operation and also that repair is not required at this site.

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