LINE 9 REVERSAL PHASE I

Condition 8 Summary Report

Submitted to:

NATIONAL ENERGY BOARD

CANADA

Prepared by:

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Pipeline Integrity Department

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1. EXECUTIVE SUMMARY

The Line 9 Reversal Phase I ("Project") approval requires the Project to file with the National Energy Board ("NEB") an updated Engineering Assessment ("EA") as stated in Order XO-E101-010-2012 Condition 8. The Condition states that:

> Enbridge must file with the Board, at least 30 days prior to applying for LTO the pipeline in the reversed direction, an updated Engineering Assessment, which includes a remaining life analysis for cracks, demonstrating that the pipeline between North Westover Pump Station and Sarnia Terminal is fit-for-service in the reversed flow direction at 5,281 kPa (766 psi). If Enbridge chooses to apply a different operating pressure for this analysis, please provide justification.

This report is a revised Fit-For-Service ("FFS") assessment in compliance with Condition 8. It includes a revised remaining-life assessment for cracks based on a maximum discharge pressure of 5151 kPa (747psi) at the Sarnia Terminal ("SA") as per the revised Maximum Operating Pressure ("MOP") profile, updated Crack management program details, revised Maximum Allowable Operating Pressure ("MAOP") profile based on the NEB licenced MOP and updated results of the crack excavation program. Updates are appropriate for the cracking condition of the line whereas the corrosion and geometry features remain as assessed within the original EA filed with the Line 9 Reversal Phase I application. Based on this updated EA, no additional recommended integrity actions are required in order to ensure the pipeline between North Westover Pump Station and Sarnia Terminal is fit-for-service.

Cracking Threat

The established programs that manage fatigue cracking and Stress Corrosion Cracking ("SCC") on the Enbridge pipeline system are designed to meet or exceed the current MOP along the length of the pipeline. The Project does not involve a change to the licensed MOP. The proposed flow reversal does not present a condition that would require a modification to the crack management program of the pipeline. Line reversal does result in a revision to the crack risk profile, however, investigative excavations completed immediately downstream of SA and results of the EA presented herein confirm that this section of line is not at an immediate threat from cracking related mechanisms. Enbridge will continue to monitor the section of pipe immediately downstream of SA and overall integrity of the line post reversal.

Planned Activities Prior to Flow Reversal

In addition to the revised cracking threat assessment presented herein, which confirms that the pipeline can be operated in a safe and reliable condition irrespective of flow direction, the integrity commitments made as part of the EA for the Line 9 Reversal Project Phase I (March 2012) have been completed. To meet these commitments, Enbridge has:

- Conducted an assessment of select geometry features recognizing that the risk associated with existing features is not considered to increase due to the line reversal;
- Conducted an intelligent valve placement analysis on Line 9 between SA and North Westover Station (“NW”) and determined optimum valve placement locations by examining the effectiveness of remote controlled sectionalizing valves in reducing volume out to high consequence areas; and
- Enhanced the Cathodic Protection (“CP”) monitoring system by installing remote monitoring equipment on all Eastern Region rectifiers.

2. PROJECT INFORMATION

2.1 Project Background

The Project proposes to reverse a section of the Enbridge Line 9 between SA and NW to accommodate Enbridge customers' request for greater capacity and access to the Ontario market.

This NPS 30 pipeline, as shown in the schematic in Figure 2.1, was originally constructed in 1975 and commissioned in June 1976 to operate in eastward flow direction as part of the Enbridge Line 9 pipeline from SA to Montreal ("ML"). The pipeline was then reversed in 1999 as part of the Line 9 Reversal Project (OH-2-97) and pursuant to NEB Order X0-JI-34-97.

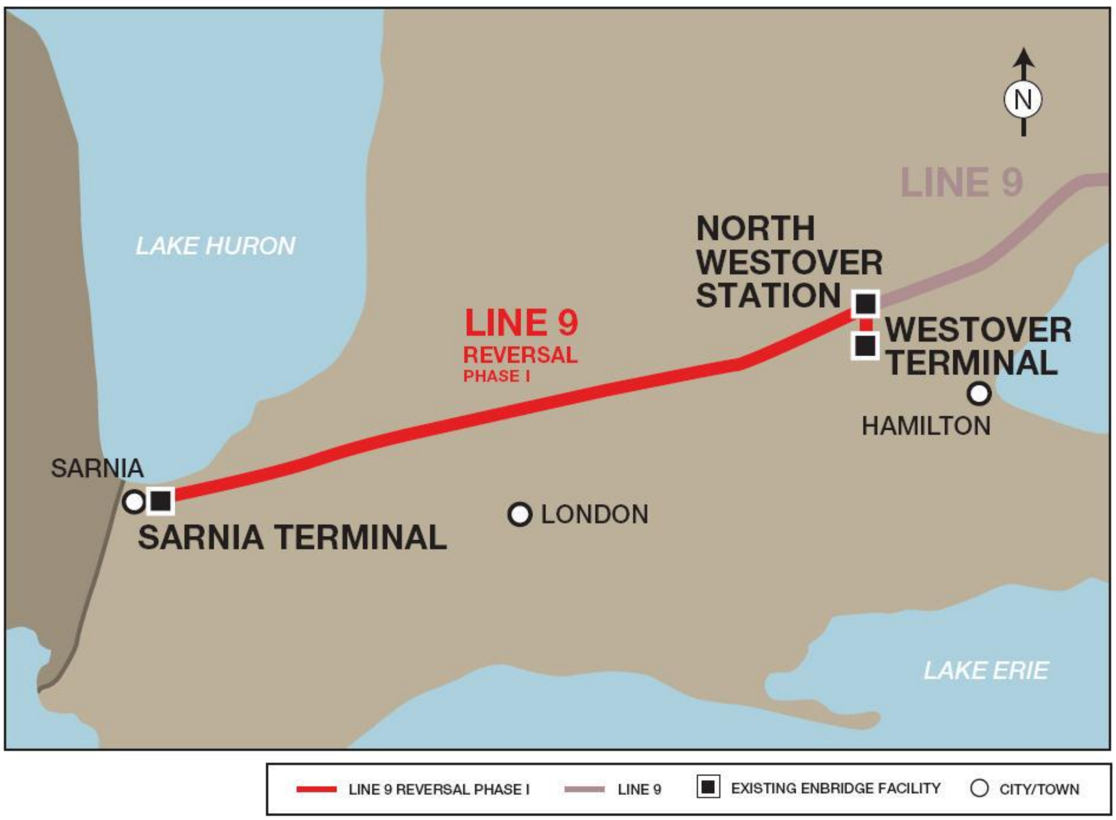

Figure 2.1 - The Project System Map

3. REVISED FFS ASSESSMENT - CRACKING

3.1 Crack Management Program - Revised

As indicated in Section 3.0 of the Engineering Assessment for Line 9 Reversal Project Phase I (March 2012), the section of pipeline between SA and NW has not experienced any in-service incidents due to cracking related mechanisms nor other threats. There were also no leaks or ruptures during the 1997 hydrostatic test of this section of pipe to a pressure equal to 125% of the pipe's MOP.

Enbridge has an established Crack Management Program to manage the threat associated with crack-related defects on its entire pipeline system. Details of Enbridge's Crack Management Program were described in the Engineering Assessment for line 9 Reversal Phase 1, March 2012, filed as part of the Line 9 Reversal Project Phase I application.

Enbridge's excavation and repair programs associated with crack management include a safety factor approach where the reference level is the MOP as determined from the original commissioning hydrostatic test. Figure 3.1 shows the MOP and hydrostatic pressures for Line 9 between SA and NW.

It is anticipated that flow reversal will result in changes to the magnitude of the pressure cycling due to the post reversal maximum discharge pressure of 5151 kPa (747psi) at Sarnia being higher than the current, typical, east-to-west operation. To re-assess the fatigue and SCC growth modeling, the potential change in severity of the pressure cycling at any location along the line was estimated by scaling the pressure data associated with the calendar quarter of most aggressive pressure cycling conditions observed at NW between 2003 and 2011, by the ratio of the maximum observed operating pressure during the quarter to the MOP at the given location. This approach will allow for the most aggressive pressure cycling data experienced in the last nine years to be conservatively scaled up to MOP. The scaled pressure data is expected to be conservatively representative of anticipated change in magnitude of pressure cycling associated with the line reversal, and it is used in the remaining life assessments presented in this EA.

It was determined that this pipeline segment has experienced the most aggressive pressure cycling in quarter 3 of 2003 between 2003 and 2011. During this quarter, operating pressures exceeded 2,344 kPa (340 psi) approximately 7% of the time whereas, for the periods between 2007 and 2011, operating pressures exceeded 2,344 kPa (340 psi) only in 2007 and for only approximately 1.1% of the time (refer to Figure 3.2). The actual pressure cycling in reversed operation will be monitored and evaluated through Enbridge's quarterly pressure cycling monitoring process and associated remaining life assessments.

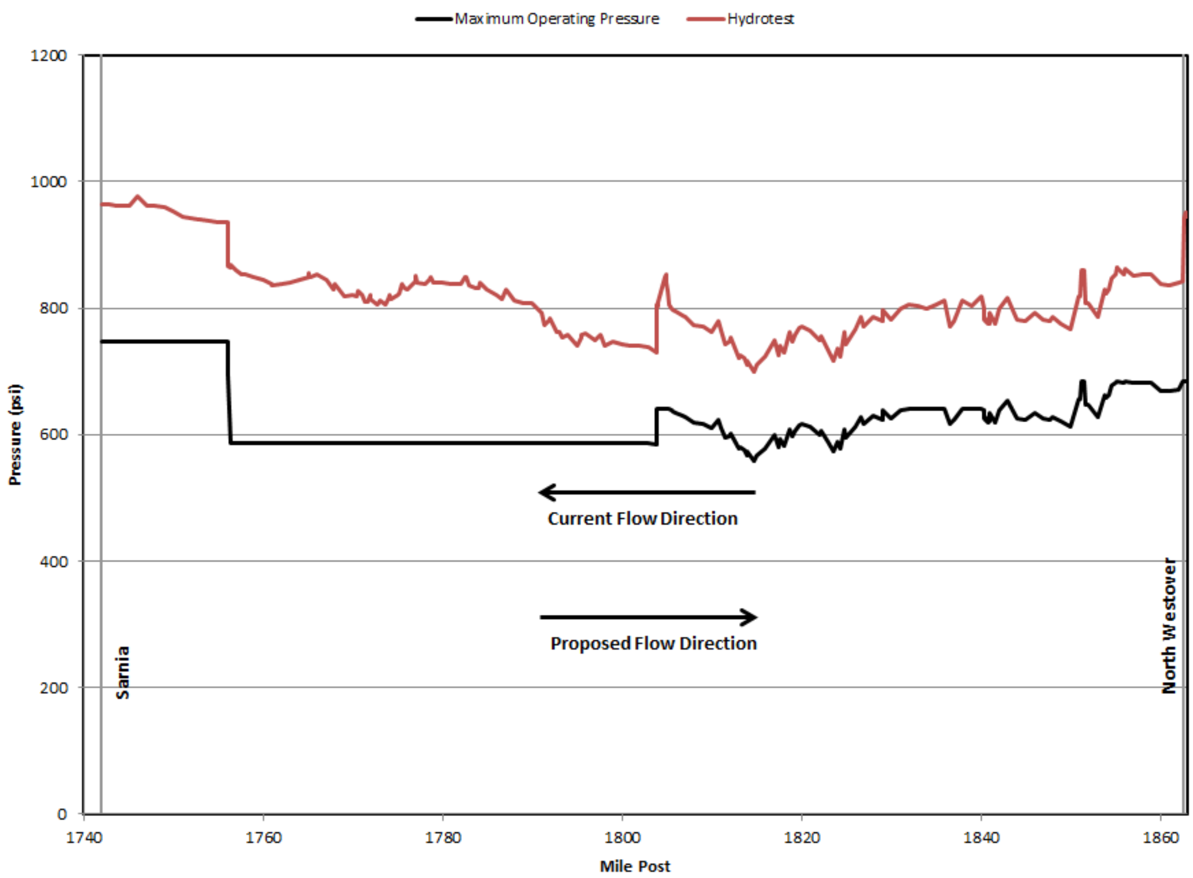

Figure 3.1 - Maximum Operating Pressure Profiles vs. Mile Post

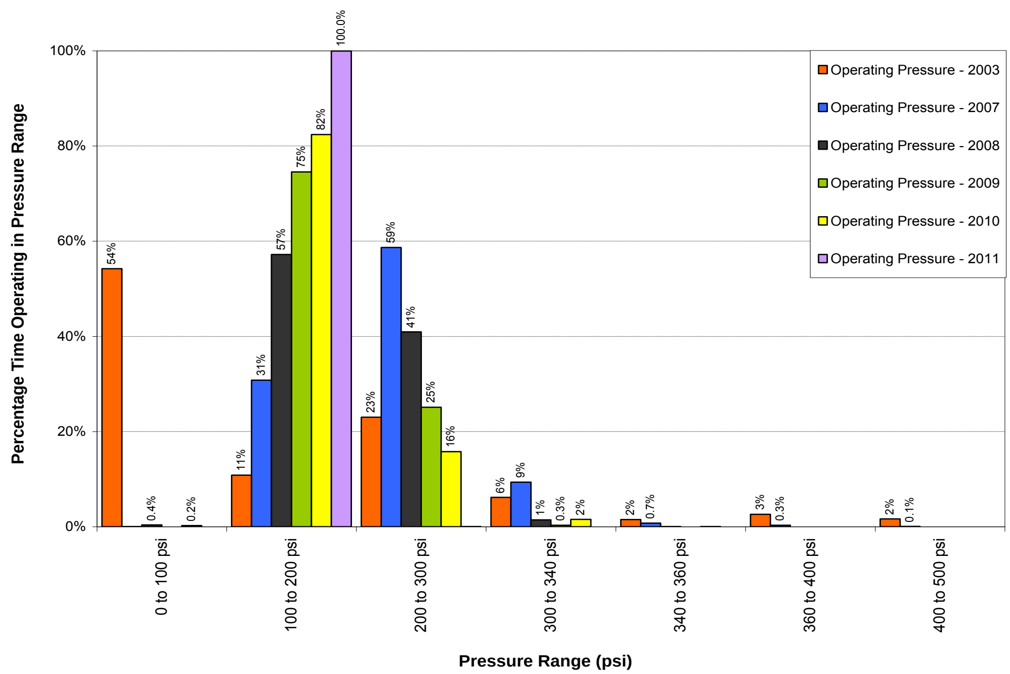

Figure 3.2 - Percentage Time Operating in Pressure Range

3.2 UT Crack Management Program – 2008 Results - Revised

3.2.1 In-line Inspection Data

The portion of Line 9 between NW and SA was inspected in 2008 using the high resolution GE UltraScanTM crack detection ("USCD") tool (owned and operated by GE Oil & Gas, PII Pipeline Solutions) in order to identify any axially orientated crack-related features including those located in the longitudinal seam weld.

In GE's final report to Enbridge, GE indicated that there were no data quality related issues (i.e. missing data, lack of sensor coverage, areas of speed excursions, etc.) associated with the inspection run.

As illustrated in **Error! Reference source not found.**, there were a total of 357 crack-like features provided in the final feature listing of the 2008 USCD report, all of which were identified by GE as being adjacent to the long seam weld. Approximately 79% (281) of those features were reported as being external features while the remaining 21% (76) features were identified as being internal features. There were no other crack feature types identified by this inspection.

The reported features are spread throughout the length of line between SA and NW; although the frequency of features varies along the length of the line there is no discernible trend (refer to **Error! Reference source not found.**).

Approximately 98% (349) of the features had reported depths <1 mm while only 2% (8) features had reported depths between 1 and 2 mm (refer to **Error! Reference source not found.**). There were no features with reported depths >2 mm.

Table 3-1 - Summary of Tool Reported Features

Feature Type	Relative Position	Radial Position	Number of Features	Percentage of Total
Crack-Like	Base Metal	External	0	0.00%
Crack-Like	Base Metal	Internal	0	0.00%
Crack-Like	Adjacent to Weld	External	281	78.71%
Crack-Like	Adjacent to Weld	Internal	76	21.29%

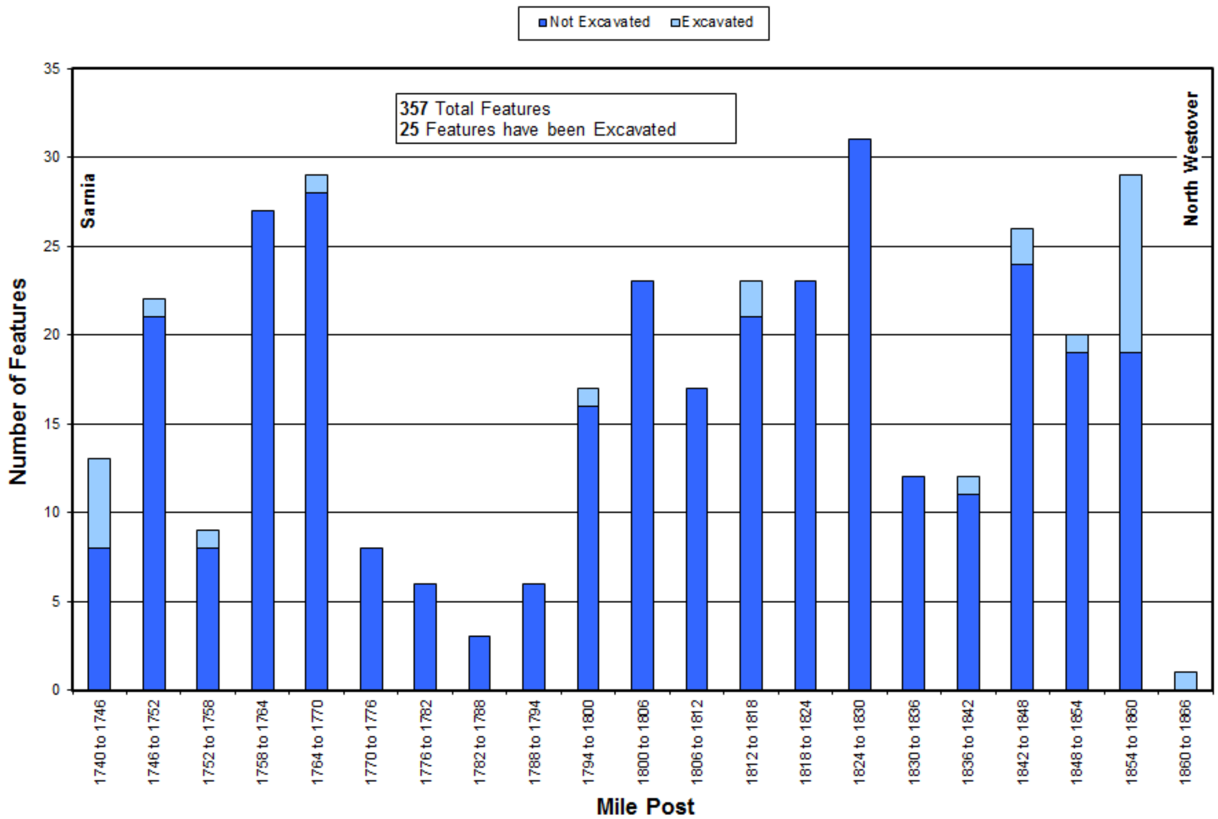

Figure 3.3 - Number of Features versus Chainage

As illustrated in **Error! Reference source not found.**4, there was only one feature with predicted burst pressures less than 125% of MOP while the vast majority (>88%) of the features had a predicted burst pressure >140% of MOP. The lowest predicted burst pressure of the reported features, as determined using the CorLAS™ software, was 5,084 kPa (737 psi) which equates to 118% of MOP (refer to **Error! Reference source not found.**). Detailed assessment of this feature leveraging field Non-Destructive Examination ("NDE") results from initial set of digs completed in 2009 resulted in a predicted burst pressure of 6,239 kPa (905 psi) which equates to 144% of MOP. This particular feature has since being excavated; the predicted burst pressure based on field dimensions was 6,612 kPa (959 psi) which equates to 153% of MOP. The lowest predicted burst pressure of a reported feature that has not yet been excavated, nor is planned for excavation, is 6,030 kPa (874 psi) which equates to 149% of MOP. The following assumptions were used as input into the CorLAS™ software to calculate the predicted burst pressures of the reported features:

- Flaw profile: rectangular profile;
- Wall thickness: the lesser of the nominal wall thickness or the wall thickness as measured by the UT wall measurement ILI tool;

- Nominal yield strength for grade 359 MPa: 359 MPa;
- Nominal tensile strength for grade 359 MPa: 455 MPa;
- Flow strength: yield strength + 68.9 MPa; and
- Charpy V-notch impact toughness: 20 J (15 ft-lb).

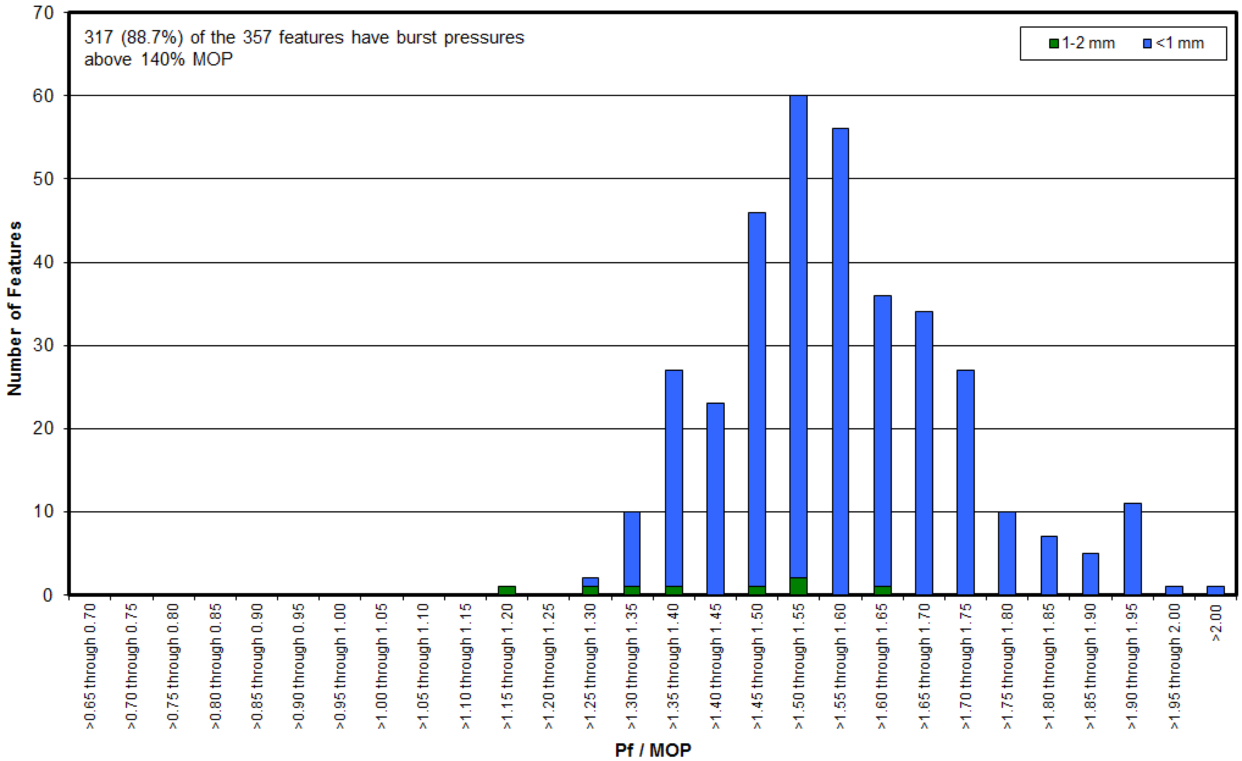

Figure 3.4 - Histogram Showing Predicted Burst Pressures for Tool Reported Crack ILI Features Prior to Dig Program

3.2.2 Results of Excavation Program

An excavation program was completed over multiple years prior to the application for reversal. A total of 23 excavations involving 25 features (refer to Figures 3.5 and 3.6) were completed based on in-line inspection data and results from the excavations were reviewed to assess ILI tool performance.

Following the 2008 USCD inspection, there were 7 excavations identified to investigate 8 features. Six (6) features were reported with depths between 1 and 2 mm and 2 crack-like features with depths less than 1mm to asses tool performance. The crack features with depths less than 1mm were proximal to geometrical features which were identified for excavation.

The aim of this initial excavation program of 8 features was to assess whether: a) the tool was performing as expected in which case additional excavations, as needed, could be identified and undertaken or b) the tool's performance was less than expected in which case GE and Enbridge would need to work together to correct the problem.

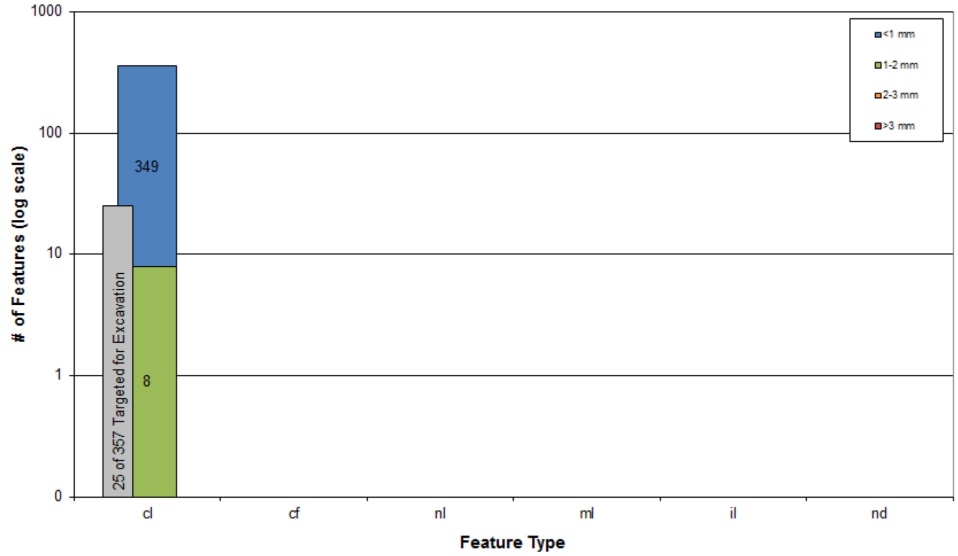

Figure 3.3 - Line 9 SA to NW Feature Depth Bins

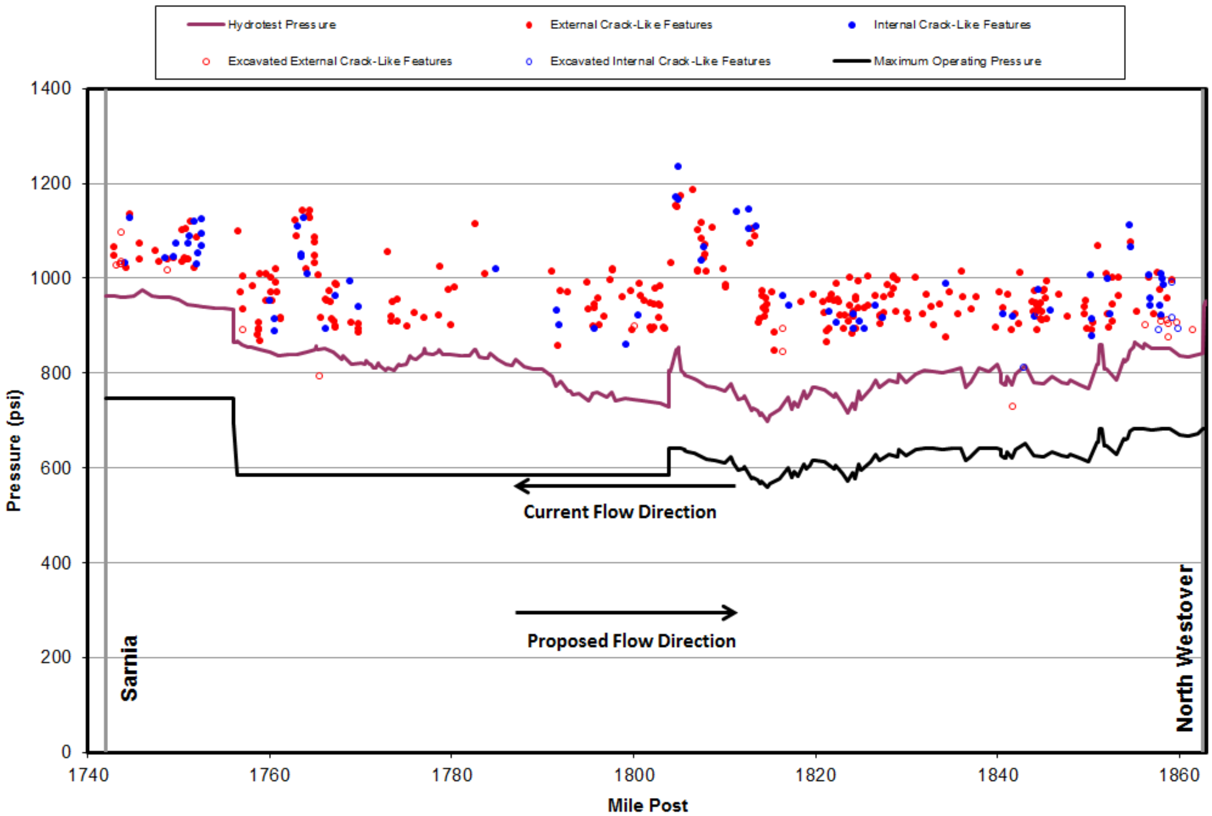

Figure 3.4 - Line 9 SA to NW Predicted Failure Pressures.

The field results from the investigative digs showed that only 2 of the 8 tool reported features identified for excavation corresponded to a field confirmed flaw.

Based on these observations and to incorporate learnings from other industry occurrences, GE completed a re-analysis of the USCD data associated with all crack-like features having a reported depth between 1 and 2 mm and identified that a classification error, albeit conservative in nature, had occurred for many of these UT reflectors.

Through the re-analysis process, GE reclassified 10 similar features previously identified within the 1 to 2 mm depth bin as irrelevant, resulting in 8 crack-like features being reported in that depth bin as opposed to the previous number of 18. In addition, there were also 3 features previously identified within the <1 mm depth bin that were re-classified as irrelevant. The revised feature listing was provided to Enbridge in May of 2011 and was subsequently used in the EA discussed below in Section 3.3.

Following the initial dig program, an additional 16 investigative excavations which targeted 19 reported CL features have since been completed based on the revised feature listing. The unity plots illustrating the comparison of ILI to field NDE data for the entire 23 digs completed to date are provided in Figure 3.5 and Figure 3.6.

The important findings from the dig program and unity plots are summarized below.

- There were no false-negatives observed in the field.
- All features were confirmed in the field to have a predicted failure pressure greater than 125% of MOP.
    - The lowest field predicted failure pressure of the ILI reported features observed in the field was 6,621 kPa or 959 psi (153% of MOP), while the lowest predicted failure pressure of an unreported feature found in the field was 7,186 kPa or 1010 psi (161% of MOP). Figure 3.6 provides a graphical depiction of the predicted failure pressure based on field-tool trending.
- Only 2 features had field measured depth greater than 1 mm and both features were consistent with ILI data; reported with a depth of 1-2 mm in the 2008 USCD feature listing.
    - The deepest field measured depth recorded during the excavation program was 1.4 mm (21% of the pipe wall thickness) which is within the tool reported depth range of 1 to 2 mm (15 to 31% of the pipe wall thickness).
- All features with a field measured depth were within +1 tool tolerance.
    - The deepest unreported feature found in the field was 1 mm deep but with length of 3 mm, which is below the tool reporting threshold for length. Figure 3.5 provides a graphical depiction of the depth based field-tool trending.
- Of the 27 Crack Like (“CL”) features excavated, 8 were confirmed in the field to be Crack Like (i.e. 19 false positives).

3.2.3 Statistical Evaluation of Dig Selection Criteria

The overall selection of features for excavation has been assessed to assure that a sufficient quantity of each category is investigated. The target sample size is defined using a proportion based calculation to determine the minimum number of features required to provide a minimum of 80% confidence that the selected features will represent the entire feature population. Enbridge views 80% to represent a statistically relevant sample size. In determining the sample size, the bound on error (“*B*” in the formula below) is fixed at 10% which is a typical value utilized for this type of assessment. The proportion-based sample size calculations are based on the following relationship:

$$n = \frac{Np(1-p)}{(N-1)\frac{B^2}{z^2} + p(1-p)}$$

n = target sample size of digs

N = population of given feature type reported by ILI

p = proportion of a feature type within the entire feature population

B = bound on error

z = z value corresponding with a chosen confidence interval

The completed dig program for Line 9 SA to NW has achieved a statistical confidence of 99% for the reported crack-like features.

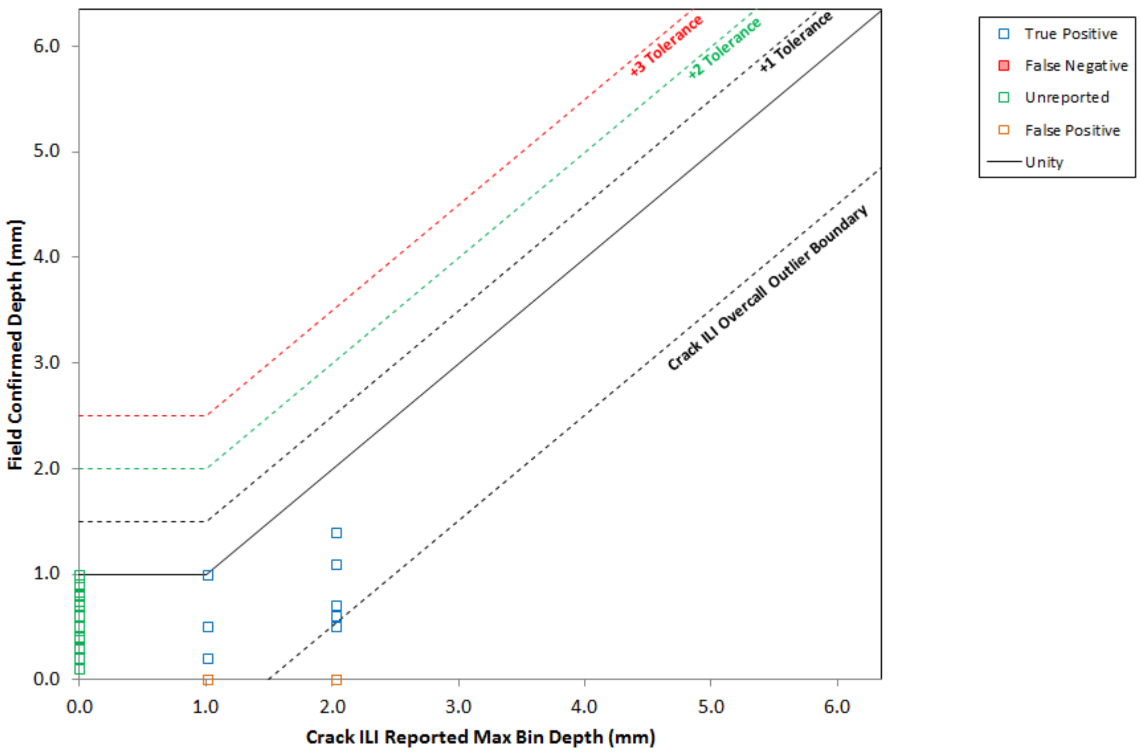

Figure 3.5 - Depth Unity Plot based on the 2008 USCD Tool Run

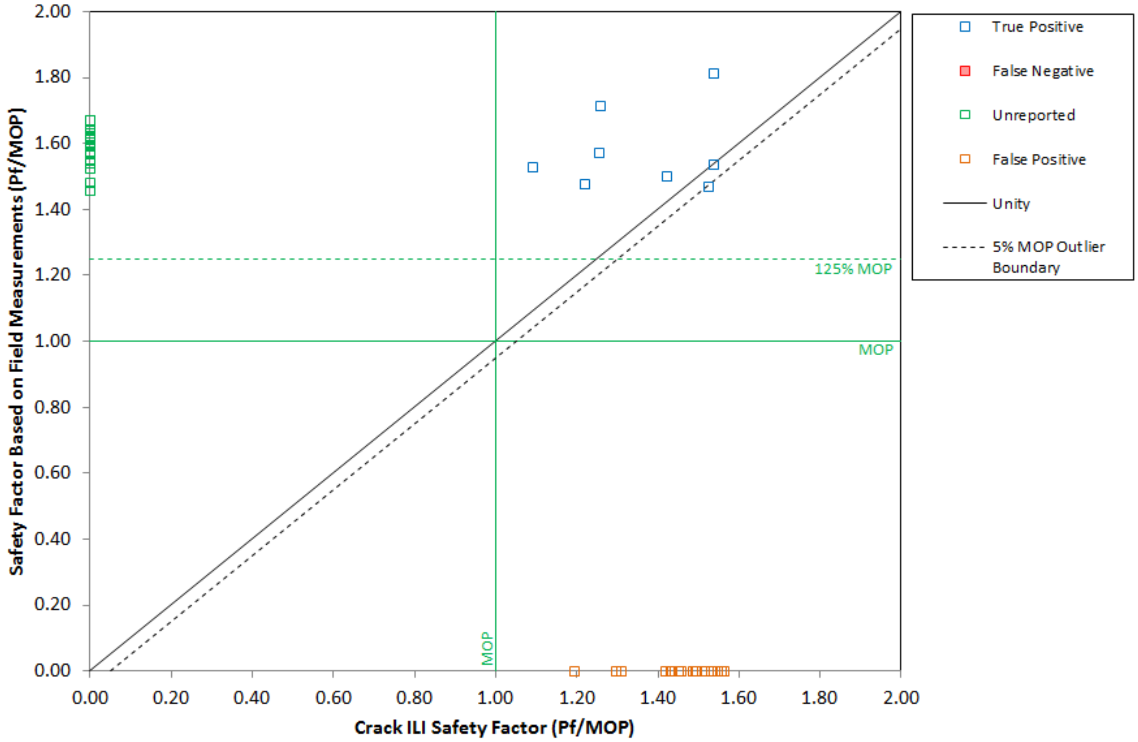

Figure 3.6 – Fitness-for-Purpose Unity Plot based on the 2008 USCD Tool Run

3.3 UT Crack Detection ILI Program – Engineering Assessments

Enbridge contracted Det Norske Veritas (Canada) LTD. ("DNV") to undertake an EA of the remaining 330 unexcavated tool reported features to determine their respective remaining lives. The remaining life assessment considered growth from both a fatigue and SCC perspective. To ensure conservatism in establishing the actual remaining life for each adjusted tool-reported feature, the lesser of the calculated fatigue or SCC remaining life was assumed. In order to compare the effect of the flow reversal on the predicted remaining lives of the features an assessment was done based on pre and post flow reversal operating conditions.

The approach used by DNV to undertake that remaining life assessment, the assumptions used in the assessment, and the subsequent results are provided below and were also summarized in the original EA.

3.4 Initial and Final Dimensions of Unexcavated Tool Reported Features - Revised

Based on the results of the excavation program described in Section 3.2.2, the depths and lengths of the unexcavated features were adjusted by +1 tool tolerance (i.e. 0.5 mm in depth and 10% in length). This implies that features with reported depths of <1 mm and 1-2 mm will have adjusted initial depths of 1.5 mm and 2.5 mm respectively. This is conservative because the deepest features found in the field and correlated to features reported by the tool in <1mm and 1-2 mm depth bins are 1 mm and 1.4 mm respectively. There was no feature that had a field measured depth that exceeded the specified +1 tool tolerance.

The final critical dimensions of each adjusted tool reported feature were subsequently calculated using the CorLASTM software. The following assumptions were used as input into those calculations:

- Flaw profile: semi-elliptical profile based on the adjusted tool reported total length and maximum depth;
- Operating Pressure (Scenario 1): 2,413 kPa or 350 psi (normal maximum discharge pressures at NW pre-flow reversal);
- Operating Pressure (Scenario 2): MOP at any given location post-flow reversal;
- Wall thickness: the lesser of the nominal wall thickness or the wall thickness as measured by the UT wall measurement ILI tool;
- Nominal yield strength for grade 359 MPa: 359 MPa;
- Nominal tensile strength for grade 359 MPa: 455 MPa;
- Flow strength: yield strength + 68.9 MPa; and
- Charpy V-notch impact toughness: 20 J (15 ft-lb).

3.5 Pressure Cycle Analysis

A loading spectrum is required for the fatigue and SCC remaining life calculations, which is obtained by performing a pressure cycle analysis on representative pressure data. Provided below are the operating histories that were used to assess the remaining lives of reported features pre and post flow reversal:

- Pre-Flow Reversal Operating Pressure History

The pressure data recorded in the third quarter of 2003 at NW was used to represent the pre-flow reversal operating pressure. This pressure data was selected because it has been deemed to be the most aggressive loading conditions that this section of Line 9 has experienced since 2003 (refer to Section 3.1).

- Post-Flow Reversal Operating Pressure History - Revised

In order to simulate the post-flow reversal operating pressure history at any given location along Line 9 SA-NW, the pressure data recorded in the third quarter of 2003 at NW was multiplied by the maximum observed operating pressure during the third quarter of 2003 at NW to the MOP at the given location.

The two pressure histories discussed above were evaluated by the rainflow cycle counting method to establish the number and magnitude of the various pressure cycles contained within the pressure data. This method of cycle counting is described in ASTM E1049, Standard Practices for Cycle Counting in Fatigue Analysis.1

Rainflow counting historically was developed to relate variable amplitude strain histories to constant amplitude fatigue data. Under nominally elastic conditions, the strain amplitude can be directly related to the stress amplitude. The technique is now widely used to relate variable amplitude fatigue loading to constant amplitude fatigue data. In typical pipeline applications, rainflow counting is applied to a representative pressure fluctuation history to produce cycle counts for a series of pressure ranges. The pressure ranges are then converted to stress ranges using the Barlow formula.

The results of the cycle counting were then used to perform the SCC and fatigue crack growth assessments discussed below.

3.5.1 SCC Growth Rate Analysis - Revised

The cycle counting program described above is capable of determining the frequency and loading rate associated with each pressure cycle that is counted. This calculation is required for SCC growth analysis. The fatigue growth analysis calculates the damage per cycle, which is independent of the frequency of the cycle. The SCC growth analysis calculates the amount of SCC growth based on the crack tip strain rate, which is frequency and loading rate dependent.

To calculate the SCC growth rate, the cyclic frequency (*f*) is used in conjunction with the R-ratio (R), maximum stress intensity factor (K_{MAX}), a constant (*C*) and yield strength (σ_y) to calculate the average crack tip displacement rate ($\dot{\delta}$), as demonstrated in previous SCC research by Beavers[2] (see Equation 1).

$$\dot{\delta} = \frac{C}{\sigma_y}\left(f \; K_{MAX}{}^{2}(1-R)\right) \qquad (1)$$

The K_{MAX} is computed using fracture mechanics principles utilizing the maximum pressure, nominal pipe dimensions and an assumed crack length. The crack lengths and depths used for these calculations were the adjusted dimensions of the tool reported features discussed above. For each of the adjusted reported features, the starting K_{MAX} value based on an operating pressure of 2,413 kPa (pre-flow reversal) or 3,393 kPa (post-flow reversal) was chosen for the SCC growth rate calculation.

Beavers also demonstrated a relationship between crack tip displacement rate and crack velocity (*v*), which is:

$$v = 0.0049 \cdot \left(\dot{\delta}\right)^{0.5478} \qquad (2)$$

By calculating the crack tip displacement rate, the amount of crack growth is computed from the crack velocity and duration of each cycle. The crack growth for all cycles is then summed and divided by the time period for the pressure history to calculate the SCC growth rate.

3.5.2 Fatigue and SCC Remaining Life Calculations

There are three fatigue crack growth regimes, as shown in Figure 3.7, where the cyclic crack growth rate (da/dN) is a function of the range of stress intensity factor (ΔK).

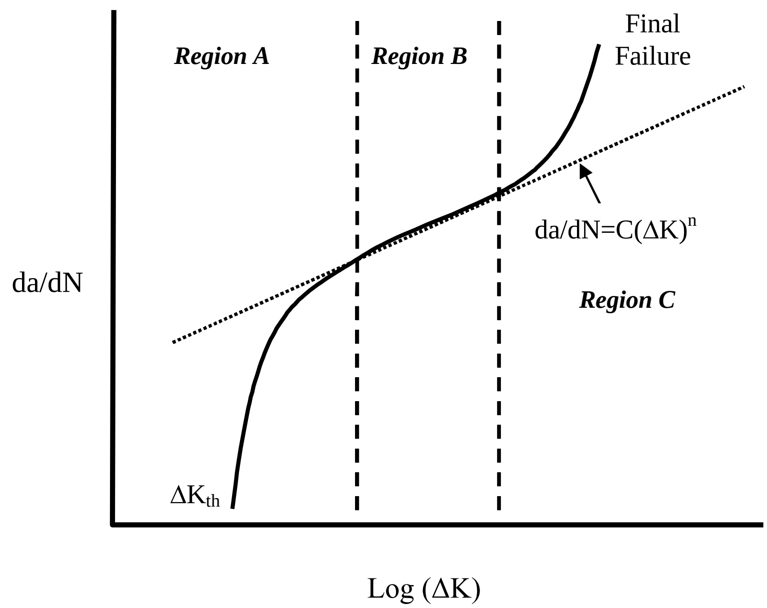

Figure 3.7 - Fatigue crack growth regimes represented as the cyclic crack growth rate (da/dN) as a function of the range in stress intensity factor (ΔK)

The range of stress intensity factor, ΔK, is a parameter relating to the cyclic stress and crack size and is the driving force for crack growth. This figure shows that crack initiation, propagation (growth), and final failure are exhibited in Region A, B, and C, respectively. The Paris region corresponds to Region B, where the cyclic crack growth rate is directly proportional to the range of stress intensity factor. The Paris Law[3,4] was used to describe this relationship:

$$\frac{da}{dN} = C(\Delta K)^n \qquad (3)$$

where C and n are constants that depend on material and environment. Values for ΔK were calculated assuming a semi-elliptical surface crack[5,6]. Thus, the remaining fatigue life is calculated by integrating the Paris Law crack growth from the initial flaw size (adjusted tool reported dimensions) to the final flaw size (critical dimensions of adjusted tool reported at pre and post flow reversal pressures (2,413 and 3,393 kPa) using the pressure cycles calculated above for the pre and post flow reversal operating pressure histories. These calculations were conducted at the upper-bound fatigue crack growth rates from API 579-1/ASME FFS-17. Using the upper-bound fatigue crack growth should provide a lower bound (conservative) remaining life.

For a cyclic crack growth rate (da/dN) in terms of inches per cycle and ΔK in terms of ksi-in$^{0.5}$, these upper bound rates correspond to the following Paris Law parameters:

- A coefficient of 8.61×10^{-10} and exponent of 3.00 for weld material

The SCC remaining life for each adjusted tool reported feature was calculated by dividing the amount of crack growth required for failure (i.e. the difference between the initial flaw size (adjusted tool reported dimensions) and the final flaw size (critical dimensions of adjusted tool reported at pre and post flow reversal pressures (2,413 and 3,393 kPa) by the SCC growth rate calculated for each feature using the approach discussed above.

To ensure conservatism in establishing the actual remaining life for each adjusted tool reported feature the lesser of the calculated fatigue or SCC remaining life was assumed.

3.6 Summary of Assessment

Based on the analysis discussed above, there are no adjusted tool reported features expected to fail at either the pre-flow reversal pressure (2,413 kPa) or the post-pressure reversal pressure (MOP) before 2016 (refer to Figure 3.8 and Figure 3.9). Enbridge will re-inspect this portion of Line 9 within 18 months following the receipt of NEB approval for the leave to open the pipeline in the reverse direction.

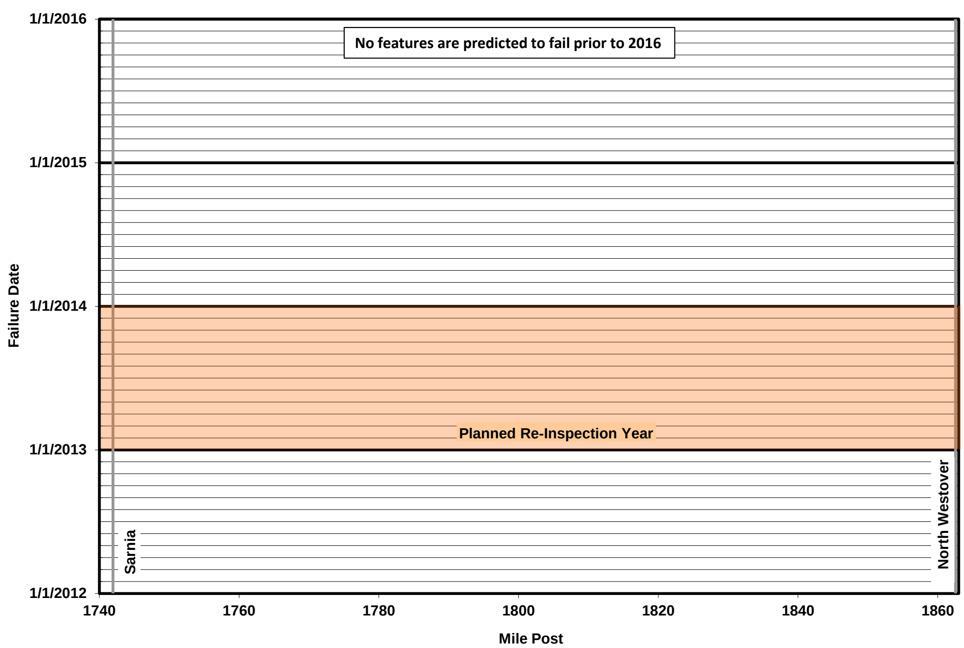

Figure 3.8 - Line 9 SA to NW Deterministic Assessment – Growth to 2,413kPa (350 psi) using Pre-Reversal Operating Pressure with +1 Tolerances added to the 2008 USCD Reported Dimensions

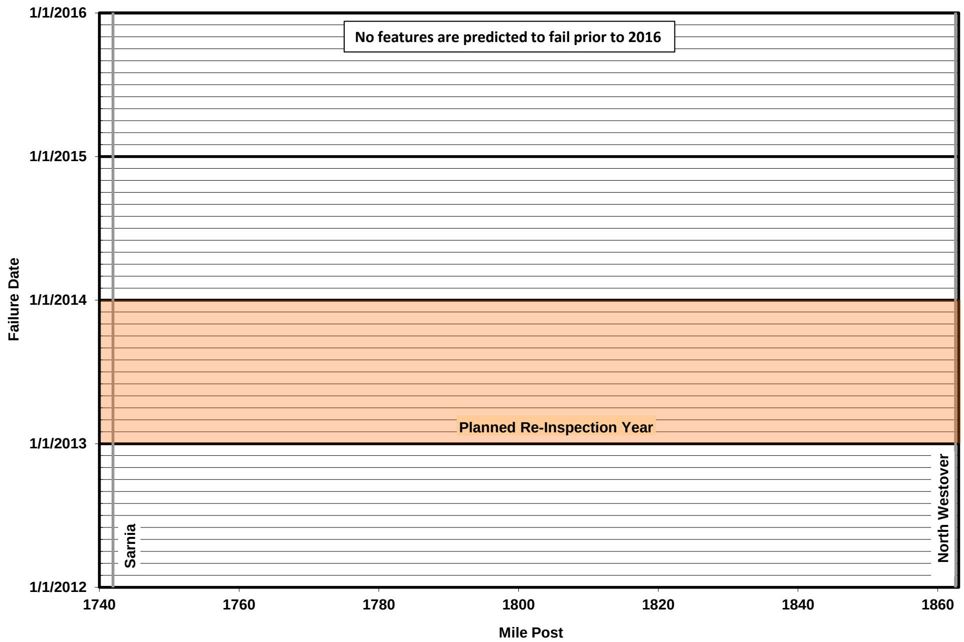

Figure 3.9 - Line 9 SA to NW Deterministic Assessment – Growth to MOP using Anticipated operating Pressure Post-Reversal with +1 Tolerances added to the 2008 USCD Flaw Dimensions

3.7 SCC

Enbridge considers that the external coating applied to a pipeline as the predominate factor determining the susceptibility of a pipeline to SCC. The section of Line 9 between SA and NW is coated with a single layer Polyethylene (“PE”) Tape; it has been well documented that other PE Tape coated pipelines with the industry have exhibited moderate to high susceptibility to SCC. Consequently, Enbridge considers the section of Line 9 between SA and NW to be susceptible to SCC.

As mentioned previously in Section 3.2, during the 2008 ILI with the GE USCD tool there were no crack-field features reported by the tool. A total of 45 SCC colonies were observed in the field as part of the dig program, all of which were below the tool’s reporting threshold, and determined to be insignificant SCC. The maximum depth of these SCC colonies was 1 mm (i.e. 15% wt) and lowest predicted failure pressure was 152% MOP. The evidence, thus far, based on the 2008 USCD tool run and subsequent excavation program is that there are no SCC colonies present in the section of Line 9 between SA and NW with

dimensions greater than the tool’s reporting threshold (60 mm deep and 1 mm long).

In addition to the excavations that were undertaken based on the findings of the USCD tool, Enbridge has also undertaken 44 other excavations since 2003 to address features reported by other ILI technologies (refer to Table 3-2). During those excavations, in which 186 m of pipeline was inspected for cracking using Magnetic Particle Inspection ("MPI"), a total of 10 SCC colonies were detected at four different locations. Field assessment of the SCC colonies determined that none of the SCC met the definition of significant SCC. Thus although shallow SCC has been detected on the portion of Line 9 between SA and NW the excavation data, collected to date, suggests that it doesn't currently present an immediate threat to the integrity of this portion of Line 9.

Enbridge will continue to monitor the portion of Line 9 between SA and NW for SCC and other cracking related mechanisms using crack detection ILI technologies. In addition, Enbridge will also continue to undertake MPI during its excavation programs based on other ILI technologies.

Table 3-2 - Listing of Historical Excavations Performed on Line 9 – SA to NW

GW	Excavation Year	Reason for Excavation	NDE Length (m)	Comments
40470	2012	Corrosion	4.42	No cracking indications found in the field
146500	2012	Corrosion	12.98	Five SCC colonies found. Maximum crack depth was 8%
12800	2009	Dent	5.45	No cracking indications found in the field
12850	2009	Corrosion	4.86	10 SCC colonies found. Maximum depth for axially oriented SCC is 18%
13360	2009	Dent	5.00	No cracking indications found in the field
17840	2009	Dent	5.00	No cracking indications found in the field
23260	2009	Dent	6.00	One SCC colony found. Maximum crack depth was 10%
24980	2009	Dent	5.15	No cracking indications found in the field
25680	2009	Dent	3.68	No cracking indications found in the field
28920	2009	Dent	5.00	No cracking indications found in the field
31280	2009	Corrosion	7.25	No cracking indications found in the field
37950	2010	Corrosion	3.29	No cracking indications found in the field
39700	2009	Dent	3.96	No cracking indications found in the field
4700	2003	Dent	2.54	8% SCC found in the field
50620	2009	Dent	5.90	No cracking indications found in the field
54070	2009	Dent	5.85	No cracking indications found in the field
55820	2009	Dent	5.50	No cracking indications found in the field
62110	2009	Corrosion	3.75	No cracking indications found in the field
62470	2009	Dent	3.60	No cracking indications found in the field
62990	2009	Dent	5.00	No cracking indications found in the field
63260	2009	Dent	3.58	No cracking indications found in the field
6530	2003	Dent	1.88	20% deep linear indication, no SCC found
7580	2003	Dent	1.94	No cracking indications found in the field
7660	2003	Dent	2.25	No cracking indications found in the field
8940	2003	Dent	1.69	No cracking indications found in the field
9070	2003	Dent	3.05	No cracking indications found in the field
10370	2003	Dent	3.30	No cracking indications found in the field
11770	2003	Dent	3.9	No cracking indications found in the field
12750	2003	Dent	2.60	No cracking indications found in the field
13100	2003	Dent	5.20	No cracking indications found in the field
14200	2003	Dent	1.75	No cracking indications found in the field
16880	2003	Dent	4.00	No cracking indications found in the field

GW	Excavation Year	Reason for Excavation	NDE Length (m)	Comments
16960	2003	Dent	4.09	No cracking indications found in the field
17890	2003	Dent	1.65	No cracking indications found in the field
60170	2003	Dent	2.45	No cracking indications found in the field
60910	2003	Dent	2.10	No cracking indications found in the field
66350	2003	Corrosion	1.32	No cracking indications found in the field
84930	2009	Dent	2.98	No cracking indications found in the field
86210	2009	Dent	5.29	No cracking indications found in the field
88390	2009	Dent	4.20	No cracking indications found in the field
88480	2003	Dent	1.97	No cracking indications found in the field
94960	2009	Dent	7.54	No cracking indications found in the field
97910	2009	Dent	2.27	No cracking indications found in the field
106940	2009	Dent	2.68	No cracking indications found in the field
146470	2003	Corrosion	3.95	No cracking indications found in the field
164230	2003	Dent	4.32	No cracking indications found in the field

Note that field assessment of these flaws determined that none of the observed SCC met the definition of "Significant SCC".

3.8 Cracking Risk Profile Pre and Post Flow Reversal - Revised

The cracking risk profile associated with the portion of Line 9 between SA and NW, pre and post flow reversal is depicted graphically in Figure 3.10. The risk profile was determined by Enbridge's Operational Risk Management group. The cracking risk profile pre and post flow reversal is essentially identical except for the first 8 km downstream of SA and the last 8 km upstream of NW. As would be expected, the cracking risk profile is calculated to be higher post-flow reversal immediately downstream of SA because this section will now see higher operating pressures than it typically has seen in the past; conversely, the cracking risk profile is calculated to be lower post-flow reversal immediately upstream of NW because this section will now see lower operating pressures than it typically has seen in the past.

To better understand the implications of a higher cracking risk profile immediately downstream of SA, post flow reversal, the results of the EA for this section of pipe were collected and are summarized below.

- There are 14 reported crack-like features in the 8 km section immediately downstream of SA.
- All of those features have depth <1 mm five of which have been assessed in the field. Only one of the five features was found observed to be crack, the crack indication was completely removed by grinding to a maximum depth of 0.2 mm. There were no indications observed at the other four locations (i.e. four false positives).
- The lowest predicted burst pressure for the remaining nine features is 136% of the MOP.

- The shortest calculated remaining life of those features is approximately 53 years.

Thus although the cracking risk profile is theoretically higher post-flow reversal immediately downstream of SA, the 2008 crack detection data, dig programs and subsequent EA suggest that this section of line is not at an immediate threat from cracking related mechanisms.

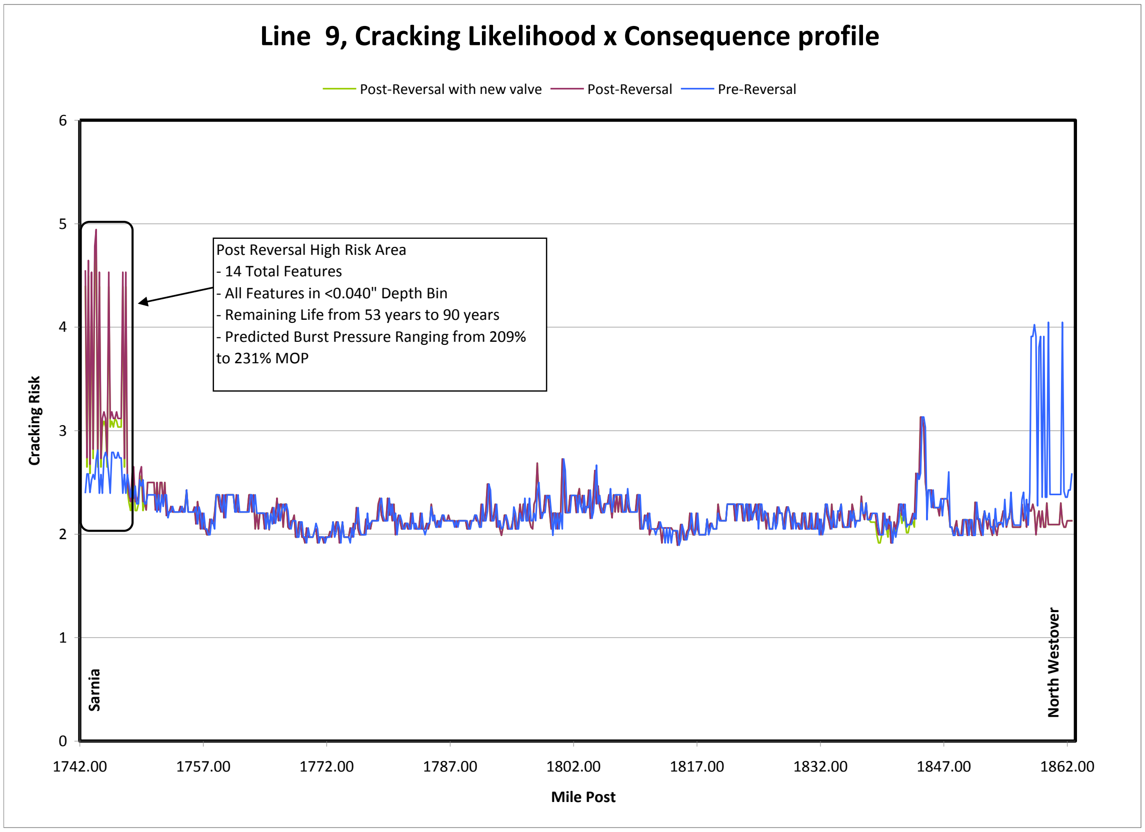

Figure 3.10 - Risk Assessment of Line 9 between SA and NW

4. CRACKING SUMMARY AND CONCLUSIONS

- Flow reversal will not require modifications to the manner in which the existing crack management program is developed or implemented;
- Based on this EA, there are presently no features reported by the 2008 crack detection inspection that are predicted to fail prior to 2016 under either east-to-west or west-to-east operating conditions.
- Enbridge will comply with NEB Order X0-E101-010-2012 and will conduct an ILI inspection for cracking features. This report confirms that the re-inspection timing is adequate.

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