National Energy Board | Office national de l'énergie

Pipeline Incident Report

Investigation Pursuant to Section 12 of the *National Energy Board Act* into the 20 July 2009 Rupture of the NOVA Gas Transmission Limited Peace River Mainline at KP 379, South of High Level, Alberta, Canada

November 2013

Canada

National Energy Board

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National Energy Board
Incident Brief

20 July 2009 Rupture of the Peace River Mainline (PRML) owned by NOVA Gas Transmission Ltd. (NGTL) and operated by TransCanada Pipelines Ltd. (TransCanada)

Incident

On 20 July 2009, the Peace River Mainline (PRML) ruptured in a remote location in Northern Alberta. 1450 $10^3 m^3$ Natural gas escaped from the pipeline and ignited. No workers or members of the public were injured. Damage to the environment was limited to local soil and vegetation.

Actions Taken by the Board

The National Energy Board (NEB or the Board) conducted an investigation from July 2009 to June 2010. The Board issued a safety order and two amendments to set the conditions for safe operation of the PRML and to ensure TransCanada took appropriate corrective actions. The Board concludes the investigation by publishing the attached report.

Findings

The Board makes seven (7) findings as to the cause and contributing factors:

1. External corrosion was the immediate cause.
2. Microbiologically Influenced Corrosion (MIC) was a contributing factor.
3. Failed Polyvinyl Chloride (PVC) coating that resulted in localized shielding of cathodic protection was a basic cause of the 20 July 2009 rupture of the PRML.
4. Inaccurate sizing of the defect by the magnetic flux leakage (MFL) in-line inspection (ILI) tool was a basic cause.
5. Inadequate field investigation criteria was a basic cause.
6. Ineffective operational control was a management system cause.
7. Inadequate inspection was a management system cause.

Corrective Actions Taken by the Company

TransCanada identified limitations to Magnetic Flux Leakage (MFL) In-line Inspection (ILI) tool technology that caused inaccurate measurement of corrosion in the rare circumstances where the geometry of corrosion features was complex. TransCanada's corrective actions focused on ILI process improvements and identified three (3) types of complex corrosion that pipeline operators should review when identified by ILI tools. They are:

- Deep corrosion defects;
- Aligned corrosion; and
- Corrosion within corrosion.

For complete account of corrective actions, and detailed descriptions and prioritization of complex corrosion, please refer to the attached published incident report.

Recommendations

The NEB makes the following recommendation:

1. NEB-regulated companies' Integrity Management Programs should readily demonstrate:
   - An evaluation of susceptibility to the threat of external corrosion;
   - For pipeline systems susceptible to external corrosion:
     - Consideration of TransCanada's complex corrosion criteria in accounting for ILI technology limitations;
     - Justification for adopting, rejecting, or otherwise adapting TransCanada's complex corrosion criteria; and,
     - Where adopted or adapted, the process should be updated in accordance with a management system approach.

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List of Abbreviations and Definitions

Basic Cause	The protective or mitigative measure that failed, allowing for a subsequent failure (immediate cause) that leads directly to an incident.
Defect	An imperfection of sufficient magnitude to warrant rejection based on the requirements of CSA Z662-07 (as defined in CSA Z662 *Oil and Gas Pipeline System Standard*).
DSAW	Double Submerged Arc Weld
EOC	Emergency Operations Centre
ILI	In-line Inspection
Immediate Cause	The protective or mitigative measure that failed, which leads directly to the occurrence of an incident.
Imperfection	A material discontinuity or irregularity that is detectable by inspection (as defined in CSA Z662 *Oil and Gas Pipeline System Standard*).
km	kilometers, 10^3 metres
Management System Cause	The management system element that failed, which allows failures associated with basic and immediate causes to occur. They are the ultimate underlying causes of an incident. The NEB determines Management System Causes consistent with its Management and Protection Program Evaluation and Audit Protocols.
MFL	Magnetic Flux Leakage, a type of in-line inspection tool
MIC	Microbiologically Influenced Corrosion
mm	millimeters, 10^{-3} metres
MPa	megapascals, 10^6 pascals
mV	millivolts, 10^{-3} volts
NEB Act	*National Energy Board Act*
NGTL	NOVA Gas Transmission Ltd., owner of the Peace River Mainline
PRML	Peace River Mainline
PVC	Polyvinyl Chloride
SCADA	Supervisory Control And Data Acquisition

SRB	Sulphate Reducing Bacteria, contributes to Microbiologically Influenced Corrosion
TCPL	TransCanada Pipeline Ltd., operator of the Peace River Mainline
TransCanada	TransCanada Pipeline Ltd., operator of the Peace River Mainline
TSB	Transportation Safety Board of Canada

Chapter 1 Overview

The National Energy Board (the NEB or the Board) derives its mandate for investigation of incidents from subsection 12.(1.1) of the NEB Act. This subsection gives the Board the authority to make:

a) findings as to the cause of the accident or factors contributing to it;
b) recommendations relating to the prevention of future similar accidents; or
c) any decision or order that the Board can make.

The purpose of this report is to publish the findings and recommendations from the NEB's investigation into the 20 July 2009 rupture of the NOVA Gas Transmission Ltd. (NGTL) Peace River Mainline (PRML). To effectively do so, the Board has structured the report to present the information in a logical format: starting with a background on the PRML (Chapter 2), details of the 20 July 2009 rupture (Chapter 3), findings (Chapter 4), recommendations (Chapter 5), and conclusions (Chapter 6).

The findings and recommendations contained in this report have the potential to improve pipeline integrity across the entire pipeline industry. The Board encourages readers to circulate this report and disseminate the information contained within.

Chapter 2 The Peace River Mainline

2.1 Historical Ownership and Jurisdiction

Peace River Oil Pipe Line Co. constructed the PRML for oil service in 1968[1]. In 1971, Alberta Gas Trunk Line (later NGTL) purchased the PRML and completed conversion to gas service by 1973. The PRML operated under the jurisdiction of the Energy Resources Conservation Board until April 2009 when the National Energy Board approved NGTL's application for change of jurisdiction[2]. Currently, NGTL owns the PRML and TransCanada Pipelines Ltd. (TransCanada) operates it under the jurisdiction of the NEB.

2.2 Location

The PRML is located in Northwestern Alberta and transports natural gas a distance of 481 km from Zama Lake to Valleyview. The PRML right of way (R.o.W.) follows a very remote route. There are no structures within the CSA class location boundaries at the failure location. Figure 1 provides a map for context.

2.3 Peace River Mainline Specifications

Table 1 provides the details of the PRML specifications[3].

Table 1: Peace River Mainline Specifications

Physical Attribute	Dimensions
Maximum Operating Pressure	5650 kPa
Length	481 km
Outside Diameter	508 mm
Wall Thickness(es)	5.56 , 6.48, 7.14, and 12.7 mm
Grade	290, 359, 386, and 414 MPa
Long Seam	Double Submerged Arc Weld (DSAW)
Coating	Polyvinyl Chloride (PVC) Tape
Original Design Specification	CSA Z183-1967

2.4 Historical Incidents and Performance

In 1973, the PRML experienced its first rupture due to geotechnical forces[4]. Since then, external corrosion has become the predominant failure mechanism, causing 16 leaks and 6 ruptures. Figure 2 provides a graphical representation of the number of pipe body leaks and ruptures over the lifecycle of the PRML.

[1] TransCanada response to NEB Information Request 1.1, dated 2 October 2010.
[2] National Energy Board Certificate GC-113, date 13 February 2009.
[3] TransCanada response to NEB Information Request 1.1, dated 2 October 2010.
[4] TransCanada response to NEB Information Request 1.1 (d), dated 2 October 2010.

Figure 1: Map of Northern Alberta and the PRML

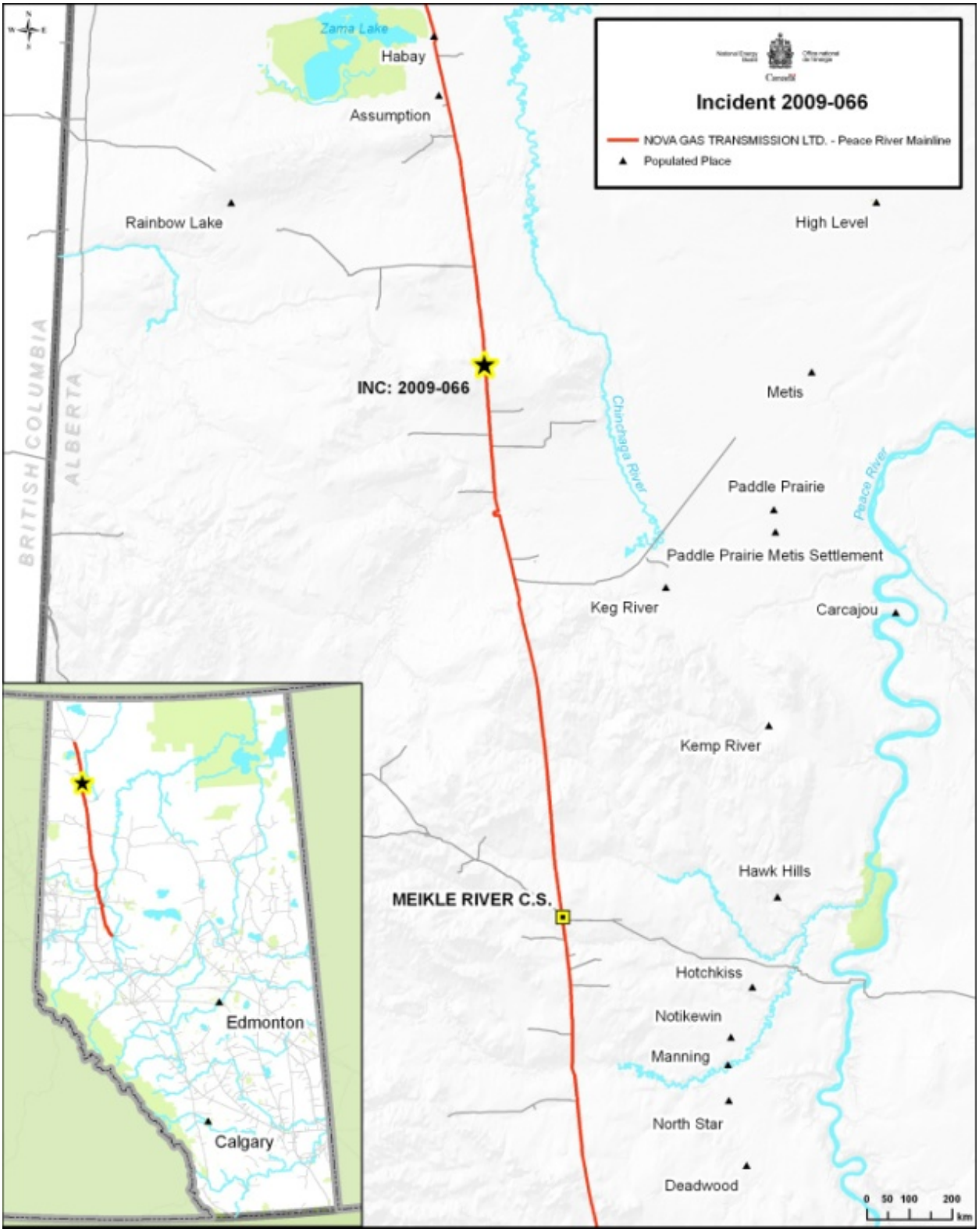
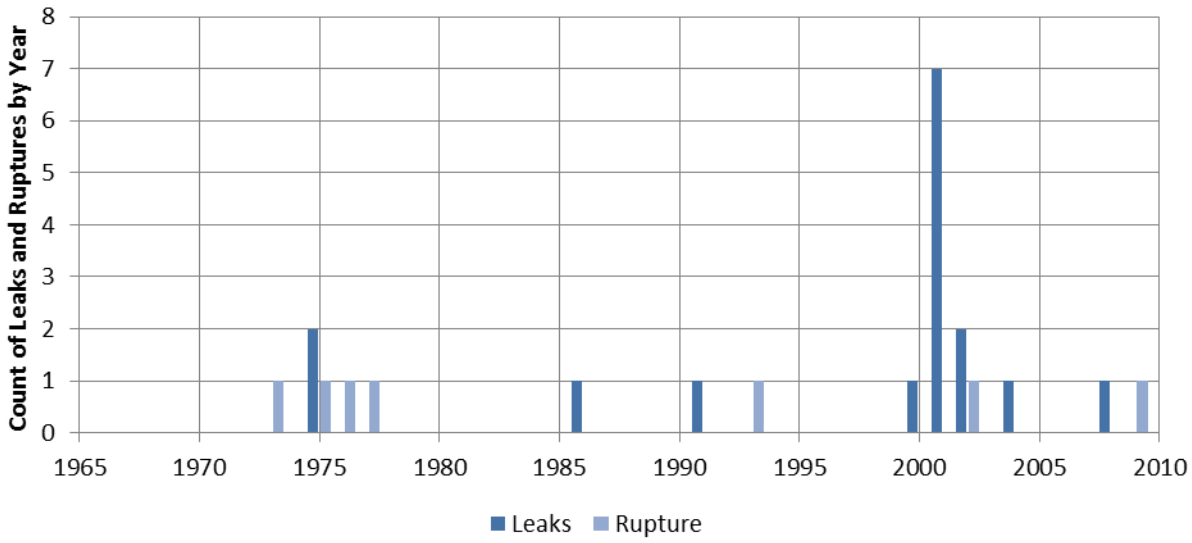


Figure 2: Peace River Mainline Leaks and Ruptures by Year



Chapter 3 PRML Rupture on 20 July 2009

3.1 Rupture and Emergency Phase

Table 2 provides a summary timeline of the 20 July 2009 rupture of the PRML and the resulting emergency response[5,6]:

Table 2: Summary Timeline of Rupture and Emergency Phase

Time	Event
9:25	PRML ruptures and ignites at Kilometre Post (KP) 379.
9:29	TransCanada's SCADA system receives multiple outage notifications.
9:51	Alberta Sustainable Resource Development notifies TransCanada's Emergency Line about a possible pipeline rupture and fire. TransCanada activates its Emergency Response processes.
10:22	TransCanada notifies its on-call responder and dispatches to site to investigate.
10:25	TransCanada activates its Calgary and Vegreville Emergency Operations Centres (EOCs).
11:15	TransCanada notifies the Transportation Safety Board's (TSB) 24-hour occurrence line.
11:21	TransCanada closes mainline valves and isolates the PRML.
12:35	TSB notifies the NEB.
13:00	Minor natural gas fire observed at failure site.
13:36	Brush fire at failure site self-extinguishes.
14:00	NEB dispatches investigator to site for arrival on 21 July 2009.
15:15	Natural gas fire self-extinguishes.
18:00	TransCanada declares emergency phase over with NEB concurrence. TransCanada stands down its EOCs.
19:00	NEB stands down its EOC.

3.2 On-Site Preliminary Investigation

NEB and TransCanada investigators arrived on-site on 21 July 2009. The TSB elected not to respond[7]. By the end of 21 July 2009, NEB and TCPL investigators confirmed the likely initiation source of the rupture with a preliminary cause of external corrosion[8]. The excessive wall thinning and corrosion observed on-site supported this preliminary finding. By 23 July 2009, the NEB completed the field portion of the response and investigation.

[5] TransCanada response to NEB Information Request 1.4, dated 2 October 2009.
[6] TransCanada detailed incident report, dated 11 May 2010.
[7] Note: The Transportation Safety Board also elected not to investigate the incident and deferred to the NEB.
[8] NEB Incident Briefing, dated 21 July 2009.

3.3 Return to Service and NEB Safety Order SG-N081-02-2009

On 29 July 2009, TransCanada informed the Board of its intentions to return the PRML to service[9]. TransCanada provided details of its proposed investigation and corrective actions, including a voluntary 10% pressure reduction. The NEB reviewed its plan and granted return to service by Safety Order SG-N081-02-2009[10] (Appendix I), conditional upon a 20% pressure reduction among other measures. TransCanada returned the PRML to service on 5 August 2009[11].

3.4 Impacts

The rupture of the PRML caused 1450 10^3m^3 of natural gas to escape and ignite, producing a flame approximately 50 metres in height[12]. The impacts of the rupture and fire are summarized below[13,14]:

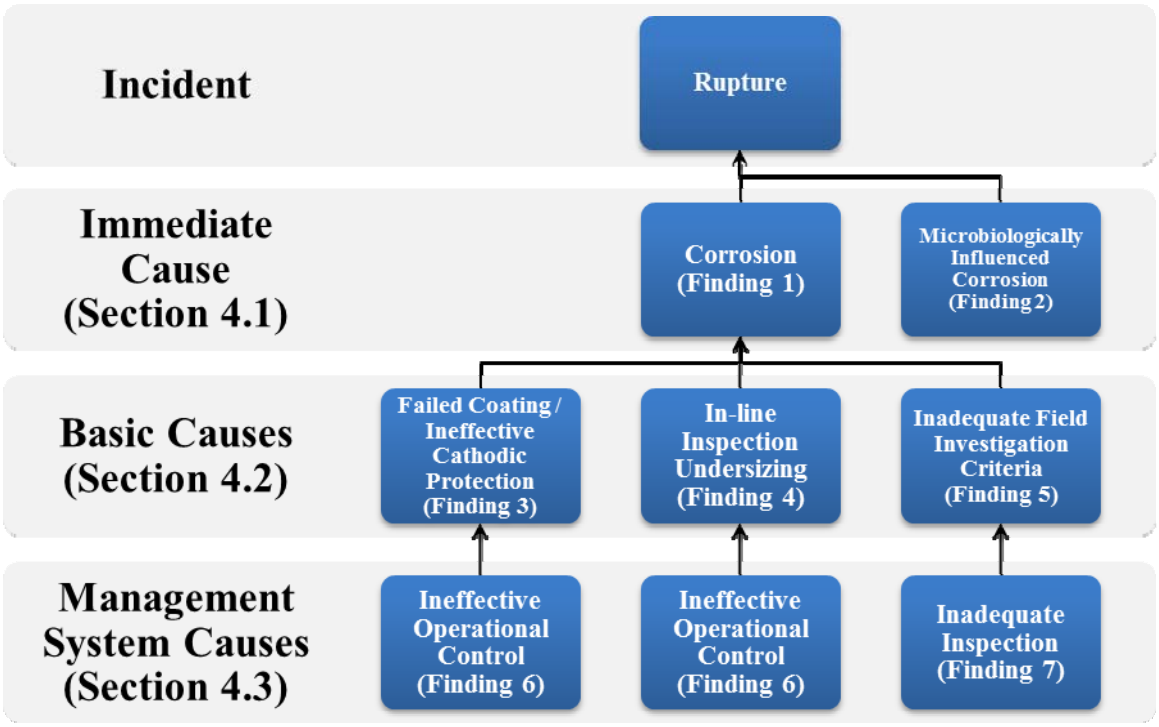
- No injuries to workers or members of the public.
- The natural gas fire caused a small brush fire to ignite, burning approximately 2 hectares of surrounding vegetation. TransCanada reclaimed the site by 7 August 2009.
- The natural gas fire burned an adjacent power line.
- The resulting outage in service affected 23 shippers, to varying degrees.

[9] TransCanada return to service letter, dated 29 July 2009.
[10] NEB Safety Order SG-N081-02-2009, dated 31 July 2009.
[11] TransCanada response to NEB Information Request 1.5, dated 2 October 2009.
[12] TransCanada response to NEB Information Request 1.4, dated 2 October 2009.
[13] TransCanada response to NEB Information Request 1.5, dated 2 October 2009.
[14] TransCanada response to NEB Information Request 1.6, dated 2 October 2009.

Chapter 4 Findings of the Investigation

This Chapter fulfills the NEB's mandate in making findings as to the cause and contributing factors[15] of the 20 July 2009 rupture of the PRML. The Board has structured this chapter in a manner that follows the causal flow chart in Figure 3. Corrective actions corresponding to each finding are described in their respective sections. The Board concludes the chapter by describing additional preventative actions.

Figure 3: Causal Flow Chart for 2009 Rupture of the PRML



4.1 Immediate Cause

The PRML ruptured when the remaining strength of the pipe walls could no longer withstand the stresses from internal pressure. In this section, the Board determines what caused the remaining strength to deteriorate and therefore determine the immediate cause of the rupture.

4.1.1 External Corrosion and Microbiologically Influenced Corrosion

Background

External corrosion occurs when pipe metal is in contact with a corrosive electrolytic solution. Microbiologically Influenced Corrosion (MIC) is a form of external corrosion where biological processes of certain bacteria create a more potent corrosive environment.

[15] Subsection 12. (1.1) (a) of the NEB Act.

Facts from the Investigation

During the response and preliminary field investigation, NEB and TransCanada investigators found visual evidence of external corrosion in the form of extensive pitting along the failed pipe[16]. The NEB investigator also found a potential rupture initiation point that corresponded with two deep corrosion pits amongst extensive external corrosion.

TransCanada contracted an independent laboratory to examine the failed pipe in accordance with the NEB's Safety Order SG-N081-02-2009 and examination protocol. The independent laboratory examination[17] drew the following conclusions:

- The cause of the failure was external corrosion.
- Microbiologically Influenced Corrosion (MIC) was a major contributing factor.
- The material properties of the examined pipe met the original design specification.
- Toughness values were lower than the current specifications; however, there were no requirements for toughness at the time of pipe manufacture.
- The examined pipe contained no evidence of stress corrosion cracking (SCC).
- RSTRENG produced accurate predictions of failure pressure based on measurements from the failed pipe and the operating pressure at the time of rupture.

The occurrence of MIC, although not common on NEB-regulated pipelines, is a threat known to TransCanada on the PRML[18]. Prior to the 2009 rupture, MIC was also a contributing factor to the 2002 rupture of the PRML[19]. The type of MIC encountered on the PRML is primarily attributed to sulphate reducing bacteria (SRB)[20]. SRB thrives in nutrient (sulphate) rich soil and can cause corrosion with particularly aggressive growth rates. The 2009 failure location had conditions that exacerbate corrosion growth rates: alternating aerobic and anaerobic conditions, as evidenced by soil samples, and the known source of food for SRB in the PVC coating adhesive.

Findings

Based on these facts, the Board makes the following Findings 1 & 2.

Finding 1. External corrosion was the immediate cause of the 20 July 2009 rupture of the PRML.

Finding 2. Microbiologically influenced corrosion was a contributing factor to the 20 July 2009 rupture of the PRML.

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[16] NEB Incident Briefing, dated 21 July 2009.
[17] Examination of Rupture From Peace River Mainline, prepared by Acuren Group Inc. and submitted by TransCanada in accordance with Condition 5 of Order SG-N081-02-2009 on 29 September 2009.
[18] TransCanada Integrity Management Process for Pipelines, submitted to the Board on 30 April 2010.
[19] TransCanada Final Failure Report on the 8 October 2002 rupture of the PRML, submitted to the Board on 4 December 2009.
[20] Examination of Rupture From Peace River Mainline, prepared by Acuren Group Inc. and submitted by TransCanada on 29 September 2009.

Corrective Actions Taken by TransCanada

TransCanada did not take corrective actions to address the immediate cause of external corrosion and contributing factor of MIC for this incident. Rather, TransCanada continues to maintain previous preventative and corrective actions to prevent MIC. These include[21]:

- Maintaining a minimum CP "ON" potential to -1000 mV to overcome the depolarizing effect of MIC;
- Improving the reliability of CP availability by near elimination of power source outages;
- Adding additional ground beds to improve current distribution of the CP system; and
- Adjusting the frequency of MGL ILI to account for the increased corrosion rates associated with MIC.

TransCanada's corrective actions specific to this incident focus on basic causes of the incident, both of which are described in the proceeding sections.

4.2 Basic Causes

For external corrosion and MIC to occur and cause the 20 July 2009 rupture of the PRML, a number of protective and mitigative systems must have failed. Such failures are basic causes of the rupture.

4.2.1 Failed PVC Coating and Shielding of Cathodic Protection

Background

The first line of defense against external corrosion is pipeline coating. An ideal coating should perform in the following ways:

- Act as a physical barrier between bare metal and the environment.
- When intact, they should shield metal from cathodic protection.
- When failed, they should allow cathodic protection to reach and protect exposed metal.

The Canadian pipeline industry commonly applied polyethylene and polyvinyl chloride (PVC) tape coatings throughout the 1960s and 1970s[22]. Both types of tape coating were prone to disbondment (loss of adhesion to pipe metal) and they continued to shield the pipeline from cathodic protection after they had failed. Seasonal ground movements, particularly in the vertical direction, develop shear stresses between the soil and tape coating and cause it to disbond and develop wrinkles (at 3 and 9 o'clock positions on the pipe). Moisture can migrate through these wrinkles and contact bare pipe metal. Although CP can penetrate disbonded PVC coating to varying degrees, it can be ineffective in preventing active corrosion of the bare metal.

[21] TransCanada letter, dated 4 February 2011.
[22] NEB Report on the Inquiry Stress Corrosion Cracking on Canadian Oil and Gas Pipelines, dated 22 November 1996.

Facts from the Investigation

The PRML is coated with PVC tape. Failed PVC tape coating was a basic cause of the 6 historical ruptures and 16 leaks on the PRML[23]. The rupture ignition entirely burned off the PVC coating on the failed joint and the condition of the coating could not be directly observed. However, the independent laboratory examination report found PVC coating on the downstream section of failed pipe to be in very poor condition[24]. Further, corrosion on the failed joint had patterns consistent with failed tape coating – extensive corrosion at 3 and 9 o'clock and corrosion in spiral patterns matching the spiral application of the coating.

TransCanada maintains cathodic protection in compliance with Canadian Standards Association (CSA) Standard Z662-07 and Canadian Gas Association recommended practice OCC-1 to protect areas where the PVC coating may have failed-safe[25]. To mitigate against the threat of MIC, TransCanada applies a minimum cathodic protection "On" potential criterion of -1000 mV CSE (Copper (II) Sulphate Standard Electrode). This extra level of cathodic protection is intended to overcome the detrimental effects of MIC at open coating holidays[26].

The NEB acknowledges and clarifies that cathodic protection did not prevent corrosion at KP 379 because of shielding from failed PVC coating and not because of improper application.

Finding

Based on these facts, the Board makes the following Finding 3.

Finding 3. Failed Polyvinyl Chloride (PVC) coating that resulted in localized shielding of cathodic protection was a basic cause of the 20 July 2009 rupture of the PRML.

Corrective Actions Taken by TransCanada

TransCanada focused its corrective actions at improving processes for ILI interpretation, and investigation and repair of defects, which are described in section 4.2.2. Corrective actions did not include a standalone recoating program for economic reasons and to avoid associated environmental impacts, service interruptions, and potential integrity problems[27]. Although the ILI process improvements were not directly intended to improve the coating and cathodic protection systems, they had the indirect effect of repairing coating at priority areas of external corrosion. These corrective actions, also in 4.2.2, cause more ILI features to be investigated in a prioritized manner, indirectly resulting in a prioritized recoating program.

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[23] Note: the PRML was not under NEB jurisdiction for any of these leaks or ruptures, so the Board makes this inference based on historical information.
[24] Examination of Rupture From Peace River Mainline, prepared by Acuren Group Inc. and submitted by TransCanada in accordance with Condition 5 of Order SG-N081-02-2009 on 29 September 2009.
[25] TransCanada detailed incident report, dated 11 May 2010.
[26] TransCanada detailed incident report, dated 11 May 2010.
[27] TransCanada letter, dated 4 February 2011.

4.2.2 Defect Undersizing by In-Line Inspection and Inadequate Field Investigation Criteria

Background

Pipeline operators typically mitigate the threat of external corrosion by taking the following steps:

1. Identification of corrosion imperfections in the pipeline by in-line inspection (ILI) with magnetic flux leakage tools (MFL).
2. Field investigation of ILI features that exceed, or potentially exceed, the limits set by clause 10.9.2 of CSA Z662-07, with some accounting for errors from the ILI tool.
3. Recoating, repair, or removal of the corrosion, according to the requirements of clause 10.9.2 of CSA Z662-07.

Successful mitigation of external corrosion by the above method is dependent on the MFL tool's capability to accurately size features and a company's appropriate setting of investigation criteria to account for tool error and prevent corrosion from exceeding the limits set by CSA.

Facts from the Investigation

The failure at KP 379 was indicative of ineffective mitigation of external corrosion. The NEB investigated TransCanada's corrosion mitigation processes to determine their role in the failure, including ILI characterization of features, field investigation of ILI features, and repair of features beyond the CSA limits.

Comparison of MFL measurements and predictions allowed all parties to the investigation to conclude that the MFL tool undersized the failed feature at KP 379. Table 3 compares the 2007 MFL ILI measurements and predictions to the actual measurements post-failure and illustrates the degree of under-sizing in depth and failure pressure. TransCanada's post-failure review with the ILI vendor determined that the complex geometry of the feature (i.e. deep corrosion, corrosion within corrosion, and) challenged the MFL tool's ability to accurately size the feature. Additionally, the vendor determined that no significant growth occurred in adjacent areas and therefore growth predictions were not a factor in the failure.

Table 3: Comparison of ILI and Actual Measurements

Characteristic	2007 MFL ILI Measurement / Prediction	2009 Post-Failure Measurement
Depth(s)	Several anomalies with a maximum depth of 71% wall thickness.	Several corrosion pits with maximum depth of 95% wall thickness[28].
Failure Pressure	8310 kPa (prediction on the basis of ILI measurements).	5540 kPa[29]

[28] Examination of Rupture From Peace River Mainline, prepared by Acuren Group Inc. and submitted by TransCanada in accordance with Condition 5 of Order SG-N081-02-2009 on 29 September 2009.
[29] Examination of Rupture From Peace River Mainline, prepared by Acuren Group Inc. and submitted by TransCanada in accordance with Condition 5 of Order SG-N081-02-2009 on 29 September 2009.

The NEB's review of TransCanada's corrosion field investigation criteria determined that the criteria were compliant with CSA Z662-07 but did not adequately account for complex geometries of corrosion that would challenge the MFL tool's detection capabilities. Table 4 compares the CSA requirements to TransCanada's pre-failure investigation criteria. The MFL tool's limitations for complex geometries of corrosion were unforeseen in the pipeline industry and unaccounted for in TransCanada's field investigation criteria. Ultimately, the MFL tool undersized a critical corrosion feature, TransCanada's criteria did not trigger a field investigation, and the feature grew unmitigated to failure on 20 July 2009.

Table 4: TransCanada Field Investigation Criteria

Definition of Corrosion Defect (Clause 10.9.2.5 of CSA Z662-07)	Corresponding TransCanada Field Investigation Criteria	Explanatory Notes
Actual Depth > 80% wall thickness	ILI Feature Depth > 75% wall thickness	Deterministic criteria. MFL tool uncertainty accounted for by using lower field investigation criteria.
	Probability of Leak > 1E-2 /defect-year	Probabilistic criteria according to non-mandatory Annex O of CSA Z662-07. Probabilistic model accounts for tool uncertainty, growth, model equations, and material properties. Implemented 2007.
Failure Pressure ≤ 1.25 x Maximum Operating Pressure ($P_{Fail} \leq 1.25$ MOP)	Predicted Failure Pressure ≤ 1.25 x Maximum Operating Pressure ($P_{Fail} \leq 1.25$ MOP)	Deterministic criteria.
	Probability of Rupture > 6E-4 /defect-year (2007 ILI) or 4.4E-4 /defect-year (2010 ILI)	Probabilistic criteria according to non-mandatory Annex O of CSA Z662-07. Probabilistic model accounts for tool uncertainty, growth, model equations, and material properties. Implemented 2007.

TransCanada undertook extensive corrective actions to address the MFL tool's limitations and account for this in their field investigation criteria. These and additional NEB imposed corrective actions are described later under corrective actions.

Findings

Based on these facts, the Board makes the following Findings 4 & 5:

Finding 4. The MFL ILI tool's inability to accurately characterize complex geometries of corrosion was a was a basic cause of the 20 July 2009 rupture of the PRML.

Finding 5. Inadequate field investigation criteria was a basic cause of the 20 July 2009 rupture of the PRML.

Corrective Actions Taken by TransCanada

Since the MFL tool is limited by technology in its ability to accurately size complex geometries of corrosion, TransCanada's corrective actions focused on supplementing the field investigation criteria to account for the limitation. In its ILI process improvement plan, TransCanada proposed a new set of field investigation criteria with four (4) sub-criteria to address aspects of complex geometries of corrosion. The criteria, referred to as "Complex Corrosion Criteria," were designed to identify coincidence of deep corrosion (>70% wall thickness), relatively deep corrosion features (>50% wall thickness) in close proximity to each other, and corrosion within corrosion. TransCanada also proposed a fourth criterion as a vendor quality assurance check to determine whether omission of a metal loss feature would bridge existing clusters and have significant impact on failure pressure. Figures 4-7 provide a detailed description and illustration of each of the Complex Corrosion Criteria[30].

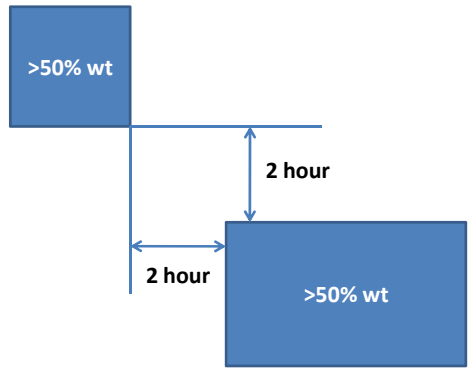
Figure 4: Criterion 1 Deep Defects

Purpose:
- Identify deeper defects > 70% wall thickness (wt).
- Scrutinize for possible under-sizing.
- Improve reported sizing.

Vendor Process:
- Apply extra quality assurance where ILI feature >65% wall thickness (wt).
- Manually assess and review of sizing.
- Report on list of deeper defects.

[30] TransCanada presentation to the Board, dated 15 October 2009.

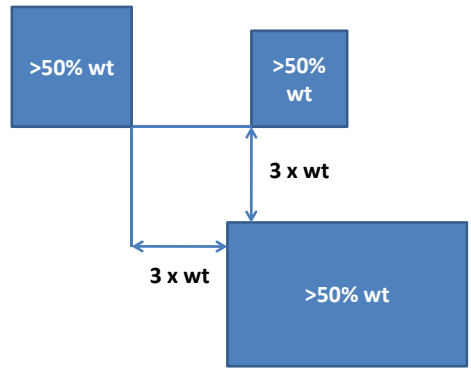
Figure 5: Criterion 2 Aligned Corrosion



Purpose:
- Identify anomalies in close proximity with deeper defects.
- Identify weakened joints due to multiple defects.
- Identify extensive corrosion associated with significantly deteriorated coating.

Vendor Process:
- Group all features within a 2 hour[31] position in length and width with corrosion >50% wall thickness

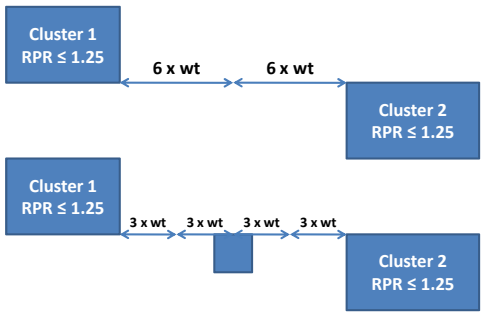
Figure 6: Criterion 3 Corrosion within Corrosion



Purpose:
- Identify where interacting signals may compromise sizing.
- Identify clusters with deeper defects to review for overlapping signals or underlying metal loss response.

Vendor Process:
- Identify 3 or more anomalies with depth ≥50% wall thickness (wt) within 3 x wt of each other.
- If review finds interacting signals, subject features to additional scrutiny and account for these defects in sizing.
- Boxes with signal interaction reported.

Figure 7: Criterion 4 Vendor Quality Assurance - Bridging Corrosion



Purpose:
- Quality check where the omission of metal loss feature would bridge existing clusters with significant impact on RPR.

Vendor Process:
- Review extended areas of 6 wt x 6 wt grouping with RPR ≤ 1.25.
- Check if any defects were missed that may join two existing 3 wt x 3 wt clusters into a single 3 wt x 3 wt cluster.
- Manually verify for changes in RPR.
  (Note: this criterion applies only at the vendor level of analysis)

Since the Complex Corrosion Criteria represented a new set of field investigation criteria, the Board directed TransCanada to validate the process improvements with a conventional pressure test by way of Condition 6 of the Safety Order SG-N081-02-2009. Over the winter of 2009/10, TransCanada implemented its ILI process improvements and completed investigative digs for the

[31] Note: 1 hour of pipe diameter equates to 1/12 of the circumference. In the case of the PRML, 1 hour = 133 mm.

northern half of the PRML. On 2 March 2010, TransCanada conducted a pressure test on a representative sample of the PRML[32]. The hydrostatic pressure test was successful and provided validation that TransCanada identified and repaired all critical areas of complex corrosion in the representative section. Field correlation of ILI features further supported validation of the complex corrosion criteria. TransCanada also confirmed that the MFL tool limitations occurred only in situations where corrosion met all three Complex Corrosion Criteria.

Regarding corrective actions for the existing field investigation criteria, the criterion for failure pressure required no alteration while the NEB imposed a more conservative criterion for depth of 70% wall thickness or deeper. The NEB took this action as an extra level of conservatism for safety, given the PRML's history of corrosion related leaks and ruptures. The rationale for imposing the 70% wall thickness criterion is to cause TransCanada to conservatively account for the tool limitations (up to 80% wall thickness) and error (+/- 10% wall thickness with an 80% confidence interval).

4.3 Management System Causes

The Board audits regulated companies to its Management and Protection Program Evaluation and Audit Protocols[33]. The Board also uses these protocols to attribute a management system cause to incidents.

4.3.1 Ineffective Operational Control

Background

Under the management system element *Operational Control – Normal Operations*, the NEB expects companies to have mitigative, preventive, and protective measures to reduce or eliminate risks and hazards at their source.

Facts from the Investigation

TransCanada intends for its Integrity Management Process for Pipelines (IMPP) to function as a management system to meet the NEB's requirements for a Pipeline Integrity Management Program. In the case of the 20 July 2009 rupture of the PRML, three specific operational controls experienced coinciding ineffectiveness for preventing corrosion at KP 379: external coating, cathodic protection, and in-line inspection. The details of these operational control failures were described extensively in section 4.2. The NEB found no other operational control deficiencies related to this failure.

Finding

Based on these facts, the Board makes Finding 6:

Finding 6. Ineffective operational control was a management system cause of the 20 July 2009 rupture of the PRML.

[32] TransCanada detailed incident report, dated 11 May 2010.
[33] NEB Management and Protection Program Evaluation and Audit Protocols, dated 8 June 2010.

Corrective Actions Taken by TransCanada

TransCanada undertook corrective actions to address the ineffectiveness of each operational control, as previously described in section 4.2.

4.3.2 Inadequate Inspection

Background

Under the management system element *Inspection, Measurement, and Monitoring*, the NEB expects companies to have programs for making qualitative and quantitative measures for evaluating the management and protection programs.

Facts from the Investigation

TransCanada's IMPP implements a number of inspection processes, including field investigation of ILI features. In the case of the failed feature at KP 379, the criteria for field investigation were inadequate to trigger inspection of a critical corrosion feature. The nature of the complex geometry of this corrosion exposed an unforeseen tool limitation, which the field investigation criterion did not account for.

Finding

Based on these facts, the Board makes Finding 7:

Finding 7. Inadequate inspection was a management system cause of the 20 July 2009 rupture of the PRML.

Corrective Actions Taken by TransCanada

TransCanada undertook corrective actions to address the inadequacy of inspection, specifically with creation of new complex corrosion field investigation criteria described previously in section 4.2.

4.4 Other Preventative and Mitigative Measures

4.4.1 PRML South of Meikle River Compressor Station

In the Board's Safety Order SG-N081-02-2009, Condition 3 placed an expiry date on the operation of the PRML under pressure restriction. If TransCanada continued to operate the PRML unmitigated under the pressure restriction, condition 3 required an application within 15 days of 30 May 2010 to make the case for continued safe operation under a pressure restriction. The Board imposed this condition to ensure operation would not continue indefinitely without mitigation of potential corrosion growth.

In undertaking its corrective actions and ILI process improvements, TransCanada requested to split the resulting investigative digs corresponding to the section North of Meikle River Compressor Station in 2009/2010 and South of Meikle River Compressor Station in

2010/2011[34]. The Board approved the request, notwithstanding the expiry on operation under a pressure restriction[35]. On 14 June 2010, TransCanada applied for continued operation of the PRML South of Meikle River Compressor Station[36]. TransCanada detailed its plans to decommission the PRML South of Meikle River in early 2011 and proposed further pressure restrictions to mitigate the effects of corrosion growth. The Board amended its Safety Order by AO-2-SG-N081-02-2009[37] and AO-3-SG-N081-02-2009, resulting in the following progressive pressure restrictions for the PRML South of Meikle River Compressor Station:

- a 25% pressure reduction from the MOP to 4238 kPa until 31 December 2010;
- a minimum 45% pressure reduction to no greater than 3110 kPa between 1 January 2011 and the sooner of 31 March 2011 or the date of isolation of the PRML; and
- a minimum 94% pressure reduction to no greater than 340 kPa after the sooner of 31 March 2011 and the date of isolation of the PRM.

The NEB expects TransCanada's application to decommission the PRML south of Meikle River Compressor Station in the coming months.

4.4.2 Return to Maximum Operating Pressure North of Meikle River Compressor Station

By 11 May 2010, TransCanada had fulfilled all of its corrective actions and conditions for the section of the PRML North of Meikle River Compressor Station and applied for return to the maximum operating pressure. The Board determined that TransCanada had taken all appropriate corrective and granted the return to maximum operating pressure. However, the Board believed additional actions were required for the prevention of similar future incidents. The Board amended its Safety Order by AO-2-SG-N081-02-2009 to cause TransCanada to improve its leak detection programs and improve on historical performance.

4.4.3 Improvements to Continuous Monitoring

Condition 7 of the Board's Safety Order SG-N081-02-2009 required TransCanada to improve its continuous monitoring program. In its initial filings[38,39] TransCanada ruled out corrective actions for continuous monitoring. The Board originally deferred its decision to the conclusion of the investigation[40], then in June 2010 directed TransCanada to improve its leak detection programs to satisfy the condition[41].

On 17 August 2010, the Board approved TransCanada's proposal with amendments[42], resulting in a performance based leak detection program with the following frequency of instrumented aerial surveys:

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[34] TransCanada condition 6 filing, dated 2 December 2009.
[35] NEB letter TransCanada, dated 18 December 2009.
[36] TransCanada application pursuant to Condition 3, dated 14 June 2010.
[37] Board Amending Order AO-2-SG-N081-02-2009, dated 30 June 2010.
[38] TransCanada Condition 7 filing, dated 26 October 2009.
[39] TransCanada amended Condition 7 filing, dated 30 November 2009.
[40] NEB letter to TransCanada, dated 18 December 2009.
[41] NEB letter to TransCanada, dated 30 June 2010.
[42] NEB letter to TransCanada, dated 17 August 2010.

- Initial frequency increases from annual to quarterly.
- Quarterly frequency may decrease to every six months if TransCanada does not detect leaks four (4) consecutive surveys.
- Biannual frequency may decrease to annual if TransCanada does not detect leaks four (4) consecutive surveys.
- Frequency shall return to the previous interval if a leak occurs at any time.

4.4.4 Improvements on Historical Performance

The performance of the PRML has been historically challenged by external corrosion, as documented in section 2.4 of this report. In its 30 June 2010 letter, the NEB communicated to TransCanada that it must improve upon the historical performance of the PRML. Condition 11 on Order AO-2-SG-N081-02-2009 caused TransCanada to develop a long-term continuous improvement plan for improving the historic leak and rupture performance of the integrity of the PRML. TransCanada's plan proposed improvements in the following areas:

- ILI Run and Data Quality
- ILI Data Analysis
- ILI Tool Validation
- Risk and Reliability Methodology and Targets
- Corrosion Growth Analysis
- Monitoring Using Cathodic Protection Surveys and Leak Detection Surveys

On 22 February 2011, the NEB accepted and approved TransCanada's long-term continuous improvement plan. The NEB continues to monitor TransCanada's progress on these improvements.

Chapter 5 Recommendations

This Chapter fulfills the NEB's mandate for making recommendations for the prevention of similar future incidents[43].

5.1 Recommendations to TransCanada

TransCanada's corrective actions, both voluntary and Board imposed, can reasonably be expected to have the effect of preventing similar future incidents. Therefore, the Board makes no new recommendations for the prevention of similar future incidents.

5.2 Recommendations to NEB-Regulated Companies

The NEB makes recommendation 1 to all pipeline companies under NEB jurisdiction. TransCanada's complex corrosion criteria can reasonably be expected to have the effect of preventing similar future incidents on the PRML. Since the progression of corrosion on the PRML is of an advanced nature, compared to other pipelines, early adoption of these complex corrosion criteria may prevent similar future incidents on other pipeline systems. For that reason, the Board makes the following recommendation to all companies under NEB jurisdiction.

Recommendation 1. NEB-regulated pipeline companies' Integrity Management Programs should readily demonstrate:

- An evaluation of susceptibility to the threat of external corrosion;
- For pipeline systems susceptible to external corrosion:
  - Consideration of TransCanada's complex corrosion criteria in accounting for ILI measurement uncertainty;
  - Justification for adopting, rejecting, or otherwise adapting TransCanada's complex corrosion criteria; and,
  - Where adopted or adapted, the process should be updated in accordance with a management system approach.

[43] Subsection 12.(1.1) (b) of the NEB Act.

The NEB regularly conducts integrity audits, inspections, and other compliance activities. The NEB will take the opportunity on its compliance activities to verify Recommendation 1 with regulated companies. This recommendation may have the direct impact of preventing similar future incidents, and therefore the NEB expects full cooperation on this matter from regulated companies.

Chapter 6 Conclusions

The NGTL Peace River Mainline rupture on 20 July 2009 was an unacceptable incident. Fortunately, it resulted in minimal impacts to safety, the environment, property, and economic efficiency. The National Energy Board's investigation and TransCanada's corrective actions have two ongoing benefits: the criteria to which TransCanada manages the Peace River Mainline are more stringent today than it was before 20 July 2009 and learnings from this incident have potential to improve pipeline integrity across the pipeline industry.

The NEB's investigation spanned July 2009 to June 2010 and resulted in the issuance of a Safety Order and two amendments. The Board made seven (7) findings as to the cause of the incident and the factors contributing to it. In addition, the Board made one (1) recommendation to all NEB-regulated companies for the prevention of similar future incidents. The publishing of this report concludes the NEB's investigation.

Appendix I NEB Regulatory Actions

The National Energy Board's investigation of the 20 July 2009 rupture of the NGTL Peace River Mainline required the issuance of a Safety Order and two amendments. The Table below summarizes the Board's regulatory actions, including Orders, Amending Orders, and attached.

Order	Condition
SG-N081-02-2009	1. TransCanada shall comply with all commitments referred to in its 29 July 2009 correspondence to the Board, unless and to the extent that the commitments have been modified in this Order.
SG-N081-02-2009	2. The Peace River Mainline from MLV 20 to MLV 170 shall operate under a minimum 20% pressure reduction to no greater than 4521 kPa, until otherwise directed by the Board. Consideration shall be given to further reducing the operating pressure when excavations or maintenance activities are being performed to ensure worker safety. [Amended by AO-2-SG-N081-02-2009 & AO-3-SG-N081-02-2009]
AO-2-SG-N081-02-2009	2. Unless the Board otherwise directs, the Peace River Mainline from MLV 111 to MLV 20 shall operate under the following specified pressure restrictions: a. A minimum 25% pressure reduction to no greater than 4238 kPa until 31 December 2010. b. A minimum 94% pressure reduction to no greater than 340 kPa after 31 December 2010. Consideration shall be given to further reducing the operating pressure when excavations or maintenance activities are being performed to ensure worker safety. [Amended by AO-3-SG-N081-02-2009]

AO-3-SG-N081-02-2009	2. Unless the Board otherwise directs, the Peace River Mainline from MLV 111 to MLV 20 shall operate under the following specified pressure restrictions: a. A minimum 25% pressure reduction to no greater than 4238 kPa until, and including, 31 December 2010. b. A minimum 45% pressure reduction to no greater than 3110 kPa between 1 January 2011 and the sooner of 31 March 2011 or the date of isolation of the PRML. c. A minimum 94% pressure reduction to no greater than 340 kPa after the sooner of 31 March 2011 and the date of isolation of the PRML. Consideration shall be given to further reducing the operating pressure when excavations or maintenance activities are being performed to ensure worker safety.
SG-N081-02-2009	3. In the event the pressure restriction referred to in this Order remains in effect beyond 30 May 2010, TransCanada shall within 15 days thereafter apply to the Board for continued operation of the Peace River Mainline.
SG-N081-02-2009	4. TransCanada shall immediately notify the Board of any condition or information which may have an adverse effect on the safe operation of the Peace River Mainline (including, but not limited to, abnormal or upset condition, overpressure, or revised corrosion growth rate).
SG-N081-02-2009	5. TransCanada shall, within 60 days of the date of this Order, submit an independent laboratory analysis report, concerning the cause and contributing factors of the 20 July 2009 rupture.
SG-N081-02-2009	6. TransCanada shall, within 90 days of the date of this Order, submit for approval of the Board a plan for validating and measuring the effectiveness of the ILI process improvements committed to in its 29 July 2009 letter. The validation shall include, but is not limited to, either hydrostatic or pneumatic testing of a selected portion of the Peace River Mainline. The selected portion shall be, to the extent possible, representative of the portion of the pipeline that ruptured on 20 July 2009 containing similar defects. Consideration shall be given to portions of the pipeline where ILI process improvements result in the greatest number of excavations and repairs. [Amended by AO-1-SG-N081-02-2009]

AO-1- SG-N081-02-2009	6. TransCanada shall, *no later than 30 November 2009*, submit for approval of the Board a plan for validating and measuring the effectiveness of the ILI process improvements committed to in its 29 July 2009 letter. The validation shall include, but is not limited to, either hydrostatic or pneumatic testing of a selected portion of the Peace River Mainline. The selected portion shall be, to the extent possible, representative of the portion of the pipeline that ruptured on 20 July 2009 containing similar defects. Consideration shall be given to portions of the pipeline where ILI process improvements result in the greatest number of excavations and repairs.
SG-N081-02-2009	7. TransCanada shall, within 90 days of the date of this Order, submit for approval of the Board a plan for improvements to the programs for continuous monitoring of the operation, condition of the pipe, and right-of-way. The plan shall be based upon findings of the cause and contributing factors of the 20 July 2009 rupture.
SG-N081-02-2009	8. TransCanada shall submit to the Board a quarterly status report, commencing 30 September 2009, and continuing until otherwise directed. The report shall include: a. Findings and status of TransCanada's ongoing investigation; b. In-Line Inspection (ILI) process improvements; c. Status of excavation program and validation of process improvements; d. Changes to practices, procedures, and programs for any portion of the NGTL e. pipeline systems, as a result of TransCanada's investigation; and f. Status of compliance with conditions in this Order.
SG-N081-02-2009	9. TransCanada shall use a leak excavation criterion of at least 70% of the nominal wall thickness for ILI features. Expected growth of features since the last ILI shall also be considered. [Amended by AO-3-SG-N081-02-2009]

AO-3-SG-N081-02-2009	9. TransCanada shall use a leak excavation criterion as follows: a. At least 80% of the nominal wall thickness between MLV 20 and MLV 110, except as the Board directed in its 21 December 2010 letter. b. At least 70% of the nominal wall thickness between MLV 110 and 170. Expected growth of features since the last ILI shall also be considered.
AO-2-SG-N081-02-2009	10. Unless the Board otherwise directs, TransCanada shall use a leakage limit state in its reliability model which prevents, to the extent practicable, corrosion from exceeding the defect limits in accordance with Clause 10.9.2.7 of CSA Z662-07.
AO-2-SG-N081-02-2009	11. Unless the Board otherwise directs, TransCanada shall within 60 days of the date of this Order submit a long-term continuous improvement plan for improving the historic leak and rupture performance of the integrity of the PRML. The improvement plan shall include, but is not limited to, the revision of PRML leakage and rupture reliability targets and the associated mitigative measures. Note: For reference, the Board has determined the historical performance of the PRML to be 7.9E-4 leaks/year-km and 3E-4 ruptures/year-km.