Northern Gateway Pipelines Limited Partnership

Semi-Quantitative Risk Assessment

February 2013 Update Route Rev V

Submitted in Response to Northern Gateway Undertaking U-42

Enbridge Northern Gateway Project

Project No. 407016-00013

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EXECUTIVE SUMMARY

This *Semi-Quantitative Risk Assessment*: *February 2013 Update Route Rev V* (SQRA) was prepared by WorleyParsons Canada Services Ltd. (WorleyParsons) for the Enbridge Northern Gateway Project (the Project).

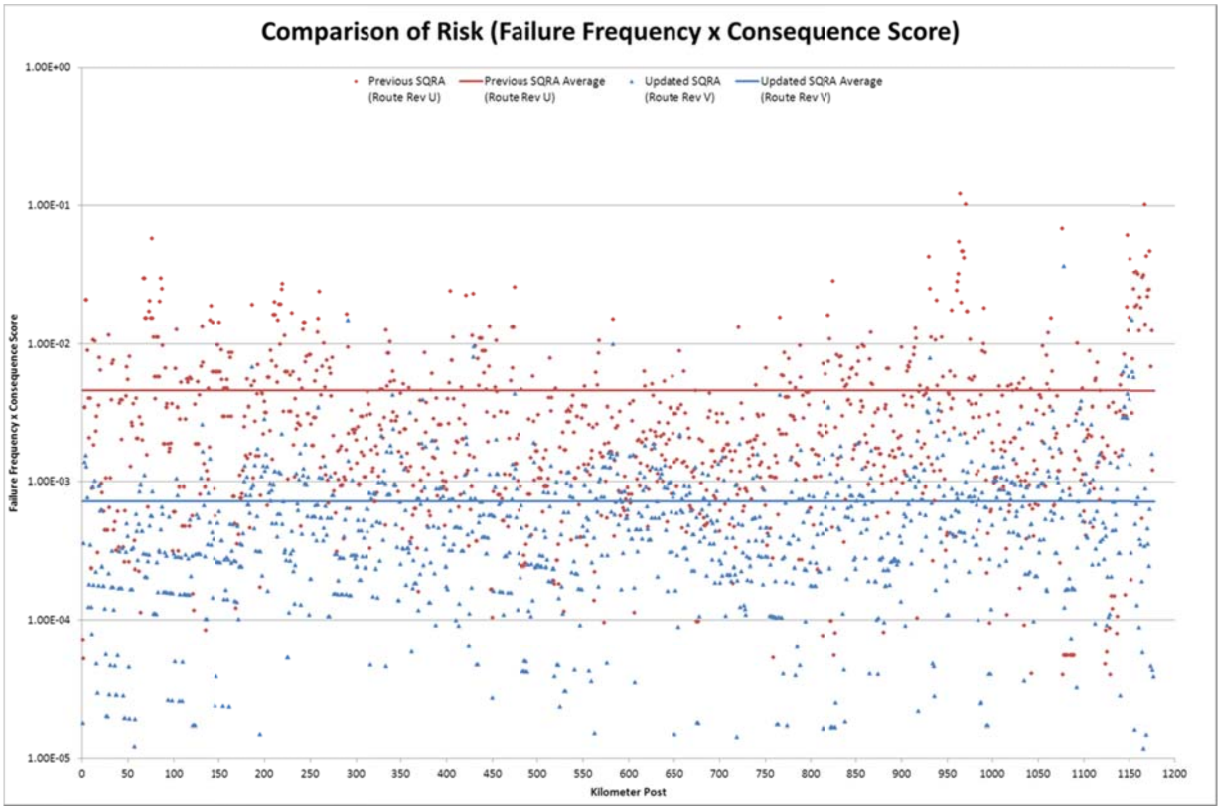
This updated SQRA provides a consolidated document that reflects the changes to the design basis and the route since the previous filing, and in particular the changes to pipeline wall thickness and valve spacing as a result of commitments made by Northern Gateway. It was prepared to respond specifically to an undertaking given by Northern Gateway to an intervenor (U-42) during the course of the Final Questioning portion of the Prince George phase of the JRP hearing. The undertaking sought an update to the previously filed SQRA (B75-2) to compare the assessed risk of the pipeline taking into account Northern Gateway's commitment to implement engineering, design and operation measures to enhance the safety and reliability of the pipelines over and above standard industry practice. This updated SQRA takes into account these measures, other commitments and engineering design refinements.

The assessment methodology follows the definitions and guidelines provided in Canadian Standards Association (CSA) CSA Z662-11, *Guidelines for Risk Assessment of Pipelines*. The magnitude of risk as defined by this standard is the combination of the frequency or likelihood of an event and the consequence of the event if it happens.

Risk severity was evaluated through a risk matrix developed for the Project as a combination of the frequency and the consequence of a full-bore rupture. In addition to conveying descriptive risk severity by means of a risk matrix, and to facilitate a comparison in results between the previous SQRA and this update, risk scoring (defined as a product of failure frequency and consequences) was also used. Using this method, risk results are influenced equally by changes in failure frequency and consequences. This method is useful for a determination of a directional change to risk.

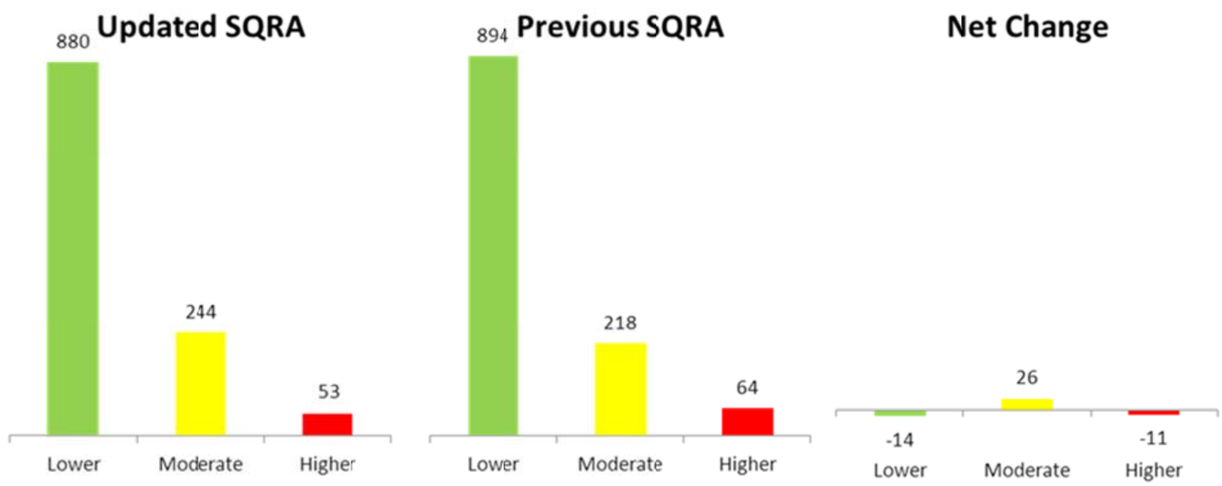
Northern Gateway's commitments to increased wall thickness provide additional protection against a number of threats, additional geotechnical assessments have resulted in lowering the frequency of geohazard failure, and an increased numbers of valves will reduce potential volumes of releases. The return period of a full-bore rupture has gone from 240 years to 464 years.

The risk reduction along the pipeline route is shown in the following figure that compares the results of the previous SQRA to the updated SQRA.



Based on the product of frequency and consequence the risk has been reduced by 84%.

The risk matrix that was used in the previous SQRA for conveying risk results is not as sensitive to changes in failure frequency as it is to changes in consequences. Nevertheless, using the risk matrix, the number of higher risk segments has been reduced by 11.



Risk Severity Ratings and Comparison to previous SQRA

The terrain and geotechnical conditions that this pipeline traverses are similar to those of other liquid transmission pipelines in Canada and throughout the world. The products to be carried by the pipelines are also carried by other existing pipelines in Canada and the United States.

This SQRA was based on assessing risk from a full-bore rupture on the proposed oil pipeline. Northern Gateway recognizes that a release of any magnitude from the pipeline is unacceptable and will undertake additional work during the detailed design phase to identify and apply mitigation to minimize risk of a release.

Further work will be undertaken by Northern Gateway in detailed design, construction and operations using the liquid pipeline risk assessment and management tools developed by Enbridge as part of its continuous improvement in these areas.

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1. INTRODUCTION

This *Semi-Quantitative Risk Assessment*: *February 2013 Update Route Rev V* ((this SQRA) was prepared by WorleyParsons Canada Services Ltd. (WorleyParsons) for the Enbridge Northern Gateway Project (the Project). This SQRA report is supported by an updated Report on Quantitative Geohazard Assessment prepared by AMEC Environment & Infrastructure, a division of AMEC Americas Limited, (AMEC) contained in Attachment 3.

Consistent with the guidance that was given during the JRP process to characterize full-bore rupture effects; this SQRA report continues to focus on full-bore ruptures. From the perspective of a risk-based approach to design as well as consequence mitigation, the focus of this assessment is on ruptures because ruptures have the potential for the most extreme consequence. Consequence mitigation measures that are developed and incorporated into the design for mitigating ruptures will also be effective in mitigating less significant releases.

1.1 Purpose of the Update to the Semi-Quantitative Risk Assessment

Since the previous SQRA filing (B75-2) in June 2012, Northern Gateway committed to additional engineering, design and operation measures to enhance the safety and reliability of the pipelines over and above standard industry practice (B83-2). During the course of the Final Questioning portion of the JRP hearing, questions were directed by an intervenor to Northern Gateway in respect of these measures, its commitment to refine its engineering design, and how these measures would reduce risk (93T15087 – 15159). To be responsive to these questions, Northern Gateway provided an undertaking (U-42) to update the SQRA to take into account these measures and other commitments and engineering design refinements, including:

1. A commitment to increasing the wall thickness of the pipe and in particular where the pipeline crosses the Fraser, Skeena and Kitimat drainages.
2. A commitment to increasing the number of block valves along the route to reduce the volume of potential releases.
3. A route revision to move the pipelines south, farther away from the Morice River.
4. Changes to pump station locations.
5. Route Revision V, filed in December 2012, which incorporates the above measures, commitments and design refinements.
6. Refinements in geohazard assessment and determination.

This update to the SQRA was prepared to respond specifically to the undertaking given by Northern Gateway and provides a consolidated document that reflects the changes to the design basis and the route since the previous filing based on Route Rev U, as well as updates that were provided during the IR process in August and September of 2012.

This document describes and updates:

1. the components and methodology of the risk assessment, including the geotechnical threat evaluation, the frequency assessment and the risk evaluation;
2. the results of the risk assessment; and
3. a discussion of these results and next steps.

In addition to conveying descriptive risk severity by means of a risk matrix, and to facilitate a comparison in results between the previous SQRA and this update, risk assessment scoring (product of failure frequency and consequences) is used.

1.2 Background

1.2.1 Project description

Northern Gateway, a subsidiary of Enbridge Pipelines Inc., has initiated the regulatory phase of the Project to obtain the required approvals. The Project is being developed to provide pipelines and associated facilities to transport approximately 83,400 m^3/d (525,000 bbl/d) of oil from Bruderheim, Alberta, to Kitimat, British Columbia (BC), and approximately 30,700 m^3/d (193,000 bbl/d) of condensate from Kitimat to Bruderheim. It includes the following major components for Route Rev V:

- an oil pipeline, 914 mm OD (NPS 36) approximately 1,178-km long, extending from the outlet of the Bruderheim Station to the Kitimat Terminal
- a condensate pipeline, 508 mm OD (NPS 20) approximately 1,178-km long, located in the same right-of-way (ROW) as the oil pipeline and extending from Kitimat Terminal to the Bruderheim Station
- the Bruderheim Station, consisting of the oil initiating pump station and condensate receiving facilities
- eight intermediate pump stations located at intervals along the pipelines
- a 6.5-km-long tunnel and a 6.6-km-long tunnel to route the oil and condensate pipelines through the Clore River and Hoult Creek valleys
- Kitimat Terminal, which will comprise the following:
    - a tank terminal including oil tanks, condensate tanks and associated infrastructure
    - a marine terminal including two tanker berths and one utility berth
    - an initiating condensate pump station
    - oil receiving facilities

1.3 Terminology

Table 1 provides definitions for terminology used in this report. Appendix A lists abbreviations used in this document.

Table 1: Terms and definitions used in this report

Term	Definition
Consequence	The effect of a hydrocarbon spill on individuals or populations, property, or the environment.
Consequence area	Term provided by the Joint Review Panel in their request for additional information as “onshore and/or offshore including but not limited to: wildlife reserves, occupied areas, Indian Reserves, urban areas or towns, water bodies, federal or provincial campgrounds and parks and town water intake locations”. This term has been subsequently replaced by “high consequence area” in Northern Gateway’s assessment.
Frequency	The likelihood of an event, expressed qualitatively or quantitatively (such as failures per km-year) or as a return period.
Geohazard	A threat from a naturally-occurring geological process or condition that may lead to damage. The process may be triggered by natural or anthropogenic causes. For the purposes of this assessment, the damage is damage to the pipeline that might lead to a rupture. Examples include mass wasting, deep seated slides, debris flows, rock fall, avalanches and hydrological events. Also referred to as geotechnical hazard.
High consequence area (HCA)	Equivalent to and supersedes the term “consequence area” for Northern Gateway’s assessment (see Appendix B).
Project effects assessment area (PEAA)	The maximum area where Project-specific environmental effects can be predicted or measured with a reasonable degree of accuracy and confidence.
Return Period	A measure of frequency of an event expressed in years. The return period represents the average interval between events over an extended period of time.
Risk	A compound measure of the frequency and severity (consequences) of an adverse effect.
Risk assessment	The process of risk analysis and risk evaluation.
Risk-based approach to design	An iterative process that evaluates and prioritizes risks and the affiliated risk-drivers that are associated with a preliminary design, and then establishes mitigation measures to be incorporated into the final design to address the identified principal risks.
Rupture (full-bore rupture)	A type of failure of the oil pipeline which allows the product to be released in an unconstrained manner into the surrounding environment.
Spill trajectory modelling	A numerical modelling technique that estimates the extent of a spill based on modelled release outputs, topographical and hydrodynamic parameters.

2. OVERVIEW

2.1 Semi-Quantitative Risk Assessment

As defined in Food and Agriculture Organization (2009), semi-quantitative risk assessment provides an intermediary level between the textual evaluation of qualitative risk assessment and the numerical evaluation of quantitative risk assessment, by evaluating risks using a scoring approach. It offers a more consistent and rigorous approach to assessing and comparing risks and risk management strategies than does qualitative risk assessment, and avoids some of the greater ambiguities that a qualitative risk assessment may produce.

As employed in this analysis, semi-quantitative risk assessment incorporates a quantitative evaluation of failure frequency and a semi-quantitative evaluation of consequence. The characterization of risk in this SQRA is sensitive to design parameters, and so it is a useful tool for providing guidance in a risk-based approach to design, whereby the potential for risk reduction through alteration of those design parameters can be investigated.

In addition to conveying descriptive risk severity by means of a risk matrix, and to facilitate a comparison in results between the previous SQRA and this update, risk scoring as a product of failure frequency and consequences was also used. Using this method, risk results are influenced equally by changes in failure frequency and consequences. Consequently, this method is useful for a determination of a directional change to risk.

2.2 Northern Gateway Oil Spill Risk Assessment Timeline

Information on the environmental effects of spills and the management of spills (including ruptures) for the pipelines was provided in Volume 7B of the Project's National Energy Board (NEB) Section 52 Application (B3-20, B3-21).

Following a review of the Application, the JRP in its Panel Session Results and Decision dated 19 January 2011, determined that additional information on the pipelines' design and risk assessment was required prior to issuing a hearing order for the Project. Northern Gateway was requested to provide:

> *Geographically referenced maps at a 1:25,000 scale (such as GIS) describing the geographical extent, on land and water, from potential hydrocarbon releases on consequence areas. The potential hydrocarbon release volumes shall be determined based on full-bore ruptures within each kilometre post distance.*

In March 2011, Northern Gateway filed (B20) pipeline maps showing the extent of releases based on a full-bore rupture scenario for the oil pipeline and the consequence areas. Northern Gateway also provided pipeline plots showing elevations and potential volumes from releases.

In June 2012, the SQRA for Route Rev U was filed (B75-2). It built on the work completed in March 2011 by developing a process to assess the frequency, consequences, and resulting risk of a full-bore rupture scenario to the high consequence areas (HCAs).

Prior to the commencement of the oral questioning phase of the hearings, Northern Gateway filed an update to the full-bore spill extent mapping for Route Rev U that showed the effect of the additional valves that were committed to in July 2012 (Reference B109-16 to B109-23; B130-02 to B130-20).

The risk assessment presented in this report builds on the previous SQRA (B75-2) and the methodology previously developed. It provides a consolidated document that reflects changes to the design basis and updates the results to Route Rev V.

2.3 Assessment Methodology Overview

The assessment methodology follows the definitions and guidelines provided in Canadian Standards Association (CSA) CSA Z662-11, *Guidelines for Risk Assessment of Pipelines,* Annex B (CSA 2011). The magnitude of risk, as defined by this standard, is the combination of the frequency or probability of an event and the consequence of the event if it happens. The methodology shown in Figure 1 was described in detail in the Framework *for Semi-Quantitative Risk Evaluation*, Response to JRP IR 8.1 (B47-11).

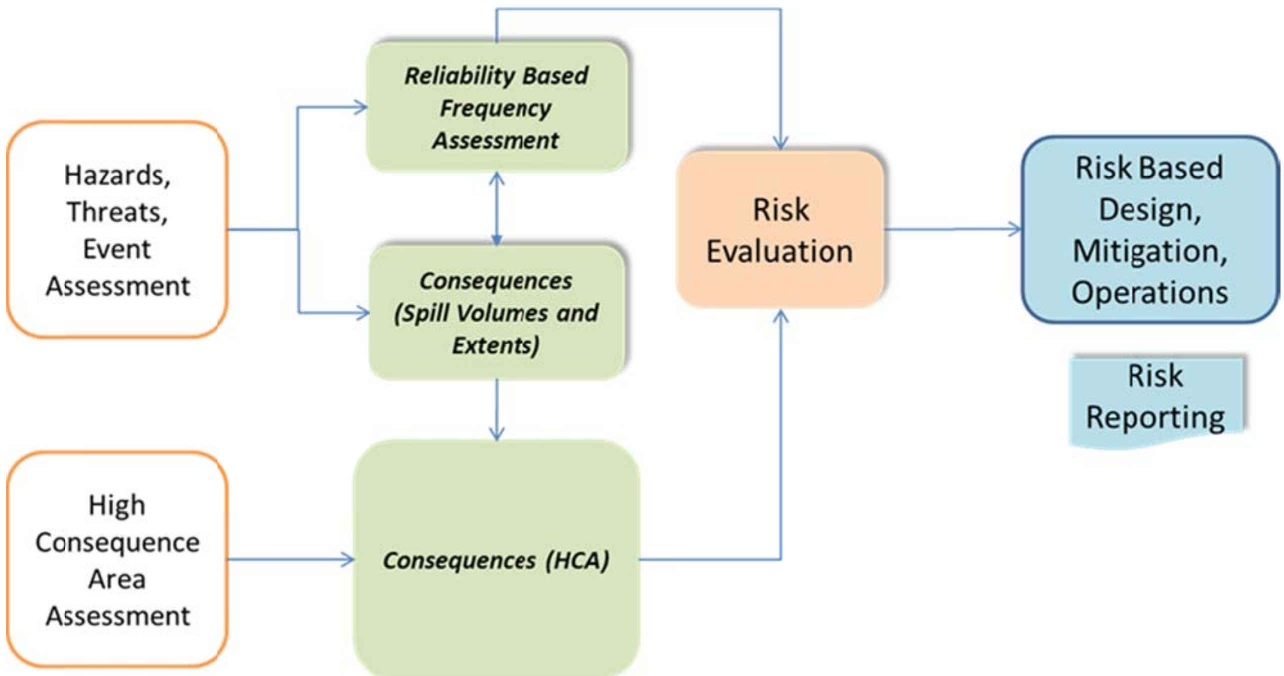


Figure 1: Overview of methodology

WorleyParsons engaged Dynamic Risk Assessment Systems Inc. (Dynamic) on behalf of Northern Gateway to develop a quantitative failure frequency model for threats (except for the geohazards discussed in section 3.2) associated with the construction and operation of the pipeline system. Historical pipeline industry failure statistics are not representative of modern pipeline designs, materials and operating practices. The threat-based approach developed by Dynamic uses actual operating data from recently constructed (modern) pipelines with similar technology and products in conjunction with reliability-based methods (where relevant to the threat being considered) to predict potential failure mechanisms.

AMEC Environment and Infrastructure (AMEC) was engaged to provide a quantitative assessment of geohazard failure frequency, building on AMEC's original work identifying geohazards for the Project.

3. HAZARDS, THREATS AND EVENT IDENTIFICATION

3.1 Pipeline System Threats

As a starting point to the Risk Assessment, Dynamic conducted a Threat Assessment Workshop in December 2011 at the Enbridge offices in Edmonton, Alberta. Enbridge operations, maintenance and pipeline integrity representatives participated in the workshop. Documentation of the threat assessment workshop was provided in the previous SQRA filing (B75-2).

The objective of the threat assessment workshop was to identify and discuss potential threats to a pipeline system considering materials, design, construction and operational variables. Through this review, the relevance and severity of each threat was assessed in the context of the proposed pipelines.

Relevant threats to the proposed pipelines were identified as follows:

- external corrosion
- internal corrosion
- materials and manufacturing defects
- construction (welding, fabrication and installation) defects
- third-party damage
- incorrect operations
- equipment failures (such as at pump stations)

The *Quantitative Failure Likelihood Assessment* report was prepared as Attachment 2 to the previous SQRA filing (B75-2).

3.2 Geotechnical Hazards and Threats

Geotechnical threats along the pipeline route were identified and initially presented in Application Volume 3, Appendix E-1 - *Overall Geotechnical Report on the Pipeline Route Revision R for the Enbridge Northern Gateway Project*, March 2010. Appendix B, Table B-1 of the Report provided a comprehensive description of the geohazards identified. Much of geotechnical work supporting the Application was used to eliminate significant hazards through routing choices.

In the response to the JRP request for additional information (B20, March 2011), Northern Gateway provided additional discussion of the threats associated with the areas of high geotechnical risk and for routing through the Rocky and Coast Mountains with areas of mass wasting. In the response, examples were provided to illustrate in more detail the process used, geotechnical issues and mitigation to be employed.

The *Report on Quantitative Geohazard Assessment* was prepared as Attachment 4 to the previous SQRA filing (B75-2) and is now updated for Route Rev V as Attachment 3 of the updated SQRA.

The geohazard evaluation considers threats within the project effects assessment area (PEAA), as well as hazards outside this corridor that could potentially affect the pipelines. For example, rock fall, avalanches, debris flows and various forms of slides are assessed to distances of sometimes several kilometres from the Route Revision V and are assessed to the height of land above the corridor where appropriate. Approximately 140 km of the route (12%) has associated geotechnical threats. The reduction in reported length from the previous SQRA results from improved accuracy in the geotechnical threat assessment.

4. FULL-BORE RUPTURE FAILURE FREQUENCY ASSESSMENTS

A summary of the methodology and results of failure frequency assessments is provided in this section.

4.1 Pipeline System Failure Frequency

The following sections summarize the methods employed and reports on the results of the failure frequency assessments undertaken by Dynamic as revised for Route Rev V.

There are two changes of note to the analysis. The first change made was to use actual threat extents rather than ascribing the maximum threat within each kilometre to the entire segment. The second change made was to use a mechanical damage model to account for increased wall thickness in the assessment of failure likelihood due to rockfall. These two changes are documented in Attachment 1 – Failure Likelihood Assessment Modifications – Route Rev. V as a follow-up to Attachment 2 of the previous SQRA filing (B75-2).

4.1.1 External corrosion

4.1.1.1 Summary of methods

The reliability approach for external corrosion employs the superimposition of an analog in-line inspection (ILI) dataset upon the design and materials for the Northern Gateway oil pipeline, factoring in tool measurement error and corrosion growth rates. The reliability analysis models how pipeline materials and design responds to a degradation process.

After a review of candidate ILI datasets, the external wall loss feature list from the 2010 ILI of Enbridge's Line 4 (Bethune Station–Regina Terminal) was selected as the appropriate analog dataset. Several factors were considered in selecting that inspection dataset to ensure that it could be established as being representative of corrosion performance anticipated for the Northern Gateway pipelines. The standards for coating types, coating specifications and cathodic protection are the same as those anticipated for Northern Gateway.

The methodology employs a probabilistic simulation approach where the growth of corrosion features can be simulated over time. From a baseline of zero, the model will predict how design parameters will affect the change in failure likelihood over time.

4.1.1.2 Results

The results for the updated SQRA show a significant increase in time to a measureable probability of corrosion failure compared to the previous SQRA due to the increase in wall thickness along the pipeline as a result of commitments made in July 2012.

The models run for external corrosion did not show any measurable probabilities of corrosion failure until after 24 years of simulated operation. In the previous SQRA this number was 11 years. The model does not incorporate inspection and maintenance.

In practice, because the pipeline will be in-line inspected several times within the 24-year period prior to the theoretical first possible failure, external corrosion threats will be effectively managed to a negligible level for the life of the pipeline. Furthermore, because of the increased resistance to rupture that is attributed to the increase in wall thickness, the theoretical potential for failure to occur by rupture (as a result of external corrosion) rather than by leak has been virtually eliminated.

4.1.2 Internal corrosion

4.1.2.1 Summary of methods

As in the approach for external corrosion, an analog ILI dataset was chosen and superimposed on the preliminary Northern Gateway design and materials, factoring in tool measurement error and corrosion growth. To ensure that the internal corrosion mechanism and corrosivity that is represented by the analog ILI dataset are representative of those that would be expected in the Northern Gateway pipelines, the following factors were examined: water content, erosion and corrosion, flow velocity, flow mode, temperature, susceptibility to under-deposit corrosion (such as solid deposition, microbiologically-induced corrosion potential, and water chemistry), and mitigation measures (use of inhibition, biocides, or pigging).

Through this process, it was determined that the ILI data obtained from Enbridge's NPS 36 Line 4 would be most representative of the corrosivity conditions expected on the Northern Gateway oil pipeline.

Approximately 10,000 km-years' (distance of pipeline inspected times the number of years of operation) worth of ILI data from the NPS 36 Line 4 was reviewed.

4.1.2.2 Results

No evidence of active internal corrosion was found.

The pipeline will operate in fully-turbulent mode, resulting in full entrainment of what little water is present (the maximum basic sediment and water tariff specification for the Northern Gateway oil pipeline is 0.5%). Therefore, as a result of these operating conditions, no significant internal corrosion is expected on this pipeline and the failure probability for this threat is negligible.

4.1.3 Materials and manufacturing defects

4.1.3.1 Summary of methods

Material defect failures are failures that are a direct result of the presence of pipe body or seam weld defects. The threat of materials and manufacturing defects does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. We therefore employed a baseline failure frequency derived from industry failure statistics, modified by an adjustment factor to account for modern pipeline materials, design, and installation practices.

Failure statistics by cause for hazardous liquid pipelines were published by Restrepo et al (2009). This report describes failure incidents for various causes and sub-causes occurring over the 170,000-mile hazardous liquid pipeline infrastructure in the U.S. from the period January 2002 to December 2005.

PHMSA data were used since they are based on a large database of pipeline failures, including both leaks and ruptures, which are derived from significant pipeline infrastructure. As such, these failure incident data have a large degree of statistical relevancy. Furthermore, the PHMSA incident failure database contains information associated with each incident that affords the ability to ensure the relevancy of the data to the pipeline being modelled and enables conclusions to be drawn relative to issues such as the magnitude of release for associated threats, and the underlying causes of failure.

4.1.3.2 Results

In Restrepo (2009), 19 failures were attributed to material defects. This equates to a failure frequency of 1.7×10^{-5} failures/km-year.

The most modern pipelines considered in Restrepo were constructed in the 1980s and 1990s, and had a normalized incident rate that was 15% of the pipeline infrastructure as a whole. To account for this effect, a modern construction adjustment factor of 0.15 was employed in the calculation of materials defects failure frequency. This results in a failure likelihood of 2.6×10^{-6} failures/km-year.

To establish release outcomes associated with materials defects, the PHMSA leak database (2002 to 2009) was queried for onshore, large-diameter pipelines. Two failure incidents were found; one a leak, and the other a full-bore rupture. Therefore, based on this industry experience, an assumption was made that 50% of all materials defects failures result in full-bore ruptures, and the other 50% result in leaks.

Under this assumption, the resultant failure likelihood for a full-bore rupture would be 1.3×10^{-6} failures/km-year.

4.1.4 Construction (welding and installation) defects

4.1.4.1 Summary of methods

Construction defect failures are failures that are attributed to construction or installation defects, such as girth weld defects. The threat of construction defects does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Therefore, the approach that was used to estimate the frequency of occurrence for this threat employs a baseline failure frequency derived from industry failure statistics, modified by an adjustment factor to account for modern pipeline materials, design, and installation practices.

In Restrepo (2009), failure incidents for various causes and sub-causes occurring over the 170,000-mile hazardous liquid pipeline infrastructure in the U.S. over the period January 2002 to December 2005 are reported. Data from this study was used to derive baseline failure rates for construction-related defects and equipment failure.

4.1.4.2 Results

In the four-year period examined, three sub-causes were related to the major threat category of construction defects failure. These construction defects failure sub-causes were as follows:

- body of pipe failures, such as dents (16)
- butt weld failures (15)
- fillet weld failures (9)

Combined, these 40 failures represent a failure frequency of 3.7×10^{-5} failures/km-year. This value was employed as the baseline failure frequency for construction defects.

A review of the construction defects failure statistics determined that the normalized rate of materials defects incidents varied by decade of construction.

The most modern pipelines that were considered in the study (constructed in the 1980s and 1990s) had a normalized incident rate that was 60% of the pipeline infrastructure as a whole. To account for this effect, a modern construction adjustment factor of 0.60 was employed in the calculation of construction defects failure frequency, resulting in a failure likelihood of 2.2×10^{-5} failures/km-year.

Absent some large-scale outside force, failures due to construction defects such as girth weld defects, which are oriented in the plane of the principal pressure-containing stresses, fail by a leak mechanism, rather than by a rupture, and the probability for a full-bore rupture is negligible. This is consistent with the findings of a review of failure incidents from the PHMSA leak database related to construction defects.

4.1.5 Third-party damage

4.1.5.1 Summary of methods

The potential for strikes and damage to any size pipeline increases with human activity such as excavation, oil and gas activity, and road works. Proximity to urban areas and settlements or to commercial operations creates an increased potential for third-party damage.

There is evidence that, even with proximity to urban or commercial areas, the threat is limited to pipeline strikes from larger machines. Chen and Nessim (1999) demonstrated that machines smaller than excavators do not significantly affect predicted failure probability.

The probability that there may be an excavator strike is dependent on both site-specific and operational factors that are combined using a fault tree approach outlined by Chen and Nessim (1999). Factors considered include the following:

- land use (defines overall frequency of excavation on pipeline ROW)
- placement frequency of pipeline marker signs
- use of buried marker tape at crossings
- third-party requirements regarding notification of intent to excavate
- pipeline patrol frequency
- depth of cover

Land use is a key factor in the third-party damage model that influences the probability of impact by an excavator.

The dominant land use is active or inactive logging operations as well as active oil and gas sites. Only 87 km (7% of the route) through the Rocky Mountains and the Coast Ranges was classified as “very remote” without any commercial or recreational land use evident. Low density residential is associated with Burns Lake while the Industrial designation is associated with the route extent near Kitimat and the terminal.

Figure 2 illustrates the distribution of land use types along the route.

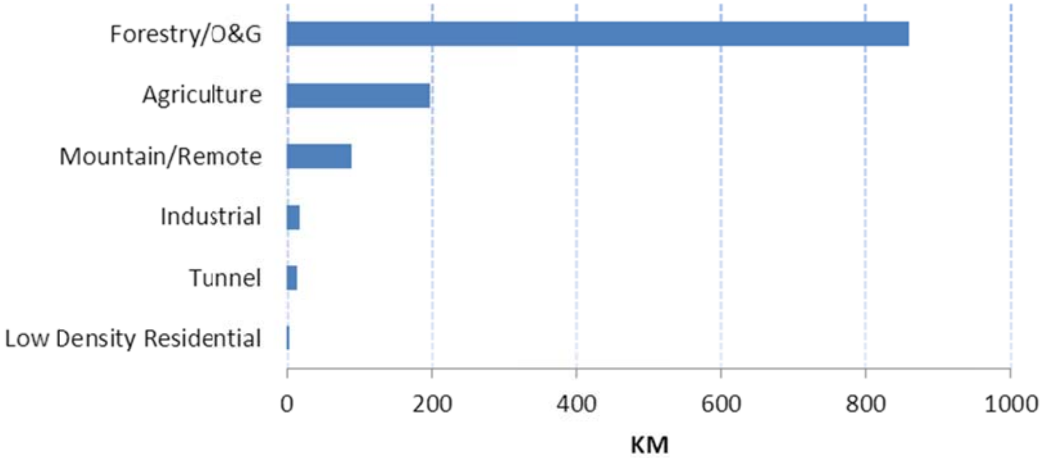


Figure 2: Land use distribution (Route Rev V)

4.1.5.2 Results

A fault tree hit-frequency model in conjunction with a probabilistic damage resistance algorithm was used to calculate the frequency of failure for defined segments along the pipeline route. This frequency was then adjusted for the percentage of incidents that would result in a full-bore rupture. The percentage for full-bore rupture from third-party damage failures are 25%, based on the mechanical damage incidents reported by Chen and Nessim (1999). Figure 3 shows the results for Route Rev V.

The results for the updated SQRA show a significant decrease in predicted failure frequency compared to the previous SQRA due to the increase in wall thickness along the pipeline as a result of commitments made in July 2012. The significant reduction in modelled failure likelihood attributed to increased wall thickness is supported by two incident databases. The PHMSA hazardous liquid incident database (2002-2009) shows no third-party failure for any onshore pipeline where the wall thickness was greater than 16 mm. This is 3.8 mm thinner than the thinnest wall thickness on the oil pipeline. The European incident database (European Gas Pipeline Incident Data Group [EGIG] 2011) shows no record of third-party failure for any wall thickness greater than 15 mm.

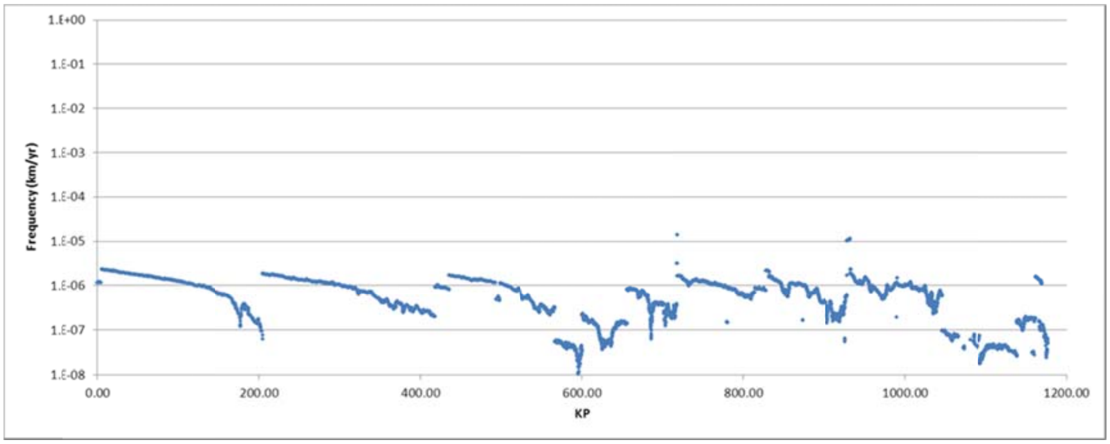


Figure 3: Frequency of third-party damage creating a full-bore rupture (Route Rev V)

4.1.6 Incorrect operations

4.1.6.1 Summary of methods

Incorrect operations failures are related to a failure to follow set procedures during the operation of a pipeline. The threat of incorrect operations does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Therefore, the approach that was used to estimate the frequency of occurrence for this threat employs a baseline failure frequency derived from industry failure statistics, modified by an adjustment factor to account for modern pipeline materials, design, and installation practices.

Estimates of failure frequency were based on operating incident data related to this threat, modified by an adjustment factor. The adjustment factor was derived from a questionnaire developed by Dynamic and administered to Enbridge Operations and other subject matter experts during the threat assessment workshop. The questionnaire is based on the *Pipeline Risk Manual,* Third Edition by W.K. Muhlbauer (2004) and incorporates elements from API RP 581 *Risk-Based Inspection Technology*. It covered topics that were intended to gauge the anticipated performance of Northern Gateway operations in terms of the causal factors of failure related to incorrect operations. The methodology for assigning the adjustment factor based on the questionnaire results was derived from API RP 581.

4.1.6.2 Results

Restrepo (1999) attributes 61 failures to incorrect operations over the 170,000-mile hazardous liquid pipeline infrastructure in the U.S. over the period January 2002 to December 2005. This equates to a failure frequency of 5.607×10^{-5} failures/km-year.

The final adjusted failure frequency was determined to be 1.828 × 10^{-5} failures/km-year.

To establish release outcomes associated with incorrect operations, the PHMSA leak database (2002 to 2009) was sorted for onshore, large-diameter (≥NPS 20) pipelines transporting hazardous liquids, and ten failures related to incorrect operations were found none of which created a full-bore rupture. Therefore, the probability of incurring full-bore failures related to incorrect operations is considered negligible.

4.1.7 Equipment failure

4.1.7.1 Summary of methods

Equipment failure encompasses the failure of non-pipe components and equipment, such as pumps, seals, valves and flanges. Except for block valves and other equipment along the ROW, failures associated with this threat occur at stations. The threat of equipment failure does not lend itself to failure likelihood estimation using a reliability approach due to the lack of a limit state model that is supported by probability distributions for its input parameters. Therefore, the approach that was used to estimate the frequency of occurrence for this threat employs a baseline failure frequency derived from industry failure statistics, modified by an adjustment factor to account for modern pipeline materials, design, and installation practices.

4.1.7.2 Results

Restrepo (1999) identified failure incident data for four sub-causes related to the major threat category of equipment failure as follows:

- ruptured or leaking seal or pump packing (64 failures)
- component failure (45 failures)
- malfunction of control or relief equipment (45 failures)
- stripped threads (30 failures)

Combined, these 184 failures over the four-year period over which data were collected represent a failure frequency of 1.7 × 10^{-4} failures/km-year. In the PHMSA database, there are no full-bore ruptures associated with this threat.

Therefore, the probability of incurring full-bore failures related to this threat is considered negligible.

4.2 Geohazards and Hydrological Threats

The following sections summarize the methods employed and reports on the results of the failure frequency assessments undertaken by AMEC. Details of the methodology and a table of results are found in Attachment 3.

The AMEC assessment was undertaken with respect to geohazard events that would have the potential to initiate a full-bore rupture event in the pipeline. A key distinction is made between events that may occur that could affect terrain in a hazard impact area versus events that may occur that could damage the pipeline itself to the point that full-bore rupture could occur.

4.2.1 Summary of methods

The approach follows the general outline of the hazard assessment methods presented by Rizkalla, Read and O'Neil in Chapter 6 of Rizkalla (2008).

The method employed uses four key index values, or factors, to provide a numerical expression that determines the susceptibility of the pipeline to particular geohazards at discrete locations.

These factors are described in the following sections.

4.2.1.1 Occurrence factor (potential for hazard)

The occurrence factor expresses the potential for a particular geohazard to occur in a specific hazard impact zone. The factor is expressed as a value from 0 to 1, with 0 being defined as "not possible", and 1 being "defined or documented occurrence".

4.2.1.2 Frequency factor

The frequency factor used in this assessment represents the inverse of the return period for the occurrence of a particular geohazard, expressed as events per year. In general, the return period considered provides an estimated frequency for all occurrences of a specific hazard at the given location, including damaging and non-damaging events.

4.2.1.3 Vulnerability factor

Vulnerability factor estimates the ability of the pipeline to withstand the imposed effects of a geohazard event. The factor ranges from 0 (no damage in the event of the hazard occurrence) to 1 (full-bore rupture in all geohazard occurrence situations).

For the purposes of this assessment, vulnerability is the fraction of geohazard occurrences at a specific location that would lead to a damaging event, and specifically, the fraction that would result in a full-bore rupture.

4.2.1.4 Mitigation factor

Geohazard mitigation will reduce either the vulnerability of the pipeline (such as deeper burial) or frequency of occurrence (such as slope stabilization). Mitigation measures will be implemented where elevated hazard levels are identified.

In this evaluation, the mitigation factor is an expression of the effects of implementing mitigation strategies that either increase the resistance of the pipeline to potential damage by a particular geohazard, or reduce the frequency of occurrence of a particular geohazard. Potential mitigation options are identified in each of the detailed geohazard process descriptions referenced later in this report.

Standard mitigation methods were identified for each identified geohazard occurrence. Further review, adjustment and implementation of mitigation options is expected throughout the design, construction and operation of the pipelines as part of the ongoing hazard and risk assessment process that will occur throughout the life of the pipelines.

4.2.1.5 Results

Due to the nature of the underlying uncertainty, assessments were made on an order-of-magnitude basis. Each geohazard was assessed as having a specific failure factor and the results are reported as a frequency per threat independent of length of pipe affected. Particularly in the mountain areas, there may be more than one geohazard that affects a particular segment.

It should be recognized that there is overlap between some of the geohazards. Specifically, the overlaps include the following groups:

1. Streams: Scour and Lateral Migration
2. Streams on alluvial fans: Avulsion, Scour and possibly Debris Flow

Thus, some of geohazards are not independent of each other. This makes a difference when the level of hazard is assessed by adding the various probabilities together where multiple hazards occur. Since the events are not independent (the same event might trigger both lateral erosion and scour), the addition of the hazards along the pipeline route as though they were independent results in a higher risk than may actually be the case.

Most of the geohazards are concentrated in the Rocky Mountains and Coast Mountains but there are also geohazards such as the crossing of the Smoky River in Alberta. Along the route, the frequency of occurrence of most of the identified geohazards fall below 10^{-7} events per year with current proposed levels of mitigation.

4.3 Summary of Results for Full-Bore Rupture Failure Frequencies

Table 2: Threats with full-bore rupture failure frequencies that do not vary along the route

Threat or Hazard	Assessed Value (per km-year)	Comments
External corrosion	Negligible	Failure not predicted for the time period evaluated (for example, no failures are predicted to occur between regular in-line assessments).
Internal corrosion	Negligible	No evidence of internal corrosion in analog data or supporting evidence.
Materials and manufacturing defects	1.3×10^{-6}	Significant improvement in performance with modern manufacturing processes.
Construction defects	Negligible	Associated primarily with welding defects or improper handling and installation, leading to dents. Databases employed in this assessment do not identify full-bore rupture potential associated with this threat.
Incorrect operations	Negligible	Databases employed in this assessment do not identify full-bore rupture potential associated with this threat.
Equipment failure	Negligible	Databases employed in this assessment do not identify full-bore rupture potential associated with this threat.

Table 3: Threats with frequencies that vary along the route for a full-bore rupture

Threat or Hazard	Median Value	Highest Value	Lowest Value	Comments
Third-party damage	1.9×10^{-7} per km-year	2.7×10^{-6} per km-year	Negligible	Most areas of the pipeline are remote with low potential for third-party impacts.
Geohazards (includes hydrological)	Negligible	5.5×10^{-5}	Negligible	Highest potential for geohazards are found in the Coast Ranges and associated with larger watercourses in Western Alberta.

4.3.1 Combined full-bore rupture frequencies

Rupture frequencies for individual threats are combined for each kilometre segment, to provide the result that is illustrated in Figure 4. The underlying dominant pattern is the frequency of full-bore rupture from a third-party damage event. This is punctuated by geohazards in localized areas, such as river crossings along the route and, in particular, for the Coast Mountain section.

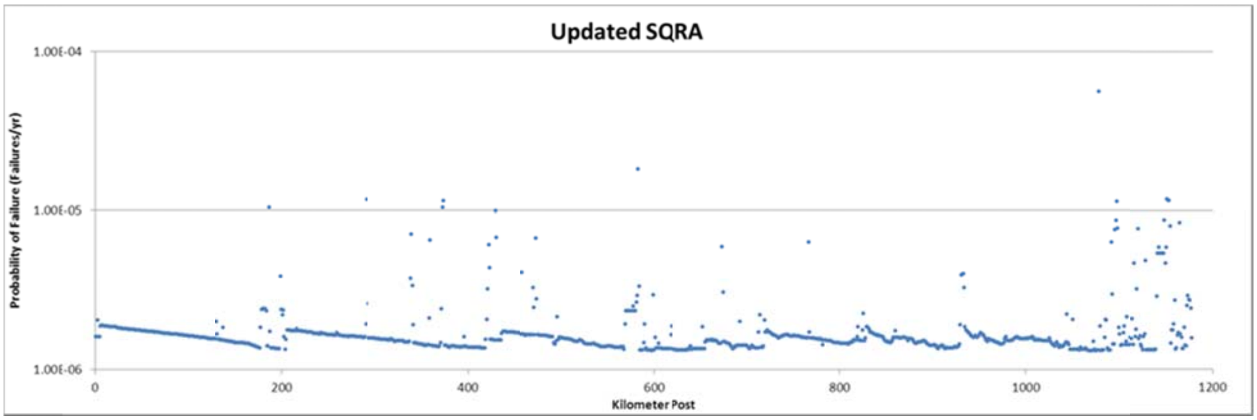


Figure 4: Full-bore rupture frequency (Route Rev. V)

A comparison of rupture frequency along the route between the previous SQRA and the updated SQRA is illustrated in the following figures. Figure 5 shows the rupture frequency for the previous SQRA (Route Rev U), and Figure 6 shows a comparison between the previous SQRA and the updated SQRA rupture frequencies in a single chart.

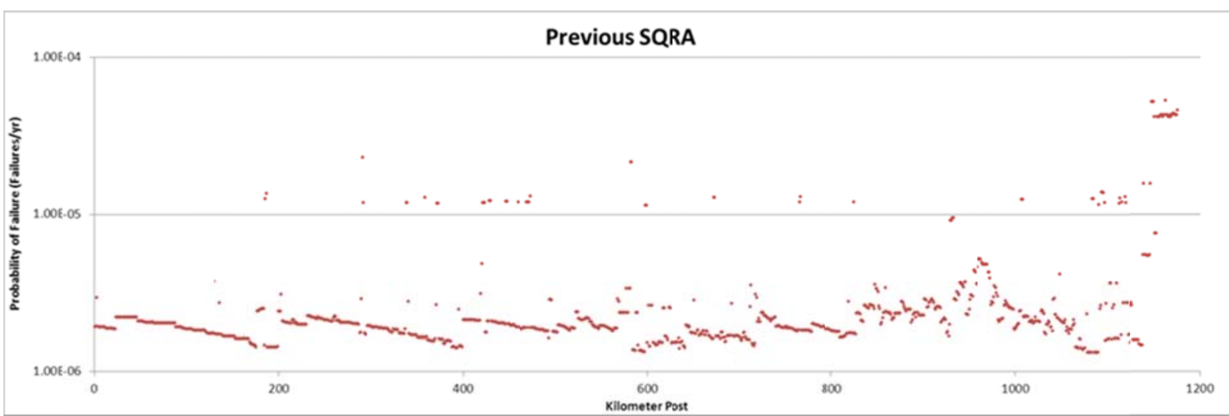


Figure 5: Full-bore rupture frequency previous SQRA (Route Rev. U)

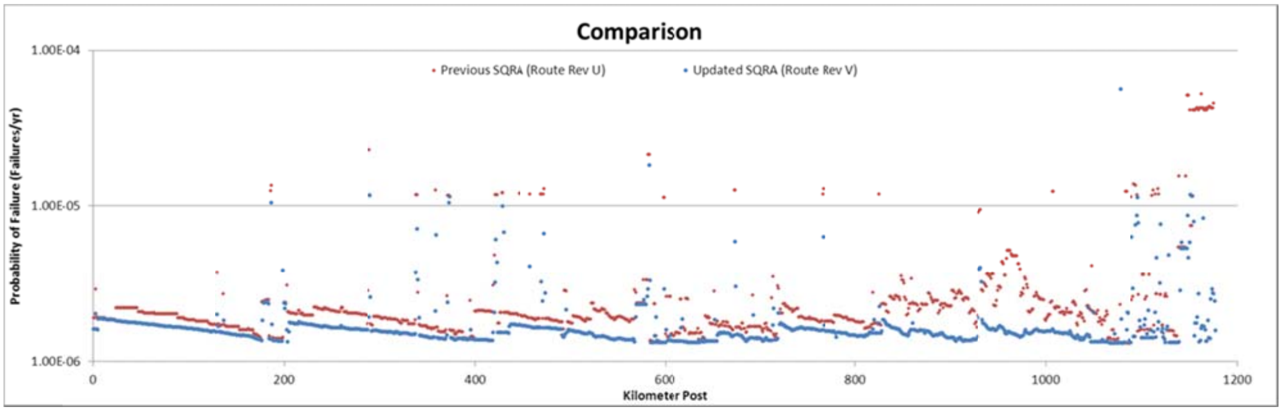


Figure 6: Rupture frequency comparison – previous SQRA to updated SQRA

4.4 Spill Return Period

A calculation was undertaken using 1,178 segments for the total length of the pipeline so that each segment was assigned a rupture frequency, based on a consideration of all threats. This calculation has identified a return period of a full-bore rupture of 464 years for the entire pipeline. This compares to a full-bore rupture return period of 240 years for the previous SQRA.

5. ASSESSING CONSEQUENCES

5.1 Full-Bore Rupture Volumes and Spill Extents

5.1.1 Volume out calculations

The potential maximum release for a full-bore rupture is calculated using the throughput volume, pipeline elevation profile, and locations of block valves to provide an estimated volume of a spill release at any point along the pipeline. The model assumes that

- a full-bore rupture event occurs with complete release of the product;
- the maximum throughput is 92,700 m3/d (583,000 bbl/d);
- a 10-minute spill detection time followed by a 3-minute valve activation time; and
- oil continues to be released based on static (gravity) drawdown on either side of the rupture location.

For the static release calculation the topographic profile determines the amount of release due to gravity drainage taking into account all natural profile constraints. The model also takes into account the “siphon effect’ caused by the complete blockage of the pipeline at the valve location restraining a ‘head’ of product behind each natural constraint equivalent to the atmospheric pressure at the location of the breach.

Table 4 below shows a summary of changes in median potential releases from the previous SQRA to the updated SQRA derived from the Preliminary Valve Location Engineering Assessment Rev F (B190-3).

Table 4: Median volume out comparison (m^3)

	Entire Pipeline	Alberta	British Columbia
Previous SQRA May 2012	1939	2307	1724
Updated SQRA February 2013	1601	2031	1447

5.1.2 Full-bore rupture spill extents

Spill modelling for Route Rev V was conducted by Applied Science Associates using their proprietary OILMAP Land model. Attachment 2 outlines the methodology and assumptions associated with this software which is unchanged from previous filings. The spill extent model for the full-bore rupture scenario uses the following assumptions and inputs:

- a maximum volume release of hydrocarbons from the spill volume model
- release of entire volume to surface

- watercourse discharges based on a maximum mean monthly discharge*

  *Note: The mean discharge for each month is averaged over a number of years. This results in 12 values. The model then uses the maximum of this dataset.

Approximately 80% of these full-bore spills, if allowed to spread and move freely without any mitigation for 12 hours, are conservatively assumed to enter directly or indirectly into a watercourse or other body of water. Once the spill has entered a watercourse, the distance travelled is proportional to the watercourse speed. This is illustrated in Table 5 as updated from the previous SQRA

Table 5: Full-bore rupture extent without mitigation or emergency response

Modelled Spill Extent Feature	Number of Spills	% of Total
Land-based only	142	12.2
Land-based outside 1-km corridor	67	5.8
Water-transported	1022	87.8
Water-transported outside 1-km corridor	994	85.4
Water-transported outside 10-km corridor	431	37.0
Total spill extents modelled	1164	-

In this table, water-transported includes all spills that start on land before entering water or that enter directly into a watercourse or waterbody.

5.2 High Consequence Areas

5.2.1 Definitions

In response to the JRP request of 19 January 2011, consequence areas were identified within the PEAA, the 1-km-wide zone established for much of the Project's environmental and socio-economic assessment. Other consequence areas were defined outside the PEAA (such as parks, urban areas, watercourses and water intakes) as part of the spill trajectory modelling that defined a theoretical maximum spill extent. Maps showing the consequence areas identified by Northern Gateway were included in the response (JRP 2011).

Northern Gateway has adopted the term HCA to align with Enbridge nomenclature. Consequence areas previously defined will now be referred to as HCAs.

HCAs include the following:

- officially designated protected areas that include federal and provincial parks, conservancies, and ecological and wildlife reserves
- settlements that include hamlets, villages, towns and cities
- Indian reserves
- licenced water withdrawal locations related to human consumption or other uses such as for industry and agriculture
- watercourses with species at risk, fish species with conservation concern or harvested fish species
- wildlife habitat, contains species likely to interact strongly with oil and is likely to contain species at risk
- wetlands, fens and marshes

Definitions for HCAs are included in Appendix B.

5.2.2 Consequence scoring factors

5.2.2.1 High consequence area sensitivity ranking

HCAs are ranked based on sensitivity to an oil spill event. For example, watercourses with species at risk are ranked higher than other HCAs. Similarly, although many fish-bearing watercourses are identified as HCAs, those that contain species at risk or have a conservation concern are ranked higher than other watercourses.

5.2.2.2 Volume factor

As discussed earlier, spill volumes were calculated for each kilometre of the route and vary based on a number of factors such as topography and valve placement. Spill volumes were ranked and this ranking was used to modify the consequence score.

5.2.2.3 Accessibility factor

Ease of access, either by highway or paved road close to the ROW, decreases the response time to access the spill location. Conversely, remote areas not serviced by existing roads would potentially increase the response time to the pipeline spill location. The accessibility to each kilometre segment of the pipeline is ranked according to whether the segment has nearby road access and whether the road is for all-weather or seasonal use only and this ranking was used to modify the consequence score.

The current scoring system does not account for existing logging roads likely to be upgraded to provide access during operations, and only considers the current state of access. An example is in the Morice re-route area where proximity to the existing forest service road gave many segments a high access score. The re-route is now accessible through logging roads which at the time of the updated SQRA are seasonal and have a lower score.

5.3 Consequence Scoring

A GIS was used to map and identify the intersections of spill trajectories with mapped HCAs. The output was used by the Risk Assessment Program to calculate a consequence score for each pipeline kilometre segment according to the logic in Figure 7 below.

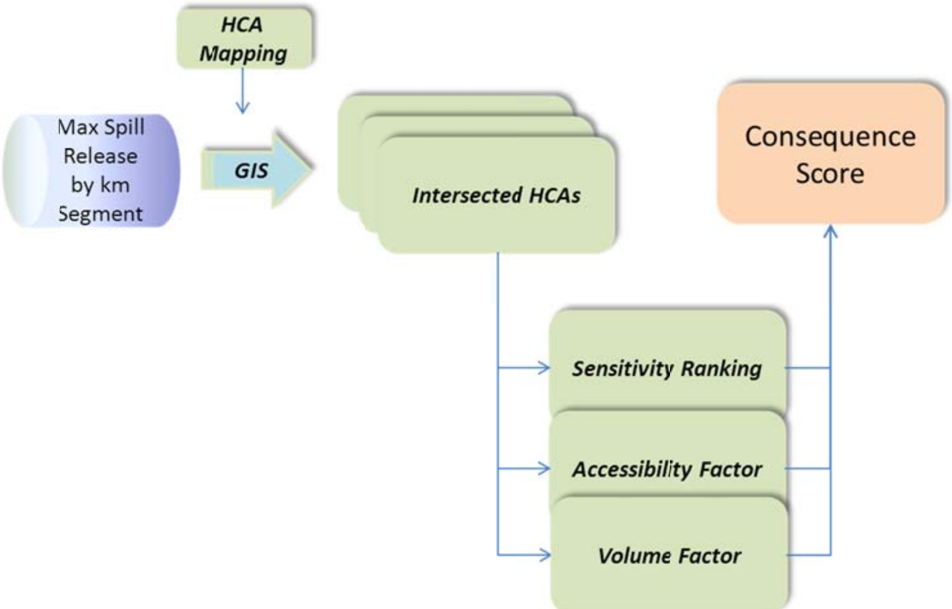


Figure 7: Consequence scoring

There are two parts to consequence scoring and ranking. The first is to derive a score for an individual pipeline segment based on the number of HCAs a spill would affect. The effect is additive. The second part of consequence scoring is to derive a ranking of HCAs based on the potential for an HCA to be intersected by trajectories from a single 1-km segment of pipeline. While probability for each segment might be relatively low, the resultant probability of an event affecting an HCA will be higher.

5.4 Consequence Scoring by Pipeline Segment

The consequence scoring has identified specific segments as well as extended zones along the pipeline which have higher consequences from a full-bore rupture.

5.5 High Consequence Area Impacts

The table below depicts higher consequence watercourses that are potentially affected by the greatest number of segments and the calculated probability for the potential to be affected by a full-bore rupture. This combined probability is a function of the probability of failure assessed for each of the individual segments. Table 6 shows the return period and also shows a comparison of the calculated return periods for these watercourses between the previous and updated SQRA.

Table 6: Comparison of higher consequence watercourses

		SQRA June 2012	SQRA January 2013
Higher consequence watercourses	Kilometre segments	Return period (years)	Return period (years)
Athabasca River	31	12,000	17,000
Smoky River	34	12,000	17,250
Missinka River	41	14,000	17,250
Morice River	14	16,000	50,000
Gosnell Creek	21	24,000	35,750
Kitimat River	29	2,200	8,250

The Kitimat River has the shortest calculated return period of full-bore rupture at this time mostly due to the geohazards in the upper Kitimat River valley. However, it is anticipated that further design and additional refinements to the mitigation proposed will reduce the failure likelihood similar to other higher consequence watercourses.

Northern Gateway undertook a more detailed assessment of the Upper Kitimat River to further identify design and mitigation measures to reduce the risk and consequence in this area (B83-8). During future design phases other higher consequence locations will similarly be assessed and an appropriate level of mitigation implemented.

5.6 Translation of Consequence Scoring into Consequence Ranking

Consequence scores were translated into a descriptive consequence rank using the categories in Table 7.

Table 7: Consequence matrix

Category	Lower	Moderate	Higher
Description	A full-bore rupture from this segment affects only lower ranked high consequence areas. In this category it is likely that the spill only affects one high consequence area.	A full-bore rupture from this segment affects low and moderate-ranked high consequence areas. There will likely be multiple high consequence areas affected.	A full-bore rupture from this segment affects higher-ranked high consequence areas. Spills in this category will also affect multiple high consequence areas.

The descriptions and criteria for the categories of Lower, Moderate and Higher were established by Northern Gateway. The dataset was then divided into the three categories based on the descriptions. While the choice of boundaries is a matter of judgement, there is a good alignment with the definitions.

6. RISK ASSESSMENT

6.1 Methodology

The combination of failure frequency and consequence determines the risk. In this update to the SQRA risk is determined in 2 ways – Risk Severity Classification and Risk Scoring.

Risk severity classification combines the frequency of a full-bore rupture for each segment along with consequence score for each segment using a risk matrix.

The risk matrix developed for the SQRA (see Figure 8) is intended as a way to classify pipeline segments into descriptive categories. The matrix is weighted to consequence and is less sensitive to frequency. This approach reflects a risk perception that high consequence but low probability events have more relative risk than lower consequence, more frequent events.

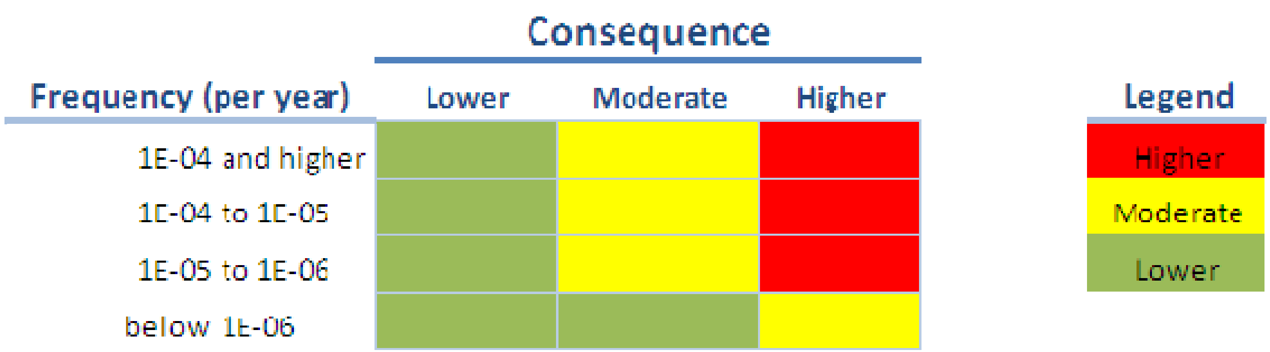


Figure 8: Risk matrix

A risk matrix is useful as a classification tool. However, it is often too coarse to be useful when comparing different levels of mitigation as is now seen with the differences in wall thickness between Route Rev V and Route Rev U. To facilitate a comparison between the previous SQRA and the updated SQRA, an additional calculation was undertaken where a risk score is calculated based on the following formula:

$$\text{Risk Score} = \text{Consequence Score} \times \text{Frequency}$$

The results of this calculation are useful to provide comparisons and to identify any improvement in risk as a result of mitigation that changes the frequency or consequence for this update to the SQRA as well as any additional changes that will be undertaken during the detailed engineering phases.

6.2 Results

There is an overall decrease in risk. This is largely due to:

- Improvements in the failure frequency as a result of wall thickness changes.
- Improvements in the failure frequency as a result of further geotechnical assessments and identification of additional mitigation.
- An improvement to consequence scores by reduced spill extents as a result of additional valves.

The reduction in risk is most clearly shown, directionally by the risk scoring (product of failure frequency and consequences). The risk severity approach (Matrix) shows an 11 km decrease (17%) in high severity segments.

6.2.1 Risk severity by pipe segment

Figure 9 shows the risk severity results for the updated SQRA, the previous SQRA and a comparison of severity results. Out of 1,178 pipeline kilometre segments, 880 segments (75%) are classified as lower risk, while 53 segments (4%) classified as higher risk. The remaining 244 segments (21%) fall into the moderate risk category.

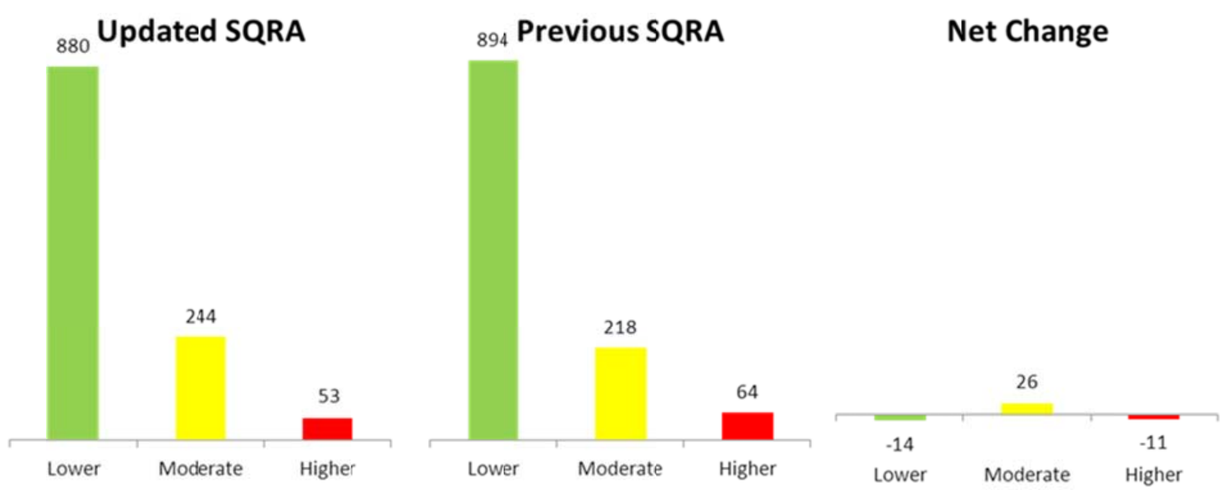


Figure 9: Risk severity for Route Rev. V and comparison with previous SQRA (Route Rev. U)

The number of higher risk segments has decreased by 11. The Morice re-route added 16 additional moderate segments. Two were from the additional length of that section. Fourteen segments are now ranked moderate due to a change in access scoring and the intersection of potential spill extents with wetlands on the bench above the Morice River. While this re-route has created a significant buffer zone between the pipeline and the Morice that has improved the opportunity for an effective emergency response, this positive effect is not reflected in the current scoring system. The creation of a significant buffer zone between the pipeline and the Morice River is illustrated in the figure in Appendix C.

Route Rev U in the Morice re-route area was in close proximity to the existing forest service road which gave many pipeline segments a high access score. The re-route is now in proximity to a network of logging roads which at the time of the risk assessment are seasonal (not plowed in winter) and therefore are given a lower score in the updated SQRA. Potential spill extents also intersect a number of wetlands up-gradient of the Morice River that were not present in the Route Rev U corridor. The combination of the additional wetlands in the Route Rev V corridor and a lower access score has resulted in the increase of the number of moderate risk pipeline segments.

6.2.2 Risk severity by physiographic region

Figure 10 shows the proportion of risk severity classification by physiographic region. The Alberta Plateau section of BC is included with Alberta Uplands in this chart.

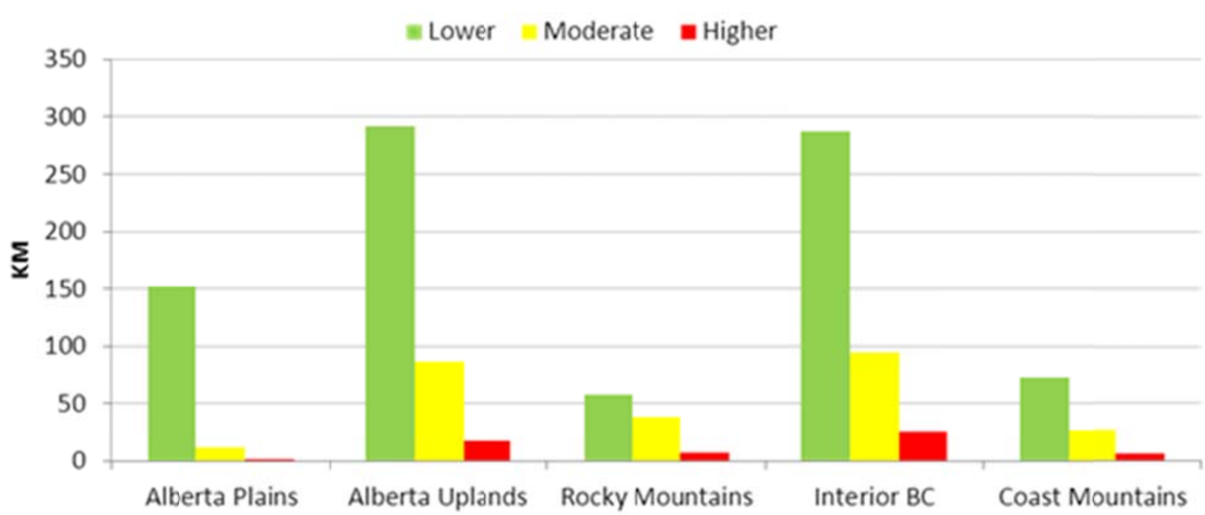
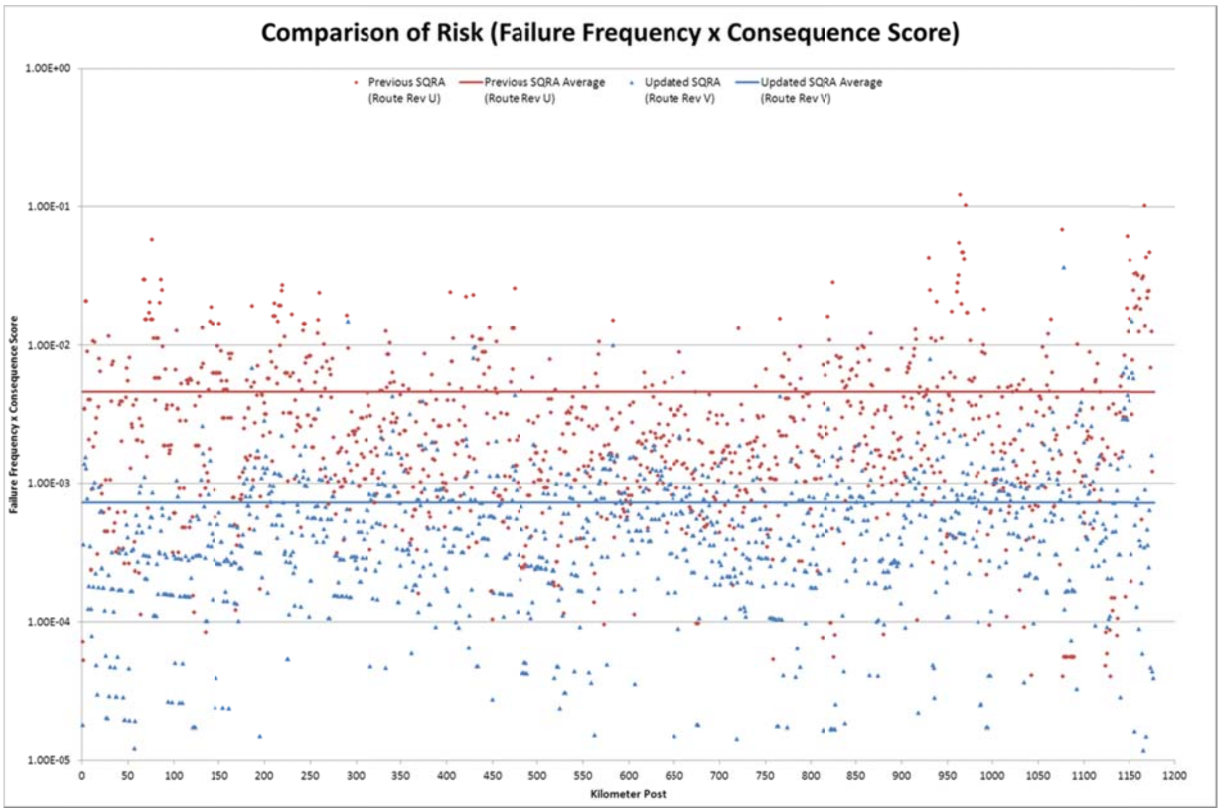


Figure 10: Risk severity classification by physiographic region (Route Rev V)

6.2.3 Risk scoring results

The average risk score (product of failure frequency and consequence score) for the previous SQRA was 4.60E-03 while the updated SQRA average risk score is now 7.25E-04 resulting in an 84% reduction in overall risk score. A comparison of the risk scoring along the pipeline route is shown in Figure 11.

Figure 11: Comparison of risk scoring along the pipeline route



7. DISCUSSION OF RESULTS

7.1 Conclusions

Northern Gateway's commitments to increased wall thickness and increased number of valves on both pipelines have resulted in a significant overall reduction of risk over the entire length of the pipeline.

The major re-route in the Morice River area that has moved the pipelines up to 3.5 km south of the Route U alignment has reduced the number of geohazards. This is reflected in the reduction of a spill return period by a factor of three for that segment. In addition, the re-route has reduced the number of spill trajectories that directly reach the Morice River and has improved the opportunity for an effective emergency response along the forest service road where spills can be intercepted before reaching the river.

Full-bore rupture frequencies associated with manufacturing defects and corrosion, both internal and external, are expected to be extremely low. The models run for external corrosion did not show any measurable probabilities of corrosion failure until after 24 years of simulated operation. In the previous SQRA this number was 11 years. In practice, because the pipeline will be in-line inspected several times as part of the Enbridge integrity management program prior to the theoretical first possible failure, external corrosion threats will be effectively managed to a negligible level for the life of the pipeline. Furthermore, because of the increased resistance to rupture that is attributed to the increase in wall thickness, the theoretical potential for failure to occur by rupture rather than by leak has been virtually eliminated.

Frequencies associated with third-party threats are expected to be very low. In reality, while the reliability analysis that was used as the basis of failure frequency prediction indicates a finite potential for failure due to third-party damage, neither the PHMSA hazardous liquids database (2002-2009) nor the EGIG incident database shows a past history of third-party damage failures in pipelines having wall thickness as high as even the thinnest wall thickness that will be used on the oil pipeline.

Geohazards in specific areas such as the Upper Kitimat Valley and watercrossings in Western Alberta represent the highest level of threat to the pipeline system. Northern Gateway will design the pipeline system based upon detailed identification of geohazards, specific engineering design, and application of Project-specific operating procedures to address these threats.

7.2 Risk-Based Approach to Design and Mitigation

A risk-based approach to design is embedded in the Enbridge engineering standards and will be a core feature of design engineering for the Project. While results generated by the risk assessment will be used to guide the final design, some mitigation measures that were identified through the risk assessment process have already been incorporated into the current design. For example, extensive studies relating to geotechnical hazard identification and routing have ensured that many hazards were avoided through the routing process. Another example is the strategic watercourse assessment process that was used to screen for environmental, geotechnical and construction risks at important watercourse crossings and to provide site-specific recommendations.

This SQRA was based on assessing risk from a full-bore rupture on the proposed oil pipeline. Northern Gateway recognizes that a release of any magnitude from the pipeline is unacceptable and will undertake additional work during the detailed design phase to apply mitigation to minimize risk of a release of any magnitude.

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APPENDIX A: ABBREVIATIONS

Abbreviation	Term
bbl/d	barrels per day
CA	consequence area
CSA	Canadian Standards Association
GIS	Geographic Information System
HCA	high consequence area
ILI	In-Line Inspection
IR	information request
JRP	Joint Review Panel
km	kilometres
km-year	kilometre years
m^3/d	cubic metres per day
mm	millimetres
NEB	National Energy Board
Northern Gateway	Northern Gateway Pipelines Limited Partnership
NPS	nominal pipe size
OD	outside diameter
PEAA	project effects assessment area
PHMSA	US Department of Transportation Pipeline and Hazardous Materials Safety Administration
RAP	Risk Assessment Program
ROW	right-of-way
SQRA	Semi-Quantitative Risk Assessment
the Project	the Enbridge Northern Gateway Project
this report	this Semi-Quantitative Risk Assessment
WorleyParsons	WorleyParsons Canada Services Ltd.

APPENDIX B: HIGH CONSEQUENCE AREA DEFINITIONS

The following definitions were set out in the Northern Gateway Response to Request for Additional Information, from the Joint Review Panel Session Results and Decision, dated 19 January 2011. High consequence areas (HCAs) were mapped and included in this response.

The decision states the following guideline for HCAs:

> *"Consequence areas can be onshore and/or offshore including, but not limited to: wildlife reserves, occupied areas, Indian Reserves, urban areas or towns, water bodies, federal or provincial campgrounds and parks and town water intake locations."*

Northern Gateway has elaborated on this guideline and has described HCAs according to the following broad categories.

Officially Designated Protected Areas

Federal and provincial protected areas that are shown as HCAs include the following:

- federal national parks,
- provincial parks (in BC, Class A, B, and C parks),
- provincial conservancies,
- provincial ecological reserves, and
- provincial wildlife reserves.

Campgrounds within federal and provincial parks and protected areas are also included as HCAs.

Settlements

Human settlements that are shown as HCAs include hamlets, villages, towns and cities, but not rural areas with sparse and isolated settlements or isolated residential parcels.

Indian Reserves

Areas that are designated by the federal government as Indian reserves under the *Indian Act* are shown as HCAs.

Water Use

Licenced sites related to human consumption and other uses (such as Industrial, agricultural) are shown as HCAs.

In Alberta, water licence data were obtained from Alberta Environment (Alberta Environment 2010). This includes both ground water and surface water intake locations for all purposes with sufficient attribute information on licences to allow Northern Gateway to segregate licenses by purpose, such as human consumption. Joint Review Panel Session Results and Decision, dated 19 January 2011 A: *Maps Showing Consequence Areas of Potential Volume Releases*, March 2011, Page 9.

In BC, water licence data were obtained from GeoBC's data discovery provincial government service (GeoBC 2011). The data included:

- BC points of diversion, such as licenced surface water intake sites for all purposes, but exclude groundwater intakes.
- Water intake extraction points for human consumption, such as for human drinking water systems under the authorization of a Health Authority in BC. The information includes both surface and groundwater sources but does not include storage or treatment facilities.

Watercourses

Watercourses are shown as HCAs if they contain species at risk (fish or amphibian), fish species of conservation concern or harvested fish species. Other watercourses are shown on the map but not designated as HCAs.

Information on fish distribution was based on field programs carried out for Northern Gateway from 2005 to 2009 (Whelen et al. 2010), as well as other available data. The presence of species at risk was a criterion for defining a fisheries HCA, because these species are of management concern and would be vulnerable to contact with oil.

Wildlife

Wildlife habitat is shown as a HCA if it meets the following conditions:

- It contains species likely to interact strongly with oil. An interaction is considered strong when the species is both likely to contact oil (should a spill occur) and to have elevated mortality rates. Amphibians are considered the group most sensitive to spills, followed by some aquatic birds that actively forage in wetlands (described more fully in the Wetlands section).

- It is likely to have species at risk as per Environment Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered, Threatened, or Special Concern (COSEWIC 2008); by BC as Blue or Red listed (BC CDC 2008); or by Alberta as At Risk.

The most sensitive stream-dwelling species at risk is likely to be the coastal tailed frog (which is federally listed as Special Concern and Blue-listed in BC). Both field data and habitat suitability modelling were used to identify streams with habitat for the coastal tailed frog.

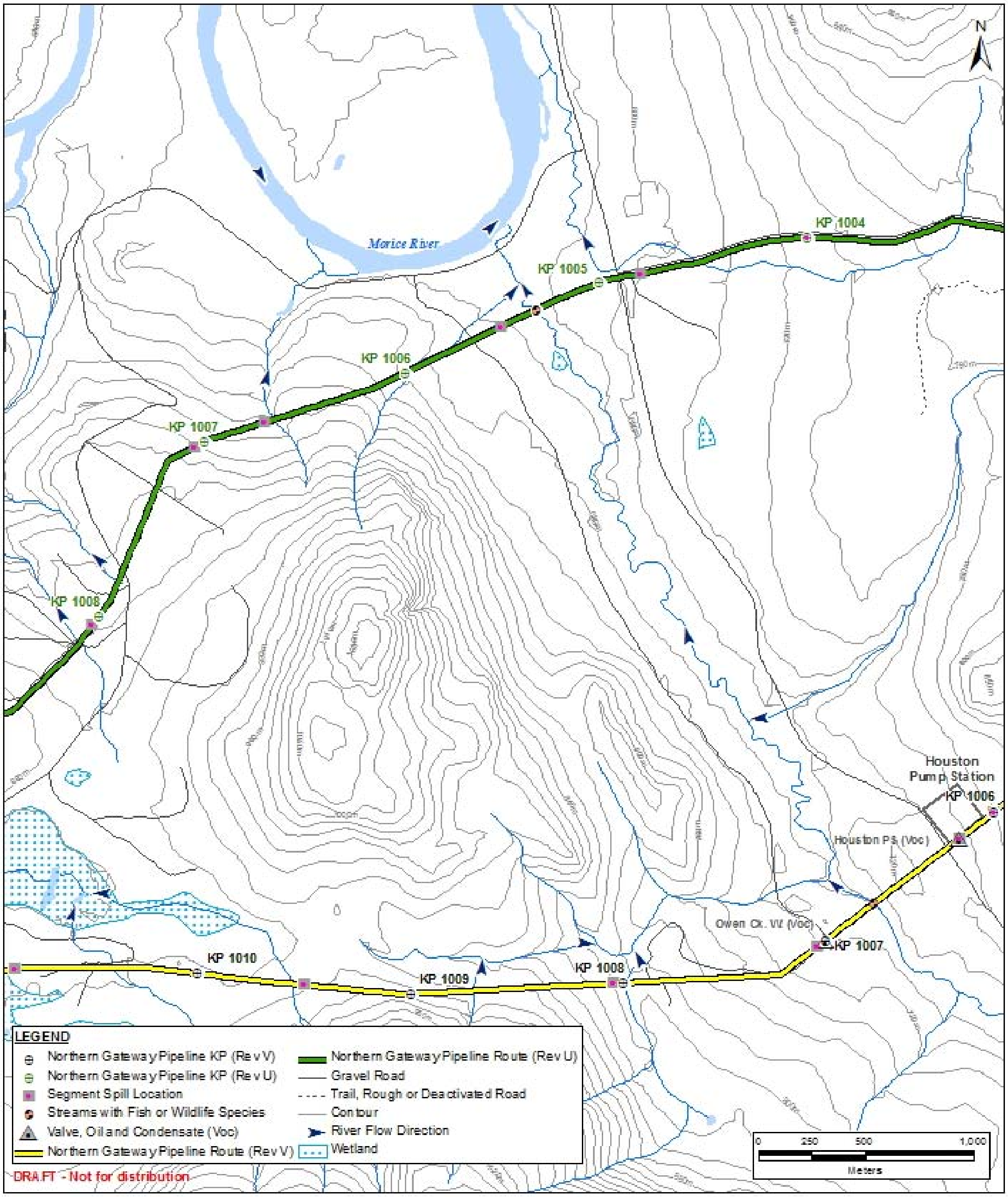
Wetlands

Fens and marshes are shown as HCAs for two reasons. First, herbaceous and bryophyte cover could be affected by contact with oil and their recovery rate may be slow. Second, these open water wetlands may be important as wildlife habitat, fish habitat or potential rare plant habitat, all of which have unique hydrological regimes.

Wildlife species at risk that use open water include horned grebe, trumpeter swan, white-winged scoter, American bittern, great blue heron, sandhill crane, yellow rail, rusty blackbird, coastal tailed frog, and western toad. Several species at risk use wetlands but forage above water and are less likely to be exposed to oil (such as Nelson's sparrow, Le Conte's sparrow and rusty blackbird). Three ecosystems (bogs, swamps and floodplains) are not considered as HCAs because they are dominated by tree or shrub species whose root structure would be less affected by an oil spill than lowland types (Walker et al. 1978).

Information on wetlands was developed as part of terrestrial ecosystem mapping (TEM) for the Project. In Alberta, the wetlands are typically mapped according to ecosite phase (Beckingham and Archibald 1996; Beckingham et al. 1996; Wheatley and Bentz 2002). In BC, wetlands are mapped according to the guide *Wetlands of British Columbia* (Mackenzie and Moran 2004), as well as the Ministry of Forest's BEC *Field Guides* (Banner et al. 1993a,1993b; DeLong 2003, 2004; Delong et al. 1990, 1993, 1994). Fens and marshes were mapped in the PEAA from 2008 to 2009 and following standards for TEM in BC (RIC 1998).

APPENDIX C: BUFFER CREATED BY MORICE RE-ROUTE



APPENDIX D: LIST OF ATTACHMENTS

This appendix lists attachments to this document.

No.	Description	File name	Revision
1	Failure Likelihood Assessment Modifications - Route Rev. V	Dynamic Risk, January 2013	Final
2	Simulations of Hypothetical Oil Releases from the Northern Gateway Pipeline - Route Rev. V	ASA January 14, 2013	Final
3	Report on Quantitative Geohazard Assessment – Route Rev. V	AMEC File: EG0926008 2100 800	Final

Attachment 1: Failure Likelihood Assessment Modifications - Route Rev. V

Northern Gateway Pipelines Limited Partnership

ENBRIDGE
NORTHERN
GATEWAY PIPELINES

Failure Likelihood Assessment Modifications for Route Rev. V

January 18, 2013

Prepared by:

Dynamic Risk Assessment Systems, Inc.
Risk Assessment • Pipeline Integrity • Engineering • GIS • Data Management & Software

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Table of Contents

1. Introduction

The Semi-Quantitative Risk Assessment (SQRA) is being re-issued so that it is specific to Route Rev. V. Supporting the re-issue of the SQRA, the quantitative failure likelihood analysis was repeated using the approach documented in Attachment 2 of the SQRA document previously filed in June 2012 (B75-2). The purpose of this report is to document the changes that were made in the quantitative failure likelihood approach.

2. Background

The approach described in Attachment 2 of B75-2 provides a mechanism for estimating normalized failure frequency, expressed in units of failures/km.yr, with ‘failures’ being further subdivided into ‘leaks’ and ‘ruptures’. This process is undertaken for each threat, so that the results can then be combined to provide a normalized failure frequency value for all threats combined.

3. Description of Enhancements to Failure Likelihood Approach

The quantitative failure likelihood approach described in the updated SQRA document was used for the Route Rev. V alignment as an update to the approach used for the Route Rev. U alignment. Further enhancements to the approach included:

- Increased resolution in segmentation of results;
- Consideration of the effect increased wall thickness and its influence on resistance to failure by rockfall; and,
- Consideration of revised geohazard assessment, as is documented separately[1]

These enhancements are described in further detail in the Sections below.

3.1. Increased Resolution in Segmentation of Results

Failure frequency estimates that were generated for the purposes of the previous SQRA document (B75-2) employed a highly-conservative segmentation process that significantly over-represented values of failure frequency for each 1 km section. The failure frequency and spill return period estimates for pipeline segments that were composed of multiple 1 km sections were correspondingly highly conservative values. The reason for the conservatism was due to the way that failure likelihood estimates were initially generated for each 1 km section from failure frequency values for each dynamic segment. A dynamic segment is defined as a change in any parameter that forms the basis of a unique estimate of failure frequency. These dynamic segmentation parameters are:

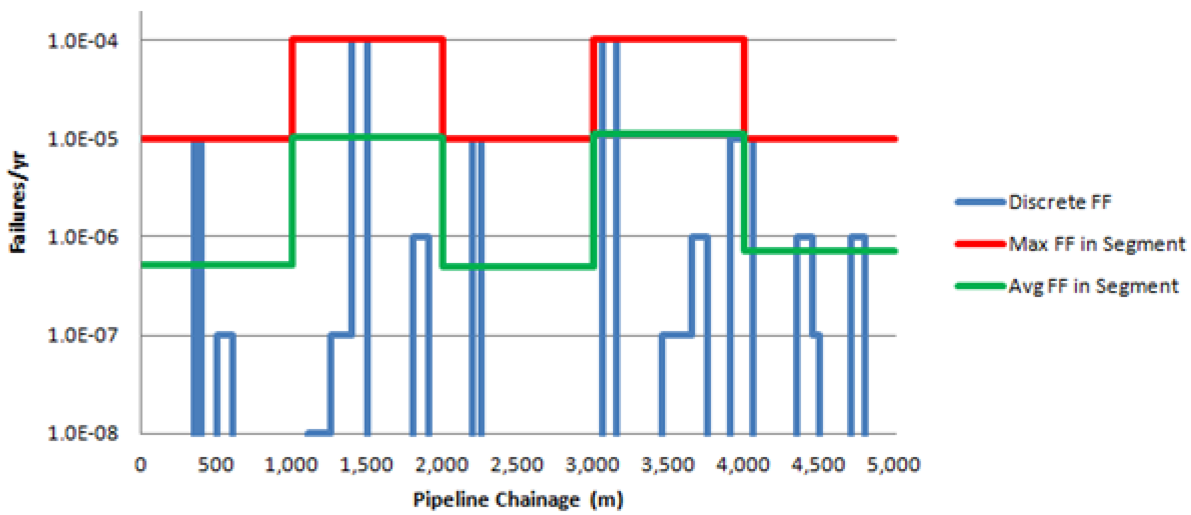
- Operating Pressure;
- Wall Thickness; and,
- Uniquely Identified Geotechnical / Hydrological Threat

Each individual 1km segment is typically composed of multiple dynamic segments. For the purposes of generating failure frequency estimates in the previous SQRA document (B75-2), a rule was adopted that failure frequency value associated with the highest-value dynamic segment would apply to the entire 1 km segment. This practice resulted in significant over-representations of failure frequency, since the failure frequency values that might exist for only a few metres would be applied against an entire 1 km segment.

A much more accurate and representative means of expressing failure frequency for each 1 km segment is to length-average the failure frequency values associated with each dynamic segment within each 1 km segment. The difference between the two approaches is illustrated in Figure 1.

[1] "Report on Quantitative Geohazard Assessment Proposed Northern Gateway Pipelines Route Revision V (Revised January 23, 2013).

Figure 1
Comparison of Failure Frequency Segmentation Approaches



In Figure 1, the blue line (labelled 'Discrete FF') represents the failure frequency plot for a given threat at the finest resolution available (i.e., at the dynamic segment level). The red line represents the failure frequency plot that is obtained using a business rule that requires that the maximum failure frequency in any dynamic segment be reported for each 1 km section. This was the approach that was adopted in the previous SQRA (B75-2). The green line represents the failure frequency plot that is obtained using a business rule that requires that the length-averaged failure frequency over each 1 km section be reported for that section. This is the approach that was adopted in the updated SQRA.

3.2. Consideration of Effect of Increased Wall Thickness in Evaluation of Rockfall Failure Freqeuncy

Increased wall thickness is an effective means of mitigating against mechanical damage threats. This effect of increased resistance to mechanical damage is illustrated by the limit state equations for gouge-in-dent and puncture, as reported in Equations 6 and 16 of Attachment 2 of B75-2. It is also reflected in industry failure statistics. The EGIG report on pipeline failure incidents, which reports failures due to 3rd Party Damage as a function of wall thickness illustrates that there are no 3rd Party Damage incidents in pipelines where the wall thickness exceeds 15mm.[2]

[2] 8th Report of the European Gas Pipeline Incident Group, Doc. Number EGIG 11.R.0402 (version 2), December 2011.

The effect of increased wall thickness was reflected in the re-evaluation of failure frequency due to the 3rd Party Damage when Northern Gateway increased its wall thicknesses, however until now, no similar consideration was given to the evaluation of the threat of failure due to rockfall, even though the failure mechanism associated with rockfall is related to mechanical damage. In order to more accurately reflect the mechanical damage mitigation effect of increased wall thickness, a 'Wall Thickness Mitigation Factor' was derived and applied against the threat of failure by rockfall. This mitigation factor was developed using the reliability methods reported for gouge-in-dent and puncture failure mechanisms in Section 2.3.2 of Attachment 2 of B75-2. The mitigation factor was defined as the ratio:

$$\frac{\textit{Probability of Failure, Given and Impact (New Wall Thickness)}}{\textit{Probability of Failure, Given and Impact (Previous Wall Thickness)}}$$

In the above relationship, 'Probability of Failure, Given an Impact' was calculated using the mechanical damage reliability model reported in Section 2.3.2 of Attachment 2 of the previous SQRA (B75-2). In this respect, the mechanical damage reliability model was used as a means of quantitatively expressing the resistance to failure by mechanical damage, and the rockfall failure frequency prior to the increase in wall thickness was used as a baseline against which the post-wall thickness-increase failure frequency values were derived.

WorleyParsons

resources & energy

ENBRIDGE NORTHERN GATEWAY PIPELINES

Attachment 2: Simulations of Hypothetical Oil Releases from the Northern Gateway Pipeline – Route Rev. V

REPORT

Simulations of Hypothetical Oil Releases from the Northern Gateway Pipeline – Route Rev. V

ASA Project Number: 2011-298

PREPARED FOR:

WorleyParsons Canada

AUTHOR:

Chris Galagan

DATE SUBMITTED

14 January, 2013

RPS asa

Introduction

The OILMAP Land model system was used to simulate releases of oil from points along the proposed Northern Gateway Pipeline route (Rev-V). This report describes the OILMAP Land model system, documents the model inputs, calculation methods and model outputs from simulations of oil spills from the Rev-V pipeline route. The model results are delivered separately as ESRI shape files.

Spill Scenarios

The OILMAP Land model was used to simulate 1164 individual spills along the length of the pipeline route Rev-V. Figure 1 shows the pipeline route with the hydrologic zones overlaid, and the release volumes. The oil release volumes range from 986 to 5,227 m^3, with a median volume of 2,104 m^3. The spill point locations and volumes were provided by WorleyParsons Canada on 6 December, 2012.

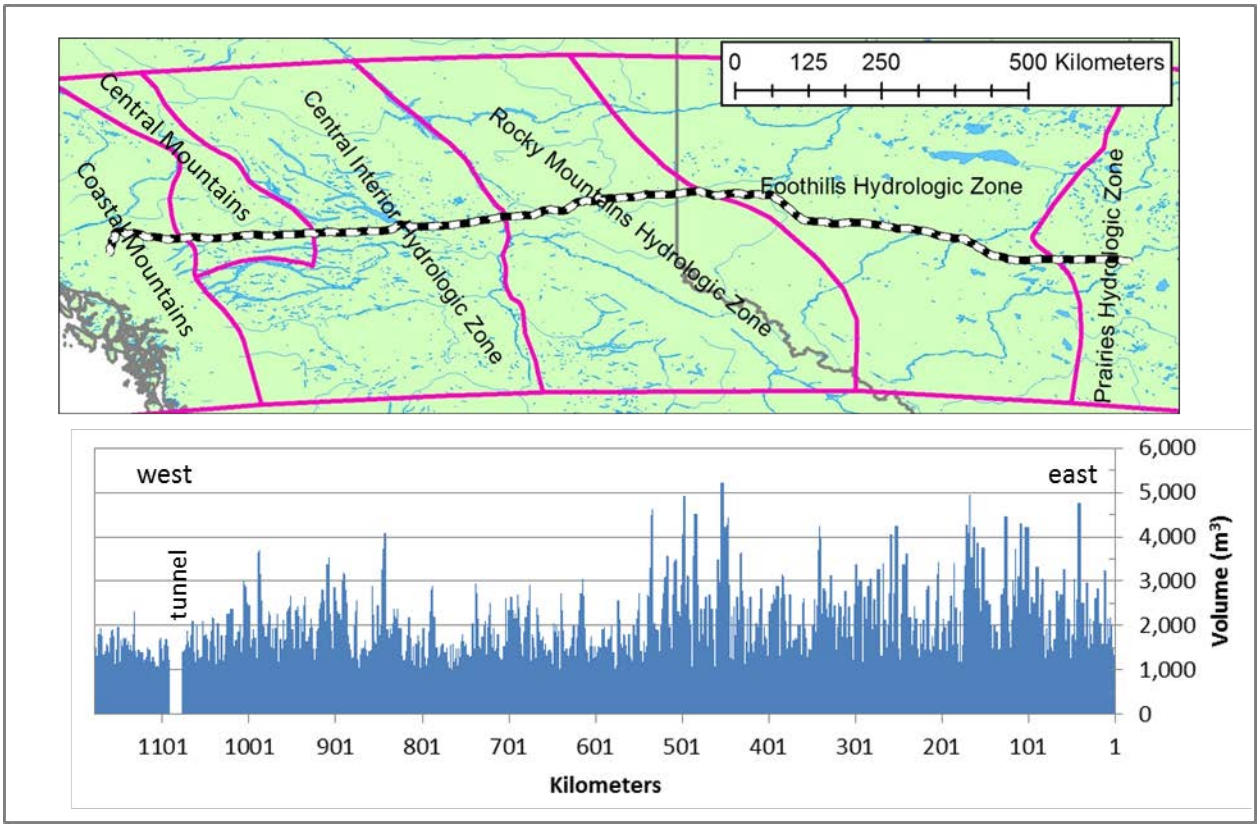


Figure 1. Map showing the pipeline route (above) with hydrologic zones and graph of the oil spill volumes used in the model simulations.

The model was allowed to run 12 hours from the start of each spill so that the resulting spill pathways are time constrained. It is possible for any of these spills to stop flowing prior to 12 hours if all of the spilled volume has been released and this volume is accounted for. For example, if an individual release duration is 1 hour and the oil flows over land and pools in a depression in the land surface in less than 12 hours, the resulting pathway provides the maximum predicted oil path. In this case the oil cannot move any farther because the entire spill volume is contained on land. On the other hand, if the spill immediately enters a river and travels downstream, it is stopped after 12 hours, even if there is oil available in the river to continue on downstream.

Environmental Conditions

River flow used for all of the modeling corresponds to the maximum monthly discharge condition. Maximum monthly discharge was computed using historical data from gauges within each of the hydrological zones encompassing the pipeline route (Figure 1). The maximum monthly discharge is defined as the highest of the mean monthly flows recorded at each gauge for the entire period of record. This flow condition frequently corresponds to the spring runoff period. Using the maximum monthly discharge data derived from the stream gauges, AMEC (Monica Wagner, personal communication) determined the relationship between the drainage area and flow for each gauged stream.

$$Q = a * DA^{b}$$

Q = stream flow
DA = drainage basin area

ASA used this relationship and the values for a and b listed in Table 1 to determine stream flow for every stream reach of a known drainage area. Drainage areas were determined using the Canadian Digital Elevation Data (CDED).

Table 1. Flow-drainage area relationships for maximum monthly flow conditions provided by AMEC (Monica Wagner, July, 2012).

			Max Monthly Flow $Q=a*DA^b$	
Hydrologic Zone	**Maximum Flow Month**	**Applicable Drainage Areas (km^2)**	**a**	**b**
Prairies	April	All	0.0006	0.9665
Foothills	April	0 - 450	0.0093	0.9626
	May	> 450	0.0022	1.1978
Rocky Mountains	May	0 - 1,000	0.0341	1.0388
	June	> 1,000	0.0154	1.1524
Central Interior	May	0 – 1000	0.0815	0.7947
	April	> 1000	0.0257	0.9691
Central Mountains	June	All	0.0634	0.9808
Coastal Mountains	June	All	0.4887	0.8111

The mean annual flow for each stream reach was determined using the same methodology but with annual mean flow data from selected stream gauges. Table 2 provides the drainage area and flow relationships corresponding to the mean annual flow condition.

Table 2. Flow-drainage area relationships for mean annual flow conditions provided by AMEC (Monica Wagner, July, 2012).

	Mean Annual Flow	
	$Q=a*DA^b$	
Hydrologic Zone	**a**	**b**
Prairies	0.00060	1.1349
Foothills	0.00110	1.2252
Rocky Mountains	0.0117	1.0967
Central Interior	0.00930	0.960
Central Mountains	0.0242	1.0124
Coastal Mountains	0.3329	0.7797

RPS ASA used the method developed by Jobson (Jobson, 1996) to calculate current speed for each stream reach within the pipeline drainage. Jobson looked at time of travel data from 980 individual reaches in 90 different rivers in the U.S. having a range of size, stream bed slope and geomorphic type. He developed a regression equation that can be used to calculate current speed if drainage area, slope, mean annual and maximum monthly flow are known:

$$V_p = 0.094 + 0.0143 \times (D'_a)^{0.919} \times (Q'_a)^{-0.469} \times S^{0.159} \times \frac{Q}{D_a}.$$

V_p = current speed
D_a = drainage area
S = reach slope
Q_a = mean annual discharge
Q = maximum monthly discharge

$$D'_a = \frac{D_a^{1.25} \times \sqrt{g}}{Q_a} \qquad Q'_a = \frac{Q}{Q_a}.$$

Using the data analyzed by Jobson, the equation for V_p has an R^2 value of 0.70 and an RMS error of 0.157 m/s.

Calculating the Spill Pathways

The OILMAP land model uses a gridded representation of the land surface to determine the overland pathway of the spilled liquid as it flows down slope. Land elevation data for this purpose were obtained from the Canadian Digital Elevation Data (CDED) web site (www.geobase.ca). For oil in any single grid cell, the model moves the spill to the lowest of the 8 neighboring cells using the standard D8 method (O'Callaghan and Mark, 1984). This process is repeated to determine the downslope spill pathway. The individual CDED elevation grid cells measure 24 meters by 14 meters and small features such as ditches that steer oil are not represented.

Streams and other surface water features are defined using the National Hydro Network (NHN) data. Streams are single line features with a single width and no depth. Lakes/ponds/reservoirs are polygons with no depth defined.

Oil Properties

The oil used in the modeling is synthetic crude with the properties listed in Table 3.

Table 3. Properties of the oil used in the modeling.

API	**Density** at 25° C (g/cm^3)	**Viscosity** at 25° C (cP)
30.6	0.8669	0.4667

Description of the OILMAP Land Model

The OILMAP Land model is used to determine the overland and downstream pathways of spills from pipelines where data describing the terrestrial and surface water environments are as described above.

Overland Transport

Starting at the spill location, the model determines the steepest descent direction in the eight adjacent cells of the elevation grid. The oil moves to the neighboring cell with the lowest elevation. This process repeats successively until a flat area or depression is reached. In a depression area, the depression is filled before the spill continues down slope. Overland flow of the oil continues until the path reaches a stream or other surface water feature, or until the total spill volume is depleted from loss to the land surface and evaporation. The final spill path forms a chain of channels and pooled sections. A channel section is where no pooling occurs and the width of the spill path is dependent on the slope of the land surface. A pooled section consists of an area of one or more contiguous elevation grid cells that form a depression in which the spilled product has collected.

As the oil flows down slope, oil mass is lost through adhesion to surface vegetation, puddle formation on the ground surface and pooling in depressions. The rate of oil loss to these processes is dependent primarily on the physical characteristics of the land surface (vegetation type, land cover, soil type, slope). Different land cover types retain different amounts of oil as a spill passes over the land surface. The volume of oil retained along the oiled path from the adherence and puddle processes is defined as the path length times the path width times a constant oil thickness. The oiled path width is related to the slope of the land surface as determined from the elevation grid.

The constant oil loss thickness is specified for each land cover type defined in a land type grid that matches the size and extent of the elevation grid. Each cell in the land type grid is assigned an oil loss thickness so that as oil traverses the land the loss to each land type is calculated. This loss value varies between 2 and 200 millimeters for the range of land cover types typically encountered. These oil loss rates are based on surface hydrologic studies (ASCE 1969, Kouwen 2001, and Schwartz et al 2002) for surface water runoff modeling.

Separate from adhesion and puddle losses, oil lost to pooling on the land surface is the volume of oil retained within depressions defined in the land elevation grid. The oil lost as oil traverses the land is the sum of adhesion, puddle formation, pooling in large depressions and evaporation.

The predicted overland travel path is only as good as the elevation data. Even with high resolution gridded data, features that steer oil are only captured with a site visit and field mapping. Land spill model results should be viewed with a clear understanding of how accurately the elevation data capture the land features over which the oil travels.

Water Transport

Once the spilled oil enters a stream it is transported through the stream network at a velocity defined by the speed and direction of surface currents in each stream reach. While in the stream network, oil is lost by adhesion to the shore and by evaporation to the atmosphere. A maximum total travel time and stream velocity control the distance traveled downstream. Travel times are typically defined in spill response plans as the time required to respond to and stop a catastrophic release. oil is modeled to travel downstream until all available oil is lost to the shoreline or to evaporation, or the simulation reaches the maximum downstream travel time.

When oil encounters a lake the slick will spread across the lake surface until it covers the entire lake or it reaches a minimum thickness. If the minimum thickness is reached, spreading stops and the oil travels no farther. The minimum thickness can be varied according to the oil type. If oil covers the lake surface before reaching the minimum thickness it continues down any out-flowing streams at the surface current velocity specified for the stream reach.

Oil loss to stream shorelines occurs as oil is transported downstream by surface currents. Five different stream shore types are defined, each with a specified bank width and oil loss thickness. Oil volume lost to the shoreline is calculated as the length of the shoreline oiled times the specified bank width times the oil thickness. Typical shoreline loss values for synthetic crude are listed below.

Shore Type	Shore Width (m)	Oil Thickness (mm)	Hydrologic Zone(s)
Bedrock	0.5	1	
Gravel	1	2	Rocky Mountains Central Mountains
Sand/Gravel	2	3	Foothills Central Interior Coastal Mountains
Sand	5	4	Prairies
Marsh	20	6	

Because streams are defined by single lines with a fixed width, braided streams and streams with numerous islands and sand bars are underrepresented in terms of the length of shoreline available to accumulate oil. In addition, the model routes oil along a single stream pathway even through areas of braided streams with bifurcated channels. The model follows the stream designated in the NHN dataset as the primary pathway.

Aside from the processes described above, the OILMAP Land model does not account for a number of oil fate processes that occur when oil travels down rivers. These processes include: collection of oil in quiescent pools which may exist in meander bends or in other places where currents are slow enough for oil to collect; entrainment of oil into the water column by turbulent mixing present in rapids or spillways; adherence of small oil droplets to fine sediment particles that potentially sink to the bottom and accumulate in river bed sediment; creation of tar balls and tar mats from weathered oil that may collect on the river bed; sequestration of oil to the groundwater or hyporheic zone below the river bed. All of these processes are important in determining the ultimate fate of the spilled oil, but they are beyond the capabilities of the data utilized and the OILMAP Land model.

Evaporation

Oil evaporates as it spreads over land or water. The most volatile hydrocarbons (low carbon number) evaporate most rapidly, typically in less than a day and sometimes in under an hour (McAuliffe, 1989). The spill model uses the Evaporative Exposure model of Stiver and Mackay (1984) to predict the volume fraction evaporated.

Several simplifying assumptions are made that directly affect the amount of oil predicted to evaporate. In general, the rate of evaporation depends on surface area, oil thickness, and vapor pressure, which are functions of the composition of the oil, wind speed and air and land temperature. The mass of oil evaporated is particularly sensitive to the surface area of the spreading oil and the time period over which evaporation is calculated. On the land surface, area and evaporation time are functions of the slope defined by the elevation grid. Steeper slopes cause the oil to travel faster but along a narrower path, while a lower slope slows the speed of advance and increases the width of the oiled path.

In the stream network, oil surface area and evaporation time are functions of the stream surface area (total length of the oiled stream times the fixed width) and stream velocity. oil loss to evaporation ceases once the total oil spill volume is released and overland travel stops, or if oil enters a stream, once the stream maximum travel time is reached and flow in the stream network stops. In reality, oil will continue to evaporate from the ground or water surface, increasing the total evaporation amount. This conservative calculation of evaporative loss is consistent with a worst-case scenario approach.

Model Results

The pipeline route was broken out into six separate segments (shown in Figure 2) for the purposes of modeling the spills. The output from the model for each pipeline segment is provided in separate polygon shape files. The files are named using the spill scenario name (Enb1a, Enb1b, etc.) which correspond to the pipeline segments shown. The shape files provided include polygons depicting the entire overland and downstream oil pathways. The files are named ‘Enb1a_Final.shp’, etc. A second set of shape files using the same naming convention contain points which indicate the travel times for oil in streams.

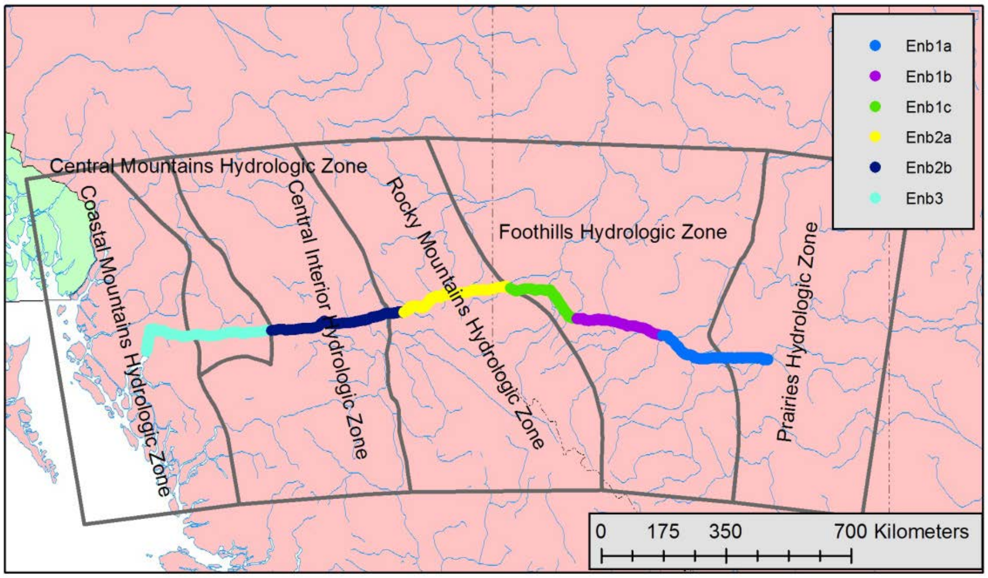


Figure 2. Pipeline segments used in the application of the OILMAP Land model.

The oil mass balance for all spills of oil from the Rev-V pipeline is summarized in Table 4.

Table 4. Oil mass balance for all oil spills.

Location		Volume (m^3)
On Land	Minimum	0.0
	Maximum	4,489
	Mean	263
Evaporated	Minimum	0
	Maximum	41
	Mean	4
In Rivers	Minimum	0
	Maximum	5,220
	Mean	1,708
In Lakes	Minimum	0
	Maximum	4,757
	Mean	127

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Attachment 3: Report on Quantitative Geohazard Assessment - Route Rev. V

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Report on
Quantitative Geohazard Assessment
Proposed Northern Gateway Pipelines
Route Revision V
(Revised January 23, 2013)

Submitted to:

Northern Gateway Pipelines Inc.
Calgary, Alberta

Submitted by:

AMEC Environment & Infrastructure,
a Division of AMEC Americas Limited
Burnaby, BC

January 23, 2013

AMEC File: EG0926008 2100 800

Document Control No.: 1170-RG-20130110

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IMPORTANT NOTICE

EXECUTIVE SUMMARY

This report presents the results of an expanded quantitative geohazard assessment to identify and characterize geohazards that could potentially affect the proposed Northern Gateway Pipeline Project oil and condensate pipelines proposed to be constructed between Bruderheim, Alberta and Kitimat, British Columbia. The geohazard assessment discussed in this report is part of a wider hazard and risk assessment for the pipelines and other infrastructure being carried out by others and the results are intended to be incorporated into an overall pipeline risk assessment.

Geotechnical threats along the pipeline were identified and initially presented in Application Volume 3, Appendix E-1 - Overall Geotechnical Report on the Pipeline Route Revision R for the Enbridge Northern Gateway Project, March 2010. Appendix B, Table B-1 of the application provided a comprehensive description of the geohazards identified. Much of geotechnical work supporting the application was used to eliminate many significant hazards through routing choices.

In the response to the JRP request for additional information (B20, March 2011), Northern Gateway provided additional discussion of the threats associated with the areas of high geotechnical risk and for routing through the Rocky and Coast Mountains with areas of mass wasting. In the response, examples were provided to illustrate in more detail the process used, geotechnical issues and mitigation to be employed.

The Report on Quantitative Geohazard Assessment was prepared as Attachment 4 to the SQRA filing in March 2012 (B69-6) and is now updated in the present revision of the report for Route Rev V.

This Quantitative Geohazard Assessment expands report on the qualitative geohazard assessment presented in the Overall Geotechnical Report but excludes discussion of the consequences since they are discussed within the overall pipeline risk assessment. The present geohazard assessment was undertaken with respect to a Loss of Containment (LoC) event. The assessment in the Overall Geotechnical Report included definition of 170 individual geohazard occurrences within 13 categories which were incorporated into the present updated work as applicable. However, it should be noted that the present report work deals strictly with events with the potential for loss of containment and thus some of the geohazards in the previous work, such as wind erosion, do not appear in the present assessment.

The present assessment was made on the basis of the Revision V route and all kilometre stations have been revised to refer to that route. A previous version of this report was based on route revision U and was filed April 30, 2012. The present report also includes any recently identified geohazards, updates of geohazards based on recent fieldwork and additional LiDAR as well as some clarification of the text.

The hazards assessed included mass movement events (deep-seated slides, shallow to moderately deep slides, and rockfall), stream flow and erosion events (scour, lateral migration, avulsion and debris flow), avalanches, and seismically triggered movements such as lateral spreading. No rock topples, rock avalanches, or sackung failures that would affect the proposed route have been identified and so are not included in the foregoing list. The locations of all geohazards were reassessed relative to the previous work and were defined to resolutions of up to 20 m along the route. Start and end kilometre locations were assessed relative to the route stationing. A total of 363 geohazard occurrences were defined.

The assessments of certain hazards were not limited to the Project Assessment Corridor, which is typically 1 km wide. Hazards outside this corridor that could potentially affect the pipeline were assessed as far from the Rev V centerline as necessary to make sure that all applicable geohazards were included. Thus, rockfall, avalanches, debris flows and various forms of slides were assessed to distances of sometimes several kilometres from the Rev V route and were typically assessed to the height of land. Assessments of other hazards also extended outside the corridor as necessary, for example, lateral erosion and avulsion.

A susceptibility assessment approach was used as defined in Rizkalla (2008) within the framework of a quantitative hazard assessment to determine a predicted likelihood of failure. The method developed for this project uses four key index values, or factors, to provide a numerical expression to estimate the susceptibility of the pipeline to particular geohazards at discrete locations.

In this study, the following definitions were used:

Risk = **Probability** of Hazard Occurrence x **Vulnerability** of the Pipeline to the Hazard x **Consequences**

Probability of a geohazard causing a LoC event = **Probability** of Hazard Occurrence x **Vulnerability** of the Pipeline to the Hazard

For the purposes of this assessment, the probability of pipeline loss of containment due to discrete geohazards has been approximately assessed based on expert judgement including input from an expert panel. Results are expressed as events/year per linear section of pipeline. Because the results are expressed quantitatively, the assessment is considered to be quantitative and has been based on judgement.

As defined above, susceptibility is the product of the factors for occurrence, frequency, vulnerability and mitigation. Susceptibility to a loss of containment (FLOC) event expressed in terms of events per year at any location or segment (i) is expressed numerically as:

$$\text{Susceptibility} = F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)\backslash}$$

A similar form of this method was used for geohazard assessment of the Mackenzie Valley Gas Pipeline Project, previously reviewed by the National Energy Board, and was accepted as a suitable approach in the NEB's Reason for Decision (National Energy Board, 2010).

It should be recognized that the results of the assessment are conditional on the application of the proposed or equivalent mitigations. The mitigations have been selected in accordance with standard and appropriate pipeline construction practices. The mitigation strategies and locations shown are preliminary and will be further considered and refined at the detailed engineering stage of the Project. A summary of the mitigation methods considered for each defined geohazard is contained in the report appendices.

The results of the geohazard analyses are summarized relative to the various geohazards as well as individual description sheets for each individually identified hazard listed sequentially by Rev V kilometre post.

The frequency of loss of containment is presented for each specified hazard impact location relative to the Rev V chainage. The mitigated frequency values typically ranged from 1 x 10^{-10} to 1 x10^{-4} events/year.

1.0 INTRODUCTION

AMEC Environment & Infrastructure (AMEC), a division of AMEC Americas Limited, was retained by Northern Gateway Pipelines Inc. (Northern Gateway) to provide geotechnical engineering services in support of geohazard assessments for the proposed Northern Gateway Pipeline Project route. The purpose of the geohazard assessments were to identify and characterize geohazards that could potentially affect the planned oil and condensate pipelines proposed to be constructed between Bruderheim, Alberta and Kitimat, British Columbia.

Geotechnical threats along the pipeline were identified and initially presented in Application Volume 3, Appendix E-1 - Overall Geotechnical Report on the Pipeline Route Revision R for the Enbridge Northern Gateway Project, March 2010. Appendix B, Table B-1 of the application provided a comprehensive description of the geohazards identified. Much of geotechnical work supporting the application was used to eliminate many significant hazards through routing choices.

In the response to the JRP request for additional information (B20, March 2011), Northern Gateway provided additional discussion of the threats associated with the areas of high geotechnical risk and for routing through the Rocky and Coast Mountains with areas of mass wasting. In the response, examples were provided to illustrate in more detail the process used, geotechnical issues and mitigation to be employed.

The Report on Quantitative Geohazard Assessment was prepared as Attachment 4 to the SQRA filing in March 2012 (B69-6) and is now updated in the present revision of the report for Route Rev V.

This Quantitative Geohazard Assessment expands report on the qualitative geohazard assessment presented in the Overall Geotechnical Report but excludes discussion of the consequences since they are discussed within the overall pipeline risk assessment. The present geohazard assessment was undertaken with respect to a Loss of Containment (LoC) event. The assessment in the Overall Geotechnical Report included definition of 170 individual geohazard occurrences within 13 categories which were incorporated into the present updated work as applicable. However, it should be noted that the present report work deals strictly with events with the potential for loss of containment and thus some of the geohazards in the previous work, such as wind erosion, do not appear in the present assessment.

The present geohazard assessment was undertaken with respect to a Loss of Containment (LoC) event. The geohazard assessment has considered that all loss of containment events would be full rupture events regardless of the actual size of the opening in the pipeline. This is a conservative assumption because there is a broad spectrum of opening sizes from full bore rupture down to pin-holes that could be considered under various geohazard scenarios.

At this time, non LoC events such as damage to pipeline coating are not included in this assessment. The assessment was made with respect to pipeline route Revision (Rev) V. Note that some of the previous geotechnical documentation refers to Rev R. While the kilometre posts and differences vary along the route, Rev R route is approximately 5.7 km shorter than Rev V.

The geohazard assessment discussed in this report is part of a wider hazard and risk assessment for the pipelines and other infrastructure being carried out by others.

Note that this document is a revised version of the Report on Quantitative Geohazard Assessment Proposed Northern Gateway Pipelines which was submitted for filing April 30, 2012. The following revisions have been made:

1. The assessment has been updated to route revision V (Rev V). The most significant route changes have been made near the Alexander Indian Reserve and the Morice River. Geohazards within these and other revised sections were identified and included in this report. Geohazards on previous route segments no longer followed have been changed to legacy geohazards (further explained in Section 4.4).
2. Additional LiDAR has been acquired at several locations including areas near Bald Mountain Creek, Pinto Creek, Two Creek and the Sakwatamau River. Hazards identified as a result of review of this additional LiDAR are included.
3. Additional field reconnaissance and review of existing data has occurred since the preceding version of this report. Any changes in the understanding of existing hazards or newly identified hazards have been incorporated.
4. In the lower Kitimat Valley, glaciomarine clay might be present in some areas and might give rise to a lateral spreading hazard. Areas where this hazard is likely to occur have been avoided; however, it is possible that future investigations might indicate areas where hte hazard is present. In the previous version of this report, the calculated frequency of loss of containment (FLOC) for areas potentially subject to lateral spreading hazard was presented as an unmitigated value. To be consistent with the treatment of other hazard types, this version presents the mitigated FLOC values. Mitigation methods include rerouting, excavation of shallow layers, or trenchless methods to go under the deposit. The level of mitigation assumed is consistent with some residual low level hazard remaining which is conservative.
5. Further refinement of geohazard boundaries has been carried out.
6. The hazard impact zone kilometre post locations used the present report were defined to a 20 m resolution (previously 50 m) which may exceed the accuracy with which the boundaries can be defined at this point, particularly where LiDAR is not yet available or where field reconnaissances have not been undertaken. Boundaries will be refined as results of additional investigation and LiDAR become available.

1.1 Purpose and Nature of a Geohazard Assessment

Relative to other types of hazards, geohazards represent a special class of potential threats to a pipeline (Rizkalla, 2008). A geohazard, as defined in this report, is a threat related to a geological, geotechnical, or hydrotechnical condition or process that may exist along the pipeline route.

A geohazard assessment is a means of identifying and characterizing potential geohazards for the purposes of evaluating the susceptibility of the pipeline to damage along the planned right-of-way. In this report, the geohazard assessment is viewed from the perspective of vulnerability. Vulnerability considers the potential for a given geohazard occurrence to damage the pipeline and that not all geohazard occurrences may damage the pipeline to the point that a LoC event occurs.

The purpose of this report is to present the methods, assumptions and results of the geohazard assessment. As indicated, the results are intended to be incorporated into an overall pipeline risk assessment. The study expands on the existing qualitative geohazard assessment presented in the previous Project filings. As noted above, the present study specifically focuses on geohazards that might result in a loss of containment of the pipeline, but excludes discussion of the consequences since they are discussed within the overall pipeline risk assessment.

1.2 Organization

This geohazard assessment report includes the following subjects and sections:

- Section 2.0: Key definitions of concepts used in this assessment and limitations of the assessment.
- Section 3.0: Discussion of the difference between the present quantitative geohazard assessment and the previous qualitative geohazard assessment that was included in the Project filings to date.
- Section 4.0: Discussion of the present Quantitative Geohazard Assessment for the Project.
- Section 5.0: Results.
- Appendix A: Ranking sheets for each geohazard type to guide the assignment of factors to determine the frequency of loss of containment.
- Appendix B:
    - List of geohazards sorted by kilometre including start and end of the hazard along the route.
    - List of geohazards sorted by geohazard type.
    - Detailed records of the individual geohazards.
- Appendix C: Summary of proposed mitigations and engineering controls to reduce the frequency of loss of containment events from identified geohazards.

2.0 KEY DEFINITIONS AND CONCEPTS

2.1 Geohazard

A geohazard is a threat from a naturally occurring geological, geotechnical or hydrotechnical process or condition that may lead to damage. The process may be triggered by natural or anthropogenic causes. For the purposes of this assessment, the damage considered is loss of containment.

2.2 Risk

In the present assessment, a modified definition of the general expression of risk is adopted which incorporates pipeline vulnerability (the conditional probability of damage given the occurrence of a geohazard).

Risk = Probability of Hazard Occurrence x Vulnerability of the Pipeline to the Hazard x Consequences of Pipeline Failure

Probability of a geohazard causing a LoC event = Probability of Hazard Occurrence x Vulnerability of the Pipeline to the Hazard

This report discusses the probability or likelihood of various geohazard events and the conditional probability of loss of containment based on pipeline vulnerability. As discussed elsewhere in the report, the consequences of the event and, therefore, the risk, will be discussed by others. However, it should particularly be noted that the terms risk and hazard are not interchangeable.

2.3 Qualitative, Semi-Quantitative and Quantitative Assessments

The results of a hazard assessment, and ultimately a risk assessment, can be expressed in the form of qualitative expressions (high/low), semi-quantitative (ranked indices) or quantitative (numerical probabilistic) expressions. The choice between these different forms of hazard assessment is often based on the availability and type of data and may evolve over the course of the project. It should be noted that all three approaches are recognized as appropriate in CSA-Z662 if applied within a well-defined framework in a systematic manner.

For the purposes of this assessment, the probability of pipeline loss of containment due to discrete geohazards has been approximately assessed. The assessment incorporates factors evaluated using expert judgement yielding results suitable for incorporation within the overall pipeline risk assessment. Results are expressed as events/year per linear section of pipeline. Because the results are expressed quantitatively, the assessment is considered to be quantitative and has been based on judgement.

2.4 Hazard Impact Zone

The hazard impact zone is defined as the overall zone of influence of a specific geohazard, and is defined in a 3-dimensional sense. That is, the start and end of the hazard zone along the proposed pipeline route have been defined relative to Rev V kilometre posts, and the depth of cover over the pipeline has been taken into consideration. The potential for a specific hazard to affect a buried pipeline affects the choice of mitigation for several hazards such as scour or lateral erosion.

2.5 Locations Assessed

The assessment was made on the basis of the Rev V route. As discussed in other filed materials, the Rev V route is the centerline of an assessment area and the actual pipeline centerlines may vary as additional work is undertaken. However, for the purposes of the assessment, a centreline is needed and the Rev V route was selected.

It should also be noted that the assessment of certain hazards was not limited to the Project Assessment Corridor, which is typically 1 km wide. Thus, hazards outside this corridor that could potentially affect the pipeline were assessed as far as necessary to make sure that all applicable geohazards were included. Thus, rockfall, avalanches, debris flows and various forms of slides were assessed to distances of sometimes several kilometres from the Rev V route and were typically assessed to the height of land. Assessments of other hazards also extended outside the corridor as necessary, for example, lateral erosion and avulsion.

2.6 The Necessary Role of Engineering Judgement in Geohazard Assessment

2.6.1 Engineering Judgement

Engineering judgement plays a key role in the hazard assessment presented in this report. Engineering judgement is the expression of the familiar experience and considers the form of the problem, location of the study area, type of development, methods of analysis and construction operational practice. In many geotechnical engineering applications, engineering judgement is relied upon to provide suitable bounds on potential outcomes based on a range of potential inputs and scenarios. The reliance on judgement in the geotechnical engineering community is necessary due to geological uncertainty that may vary over short and long distances. Engineering judgement has been and will be complemented by site specific ground investigations, available literature, case histories, and other such information. However, since subsurface knowledge is necessarily always incomplete, some level of engineering judgement is always required in geotechnical engineering.

2.6.2 Expert Panel

An expert panel was used to review the engineering judgements and assignments of the various factors on a general basis for the Project. The panel consisted of the following personnel:

- Gregg O'Neil, P.Eng., Klohn Crippen Berger, Calgary
- Pete Barlow, P.Eng., AMEC Environment and Infrastructure, Edmonton
- Rod Read, Ph.D., P.Eng. P.Geol., WorleyParsons, Calgary
- Clive MacKay, P.Eng. P.Geol., WorleyParsons, Calgary

2.6.3 Order-of-Magnitude Approach

During the assignment of the factors in the hazard assessment, a general order-of-magnitude approach was used in most cases. The order-of-magnitude approach is appropriate since the factors assigned were based on judgement. For example, a geohazard with annual probabilities of occurrence of 0.1, 0.01, 0.001 would correspond to 10 year, 100 year and 1000 year return periods, respectively. Other factors were similarly assessed based on orders of magnitude.

2.7 Susceptibility Assessment

A susceptibility assessment approach was used as defined in Rizkalla (2008) within the framework of a quantitative hazard assessment to determine a predicted likelihood of failure. The method developed for this project uses four key index values, or factors, to provide a numerical expression to estimate the susceptibility of the pipeline to particular geohazards at discrete locations. The evaluation relies on expert judgement. The factors, defined below, include Occurrence, Frequency, Vulnerability, and Mitigation.

$$\text{Susceptibility} = F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$$

Where;

$I_{(i)}$ = Factor from 0 to 1 expressing the potential for the geohazard to occur at location i.

$F_{(i)}$ = Frequency of occurrence for a specific geohazard at location i expressed in events per year;

$V_{(i)}$ = Vulnerability is the conditional probability of total system loss (LoC event) given the occurrence of a specific geohazard at a specific location. It can also be expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.

$M_{(i)}$ = Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to the geohazard occurrence at location i.

Thus, Susceptibility, $F_{LOC(i)}$ has units of frequency (events per year). The various parameters are discussed further below.

2.8 Occurrence Factor

The occurrence factor ($I_{(i)}$) expresses the potential for a particular geohazard to occur in a specific hazard impact zone. The factor is expressed as a value from 0 to 1, with 0 being defined as “not possible”, and 1 being “defined or documented occurrence”. Intermediate values were chosen based on comparison of the route conditions to the screening criteria based on expert judgement.

2.9 Frequency

The frequency values ($F_{(i)}$) used in this assessment represent the inverse of return period for the occurrence of a particular geohazard, expressed as events per year. The return periods provided are based on expert judgement. Guidance for the definition of the appropriate return period at each site is provided in the detailed process descriptions discussed later in this report.

In general, the return period considered provides an estimated frequency for all occurrences of a specific hazard at the given location, including damaging and non-damaging events. This is appropriate for many hazards such as deep-seated slides where the nature of the hazard means that all of the potential events might lead to a LoC event. However, there are a few hazards (for example, avalanches) where both small and large events might occur. The small events are not considered to be events that would lead to a LoC event. In these cases, the frequency was selected for events sufficiently large to possibly trigger a LoC event.

2.10 Vulnerability Factor

Vulnerability ($V_{(i)}$) estimates the ability for the pipeline to withstand the imposed effects of a geohazard. The factor ranges from 0 (no damage in the event of the hazard occurrence) to 1 (loss of containment in all situations). For the purposes of this assessment, vulnerability is the fraction of geohazard occurrences at a specific location that would lead to a damaging event and, specifically, the fraction that would result in a loss of containment.

The fraction of events that could potentially cause a loss of containment was approximately evaluated and assigned for each specific geohazard type. This fraction within each hazard type was often based on relevant parameters such as the hazard scale, local terrain conditions and alignment geometry relative to the hazard. For example, the vulnerability of a pipeline crossing a channel subject to debris flow and avalanche hazards depends, in part, on channel gradient (which affects whether erosion or deposition are likely to occur). While many hazard attributes and terrain conditions that affect the vulnerability can easily be measured; the assigned numerical value must be estimated based on professional judgement and previous experience or records of events that have occurred on other pipelines.

As a further example, the authors are not aware of debris flows, avulsion or snow avalanche causing a LoC within British Columbia/Alberta on other large diameter pipelines such as the Vancouver Island and Kinder Morgan TransMountain lines. These hazards therefore have been assigned lower vulnerabilities relative to other hazards such as deep-seated slides which have several known cases where pipeline rupture has occurred.

The vulnerability is also linked to the properties of the pipeline steel including strength, wall thickness, resistance to fracture propagation and other factors. For some cases, such as lateral erosion, damage thresholds have been estimated based on previous work with similar pipelines. For example, the pipeline was considered to be relatively resistant to failure for unsupported lengths of up to 25 m if exposed by lateral erosion by a river; however the vulnerability to failure increases where longer spans may be exposed. Appendix A provides details on the criteria used to evaluate each individual hazard including their vulnerabilities.

It is assumed that the pipelines will be designed and constructed in general accordance with good pipeline design and construction as practiced in western Canada since the behaviour of previously constructed pipelines, including pipelines through the Coast Mountains, is part of the experience base used to assess the hazards. A further assumption was made that steel with adequate toughness to prevent fracture propagation will be used in areas subject to geohazards, similar to other recently constructed pipelines in western Canada which formed part of the experience base of the expert panel and authors.

2.11 Mitigation Factor

Mitigation ($M_{(i)}$) is a factor operating either on the vulnerability or frequency of occurrence, depending on the nature of the mitigation and is implemented in the design, construction and/or operation of the pipeline where elevated hazard levels are identified. This factor is an expression of the effects of implementing mitigation strategies in the project design that either increase the resistance of the pipeline to potential damage by a particular geohazard, or reduce the frequency of occurrence of a particular geohazard. Potential mitigation options are identified in each of the detailed geohazard process descriptions referenced later in this report.

The mitigation methods were defined for each identified geohazard occurrence. The mitigation options are preliminary and will be revised and adjusted during further more detailed investigations and design. Further review, adjustment and implementation of mitigation options is expected throughout the design, construction and operation of the pipelines as part of the ongoing hazard and risk assessment process that will occur throughout the life of the pipelines.
The mitigation factors were established based on engineering judgement and previous experience of the performance of such measures on other pipelines.

The mitigation factors were modified by a manual adjustment factor in two cases:

1. Where several mitigative methods or factors were applied, the total reduction of frequency of occurrence may not be as great as implied by multiplying the factors. In this case the total effect of the various mitigations was reduced.
2. For certain mitigations, the mitigation may reduce the frequency of occurrence more than was assumed for the standard case. In these cases, the mitigation effectiveness was increased .

The mitigation values for 20 of the 363 geohazards were adjusted using the manual adjustment factor.

2.12 Considerations for the Work

The following points discuss some key considerations with respect to the work:

1. The work was based on available information including air based and ground based site reconnaissances and investigations, interpretation of available satellite and airphoto imagery, topographic mapping, published information and other unpublished information. As additional investigative work is undertaken, the assessments provided may be revised.
2. The general methods of proposed mitigation have been outlined. Detailed mitigation design will be undertaken during the detailed investigation and design phases of the Project.
3. It is likely that some of the assessments will change as additional information is received.
4. Where there is not sufficient information available, the assessments have been made using assumptions that may be conservative. For example, for rockfall hazard areas, the assumption has been made that very large blocks sufficient to cause a LoC event could fall and would impact on the pipeline in such a way as to cause an LoC event. In reality, it is possible that future work will show that the geology of a particular outcrop is not conducive to falls of very large rock blocks, the blocks would not have sufficient impact velocity to penetrate to and puncture the pipeline, or the pipeline is not located within the run out pathway of a potential rockfall.
5. Some of the mitigation techniques may require construction methods or routing that vary from those previously filed. In some cases, routing changes may be required from a mitigation point-of-view. In other cases, variations in stream crossing methods may be required for mitigation of slope stability conditions.

6. The assessment of the hazard impacts on the pipeline system assumes that the pipe steel has adequate toughness such that fractures will not propagate.
7. Secondary events triggered as a result of an initial event have not been considered at this point since the probability of the chain of two events leading to a LoC event is relatively low. For example, a seismic event is one potential trigger for slide movements, but the hazards of such slide movements are already included and other trigger events such as extreme precipitation events would likely have a higher probability. Seismic triggers of slides will be further considered during detailed design in the event that weak materials on which failure has not occurred to date are found during further investigations.

3.0 PREVIOUS GEOHAZARD ASSESSMENT FOR THE PROJECT

An initial geohazard assessment for the Project was carried out based on Route Rev R, and was presented in the May 2010 filing in Appendix E, “Overall Geotechnical Report” in Volume 3. The initial assessment ranked various geohazards along the project route using a five by five matrix defined by estimates of likelihood of occurrence of the geohazard and consequence of occurrence. The preliminary geohazard risk assessment was qualitative and included definition of 170 individual geohazard occurrences within 13 categories. This dataset included an evaluation of the unmitigated and mitigated scenarios for pipeline design through the defined hazard impact areas.

The existing inventory of 170 geohazards was reviewed and incorporated into the present updated work. However, it should be noted that the present report work deals strictly with events with the potential for loss of containment and thus some of the geohazards in the preliminary work, such as wind erosion, do not appear in the present assessment. It is noted that future work related to geohazards may include consideration for the effects of geohazards on other project elements and geohazards that may result in damage that does not immediately involve loss of containment, such as coating damage.

The present assessment differs from the previous 2010 assessment in several key areas:

1. In many cases, hazards were defined at specific points along the pipeline in the previous assessment. For example, a debris flow might be defined as intersecting the pipeline at a specific kilometre post. In the present study, the pipeline length affected has been defined in all cases.
2. In some cases in the previous assessment, a specific hazard was defined over a broader area of pipeline route than it actually affected. For example, the present study defines seven potential avalanche hazards along Hoult Creek, each with a specific defined length, whereas the previous study indicated that avalanche hazard was present along the entire length of the route in the Hoult Creek valley. This previous approach would overestimate the risk in the present study since the hazard (avalanches in this case) is only present in specific areas.
3. In the previous study, some hazards were lumped together where they occur at the same location. Co-location of debris flows and avulsion is an example of this. In the present study, these hazards are discussed separately, although it is noted that the mitigation methods may overlap and need to be coordinated in the design and construction of the pipeline.
4. Some additional hazard locations were added to the present study. These were not included in the previous study because they had a low potential for posing a serious threat to the pipeline. In other cases, hazards were added on the basis of additional knowledge that has been acquired during further investigations since the original assessment was compiled. In this respect, the potential for occurrence of various

hazards has been reassessed along the entire pipeline using the most recently available information.

5. Some hazards have also been added in areas where the pipeline route has been significantly revised since route Rev R. In other cases, reroutes have routed the pipeline away from some hazards. These have been retained in the database but have been assigned $F_{(i)}$ = 0 (legacy geohazard).

4.0 GEOHAZARD ASSESSMENT PROCESS USED TO SUPPORT PIPELINE RISK ASSESSMENT

As discussed above, the geohazard assessment presented in this report was carried out from the perspective of a susceptibility assessment. A susceptibility assessment includes the consideration of the potential for occurrence and the return period, but also includes the recognition that some processes may occur without damage to pipeline (vulnerability), and that mitigation will reduce the exposure to a threat.

As defined above, susceptibility is the product of the factors for occurrence (I), frequency (F), vulnerability (V) and mitigation (M). Susceptibility to a loss of containment (FLOC) event expressed in terms of events per year at any location or segment (i) is expressed numerically as:

$$\text{Susceptibility} = F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$$

A similar form of this method was used for geohazard assessment of the Mackenzie Valley Gas Pipeline Project, previously reviewed by the National Energy Board, and was accepted as a suitable approach in the NEB's Reason for Decision (National Energy Board, 2010).

The geohazard assessment work included establishing the list of geohazards along the route that could result in a potential LoC event, identification of the possible occurrence areas, definition of the unmitigated susceptibility factors at each location and definition of appropriate mitigation strategies. The assessment process is discussed further in the following sections.

4.1 Geohazard List used for Geohazard Assessment

Table 1, below, lists the geohazards considered in the current assessment. The list was developed based on the work of the Project team to date, and as noted above, is restricted to events that could potentially lead to loss of containment. Detailed descriptions of each of the geohazards are presented in Appendix A.

Table 1: List of Geohazards Assessed

Category Name	Acronym	Description
Avulsion	AVU	Channel switching or erosion of a new channel on an alluvial fan. Does not include channel changes or lateral erosion in streams not on alluvial fans.
Debris Flow	DF	A very rapid flow of saturated debris in a steep, confined channel.
Avalanche	AVA	Rapid down-slope movement of snow and ice, possibly with entrained debris. Does not include rock avalanches (note that no rock avalanche hazard was found along or close to the route).
Rockfall	RF	Direct fall and rolling rocks from rock bluffs, rock or rock cuts, and/or colluviums or soil slopes.
Slide – shallow to moderately deep	SM	Translational sliding of soil or rock with a rupture surface less than 10-15 m deep.
Deep-seated slide	DS	Translational, rotational or compound sliding of soil or rock with a rupture surface greater than 15 m deep.
Scour	SC	Erosion of particles from a stream bed to produce either temporary or permanent downcutting.
Lateral Migration	LM	The lateral movement of a stream channel as a result of erosion and undercutting of banks. Reoccupation of subchannels and channel switching in meandering or braided systems is also considered to be lateral erosion for the purposes of this study and not avulsion.
Lateral Spreading	LS	Lateral ground displacements as a result of liquefaction or weakening of loose or soft geological units as a result of seismic shaking. Includes lateral movement toward a topographic break as well as Transient Ground Deformation (TDG) that may not move toward a topographic break.

No rock topples, rock avalanches, or sackung failures that would affect the proposed route have been identified and so are not included in the foregoing list. Karst hazards were identified in the previous assessment along former version of the route; however, no karst has been identified on route Rev V.

4.2 Detailed Descriptions of Geohazards

Appendix A includes detailed ranking sheets for the geohazards outlined in Table 1. The ranking sheets summarize the basis for the susceptibility approach as well as assumptions and guidance on the assignment of the I, F, V, and M factors for site specific evaluation. Additional comments providing the rationale for choice of various factors are included in the detailed geohazard summary sheets attached in Appendix B.

4.3 Definition of Potential Geohazard Impact Areas

Using the ranking sheets in Appendix A and existing project data, the pipeline route was evaluated to determine potential geohazard impact areas. The assessment area used for the purposes of the geohazard assessment included areas beyond the nominally 1 km wide assessment corridor where potential initiation zones or run-out lengths for geohazards that could potentially impact the pipeline route warranted.

4.4 Database Management of Site Specific Data

A total of 363 geohazard occurrence locations were identified in the present study. To handle the increased amount of data, a project specific geohazard database was created. The output from the database is included in Appendix B and is described below.

Each hazard is presented in the database as a “Geohazard Detail” record. The records have a unique number (ID) for each identified hazard. The identification number does not imply location but is simply assigned in serial fashion as the data is uploaded. Note that the geohazard identifications for the original 170 geohazard occurrences in the Overall Geotechnical Report are included as the “Feature” number. These numbers are not actively used in the present data base but are included to allow correlation with the previous report. Reference information is provided which allows the user to determine the source from which the particular hazard was identified.

As discussed above, certain hazards identified at earlier stages of the Project that pertain to former revisions of the proposed route are included in the database for consistency with previously filed reports. These relict or “Legacy” records are no longer considered to have potential impacts on the current Rev V alignment since they have been mitigated by routing changes. These records have been flagged and their occurrence, frequency and vulnerability factors have been set to zero. This treatment maintains consistency with previous filings and retains the hazard for detailed consideration in case of future reroutes in the general area.

Other hazards within the database have been flagged as requiring a “Reroute” for mitigation purposes. The reroutes are relative to the current Rev V alignment but at the time of writing have not been formally accepted in the Project Routing Process (Route Committee).

5.0 RESULTS OF GEOHAZARD ANALYSES

The results of the geohazard analyses are attached in Appendix B which contains both a summary of the results and the individual description sheets for each individually identified hazard listed sequentially by Rev V kilometre post. Appendix C provides a summary of the mitigations considered for each defined geohazard.

The frequency of loss of containment is presented for each specified hazard impact location relative to the Rev V chainage. The mitigated frequency values typically ranged from 1 x 10^{-10} to 1 x10^{-4} events/year. The statistical compilation and assembly of frequency data into an overall probability of failure for the full length of the pipeline is beyond the scope of this report.

It should be recognized that the data presented in the Appendices are conditional on the application of the proposed or equivalent mitigations. The mitigations have been selected in accordance with standard and appropriate pipeline construction practices. Note that the mitigation strategies and locations shown are preliminary and will be further considered and refined at the detailed engineering stage of the Project.

6.0 LIMITATIONS AND CLOSURE

Assessments and related information presented herein are based on a geotechnical evaluation of the work and other information noted. The results of the geohazard assessment are intended to provide baseline information to be used within the context of an overall pipeline risk assessment. It is assumed that the assessments will continue to be updated as the Project evolves. If conditions other than those reported are noted during subsequent phases of the project, AMEC should be notified and be given the opportunity to review and revise the current recommendations, if necessary. The assessments presented herein may not be valid if an adequate level of review or inspection is not provided during construction.

This report has been prepared for the exclusive use of Northern Gateway Inc and its consultants for specific application as discussed in this report. The assessments are intended to be used within the overall framework of risk assessment by persons and organizations familiar with and having suitable skills in risk assessment. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted geotechnical and hydrotechnical engineering practices. No other warranty, expressed or implied, is made.

Respectfully submitted,

AMEC Environment & Infrastructure,
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APPENDIX A

Ranking Sheets for each Geohazard Assessed

GEOHAZARD DESCRIPTION: **SNOW AVALANCHE**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where; $F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
	$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
	$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
	$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
	$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
I_i	<u>General Process Description</u> Rapid down-slope movement of snow and ice, possibly with entrained debris. Mechanism excludes rock or debris avalanches which are described in a separate category. <u>Required Conditions for Occurrence</u> 1. Significant snow accumulations in mountainous terrain. 2. Failure of snowpack on a weak snow/ice layer. 3. Release zones are typically inclined between 30° and 50°[1]. <u>Definition of Initial Areas of Concern (Screening Criteria)</u> 1. Mountain ranges with high snow accumulations and high relief (Coast Mountains and Rocky Mountains physiographic region). 2. Release and transport zones must exceed 30 degrees. 3. Natural, sparsely forested or bare slopes that define tracks originating from upland release zones. 4. Mountain gully and stream channels steeper than 30°. <u>Additional Information used for refine the hazard occurrence areas</u> 1. Existing Avalanche Study carried out in the Coast Ranges. 2. Field review data (documented in Table B-1). 3. Field review aerial oblique photos. 4. Corridor mapping showing avalanche terrain units. 5. Google Earth and other suitable imagery.	0 = Not Possible (does not meet any screening criteria) 0.01 Theoretically probable to occur at this location (site is either a high snow accumulation area, or has sustained slopes for several hundred metres steeper than 30 degrees above the pipeline, but not both) 0.1 = Credible potential occurrence at this location. (meets all screening criteria with the exception of a lack of trees indicating regular occurrence) 1.0 = Defined occurrence (documented past occurrence via publication, field confirmation, or both)
F_i	<u>Triggering Mechanisms</u> Overloading of a weak layer of snow/ice contained within the snow pack. Formation of weak layer may be a result of previous weather patterns. Often triggered by storm events (rapid loading, snow accumulation, rainfall) or associated weather changes such as temperature change or precipitation, but can also include seismic shaking and direct physical disturbances in the release zone. Dominant factors are seasonal weather patterns and recurrence of major storms. High frequency of occurrence (can include more than 1 per year per site). <u>Potential Secondary Geohazard(s) Triggered</u> Avalanche damming of streams in accumulation areas can result in stream avulsion and erosion in areas outside the previous stream channel. Also, potentially debris flows and flooding.	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs 0.001 = once in 1000 yrs

[1] BC Forest Service Avalanche Guide

GEOHAZARD DESCRIPTION: **SNOW AVALANCHE**

<table>
<tr><th>Factor</th><th>Considerations for Assigning Value to Each Factor</th><th>Guidance for Assigning Value to Factor</th></tr>
<tr><td>V_i[2]</td><td><u>Description of Effects in Hazard Impact Area</u>
Release Zone – terrain with average slopes in the range of 30° to 50°. Snow depletion and minor surface debris entrainment is expected, although failure is generally within the snow pack and above a plane defined by the ground surface asperities. For routing of a standard buried pipeline in a release zone use V = 0.001.

Transport Zone – open slope or channelized flow downslope of initiation zone with a slope steeper than 30°. Snow and debris entrainment are possible through this area. For routing of a buried pipeline at standard cover depths in a transport zone use V = 0.1.

Deposition Zone – deceleration and deposition of snow and debris occurs on slopes between 8 to 12° or steeper. Expect restricted access and debris accumulations. For routing of a buried pipeline at standard cover depths in a deposition zone, use V = 0.001.

Consideration for above ground structures in any of the above noted zones - use V = 1.0.</td><td>0 = Hazard occurrence would not result in LOC.

0.001 = 0.1% of hazard occurrences would likely result in LOC.

0.01 = 1 % of hazard occurrences would likely result in LOC.

0.1 = 10 % of hazard occurrences would likely result in LOC.

1.0 = Each occurrence of hazard would likely result in LOC.</td></tr>
<tr><td>$M_{(i)}$</td><td><u>Mitigation Options</u>[3]
1. Options to Reduce Frequency
Avalanche Control Programs can be used to limit potential release volumes and reduce the size of potential events. Also various constructions to increase anchoring or roughness (used in areas such as the Alps).

2. Options to Reduce Vulnerability
Avoid by routing.
Increase depth of cover where appropriate.
Use heavy wall or concrete coated pipe to resist potential debris impacts.
Use deflection berms.</td><td>Avalanche Control; use,
$M_{(i)}$ = 0.01

Concrete Coating or Protection; use,
$M_{(i)}$ = 0.1

Deep Burial; use,
$M_{(i)}$ = 0.01

Deflection Berms; use,
$M_{(i)}$ = 0.01

Heavy wall Pipe; use,
$M_{(i)}$ = 0.1</td></tr>
</table>

Revised to March 7, 2012

[2] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.

[3] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

ENBRIDGE NORTHERN GATEWAY PIPELINES

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GEOHAZARD DESCRIPTION: **AVULSION**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where;	$F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
		$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
		$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
		$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
		$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**<u>General Process Description</u>** Avulsion is a process where stream flow is diverted out of an established channel onto adjacent, usually lower elevation terrain. For the purposes of the present study, avulsion is confined to alluvial fans. Lateral erosion (lateral migration of a channel) and channel switching/reoccupation within a floodplain system are not included and are assessed under lateral erosion. Avulsion is the principal factor resulting in the natural construction of alluvial fans and deltas. Avulsion is a characteristic of aggrading stream channels, and is not normally a concern in channels that are actively downcutting unless the channel is blocked by some external means. Avulsion typically occurs on fans as a result of aggradation that results in the channel being higher than adjacent parts of the fan followed by channel switching to a lower part of the fan. Avulsion may also be triggered by blocking of a stream channel such as by debris flows or avalanche debris. Generally, the presence of alluvial fans, deltas, and braided stream channels indicate that avulsion is possible and has occurred in the past. Alluvial fans are typically located at the junction of a steep upper stream reach and lower gentle reach that promotes rapid sedimentation. **<u>Required Conditions for Occurrence and Definition of Initial Areas of Concern (Screening Criteria)</u>** 1. Stream channel on an alluvial fan system where the stream channel is not laterally constrained. 2. Sedimentation occurring so that channel is aggrading and/or source of external blockage such as avalanche deposits (warm rain on snow events) or debris flows. **<u>Additional Information used for refine the hazard occurrence areas</u>** 1. Terrain studies and airphoto review. 2. Field review data (documented in Table B-1). 3. Review of aerial oblique photos taken during field visits. 4. Google Earth and other suitable imagery along the corridor. 5. Local area experience.	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically possible to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)

GEOHAZARD DESCRIPTION: **AVULSION**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$F_{(i)}$	**Triggering Mechanisms** Flood flows with high sedimentation, debris flows, ice jams, avalanche damming may trigger avulsion. Avulsion can also be significantly influenced by anthropogenic activities on an alluvial fan such as construction of roads or other disturbance that disrupts the topography. Natural processes can be estimated, but anthropogenic activities cannot. **Potential Secondary Geohazard(s) Triggered** Avulsion can lead to scour, lateral erosion and flooding as the stream flow establishes a new channel.	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs 0.001 = once in 1000 yrs
$V_{(i)}$[1]	**Description of Effects in Hazard Impact Area** Pipeline damage typically involves coating damage, denting or scratching. For standard crossing burial depths within a zone of potential avulsion (pipeline running across fan), use V = 0.01 (large streams) to 0.001 (smaller streams). For above ground facilities, use V = 0.1.	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	Mitigation Options[2] **Options to Reduce Frequency** 1. Use routing to locate crossings high on an alluvial fan where the channel may be more confined and the length of pipeline potentially subject to lateral erosion is reduced. 2. Avoid fans and other areas where avulsion may occur. **Options to Reduce Vulnerability** 1. Construct the pipeline below maximum scour depth across the zone of potential avulsion considering long term flows in the 1:100 or 1:200 year range. Guidance from past events should be considered. 2. Use heavy wall or concrete coated pipe to increase the resistance to damage in case of exposure. 3. Construct berms, stream training or fills to protect above ground facilities or some parts of a buried pipeline.	Trenchless Methods with depths beyond max theoretical scour depth and beyond limits of channel movements; use $M_{(i)}$ = 0.001 Heavy-wall Pipe; use, $M_{(i)}$ = 0.1 Berms or stream training, use, $M_{(i)}$ = 0.1 Pipeline below maximum predicted scour depth along alluvial fan impact area; use, $M_{(i)}$ = 0.01

Revised to March 7, 2012

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.

[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

GEOHAZARD DESCRIPTION: **DEBRIS FLOW**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where;	$F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
		$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
		$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
		$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
		$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	<u>General Process Description</u> A rapidly moving, mixture of soils, rock, organic debris, water and/or snow and ice. Within the project corridor, channelized debris flows predominate. Debris flows typically result from accumulations of fluvial and colluvial debris along or adjacent to a stream channel that are mobilized by high stream flows. The high-density mixture of debris can move large bounders and may cause significant erosion along the path of the flow. Deposition occurs where the channel gradient decreases and may result in the deposition of an alluvial fan over time. <u>Required Conditions for Occurrence</u> 1. Stream channels with steep upstream gradients (typically>7°) 2. Upstream valley includes valley walls that confine the channel and are steep (typically>20°) soil or rock slopes. 3. Significant accumulations of debris and sediment available to be mobilized (high erosion rates or young geological environment). 4. Potential for high stream flows, either due to high precipitation or to high precipitation on snow (warm rain on snow events) coupled with watershed conditions collect water from a larger area to produce high flows and that have low times of concentration (little surface flow attenuation) (small mountain valleys and basins). <u>Definition of Initial Areas of Concern (Screening Criteria)</u> 1. Steep stream channels that cross the route in high relief active terrain with significant tributary area (usually a basin at the uphill end) in areas with high precipitation (typically Rocky Mountains and Coast Mountains physiographic regions). 2. Stream channels that cross the route that include alluvial fans downstream from steeper areas. <u>Additional Information used for refine the hazard occurrence areas</u> 1. Field review data (documented in Table B-1). 2. Analysis of LIDAR and aerial photo imagery. 3. Published information on occurrences, if available.	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically probable to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)
$F_{(i)}$	**<u>Triggering Mechanisms</u>** Significant storm-level precipitation events are the most likely trigger, although avalanche and landslide dam breaches may also trigger a debris flow. Each major storm (typically >25 year return period storm) is not a direct trigger as sufficient time is required to accumulate debris for along the channel for re-current events.	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as;

GEOHAZARD DESCRIPTION: **DEBRIS FLOW**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
	<u>**Potential Secondary Geohazard(s) Triggered**</u> Debris flows are highly erosive events, and can cause significant erosion in the initiation and transportation areas and deposit sediment in the accumulation area (either lower part of stream channel or alluvial fan), thus secondary effects could include flooding, avulsion, scour and lateral erosion. Impact loading on exposed structures (either above ground or due to scour) is a consideration.	1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs 0.001 = once in 1,000 yrs
$V_{(i)}$[1]	<u>**Description of Potential Effects in Hazard Impact Area**</u> **Depletion Zone** – Significant erosion in the channel is expected in the upper portions of the debris flow. For routing of buried pipeline at standard cover depths through a potential depletion/transport zone use V = 1.0 since depletion could result in significant loss of support and potentially expose the pipe to direct impacts and lateral loads. **Transport Zone** – Significant scour may occur through the transport zone, which for the purposes of this study, is defined as channels steeper than 15° in either confined or open reaches subject to potential debris flows. For routing of buried pipeline at standard cover depths through a potential transport zone use V = 0.1 **Deposition and Erosion Zones** – The deceleration and deposition of slide debris is a function of the debris volume, channel gradient and confinement within the channel from gully sidewalls. Smaller flow volumes in unconfined channels may transition from erosion to deposition of mobilized debris at channel gradients around 15°. Larger, confined flows may continue to erode bed materials until reaching flatter terrain with slopes as flat as 1°. For routing of a buried pipeline at standard cover depths in a zone of deposition/erosion (channel gradients between 1 – 15° in the immediate vicinity of the pipeline), use V =0.01. Note that avulsion is considered separately, but may be triggered by debris flow. **Consideration for Above Ground Structures – use V = 10 for above ground facilities.**	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	<u>Mitigation Options</u>[2] 1. **Options Acting to Reduce Frequency** Could use debris catchment structures and floodwater control structures. Assumes a long-term maintenance and cleaning program is established for such infrastructure. 2. **Options Acting to Reduce Vulnerability** Avoid routing using standard pipeline burial or any above ground structures (unless suitable clearance is provided) through potential debris flow areas, particularly in areas where high erosion may occur. Consider deep burial, such as below 200 year scour elevation or by local correlations to other events.	Debris Catchment or Floodwater Control Structures upstream of Route; use, $M_{(i)}$ = 0.01 Deep Burial (below maximum 200 year return period scour depth); use, $M_{(i)}$ = 0.01 Diversion Berms for Flood Flows; use, $M_{(i)}$ = 0.1 Heavy wall Pipe; use, $M_{(i)}$ = 0.1

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.
[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

ENBRIDGE NORTHERN GATEWAY PIPELINES

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GEOHAZARD DESCRIPTION: **DEBRIS FLOW**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
	Diversion structures such as berms may be used to protect selected areas. Use protective materials or thicker pipe (eg., concrete coating or heavy wall pipe)	Concrete Coating or Protection; use, $M_{(i)} = 0.01$

Revised to March 7, 2012

GEOHAZARD DESCRIPTION: **DEEP-SEATED SLIDES**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where;	$F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
		$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
		$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
		$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
		$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**General Process Description** Slides in soil and/or rock more than 10 to 15 m deep that typically occur on weak layers or through weak geological units. Movement rates are typically variable and may often be episodic. These types of slides can occur on low gradient slopes where weak materials are present, although not exclusively. This hazard excludes toppling failures that may be deep-seated as they are dealt with separately. **Required Conditions for Occurrence** 1. Weak geological layers or units at depths of at least 10 to 15 m and/or where high groundwater pressures exist at depth. 2. Failure surface must daylight. 3. Slopes steeper than residual friction angles of the underlying weak materials. **Definition of Initial Areas of Concern (Screening Criteria)** 1. Areas underlain by weak geological units with slopes in excess of about 8 degrees. (Note that $Ø_r$ is typically about 8° in medium to high plastic clay sediments in Alberta and BC. Glaciomarine sediments may vary.) Weak geological units include: • glaciolacustrine and sedimentary rock sequences in Alberta; • glaciolacustrine soils throughout the central interior of BC; • some volcanic rocks may contain weak clay layers and, • glaciomarine deposits in coastal BC areas. **Additional Information used for refine the hazard occurrence areas** • Field Review data (documented in Table B-1). • LIDAR datasets. • Available airphoto imagery. • Existing published mapping.	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically possible to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)
$F_{(i)}$	**Triggering Mechanisms** Deep–seated landslides can include new slides and old re-activated slides. Sliding triggers, or changes in movement rates are often linked to precipitation patterns (high precipitation over a period of at least a few months) and/or slope profile changes associated with anthropogenic	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such

GEOHAZARD DESCRIPTION: **DEEP-SEATED SLIDES**

<table>
<tr><th>Factor</th><th>Considerations for Assigning Value to Each Factor</th><th>Guidance for Assigning Value to Factor</th></tr>
<tr><td></td><td>causes or toe erosion by stream flow. For actively sliding areas, use F = 1.
<u>Potential Secondary Geohazard(s) Triggered</u>
For rapid movements, damming of streams can result in flooding or stream avulsion, although this is rare.</td><td>as;

1 = once in 1 yr
0.1 = once in 10 yrs
0.01 = once in 100 yrs
0.001 = once in 1000 yrs</td></tr>
<tr><td>$V_{(i)}$[1]</td><td><u>Description of Effects in Hazard Impact Area</u>
For cases where the pipeline route crosses a high angle (>10°) deep-seated landslide, use V = 1.0 since the slide may be capable off larger and more rapid movements.

If the pipeline is routed through deep-seated landslide with slope angles less than 10° (approaching the residual angle of friction), lower rates of movement may be more amenable to monitoring, use V = 0.1.

For routing of a buried pipeline at standard cover depths above the scarp or beyond the toe of the slide, use V = 0.01, with the exception of a buffer zone equivalent to a distance extending 10% of the slide width in either direction. For a route through this buffer zone, use V = 0.1 unless there are documented reasons why the pipeline will not be subject to interaction with the slide as the toe area may be subject to shear forces/displacement from the slide, and the scarp may be subject to retrogression.

Lateral buffer zones should be equivalent to similar factors as discussed above, although the buffer zone should be estimated for each location based on geology and topography.</td><td>0 = Hazard occurrence would not result in LOC.
0.001 = 0.1% of hazard occurrences would likely result in LOC.
0.01 = 1 % of hazard occurrences would likely result in LOC.
0.1 = 10 % of hazard occurrences would likely result in LOC.
1.0 = Each occurrence of hazard would likely result in LOC.</td></tr>
<tr><td>$M_{(i)}$</td><td><u>Mitigation Options</u>[2]

1. Options to Reduce Frequency
Removal of material from the crest and slope grading, counterweight berms, dewatering/drainage, erosion protection and surface water management, although for very large slides these measures may not be practical. If suitable, reduce the frequency factor by one order of magnitude.

2. Options to Reduce Vulnerability
Avoid routing in slide zones by routing around or under.
Routing options below may include HDD or other similar deep burial installations that avoid the landslide hazard zone. Note that if routing below is chosen, investigations or monitoring may be required to confirm the limits of the potential or active slide. Monitoring would be assumed to continue throughout the life of the project subject to revision based on detailed investigations.</td><td>Deep Burial (below slide); use,
$M_{(i)}$ = 0.001
Surface water and/or groundwater control
$M_{(i)}$ = 0.1
Monitoring of slope stability conditions; use,
$M_{(i)}$ = 0.1
Reroute; use,
$M_{(i)}$ = 0.001
River training and/or riprap; use,
$M_{(i)}$ = 0.01
Major slope and crest grading; use,
$M_{(i)}$ = 0.01
Shallow grading; use,
$M_{(i)}$ = 0.1</td></tr>
</table>

Revised to March 7, 2012

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.
[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

GEOHAZARD DESCRIPTION: **LATERAL EROSION**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where; $F_{LOC(i)}$ = $I_{(i)}$ = $F_{(i)}$ = $V_{(i)}$ = $M_{(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year; Factor from 0 to 1 expressing the potential for the geohazard to occur at location i, Frequency of occurrence of the geohazard at location i expressed in events per year; Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions. Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**General Process Description** Lateral erosion is the ongoing process of stream lateral erosion due to erosion along the side of a stream channel by moving water. Lateral erosion is a normal stream process and may involve meandering of the stream, erosion at a single point or bend, formation of multiple or braided channels or other forms of erosion. Reoccupation of subchannels and channel switching in meandering or braided systems is considered lateral erosion for the purposes of this study. Avulsion on alluvial fans is not included in lateral erosion. Rates of lateral erosion depend on many factors including material types (sand and silt may be more readily eroded than clay or rock), variations in flow, sediment load, gradient and other factors. Streams flowing in bedrock channels are typically not susceptible to significant rates of lateral migration. Generally, the presence of past lateral erosion provides some guidance that future lateral erosion is possible. **Required Conditions for Occurrence** 1. Stream channel. 2. Poor quality bedrock (NE BC and Alberta profile) or sediments along the stream banks. **Definition of Initial Areas of Concern (Screening Criteria)** 1. Stream channel showing evidence of previous lateral erosion. **Additional Information used for refine the hazard occurrence areas** 1. Field review data (documented in Table B-1). 2. Airphoto review 3. Review of aerial oblique photos taken during field visits. 4. Google Earth and other suitable imagery along the corridor.	Not Possible (Screening criteria not met) 0.01 = Theoretically possible to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)
$F_{(i)}$	**Triggering Mechanisms** Lateral erosion is often an ongoing process, although significant shifts in the channel position (or consequently rate of erosion) are often the result of high flows due to high precipitation or seasonal freshet flows. Erosion rates can also be significantly influenced by anthropogenic activities upstream in the channel such as river training or bridge piers. Natural processes and existing anthropogenic influences can be estimated, but new anthropogenic activities cannot. **Potential Secondary Geohazard(s) Triggered** Lateral erosion can trigger landslides due to undercutting. Several	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs 0.001 = once in 1000 yrs

GEOHAZARD DESCRIPTION: **LATERAL EROSION**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
	categories of landslides can be involved, from shallow slides through to deep-seated slides of various types.	Where probabilities apply to lateral erosion beyond the sagbend location.
$V_{(i)}$[1]	<u>Description of Effects in Hazard Impact Area</u> Pipelines may be exposed or cover removed by lateral erosion near pipeline crossings due to lateral erosion beyond the sagbend. Pipelines running parallel to a stream may also be subject to erosion. Where the pipeline is undercut, loss of containment might occur for long spans or where debris or large boulders impact the pipeline. Where large spans occur as a result of undercutting, vibration may result in fatigue and failure. Partial exposures may result in coating damage, denting, or abrasion damage. For standard burial depths and sagbends located within the zone of potential lateral stream migration, use V = 0.001, unless the exposure lengths would be expected to be in excess of 25 m, in which case use V = 0.1. A LoC event from lateral erosion was assumed to require exposure of more than 25 m of pipeline based on preliminary (probably slightly conservative) assessments of lengths required for vibration fatigue or debris loading. For the purposes of this assessment, a channel width of 50 m was considered the minimum width which could potentially expose lengths in excess of 25 m. Where the proposed pipeline is parallel to a mobile stream, lateral migration of a smaller channel (<50 m) may result in exposures greater than 25 m depending on local conditions and this hazard was included where applicable.	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	<u>Mitigation Options</u>[2] **Options to Reduce Frequency** 1. Install river training measures such as rock groynes, spurs, weirs or armour banks to control stream channel location at the crossing. However, these measures may not be successful in the long term and need to be approached with site specific studies and designs that include commitments for follow-up monitoring and maintenance. **Options to Reduce Vulnerability** 1. Locate sag bends behind long-term lateral migration channel limits established by hydrotechnical design. 2. Use routing to locate crossings in areas of channel less susceptible to lateral erosion. 3. Use trenchless methods to install the pipeline bellow the envelope of lateral erosion. . 4. Use heavy wall or concrete coated pipe to increase the resistance to damage in case of exposure.	Armoured stream banks suitably designed; use, $M_{(i)}$ = 0.01 River training measures suitably designed; use, $M_{(i)}$ = 0.01 Sag bends beyond long-term hydrotechnical design limits; use, $M_{(i)}$ = 0.001 Trenchless Methods enter/exit outside extents of lateral migration use $M_{(i)}$ = 0.001 Heavy wall Pipe; use, $M_{(i)}$ = 0.1 Concrete coating or protection; use, $M_{(i)}$ = 0.1 Reroute; use, $M_{(i)}$ = 0.01 to 0.001 depending on distance and stream characteristics.

Revised to March 7, 2012

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.

[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

GEOHAZARD DESCRIPTION: **LATERAL SPREADING**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where; $F_{LOC(i)}$ = $I_{(i)}$ = $F_{(i)}$ = $V_{(i)}$ = $M_{(i)}$ =	$F_{LOC(i)}$ = Frequency of a loss of containment event due to geohazard at location I, expressed in events per year; $I_{(i)}$ = Factor from 0 to 1 expressing the potential for the geohazard to occur at location i, $F_{(i)}$ = Frequency of occurrence of the geohazard at location i expressed in events per year; $V_{(i)}$ = Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions. $M_{(i)}$ = Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**General Process Description** Permanent lateral ground displacements involving movement of material on nearly flat terrain due to liquefaction of strain softening typically under seismic conditions. Movement may be toward an unsupported slope or may be transient (Transient Ground Deformation). Movement rates are rapid, and can occur on very low gradient slopes where weak materials are present. Note that seismically triggered slides or slide movement on deep-seated or shallow to moderately deep slides are considered under those categories. **Required Conditions for Occurrence** 1. Loose/soft soil units, typically including sands, although interlayered deposits of silt and clay with high moisture content may be susceptible. 2. Slopes, even as gentle as 1° to 2°, may provide sufficient gradient to allow permanent downslope movement of liquefied materials. 3. Earthquake ground motions sufficient to result in liquefaction. **Definition of Initial Areas of Concern (Screening Criteria)** 1. Areas underlain by significant deposits of loose and weak geological units. 2. Areas subject to seismic shaking of sufficient strength to result in liquefaction (Coastal Ranges and Rocky Mountains physiographic regions) Weak geological units include: • glaciolacustrine soils, and • glaciomarine soils. **Additional Information used for refine the hazard occurrence areas** • Field Review data (documented in Table B-1). • LIDAR datasets. • Available airphoto imagery. • Existing published mapping. • Seismic Report (Atkinson, 2009)	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically probable to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)

GEOHAZARD DESCRIPTION: **LATERAL SPREADING**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$F_{(i)}$	**Triggering Mechanisms** For the purposes of preliminary assessment, an estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading in combination with weak layers or materials. Use peak ground acceleration data presented in the Overall Geotechnical Report (AMEC, 2010). If weak materials are found during further investigations, this criteria will be reviewed. Potential Secondary Geohazard(s) Triggered Disruption of drainage patterns and movement of larger masses can result in damming of streams, avulsion, and lateral erosion.	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs 0.001 = once in 1000 yrs
$V_{(i)}$[1]	Description of Effects in Hazard Impact Area For cases where the pipeline route crosses a high angle slopes (>5°) area susceptible to liquefaction, use V = 1.0. For cases where the pipeline route crosses a low angle slopes (<5° and >1°) area susceptible to liquefaction, use V = 0.1.	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	Mitigation Options[2] 1. **Options to Reduce Frequency** Ground improvement methods that could include methods such as pre-loading consolidation, dynamic compaction, vertical drains or construction of shear keys in shallow deposits. 2. **Options to Reduce Vulnerability** Avoid routing in liquefaction zones by routing around or under. Routing options below may include HDD or other similar deep burial installations that avoid the hazard zone, although some areas may be too deep for this to be a potential solution.	Ground Improvement; use, $M_{(i)}$ = 0.5 Deep Burial (below slide – may include HDD); use, $M_{(i)}$ = 0.01 Reroute; use, $M_{(i)}$ = 0.001

Revised to March 7, 2012

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.

[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

ENBRIDGE NORTHERN GATEWAY PIPELINES

amec

GEOHAZARD DESCRIPTION: **ROCK FALL**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where;	$F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
		$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
		$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
		$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
		$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**General Process Description** Direct fall and rolling rocks from rock bluffs, rock or rock cuts, and/or colluvium or soil slopes. For purposes of pipeline integrity review (LoC event), only particles 2 m or larger are considered. Such particles with suitable velocities at impact to affect the pipeline are assumed to be present unless otherwise known to be absent. **Required Conditions for Occurrence** The following are considered necessary to initiate a rock fall 1. Steep (>40°) colluvial slopes with suitably size particles that could be undermined by erosion; or 2. Natural steep rock outcrops or slopes with discontinuities that bound suitably large particles that might release; or, 3. Steep soil slopes (>40°) containing large boulders that could be released by erosion or undercutting. To initiate release, local slopes >40° are typically required. **Definition of Initial Areas of Concern (Screening Criteria)** 1. Slopes steeper than 40°. 2. Areas with shallow to no soil (bedrock outcrop sources). 3. Bouldery colluvium deposits or other boulder soil deposits (eg., some mountain tills). 4. Rock may run out to a shadow area defined as 27° below the source. **Additional Information used for refine the hazard occurrence areas** 1. Field review data (documented in Table B-1) and field photos. 2. Analysis of LIDAR and aerial photo imagery. 3. Published information on occurrences, if available.	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically possible to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)
$F_{(i)}$	**Triggering Mechanisms** Rockfall is typically the result of ongoing erosion of bluffs and steep colluvial slopes related to changes in moisture (storm events), temperature (freeze-thaw action), sliding, creep and erosion and seismic events. Suitably oriented and spaced discontinuity patterns are required to form rock blocks that may release. Often rockfall is an ongoing process and activity is defined as at least once per year (F = 1). Potential zones showing no active rockfall could be considered to produce events at a reduced scale related to major 100 year return period storms or significant seismic events if deemed appropriate. Areas	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs

	with boulders that have grown over with moss and/or trees suggest reduced or infrequent activity. Note that boulders may be present due to other glacial processes such as glacial erratic and may not be evidence of past rock fall. **Potential Secondary Geohazard(s) Triggered** None.	0.001 = once in 1000 yrs
$V_{(i)}$[1]	**Description of Effects in Hazard Impact Area** **Depletion Zone** – Not applicable for routing. **Runout Zone** – Standard cover depths for pipelines provide soil cover that will cushion the effects of direct rock impacts on the pipeline depending on block sizes and the location of the drop area vs. the rolling area. For buried infrastructure at standard depths use V = 0.1 to 1.0 for areas subject to direct falls or bouncing rock particles, and 0.01 to 0.1 for rolling rocks depending on potential block sizes, velocities and geometry. **Consideration for Above Ground Facilities** – Due to the risk of high lateral impact loading, use V = 1.0 for surface facilities.	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	Mitigation Options[2] 1. **Options to Reduce Frequency** a. Scaling or mechanical support (rock anchors) of rock bluffs or soil slopes. Note that ongoing monitoring is required for the application of a modified vulnerability as weathering and erosion will produce additional unstable materials over time. b. Draped mesh or rock fall fences (depending on geometry, may be more appropriate to consider under vulnerability). Monitoring and maintenance required. c. Control excavations and natural erosion so that undercutting does not occur. 2. **Options to Reduce Vulnerability** a. Avoid areas subject to rock fall. b. Avoid above ground facilities in areas subject to rock fall. c. Increase depth of cover, provide concrete coating on pipeline, provide protection above the pipeline (reinforced concrete slabs, embedment in concrete, steel plates), deflector berms or fills, place pipeline in location where rock fall will project over grade or install portal canopy. d. Provide increased compaction of backfill or selected backfill to reduce penetration.	Mechanical rock support and/or scaling; use, $M_{(i)} = 0.1$ Draped mesh or rock catch fences; use, $M_{(i)} = 0.01$ Deep Burial (established based on maximum particle impact energy) and/or extra compaction; use, $M_{(i)} = 0.01$ Diversion Berms; use, $M_{(i)} = 0.1$ Heavy wall Pipe; use, $M_{(i)} = 0.1$ Concrete Coating or Protection; use, $M_{(i)} = 0.1$ Protective Plates or Slabs; use, $M_{(i)} = 0.1$ Portal Canopy; use, $M_{(i)} = 0.001$ Foregoing factors vary according to local conditions.

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.
[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

GEOHAZARD DESCRIPTION: **SCOUR EROSION**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where; $F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
	$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
	$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
	$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
	$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**General Process Description** Scour is the erosion of particles from a stream bed. The co-dependent process of in-filling may also occur, and the scour may be temporary, short term or permanent. Scour generally increases during high flows and at obstacles (eg., bridge piers), at bends and at channel confluences. Major controls include channel shape, velocity and volume of the moving water as well as the character of the stream bottom sediments (particle size). Sand wave movement is also included within the effects of scour. Generally scour occurs to some degree in all stream channels except that rates may be negligible in strong rock channels. Scour also includes removal of loose backfill under high flows such as in a bedrock trench. **Required Conditions for Occurrence** 1. Stream channel except channels in hard rock with suitable backfill. **Definition of Initial Areas of Concern (Screening Criteria)** 1. Any stream channel except channels in hard rock with suitable backfill. 2. High scour may occur in stream channels with highly erodible bed materials (sand or silt on low to moderate gradient channels) and where high flows occur. **Additional Information used for refine the hazard occurrence areas** 1. Hydrotechnical studies. 2. Field review data (documented in Table B-1). 3. Review of aerial oblique photos taken during field visits. 4. Google Earth and other suitable imagery along the corridor. 5. River bottom bathymetry. 6. Local area experience.	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically possible to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)
$F_{(i)}$	**Triggering Mechanisms** Significant scour events (i.e. rate of erosion) are often the result of high flows due to high precipitation or seasonal freshet flows. Erosion rates can also be significantly influenced by anthropogenic activities upstream in the channel such as river training or installation of bridge piers. Natural processes and anthropogenic influences can be estimated, but future anthropogenic activities cannot. Significant scour events are typically linked to a given estimated runoff event varying from 25 to 200 year return period.	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs

GEOHAZARD DESCRIPTION: **SCOUR EROSION**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
	Potential Secondary Geohazard(s) Triggered Scour can trigger land sliding on stream banks due to undercutting. Several categories of landslides can be involved, from shallow slides through to deep-seated slides of various types.	0.001 = once in 1000 yrs
$V_{(i)}$[1]	Description of Effects in Hazard Impact Area Pipelines may be exposed, or the cover material may be reduced, by scour at pipeline crossings. Where scour exposes or undermines the pipeline a loss of containment might occur where debris, large boulders, equipment or boats impact the pipeline. Where scour occurs along a significant length of the pipeline perpendicular to stream flow, long unsupported spans may be subject to vibration and fatigue related failure as a result of vortex shedding downstream of the pipe exposed in the stream. Partial exposures may result in coating damage, denting, or abrasion damage. For standard crossing burial depths within a zone of potential scour, use V = 0.001, unless the exposure lengths would be expected to be in excess of 25 m (large rivers only)[2], in which case use V = 0.1.	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	Mitigation Options[3] **Options to Reduce Frequency** 1. Install channel lining materials such as riprap or concrete backfill (rock channels) to control scour at the crossing. However, such measures may not be successful in the long term and need to be approached with site specific studies and designs that include commitments for follow-up monitoring and maintenance. 2. Use routing to locate crossings in areas of channel less susceptible to scour. **Options to Reduce Vulnerability** 1. Construct the pipeline below the predicted maximum scour depth established based on site specific design using a long-term flow recurrence interval such as 1:100 or 1:200 year flows. 2. Install appropriately designed protective measures such as sills or riprap the channel to provide scour protection. Such measures may require maintenance and monitoring.	Armoured / lined channel bottom; use, $M_{(i)}$ = 0.01 Pipeline below maximum predicted scour depth for 1:100 or 1:200 year peak flows; use, $M_{(i)}$ = 0.001 Trenchless Methods with depths beyond max theoretical scour depth; use $M_{(i)}$ = 0.001 Heavy-wall Pipe; use, $M_{(i)}$ = 0.1 Concrete Coated Pipe; use, $M_{(i)}$ = 0.1 provided that maximum span length cannot be exceeded.

Revised to March 7, 2012

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.

[2] For the purposes of LOC event evaluation, scour areas of concern are restricted to those areas that LOC is possible, and therefore watercourses with a channel width of 50 m or more at the crossing for the basis of areas of concern. Additional details around this assumption are discussed under Lateral Erosion.

[3] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

GEOHAZARD DESCRIPTION: **SHALLOW TO MODERATELY DEEP SLIDES**

GOVERNING EQUATION RELATING THE FREQUENCY OF A LOSS OF CONTAINMENT (LOC) EVENT RELATED TO GEOHAZARD IS DEFINED AS: $F_{LOC(i)} = I_{(i)} \times F_{(i)} \times V_{(i)} \times M_{(i)}$	Where;	$F_{LOC(i)}$ =	Frequency of a loss of containment event due to geohazard at location I, expressed in events per year;
		$I_{(i)}$ =	Factor from 0 to 1 expressing the potential for the geohazard to occur at location i,
		$F_{(i)}$ =	Frequency of occurrence of the geohazard at location i expressed in events per year;
		$V_{(i)}$ =	Vulnerability of the pipeline to loss of containment events expressed as a fraction of total geohazard occurrences that would result in loss of containment. The unmitigated case assumes standard mainline construction and operation conditions.
		$M_{(i)}$ =	Mitigation effects expressed as a reduction factor on either $V_{(i)}$ or $F_{(i)}$ representing the resultant reduction in geohazard occurrence or reduced potential for loss of containment due to geohazard occurrence due to potential site specific mitigation(s) applied at location i.

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$I_{(i)}$	**General Process Description** Translational slides in soil and/or rock less than 10 to 15 m deep within weak geological units, generally on relatively steep slopes (as compared to deep-seated slides) and man-made cuts. Movement rates are typically variable, and dependent on material type. Runout lengths are typically less than 3 times the total height of the slide and the failed material behaves in a coherent manner (distinguishing factors between other failure mechanisms such as flow slides, rock fall, and debris flows). Toppling failures are discussed separately. Shallow slides often occur on deep-seated slides in response to the disturbance and movement of the deep slide – for the purpose of geohazard risk assessment, such slides are included in the movement and geohazard conditions of the deep-seated slide. **Required Conditions for Occurrence** The combination of slope angle, pore pressure and strength along the sliding surface must allow for sliding to occur. Sliding typically occurs in weak geological materials such as glaciolacustrine, glaciomarine, or weak sedimentary rocks, or in disturbed, softened, weathered and/or colluvial materials. Groundwater pressure and surface water flow are often contributing factors. Slides may occur where slopes are subject to undercutting erosion by stream flow, cuts or fills on steep terrain, or where significant natural or man-made surface vegetation disturbances have occurred (logging, clearing or forest fires). **Definition of Initial Areas of Concern (Screening Criteria)** Areas within the proposed route corridor that have slopes equal to, or greater than, the assumed frictional strength of the surficial deposits (defined by ϕ'), define the initial areas of interest. For the purposes of screening the following critical slope angles are used, although it is noted that values could vary depending on actual geological conditions and numerous slopes at angles greater than those below may be stable: 1. Glaciofluvial deposits: slopes>36°. 2. Till deposits in Alberta: slopes>28°. 3. Till deposits in BC: slopes>30°. 4. Glaciolacustrine soils: slopes>18°. 5. Glaciomarine soils: Slopes>5° (note that flow slides and lateral spreading are considered in other geohazard categories). **Additional Information used for refine the hazard occurrence areas** 1. Field review data (documented in Table B-1) and field photos. 2. Analysis of LIDAR and aerial photo imagery. 3. Published information on occurrences, if available.	0 = Not Possible (Screening criteria not met) 0.01 = Theoretically possible to occur at this location (screening criteria are only partially met) 0.1 = Credible potential occurrence at this location. (All screening criteria met, and in region where other events are known to have occurred, but no evidence of occurrence at location) 1.0 = Defined occurrence at this location (documented past occurrence via publication or field confirmation, or both)

GEOHAZARD DESCRIPTION: **SHALLOW TO MODERATELY DEEP SLIDES**

Factor	Considerations for Assigning Value to Each Factor	Guidance for Assigning Value to Factor
$F_{(i)}$	**Triggering Mechanisms** Shallow to moderately deep landslides can include new slides, old re-activated slides and shallow slides on deeper slides (evaluated as part of the deep-seated slide geohazard). Sliding triggers, or changes in movement rates are typically linked to long-term precipitation patterns and/or slope profile changes due to anthropogenic causes or toe erosion by streamflow. Dominant factors related to triggering include high precipitation or runoff, erosion (high stream flow) or man-made cuts or fills. **Potential Secondary Geohazard(s) Triggered** Landslide deposits can dam or divert streams and result in flooding or stream avulsion. Lateral erosion and scour in areas outside the previous stream channel through landslide debris or at the margins of the landslide deposit can occur.	If Triggering Mechanism is linked to historic database information, use the relevant frequency-magnitude data; otherwise use guideline such as; 1 = once in 1 yr 0.1 = once in 10 yrs 0.01 = once in 100 yrs 0.001 = once in 1000 yrs
$V_{(i)}$[1]	**Description of Effects in Hazard Impact Area** **Depletion Zone and Slide Area** – Significant soil depletion is expected in the upper portions of the landslide area. Retrogression may occur where the initial failure leaves a steep exposed headwall. Retrogression limits will be determined on a case by case basis based on regional slide morphology in similar terrain units. Damage is typically restricted to loss of cover soil, scratches or denting. Shallow slides are typically not sufficiently long to result in critical loading in an axial direction. For routing of a buried pipeline at standard cover depths through a potential depletion zone with movement parallel to the pipeline length use V = 0.001 except 0.01 for large slides. If the direction of expected movement is across pipeline and/or larger moderately deep seated slides are probable use V = 0.01 to 0.1.	0 = Hazard occurrence would not result in LOC. 0.001 = 0.1% of hazard occurrences would likely result in LOC. 0.01 = 1 % of hazard occurrences would likely result in LOC. 0.1 = 10 % of hazard occurrences would likely result in LOC. 1.0 = Each occurrence of hazard would likely result in LOC.
$M_{(i)}$	**Mitigation Options**[2] **Options to Reduce Frequency** 1. Could use stabilization berms, removal of crest materials, dewatering/drainage, erosion protection and surface water management. 2. Suitable design of grading along the RoW. Avoidance of oversteepened cut and fill areas from other projects. **Options to Reduce Vulnerability** 1. As appropriate, avoid slide areas. 2. Place the pipeline below the depth of sliding.	Minor slope and crest grading; use, $M_{(i)} = 0.1$ Major slope and crest grading; use, $M_{(i)} = 0.01$ Drainage and groundwater control; use, $M_{(i)} = 0.1$ Surface water control; use, $M_{(i)} = 0.1$ Toe berm; use, $M_{(i)} = 0.1$ Deep burial below slide; use, $M_{(i)} = 0.001$ Monitoring of slope stability conditions; use, $M_{(i)} = 0.1$ Reroute; use, $M_{(i)} = 0.001$

Revised to March 7, 2012

[1] Effects are described relative to a pipeline elements built using standard mainline pipe and construction methods.

[2] For locations where more than 1 mitigation option is chosen, factors are multiplicative, not additive.

APPENDIX B

List and Details of Geohazards

-List of geohazards by kilometre
-List of geohazards by type
-Details of geohazards

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
459	SC	38	Gold Creek			0	0	0	1.00E+00	1	0.00E+00
343	LM	38	Gold Creek			0	0	0	1.00E+00	1	0.00E+00
383	SM	36	Gold Creek			0	0	0	1.00E+00	1	0.00E+00
434	SC		North Saskatchewan River	2.58	3	1	0.01	0.1	1.00E-03	1	1.00E-06
373	SM	2	North Saskatchewan River west valley slope	3	4.1	0	0	0	1.00E+00	1	0.00E+00
435	SC		Riviere Qui Barre	62.8	62.96	1	0.01	0.001	1.00E-03	1	1.00E-08
326	LM		Riviere Qui Barre	62.8	62.96	1	0.01	0.001	1.00E-03	1	1.00E-08
327	LM	3	Pembina River	130.78	131.06	1	0.01	0.1	1.00E-03	1	1.00E-06
436	SC	3	Pembina River	130.78	131.06	1	0.01	0.1	1.00E-03	1	1.00E-06
516	SM		Paddle River East valley slope	137.18	137.48	1	0.1	0.01	1.00E-03	1	1.00E-06
437	SC		Paddle River	137.4	137.66	1	0.01	0.001	1.00E-03	1	1.00E-08
328	LM		Paddle River	137.4	137.66	1	0.01	0.001	1.00E-03	1	1.00E-08
329	LM	4	Little Paddle River	162.82	163.18	1	0.01	0.001	1.00E-03	1	1.00E-08
438	SC	4	Little Paddle River	162.82	163.18	1	0.01	0.001	1.00E-03	1	1.00E-08
59	DS	5	Swan Hills southeast of Whitecourt	177.52	183.94	1	0.001	0.1	1.00E-02	1	1.00E-06
530	SM		Swan Hills Area East of Whitecourt	183.5	183.8	0.1	0.01	0.01	1.00E-03	1	1.00E-08
330	LM	7	Athabasca River	186.18	187.02	1	0.1	0.1	1.00E-03	1	1.00E-05
439	SC	7	Athabasca River	186.18	187.02	1	0.01	0.1	1.00E-03	1	1.00E-06
60	DS	9	North approach to Athabasca River	187	187.14	0	0	0	1.00E+00	1	0.00E+00
374	SM	8	North approach to Athabasca River	187	187.14	1	1	0.001	1.00E-03	1	1.00E-06
527	DS		East approach slope to Sakwatamau River	198.75	199.1	1	1	1	1.00E-05	1	1.00E-05
440	SC	10	Sakwatamau River	199.06	200.16	1	0.01	0.001	1.00E-03	1	1.00E-08
331	LM	10	Sakwatamau River	199.06	200.16	1	0.01	0.001	1.00E-03	1	1.00E-08
375	SM	11	Narrow corridor near Sakwatamau River	200.16	202.26	1	0.1	0.01	1.00E-03	1	1.00E-06
376	SM	12	Tributary to Chickadee Creek valley slopes	215.16	215.56	0.1	0.1	0.001	1.00E-02	1	1.00E-07
441	SC	13	Chickadee Creek	218.46	218.62	1	0.01	0.001	1.00E-03	1	1.00E-08
332	LM	13	Chickadee Creek	218.46	218.62	1	0.01	0.001	1.00E-03	1	1.00E-08
333	LM	14	Two Creek	241.2	242.4	1	0.01	0.001	1.00E-03	1	1.00E-08
442	SC	14	Two Creek	241.2	242.4	1	0.01	0.001	1.00E-03	1	1.00E-08
528	SM		East of Two Creek	241.5	241.65	0	1	0.01	1.00E-03	1	0.00E+00
529	SM		East approach slopes of Two Creek	241.65	241.85	0	0.1	0.001	1.00E-02	1	0.00E+00
377	SM	15	East approach slope to Iosegun River	257.96	258.2	0.1	0.1	0.001	1.00E-02	1	1.00E-07

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
443	SC	17	Iosegun River	258.2	258.48	1	0.01	0.001	1.00E-03	1	1.00E-08
334	LM	17	Iosegun River	258.2	258.48	1	0.01	0.001	1.00E-03	1	1.00E-08
426	SM		West approach slope to Iosegun River	258.48	259.06	0.1	0.1	0.001	1.00E-03	1	1.00E-08
61	DS	19	East Approach to Little Smoky River	289.7	290.1	0.1	0.01	1	1.00E-03	10	1.00E-06
378	SM		East Approach slope to Little Smoky River	289.72	290.02	0.1	0.01	0.01	1.00E-02	10000	1.00E-07
444	SC	20	Little Smoky River crossing	290.02	290.56	1	0.01	0.1	1.00E-03	1	1.00E-06
335	LM	20	Little Smoky River crossing	290.02	290.56	1	0.1	0.1	1.00E-03	1	1.00E-05
62	DS	21	West Approach Slope to Little Smoky River	290.6	291.1	1	0.01	1	1.00E-03	10	1.00E-05
445	SC	22	Waskahigan River	317.1	317.9	1	0.01	0.001	1.00E-03	1	1.00E-08
336	LM	22	Waskahigan River	317.1	317.9	1	0.01	0.001	1.00E-03	1	1.00E-08
446	SC		Incised creek valley draining to north	331.64	331.76	1	0.01	0.001	1.00E-03	1	1.00E-08
447	SC		Incised creek valley draining to north	334.5	334.58	1	0.01	0.001	1.00E-03	1	1.00E-08
337	LM	23	Deep Valley Creek	337.9	338.36	1	0.1	0.001	1.00E-03	1	1.00E-07
448	SC	23	Deep Valley Creek	337.9	338.36	1	0.01	0.001	1.00E-03	1	1.00E-08
517	DS		Deep Valley Creek West valley slopes	338.78	339.42	1	1	0.1	1.00E-04	1	1.00E-05
518	SM		Tributrary to Deep Valley Creek East valley slopes	339.86	340.06	1	1	0.001	1.00E-02	1	1.00E-05
449	SC	24	Tributary to Deep Valley Creek	340.06	340.22	1	0.01	0.001	1.00E-03	1	1.00E-08
338	LM	24	Tributary to Deep Valley Creek	340.06	340.222	1	0.01	0.001	1.00E-03	1	1.00E-08
519	SM		Tributrary to Deep Valley Creek West valley slopes	340.22	340.34	1	1	0.001	1.00E-02	1	1.00E-05
520	SM		West of Tributary to Deep Valley Creek	340.34	341	0.1	1	0.01	1.00E-04	0.1	1.00E-07
521	SM		Creek crossing west of tributary to Deep Valley Creek	341	341.42	1	1	0.01	1.00E-04	0.1	1.00E-06
522	SC		Creek crossing west of tributary to Deep Valley Creek	341.32	341.34	1	0.01	0.001	1.00E-03	1	1.00E-08
450	SC		Tributaries to Simonette	353.56	353.58	1	0.01	0.001	1.00E-03	1	1.00E-08
451	SC		Tributaries to Simonette	354.58	354.62	1	0.01	0.001	1.00E-03	1	1.00E-08
452	SC		Tributaries to Simonette	355.18	355.22	1	0.01	0.001	1.00E-03	1	1.00E-08
453	SC		Tributaries to Simonette	356.38	356.4	1	0.01	0.001	1.00E-03	1	1.00E-08
454	SC		Tributaries to Simonette	357.26	357.32	1	0.01	0.001	1.00E-03	1	1.00E-08
339	LM	27	Simonette River	358.94	359.46	1	0.1	0.1	1.00E-03	1	1.00E-05
455	SC	27	Simonette River	358.94	359.46	1	0.01	0.1	1.00E-03	1	1.00E-06
63	DS	28	East valley slope of Latornell River	370.94	371.28	1	1	0.1	1.00E-05	0.01	1.00E-06
456	SC	29	Latornell River	371.26	371.3	1	0.01	0.001	1.00E-03	1	1.00E-08

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
340	LM	29	Latornell River	371.26	371.3	1	0.01	0.001	1.00E-03	1	1.00E-08
495	DS	28	West valley slope of Latornell River	371.3	372	1	1	0.1	1.00E-05	0.01	1.00E-06
64	DS	30	West of Latornell River	372.1	374	0.1	0.1	1	1.00E-03	1	1.00E-05
380	SM	32	Tributary to Smoky River valley slopes	395.02	395.22	1	0.1	0.001	1.00E-02	1	1.00E-06
341	LM	31	Tributary to Smoky River	395.1	395.12	1	0.01	0.001	1.00E-03	1	1.00E-08
457	SC	31	Tributary to Smoky River	395.1	395.12	1	0.01	0.001	1.00E-03	1	1.00E-08
381	SM		Tributary to Smoky River valley slopes	403.58	403.96	0.01	0.01	0.001	1.00E-02	1	1.00E-09
382	SM		East valley slope of Smoky River	419.4	419.9	0.01	0.01	0.01	1.00E-02	1	1.00E-08
65	DS	33	East valley slope of Smoky River	419.5	419.9	0.1	0.01	1	1.00E-03	1	1.00E-06
458	SC	34	Smoky River floodplain	420.18	421.74	1	0.01	0.1	1.00E-03	1	1.00E-06
342	LM	34	Smoky River floodplain	420.18	421.74	1	0.1	0.1	1.00E-04	10	1.00E-06
66	DS	35	West valley slope of Smoky River	421.7	422.28	1	1	0.1	1.00E-04	1	1.00E-05
384	SM	39	Big Mountain Creek valley slopes	428.16	429.52	1	0.1	0.01	1.00E-02	10	1.00E-05
460	SC	41	Big Mountain Creek	428.92	429.28	1	0.01	0.001	1.00E-03	1	1.00E-08
344	LM	41	Big Mountain Creek	428.92	429.28	1	0.01	0.001	1.00E-03	1	1.00E-08
385	SM	42	Bald Mountain Creek west valley slopes	446.4	446.76	0.1	0.1	0.001	1.00E-03	1	1.00E-08
461	SC	43	Bald Mountain Creek	446.64	446.72	1	0.01	0.001	1.00E-03	1	1.00E-08
345	LM	43	Bald Mountain Creek	446.64	446.72	1	0.01	0.001	1.00E-03	1	1.00E-08
462	SC		Wilson Creek	453.66	453.86	1	0.01	0.001	1.00E-03	1	1.00E-08
346	LM		Wilson Creek	453.66	453.86	1	0.01	0.001	1.00E-03	1	1.00E-08
386	SM		Tributary to Iroquois Creek valley slopes	458.76	459	1	1	0.001	1.00E-02	1	1.00E-05
387	SM		Pinto Creek meander bend 1	470.84	471.08	1	1	0.01	1.00E-03	1	1.00E-05
424	SM		Pinto Creek meander bend 2	473	473.5	1	1	0.01	1.00E-03	1	1.00E-05
68	SM	46	Pinto Creek East valley slope	474.02	474.12	1	1	0.01	1.00E-04	0.1	1.00E-06
463	SC		Pinto Creek	474.2	474.28	1	0.01	0.001	1.00E-03	1	1.00E-08
427	SM		Pinto Creek West valley slope	474.34	474.44	1	1	0.01	1.00E-03	1	1.00E-05
69	DS	47	Wapiti River area	494.9	495.2	0	0	0	1.00E+00	1	0.00E+00
464	SC		Wapiti River	494.94	495.6	0.1	0.01	0.1	1.00E-03	1	1.00E-07
388	SM		Ridge on West Side of Wapiti River	496.3	497	0.1	0.01	0.01	1.00E-01	100	1.00E-06
465	SC		South Redwillow River	534.12	534.18	0.1	0.01	0.001	1.00E-03	1	1.00E-09
347	LM		South Redwillow River	534.12	534.18	0.1	0.001	0.001	1.00E-03	1	1.00E-10
466	SC		Kinuseo Creek	568.2	568.26	1	0.01	0.001	1.00E-03	1	1.00E-08
389	SM	48	Quintette Mountain area rock cuts	568.4	581.78	0.1	0.1	0.001	1.00E-01	1	1.00E-06
4	AVU	49	Quintette Creek	577.3	577.46	1	0.1	0.001	1.00E-02	1	1.00E-06
245	DF	50	Tributary to Kinuseo Creek	579.94	580.04	0.01	0.01	0.01	1.00E-02	1	1.00E-08

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ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
348	LM	51	Kinuseo Creek near alignment	580.7	581.8	0.01	0.001	0.1	1.00E+00	1	1.00E-06
246	DF		Five Cabin Creek	582.16	583.1	1	0.1	0.01	1.00E-02	1	1.00E-05
5	AVU	52	Five Cabin Creek	582.16	583.1	1	0.1	0.01	1.00E-02	1	1.00E-05
349	LM	53	Kinuseo Creek near alignment	587.74	587.74	0.1	0.01	0.1	1.00E-02	1	1.00E-06
497	AVU		Tributary to Kinuseo	588.86	589.6	1	0.1	0.001	1.00E-02	1	1.00E-06
467	SC		Kinuseo Creek	590.3	590.68	1	0.01	0.001	1.00E-03	1	1.00E-08
428	LM	53	Kinuseo Creek	590.3	590.68	1	0.1	0.001	1.00E-03	1	1.00E-07
390	SM	54	Tributary of Murray River	598.82	598.98	1	1	0.01	1.00E-03	1	1.00E-05
468	SC		Murray River	600.8	600.92	1	0.01	0.1	1.00E-03	1	1.00E-06
350	LM		Murray River	600.8	600.92	1	0.1	0.01	1.00E-03	0.1	1.00E-06
392	SM	56	Hook Creek east approach slopes	604.6	604.64	1	1	0.001	1.00E-03	1	1.00E-06
351	LM	57	Hook Creek	604.64	604.76	1	0.1	0.001	1.00E-03	1	1.00E-07
469	SC	57	Hook Creek	604.64	604.76	1	0.01	0.001	1.00E-03	1	1.00E-08
545	SM		Hook Creek west approach slope	604.76	604.8	1	1	0.001	1.00E-03	1	1.00E-06
226	AVA		Pass through Rockies	614	614.2	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
227	AVA		Pass through Rockies	615	615.2	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
247	DF	58	Pass through Rockies	616.12	616.54	0	0.001	0.01	1.00E+00	1	0.00E+00
6	AVU		Pass through Rockies	617.7	618.52	0.1	0.01	0.001	1.00E+00	1	1.00E-06
228	AVA	59	Pass through Rockies	618.5	618.6	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
393	SM	60	Pass through Rockies	619.2	625.7	0.1	0.1	0	1.00E+00	1	0.00E+00
229	AVA	59	Pass through Rockies	622.1	622.25	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
33	RF	63	Pass through Rockies	623.55	623.7	0.1	0.1	0.01	1.00E-02	0.1	1.00E-06
230	AVA	59	Pass through Rockies	624.3	624.32	0.01	0.001	0.001	1.00E+00	1	1.00E-08
231	AVA	59	Pass through Rockies	624.48	624.54	0.01	0.001	0.001	1.00E+00	1	1.00E-08
232	AVA	59	Pass through Rockies	625.5	625.6	0.01	0.001	0.001	1.00E+00	1	1.00E-08
394	SM	64	Headwaters of Hominka River	627.3	628.7	0.1	0.1	0	1.00E+00	1	0.00E+00
248	DF		Headwaters of Missinka River	629.7	629.8	0	0.001	0.01	1.00E+00	1	0.00E+00
249	DF		Headwaters of Missinka River	630.35	630.4	0	0.001	0.01	1.00E+00	1	0.00E+00
250	DF		Missinka River	632.1	632.2	0	0.001	0.01	1.00E+00	1	0.00E+00
251	DF	69	Tributary to Missinka River	633.92	633.96	0.01	0.01	0.01	1.00E-02	1	1.00E-08
252	DF	69	Tributary to Missinka River	635.06	635.12	0.1	0.01	0.01	1.00E-02	1	1.00E-07
395	SM	70	Valley slopes of Tributary to Missinka River	636.7	639.3	0.1	0.1	0	1.00E+00	1	0.00E+00
253	DF	69	Tributary to Missinka River	637.14	637.2	0.1	0.01	0.01	1.00E-02	1	1.00E-07
254	DF	69	Tributary to Missinka River	637.3	637.3	0	0.001	0.01	1.00E+00	1	0.00E+00

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ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
233	AVA	71	Valley slopes of Tributary to Missinka River	637.9	638	0	0	0	1.00E+00	1	0.00E+00
7	AVU	68	Tributary to Missinka River	638.48	638.64	0.1	0.01	0.001	1.00E-02	1	1.00E-08
255	DF	69	Tributary to Missinka River	638.48	638.64	0.1	0.01	0.01	1.00E-02	1	1.00E-07
234	AVA	71	Valley slopes of Tributary to Missinka River	638.9	639.3	0.1	0.001	0.001	1.00E+00	1	1.00E-07
256	DF	69	Tributary to Missinka River	638.9	638.9	0	0.001	0.01	1.00E+00	1	0.00E+00
257	DF		Tributary to Missinka River	639.58	639.6	0.01	0.01	0.01	1.00E-02	1	1.00E-08
396	SM	72	Missinka River valley slopes	642.68	643.7	0.1	0.1	0	1.00E+00	1	0.00E+00
470	SC		Missinka River	643.38	643.46	1	0.01	0.001	1.00E-03	1	1.00E-08
397	SM	73	Missinka River area	643.7	668.7	0.1	0.1	0	1.00E+00	1	0.00E+00
258	DF		Tributary to Missinka River	645.94	645.96	0.01	0.01	0.01	1.00E-02	1	1.00E-08
259	DF		Tributary to Missinka River	646.7	647.24	0.01	0.01	0.01	1.00E-02	1	1.00E-08
471	SC		Missinka River	648.1	648.2	1	0.01	0.001	1.00E-03	1	1.00E-08
260	DF		Tributary to Missinka River	652.1	652.56	0.1	0.01	0.01	1.00E-02	1	1.00E-07
498	AVU		Tributary to Missinka River	652.1	652.56	1	0.1	0.001	1.00E-02	1	1.00E-06
261	DF		Tributary to Missinka River	655.1	655.22	0.1	0.01	0.01	1.00E-02	1	1.00E-07
262	DF		Tributary to Missinka River	656.26	656.36	0.1	0.01	0.01	1.00E-02	1	1.00E-07
263	DF		Tributary to Missinka River	659.66	659.76	0.1	0.01	0.01	1.00E-02	1	1.00E-08
264	DF		Tributary to Missinka River	661.36	661.46	0.1	0.01	0.01	1.00E-02	1	1.00E-07
265	DF		Tributary to Missinka River	662.02	662.26	0.1	0.01	0.01	1.00E-02	1	1.00E-07
266	DF		Tributary to Missinka River	665.22	665.3	0.1	0.01	0.01	1.00E-02	1	1.00E-07
267	DF		Tributary to Missinka River	666.46	666.54	0.1	0.01	0.01	1.00E-02	1	1.00E-07
268	DF		Tributary to Missinka River	667.82	668.58	0	0.001	0.01	1.00E+00	1	0.00E+00
352	LM	77	Parsnip River	673.6	674.14	1	0.1	0.1	1.00E-03	1	1.00E-05
472	SC	77	Parsnip River	673.6	674.14	1	0.01	0.1	1.00E-03	1	1.00E-06
398	SM	75	West of Parsnip River	673.84	675.24	0.1	0.1	0	1.00E+00	1	0.00E+00
399	SM	78	West of Wichcika Creek	682	688	0.1	0.1	0	1.00E+00	1	0.00E+00
353	LM	82	Tributary to Chuchinka Creek near alignment	689.8	700.8	0	0	0	1.00E+00	1	0.00E+00
400	SM	81	Tributary to Chuchinka Creek area	689.8	700.8	0.1	0.1	0	1.00E+00	1	0.00E+00
8	AVU	82	Tributary to Chuchinka Creek	692.06	692.64	0.1	0.01	0.001	1.00E+00	1	1.00E-06
494	LM		Tributary to Chuchinka Creek	705.66	705.86	1	0.1	0.001	1.00E-03	1	1.00E-07
401	SM	84	Angusmac Creek East Valley Slope	712.66	713.16	1	0.1	0.001	1.00E-02	10	1.00E-06
354	LM	86	Angusmac Creek	713.16	713.44	1	1	0.001	1.00E-03	1	1.00E-06
473	SC	86	Angusmac Creek	713.16	713.44	1	0.01	0.001	1.00E-03	1	1.00E-08

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499	SM	84	Angusmac Creek West Valley Slopes	713.55	713.9	1	0.1	0.001	1.00E-02	10	1.00E-06
474	SC	87	Crooked River	720.88	721.36	1	0.01	0.001	1.00E-03	1	1.00E-08
355	LM	87	Crooked River	720.88	721.36	1	0.1	0.001	1.00E-03	1	1.00E-07
356	LM	90	Muskeg River	750.8	750.9	1	0.01	0.001	1.00E-03	1	1.00E-08
475	SC	90	Muskeg River	750.8	750.9	1	0.01	0.001	1.00E-03	1	1.00E-08
357	LM	91	Salmon River	765.44	765.9	1	1	0.01	1.00E-03	1	1.00E-05
476	SC	91	Salmon River	765.44	765.9	1	0.01	0.001	1.00E-03	1	1.00E-08
402	SM	92	West valley slope of Salmon River	765.9	766.14	1	1	0.001	1.00E-03	1	1.00E-06
523	SM		Tributary to Beaver Lake	782.38	782.58	0.1	0.1	0.001	1.00E-03	1	1.00E-08
403	SM		Necoslie River valley slopes	818.92	819.32	1	0.1	0.01	1.00E-03	1	1.00E-06
477	SC		Necoslie River	819.32	819.46	1	0.01	0.001	1.00E-03	1	1.00E-08
70	DS	94	Stuart River East valley slope	824.3	824.6	0.01	0.001	1	1.00E-03	1	1.00E-08
478	SC		Stuart River	824.76	825.08	1	0.01	0.1	1.00E-03	1	1.00E-06
71	DS	94	Stuart River West valley slope	825	825.5	0.01	0.001	0.1	1.00E-01	1	1.00E-07
404	SM	95	Stuart River West valley slope	825.02	825.08	1	1	0.1	1.00E-04	0.1	1.00E-05
524	SM		Sutherland River East valley slope	859.24	859.4	1	1	0.001	1.00E-03	1	1.00E-06
500	SC		Sutherland River	859.4	859.48	1	0.01	0.001	1.00E-03	1	1.00E-08
515	LM		Maxan Creek	951.2	951.58	1	0.01	0.001	1.00E-03	1	1.00E-08
405	SM	98	Klo Creek East valley slopes	977.34	977.96	1	0.1	0.001	1.00E-03	1	1.00E-07
546	SM		Klo Creek east approach Lower slopes	978.3	978.44	1	0.1	0.001	1.00E-03	1	1.00E-07
479	SC	97	Klo Creek	978.44	978.68	1	0.01	0.001	1.00E-03	1	1.00E-08
358	LM	97	Klo Creek	978.44	978.68	1	0.1	0.001	1.00E-03	1	1.00E-07
501	SM	98	Klo Creek West valley slopes	978.68	978.72	1	0.1	0.001	1.00E-03	1	1.00E-07
359	LM		Buck Creek	989.78	990.16	1	0.1	0.001	1.00E-03	1	1.00E-07
480	SC		Buck Creek	989.78	990.16	1	0.01	0.001	1.00E-03	1	1.00E-08
481	SC		Owen Creek	1005.2	1005.4	0	0.01	0.001	1.00E-03	1	0.00E+00
541	SM		Owen Creek East Approach Slopes	1006.58	1006.7	1	0.01	0.001	1.00E-03	1	1.00E-08
532	LM		Owen Creek	1006.7	1006.72	1	0.01	0.001	1.00E-03	1	1.00E-08
323	DS		West of Owen Creek	1006.7	1007.1	0	0.1	0.1	1.00E-03	1	0.00E+00
543	SM		Owen Creek West Approach Slopes	1006.72	1006.8	0.1	0.01	0.001	1.00E-02	1	1.00E-08
534	SM		Fenton Creek East Approach Slope	1012.74	1012.78	0.1	0.01	0.001	1.00E-03	1	1.00E-09
482	SC		Fenton Creek	1012.78	1012.8	1	0.01	0.001	1.00E-03	1	1.00E-08
533	LM		Fenton Creek	1012.78	1012.8	1	0.1	0.001	1.00E-03	1	1.00E-07
542	SM		Fenton Creek West Approach Slope	1012.8	1012.86	0.1	0.01	0.001	1.00E-03	1	1.00E-09
540	SM		24.5 Mile Creek East approach slope	1018.36	1018.4	1	0.01	0.001	1.00E-03	1	1.00E-08

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
539	LM		24.5 Mile Creek	1018.4	1018.42	1	0.1	0.001	1.00E-05	1	1.00E-09
406	SM	100	Lamprey Creek East valley slopes	1021	1022	0	0	0	1.00E-03	1	0.00E+00
537	SM		Lamprey Creek East approach slope	1024.36	1024.66	1	0.01	0.001	1.00E-04	1	1.00E-09
483	SC		Lamprey Creek	1024.66	1024.84	1	0.01	0.001	1.00E-03	1	1.00E-08
535	LM		Lamprey Creek	1024.66	1024.84	1	0.1	0.001	1.00E-03	1	1.00E-07
407	SM	101	Cedric Creek valley slopes	1028.3	1029.1	0	0	0	1.00E-03	1	0.00E+00
360	LM	102	Cedric Creek	1028.45	1028.55	0	0	0	1.00E-03	1	0.00E+00
485	SC	102	Cedric Creek	1028.45	1028.55	0	0	0	1.00E-03	1	0.00E+00
538	SC		Cedric Creek	1032.72	1032.74	0.1	0.01	0.001	1.00E-03	1	1.00E-09
408	SM	103	Side slopes of Morice River valley	1035.1	1038.1	0	0.1	0.01	1.00E-03	1	0.00E+00
484	SC		Morice River	1043.06	1043.42	1	0.01	0.1	1.00E-03	1	1.00E-06
544	LM		Morice River	1043.06	1043.42	1	0.01	0.1	1.00E-03	1	1.00E-06
9	AVU	105	Crystal Creek	1049	1049.36	1	0.1	0.01	1.00E-03	1	1.00E-06
269	DF	106	Crystal Creek	1049	1049.36	1	0.1	0.01	1.00E-03	1	1.00E-06
270	DF	107	Tributary to Gosnell Creek	1055.02	1055.1	0.1	0.01	0.01	1.00E-02	1	1.00E-07
271	DF	107	Tributary to Gosnell Creek	1057.34	1057.72	0.1	0.01	0.01	1.00E-02	1	1.00E-07
272	DF		Tributary to Gosnell Creek	1058.24	1058.7	0.1	0.01	0.01	1.00E-02	1	1.00E-07
273	DF		Tributary to Gosnell Creek	1059.6	1060	0.01	0.01	0.01	1.00E-02	1	1.00E-08
10	AVU		Tributary to Gosnell Creek	1061.82	1062	0.01	0.001	0.001	1.00E+00	1	1.00E-08
361	LM	108	Gosnell Creek	1063.76	1064.08	1	0.1	0.001	1.00E-03	1	1.00E-07
486	SC	108	Gosnell Creek	1063.76	1064.08	1	0.01	0.001	1.00E-03	1	1.00E-08
274	DF	110	Tributary to Burnie River Fan	1071.06	1072.06	0.1	0.01	0.01	1.00E-02	1	1.00E-07
11	AVU	109	Tributary to Burnie River Fan	1071.06	1072.06	1	0.01	0.001	1.00E-02	1	1.00E-07
409	SM	112	East approach slope to Burnie and Clore River valleys	1075.2	1075.65	0.1	0.01	0.01	1.00E-03	1	1.00E-08
526	LM		Tributary to Burnie River	1076.3	1076.56	1	0.01	0.001	1.00E-03	1	1.00E-08
525	SC		Tributary to Burnie River	1076.3	1076.56	1	0.01	0.001	1.00E-03	1	1.00E-08
362	LM	114	Clore River	1077.4	1077.94	1	1	1	1.00E-04	100	1.00E-04
487	SC	114	Clore River	1077.4	1077.94	1	0.01	0.1	1.00E-03	1	1.00E-06
235	AVA		Clore Tunnel - East Portal	1077.95	1078.55	0.01	0.001	0.1	1.00E+00	1	1.00E-06
236	AVA	117	Clore Tunnel - West Portal	1083.78	1084.6	0.01	0.001	0.001	1.00E+00	1	1.00E-08
410	SM	115	Tributary to Clore River and adjacent areas	1083.78	1084.6	1	0.1	0.001	1.00E-02	1	1.00E-06
34	RF	118	Clore Tunnel - West Portal	1083.78	1084.6	0.01	0.01	0.01	1.00E+00	1	1.00E-06
35	RF	118	Tributary to Clore River crossing	1084.9	1084.94	1	0.1	0	1.00E+00	1	0.00E+00

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
275	DF	116	Tributary to Clore River crossing	1084.9	1084.94	0.01	0.01	0	1.00E-03	1	0.00E+00
237	AVA	117	Hoult Tunnel - East Portal	1084.95	1085.3	0	0.001	0.001	1.00E+00	1	0.00E+00
36	RF	118	Hoult Tunnel - East Portal	1085.64	1086.02	0.1	0.01	0.01	1.00E+00	1	1.00E-05
37	RF	120	Hoult Tunnel - West Portal	1090.08	1091.3	0.1	0.01	0.01	1.00E+00	1	1.00E-05
238	AVA	119	Hoult Tunnel - West Portal	1090.08	1091.3	0.01	0.001	0.001	1.00E+00	1	1.00E-08
276	DF	121	Hoult Creek	1092.02	1092.08	0.01	0.01	0	1.00E-03	1	0.00E+00
38	RF	122	Hoult Creek	1092.02	1092.08	0.001	0.001	1	1.00E+00	1	1.00E-06
363	LM	123	Hoult Creek	1092.02	1092.08	0.01	0.001	0.001	1.00E-03	1	1.00E-11
411	SM	124	Hoult Creek and Upper Kitimat River valley	1092.12	1106.42	0.1	0.1	0.001	1.00E-02	10	1.00E-07
277	DF	121	Hoult Creek Valley	1093.1	1093.12	1	0.1	0.1	1.00E-04	1	1.00E-06
502	DF	121	Hoult Creek Valley	1094.08	1094.1	0.1	0.01	0.1	1.00E-02	1	1.00E-06
240	AVA	125	Hoult Creek Valley	1094.48	1095.1	1	0.01	0.001	1.00E-02	1	1.00E-07
278	DF	121	Hoult Creek Valley	1094.48	1095.1	1	0.1	0.01	1.00E-02	1	1.00E-05
39	RF	122	Hoult Creek Valley	1094.48	1095.1	1	0.01	0.01	1.00E-02	1	1.00E-06
12	AVU		Hoult Creek Valley	1094.48	1095.1	1	0.1	0.001	1.00E-02	1	1.00E-06
503	AVU		Hoult Creek Valley	1095.1	1095.38	1	0.1	0.001	1.00E-02	1	1.00E-06
241	AVA	125	Hoult Creek Valley	1095.1	1095.38	0.1	0.01	0.001	1.00E-02	1	1.00E-08
40	RF	122	Hoult Creek Valley	1095.1	1095.38	1	0.01	0.01	1.00E-02	1	1.00E-06
279	DF	121	Hoult Creek Valley	1095.1	1095.38	1	0.1	0.01	1.00E-02	1	1.00E-05
41	RF	122	Hoult Creek Valley	1095.38	1095.78	1	0.01	0.01	1.00E-02	1	1.00E-06
13	AVU		Hoult Creek Valley	1095.38	1095.78	1	0.1	0.001	1.00E-02	1	1.00E-06
280	DF	121	Hoult Creek Valley	1095.38	1095.78	0.1	0.01	0.1	1.00E-02	1	1.00E-06
14	AVU		Hoult Creek Valley	1095.82	1096.84	1	0.1	0.001	1.00E-02	1	1.00E-06
42	RF	122	Hoult Creek Valley	1095.82	1096.84	1	0.01	0.01	1.00E-02	1	1.00E-06
281	DF	121	Hoult Creek Valley	1095.82	1096.84	1	0.1	0.01	1.00E-02	1	1.00E-05
242	AVA	125	Hoult Creek Valley	1095.82	1096.84	0.1	0.01	0.001	1.00E-02	1	1.00E-08
282	DF	121	Hoult Creek Valley	1096.84	1097.06	0.1	0.01	0.1	1.00E-02	1	1.00E-06
504	AVU		Hoult Creek Valley	1096.84	1097.06	1	0.1	0.001	1.00E-02	1	1.00E-06
43	RF	122	Hoult Creek Valley	1096.84	1097.06	1	0.01	0.01	1.00E-02	1	1.00E-06
283	DF	121	Hoult Creek Valley	1097.06	1097.2	0.1	0.01	0.1	1.00E-02	1	1.00E-06
505	AVU		Hoult Creek Valley	1097.06	1097.2	1	0.1	0.001	1.00E-02	1	1.00E-06
44	RF	122	Hoult Creek Valley	1097.06	1097.2	1	0.01	0.01	1.00E-02	1	1.00E-06
509	RF	122	Hoult Creek Valley	1097.22	1097.38	1	0.01	0.01	1.00E-02	1	1.00E-06
508	AVU		Hoult Creek Valley	1097.22	1097.38	1	0.1	0.001	1.00E-02	1	1.00E-06

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
506	DF	121	Hoult Creek Valley	1097.22	1097.38	0.1	0.01	0.1	1.00E-02	1	1.00E-06
511	RF	122	Hoult Creek Valley	1097.38	1097.48	1	0.01	0.01	1.00E-02	1	1.00E-06
510	AVU		Hoult Creek Valley	1097.38	1097.48	1	0.1	0.001	1.00E-02	1	1.00E-06
507	DF	121	Hoult Creek Valley	1097.38	1097.48	0.1	0.01	0.1	1.00E-02	1	1.00E-06
284	DF	121	Hoult Creek Valley	1097.48	1098.04	1	0.1	0.1	1.00E-03	1	1.00E-05
243	AVA	125	Hoult Creek Valley	1097.48	1098.04	1	0.01	0.001	1.00E-03	1	1.00E-08
45	RF	123	Hoult Creek Valley	1097.48	1098.04	1	0.01	0.01	1.00E-03	1	1.00E-07
15	AVU		Hoult Creek Valley	1097.48	1098.04	1	0.1	0.001	1.00E-03	1	1.00E-07
412	SM	128	Hunter Creek valley slopes	1099.05	1104.2	0	0	0	1.00E-03	1	0.00E+00
46	RF	124	Hoult Creek Valley	1099.06	1099.28	0.01	0.001	0.001	1.00E+00	1	1.00E-08
285	DF	121	Hoult Creek Valley	1099.06	1099.28	0.01	0.01	0.01	1.00E+00	1	1.00E-06
16	AVU		Hoult Creek Valley	1099.06	1099.28	0.01	0.01	0.001	1.00E+00	1	1.00E-07
488	SC	126	Hunter Creek	1103.86	1104.22	1	0.01	0.001	1.00E-03	1	1.00E-08
286	DF	127	Hunter Creek	1103.86	1104.22	1	0.1	0.01	1.00E-03	1	1.00E-06
17	AVU	126	Hunter Creek	1103.86	1104.22	1	0.1	0.1	1.00E-04	1	1.00E-06
287	DF	130	Upper Kitimat River valley	1106.56	1106.62	0.1	0.01	0.1	1.00E-02	1	1.00E-06
413	SM	131	Upper Kitimat River valley	1106.62	1124.62	0.1	0.1	0.001	1.00E-02	1	1.00E-07
18	AVU	129	Upper Kitimat River valley	1106.96	1107.42	0.1	0.01	0.001	1.00E-02	1	1.00E-08
288	DF	130	Upper Kitimat River valley	1106.96	1107.42	0.1	0.1	0.01	1.00E-02	1	1.00E-06
47	RF	135	Upper Kitimat River valley	1106.96	1107.42	0.01	0.001	0.01	1.00E-02	1	1.00E-09
19	AVU	129	Upper Kitimat River valley	1107.52	1107.8	0.1	0.01	0.001	1.00E-02	1	1.00E-08
289	DF	130	Upper Kitimat River valley	1107.52	1107.8	1	0.1	0.01	1.00E-03	1	1.00E-06
20	AVU		Upper Kitimat River valley	1110.36	1110.44	1	0.1	0.001	1.00E-02	1	1.00E-06
290	DF	134	Upper Kitimat River valley	1110.36	1110.44	0.1	0.1	0.01	1.00E-02	1	1.00E-06
21	AVU		Upper Kitimat River valley	1113.38	1113.4	0.01	0.01	0.001	1.00E-02	1	1.00E-09
291	DF	134	Upper Kitimat River valley	1113.38	1113.4	0.1	0.1	0.1	1.00E-02	1	1.00E-05
292	DF	134	Upper Kitimat River valley	1113.7	1113.8	0.01	0.01	0.1	1.00E-02	1	1.00E-07
414	SM		North Side Kitimat River	1113.7	1113.82	1	1	0.001	1.00E-03	1	1.00E-06
22	AVU		Upper Kitimat River valley	1114.04	1114.12	0.1	0.01	0.001	1.00E-02	1	1.00E-08
293	DF	134	Upper Kitimat River valley	1114.04	1114.12	0.01	0.01	0.1	1.00E-02	1	1.00E-07
294	DF	134	Upper Kitimat River valley	1114.68	1114.74	0.1	0.01	0.1	1.00E-02	1	1.00E-06
23	AVU		Upper Kitimat River valley	1114.68	1114.74	1	0.1	0.001	1.00E-02	1	1.00E-06
48	RF	135	Upper Kitimat River valley	1114.86	1114.98	1	0.1	0.01	1.00E-02	1	1.00E-05
295	DF	134	Upper Kitimat River valley	1114.86	1114.98	0.1	0.01	0.1	1.00E-02	1	1.00E-06
24	AVU		Upper Kitimat River valley	1114.86	1114.98	0.1	0.01	0.001	1.00E-02	1	1.00E-08

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
512	DF	134	Upper Kitimat River valley	1115.28	1115.32	0.01	0.01	0.1	1.00E-02	1	1.00E-07
513	DF	134	Upper Kitimat River valley	1115.6	1135.64	0.01	0.01	0.1	1.00E-02	1	1.00E-07
25	AVU		Upper Kitimat River valley	1116.28	1116.6	0.1	0.01	0.001	1.00E-02	1	1.00E-08
244	AVA	132	Upper Kitimat River valley	1116.28	1116.6	0.01	0.001	0.001	1.00E-02	1	1.00E-10
296	DF	134	Upper Kitimat River valley	1116.28	1116.6	0.1	0.1	0.1	1.00E-02	1	1.00E-05
49	RF	135	Upper Kitimat River valley	1116.28	1116.6	0.1	0.01	0.01	1.00E-02	1	1.00E-07
297	DF	134	Upper Kitimat River valley	1117.16	1117.28	0.1	0.01	0.1	1.00E-02	1	1.00E-06
26	AVU		Upper Kitimat River valley	1117.94	1118.36	0.1	0.01	0.001	1.00E-02	1	1.00E-08
298	DF	134	Upper Kitimat River valley	1117.94	1118.36	0.1	0.01	0.1	1.00E-02	1	1.00E-06
299	DF	134	Upper Kitimat River valley	1119.36	1119.52	0.1	0.1	0.1	1.00E-02	1	1.00E-05
27	AVU		Upper Kitimat River valley	1119.38	1119.6	1	0.1	0.001	1.00E-02	1	1.00E-06
50	RF	135	Upper Kitimat River valley	1119.44	1120.24	0.1	0.01	0.01	1.00E-02	1	1.00E-07
300	DF	134	Upper Kitimat River valley	1120	1120.62	0.1	0.1	0.1	1.00E-02	1	1.00E-05
28	AVU		Upper Kitimat River valley	1120	1120.62	0.1	0.01	0.001	1.00E-02	1	1.00E-08
366	LM	136	Upper Kitimat River valley	1120.9	1121.4	0	0.001	0.001	1.00E+00	1	0.00E+00
301	DF	134	Upper Kitimat River valley	1121.22	1121.34	0.1	0.01	0.01	1.00E-02	1	1.00E-07
29	AVU		Upper Kitimat River valley	1121.22	1121.34	0.1	0.001	0.001	1.00E-02	1	1.00E-09
302	DF	134	Upper Kitimat River valley	1121.94	1122.1	0.1	0.01	0.1	1.00E-02	1	1.00E-06
30	AVU		Upper Kitimat River valley	1121.94	1122.1	1	0.1	0.001	1.00E-02	1	1.00E-06
51	RF	135	Upper Kitimat River valley	1126.12	1128.26	1	0.01	0.01	1.00E-02	1	1.00E-06
31	AVU		Upper Kitimat River valley	1127.48	1127.82	0.1	0.01	0.001	1.00E-02	1	1.00E-08
303	DF		Upper Kitimat River valley	1127.48	1127.82	0.1	0.01	0.01	1.00E-02	1	1.00E-07
489	SC	137	Chist Creek	1128.26	1128.6	1	0.01	0.001	1.00E-03	1	1.00E-08
367	LM	137	Chist Creek	1128.26	1128.6	1	0.1	0.01	1.00E-02	1	1.00E-05
514	SC		Cecil Creek	1136.68	1136.74	1	0.01	0.001	1.00E-03	1	1.00E-08
415	SM	143	Eastern flank on Iron Mountain	1140.62	1149.52	0.1	0.0004	0.1	1.00E+00	1	4.00E-06
429	LS	142	Eastern flank on Iron Mountain	1140.62	1149.52	0	0	0	1.00E+00	1	0.00E+00
416	SM	139	Eastern flank on Iron Mountain	1141	1142.6	0	0	0	1.00E+00	1	0.00E+00
52	RF	141	Eastern flank on Iron Mountain	1142.4	1142.52	1	0.1	0.1	1.00E-03	1	1.00E-05
53	RF	144	Southeast flank of Iron Mountain	1148.6	1148.7	1	0.1	0.1	1.00E-03	1	1.00E-05
417	SM	146	North of Wedeene River	1148.7	1149.1	0.1	0.01	0.01	1.00E+00	1	1.00E-05
72	DS	145	North of Wedeene River	1149	1149.7	0	0	0	1.00E+00	1	0.00E+00
430	LS	147	Wedeene River area	1149.52	1152.32	0.1	0.0004	1	1.00E-02	1	4.00E-07
490	SC		Wedeene River	1150.08	1150.14	1	0.01	0.1	1.00E-03	1	1.00E-06
418	SM	146	Wedeene River west valley slope	1150.18	1150.38	1	0.01	0.001	1.00E-03	1	1.00E-08

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
73	DS	145	Wedeene River West Approach	1150.6	1154.5	0.01	0.001	1	1.00E+00	1	1.00E-05
431	LS	148	Little Wedeene River Area	1152.32	1155.82	0.1	0.0004	0.1	1.00E-02	1	4.00E-08
419	SM	149	Little Wedeene River Area	1152.32	1155.82	0	0	0	1.00E+00	1	0.00E+00
420	SM	150	Little Wedeene River North terrace face	1153.74	1153.86	1	0.1	0.001	1.00E-02	1	1.00E-06
368	LM	151	Little Wedeene River	1154.1	1154.86	1	0.01	0.1	1.00E-03	1	1.00E-06
491	SC	151	Little Wedeene River	1154.1	1154.86	1	0.01	0.1	1.00E-03	1	1.00E-06
432	LS	152	Kitimat Area	1155.82	1177.62	0.1	0.0004	1	1.00E-02	1	4.00E-07
421	SM	153	Kitimat Area	1155.82	1177.62	0	0	0	1.00E+00	1	0.00E+00
369	LM	154	West of Kitimat River	1158.8	1160	0.1	0.01	0.1	1.00E-02	100	1.00E-06
370	LM	155	Kitimat River near gravel pit	1164	1164.64	1	0.01	0.1	1.00E-02	100	1.00E-05
371	LM	156	Anderson Creek	1169.1	1169.26	0.1	0.01	0.001	1.00E+00	1	1.00E-06
492	SC	156	Anderson Creek	1169.1	1169.26	1	0.01	0.001	1.00E-03	1	1.00E-08
304	DF	159	Moore Creek	1170.38	1170.5	0.1	0.01	0	1.00E-03	1	0.00E+00
54	RF		Moore Creek	1170.38	1170.5	0.1	0.01	0	1.00E+00	1	0.00E+00
55	RF	161	West side of Kitimat Arm	1171.92	1173.64	1	0.1	0.1	1.00E-04	1	1.00E-06
422	SM	160	West side of Kitimat Arm	1172.52	1176.72	1	1	0.001	1.00E-03	1	1.00E-06
372	LM	163	West side of Kitimat Arm	1174.48	1174.66	0.01	0.001	0.001	1.00E+00	1	1.00E-08
305	DF	162	West side of Kitimat Arm	1174.48	1174.66	0.1	0.01	0.01	1.00E-02	1	1.00E-07
57	RF	161	West side of Kitimat Arm	1175.4	1175.8	0	0	0	1.00E+00	1	0.00E+00
493	SC	163	West side of Kitimat Arm	1175.48	1174.66	1	0.01	0.001	1.00E-03	1	1.00E-08
56	RF	161	West side of Kitimat Arm	1175.76	1177.3	0.01	0.001	0.01	1.00E+00	1	1.00E-07
74	DS	166	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00
433	LS	167	Kitimat Terminal	1177.6	1177.6	0.01	0.0004	1	1.00E-02	1	4.00E-08
423	SM	165	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00
58	RF	170	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00
306	DF	169	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00

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Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
226	AVA		Pass through Rockies	614	614.2	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
227	AVA		Pass through Rockies	615	615.2	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
228	AVA	59	Pass through Rockies	618.5	618.6	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
229	AVA	59	Pass through Rockies	622.1	622.25	0.01	0.0001	0.001	1.00E+00	1	1.00E-09
230	AVA	59	Pass through Rockies	624.3	624.32	0.01	0.001	0.001	1.00E+00	1	1.00E-08
231	AVA	59	Pass through Rockies	624.48	624.54	0.01	0.001	0.001	1.00E+00	1	1.00E-08
232	AVA	59	Pass through Rockies	625.5	625.6	0.01	0.001	0.001	1.00E+00	1	1.00E-08
233	AVA	71	Valley slopes of Tributary to Missinka River	637.9	638	0	0	0	1.00E+00	1	0.00E+00
234	AVA	71	Valley slopes of Tributary to Missinka River	638.9	639.3	0.1	0.001	0.001	1.00E+00	1	1.00E-07
235	AVA		Clore Tunnel - East Portal	1077.95	1078.55	0.01	0.001	0.1	1.00E+00	1	1.00E-06
236	AVA	117	Clore Tunnel - West Portal	1083.78	1084.6	0.01	0.001	0.001	1.00E+00	1	1.00E-08
237	AVA	117	Hoult Tunnel - East Portal	1084.95	1085.3	0	0.001	0.001	1.00E+00	1	0.00E+00
238	AVA	119	Hoult Tunnel - West Portal	1090.08	1091.3	0.01	0.001	0.001	1.00E+00	1	1.00E-08
240	AVA	125	Hoult Creek Valley	1094.48	1095.1	1	0.01	0.001	1.00E-02	1	1.00E-07
241	AVA	125	Hoult Creek Valley	1095.1	1095.38	0.1	0.01	0.001	1.00E-02	1	1.00E-08
242	AVA	125	Hoult Creek Valley	1095.82	1096.84	0.1	0.01	0.001	1.00E-02	1	1.00E-08
243	AVA	125	Hoult Creek Valley	1097.48	1098.04	1	0.01	0.001	1.00E-03	1	1.00E-08
244	AVA	132	Upper Kitimat River valley	1116.28	1116.6	0.01	0.001	0.001	1.00E-02	1	1.00E-10

18 Records

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
4	AVU	49	Quintette Creek	577.3	577.46	1	0.1	0.001	1.00E-02	1	1.00E-06
5	AVU	52	Five Cabin Creek	582.16	583.1	1	0.1	0.01	1.00E-02	1	1.00E-05
497	AVU		Tributary to Kinuseo	588.86	589.6	1	0.1	0.001	1.00E-02	1	1.00E-06
6	AVU		Pass through Rockies	617.7	618.52	0.1	0.01	0.001	1.00E+00	1	1.00E-06
7	AVU	68	Tributary to Missinka River	638.48	638.64	0.1	0.01	0.001	1.00E-02	1	1.00E-08
498	AVU		Tributary to Missinka River	652.1	652.56	1	0.1	0.001	1.00E-02	1	1.00E-06
8	AVU	82	Tributary to Chuchinka Creek	692.06	692.64	0.1	0.01	0.001	1.00E+00	1	1.00E-06
9	AVU	105	Crystal Creek	1049	1049.36	1	0.1	0.01	1.00E-03	1	1.00E-06
10	AVU		Tributary to Gosnell Creek	1061.82	1062	0.01	0.001	0.001	1.00E+00	1	1.00E-08
11	AVU	109	Tributary to Burnie River Fan	1071.06	1072.06	1	0.01	0.001	1.00E-02	1	1.00E-07
12	AVU		Hoult Creek Valley	1094.48	1095.1	1	0.1	0.001	1.00E-02	1	1.00E-06
503	AVU		Hoult Creek Valley	1095.1	1095.38	1	0.1	0.001	1.00E-02	1	1.00E-06
13	AVU		Hoult Creek Valley	1095.38	1095.78	1	0.1	0.001	1.00E-02	1	1.00E-06
14	AVU		Hoult Creek Valley	1095.82	1096.84	1	0.1	0.001	1.00E-02	1	1.00E-06
504	AVU		Hoult Creek Valley	1096.84	1097.06	1	0.1	0.001	1.00E-02	1	1.00E-06
505	AVU		Hoult Creek Valley	1097.06	1097.2	1	0.1	0.001	1.00E-02	1	1.00E-06
508	AVU		Hoult Creek Valley	1097.22	1097.38	1	0.1	0.001	1.00E-02	1	1.00E-06
510	AVU		Hoult Creek Valley	1097.38	1097.48	1	0.1	0.001	1.00E-02	1	1.00E-06
15	AVU		Hoult Creek Valley	1097.48	1098.04	1	0.1	0.001	1.00E-03	1	1.00E-07
16	AVU		Hoult Creek Valley	1099.06	1099.28	0.01	0.01	0.001	1.00E+00	1	1.00E-07
17	AVU	126	Hunter Creek	1103.86	1104.22	1	0.1	0.1	1.00E-04	1	1.00E-06
18	AVU	129	Upper Kitimat River valley	1106.96	1107.42	0.1	0.01	0.001	1.00E-02	1	1.00E-08
19	AVU	129	Upper Kitimat River valley	1107.52	1107.8	0.1	0.01	0.001	1.00E-02	1	1.00E-08
20	AVU		Upper Kitimat River valley	1110.36	1110.44	1	0.1	0.001	1.00E-02	1	1.00E-06
21	AVU		Upper Kitimat River valley	1113.38	1113.4	0.01	0.01	0.001	1.00E-02	1	1.00E-09
22	AVU		Upper Kitimat River valley	1114.04	1114.12	0.1	0.01	0.001	1.00E-02	1	1.00E-08
23	AVU		Upper Kitimat River valley	1114.68	1114.74	1	0.1	0.001	1.00E-02	1	1.00E-06
24	AVU		Upper Kitimat River valley	1114.86	1114.98	0.1	0.01	0.001	1.00E-02	1	1.00E-08
25	AVU		Upper Kitimat River valley	1116.28	1116.6	0.1	0.01	0.001	1.00E-02	1	1.00E-08
26	AVU		Upper Kitimat River valley	1117.94	1118.36	0.1	0.01	0.001	1.00E-02	1	1.00E-08
27	AVU		Upper Kitimat River valley	1119.38	1119.6	1	0.1	0.001	1.00E-02	1	1.00E-06
28	AVU		Upper Kitimat River valley	1120	1120.62	0.1	0.01	0.001	1.00E-02	1	1.00E-08
29	AVU		Upper Kitimat River valley	1121.22	1121.34	0.1	0.001	0.001	1.00E-02	1	1.00E-09
30	AVU		Upper Kitimat River valley	1121.94	1122.1	1	0.1	0.001	1.00E-02	1	1.00E-06
31	AVU		Upper Kitimat River valley	1127.48	1127.82	0.1	0.01	0.001	1.00E-02	1	1.00E-08

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC

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Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
245	DF	50	Tributary to Kinuseo Creek	579.94	580.04	0.01	0.01	0.01	1.00E-02	1	1.00E-08
246	DF		Five Cabin Creek	582.16	583.1	1	0.1	0.01	1.00E-02	1	1.00E-05
247	DF	58	Pass through Rockies	616.12	616.54	0	0.001	0.01	1.00E+00	1	0.00E+00
248	DF		Headwaters of Missinka River	629.7	629.8	0	0.001	0.01	1.00E+00	1	0.00E+00
249	DF		Headwaters of Missinka River	630.35	630.4	0	0.001	0.01	1.00E+00	1	0.00E+00
250	DF		Missinka River	632.1	632.2	0	0.001	0.01	1.00E+00	1	0.00E+00
251	DF	69	Tributary to Missinka River	633.92	633.96	0.01	0.01	0.01	1.00E-02	1	1.00E-08
252	DF	69	Tributary to Missinka River	635.06	635.12	0.1	0.01	0.01	1.00E-02	1	1.00E-07
253	DF	69	Tributary to Missinka River	637.14	637.2	0.1	0.01	0.01	1.00E-02	1	1.00E-07
254	DF	69	Tributary to Missinka River	637.3	637.3	0	0.001	0.01	1.00E+00	1	0.00E+00
255	DF	69	Tributary to Missinka River	638.48	638.64	0.1	0.01	0.01	1.00E-02	1	1.00E-07
256	DF	69	Tributary to Missinka River	638.9	638.9	0	0.001	0.01	1.00E+00	1	0.00E+00
257	DF		Tributary to Missinka River	639.58	639.6	0.01	0.01	0.01	1.00E-02	1	1.00E-08
258	DF		Tributary to Missinka River	645.94	645.96	0.01	0.01	0.01	1.00E-02	1	1.00E-08
259	DF		Tributary to Missinka River	646.7	647.24	0.01	0.01	0.01	1.00E-02	1	1.00E-08
260	DF		Tributary to Missinka River	652.1	652.56	0.1	0.01	0.01	1.00E-02	1	1.00E-07
261	DF		Tributary to Missinka River	655.1	655.22	0.1	0.01	0.01	1.00E-02	1	1.00E-07
262	DF		Tributary to Missinka River	656.26	656.36	0.1	0.01	0.01	1.00E-02	1	1.00E-07
263	DF		Tributary to Missinka River	659.66	659.76	0.1	0.01	0.01	1.00E-02	1	1.00E-08
264	DF		Tributary to Missinka River	661.36	661.46	0.1	0.01	0.01	1.00E-02	1	1.00E-07
265	DF		Tributary to Missinka River	662.02	662.26	0.1	0.01	0.01	1.00E-02	1	1.00E-07
266	DF		Tributary to Missinka River	665.22	665.3	0.1	0.01	0.01	1.00E-02	1	1.00E-07
267	DF		Tributary to Missinka River	666.46	666.54	0.1	0.01	0.01	1.00E-02	1	1.00E-07
268	DF		Tributary to Missinka River	667.82	668.58	0	0.001	0.01	1.00E+00	1	0.00E+00
269	DF	106	Crystal Creek	1049	1049.36	1	0.1	0.01	1.00E-03	1	1.00E-06
270	DF	107	Tributary to Gosnell Creek	1055.02	1055.1	0.1	0.01	0.01	1.00E-02	1	1.00E-07
271	DF	107	Tributary to Gosnell Creek	1057.34	1057.72	0.1	0.01	0.01	1.00E-02	1	1.00E-07
272	DF		Tributary to Gosnell Creek	1058.24	1058.7	0.1	0.01	0.01	1.00E-02	1	1.00E-07
273	DF		Tributary to Gosnell Creek	1059.6	1060	0.01	0.01	0.01	1.00E-02	1	1.00E-08
274	DF	110	Tributary to Burnie River Fan	1071.06	1072.06	0.1	0.01	0.01	1.00E-02	1	1.00E-07
275	DF	116	Tributary to Clore River crossing	1084.9	1084.94	0.01	0.01	0	1.00E-03	1	0.00E+00
276	DF	121	Hoult Creek	1092.02	1092.08	0.01	0.01	0	1.00E-03	1	0.00E+00
277	DF	121	Hoult Creek Valley	1093.1	1093.12	1	0.1	0.1	1.00E-04	1	1.00E-06
502	DF	121	Hoult Creek Valley	1094.08	1094.1	0.1	0.01	0.1	1.00E-02	1	1.00E-06
278	DF	121	Hoult Creek Valley	1094.48	1095.1	1	0.1	0.01	1.00E-02	1	1.00E-05

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
279	DF	121	Hoult Creek Valley	1095.1	1095.38	1	0.1	0.01	1.00E-02	1	1.00E-05
280	DF	121	Hoult Creek Valley	1095.38	1095.78	0.1	0.01	0.1	1.00E-02	1	1.00E-06
281	DF	121	Hoult Creek Valley	1095.82	1096.84	1	0.1	0.01	1.00E-02	1	1.00E-05
282	DF	121	Hoult Creek Valley	1096.84	1097.06	0.1	0.01	0.1	1.00E-02	1	1.00E-06
283	DF	121	Hoult Creek Valley	1097.06	1097.2	0.1	0.01	0.1	1.00E-02	1	1.00E-06
506	DF	121	Hoult Creek Valley	1097.22	1097.38	0.1	0.01	0.1	1.00E-02	1	1.00E-06
507	DF	121	Hoult Creek Valley	1097.38	1097.48	0.1	0.01	0.1	1.00E-02	1	1.00E-06
284	DF	121	Hoult Creek Valley	1097.48	1098.04	1	0.1	0.1	1.00E-03	1	1.00E-05
285	DF	121	Hoult Creek Valley	1099.06	1099.28	0.01	0.01	0.01	1.00E+00	1	1.00E-06
286	DF	127	Hunter Creek	1103.86	1104.22	1	0.1	0.01	1.00E-03	1	1.00E-06
287	DF	130	Upper Kitimat River valley	1106.56	1106.62	0.1	0.01	0.1	1.00E-02	1	1.00E-06
288	DF	130	Upper Kitimat River valley	1106.96	1107.42	0.1	0.1	0.01	1.00E-02	1	1.00E-06
289	DF	130	Upper Kitimat River valley	1107.52	1107.8	1	0.1	0.01	1.00E-03	1	1.00E-06
290	DF	134	Upper Kitimat River valley	1110.36	1110.44	0.1	0.1	0.01	1.00E-02	1	1.00E-06
291	DF	134	Upper Kitimat River valley	1113.38	1113.4	0.1	0.1	0.1	1.00E-02	1	1.00E-05
292	DF	134	Upper Kitimat River valley	1113.7	1113.8	0.01	0.01	0.1	1.00E-02	1	1.00E-07
293	DF	134	Upper Kitimat River valley	1114.04	1114.12	0.01	0.01	0.1	1.00E-02	1	1.00E-07
294	DF	134	Upper Kitimat River valley	1114.68	1114.74	0.1	0.01	0.1	1.00E-02	1	1.00E-06
295	DF	134	Upper Kitimat River valley	1114.86	1114.98	0.1	0.01	0.1	1.00E-02	1	1.00E-06
512	DF	134	Upper Kitimat River valley	1115.28	1115.32	0.01	0.01	0.1	1.00E-02	1	1.00E-07
513	DF	134	Upper Kitimat River valley	1115.6	1135.64	0.01	0.01	0.1	1.00E-02	1	1.00E-07
296	DF	134	Upper Kitimat River valley	1116.28	1116.6	0.1	0.1	0.1	1.00E-02	1	1.00E-05
297	DF	134	Upper Kitimat River valley	1117.16	1117.28	0.1	0.01	0.1	1.00E-02	1	1.00E-06
298	DF	134	Upper Kitimat River valley	1117.94	1118.36	0.1	0.01	0.1	1.00E-02	1	1.00E-06
299	DF	134	Upper Kitimat River valley	1119.36	1119.52	0.1	0.1	0.1	1.00E-02	1	1.00E-05
300	DF	134	Upper Kitimat River valley	1120	1120.62	0.1	0.1	0.1	1.00E-02	1	1.00E-05
301	DF	134	Upper Kitimat River valley	1121.22	1121.34	0.1	0.01	0.01	1.00E-02	1	1.00E-07
302	DF	134	Upper Kitimat River valley	1121.94	1122.1	0.1	0.01	0.1	1.00E-02	1	1.00E-06
303	DF		Upper Kitimat River valley	1127.48	1127.82	0.1	0.01	0.01	1.00E-02	1	1.00E-07
304	DF	159	Moore Creek	1170.38	1170.5	0.1	0.01	0	1.00E-03	1	0.00E+00
305	DF	162	West side of Kitimat Arm	1174.48	1174.66	0.1	0.01	0.01	1.00E-02	1	1.00E-07
306	DF	169	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00

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Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
59	DS	5	Swan Hills southeast of Whitecourt	177.52	183.94	1	0.001	0.1	1.00E-02	1	1.00E-06
60	DS	9	North approach to Athabasca River	187	187.14	0	0	0	1.00E+00	1	0.00E+00
527	DS		East approach slope to Sakwatamau River	198.75	199.1	1	1	1	1.00E-05	1	1.00E-05
61	DS	19	East Approach to Little Smoky River	289.7	290.1	0.1	0.01	1	1.00E-03	10	1.00E-06
62	DS	21	West Approach Slope to Little Smoky River	290.6	291.1	1	0.01	1	1.00E-03	10	1.00E-05
517	DS		Deep Valley Creek West valley slopes	338.78	339.42	1	1	0.1	1.00E-04	1	1.00E-05
63	DS	28	East valley slope of Latornell River	370.94	371.28	1	1	0.1	1.00E-05	0.01	1.00E-06
495	DS	28	West valley slope of Latornell River	371.3	372	1	1	0.1	1.00E-05	0.01	1.00E-06
64	DS	30	West of Latornell River	372.1	374	0.1	0.1	1	1.00E-03	1	1.00E-05
65	DS	33	East valley slope of Smoky River	419.5	419.9	0.1	0.01	1	1.00E-03	1	1.00E-06
66	DS	35	West valley slope of Smoky River	421.7	422.28	1	1	0.1	1.00E-04	1	1.00E-05
69	DS	47	Wapiti River area	494.9	495.2	0	0	0	1.00E+00	1	0.00E+00
70	DS	94	Stuart River East valley slope	824.3	824.6	0.01	0.001	1	1.00E-03	1	1.00E-08
71	DS	94	Stuart River West valley slope	825	825.5	0.01	0.001	0.1	1.00E-01	1	1.00E-07
323	DS		West of Owen Creek	1006.7	1007.1	0	0.1	0.1	1.00E-03	1	0.00E+00
72	DS	145	North of Wedeene River	1149	1149.7	0	0	0	1.00E+00	1	0.00E+00
73	DS	145	Wedeene River West Approach	1150.6	1154.5	0.01	0.001	1	1.00E+00	1	1.00E-05
74	DS	166	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00

18 Records

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
343	LM	38	Gold Creek			0	0	0	1.00E+00	1	0.00E+00
326	LM		Riviere Qui Barre	62.8	62.96	1	0.01	0.001	1.00E-03	1	1.00E-08
327	LM	3	Pembina River	130.78	131.06	1	0.01	0.1	1.00E-03	1	1.00E-06
328	LM		Paddle River	137.4	137.66	1	0.01	0.001	1.00E-03	1	1.00E-08
329	LM	4	Little Paddle River	162.82	163.18	1	0.01	0.001	1.00E-03	1	1.00E-08
330	LM	7	Athabasca River	186.18	187.02	1	0.1	0.1	1.00E-03	1	1.00E-05
331	LM	10	Sakwatamau River	199.06	200.16	1	0.01	0.001	1.00E-03	1	1.00E-08
332	LM	13	Chickadee Creek	218.46	218.62	1	0.01	0.001	1.00E-03	1	1.00E-08
333	LM	14	Two Creek	241.2	242.4	1	0.01	0.001	1.00E-03	1	1.00E-08
334	LM	17	Iosegun River	258.2	258.48	1	0.01	0.001	1.00E-03	1	1.00E-08
335	LM	20	Little Smoky River crossing	290.02	290.56	1	0.1	0.1	1.00E-03	1	1.00E-05
336	LM	22	Waskahigan River	317.1	317.9	1	0.01	0.001	1.00E-03	1	1.00E-08
337	LM	23	Deep Valley Creek	337.9	338.36	1	0.1	0.001	1.00E-03	1	1.00E-07
338	LM	24	Tributary to Deep Valley Creek	340.06	340.222	1	0.01	0.001	1.00E-03	1	1.00E-08
339	LM	27	Simonette River	358.94	359.46	1	0.1	0.1	1.00E-03	1	1.00E-05
340	LM	29	Latornell River	371.26	371.3	1	0.01	0.001	1.00E-03	1	1.00E-08
341	LM	31	Tributary to Smoky River	395.1	395.12	1	0.01	0.001	1.00E-03	1	1.00E-08
342	LM	34	Smoky River floodplain	420.18	421.74	1	0.1	0.1	1.00E-04	10	1.00E-06
344	LM	41	Big Mountain Creek	428.92	429.28	1	0.01	0.001	1.00E-03	1	1.00E-08
345	LM	43	Bald Mountain Creek	446.64	446.72	1	0.01	0.001	1.00E-03	1	1.00E-08
346	LM		Wilson Creek	453.66	453.86	1	0.01	0.001	1.00E-03	1	1.00E-08
347	LM		South Redwillow River	534.12	534.18	0.1	0.001	0.001	1.00E-03	1	1.00E-10
348	LM	51	Kinuseo Creek near alignment	580.7	581.8	0.01	0.001	0.1	1.00E+00	1	1.00E-06
349	LM	53	Kinuseo Creek near alignment	587.74	587.74	0.1	0.01	0.1	1.00E-02	1	1.00E-06
428	LM	53	Kinuseo Creek	590.3	590.68	1	0.1	0.001	1.00E-03	1	1.00E-07
350	LM		Murray River	600.8	600.92	1	0.1	0.01	1.00E-03	0.1	1.00E-06
351	LM	57	Hook Creek	604.64	604.76	1	0.1	0.001	1.00E-03	1	1.00E-07
352	LM	77	Parsnip River	673.6	674.14	1	0.1	0.1	1.00E-03	1	1.00E-05
353	LM	82	Tributary to Chuchinka Creek near alignment	689.8	700.8	0	0	0	1.00E+00	1	0.00E+00
494	LM		Tributary to Chuchinka Creek	705.66	705.86	1	0.1	0.001	1.00E-03	1	1.00E-07
354	LM	86	Angusmac Creek	713.16	713.44	1	1	0.001	1.00E-03	1	1.00E-06
355	LM	87	Crooked River	720.88	721.36	1	0.1	0.001	1.00E-03	1	1.00E-07
356	LM	90	Muskeg River	750.8	750.9	1	0.01	0.001	1.00E-03	1	1.00E-08
357	LM	91	Salmon River	765.44	765.9	1	1	0.01	1.00E-03	1	1.00E-05

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
515	LM		Maxan Creek	951.2	951.58	1	0.01	0.001	1.00E-03	1	1.00E-08
358	LM	97	Klo Creek	978.44	978.68	1	0.1	0.001	1.00E-03	1	1.00E-07
359	LM		Buck Creek	989.78	990.16	1	0.1	0.001	1.00E-03	1	1.00E-07
532	LM		Owen Creek	1006.7	1006.72	1	0.01	0.001	1.00E-03	1	1.00E-08
533	LM		Fenton Creek	1012.78	1012.8	1	0.1	0.001	1.00E-03	1	1.00E-07
539	LM		24.5 Mile Creek	1018.4	1018.42	1	0.1	0.001	1.00E-05	1	1.00E-09
535	LM		Lamprey Creek	1024.66	1024.84	1	0.1	0.001	1.00E-03	1	1.00E-07
360	LM	102	Cedric Creek	1028.45	1028.55	0	0	0	1.00E-03	1	0.00E+00
544	LM		Morice River	1043.06	1043.42	1	0.01	0.1	1.00E-03	1	1.00E-06
361	LM	108	Gosnell Creek	1063.76	1064.08	1	0.1	0.001	1.00E-03	1	1.00E-07
526	LM		Tributary to Burnie River	1076.3	1076.56	1	0.01	0.001	1.00E-03	1	1.00E-08
362	LM	114	Clore River	1077.4	1077.94	1	1	1	1.00E-04	100	1.00E-04
363	LM	123	Hoult Creek	1092.02	1092.08	0.01	0.001	0.001	1.00E-03	1	1.00E-11
366	LM	136	Upper Kitimat River valley	1120.9	1121.4	0	0.001	0.001	1.00E+00	1	0.00E+00
367	LM	137	Chist Creek	1128.26	1128.6	1	0.1	0.01	1.00E-02	1	1.00E-05
368	LM	151	Little Wedeene River	1154.1	1154.86	1	0.01	0.1	1.00E-03	1	1.00E-06
369	LM	154	West of Kitimat River	1158.8	1160	0.1	0.01	0.1	1.00E-02	100	1.00E-06
370	LM	155	Kitimat River near gravel pit	1164	1164.64	1	0.01	0.1	1.00E-02	100	1.00E-05
371	LM	156	Anderson Creek	1169.1	1169.26	0.1	0.01	0.001	1.00E+00	1	1.00E-06
372	LM	163	West side of Kitimat Arm	1174.48	1174.66	0.01	0.001	0.001	1.00E+00	1	1.00E-08

54 Records

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
429	LS	142	Eastern flank on Iron Mountain	1140.62	1149.52	0	0	0	1.00E+00	1	0.00E+00
430	LS	147	Wedeene River area	1149.52	1152.32	0.1	0.0004	1	1.00E-02	1	4.00E-07
431	LS	148	Little Wedeene River Area	1152.32	1155.82	0.1	0.0004	0.1	1.00E-02	1	4.00E-08
432	LS	152	Kitimat Area	1155.82	1177.62	0.1	0.0004	1	1.00E-02	1	4.00E-07
433	LS	167	Kitimat Terminal	1177.6	1177.6	0.01	0.0004	1	1.00E-02	1	4.00E-08

5 Records

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
33	RF	63	Pass through Rockies	623.55	623.7	0.1	0.1	0.01	1.00E-02	0.1	1.00E-06
34	RF	118	Clore Tunnel - West Portal	1083.78	1084.6	0.01	0.01	0.01	1.00E+00	1	1.00E-06
35	RF	118	Tributary to Clore River crossing	1084.9	1084.94	1	0.1	0	1.00E+00	1	0.00E+00
36	RF	118	Hoult Tunnel - East Portal	1085.64	1086.02	0.1	0.01	0.01	1.00E+00	1	1.00E-05
37	RF	120	Hoult Tunnel - West Portal	1090.08	1091.3	0.1	0.01	0.01	1.00E+00	1	1.00E-05
38	RF	122	Hoult Creek	1092.02	1092.08	0.001	0.001	1	1.00E+00	1	1.00E-06
39	RF	122	Hoult Creek Valley	1094.48	1095.1	1	0.01	0.01	1.00E-02	1	1.00E-06
40	RF	122	Hoult Creek Valley	1095.1	1095.38	1	0.01	0.01	1.00E-02	1	1.00E-06
41	RF	122	Hoult Creek Valley	1095.38	1095.78	1	0.01	0.01	1.00E-02	1	1.00E-06
42	RF	122	Hoult Creek Valley	1095.82	1096.84	1	0.01	0.01	1.00E-02	1	1.00E-06
43	RF	122	Hoult Creek Valley	1096.84	1097.06	1	0.01	0.01	1.00E-02	1	1.00E-06
44	RF	122	Hoult Creek Valley	1097.06	1097.2	1	0.01	0.01	1.00E-02	1	1.00E-06
509	RF	122	Hoult Creek Valley	1097.22	1097.38	1	0.01	0.01	1.00E-02	1	1.00E-06
511	RF	122	Hoult Creek Valley	1097.38	1097.48	1	0.01	0.01	1.00E-02	1	1.00E-06
45	RF	123	Hoult Creek Valley	1097.48	1098.04	1	0.01	0.01	1.00E-03	1	1.00E-07
46	RF	124	Hoult Creek Valley	1099.06	1099.28	0.01	0.001	0.001	1.00E+00	1	1.00E-08
47	RF	135	Upper Kitimat River valley	1106.96	1107.42	0.01	0.001	0.01	1.00E-02	1	1.00E-09
48	RF	135	Upper Kitimat River valley	1114.86	1114.98	1	0.1	0.01	1.00E-02	1	1.00E-05
49	RF	135	Upper Kitimat River valley	1116.28	1116.6	0.1	0.01	0.01	1.00E-02	1	1.00E-07
50	RF	135	Upper Kitimat River valley	1119.44	1120.24	0.1	0.01	0.01	1.00E-02	1	1.00E-07
51	RF	135	Upper Kitimat River valley	1126.12	1128.26	1	0.01	0.01	1.00E-02	1	1.00E-06
52	RF	141	Eastern flank on Iron Mountain	1142.4	1142.52	1	0.1	0.1	1.00E-03	1	1.00E-05
53	RF	144	Southeast flank of Iron Mountain	1148.6	1148.7	1	0.1	0.1	1.00E-03	1	1.00E-05
54	RF		Moore Creek	1170.38	1170.5	0.1	0.01	0	1.00E+00	1	0.00E+00
55	RF	161	West side of Kitimat Arm	1171.92	1173.64	1	0.1	0.1	1.00E-04	1	1.00E-06
57	RF	161	West side of Kitimat Arm	1175.4	1175.8	0	0	0	1.00E+00	1	0.00E+00
56	RF	161	West side of Kitimat Arm	1175.76	1177.3	0.01	0.001	0.01	1.00E+00	1	1.00E-07
58	RF	170	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00

28 Records

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
459	SC	38	Gold Creek			0	0	0	1.00E+00	1	0.00E+00
434	SC		North Saskatchewan River	2.58	3	1	0.01	0.1	1.00E-03	1	1.00E-06
435	SC		Riviere Qui Barre	62.8	62.96	1	0.01	0.001	1.00E-03	1	1.00E-08
436	SC	3	Pembina River	130.78	131.06	1	0.01	0.1	1.00E-03	1	1.00E-06
437	SC		Paddle River	137.4	137.66	1	0.01	0.001	1.00E-03	1	1.00E-08
438	SC	4	Little Paddle River	162.82	163.18	1	0.01	0.001	1.00E-03	1	1.00E-08
439	SC	7	Athabasca River	186.18	187.02	1	0.01	0.1	1.00E-03	1	1.00E-06
440	SC	10	Sakwatamau River	199.06	200.16	1	0.01	0.001	1.00E-03	1	1.00E-08
441	SC	13	Chickadee Creek	218.46	218.62	1	0.01	0.001	1.00E-03	1	1.00E-08
442	SC	14	Two Creek	241.2	242.4	1	0.01	0.001	1.00E-03	1	1.00E-08
443	SC	17	Iosegun River	258.2	258.48	1	0.01	0.001	1.00E-03	1	1.00E-08
444	SC	20	Little Smoky River crossing	290.02	290.56	1	0.01	0.1	1.00E-03	1	1.00E-06
445	SC	22	Waskahigan River	317.1	317.9	1	0.01	0.001	1.00E-03	1	1.00E-08
446	SC		Incised creek valley draining to north	331.64	331.76	1	0.01	0.001	1.00E-03	1	1.00E-08
447	SC		Incised creek valley draining to north	334.5	334.58	1	0.01	0.001	1.00E-03	1	1.00E-08
448	SC	23	Deep Valley Creek	337.9	338.36	1	0.01	0.001	1.00E-03	1	1.00E-08
449	SC	24	Tributary to Deep Valley Creek	340.06	340.22	1	0.01	0.001	1.00E-03	1	1.00E-08
522	SC		Creek crossing west of tributary to Deep Valley Creek	341.32	341.34	1	0.01	0.001	1.00E-03	1	1.00E-08
450	SC		Tributaries to Simonette	353.56	353.58	1	0.01	0.001	1.00E-03	1	1.00E-08
451	SC		Tributaries to Simonette	354.58	354.62	1	0.01	0.001	1.00E-03	1	1.00E-08
452	SC		Tributaries to Simonette	355.18	355.22	1	0.01	0.001	1.00E-03	1	1.00E-08
453	SC		Tributaries to Simonette	356.38	356.4	1	0.01	0.001	1.00E-03	1	1.00E-08
454	SC		Tributaries to Simonette	357.26	357.32	1	0.01	0.001	1.00E-03	1	1.00E-08
455	SC	27	Simonette River	358.94	359.46	1	0.01	0.1	1.00E-03	1	1.00E-06
456	SC	29	Latornell River	371.26	371.3	1	0.01	0.001	1.00E-03	1	1.00E-08
457	SC	31	Tributary to Smoky River	395.1	395.12	1	0.01	0.001	1.00E-03	1	1.00E-08
458	SC	34	Smoky River floodplain	420.18	421.74	1	0.01	0.1	1.00E-03	1	1.00E-06
460	SC	41	Big Mountain Creek	428.92	429.28	1	0.01	0.001	1.00E-03	1	1.00E-08
461	SC	43	Bald Mountain Creek	446.64	446.72	1	0.01	0.001	1.00E-03	1	1.00E-08
462	SC		Wilson Creek	453.66	453.86	1	0.01	0.001	1.00E-03	1	1.00E-08
463	SC		Pinto Creek	474.2	474.28	1	0.01	0.001	1.00E-03	1	1.00E-08
464	SC		Wapiti River	494.94	495.6	0.1	0.01	0.1	1.00E-03	1	1.00E-07
465	SC		South Redwillow River	534.12	534.18	0.1	0.01	0.001	1.00E-03	1	1.00E-09
466	SC		Kinuseo Creek	568.2	568.26	1	0.01	0.001	1.00E-03	1	1.00E-08

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
467	SC		Kinuseo Creek	590.3	590.68	1	0.01	0.001	1.00E-03	1	1.00E-08
468	SC		Murray River	600.8	600.92	1	0.01	0.1	1.00E-03	1	1.00E-06
469	SC	57	Hook Creek	604.64	604.76	1	0.01	0.001	1.00E-03	1	1.00E-08
470	SC		Missinka River	643.38	643.46	1	0.01	0.001	1.00E-03	1	1.00E-08
471	SC		Missinka River	648.1	648.2	1	0.01	0.001	1.00E-03	1	1.00E-08
472	SC	77	Parsnip River	673.6	674.14	1	0.01	0.1	1.00E-03	1	1.00E-06
473	SC	86	Angusmac Creek	713.16	713.44	1	0.01	0.001	1.00E-03	1	1.00E-08
474	SC	87	Crooked River	720.88	721.36	1	0.01	0.001	1.00E-03	1	1.00E-08
475	SC	90	Muskeg River	750.8	750.9	1	0.01	0.001	1.00E-03	1	1.00E-08
476	SC	91	Salmon River	765.44	765.9	1	0.01	0.001	1.00E-03	1	1.00E-08
477	SC		Necoslie River	819.32	819.46	1	0.01	0.001	1.00E-03	1	1.00E-08
478	SC		Stuart River	824.76	825.08	1	0.01	0.1	1.00E-03	1	1.00E-06
500	SC		Sutherland River	859.4	859.48	1	0.01	0.001	1.00E-03	1	1.00E-08
479	SC	97	Klo Creek	978.44	978.68	1	0.01	0.001	1.00E-03	1	1.00E-08
480	SC		Buck Creek	989.78	990.16	1	0.01	0.001	1.00E-03	1	1.00E-08
481	SC		Owen Creek	1005.2	1005.4	0	0.01	0.001	1.00E-03	1	0.00E+00
482	SC		Fenton Creek	1012.78	1012.8	1	0.01	0.001	1.00E-03	1	1.00E-08
483	SC		Lamprey Creek	1024.66	1024.84	1	0.01	0.001	1.00E-03	1	1.00E-08
485	SC	102	Cedric Creek	1028.45	1028.55	0	0	0	1.00E-03	1	0.00E+00
538	SC		Cedric Creek	1032.72	1032.74	0.1	0.01	0.001	1.00E-03	1	1.00E-09
484	SC		Morice River	1043.06	1043.42	1	0.01	0.1	1.00E-03	1	1.00E-06
486	SC	108	Gosnell Creek	1063.76	1064.08	1	0.01	0.001	1.00E-03	1	1.00E-08
525	SC		Tributary to Burnie River	1076.3	1076.56	1	0.01	0.001	1.00E-03	1	1.00E-08
487	SC	114	Clore River	1077.4	1077.94	1	0.01	0.1	1.00E-03	1	1.00E-06
488	SC	126	Hunter Creek	1103.86	1104.22	1	0.01	0.001	1.00E-03	1	1.00E-08
489	SC	137	Chist Creek	1128.26	1128.6	1	0.01	0.001	1.00E-03	1	1.00E-08
514	SC		Cecil Creek	1136.68	1136.74	1	0.01	0.001	1.00E-03	1	1.00E-08
490	SC		Wedeene River	1150.08	1150.14	1	0.01	0.1	1.00E-03	1	1.00E-06
491	SC	151	Little Wedeene River	1154.1	1154.86	1	0.01	0.1	1.00E-03	1	1.00E-06
492	SC	156	Anderson Creek	1169.1	1169.26	1	0.01	0.001	1.00E-03	1	1.00E-08
493	SC	163	West side of Kitimat Arm	1175.48	1174.66	1	0.01	0.001	1.00E-03	1	1.00E-08

65 Records

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
383	SM	36	Gold Creek			0	0	0	1.00E+00	1	0.00E+00
373	SM	2	North Saskatchewan River west valley slope	3	4.1	0	0	0	1.00E+00	1	0.00E+00
516	SM		Paddle River East valley slope	137.18	137.48	1	0.1	0.01	1.00E-03	1	1.00E-06
530	SM		Swan Hills Area East of Whitecourt	183.5	183.8	0.1	0.01	0.01	1.00E-03	1	1.00E-08
374	SM	8	North approach to Athabasca River	187	187.14	1	1	0.001	1.00E-03	1	1.00E-06
375	SM	11	Narrow corridor near Sakwatamau River	200.16	202.26	1	0.1	0.01	1.00E-03	1	1.00E-06
376	SM	12	Tributary to Chickadee Creek valley slopes	215.16	215.56	0.1	0.1	0.001	1.00E-02	1	1.00E-07
528	SM		East of Two Creek	241.5	241.65	0	1	0.01	1.00E-03	1	0.00E+00
529	SM		East approach slopes of Two Creek	241.65	241.85	0	0.1	0.001	1.00E-02	1	0.00E+00
377	SM	15	East approach slope to Iosegun River	257.96	258.2	0.1	0.1	0.001	1.00E-02	1	1.00E-07
426	SM		West approach slope to Iosegun River	258.48	259.06	0.1	0.1	0.001	1.00E-03	1	1.00E-08
378	SM		East Approach slope to Little Smoky River	289.72	290.02	0.1	0.01	0.01	1.00E-02	10000	1.00E-07
518	SM		Tributrary to Deep Valley Creek East valley slopes	339.86	340.06	1	1	0.001	1.00E-02	1	1.00E-05
519	SM		Tributrary to Deep Valley Creek West valley slopes	340.22	340.34	1	1	0.001	1.00E-02	1	1.00E-05
520	SM		West of Tributary to Deep Valley Creek	340.34	341	0.1	1	0.01	1.00E-04	0.1	1.00E-07
521	SM		Creek crossing west of tributary to Deep Valley Creek	341	341.42	1	1	0.01	1.00E-04	0.1	1.00E-06
380	SM	32	Tributary to Smoky River valley slopes	395.02	395.22	1	0.1	0.001	1.00E-02	1	1.00E-06
381	SM		Tributary to Smoky River valley slopes	403.58	403.96	0.01	0.01	0.001	1.00E-02	1	1.00E-09
382	SM		East valley slope of Smoky River	419.4	419.9	0.01	0.01	0.01	1.00E-02	1	1.00E-08
384	SM	39	Big Mountain Creek valley slopes	428.16	429.52	1	0.1	0.01	1.00E-02	10	1.00E-05
385	SM	42	Bald Mountain Creek west valley slopes	446.4	446.76	0.1	0.1	0.001	1.00E-03	1	1.00E-08
386	SM		Tributary to Iroquois Creek valley slopes	458.76	459	1	1	0.001	1.00E-02	1	1.00E-05
387	SM		Pinto Creek meander bend 1	470.84	471.08	1	1	0.01	1.00E-03	1	1.00E-05
424	SM		Pinto Creek meander bend 2	473	473.5	1	1	0.01	1.00E-03	1	1.00E-05
68	SM	46	Pinto Creek East valley slope	474.02	474.12	1	1	0.01	1.00E-04	0.1	1.00E-06
427	SM		Pinto Creek West valley slope	474.34	474.44	1	1	0.01	1.00E-03	1	1.00E-05
388	SM		Ridge on West Side of Wapiti River	496.3	497	0.1	0.01	0.01	1.00E-01	100	1.00E-06
389	SM	48	Quintette Mountain area rock cuts	568.4	581.78	0.1	0.1	0.001	1.00E-01	1	1.00E-06
390	SM	54	Tributary of Murray River	598.82	598.98	1	1	0.01	1.00E-03	1	1.00E-05
392	SM	56	Hook Creek east approach slopes	604.6	604.64	1	1	0.001	1.00E-03	1	1.00E-06
545	SM		Hook Creek west approach slope	604.76	604.8	1	1	0.001	1.00E-03	1	1.00E-06

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
393	SM	60	Pass through Rockies	619.2	625.7	0.1	0.1	0	1.00E+00	1	0.00E+00
394	SM	64	Headwaters of Hominka River	627.3	628.7	0.1	0.1	0	1.00E+00	1	0.00E+00
395	SM	70	Valley slopes of Tributary to Missinka River	636.7	639.3	0.1	0.1	0	1.00E+00	1	0.00E+00
396	SM	72	Missinka River valley slopes	642.68	643.7	0.1	0.1	0	1.00E+00	1	0.00E+00
397	SM	73	Missinka River area	643.7	668.7	0.1	0.1	0	1.00E+00	1	0.00E+00
398	SM	75	West of Parsnip River	673.84	675.24	0.1	0.1	0	1.00E+00	1	0.00E+00
399	SM	78	West of Wichcika Creek	682	688	0.1	0.1	0	1.00E+00	1	0.00E+00
400	SM	81	Tributary to Chuchinka Creek area	689.8	700.8	0.1	0.1	0	1.00E+00	1	0.00E+00
401	SM	84	Angusmac Creek East Valley Slope	712.66	713.16	1	0.1	0.001	1.00E-02	10	1.00E-06
499	SM	84	Angusmac Creek West Valley Slopes	713.55	713.9	1	0.1	0.001	1.00E-02	10	1.00E-06
402	SM	92	West valley slope of Salmon River	765.9	766.14	1	1	0.001	1.00E-03	1	1.00E-06
523	SM		Tributary to Beaver Lake	782.38	782.58	0.1	0.1	0.001	1.00E-03	1	1.00E-08
403	SM		Necoslie River valley slopes	818.92	819.32	1	0.1	0.01	1.00E-03	1	1.00E-06
404	SM	95	Stuart River West valley slope	825.02	825.08	1	1	0.1	1.00E-04	0.1	1.00E-05
524	SM		Sutherland River East valley slope	859.24	859.4	1	1	0.001	1.00E-03	1	1.00E-06
405	SM	98	Klo Creek East valley slopes	977.34	977.96	1	0.1	0.001	1.00E-03	1	1.00E-07
546	SM		Klo Creek east approach Lower slopes	978.3	978.44	1	0.1	0.001	1.00E-03	1	1.00E-07
501	SM	98	Klo Creek West valley slopes	978.68	978.72	1	0.1	0.001	1.00E-03	1	1.00E-07
541	SM		Owen Creek East Approach Slopes	1006.58	1006.7	1	0.01	0.001	1.00E-03	1	1.00E-08
543	SM		Owen Creek West Approach Slopes	1006.72	1006.8	0.1	0.01	0.001	1.00E-02	1	1.00E-08
534	SM		Fenton Creek East Approach Slope	1012.74	1012.78	0.1	0.01	0.001	1.00E-03	1	1.00E-09
542	SM		Fenton Creek West Approach Slope	1012.8	1012.86	0.1	0.01	0.001	1.00E-03	1	1.00E-09
540	SM		24.5 Mile Creek East approach slope	1018.36	1018.4	1	0.01	0.001	1.00E-03	1	1.00E-08
406	SM	100	Lamprey Creek East valley slopes	1021	1022	0	0	0	1.00E-03	1	0.00E+00
537	SM		Lamprey Creek East approach slope	1024.36	1024.66	1	0.01	0.001	1.00E-04	1	1.00E-09
407	SM	101	Cedric Creek valley slopes	1028.3	1029.1	0	0	0	1.00E-03	1	0.00E+00
408	SM	103	Side slopes of Morice River valley	1035.1	1038.1	0	0.1	0.01	1.00E-03	1	0.00E+00
409	SM	112	East approach slope to Burnie and Clore River valleys	1075.2	1075.65	0.1	0.01	0.01	1.00E-03	1	1.00E-08
410	SM	115	Tributary to Clore River and adjacent areas	1083.78	1084.6	1	0.1	0.001	1.00E-02	1	1.00E-06
411	SM	124	Hoult Creek and Upper Kitimat River valley	1092.12	1106.42	0.1	0.1	0.001	1.00E-02	10	1.00E-07
412	SM	128	Hunter Creek valley slopes	1099.05	1104.2	0	0	0	1.00E-03	1	0.00E+00
413	SM	131	Upper Kitimat River valley	1106.62	1124.62	0.1	0.1	0.001	1.00E-02	1	1.00E-07

Geohazard List

ID	Category	Feature	Location	KP (Rev V) Start	End	OF	EF	VF	MO	FManual	FLOC
414	SM		North Side Kitimat River	1113.7	1113.82	1	1	0.001	1.00E-03	1	1.00E-06
415	SM	143	Eastern flank on Iron Mountain	1140.62	1149.52	0.1	0.0004	0.1	1.00E+00	1	4.00E-06
416	SM	139	Eastern flank on Iron Mountain	1141	1142.6	0	0	0	1.00E+00	1	0.00E+00
417	SM	146	North of Wedeene River	1148.7	1149.1	0.1	0.01	0.01	1.00E+00	1	1.00E-05
418	SM	146	Wedeene River west valley slope	1150.18	1150.38	1	0.01	0.001	1.00E-03	1	1.00E-08
419	SM	149	Little Wedeene River Area	1152.32	1155.82	0	0	0	1.00E+00	1	0.00E+00
420	SM	150	Little Wedeene River North terrace face	1153.74	1153.86	1	0.1	0.001	1.00E-02	1	1.00E-06
421	SM	153	Kitimat Area	1155.82	1177.62	0	0	0	1.00E+00	1	0.00E+00
422	SM	160	West side of Kitimat Arm	1172.52	1176.72	1	1	0.001	1.00E-03	1	1.00E-06
423	SM	165	Kitimat Terminal	1177.6	1177.6	0	0	0	1.00E+00	1	0.00E+00

73 Records

Geohazard Detail

ID 343 **Gold Creek**

Category	Lateral Migration	**KP (Rev V) Start**		**Feature**	38
Source	Geotechnical Report	**KP (Rev V) End**			

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Estimated Frequency	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Vunerability Factor	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail ID 383 Gold Creek

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**		**Feature**	36
Source	Geotechnical Report	**KP (Rev V) End**			

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Estimated Frequency	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Vunerability Factor	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail

ID 459 **Gold Creek**

Category	Scour	**KP (Rev V) Start**		**Feature**	38
Source	Geotechnical Report	**KP (Rev V) End**			

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Estimated Frequency	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Vunerability Factor	0	Legacy record from a previous alignment. REVU does not cross Gold Creek.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail ID 434 North Saskatchewan River

Category	Scour	**KP (Rev V) Start**	2.58	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	3		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	220m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.38E-09

Geohazard Detail

ID 373

North Saskatchewan River west valley slope

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	3	**Feature**	2
Source	Geotechnical Report	**KP (Rev V) End**	4.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	The route deviates to the south to run up the west approach slope of the river valley south of a tributary stream gully. Shallow sliding in gully is avoided by routing.
Estimated Frequency	0	The route deviates to the south to run up the west approach slope of the river valley south of a tributary stream gully. Shallow sliding in gully is avoided by routing.
Vunerability Factor	0	The route deviates to the south to run up the west approach slope of the river valley south of a tributary stream gully. Shallow sliding in gully is avoided by routing.
Mitigation Options	1.00E+00	The route deviates to the south to run up the west approach slope of the river valley south of a tributary stream gully. Shallow sliding in gully is avoided by routing.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail **ID** 326 **Riviere Qui Barre**

Category	Lateral Migration	**KP (Rev V) Start**	62.8	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	62.96		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river with old meander scars/oxbows present near crossing. Meander bend east of crossing may be succeptable to migration towards route.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Very minor occurrence of fresh gravel bars. Field asessment required.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	Design should address meander bend east of crossing.

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail

ID 435 **Riviere Qui Barre**

Category	Scour	**KP (Rev V) Start**	62.8	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	62.96		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.25E-11

Geohazard Detail ID 327 Pembina River

Category	Lateral Migration	**KP (Rev V) Start**	130.78	**Feature**	3
Source	Geotechnical Report	**KP (Rev V) End**	131.06		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	High sinuosity meandering river with scars/oxbows present near crossing. River incised several meters below terraces. Tending to migrate northwest, potential for cutoffs upstream and downstream
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Only minor occurrence of fresh bars. Field asessment required.
Vunerability Factor	0.1	80m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 8.33E-10

Geohazard Detail ID 436 Pembina River

Category	Scour	**KP (Rev V) Start**	130.78	**Feature**	3
Source	Geotechnical Report	**KP (Rev V) End**	131.06		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	80m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 8.33E-10

Geohazard Detail

ID 516 | **Paddle River East valley slope**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	137.18	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	137.48		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Pipeline routed through moderately deep seated slide identified on LiDAR March 2012. Extensive high plastic glaciolacustrine clay deposits underlying approach slopes. Some of these deposits are jointed and slickensided, perhaps as a result of melting of ice blocks soon after deposition.
Estimated Frequency	0.1	Level of activity is unknown. Approaching the residual angle of friction (7° slope) and lack on tension cracks on graded adjacent RoW suggest slide is not currently moving. Requires investigation.
Vunerability Factor	0.01	Larger scale moderately deep seated slide.
Mitigation Options	1.00E-03	

Applied Mitgations	Standard Factor
Monitoring of slope stability conditions	0.1
Major slope and crest grading	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-09

Geohazard Detail

ID 328 **Paddle River**

Category	Lateral Migration	**KP (Rev V) Start**	137.4	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	137.66		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river with old meander scars/oxbows near crossing. Potential for long term meander cut-offs upstream and downstream.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Only minor occurrence of fresh bars. Field asessment required.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail ID 437 Paddle River

Category	Scour	**KP (Rev V) Start**	137.4	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	137.66		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 329 **Little Paddle River**

Category	Lateral Migration	**KP (Rev V) Start**	162.82	**Feature**	4
Source	Geotechnical Report	**KP (Rev V) End**	163.18		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Meandering river with old meander scars/oxbows near crossing. Meander bend east of crossing may be succeptable to migration towards route. Route crosses meander bend at KP 162.9.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Only minor occurrence of fresh bars. Field asessment required.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	Route crosses meander bend at KP 162.9. Reroute to avoid this meander bend should be evaluated.

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.78E-11

Geohazard Detail

ID 438 **Little Paddle River**

Category	Scour	**KP (Rev V) Start**	162.82	**Feature**	4
Source	Geotechnical Report	**KP (Rev V) End**	163.18		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	Route crosses meander bend at KP 162.9. Reroute to avoid this meander bend should be evaluated.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.78E-11

Geohazard Detail **ID** 59 **Swan Hills southeast of Whitecourt**

Category	**Deep seated slide**	**KP (Rev V) Start**	177.52	**Feature**	5
Source	Geotechnical Report	**KP (Rev V) End**	183.94		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route located across apparent deep-seated slide.
Estimated Frequency	0.001	Ancient slide, re-initiation of movement considered unlikely based on overall gradient and wide terrace at toe. Local re-activation due to local erosion might occur.
Vunerability Factor	0.1	Low angle slide (near residual angle).
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Surface water and/or groundwater control	0.1
Monitoring of slope stability conditions	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.56E-10

Geohazard Detail

ID 530 **Swan Hills Area East of Whitecourt**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	183.5	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	183.8		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Shallow to moderately deep seated slide identified from LiDAR imagery approximately 70 m west of the RevV alignment. Instability appears to be driven by the downcutting of a small tributary to the Athabasca that runs parallel to the route. Note that this location is within an apparent large deep seated slide area on the south Athabasca valley slope. No direct occurrence on proposed route however slide retrogression is considered possible.
Estimated Frequency	0.01	Active slide however has not yet retrogressed onto route.
Vunerability Factor	0.01	Direction of movement is across pipeline.
Mitigation Options	1.00E-03	Proposed reroute to the east beyond retrogression limits.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail **ID** 330 **Athabasca River**

Category	Lateral Migration	**KP (Rev V) Start**	186.18	**Feature**	7
Source	Geotechnical Report	**KP (Rev V) End**	187.02		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Sevaral subchannels carrying flow south of main channel. Lateral erosion and re-occupation of existing channels south of the present main channel are likely to occur. The crossing will need to be below lateral erosion and scour depths (deep cover) from south of the road south of the crossing to the toe of the north approach slope.
Estimated Frequency	0.1	Subchannels are carrying flow and there is a high likelihood of of increased flow in the future. Frequent occurrence of fresh bars.
Vunerability Factor	0.1	230m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.25E-08

Geohazard Detail

ID 439 **Athabasca River**

Category	Scour	**KP (Rev V) Start**	186.18	**Feature**	7
Source	Geotechnical Report	**KP (Rev V) End**	187.02		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	230m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.25E-09

Geohazard Detail

ID 60 **North approach to Athabasca River**

Category Deep seated slide

KP (Rev V) Start 187

Feature 9

Source Geotechnical Report

KP (Rev V) End 187.14

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0

Has been routed to avoid deep seated slides. Deep seated slide to the west near power lines, however geological conditions are considered less prone to sliding at crossing location.

Estimated Frequency 0

Has been routed to avoid deep seated slides.

Vunerability Factor 0

Has been routed to avoid deep seated slides.

Mitigation Options 1.00E+00

HDD crossing is proposed.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail **ID** 374 **North approach to Athabasca River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	187	**Feature**	8
Source	Geotechnical Report	**KP (Rev V) End**	187.14		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	On the north approach slope, the route is on a ridge with local groundwater piping, groundwater blow-off failures (small) and shallow slides.
Estimated Frequency	1	Expected to be relatively frequent.
Vunerability Factor	0.001	Shallow and local slides considered very unlikely to fail pipe.
Mitigation Options	1.00E-03	HDD crossing proposed entering below north valley slope.

Applied Mitgations	**Standard Factor**
Deep burial below slide	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-09

Geohazard Detail **ID** 527 **East approach slope to Sakwatamau River**

Category	Deep seated slide	**KP (Rev V) Start**	198.75	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	199.1		

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Route crosses deep seated slide on the east approach slope identified by LiDAR made available in June 2012. Slope is 30 m high where the route descends into the river valley.
Estimated Frequency	1	Level of activity is unknown, assumed to be moving.
Vunerability Factor	1	Slope angle is approximately 10°, steeper than residual angle of friction.
Mitigation Options	1.00E-05	Although slides appear to be prevalent in the area, it may be possible to micro-route through stable ground between slides. Grading and/or surface/groundwater control is also recommended.

Applied Mitgations	Standard Factor
Reroute	0.001
Major slope and crest grading	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.86E-08

Geohazard Detail ID 331 Sakwatamau River

Category	Lateral Migration	**KP (Rev V) Start**	199.06	**Feature**	10
Source	Geotechnical Report	**KP (Rev V) End**	200.16		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Subchannels on both the east and west sides, smaller dissected gravel bars and evidence of a major past channel relocation north of proposed crossing. A cut off meander may form in the future upstream (north) of the proposed crossing which could affect future lateral erosion conditions.
Estimated Frequency	0.01	Meander cutoffs partially infilled with sediment suggesting moderate frequency. Smaller migration events on active bars expected to be more frequent.
Vunerability Factor	0.001	30m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail

ID 440 | **Sakwatamau River**

Category	Scour	**KP (Rev V) Start**	199.06	**Feature**	10
Source	Geotechnical Report	**KP (Rev V) End**	200.16		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	30m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 9.09E-12

Geohazard Detail

ID 375 **Narrow corridor near Sakwatamau River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	200.16	**Feature**	11
Source	Geotechnical Report	**KP (Rev V) End**	202.26		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	There are a series of moderately deep slides along the Sakwatamau valley slopes immediately to the northeast of the route. Route crosses headscarps of slide.
Estimated Frequency	0.1	Moderate frequency of movement is expected.
Vunerability Factor	0.01	Movement is across route but at crest of slide (low soil loading).
Mitigation Options	1.00E-03	Reroute recommended subject to check that Alliance RoW boundary is at the crest of slides. Possible reroute across and to the west side of Alliance. Tight area between RoW and highway, room for reroute is dependant on further checks.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.76E-10

Geohazard Detail

ID 376 | **Tributary to Chickadee Creek valley slopes**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	215.16	**Feature**	12
Source	Geotechnical Report	**KP (Rev V) End**	215.56		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Steep, narrow gully, confined channel, slopes high on both sides (potential instabilities). Meets criteria, no defined occurrence. Field check recommended.
Estimated Frequency	0.1	No evidence of direct occurrence on route. Moderate frequency expected.
Vunerability Factor	0.001	Shallow and local slides considered unlikely to fail pipe.
Mitigation Options	1.00E-02	Minor slope grading and drainage/groundwater control recommended.

Applied Mitgations	Standard Factor
Drainage and groundwater control	0.1
Minor slope and crest grading	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 4.00E-10

Geohazard Detail ID 332 Chickadee Creek

Category Lateral Migration | **KP (Rev V) Start** 218.46 | **Feature** 13

Source Geotechnical Report | **KP (Rev V) End** 218.62

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Meandering river with tortuous path, some meander scars and oxbows.

Estimated Frequency 0.01

Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Only minor occurrence of fresh bars. Field asessment required.

Vunerability Factor 0.001

10m wide channel.

Mitigation Options 1.00E-03

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 4.00E-11

Geohazard Detail

ID 441 **Chickadee Creek**

Category	Scour	**KP (Rev V) Start**	218.46	**Feature**	13
Source	Geotechnical Report	**KP (Rev V) End**	218.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 4.00E-11

Geohazard Detail

ID 333 **Two Creek**

Category	Lateral Migration	**KP (Rev V) Start**	241.2	**Feature**	14
Source	Geotechnical Report	**KP (Rev V) End**	242.4		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river with tortuous path, meander scars and oxbows, laterally unstable. Preliminary ratings prior to ground reconnaissance.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Field asessment required.
Vunerability Factor	0.001	20m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 8.33E-12

Geohazard Detail ID 442 Two Creek

Category	Scour	**KP (Rev V) Start**	241.2	**Feature**	14
Source	Geotechnical Report	**KP (Rev V) End**	242.4		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.86E-11

Geohazard Detail

ID 528 **East of Two Creek**

Category	Slide - shallow/moderate deep
Source	Assessment based on review of avai
KP (Rev V) Start	241.5
KP (Rev V) End	241.65
Feature	

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, Rev V further south. Notes below pertain to Rev U. A segment of the route above the slope crest on the eastern side of Two Creek crosses a slide depletion zone as identified by LiDAR June 2012.
Estimated Frequency	1	Level of activity is unknown, assume active movement.
Vunerability Factor	0.01	Direction of sliding is across pipe.
Mitigation Options	1.00E-03	Requires re-route beyond the depletion zone.

Applied Mitgations	Standard Factor
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 529 **East approach slopes of Two Creek**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	241.65	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	241.85		

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, Rev V further south. Notes below pertain to Rev U. Shallow to moderately deep seated slides are visible on LiDAR near but not on the east bank of the crossing. Considered possible at location however no defined occurrence. Shallow to moderately deep seated slides occur locally on the eastern approach slopes whereever outside meander bends erode lower valley sidewalls. Slope height is approximately 15 m with an average gradient of about 8°.
Estimated Frequency	0.1	No evidence of active sliding at crossing location.
Vunerability Factor	0.001	Slide direction would be parallel to pipe.
Mitigation Options	1.00E-02	grading, surface/groundwater control and possible riprap

Applied Mitgations	Standard Factor
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 377 **East approach slope to Iosegun River**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	257.96	**Feature**	15
Source	Reroute from location in Overall Ge	**KP (Rev V) End**	258.2		

Assessment based on review of imagery and/or helicopter reconnaissance

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Steep slopes, rock underlying colluvium.
Estimated Frequency	0.1	No evidence of direct occurrence on route. Moderate frequency expected.
Vunerability Factor	0.001	Shallow and local slides considered less likely to fail pipe.
Mitigation Options	1.00E-02	Minor slope grading and drainage/groundwater control recommended.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Minor slope and crest grading	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.82E-10

Geohazard Detail

ID 334 **Iosegun River**

Category	Lateral Migration	**KP (Rev V) Start**	258.2	**Feature**	17
Source	Reroute from location in Overall Ge	**KP (Rev V) End**	258.48		
	Assessment based on review of imagery and/or helicopter reconnaissance				

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river in old glaciofluvial meltwater channel. Bottom of channel is approximately 250 m wide. The bottom of the valley is covered with muskeg.
Estimated Frequency	0.01	Glaciofluvial channel infilled with easily erodable fine grained sediments and organics, expect relatively high frequency of lateral erosion.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.86E-11

Geohazard Detail

ID 443 **Iosegun River**

Category	Scour	**KP (Rev V) Start**	258.2	**Feature**	17
Source	Geotechnical Report	**KP (Rev V) End**	258.48		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.86E-11

Geohazard Detail

ID 426 **West approach slope to Iosegun River**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	258.48	**Feature**	
Source	Reroute from location in Overall Ge	**KP (Rev V) End**	259.06		
	Assessment based on review of imagery and/or helicopter reconnaissance				

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible shallow to moderately deep seated slides on West approach to Iosegun River.
Estimated Frequency	0.1	
Vunerability Factor	0.001	
Mitigation Options	1.00E-03	Grading and groundwater/surface water control. Route crosses small diameter pipeline which must be considered. Relocation of route may be required.

Applied Mitgations	Standard Factor
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.72E-11

Geohazard Detail **ID** 61 **East Approach to Little Smoky River**

Category	**Deep seated slide**	**KP (Rev V) Start**	289.7	**Feature**	19
Source	Geotechnical Report	**KP (Rev V) End**	290.1		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Known deep seated sliding upstream and downstream of crossing. No slide found on ridge that forms route. Sliding might be triggered by undercutting of toe due to erosion. Credible potential for occurrence at this location.
Estimated Frequency	0.01	Located in area with possible weak geologic units, no deep seated slide identified at crossing location. Low frequency.
Vunerability Factor	1	Slopes steeper than angle of residual friction.
Mitigation Options	1.00E-03	Monitoring of stability conditions and rip rap or stream training subject to detailed studies. Ground and surface water control.

Applied Mitgations	**Standard Factor**
Monitoring of slope stability conditions	0.1
River training and/or riprap	0.01
Surface water and/or groundwater control	0.1

Mitigation Site-specific	10	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.43E-09

Geohazard Detail

ID 378 **East Approach slope to Little Smoky River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	289.72	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	290.02		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Moderately deep-seated slides occur upstream and downstream of crossing location along east approach slope. No indication was found of active movements on the ground, based on LiDAR and reconnaissance. Meets screening criteria with no defined occurrence at location.
Estimated Frequency	0.01	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0.01	Evidence of large slides in surrounding area, coonsidered possible for large moderately deep seated parallel to pipeline.
Mitigation Options	1.00E-02	Reroute may be required either driven by this, or other nearby geohazards. Further investigations and monitoring are recommended to check movement status of slopes. Further consideration of design and mitigative methods relative to stability conditions is anticipated during detailed design. Comprehensive ground and surface water control will be required. Vulnerable to undercutting by lateral erosion.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Surface water control	0.1
Monitoring of slope stability conditions	0.1
Reroute	0.001

Mitigation Site-specific	10000	FLOC calculated based on either reroute or combination of water control and monitoring.

Frequency Loss of Containment 1.00E-07 **FLOC/m** 3.33E-10

Geohazard Detail

ID 335 **Little Smoky River crossing**

Category	Lateral Migration	**KP (Rev V) Start**	290.02	**Feature**	20
Source	Geotechnical Report	**KP (Rev V) End**	290.56		

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Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Meandering/anastamosing river with oxbows, active bar depostion/erosion and some subchannels.
Estimated Frequency	0.1	Although the river has been reasonably stable over the last approximately 50 years, major lateral erosion has occurred in the past. Lateral erosion occurring at present. Future major changes in channel lateral erosion conditions may occur, possibly including a cut off meander downstream of the crossing. Active gravel bar erosion and deposition.
Vunerability Factor	0.1	50m wide channel.
Mitigation Options	1.00E-03	Lateral erosion could trigger renewed sliding. Trenchless crossing preferred to mitigate deep seated slide. Trenchless crossing should start near toe of east approach slope extending under river and west approach slope.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration or reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.85E-08

Geohazard Detail

ID 444 **Little Smoky River crossing**

Category	Scour	**KP (Rev V) Start**	290.02	**Feature**	20
Source	Geotechnical Report	**KP (Rev V) End**	290.56		

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Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	50m wide channel.
Mitigation Options	1.00E-03	Trenchless crossing preferred to mitigate deep seated slide. Trenchless crossing should start near toe of east approach slope extending under river and west approach slope.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.85E-09

Geohazard Detail ID 62 West Approach Slope to Little Smoky River

Category	Deep seated slide	**KP (Rev V) Start**	290.6	**Feature**	21
Source	Geotechnical Report	**KP (Rev V) End**	291.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route located across known deep-seated slide parallel to existing pipeline.
Estimated Frequency	0.01	Slide not currently active, no movement apparent during aerial assessment.
Vunerability Factor	1	Slope angle steeper than residual angle of friction.
Mitigation Options	1.00E-03	Trenchless crossing preferred to mitigate deep seated slide. Trenchless crossing should start near toe of east approach slope extending under river and west approach slope.

Applied Mitgations	Standard Factor
Surface water and/or groundwater control	0.1
Deep burial below slide or reroute	0.001

Mitigation Site-specific 10

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.00E-08

Geohazard Detail

ID 336 **Waskahigan River**

Category	Lateral Migration	**KP (Rev V) Start**	317.1	**Feature**	22
Source	Geotechnical Report	**KP (Rev V) End**	317.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Wide floodplain, lateral migration (abandoned channels and subchannels), appears to be laterally mobile.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Some indication of active gravel bar deposition. Field asessment required.
Vunerability Factor	0.001	15 m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-11

Geohazard Detail

ID 445 **Waskahigan River**

Category	Scour	**KP (Rev V) Start**	317.1	**Feature**	22
Source	Geotechnical Report	**KP (Rev V) End**	317.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15 m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-11

Geohazard Detail

ID 446 **Incised creek valley draining to north**

Category	Scour	**KP (Rev V) Start**	331.64	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	331.76		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	Streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 447 Incised creek valley draining to north

Category Scour

KP (Rev V) Start 334.5

Feature

Source Geotechnical Report

KP (Rev V) End 334.58

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Unconsolidated river bed material expected at crossing location.

Estimated Frequency 0.01

Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.

Vunerability Factor 0.001

10m wide channel.

Mitigation Options 1.00E-03

Streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 337 **Deep Valley Creek**

Category	Lateral Migration	**KP (Rev V) Start**	337.9	**Feature**	23
Source	Geotechnical Report	**KP (Rev V) End**	338.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering/braided river with oxbows, active bar depostion/erosion and some subchannels. Creek appears to be eroding very slightly toward the west on the north side and toward the east on the south side of the existing crossings. There is a minor back channel across a low elevation area of floodplain toward the south.
Estimated Frequency	0.1	Active bar deposion and erosion.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.50E-10

Geohazard Detail

ID 448 **Deep Valley Creek**

Category	Scour	**KP (Rev V) Start**	337.9	**Feature**	23
Source	Geotechnical Report	**KP (Rev V) End**	338.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location. Creek appears to be eroding very slightly toward the west on the north side and toward the east on the south side of the existing crossings. There is a minor back channel across a low elevation area of floodplain toward the south.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-11

Geohazard Detail

ID 517 **Deep Valley Creek West valley slopes**

Category	Deep seated slide	**KP (Rev V) Start**	338.78	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	339.42		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Pipeline routed through middle of deep seated slide identified on LiDAR March 2012. Likely triggered as a result of a previous meander bend undercutting slope.
Estimated Frequency	1	Level of activity unknown, assumed to be moving.
Vunerability Factor	0.1	Low angle slide (near residual angle).
Mitigation Options	1.00E-04	Recommend reroute or trenchless crossing. Route should parallel existing pipelines which climb the valley slope just to the east of the slide margins.

Applied Mitgations	**Standard Factor**
Monitoring of slope stability conditions	0.1
Deep burial below slide or reroute	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.56E-08

Geohazard Detail

ID 518

Tributary to Deep Valley Creek East valley slopes

Category Slide - shallow/moderate deep

KP (Rev V) Start 339.86

Feature

Source Geotechnical Report

KP (Rev V) End 340.06

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Moderately deep seated slides on East and West approach slopes of tributary to Deep Valley Creek identified on LiDAR March 2012. Geotechnical report had previously identified the hazard but concern has been elevated based on review of LiDAR.

Estimated Frequency 1

Level of activity is unknown. 10° slide face is steeper than angle of residual friction of low shear strength soils. Possible movement on adjacent line since grading. Active movement is assumed. Requires field assessment and monitoring of slope stability conditions.

Vunerability Factor 0.001

Slide direction is parallel to pipe.

Mitigation Options 1.00E-02

Monitoring and drainage. Recommend field reconnaisance and drill program to install instrumentation summer 2012. May require trenchless crossing (HDD).

Applied Mitgations	Standard Factor
Monitoring of slope stability conditions	0.1
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 4.00E-08

Geohazard Detail

ID 338 **Tributary to Deep Valley Creek**

Category	Lateral Migration	**KP (Rev V) Start**	340.06	**Feature**	24
Source	Geotechnical Report	**KP (Rev V) End**	340.222		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Tortuous meanders and lateral migration. Stream has limited floodplain extent at crossing location, however, subchannel on west side of crossing.
Estimated Frequency	0.01	Evidence of active bar depostion/erosion.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail

ID 449 **Tributary to Deep Valley Creek**

Category	Scour	**KP (Rev V) Start**	340.06	**Feature**	24
Source	Geotechnical Report	**KP (Rev V) End**	340.22		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 519

Tributary to Deep Valley Creek West valley slopes

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	340.22	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	340.34		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Moderately deep seated slides on East and West approach slopes of tributary to Deep Valley Creek identified on LiDAR March 2012. Geotechnical report had previously identified the hazard but concern has been elevated based on review of LiDAR.
Estimated Frequency	1	Level of activity is unknown. 10° slide face is steeper than angle of residual friction of low shear strength soils. Possible movement on adjacent line since grading. Active movement is assumed. Requires field assessment and monitoring of slope stability conditions.
Vunerability Factor	0.001	Slide direction is parallel to pipe.
Mitigation Options	1.00E-02	Monitoring and drainage. Recommend field reconnaisance and drill program to install instrumentation summer 2012. Monitoring and drainage. Recommend that field reconnaisance and drill program to install instrumentation summer 2012. May require trenchless crossing (HDD).

Applied Mitgations	**Standard Factor**
Monitoring of slope stability conditions	0.1
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 5.00E-08

Geohazard Detail

ID 520 **West of Tributary to Deep Valley Creek**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	340.34	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	341		

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	There are a series of moderately deep slides along the tributary of Deep Valley Creek slopes immediately to the south of the route identified from LiDAR imagery March 2012. Route crosses near headscarps of slides but appears to be beyond area of active sliding.
Estimated Frequency	1	Level of activity is unknown, assumed to be moving. Slope is approximately 13°.
Vunerability Factor	0.01	Direction of movement is across pipeline.
Mitigation Options	1.00E-04	Requires reroute further back from crest of valley slopes.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific	0.1	Reroute beyond possible retrogression limits of slides. Nearby slides have failed to 6°.

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.52E-10

Geohazard Detail

ID 521

Creek crossing west of tributary to Deep Valley Creek

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	341	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	341.42		

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Shallow to moderately deep slides on valley slopes of creek crossing west of Tributary to Deep Valley Creek identified on LiDAR imagery March 2012.
Estimated Frequency	1	Level of activity unknown, some post grading disturbance noted on adjacent pipeline RoW.
Vunerability Factor	0.01	Direction of sliding is across pipeline.
Mitigation Options	1.00E-04	Recommend reroute approximately 700 m upstream where valley is much smaller and any potential instabilities can be graded out.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific	0.1	Recommend reroute approximately 700 m upstream where valley is much smaller and any potential instabilities can be graded out.

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.38E-09

Geohazard Detail

ID 522

Creek crossing west of tributary to Deep Valley Creek

Category Scour

Source Assessment based on review of avai

KP (Rev V) Start 341.32

KP (Rev V) End 341.34

Feature

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 1

Unconsolidated river bed material expected at crossing location.

Estimated Frequency 0.01

Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.

Vunerability Factor 0.001

5 m wide channel.

Mitigation Options 1.00E-03

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 450 **Tributaries to Simonette**

Category	Scour	**KP (Rev V) Start**	353.56	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	353.58		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	<10m wide channel.
Mitigation Options	1.00E-03	Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 451 **Tributaries to Simonette**

Category	Scour	**KP (Rev V) Start**	354.58	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	354.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	<10m wide channel.
Mitigation Options	1.00E-03	Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 452 **Tributaries to Simonette**

Category	Scour	**KP (Rev V) Start**	355.18	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	355.22		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	<10m wide channel.
Mitigation Options	1.00E-03	Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 453 **Tributaries to Simonette**

Category	Scour	**KP (Rev V) Start**	356.38	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	356.4		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	<10m wide channel.
Mitigation Options	1.00E-03	Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail ID 454 Tributaries to Simonette

Category	Scour	**KP (Rev V) Start**	357.26	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	357.32		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	<10m wide channel.
Mitigation Options	1.00E-03	Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 339 **Simonette River**

Category	Lateral Migration	**KP (Rev V) Start**	358.94	**Feature**	27
Source	Geotechnical Report	**KP (Rev V) End**	359.46		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Broad floodplain with meander scars and oxbows. Floodplains extend to the toes of both slopes and both areas have had active erosion in the past.
Estimated Frequency	0.1	Evidence of active bar depostion/erosion with recently abandoned subchannels.
Vunerability Factor	0.1	50m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.82E-08

Geohazard Detail

ID 455 **Simonette River**

Category	Scour	**KP (Rev V) Start**	358.94	**Feature**	27
Source	Geotechnical Report	**KP (Rev V) End**	359.46		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	50m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail

ID 63 **East valley slope of Latornell River**

Category Deep seated slide

KP (Rev V) Start 370.94

Feature 28

Source Geotechnical Report

KP (Rev V) End 371.28

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 1

Known deep seated sliding at crossing location based on review of LiDAR (March 2012). Updated from deep seated slide hazard listed in Overall Geotechnical Report.

Estimated Frequency 1

Activity of slide has not been confirmed however it appears that a former road has been cut by tension cracks suggesting recent movement.

Vunerability Factor 0.1

Low angle slide (near residual angle).

Mitigation Options 1.00E-05

Recommend reroute to avoid slide hazard or trenchless crossing.

Applied Mitgations	Standard Factor
Deep burial below slide or reroute	0.001

Mitigation Site-specific 0.01

Recommend reroute to avoid slide hazard or trenchless crossing.

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.94E-09

Geohazard Detail ID 340 Latornell River

Category Lateral Migration **KP (Rev V) Start** 371.26 **Feature** 29

Source Geotechnical Report **KP (Rev V) End** 371.3

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 1

Crossing design will need to consider lateral erosion of meander bend to south and large amounts of debris that may result in significant diversions of the stream.

Estimated Frequency 0.01

Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Field asessment required.

Vunerability Factor 0.001

20m wide channel.

Mitigation Options 1.00E-03

Sag bends beyond long term hydrotechnical limits. Reroute may be required to mitigate slides on approach slopes.

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-10

Geohazard Detail

ID 456 **Latornell River**

Category	Scour	**KP (Rev V) Start**	371.26	**Feature**	29
Source	Geotechnical Report	**KP (Rev V) End**	371.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	Pipeline below maximum predicted scour depth. Reroute may be required to mitigate slides on approach slopes.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-10

Geohazard Detail **ID** 495 **West valley slope of Latornell River**

Category Deep seated slide

KP (Rev V) Start 371.3

Feature 28

Source Geotechnical Report

KP (Rev V) End 372

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 1

Known deep seated sliding at crossing location based on review of LiDAR (March 2012). Updated from deep seated slide hazard listed in Overall Geotechnical Report.

Estimated Frequency 1

Vunerability Factor 0.1

Low angle slide (near residual angle).

Mitigation Options 1.00E-05

Recommend reroute or HDD.

Applied Mitgations	Standard Factor
Deep burial below slide or reroute	0.001

Mitigation Site-specific 0.01

Recommend reroute or HDD.

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.43E-09

Geohazard Detail

ID 64 **West of Latornell River**

Category	**Deep seated slide**	**KP (Rev V) Start**	372.1	**Feature**	30
Source	Geotechnical Report	**KP (Rev V) End**	374		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Route located across or close to apparent deep-seated slide.
Estimated Frequency	0.1	Activity of slide unknown, route may be beyond crest.
Vunerability Factor	1	Slopes steeper than angle of residual friction.
Mitigation Options	1.00E-03	Subject to further work, reroute is assumed, crossing over to the west side of Alliance.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.11E-08

Geohazard Detail ID 380 Tributary to Smoky River valley slopes

Category Slide - shallow/moderate deep
KP (Rev V) Start 395.02
Feature 32

Source Geotechnical Report
KP (Rev V) End 395.22

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Stability conditions at proposed route appeared to be reasonably good, although there are slides in the general area. Route selected to avoid slides. Review of LiDAR (March 2012) suggests that crossing location is favorable relative to other locations along tributary however instabilities may exist on the west valley slope. Requires further investigation.

Estimated Frequency 0.1

No confirmation of direct occurrence on route however LiDAR suggests sliding may be possible. Requires further investigation.

Vunerability Factor 0.001

Slope height approximately 18 m at 12°.

Mitigation Options 1.00E-02

Minor slope grading and drainage/groundwater control.

Applied Mitgations	Standard Factor
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail

ID 341 **Tributary to Smoky River**

Category	Lateral Migration	**KP (Rev V) Start**	395.1	**Feature**	31
Source	Geotechnical Report	**KP (Rev V) End**	395.12		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river with some old meander scars/oxbows present near crossing.
Estimated Frequency	0.01	Meander scars and oxbows do not appear tobe recent, suggesting moderate to low frequency. Field asessment required.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 457 **Tributary to Smoky River**

Category	Scour	**KP (Rev V) Start**	395.1	**Feature**	31
Source	Geotechnical Report	**KP (Rev V) End**	395.12		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail

ID 381 **Tributary to Smoky River valley slopes**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	403.58	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	403.96		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Crossing of tributary to Smoky River. Moderately steep to steep slopes into small creek. Existing pipeline crossings to west. Local areas of moderately deep slides. Rev R (same as V) moved to the east away from the existing pipeline crossing to improve stability conditions. Screening criteria partially met, but no evidence at location.
Estimated Frequency	0.01	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0.001	
Mitigation Options	1.00E-02	Minor slope grading and drainage/groundwater control recommended.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Minor slope and crest grading	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 2.63E-12

Geohazard Detail

ID 382 **East valley slope of Smoky River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	419.4	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	419.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	No major stability concerns identified on proposed route. Area to north of existing pipeline RoWs (opposite side to proposed route) has been eroded forming locally steep gullies and bowls (possible groundwater blow-off failures, but also appears to be stable. Moderately deep slides farther to the north where the slope has been undercut by the river. Also moderately deep slides to the south. Screening criteria partially met, but no evidence at location.
Estimated Frequency	0.01	No indication of direct occurrence on route.
Vunerability Factor	0.01	Potential for larger scale event increases vulnerability.
Mitigation Options	1.00E-02	Minor slope grading and drainage/groundwater control recommended.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Minor slope and crest grading	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-12

Geohazard Detail ID 65 East valley slope of Smoky River

Category Deep seated slide

KP (Rev V) Start 419.5

Feature 33

Source Geotechnical Report

KP (Rev V) End 419.9

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename** SmokyRiver2.kmz

Occurrence Factor 0.1

The present alignment down the east slope of the valley is setback about 50 m from a relative active landslide scarp that is visible on the LiDAR image.Retrogression of the slide could impact the present alignment over time. There appears to be about 150 m setback from the existing pipeline to the north, providing room to shift the alignment at least 50 m farther away from the slide scarp. The route should parallel the south side of the existing RoW except at the crest where the route will deviate around a lease.

Estimated Frequency 0.01

No deep seated identified directly on route. Sandstone layer may improve stability conditions.

Vunerability Factor 1

Slopes steeper than angle of residual friction if high plastic clay present.

Mitigation Options 1.00E-03

Reroute. There appears to be about 150 m setback from the existing pipeline to the north, providing room to shift the alignment at least 50 m farther away from the slide scarp. The route should parallel the south side of the existing RoW except at the crest where the route will deviate around a lease.

Applied Mitgations	Standard Factor
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-10

Geohazard Detail ID 342 Smoky River floodplain

Category	Lateral Migration	**KP (Rev V) Start**	420.18	**Feature**	34
Source	Geotechnical Report	**KP (Rev V) End**	421.74		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	River is eroding to some extent both east and west at and near the crossing. Erosion is constrained to some degree by the road bridge approach fills approximately 1.2 km upstream of the crossing. Failure of these fills would allow much greater lateral erosion than at present. In the past, the river has eroded laterally over very significant distances both to the east and west. Low lying (3 m above river) fluvial terraces at base of east and west approach slopes (LiDAR).
Estimated Frequency	0.1	Documented past lateral erosion problems with other pipelines in area and observations of active lateral erosion suggest high frequency.
Vunerability Factor	0.1	200 m wide channel.
Mitigation Options	1.00E-04	HDD crossing proposed. If necessary consider self-launching riprap.

Applied Mitgations	Standard Factor
Trenchless Methods enter/exit outside extents of lateral migration	0.001
Armoured stream banks suitably designed	0.01

Mitigation Site-specific	10	Reduced mitigation effectiveness due to high lateral erosion of river.

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.88E-10

Geohazard Detail

ID 458 **Smoky River floodplain**

Category	Scour	**KP (Rev V) Start**	420.18	**Feature**	34
Source	Geotechnical Report	**KP (Rev V) End**	421.74		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	300m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 7.14E-10

Geohazard Detail ID 66 West valley slope of Smoky River

Category	Deep seated slide	**KP (Rev V) Start**	421.7	**Feature**	35
Source	Geotechnical Report	**KP (Rev V) End**	422.28		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Route located across edge of known deep-seated slide. Small tension cracks identified.
Estimated Frequency	1	Active slide.
Vunerability Factor	0.1	Low angle slide (near residual angle of friction).
Mitigation Options	1.00E-04	Requires reroute to north close to road. Monitoring of stability conditions recommended.

Applied Mitgations	**Standard Factor**
Monitoring of slope stability conditions	0.1
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 7.69E-09

Geohazard Detail **ID** 384 **Big Mountain Creek valley slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	428.16	**Feature**	39
Source	Reroute from location in Overall Ge	**KP (Rev V) End**	429.52		
	Assessment based on review of imagery and/or helicopter reconnaissance				

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Rev V route has moved relative to Rev R. LiDAR imagery suggest slides at route, further assessment with ground reconnaissance required.
Estimated Frequency	0.1	Moderate frequency is assumed subject to further work.
Vunerability Factor	0.01	Slide movement may be across pipeline.
Mitigation Options	1.00E-02	Recommend reroute or HDD.

Applied Mitgations	**Standard Factor**
Reroute or HDD	0.001

Mitigation Site-specific 10

Frequency Loss of Containment 1.00E-05 **FLOC/m** 7.35E-09

Geohazard Detail ID 344 Big Mountain Creek

Category	Lateral Migration	**KP (Rev V) Start**	428.92	**Feature**	41
Source	Reroute from location in Overall Ge	**KP (Rev V) End**	429.28		
	Assessment based on review of imagery and/or helicopter reconnaissance				

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Oxbows and meander scars near crossing indicate previous lateral erosion.
Estimated Frequency	0.01	Meander scars and oxbows do not appear recent, suggesting moderate to low frequency. Field asessment required.
Vunerability Factor	0.001	20m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-11

Geohazard Detail **ID** 460 **Big Mountain Creek**

Category	Scour	**KP (Rev V) Start**	428.92	**Feature**	41
Source	Reroute from location in Overall Ge	**KP (Rev V) End**	429.28		
	Assessment based on review of imagery and/or helicopter reconnaissance				

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.22E-11

Geohazard Detail

ID 385 **Bald Mountain Creek west valley slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	446.4	**Feature**	42
Source	Assessment based on review of avai	**KP (Rev V) End**	446.76		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible shallow sliding on 10 m high terrace front identified on west side of Creek during ground reconnaissance. Low elevation exposure on meander bend with overbank fine grained sands overlying well cemented/lithified fluvial sands and gravels.
Estimated Frequency	0.1	Sliding did not appear to be currently active during ground reconnaissance.
Vunerability Factor	0.001	Shallow sliding parallel to pipe.
Mitigation Options	1.00E-03	Ground and surface water control. Grading will reduce the potential for occurrence.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Surface water control	0.1
Minor slope and crest grading	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.78E-11

Geohazard Detail

ID 345 **Bald Mountain Creek**

Category	Lateral Migration	**KP (Rev V) Start**	446.64	**Feature**	43
Source	Assessment based on review of avai	**KP (Rev V) End**	446.72		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Oxbows and meander scars near crossing indicate previous lateral erosion.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. Some indication of undercutting and minor bar depostion. Field asessment required.
Vunerability Factor	0.001	20m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail

ID 461 **Bald Mountain Creek**

Category	Scour	**KP (Rev V) Start**	446.64	**Feature**	43
Source	Assessment based on review of avai	**KP (Rev V) End**	446.72		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail ID 346 Wilson Creek

Category	Lateral Migration	**KP (Rev V) Start**	453.66	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	453.86		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Mobile creek within flat valley bottom.
Estimated Frequency	0.01	Meander scars and oxbows do not appear to be recent, suggesting moderate to low frequency. No indication of active bar depostion. Field asessment required.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail ID 462 Wilson Creek

Category	Scour	**KP (Rev V) Start**	453.66	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	453.86		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 386 **Tributary to Iroquois Creek valley slopes**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	458.76	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	459		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Shallow to moderately deep sliding of approach slopes. Defined occurrence at location.
Estimated Frequency	1	Expected to be relatively frequent.
Vunerability Factor	0.001	
Mitigation Options	1.00E-02	Minor slope grading and drainage/groundwater control recommended.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Minor slope and crest grading	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 3.33E-08

Geohazard Detail

ID 387 **Pinto Creek meander bend 1**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	470.84	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	471.08		

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Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Moderately deep-seated slide into meander bend of Pinto Creek close to south side of existing RoW. Defined occurrence.
Estimated Frequency	1	Active movement expected.
Vunerability Factor	0.01	Sliding direction is across pipeline.
Mitigation Options	1.00E-03	Reroute from south side to north of existing RoW.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.50E-08

Geohazard Detail

ID 424 **Pinto Creek meander bend 2**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	473	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	473.5		

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Route located across moderately deep-seated slide defined on the basis of LiDAR.
Estimated Frequency	1	Active slide.
Vunerability Factor	0.01	Sliding direction is across pipeline.
Mitigation Options	1.00E-03	Recommend reroute to North side of existing RoW or HDD.

Applied Mitgations	**Standard Factor**
Reroute or HDD	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.00E-08

Geohazard Detail ID 68 Pinto Creek East valley slope

Category Slide - shallow/moderate deep

KP (Rev V) Start 474.02

Feature 46

Source Geotechnical Report

KP (Rev V) End 474.12

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Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 1

Route located across known moderately deep-seated slide.

Estimated Frequency 1

Active slide.

Vunerability Factor 0.01

Potential for larger scale event increases vulnerability.

Mitigation Options 1.00E-04

Recommend reroute or HDD. Requires further investigation for trenchless crossing. Possible microtunnelling or HDD. Other option is to replace existing pipeline and perform extensive grading.

Applied Mitgations	Standard Factor
Reroute or HDD	0.001

Mitigation Site-specific 0.1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail

ID 463 **Pinto Creek**

Category	Scour	**KP (Rev V) Start**	474.2	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	474.28		

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	Requires further investigation for trenchless crossing to mitigate scour potential. Recommend HDD or reroute.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.25E-10

Geohazard Detail

ID 427 **Pinto Creek West valley slope**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	474.34	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	474.44		

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Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Route located across known moderately deep-seated slide.
Estimated Frequency	1	Active slide.
Vunerability Factor	0.01	Potential for larger scale event increases vulnerability.
Mitigation Options	1.00E-03	Recommend reroute or HDD. Requires further investigation for trenchless crossing. Possible microtunnelling or HDD. Other option is to replace existing pipeline and perform extensive grading.

Applied Mitgations	**Standard Factor**
Reroute or HDD	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.00E-07

Geohazard Detail ID 69 Wapiti River area

Category Deep seated slide
KP (Rev V) Start 494.9
Feature 47
Source Geotechnical Report
KP (Rev V) End 495.2

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Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0 — Has been routed to avoid deep seated slides.

Estimated Frequency 0 — Has been routed to avoid deep seated slides.

Vunerability Factor 0 — Has been routed to avoid deep seated slides.

Mitigation Options 1.00E+00 — Has been routed to avoid deep seated slides.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 464 **Wapiti River**

Category	Scour	**KP (Rev V) Start**	494.94	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	495.6		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Bedrock river bed material expected at crossing location may reduce potential for scour.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	110m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.52E-10

Geohazard Detail

ID 388 **Ridge on West Side of Wapiti River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	496.3	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	497		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Shallow to moderately deep slides on ridge located on the west side of river. On south side of ridge, apparent shallow slides in rock exposed on steep slopes down to Wapiti River and colluvium. On north side of ridge, apparent moderately deep-seated slide in valley fill glaciolacustrine clay. Preliminary field and office review suggests there is sufficient room between the slide crests.
Estimated Frequency	0.01	No indication of direct occurrence on route. Movements expected to be moderately active.
Vunerability Factor	0.01	Route runs perpendicular to direction of expected sliding along the margins of meander bends.
Mitigation Options	1.00E-01	Potential mitigative measures if there is an issue include routing, surface and ground water control and (in the event of major problems), consideration of deep grading, directional drilling or other methods.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Surface water control	0.1
Monitoring of slope stability conditions	0.1

Mitigation Site-specific 100

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.67E-09

Geohazard Detail ID 347 South Redwillow River

Category	Lateral Migration	**KP (Rev V) Start**	534.12	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	534.18		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Confined and straight channel upstream, meander downstream. Rock on east side. Rock may also occur on west side but not seen. Narrow valley, the river is misfit in an old glaciofluvial meltwater channel. Channel does not show evidence of previous lateral erosion at crossing location (confined in bedrock?). Further investigation required to confirm confinement on west side.
Estimated Frequency	0.001	Possible lateral confinement in bedrock, frequency of lateral migration considered low. Requires further investigation.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	May require reroute north to avoid in-stream blasting.

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-10 **FLOC/m** 1.67E-12

Geohazard Detail ID 465 South Redwillow River

Category	Scour	**KP (Rev V) Start**	534.12	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	534.18		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Unconsolidated or bedrock river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 1.67E-11

Geohazard Detail

ID 466 **Kinuseo Creek**

Category	Scour	**KP (Rev V) Start**	568.2	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	568.26		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 389 **Quintette Mountain area rock cuts**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	568.4	**Feature**	48
Source	Geotechnical Report	**KP (Rev V) End**	581.78		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Several areas of rock cuts in the ends of ridges striking diagonally across RoW (potential for shallow sliding in soil veneers or bedrock slides). Considered credible potential for sliding.
Estimated Frequency	0.1	Occurrence considered possible upon excavation of cuts, dependent of cut orientation relative to the structural geology. Frequency difficult to assess over ~15 km section.
Vunerability Factor	0.001	Small slides unlikely to affect buried pipe.
Mitigation Options	1.00E-01	Suitable design for rock cuts includes grading and possible anchoring.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 7.46E-11

Geohazard Detail **ID** 4 **Quintette Creek**

Category	Avulsion	**KP (Rev V) Start**	577.3	**Feature**	49
Source	Geotechnical Report	**KP (Rev V) End**	577.46		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Avulsion near crossing location on upper portion of low-angle broad fan (subchannels present). The lateral extent of area of concern will need to be checked in the field. Avulsion below crossing is especially evident.
Estimated Frequency	0.1	Broad fan and presence of subchannels suggest that avulsion may occur during large storm event.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail

ID 245 **Tributary to Kinuseo Creek**

Category	Debris Flow
Source	Geotechnical Report
KP (Rev V) Start	579.94
KP (Rev V) End	580.04
Feature	50

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: low channel gradients, moderately steep valley sidewalls, significant tributary area - screening criteria only partially met.
Estimated Frequency	0.01	No indication of recent debris flow events, vegetated channel. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 10° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 348 **Kinuseo Creek near alignment**

Category	Lateral Migration	**KP (Rev V) Start**	580.7	**Feature**	51
Source	Geotechnical Report	**KP (Rev V) End**	581.8		

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Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Meander bend of Kinuseo Creek approaches route located on side slope. Mobile channel with recent (unvegetated) gravel bar erosion/deposition, meander bends and oxbows. Route 50-60 m behind crest of slope which has been undercut in the past by lateral erosion.
Estimated Frequency	0.001	Route located on sideslope above floodplain.
Vunerability Factor	0.1	30 m wide channel, but potential for larger areas of exposed pipe (pipeline parallel to lateral erosion hazard).
Mitigation Options	1.00E+00	Further review required, may require relocation to the north subject to field review.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.88E-10

Geohazard Detail

ID 5 | **Five Cabin Creek**

Category	Avulsion	**KP (Rev V) Start**	582.16	**Feature**	52
Source	Geotechnical Report	**KP (Rev V) End**	583.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	The channel is high relative to the east and west edges of the fan and has been subject to past avulsion (channel switching) over a width far in excess of the channel width with local erosion and deposition to shallow depths.
Estimated Frequency	0.1	The channel morphology and recent deposits suggest that there have been recent high flow events. Avulsion channels over the last few tens of years may occupy an area up to 800 m across.
Vunerability Factor	0.01	Large stream with high gradient.
Mitigation Options	1.00E-02	Debris flow potential on fan may necessitate deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 8.70E-09

Geohazard Detail ID 246 Five Cabin Creek

Category	Debris Flow	**KP (Rev V) Start**	582.16	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	583.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include moderate to steep channel gradient. Evidence of erosion and sediment accumulation from valley sidewalls, active channel, significant tributary area - meets screening criteria.
Estimated Frequency	0.1	Non-vegetated active channel suggests relatively frequent debris flow events. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 3° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 8.70E-09

Geohazard Detail

ID 349 **Kinuseo Creek near alignment**

Category	Lateral Migration	**KP (Rev V) Start**	587.74	**Feature**	53
Source	Geotechnical Report	**KP (Rev V) End**	587.74		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Meander bend of Kinuseo Creek approaches route located on side hill above road which has been undercut by creek. Mobile channel with recent (unvegetated) gravel bar erosion/deposition,meander bends and oxbows.
Estimated Frequency	0.01	Route located on sideslope above floodplain.
Vunerability Factor	0.1	30m wide channel, but potential for larger areas of exposed pipe (pipeline parallel to lateral erosion hazard).
Mitigation Options	1.00E-02	Recommend reroute further to the north.

Applied Mitgations	**Standard Factor**
Reroute	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-09

Geohazard Detail

ID 497 **Tributary to Kinuseo**

Category	Avulsion	**KP (Rev V) Start**	588.86	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	589.6		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Fan identified on LiDAR March 2012 shows evidence of former avulsion events (fan morphology with abandoned channels).
Estimated Frequency	0.1	Frequency is expected to correspond with major storm events.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.35E-09

Geohazard Detail

ID 428 **Kinuseo Creek**

Category	Lateral Migration	**KP (Rev V) Start**	590.3	**Feature**	53
Source	Geotechnical Report	**KP (Rev V) End**	590.68		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Flat-lying topography, historical high mobility (potential for lateral migration).
Estimated Frequency	0.1	Recent meander cutoffs/oxbows at and upstream from crossing location. Creek becomes more laterally confined downstream suggesting possible geology change.
Vunerability Factor	0.001	30m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Reroute to shorten length exposed to lateral erosion and scour should be evaluated.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.63E-10

Geohazard Detail

ID 467 **Kinuseo Creek**

Category	Scour	**KP (Rev V) Start**	590.3	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	590.68		

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	30m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Reroute to shorten length exposed to lateral erosion and scour should be evaluated.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.63E-11

Geohazard Detail

ID 390 **Tributary of Murray River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	598.82	**Feature**	54
Source	Geotechnical Report	**KP (Rev V) End**	598.98		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Possible old failures, including an apparent old slump block on the east side. Debris-mantled slopes prone to failure if disturbed. Consider screening criteria met with defined occurrence. Review of LiDAR suggests route passes along crest of groundwater blow-off failure (March 2012).
Estimated Frequency	1	Activity of slide unknown.
Vunerability Factor	0.01	Route appears to cross near crest of slide 100 m across. Further investigation required.
Mitigation Options	1.00E-03	Reroute to the north-east and away from crest of blow-off failure is assumed. Grading to consider stability conditions.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 3.33E-08

Geohazard Detail

ID 350 **Murray River**

Category	Lateral Migration	**KP (Rev V) Start**	600.8	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	600.92		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Lateral erosion towards west.
Estimated Frequency	0.1	Sand banks along west side of river are prone to erosion.
Vunerability Factor	0.01	Vulnerable areas are west end of aerial crossing and adjacent pipeline.
Mitigation Options	1.00E-03	Riprap of foundations and adjacent pipeline. Design of foundations.

Applied Mitgations	**Standard Factor**
Armoured stream banks suitably designed	0.01

Mitigation Site-specific	0.1	Riprap of foundations and adjacent pipeline - 0.1. Foundation design - 0.01

Frequency Loss of Containment 1.00E-06 **FLOC/m** 8.33E-09

Geohazard Detail

ID 468 **Murray River**

Category	Scour	**KP (Rev V) Start**	600.8	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	600.92		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	70m wide channel.
Mitigation Options	1.00E-03	Aerial crossing proposed.

Applied Mitgations	**Standard Factor**
Aerial crossing	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 8.33E-09

Geohazard Detail ID 392 Hook Creek east approach slopes

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	604.6	**Feature**	56
Source	Geotechnical Report	**KP (Rev V) End**	604.64		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Minor surface failures on approach slopes (stream undercutting). Documented occurrence.
Estimated Frequency	1	Expected to be relatively frequent.
Vunerability Factor	0.001	Shallow and local slides considered unlikely to fail pipe.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Deep burial below slide	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail

ID 351 **Hook Creek**

Category	Lateral Migration	**KP (Rev V) Start**	604.64	**Feature**	57
Source	Geotechnical Report	**KP (Rev V) End**	604.76		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided channel on floodplain within steep valley. Subchannels and active gravel bar depostion/erosion.
Estimated Frequency	0.1	Evidence of active bar deposition/erosion suggest relatively high frequency of lateral mobility due to sediment eroded from up channel areas.
Vunerability Factor	0.001	30 m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.00E-10

Geohazard Detail ID 469 Hook Creek

Category Scour | **KP (Rev V) Start** 604.64 | **Feature** 57

Source Geotechnical Report | **KP (Rev V) End** 604.76

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Unconsolidated river bed material expected at crossing location.

Estimated Frequency 0.01

Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.

Vunerability Factor 0.001

30m wide channel.

Mitigation Options 1.00E-03

HDD crossing proposed.

Applied Mitgations	Standard Factor
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 545 **Hook Creek west approach slope**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	604.76	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	604.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Minor surface failures on approach slopes (stream undercutting). Documented occurrence.
Estimated Frequency	1	Expected to be relatively frequent.
Vunerability Factor	0.001	Shallow and local slides considered unlikely to fail pipe.
Mitigation Options	1.00E-03	HDD below sliding surface

Applied Mitgations	**Standard Factor**
Deep burial below slide	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-08

Geohazard Detail

ID 226 | **Pass through Rockies**

Category	Avalanche	**KP (Rev V) Start**	614	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	614.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Avalanche track terminates 600 m above route. Area has snowpack accumulation for potential avalanche, however, slopes proximate to route are less steep and forested. Partially meets screening criteria.
Estimated Frequency	0.0001	Terminus of defined avalanche tracks are located 600 m upslope from route, frequency of events reaching pipeline is expected to be very low.
Vunerability Factor	0.001	Deposition zone or beyond - 14°
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 4.00E-12

Geohazard Detail

ID 227 **Pass through Rockies**

Category	Avalanche	**KP (Rev V) Start**	615	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	615.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Avalanche track terminates 400 m above route. Area has snowpack accumulation for potential avalanche, however, slopes proximate to route are less steep and forested. Partially meets screening criteria.
Estimated Frequency	0.0001	Terminus of defined avalanche tracks are located 400 m upslope from route, frequency of events reaching pipeline is expected to be very low.
Vunerability Factor	0.001	Deposition zone or beyond - 14°
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 4.00E-12

Geohazard Detail

ID 247 **Pass through Rockies**

Category Debris Flow

KP (Rev V) Start 616.12

Feature 58

Source Geotechnical Report

KP (Rev V) End 616.54

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0

Headwater conditions include; very poorly defined steep channel, only slightly incised with little sediment contribution from valley sidewalls, small catchment - does not meet screening criteria.

Estimated Frequency 0.001

Heavily forested channel suggests debris flow events occur very infrequently or not at all.

Vunerability Factor 0.01

Should a debris flow occur, deposition or erosion would be expected based on an approximate channel gradient of 9° in the immediate vicinity of the proposed route.

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 6 **Pass through Rockies**

Category	Avulsion	**KP (Rev V) Start**	617.7	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	618.52		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible alluvial fan. Further checks on avulsion potential recommended. Review of LiDAR March 2012 show a moderately well defined fan, avulsion potential difficult to determine.
Estimated Frequency	0.01	Heavily forested fan with no visible former channels or indications of activity/frequency, field review recommended. Channel currently occupies eastern margin, may be paleo-fan.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E+00	Deep cover mitigation to be considered if required based on further review.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.67E-09

Geohazard Detail ID 228 Pass through Rockies

Category Avalanche

KP (Rev V) Start 618.5

Feature 59

Source Geotechnical Report

KP (Rev V) End 618.6

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01

Avalanche track terminates 300 m above route. Area has snowpack accumulation for potential avalanche however slopes proximate to route are less steep and forested. Partially meets screening criteria.

Estimated Frequency 0.0001

Terminus of defined avalanche tracks are located 300 m upslope from route, frequency of events reaching pipeline is expected to be very low.

Vunerability Factor 0.001

At or beyond deposition zone - 3°

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-09 **FLOC/m** 1.00E-11

Geohazard Detail ID 393 Pass through Rockies

Category Slide - shallow/moderate deep

KP (Rev V) Start 619.2

Feature 60

Source Geotechnical Report

KP (Rev V) End 625.7

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Locally steep terrain, possibly with wet organics and steep side hills. Potential for shallow slides during construction. Considered credible potential for sliding.

Estimated Frequency 0.1

Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.

Vunerability Factor 0

Sloughing of soft soils in cuts, loss of containment event not considered possible.

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 229 **Pass through Rockies**

Category Avalanche

KP (Rev V) Start 622.1

Feature 59

Source Geotechnical Report

KP (Rev V) End 622.25

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01

Avalanche track terminates 450 m above route. Area has snowpack accumulation for potential avalanche generation, however, would need to cross 400 m of flat terrain to impact route. Partially meets screening criteria.

Estimated Frequency 0.0001

Terminus of defined avalanche tracks are located 450 m upslope from route, frequency of events reaching pipeline is expected to be very low.

Vunerability Factor 0.001

Likely beyond deposition zone - 0°

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-09 **FLOC/m** 1.00E-11

Geohazard Detail

ID 33 **Pass through Rockies**

Category	Rockfall	**KP (Rev V) Start**	623.55	**Feature**	63
Source	Geotechnical Report	**KP (Rev V) End**	623.7		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Steep slopes through mountain pass. At least one observed area of active rockfall. Detachment zone 300 m upslope, visible runout comes within 70 m. No runout tracks on route, however, within rockfall shadow.
Estimated Frequency	0.1	Evidence of active rockfall with runout close to but not crossing route. Moderately frequent event over ~2km section.
Vunerability Factor	0.01	Low relief terrain immediately surrounding route. Expect rock fragments to be decelerating and rolling.
Mitigation Options	1.00E-02	Diversion berms to be installed where required.

Applied Mitgations	**Standard Factor**
Diversion berm	0.1

Mitigation Site-specific 0.1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.55E-10

Geohazard Detail

ID 230 **Pass through Rockies**

Category Avalanche **KP (Rev V) Start** 624.3 **Feature** 59

Source Geotechnical Report **KP (Rev V) End** 624.32

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01

Section of cleared vegetation crosses route although appears to be meltwater channel from avalanches deposit area upslope.

Estimated Frequency 0.001

Terminus of defined avalanche tracks are located 500 m upslope from route, frequency of events reaching pipeline is expected to be very low. Some uncertainty over origin of section of cleared vegetation, however, it is likely meltwater channel. Requires field check.

Vunerability Factor 0.001

At or beyond deposition zone - 11°

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 231 **Pass through Rockies**

Category	Avalanche	**KP (Rev V) Start**	624.48	**Feature**	59
Source	Geotechnical Report	**KP (Rev V) End**	624.54		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Track of cleared vegetation crosses route although appears to be meltwater channel from avalanches deposited upslope.
Estimated Frequency	0.001	Terminus of defined avalanche tracks are located 500 m upslope from route, frequency of events reaching pipeline is expected to be very low. Some uncertainty over origin of section of cleared vegetation, however, it is likely meltwater channel. Requires field check.
Vunerability Factor	0.001	At or beyond deposition zone - 0°
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 232 Pass through Rockies

Category	Avalanche	**KP (Rev V) Start**	625.5	**Feature**	59
Source	Geotechnical Report	**KP (Rev V) End**	625.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Avalanche track terminates 300 m above route. Area has snowpack accumulation for potential avalanche however slopes proximate to route are less steep and forested. Partially meets screening criteria.
Estimated Frequency	0.001	Terminus of defined avalanche tracks are located 300 m upslope from route, frequency of events reaching pipeline is expected to be very low.
Vunerability Factor	0.001	Deposition zone - 13°
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 394 Headwaters of Hominka River

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	627.3	**Feature**	64
Source	Geotechnical Report	**KP (Rev V) End**	628.7		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Shallow organics and soil veneers may be subject to sliding over sloped rock. Considered credible potential for sliding.
Estimated Frequency	0.1	No evidence of direct occurrence on route. Moderate frequency expected.
Vunerability Factor	0	Sloughing of soft soils, loss of containment event not considered possible.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 248 **Headwaters of Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	629.7	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	629.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Headwater conditions include; low channel gradient, only slightly incised in open terrain. Crossing is also located beyond fan - does not meet screening criteria.
Estimated Frequency	0.001	Crossing is located in area where debris flow events are not anticipated - very infrequent if possible.
Vunerability Factor	0.01	Deposition or erosion would be expected based on an approximate channel gradient of 2° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 249 **Headwaters of Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	630.35	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	630.4		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Headwater conditions include; low channel gradient, only slightly incised in open terrain. Crossing located beyond fan - does not meet screening criteria.
Estimated Frequency	0.001	Crossing is located in area where debris flow events are not anticipated - very infrequent if possible.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 5° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 250 **Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	632.1	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	632.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Headwater conditions include; low channel gradient, only slightly incised in open terrain. Crossing located beyond fan - does not meet screening criteria.
Estimated Frequency	0.001	Crossing is located in area where debris flow events are not anticipated - very infrequent if possible.
Vunerability Factor	0.01	Deposition or erosion would be expected based on an approximate channel gradient of 2° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 251 Tributary to Missinka River

Category	Debris Flow	**KP (Rev V) Start**	633.92	**Feature**	69
Source	Geotechnical Report	**KP (Rev V) End**	633.96		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include; low gradient channel, moderately steep valley sidewalls may contribute sediment, significant headwater catchment area - screening criteria only partially met.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion would be expected based on an approximate channel gradient of 3° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail ID 252 Tributary to Missinka River

Category	Debris Flow	**KP (Rev V) Start**	635.06	**Feature**	69
Source	Geotechnical Report	**KP (Rev V) End**	635.12		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include; steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion would be expected based on an approximate channel gradient of 7° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.00E-09

Geohazard Detail

ID 395

Valley slopes of Tributary to Missinka River

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	636.7	**Feature**	70
Source	Geotechnical Report	**KP (Rev V) End**	639.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Frequent wet surface soils prone to sliding in cuts.
Estimated Frequency	0.1	Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.
Vunerability Factor	0	Sloughing of soft soils in cuts, loss of containment event not considered possible.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 253 Tributary to Missinka River

Category	Debris Flow	**KP (Rev V) Start**	637.14	**Feature**	69
Source	Geotechnical Report	**KP (Rev V) End**	637.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include; steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 7° in the immediate vicinity of the proposed route. Channel is confined.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail ID 254 Tributary to Missinka River

Category	Debris Flow	**KP (Rev V) Start**	637.3	**Feature**	69
Source	Geotechnical Report	**KP (Rev V) End**	637.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	No channel observed at location - does not meet screening criteria.
Estimated Frequency	0.001	Crossing is located in area where debris flow events are not anticipated to be a hazard - very infrequent if possible.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 7° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail

ID 233

Valley slopes of Tributary to Missinka River

Category	Avalanche	**KP (Rev V) Start**	637.9	**Feature**	71
Source	Geotechnical Report	**KP (Rev V) End**	638		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	No avalanche occurence at kp.
Estimated Frequency	0	No avalanche occurence at kp.
Vunerability Factor	0	No avalanche occurence at kp.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 7 **Tributary to Missinka River**

Category	Avulsion	**KP (Rev V) Start**	638.48	**Feature**	68
Source	Geotechnical Report	**KP (Rev V) End**	638.64		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible alluvial fan. Further checks on avulsion potential recommended.
Estimated Frequency	0.01	Paritially vegetated fan with no visible former channels or indications of activity/frequency, field review recommended.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Deep cover mitigation to be applied if required based on further review. Debris flow potential on fan may also necessitate deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail

ID 255 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	638.48	**Feature**	69
Source	Geotechnical Report	**KP (Rev V) End**	638.64		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the upper portion of the fan with an approximate channel gradient of 10° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 6.67E-10

Geohazard Detail

ID 234

Valley slopes of Tributary to Missinka River

Category	Avalanche	**KP (Rev V) Start**	638.9	**Feature**	71
Source	Geotechnical Report	**KP (Rev V) End**	639.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Two small possible avalanche tracks terminate 40 m upslope of route. Meets screening criteria with exception of lack of trees.
Estimated Frequency	0.001	Forested at crossing location, frequency of large avalanche expected to be low.
Vunerability Factor	0.001	Deposition zone - 11°
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.50E-10

Geohazard Detail

ID 256 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	638.9	**Feature**	69
Source	Geotechnical Report	**KP (Rev V) End**	638.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	No channel observed at location - does not meet screening criteria.
Estimated Frequency	0.001	Crossing is located in area where debris flow events are not anticipated to be a hazard - very infrequent if possible.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate gradient of 6° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail

ID 257 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	639.58	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	639.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: low channel gradient with steep valley sidewalls with high sediment supply potential. Large catchment area with many tributaries. Debris flow may initiate in tributary but unlikely to runout down channel and impact crossing.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 2° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 396 Missinka River valley slopes

Category Slide - shallow/moderate deep

KP (Rev V) Start 642.68

Feature 72

Source Geotechnical Report

KP (Rev V) End 643.7

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Gullied till, outwash and glaciolacustrine materials prone to shallow sliding in cuts

Estimated Frequency 0.1

Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.

Vunerability Factor 0

Sloughing of soft soils in shallow cuts, loss of containment event not considered possible.

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 470 **Missinka River**

Category	Scour	**KP (Rev V) Start**	643.38	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	643.46		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 397 **Missinka River area**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	643.7	**Feature**	73
Source	Geotechnical Report	**KP (Rev V) End**	668.7		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Glaciolacustrine deposits, moderately steep slopes, known stability problems on cuts
Estimated Frequency	0.1	Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.
Vunerability Factor	0	Sloughing of soft soils in shallow cuts, loss of containment event not considered possible.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 258 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	645.94	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	645.96		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, significant headwater catchment area. Crossing is located away from steep terrain and most of the material would likely deposit higher up to the east - screening criteria only partially met.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 6° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 259 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	646.7	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	647.24		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, significant headwater catchment area. Crossing is located away from steep terrain and most of the material would likely deposit higher up to the east - screening criteria only partially met.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion would be expected based on an approximate channel gradient of 6° in the immediate vicinity of the pipeline should a debris flow be possible. Crossing is located downgradient of fan.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail ID 471 Missinka River

Category	Scour	**KP (Rev V) Start**	648.1	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	648.2		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	40m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 260 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	652.1	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	652.56		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the upper portion of the fan with an approximate channel gradient of 6° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial may be required upon further review.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail ID 498 Tributary to Missinka River

Category	Avulsion	**KP (Rev V) Start**	652.1	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	652.56		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Review of LiDAR (March 2012) shows moderately well defined fan with with several former channel visible. Path profile drawn across fan suggest midsection is elevated relative to fan margins. Avulsion may extend over approximately 500 m.
Estimated Frequency	0.1	Forested fan however former channels are visible on LiDAR imagery.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-09

Geohazard Detail ID 261 Tributary to Missinka River

Category	Debris Flow	**KP (Rev V) Start**	655.1	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	655.22		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include; steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses fan apex with an approximate channel gradient of 12° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail

ID 262 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	656.26	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	656.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 9° in the immediate vicinity of the proposed route. Fan is located downstream.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail

ID 263 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	659.66	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	659.76		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep upstream channel gradient, moderately steep valley walls that do not show evidence of major sediment contribution. Smaller sized catchment area but still considered capable of generating debris flow - screening criteria met.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 8° in the immediate vicinity of the proposed route. Channel is confined.
Mitigation Options	1.00E-02	Deep burial may be required upon further review.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 264 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	661.36	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	661.46		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 3° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial may be required upon further review.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail

ID 265 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	662.02	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	662.26		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 5° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-02	Deep burial may be required upon further review.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail ID 266 Tributary to Missinka River

Category	Debris Flow	**KP (Rev V) Start**	665.22	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	665.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include; steep channel gradient, steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the upper portion of the fan with an approximate channel gradient of 5° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial may be required upon further review.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail

ID 267 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	666.46	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	666.54		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended. Avulsion potential should be evaluated.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the middle-portion of an incised fan with an approximate channel gradient of 4° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial may be required upon further review.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail

ID 268 **Tributary to Missinka River**

Category	Debris Flow	**KP (Rev V) Start**	667.82	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	668.58		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Headwater conditions include: very poorly defined channel, slightly incised with little sediment contribution, small catchment - does not meet screening criteria.
Estimated Frequency	0.001	Crossing is located in area where debris flow events are not anticipated to be a hazard - very infrequent if possible.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the upper portion of the fan with an approximate channel gradient of 5° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 352 Parsnip River

Category	Lateral Migration	**KP (Rev V) Start**	673.6	**Feature**	77
Source	Geotechnical Report	**KP (Rev V) End**	674.14		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Oxbows and meander scars near crossing indicate previous lateral erosion. Wide flat valley bottom (part of Rocky Mountain Trench). River channel is toward the east side. Swamp and muskeg terrain with shallow groundwater across valley bottom to west.
Estimated Frequency	0.1	Preliminary review of LiDAR indicates that lateral erosion is a possibility.
Vunerability Factor	0.1	70m wide channel (could be wider during a lateral erosion event).
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.00E-08

Geohazard Detail

ID 472 **Parsnip River**

Category	Scour	**KP (Rev V) Start**	673.6	**Feature**	77
Source	Geotechnical Report	**KP (Rev V) End**	674.14		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	70m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.67E-09

Geohazard Detail ID 398 West of Parsnip River

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	673.84	**Feature**	75
Source	Geotechnical Report	**KP (Rev V) End**	675.24		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Glaciolacustrine deposits, potentially unstable. There have been cut stability issues along the local logging roads.
Estimated Frequency	0.1	Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.
Vunerability Factor	0	Sloughing of soft soils in shallow cuts, loss of containment event not considered possible.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 399 West of Wichcika Creek

Category Slide - shallow/moderate deep

KP (Rev V) Start 682

Feature 78

Source Geotechnical Report

KP (Rev V) End 688

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Poorly drained wet terrain with moderate slopes. Shallow slides in cuts. There have been cut stability issues along the local logging roads

Estimated Frequency 0.1

Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.

Vunerability Factor 0

Sloughing of soft soils in cuts, loss of containment event not considered possible.

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 353

Tributary to Chuchinka Creek near alignment

Category Lateral Migration

KP (Rev V) Start 689.8

Feature 82

Source Geotechnical Report

KP (Rev V) End 700.8

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0

Has been routed to avoid hazard.

Route situated on sideslope above tributary to Chuchinka Creek. Lateral migration may occur on valley floor but is away from route.

Estimated Frequency 0

Has been routed to avoid hazard.

Vunerability Factor 0

Has been routed to avoid hazard.

10m channel

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 400 Tributary to Chuchinka Creek area

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	689.8	**Feature**	81
Source	Geotechnical Report	**KP (Rev V) End**	700.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Poorly drained wet terrain with moderate slopes. Shallow slides in cuts. There have been cut stability issues along the local logging roads
Estimated Frequency	0.1	Occurrence considered possible upon excavation of cuts. Frequency difficult to assess.
Vunerability Factor	0	Sloughing of soft soils in shallow cuts, loss of containment event not considered possible.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail **ID** 8 **Tributary to Chuchinka Creek**

Category	Avulsion	**KP (Rev V) Start**	692.06	**Feature**	82
Source	Geotechnical Report	**KP (Rev V) End**	692.64		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible alluvial fan. Further checks on avulsion potential recommended. Note that fan is apparently being mined for gravel, mining activities may impact avulsion hazard.
Estimated Frequency	0.01	Paritially vegetated fan with no visible former channels or indications of activity/frequency, field review recommended.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.82E-09

Geohazard Detail ID 494 Tributary to Chuchinka Creek

Category Lateral Migration
KP (Rev V) Start 705.66
Feature
Source Assessment based on review of avai
KP (Rev V) End 705.86

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1
Meander scars and point bar deposition near crossing indicate previous lateral erosion.

Estimated Frequency 0.1
Recent point bar depostion (unvegetated) suggest mobile stream.

Vunerability Factor 0.001
15 m wide channel.

Mitigation Options 1.00E-03

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.00E-10

Geohazard Detail **ID** 401 **Angusmac Creek East Valley Slope**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	712.66	**Feature**	84
Source	Geotechnical Report	**KP (Rev V) End**	713.16		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Moderately steep gullied slopes to east and west, instabilities observed during field reconnaissance.
Estimated Frequency	0.1	Occurs or immediate vicinity of route, relatively high frequency of shallow to moderate sliding is expected.
Vunerability Factor	0.001	
Mitigation Options	1.00E-02	May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 10

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.00E-09

Geohazard Detail

ID 354 **Angusmac Creek**

Category	Lateral Migration	**KP (Rev V) Start**	713.16	**Feature**	86
Source	Geotechnical Report	**KP (Rev V) End**	713.44		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided/meandering channel. Some subchannels and active gravel bar depostion/erosion. History of lateral erosion.
Estimated Frequency	1	Active bar depostion/erosion and history of lateral erosion indicate high frequency of lateral movement.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail

ID 473 **Angusmac Creek**

Category	Scour
Source	Geotechnical Report
KP (Rev V) Start	713.16
KP (Rev V) End	713.44
Feature	86

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.86E-11

Geohazard Detail

ID 499 **Angusmac Creek West Valley Slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	713.55	**Feature**	84
Source	Geotechnical Report	**KP (Rev V) End**	713.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Moderately steep gullied slopes to east and west, instabilities observed during field reconnaissance.
Estimated Frequency	0.1	Occurs or immediate vicinity of route, relatively high frequency of shallow to moderate sliding is expected.
Vunerability Factor	0.001	Shallow sliding parallel to pipe.
Mitigation Options	1.00E-02	May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 10

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-09

Geohazard Detail **ID** 355 **Crooked River**

Category	Lateral Migration	**KP (Rev V) Start**	720.88	**Feature**	87
Source	Geotechnical Report	**KP (Rev V) End**	721.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river on floodplain composed of fines and organics with many oxbow lakes. Extent of lateral erosion assessed using LiDAR imagery.
Estimated Frequency	0.1	Easily erodable fine grained sediments and organics, expect relatively high frequency of lateral erosion.
Vunerability Factor	0.001	30 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.08E-10

Geohazard Detail

ID 474 **Crooked River**

Category	Scour	**KP (Rev V) Start**	720.88	**Feature**	87
Source	Geotechnical Report	**KP (Rev V) End**	721.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	30 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.08E-11

Geohazard Detail

ID 356 **Muskeg River**

Category	Lateral Migration	**KP (Rev V) Start**	750.8	**Feature**	90
Source	Geotechnical Report	**KP (Rev V) End**	750.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering channel. No oxbows or bars evident near crossing location. Low banks in a wide valley. Channel is gently curved toward the west and may be migrating slowly toward the west. Extent of lateral migration assessed using LiDAR imagery.
Estimated Frequency	0.01	No obvious indications of high lateral mobility suggests lower frequency.
Vunerability Factor	0.001	30 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 475 **Muskeg River**

Category	Scour	**KP (Rev V) Start**	750.8	**Feature**	90
Source	Geotechnical Report	**KP (Rev V) End**	750.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	30m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 357 Salmon River

Category	Lateral Migration	**KP (Rev V) Start**	765.44	**Feature**	91
Source	Geotechnical Report	**KP (Rev V) End**	765.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Sinuous, meadering river with many oxbow lakes and meander scars. Highly mobile river with frequent debris jams. Extensive sand deposits contribute to erosion.
Estimated Frequency	1	Potential for meander cutoff or channel reoccupation.
Vunerability Factor	0.01	40 m wide channel. High mobility increases vulnerability.
Mitigation Options	1.00E-03	Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.22E-08

Geohazard Detail

ID 476 **Salmon River**

Category	Scour	**KP (Rev V) Start**	765.44	**Feature**	91
Source	Geotechnical Report	**KP (Rev V) End**	765.9		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	35m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-11

Geohazard Detail

ID 402 **West valley slope of Salmon River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	765.9	**Feature**	92
Source	Geotechnical Report	**KP (Rev V) End**	766.14		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Evidence of shallow sliding and/or groundwater piping and gully erosion (incised creeks) on west side
Estimated Frequency	1	Expected to be relatively frequent.
Vunerability Factor	0.001	Shallow sliding parallel to pipeline.
Mitigation Options	1.00E-03	Requires major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail

ID 523 **Tributary to Beaver Lake**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	782.38	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	782.58		

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Route crosses meander bend of tributrary to Beaver Lake. Possible shallow sliding in banks.
Estimated Frequency	0.1	No indication of significant stability problems based on review of LiDAR. The low-power stream is unlikely to cause significant erosion and undercutting / bank destabilization.
Vunerability Factor	0.001	Sliding in direction of pipeline.
Mitigation Options	1.00E-03	Recommend reroute around meander within corridor.

Applied Mitgations	**Standard Factor**
Reroute	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 403 **Necoslie River valley slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	818.92	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	819.32		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Aerial review suggests local sliding as a result of banks and slopes being undercut by meandering stream. Glaciolacustrine clay deposits.
Estimated Frequency	0.1	Expected to be relatively frequent.
Vunerability Factor	0.01	Potential for larger scale event increases vulnerability.
Mitigation Options	1.00E-03	May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail ID 477 Necoslie River

Category	Scour	**KP (Rev V) Start**	819.32	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	819.46		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail

ID 70 **Stuart River East valley slope**

Category	Deep seated slide	**KP (Rev V) Start**	824.3	**Feature**	94
Source	Geotechnical Report	**KP (Rev V) End**	824.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Deep-seated slides south of river crossing however none observed near route or to the north suggesting a more stable geology. Requires further field investigation. Route was located north of area of sliding.
Estimated Frequency	0.001	No deep-seated slides on route, low frequency of occurrence.
Vunerability Factor	1	Slopes steeper than angle of residual friction.
Mitigation Options	1.00E-03	HDD crossing proposed (won't mitigate). Monitoring of stability conditions and major slope and crest grading.

Applied Mitgations	**Standard Factor**
Monitoring of slope stability conditions	0.1
Major slope and crest grading	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-11

Geohazard Detail ID 478 Stuart River

Category Scour

Source Assessment based on review of avai

KP (Rev V) Start 824.76

KP (Rev V) End 825.08

Feature

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1
Unconsolidated river bed material expected at crossing location.

Estimated Frequency 0.01
Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.

Vunerability Factor 0.1
200 m wide channel.

Mitigation Options 1.00E-03
HDD crossing proposed.

Applied Mitgations	Standard Factor
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail

ID 71 **Stuart River West valley slope**

Category	Deep seated slide	**KP (Rev V) Start**	825	**Feature**	94
Source	Geotechnical Report	**KP (Rev V) End**	825.5		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Deep-seated slides south of river crossing however none observed near route or to the north suggesting a more stable geology. Requires further field investigation. Route was located north of area of sliding.
Estimated Frequency	0.001	No deep-seated slides on route, low frequency of occurrence.
Vunerability Factor	0.1	Low angle slide (near residual angle of friction).
Mitigation Options	1.00E-01	HDD crossing proposed (won't mitigate). Monitoring of stability conditions and major slope and crest grading.

Applied Mitgations	**Standard Factor**
Monitoring of slope stability conditions	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.82E-10

Geohazard Detail

ID 404 **Stuart River West valley slope**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	825.02	**Feature**	95
Source	Geotechnical Report	**KP (Rev V) End**	825.08		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Moderately deep-seated slide along lower valley wall on west side of river on lowest terrace front.
Estimated Frequency	1	Slide considered active.
Vunerability Factor	0.1	Would load sagbend/overbend interval for a trenched crossing.
Mitigation Options	1.00E-04	HDD crossing proposed.Trenchless crossing method to avoid shallow to moderately deep slide on west side.

Applied Mitgations	**Standard Factor**
Deep burial below slide	0.001

Mitigation Site-specific	0.1	HDD expected to be significantly below area of potential sliding.

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.86E-08

Geohazard Detail ID 524 Sutherland River East valley slope

Category Slide - shallow/moderate deep
Source Assessment based on review of avai
KP (Rev V) Start 859.24
KP (Rev V) End 859.4
Feature

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 1
Moderately deep seated slide on East bank of Sutherland River identified from LiDAR imagery March 2012.

Estimated Frequency 1
Level of activity is unknown, assume slide is moving.

Vunerability Factor 0.001

Mitigation Options 1.00E-03
Possible reroute to the north or south beyond extents of the slide.

Applied Mitgations	Standard Factor
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail

ID 500 **Sutherland River**

Category	Scour	**KP (Rev V) Start**	859.4	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	859.48		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15 m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 515 Maxan Creek

Category	Lateral Migration	**KP (Rev V) Start**	951.2	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	951.58		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1
Highly sinous creek within boggy floodplain. No oxbows near crossing.

Estimated Frequency 0.01
Easily erodable fine grained sediments and organics, expect relatively high lateral mobility.

Vunerability Factor 0.001
15 m wide channel.

Mitigation Options 1.00E-03

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail

ID 405 **Klo Creek East valley slopes**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	977.34	**Feature**	98
Source	Geotechnical Report	**KP (Rev V) End**	977.96		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Steep slopes with existing small failures identified north and south of route. Fine-grained soils in valley bottom. Parts of east approach slope have groundwater blow-off failures. Small failures on west slope due to stream erosion in glaciolacustrine sediments. Documented occurrence.
Estimated Frequency	0.1	Expected to be relatively frequent.
Vunerability Factor	0.001	Small failures parallel to pipeline.
Mitigation Options	1.00E-03	Major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-10

Geohazard Detail

ID 546 **Klo Creek east approach Lower slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	978.3	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	978.44		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Steep slopes with existing small failures identified north and south of route. Fine-grained soils in valley bottom. Parts of east approach slope have groundwater blow-off failures. Small failures on west slope due to stream erosion in glaciolacustrine sediments. Documented occurrence.
Estimated Frequency	0.1	Expected to be relatively frequent
Vunerability Factor	0.001	Small failures parallel to pipeline.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 7.14E-10

Geohazard Detail ID 358 Klo Creek

Category	Lateral Migration	**KP (Rev V) Start**	978.44	**Feature**	97
Source	Geotechnical Report	**KP (Rev V) End**	978.68		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Moderate sized meandering creek, bar deposition/erosion evident, old oxbows and meander scars near crossing.
Estimated Frequency	0.1	Recent lateral movement.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.00E-10

Geohazard Detail

ID 479 **Klo Creek**

Category	Scour	**KP (Rev V) Start**	978.44	**Feature**	97
Source	Geotechnical Report	**KP (Rev V) End**	978.68		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail

ID 501 **Klo Creek West valley slopes**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	978.68	**Feature**	98
Source	Geotechnical Report	**KP (Rev V) End**	978.72		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Steep slopes with existing small failures identified north and south of route. Fine-grained soils in valley bottom. Parts of east approach slope have groundwater blow-off failures. Small failures on west slope due to stream erosion in glaciolacustrine sediments. Documented occurrence.
Estimated Frequency	0.1	Expect relatively frequent shallow sliding events at location.
Vunerability Factor	0.001	Small failures parallel to pipeline.
Mitigation Options	1.00E-03	Major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.54E-10

Geohazard Detail ID 359 Buck Creek

Category Lateral Migration | **KP (Rev V) Start** 989.78 | **Feature**

Source Geotechnical Report | **KP (Rev V) End** 990.16

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

The stream is meandering with lateral erosion evident. Several oxbows along the valley bottom near and west of the crossing.

Estimated Frequency 0.1

Recent lateral migration has occurred.

Vunerability Factor 0.001

15m wide channel.

Mitigation Options 1.00E-03

Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	Standard Factor
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 3.33E-10

Geohazard Detail **ID** 480 **Buck Creek**

Category	Scour	**KP (Rev V) Start**	989.78	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	990.16		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail

ID 481 **Owen Creek**

Category	Scour	**KP (Rev V) Start**	1005.2	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1005.4		

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, notes below pertain to RevU. RevV crosses upstream. Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 541 **Owen Creek East Approach Slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1006.58	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1006.7		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Field assessment noted evidence of relict shallow slides on moderately steep slopes with shallow bedrock. Slopes 15 to 20 m high at 25°. Shallow soils over bedrock.
Estimated Frequency	0.01	No evidence of active slope movement.
Vunerability Factor	0.001	Direction of potential sliding is parallel to pipe direction.
Mitigation Options	1.00E-03	For trench crossing grade slope and implement surface and groundwater controls. For trenchless crossing install pipe below maximum possible slide depth.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 8.33E-11

Geohazard Detail ID 323 West of Owen Creek

Category Deep seated slide

KP (Rev V) Start 1006.7

Feature

Source Schwab, J.W. 2011 and review of im

KP (Rev V) End 1007.1

Hillslope and Fluvial Processes Along the Proposed Pipeline Corridor, Burns Lake to Kitimat, West Central British Columbia. Prepared for Bulkley Valley Centre for Natural Resources Research & Management. September 2011.

Legacy ☑ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor 0

RevV has been routed south to avoid, legacy.

"The corridor also crosses a large historic earth flow feature at approximately 1.5 km west of Owen Creek."
Schwab, J.W. (2011). Hillslope and Fluvial Processes Along the Proposed Pipeline Corridor, Burns Lake to Kitimat, West Central British Columbia.
Prepared for Bulkley Valley Centre for Natural Resources Research & Management. September 2011.
Located at: G:\PROJECTS\7000\VG07702 -Spectra WLNG\Reference Publications\Regional\2011 - Schwab - Hillslope and Fluvial Processes Along the Proposed Pipeline Corridor.pdf

Estimated Frequency 0.1

Level of activity unknown.

Vunerability Factor 0.1

Slope angle steeper than residual angle of friction, however, route passes through crest of slide.

Mitigation Options 1.00E-03

Reroute has been implemented

Applied Mitgations	Standard Factor
Reroute	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 532 **Owen Creek**

Category Lateral Migration

Source Assessment based on SWAT field re

KP (Rev V) Start 1006.7

KP (Rev V) End 1006.72

Feature

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Minor bank erosion, no scour. Active floodplain about 30 m wide with meandering channel. Stream banks about 1.5 m high.

Estimated Frequency 0.01

Moss growth on floodplain rocks suggest relatively infrequent lateral erosion events.

Vunerability Factor 0.001

Small stream (Channel 15 m wide x 1.5 m deep with pebbles and cobbles with some boulders to 0.8 m bed).

Mitigation Options 1.00E-03

Deep burial across floodplain for trench crossing. Proposed bored crossing to extend below/beyond potential erosion limits.

Applied Mitgations	Standard Factor
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.01E-10

Geohazard Detail

ID 543 **Owen Creek West Approach Slopes**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1006.72	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1006.8		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Field assessment noted evidence of relict shallow slides on moderately steep slopes with shallow bedrock south of the crossing location on the west approach slope. Slopes 15 to 20 m high at 25°.
Estimated Frequency	0.01	No evidence of active slope movement.
Vunerability Factor	0.001	Direction of potential sliding is parallel to pipe direction.
Mitigation Options	1.00E-02	Consider grading and ground/surface water controls as required.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.25E-10

Geohazard Detail

ID 534 **Fenton Creek East Approach Slope**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1012.74	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1012.78		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Slump-like terrain features were noted on the east approach slope 150 m downstream of crossing. The features are thought however to be derived from erosional rather than sediment-gravity processess. Requires further investigation. Traces of old shallow slide activity noted in tributary draws (on both approach slopes). Shallow sliding considered possible with no defined occurrence.
Estimated Frequency	0.01	No evidence of active slope movement.
Vunerability Factor	0.001	Direction of potential sliding is parallel to pipe direction.
Mitigation Options	1.00E-03	Grading and groundwater/surface water control. Deep burial.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 2.50E-11

Geohazard Detail ID 482 Fenton Creek

Category	Scour	**KP (Rev V) Start**	1012.78	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1012.8		

Legacy ☑ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail ID 533 Fenton Creek

Category	Lateral Migration	**KP (Rev V) Start**	1012.78	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1012.8		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Field assessment noted a braided channel 110 m downstream of crossing. Lateral mobility at crossing location requires assessment but is assumed to occur for purpose of hazard assessment.
Estimated Frequency	0.1	Major lateral erosion event assumed to coincide with 1:10 storm. Braided channels tend to be highly mobile.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-03	Set sagbends back into approach slopes to protect against channel erosion.

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.01E-09

Geohazard Detail

ID 542 **Fenton Creek West Approach Slope**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1012.8	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1012.86		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Traces of old shallow slide activity noted in tributary draws on west (and east) approach slopes. Shallow sliding possible with no defined occurrence.
Estimated Frequency	0.01	No evidence of active slope movement.
Vunerability Factor	0.001	Direction of potential sliding is parallel to pipe direction.
Mitigation Options	1.00E-03	Grading, ground and surface water control. Set pipe below rupture surface.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-09 **FLOC/m** 1.67E-11

Geohazard Detail

ID 540 **24.5 Mile Creek East approach slope**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1018.36	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1018.4		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Field assessment noted evidence of shallow to moderate depth slumping on moderately steep slopes.
Estimated Frequency	0.01	No evidence of active slope movement.
Vunerability Factor	0.001	Direction of potential sliding would be parallel to pipe.
Mitigation Options	1.00E-03	Grade slope, ground and surface water control.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-10

Geohazard Detail ID 539 24.5 Mile Creek

Category	Lateral Migration	**KP (Rev V) Start**	1018.4	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1018.42		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Floodplain is about 20 m wide and 1 m above channel elevation. Undercutting noted on outside bends. Lateral migration considered possible.
Estimated Frequency	0.1	Significant channel migration expected to correspond with 1:10 year precipitation event.
Vunerability Factor	0.001	Small stream (Channel 4 to 5 m wide x 1 m deep).
Mitigation Options	1.00E-03	Grade east slope to setback sagbend.

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.01E-09

Geohazard Detail ID 406 Lamprey Creek East valley slopes

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1021	**Feature**	100
Source	Geotechnical Report	**KP (Rev V) End**	1022		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, route move furhter to the south. Comments below pertain to RevU. East valley wall moderate to steep and about 80 m high, slide near route.
Estimated Frequency	0	No indicatation of direct occurrence on route, expected to be moderately frequent.
Vunerability Factor	0	Vulnerability expected to be higher than default value.
Mitigation Options	1.00E-03	May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 537 Lamprey Creek East approach slope

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1024.36	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1024.66		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	East approach is steep, mossy, dry with rocky soil. Field assessment noted possible shallow slide scars on slope with no evidence of recent movement. North of the route (20m) is a more well defined slide scarp mearuring about 2 X 2.5m deep by 10m wide with no signs of active movement. Shallow sliding considered possible.
Estimated Frequency	0.01	No evidence of recent movement.
Vunerability Factor	0.001	Direction of potential sliding is parellel to pipeline.
Mitigation Options	1.00E-04	Major grading with surface and groundwater control. Route has been selected to avoid steepest ground located north (downstream) of the proposed crossing towards the confluence with the Morice River.

Applied Mitgations	Standard Factor
Major slope and crest grading	0.01
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 3.33E-12

Geohazard Detail

ID 483 **Lamprey Creek**

Category	Scour	**KP (Rev V) Start**	1024.66	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1024.84		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Cobbles and boulders to 0.3 m in channel with sand and fine gravel bar deposits. Some bank erosion. Floodplain is elevated about 2 m above channel, and about 2.6 m above deepest pool scour.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	Small stream (channel at crossing about 8 m wide)
Mitigation Options	1.00E-03	Burial below depth of scour.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail ID 535 Lamprey Creek

Category	Lateral Migration	**KP (Rev V) Start**	1024.66	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1024.84		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	100 m active flood plain with low elevation terrace deposits along margins. Floodplain is elevated about 2 m above water elevation (September, 2012) with several old channels incised 1 to 1.5 m deep. Some bank erosion.
Estimated Frequency	0.1	Significant lateral erosion events expected to correspond to 1:10 storm.
Vunerability Factor	0.001	Small stream (channel at crossing about 8 m wide)
Mitigation Options	1.00E-03	Set sagbends into approach slopes and deep burial required across active floodplain to protect pipe against possible channel scour and lateral erosion.

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.56E-10

Geohazard Detail ID 407 Cedric Creek valley slopes

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1028.3	**Feature**	101
Source	Geotechnical Report	**KP (Rev V) End**	1029.1		

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Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, route move furhter to the south. Comments below pertain to RevU. Moderately deep valley with steep slopes. Potential for shallow sliding. Considered credible potential for sliding with no defined occurrence at location.
Estimated Frequency	0	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0	
Mitigation Options	1.00E-03	May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 360 **Cedric Creek**

Category	Lateral Migration	**KP (Rev V) Start**	1028.45	**Feature**	102
Source	Geotechnical Report	**KP (Rev V) End**	1028.55		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, route move furhter to the south. Comments below pertain to RevU. Channel is well incised and does not show evidence of previous lateral erosion.
Estimated Frequency	0	Forested channel with small creek, no evidence of previous lateral erosion.
Vunerability Factor	0	5m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 485 **Cedric Creek**

Category	Scour	**KP (Rev V) Start**	1028.45	**Feature**	102
Source	Geotechnical Report	**KP (Rev V) End**	1028.55		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Legacy record, route move furhter to the south. Comments below pertain to RevU. Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0	10m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 538 **Cedric Creek**

Category	Scour	**KP (Rev V) Start**	1032.72	**Feature**	
Source	Assessment based on SWAT field re	**KP (Rev V) End**	1032.74		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Field assessment carried out 800 m downstream of crossing noted channel 3 m wide x 0.6 m deep with cobbles and small boulders to 0.3 m. Small amount of stagnant water in bed. Low energy stream, significant scour is unlikely.
Estimated Frequency	0.01	
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 5.00E-11

Geohazard Detail

ID 408 **Side slopes of Morice River valley**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1035.1	**Feature**	103
Source	Geotechnical Report	**KP (Rev V) End**	1038.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Rev V does not cross sideslopes, crossing further south. Comments below pertain to RevU. Shallow soils on moderately steep, bedrock-controlled slopes (potential for shallow to moderately deep sliding along route). Considered credible potential for sliding with no defined occurrence at location.
Estimated Frequency	0.1	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0.01	Sliding direction is across pipeline.
Mitigation Options	1.00E-03	May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Drainage and groundwater control	0.1
Major slope and crest grading	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 484 **Morice River**

Category	Scour	**KP (Rev V) Start**	1043.06	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1043.42		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	70m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-09

Geohazard Detail ID 544 Morice River

Category	Lateral Migration	**KP (Rev V) Start**	1043.06	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1043.42		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Meandering river with abandoned channels.
Estimated Frequency	0.01	Expected to correspond with major storm/flooding event.
Vunerability Factor	0.1	Larger stream (70m across)
Mitigation Options	1.00E-03	Set HDD limits beyond extents of lateral erosion.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.78E-09

Geohazard Detail

ID 9 **Crystal Creek**

Category	Avulsion	**KP (Rev V) Start**	1049	**Feature**	105
Source	Geotechnical Report	**KP (Rev V) End**	1049.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Channel loses confinement as it enters the low angle valley bottom of Gosnell Creek. Braided channel with frequent subchannels indicating smaller (within ~100 m of main channel) lateral avulsion events. Further checks on larger, lateral-extent avulsion potential is recommended.
Estimated Frequency	0.1	Active subchannels and dissected bars lack vegetaion indicating frequent abandonment and reactivation. Documented avulsion events.
Vunerability Factor	0.01	Large stream 15 m wide.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail

ID 269 **Crystal Creek**

Category	Debris Flow	**KP (Rev V) Start**	1049	**Feature**	106
Source	Geotechnical Report	**KP (Rev V) End**	1049.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include: gentle to moderate channel gradient, steep valley sidewalls, high sediment supply and large tributary area. Screening criteria is only partially met however it has been identified by Schwab and Geertsema as being subject to debris flows.
Estimated Frequency	0.1	Non-vegetated active channel suggests relatively frequent debris flow events.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 3° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Bored crossing	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.78E-09

Geohazard Detail

ID 270 **Tributary to Gosnell Creek**

Category	Debris Flow	**KP (Rev V) Start**	1055.02	**Feature**	107
Source	Geotechnical Report	**KP (Rev V) End**	1055.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 7° in the immediate vicinity of the proposed route.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail ID 271 Tributary to Gosnell Creek

Category	Debris Flow	**KP (Rev V) Start**	1057.34	**Feature**	107
Source	Geotechnical Report	**KP (Rev V) End**	1057.72		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the upper portion of fan with an approximate channel gradient of 10° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.50E-10

Geohazard Detail ID 272 Tributary to Gosnell Creek

Category Debris Flow **KP (Rev V) Start** 1058.24 **Feature**

Source Geotechnical Report **KP (Rev V) End** 1058.7

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.

Estimated Frequency 0.01

Vegetated channel without indication of recent debris flows, field check recommended.

Vunerability Factor 0.01

Deposition or erosion is expected along route which crosses the middle portion of the fan with an approximate channel gradient of 7° in the immediate vicinity of the pipeline.

Mitigation Options 1.00E-02

Deep burial.

Applied Mitgations	Standard Factor
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 6.67E-10

Geohazard Detail

ID 273 **Tributary to Gosnell Creek**

Category Debris Flow

Source Geotechnical Report

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

KP (Rev V) Start 1059.6

KP (Rev V) End 1060

Feature

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01

Headwater conditions include: steep channel gradient, steep valley walls with potential for erosion and sediment accumulaltion. Significant catchment area. Route located near/beyond margins of fan - screening criteria only partially met.

Estimated Frequency 0.01

Vegetated channel without indication of recent debris flows. Crossing located significant distance from steep slopes, field check recommended.

Vunerability Factor 0.01

Deposition or erosion is expected along route which crosses the lower portion of the fan with an approximate channel gradient of 5° in the immediate vicinity of the pipeline.

Mitigation Options 1.00E-02

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-11

Geohazard Detail

ID 10 **Tributary to Gosnell Creek**

Category	Avulsion	**KP (Rev V) Start**	1061.82	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1062		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Rev V crosses creek approximately 200 m upstream of previous Rev R route where channel is more deeply incised possibly above fan. Partial legacy record from previous route.
Estimated Frequency	0.001	Possible aluvuial fan, field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.55E-11

Geohazard Detail **ID** 361 **Gosnell Creek**

Category	Lateral Migration	**KP (Rev V) Start**	1063.76	**Feature**	108
Source	Geotechnical Report	**KP (Rev V) End**	1064.08		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided channel with active bar depostion/erosion and relocation across floodplain. Abandoned channels.
Estimated Frequency	0.1	Expect frequent channel switching and lateral movement across floodplain.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.50E-10

Geohazard Detail

ID 486 **Gosnell Creek**

Category	Scour	**KP (Rev V) Start**	1063.76	**Feature**	108
Source	Geotechnical Report	**KP (Rev V) End**	1064.08		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-11

Geohazard Detail

ID 11 **Tributary to Burnie River Fan**

Category Avulsion

KP (Rev V) Start 1071.06

Feature 109

Source Geotechnical Report

KP (Rev V) End 1072.06

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Route crosses mid-section of well defined forested fan. Current channel visible from apex through to center portion of fan where it appears to diverge laterally. Further field checks recommended.

Estimated Frequency 0.01

Heavily forested fan with no visible former channels or indications of activity/frequency, field review recommended. Channel occupies center portion of fan.

Vunerability Factor 0.001

Small stream.

Mitigation Options 1.00E-02

Deep cover recommended. Debris flow potential on fan may also necessitate deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-10

Geohazard Detail **ID** 274 **Tributary to Burnie River Fan**

Category	Debris Flow	**KP (Rev V) Start**	1071.06	**Feature**	110
Source	Geotechnical Report	**KP (Rev V) End**	1072.06		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Vegetated channel without indication of recent debris flows. Crossing located significant distance from steep slopes, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the middle portion of the fan with an approximate channel gradient of 3° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-10

Geohazard Detail

ID 409

East approach slope to Burnie and Clore River valleys

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1075.2	**Feature**	112
Source	Geotechnical Report	**KP (Rev V) End**	1075.65		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible shallow slide in colluvium or till to north of route.
Estimated Frequency	0.01	No indication of direct occurrence on route.
Vunerability Factor	0.01	Vulnerability expected to to be higher than default value.
Mitigation Options	1.00E-03	Bored crossing proposed. May require major grading and drainage/groundwater control.

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.22E-11

Geohazard Detail

ID 525 | **Tributary to Burnie River**

Category	Scour	**KP (Rev V) Start**	1076.3	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1076.56		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail

ID 526 **Tributary to Burnie River**

Category	Lateral Migration	**KP (Rev V) Start**	1076.3	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1076.56		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided channel.
Estimated Frequency	0.01	Non-vegetated gravel bars.
Vunerability Factor	0.001	20 m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Sag bends beyond long-term hydrotechnical design limits	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 4.00E-11

Geohazard Detail ID 362 Clore River

Category	Lateral Migration	**KP (Rev V) Start**	1077.4	**Feature**	114
Source	Geotechnical Report	**KP (Rev V) End**	1077.94		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided channel with active bar depostion/erosion and relocation across floodplain. Abandoned channels. Active migration across wide area.
Estimated Frequency	1	Expect frequent channel switching and lateral movement across floodplain.
Vunerability Factor	1	40 m wide channel, deep flow during floods.
Mitigation Options	1.00E-04	Trenchless crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area. Crossing to be set back to account for conceivable lateral migration. A reroute to the south may provide feasible aerial or trenched crossing methods.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001
Reroute	0.001

Mitigation Site-specific	100	FLOC calculated assuming either a trenchless method outside extents of lateral migration or a reroute south.

Frequency Loss of Containment 1.00E-04 **FLOC/m** 1.85E-07

Geohazard Detail

ID 487 **Clore River**

Category	Scour	**KP (Rev V) Start**	1077.4	**Feature**	114
Source	Geotechnical Report	**KP (Rev V) End**	1077.94		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	40 m wide channel, deep flow during floods.
Mitigation Options	1.00E-03	Trenchless crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.85E-09

Geohazard Detail **ID** 235 **Clore Tunnel - East Portal**

Category	Avalanche	**KP (Rev V) Start**	1077.95	**Feature**	
Source	Bear Enterprises Report	**KP (Rev V) End**	1078.55		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Avalanche track within gully 100 m north and parallel to pipeline. Steep forested terrain with high snowpack. Terrrain confines avalanche to gully away from route. Avalanche expert report assessed no significant hazard.
Estimated Frequency	0.001	Forested along route, frequency of large avalanche expected to be low.
Vunerability Factor	0.1	Possible transport zone - 25-30°
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.67E-09

Geohazard Detail

ID 34 | **Clore Tunnel - West Portal**

Category	Rockfall	**KP (Rev V) Start**	1083.78	**Feature**	118
Source	Geotechnical Report	**KP (Rev V) End**	1084.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Moderate to steep slopes near tunnel portal. Visible rockfall runout primarily on valley walls to the south. Location of portal relative to rockfall hazard needs to be checked but is assumed to be below rock fall shadow.
Estimated Frequency	0.01	Evidence of active rockfall upslope but not crossing route. Location of portal relative to rockfall hazard needs to be checked.
Vunerability Factor	0.01	Route crosses slope of approximately 17° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E+00	No mitigation required providing portal is below rockfall shadow.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.67E-09

Geohazard Detail **ID** 236 **Clore Tunnel - West Portal**

Category	Avalanche	**KP (Rev V) Start**	1083.78	**Feature**	117
Source	Geotechnical Report	**KP (Rev V) End**	1084.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Bear Enterprises report "both portals (Clore W & Hoult E) in low angle terrain that is not subject to snow avalanche greater than size 2".
Estimated Frequency	0.001	Treed slope, frequency of large avalanche expected to be low.
Vunerability Factor	0.001	Route crosses slope of approximately 17° in the immediate vicinity of the pipeline. Deposition zone.
Mitigation Options	1.00E+00	Note that rockfall mitigation for same area may require mitigation.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.43E-11

Geohazard Detail

ID 410

Tributary to Clore River and adjacent areas

Category Slide - shallow/moderate deep

KP (Rev V) Start 1083.78

Feature 115

Source Geotechnical Report

KP (Rev V) End 1084.6

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1 — Shallow slides in colluvium.

Estimated Frequency 0.1 — Shallow slides in colluvium.

Vunerability Factor 0.001 — Shallow slides in colluvium.

Mitigation Options 1.00E-02

Applied Mitgations	**Standard Factor**
Major slope and crest grading	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 9.09E-10

Geohazard Detail

ID 35 **Tributary to Clore River crossing**

Category	Rockfall	**KP (Rev V) Start**	1084.9	**Feature**	118
Source	Geotechnical Report	**KP (Rev V) End**	1084.94		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Rockfall occurs from canyon walls of tributary to Clore
Estimated Frequency	0.1	Details of frequency not known.
Vunerability Factor	0	Aerial crossing above potential rockfall.
Mitigation Options	1.00E+00	Aerial crossing above potential rockfall.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 275 **Tributary to Clore River crossing**

Category	Debris Flow	**KP (Rev V) Start**	1084.9	**Feature**	116
Source	Geotechnical Report	**KP (Rev V) End**	1084.94		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Potential for debris flows in upper reaches, however, unlikely to occur at crossing location.
Estimated Frequency	0.01	Potential for debris flows in upper reaches, however, unlikely to occur at crossing location.
Vunerability Factor	0	Aerial crossing proposed placing pipe above debris flow hazard area.
Mitigation Options	1.00E-03	Aerial crossing proposed.

Applied Mitgations	**Standard Factor**
HDD or Aerial installation	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 237 **Hoult Tunnel - East Portal**

Category	Avalanche	**KP (Rev V) Start**	1084.95	**Feature**	117
Source	Geotechnical Report	**KP (Rev V) End**	1085.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Track well away from route, considered legacy Avalanche track 100 m SW and parallel to route. Bear Enterprises report "both portals (Clore W & Hoult E) in low angle well forested terrain that is not subject to snow avalanche greater than size 2."
Estimated Frequency	0.001	Treed slope, frequency of large avalanche expected to be low.
Vunerability Factor	0.001	Deposition zone - 20°
Mitigation Options	1.00E+00	Heavy wall or concrete coating, or protecton such as portal canopy if required by further study. Note that rockfall mitigation for same area may require concrete coating.

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 36 **Hoult Tunnel - East Portal**

Category	Rockfall	**KP (Rev V) Start**	1085.64	**Feature**	118
Source	Geotechnical Report	**KP (Rev V) End**	1086.02		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Steep slopes near tunnel portal with possible rockfall source areas. Portal and pipeline appear to the near margins of rockfall shadow. Location of portal relative to rockfall hazard needs to be checked.
Estimated Frequency	0.01	Evidence of active rockfall upslope but not crossing route. Location of portal relative to rockfall hazard needs to be checked.
Vunerability Factor	0.01	Route crosses slope at approximately 23° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E+00	Consider concrete coating or portal canopy.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.63E-08

Geohazard Detail **ID** 37 **Hoult Tunnel - West Portal**

Category	Rockfall	**KP (Rev V) Start**	1090.08	**Feature**	120
Source	Geotechnical Report	**KP (Rev V) End**	1091.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Steep slopes near tunnel portal with possible rockfall source areas. Portal and pipeline appear to the near margins of rockfall shadow. Location of portal relative to rockfall hazard needs to be checked.
Estimated Frequency	0.01	Evidence of active rockfall upslope but assumed to not cross route. Location of portal relative to rockfall hazard needs to be checked.
Vunerability Factor	0.01	Route located through runout zone, reasonably close to source areas. May be subject to bouncing and rolling rock.
Mitigation Options	1.00E+00	Consider portal canopy.

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 8.20E-09

Geohazard Detail

ID 238 **Hoult Tunnel - West Portal**

Category	Avalanche	**KP (Rev V) Start**	1090.08	**Feature**	119
Source	Geotechnical Report	**KP (Rev V) End**	1091.3		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Route descends a wooded spur, lower probability of snowpack accumulation for avalanche which typically occur in bowls or open faces. Bear Enterprises Report "The alignment corridor shown on the map appears to pose relatively small avalanche risk…The areas adjacent on either side of the wooded spur are extremely active and large avalanche areas that should be entirely avoided."
Estimated Frequency	0.001	Treed slope, frequency of large avalanche expected to be low.
Vunerability Factor	0.001	Deposition zone - 21°
Mitigation Options	1.00E+00	Portal canopy to be considered for rockfall protection.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail ID 38 Hoult Creek

Category	Rockfall	**KP (Rev V) Start**	1092.02	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1092.08		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.001	Crossing close to an area of rockfall but appears to be clear of problem area. Located beyond rockfall shadow area.
Estimated Frequency	0.001	No active rockfall at crossing location.
Vunerability Factor	1	Aerial crossing.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.67E-08

Geohazard Detail ID 276 Hoult Creek

Category Debris Flow

KP (Rev V) Start 1092.02

Feature 121

Source Geotechnical Report

KP (Rev V) End 1092.08

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01 — Potential for debris flows in upper reaches, however, unlikely to occur at crossing location.

Estimated Frequency 0.01 — Potential for debris flows in upper reaches, however, unlikely to occur at crossing location.

Vunerability Factor 0 — Aerial crossing proposed (above debris flow hazard).

Mitigation Options 1.00E-03 — Aerial crossing proposed (above debris flow hazard).

Applied Mitgations	Standard Factor
HDD or Aerial installation	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 363 **Hoult Creek**

Category	Lateral Migration	**KP (Rev V) Start**	1092.02	**Feature**	123
Source	Geotechnical Report	**KP (Rev V) End**	1092.08		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Channel is well incised and does not show evidence of previous significant lateral erosion.
Estimated Frequency	0.001	Channel is well incised and does not show evidence of previous significant lateral erosion. Frequency expected to be very low.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	Aerial crossing.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-11 **FLOC/m** 1.00E-13

Geohazard Detail

ID 411

Hoult Creek and Upper Kitimat River valley

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1092.12	**Feature**	124
Source	Geotechnical Report	**KP (Rev V) End**	1106.42		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Groundwater blow-off failures have occurred locally including during logging road construction. Slides in logging road fills have occurred in a few areas. Considered credible potential for sliding with no defined occurrence at location.
Estimated Frequency	0.1	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0.001	
Mitigation Options	1.00E-02	Deep cover, grading, drainage and groundwater control and/or surface water control as required.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific 10

Frequency Loss of Containment 1.00E-07 **FLOC/m** 6.99E-12

Geohazard Detail ID 277 Hoult Creek Valley

Category	Debris Flow	**KP (Rev V) Start**	1093.1	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1093.12		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria. Evidence of past debris flow events.
Estimated Frequency	0.1	Active channel possibly subject to relatively frequent debris flows. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route is located across incised bedrock (suspected) channel with gradient approximately 19° in the immediate vicinity of the pipeline. Fan located downslope.
Mitigation Options	1.00E-04	Deep burial concrete fill over pipe due to steep gradients.

Applied Mitgations	Standard Factor
Deep burial	0.01
Concrete coating or protection	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail ID 502 Hoult Creek Valley

Category	Debris Flow	**KP (Rev V) Start**	1094.08	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1094.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep upslope valley walls with potential for erosion and sediment accumulaltion. Small catchment area limits debris flow potential however events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses confined reach with gradient approximately 15° in the immediate vicinity of the pipeline. Fan located dowslope.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.00E-08

Geohazard Detail **ID** 12 **Hoult Creek Valley**

Category Avulsion

Source Geotechnical Report

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

KP (Rev V) Start 1094.48

KP (Rev V) End 1095.1

Feature

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Route crosses lower section of steep, well-defined fan. Very active channel upslope with debris flows and avalanches affecting drainage paths on fan. Review of LiDAR (March 2012) shows the channel is located in the middle of the fan but has been subject to past avulsion (channel switching) over a width of 400 m or more (far in excess of the channel width) with local erosion and deposition to shallow depths.

Estimated Frequency 0.1

Based on the apparent activity (sediment supply, debris flow, avalanche) of upslope channel, avulsion frequency is expected to be high.

Vunerability Factor 0.001

Small stream.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.82E-09

Geohazard Detail ID 39 Hoult Creek Valley

Category	Rockfall	**KP (Rev V) Start**	1094.48	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1095.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located near margins of rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however, moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 12° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.61E-09

Geohazard Detail ID 240 Hoult Creek Valley

Category Avalanche

KP (Rev V) Start 1094.48

Feature 125

Source Geotechnical Report

KP (Rev V) End 1095.1

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Defined avalanche track crosses route, bare slopes.

Estimated Frequency 0.01

Located at base of avalanche track, moderate frequency of very large avalanches.

Vunerability Factor 0.001

Deposition zone - 12°

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.82E-10

Geohazard Detail **ID** 278 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1094.48	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1095.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria. Evidence of past debris flow events.
Estimated Frequency	0.1	Active channel possibly subject to relatively frequent debris flows. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected at route which crosses the lower portion of fan with an approximate channel gradient of 12° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.67E-08

Geohazard Detail

ID 40 **Hoult Creek Valley**

Category	Rockfall	**KP (Rev V) Start**	1095.1	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1095.38		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located near margins of rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 10° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 3.57E-09

Geohazard Detail

ID 241 **Hoult Creek Valley**

Category	Avalanche	**KP (Rev V) Start**	1095.1	**Feature**	125
Source	Geotechnical Report	**KP (Rev V) End**	1095.38		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Avalanche track 70 m north of route. Steep terrain with high snowpack, meets screening criteria with exception of lack of trees.
Estimated Frequency	0.01	Treed slope, frequency expected to be low. Smaller catchment may limit frequency of large avalanches.
Vunerability Factor	0.001	Deposition zone - 10°
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.33E-11

Geohazard Detail

ID 279 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1095.1	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1095.38		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria. Evidence of past debris flow events.
Estimated Frequency	0.1	Active channel possibly subject to relatively frequent debris flows. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the lower portion of the fan with an approximate channel gradient of 10° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 3.33E-08

Geohazard Detail

ID 503 **Hoult Creek Valley**

Category	Avulsion	**KP (Rev V) Start**	1095.1	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1095.38		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route crosses lower section of steep, well-defined fan. Very active channel upslope with debris flows and avalanches affecting drainage paths on fan. Review of LiDAR (March 2012) shows the channel is located in the middle of the fan but has been subject to past avulsion (channel switching) over a width of 400 m or more (far in excess of the channel width) with local erosion and deposition to shallow depths.
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow, avalanche) of upslope channel, avulsion frequency is expected to be high.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 3.33E-09

Geohazard Detail ID 13 Hoult Creek Valley

Category	Avulsion	**KP (Rev V) Start**	1095.38	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1095.78		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route crosses lower section of steep well defined fan. Very active channel upslope with debris flows and avalanches affecting drainage paths on fan.
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow, avalanche) of upslope channel, avulsion frequency is expected to be high
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail ID 41 Hoult Creek Valley

Category	Rockfall	**KP (Rev V) Start**	1095.38	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1095.78		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located near edge of rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosseslower portion of fan with slope of approximately 15-20° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	Check block size. Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail

ID 280 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1095.38	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1095.78		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for erosion and sediment accumulaltion. Small catchment area limits debris flow potential, however, events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Field check recommended.
Vunerability Factor	0.1	Transport zone - Route crosses lower portion of fan with gradient approximately 15-20° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail ID 14 Hoult Creek Valley

Category	Avulsion	**KP (Rev V) Start**	1095.82	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1096.84		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route crosses lower section of steep well defined fan. Very active channel upslope with debris flows and avalanches affecting drainage paths on fan.
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow, avalanche) of upslope channel, avulsion frequency is expected to be high
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.05E-09

Geohazard Detail

ID 42 **Hoult Creek Valley**

Category Rockfall

KP (Rev V) Start 1095.82

Feature 122

Source Geotechnical Report

KP (Rev V) End 1096.84

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located near edge of rockfall shadow.

Estimated Frequency 0.01

Active channel with many potential source areas, however moss and vegetation on rockfall debris suggest infrequent events.

Vunerability Factor 0.01

Route crosses fan with slope of approximately 11° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 9.80E-10

Geohazard Detail

ID 242 **Hoult Creek Valley**

Category	Avalanche	**KP (Rev V) Start**	1095.82	**Feature**	125
Source	Geotechnical Report	**KP (Rev V) End**	1096.84		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Multiple avalanche tracks finger out on fan terminating within 40 m of route. Meets screening criteria with exception of lack of trees.
Estimated Frequency	0.01	Treed slope, frequency of large avalanche expected to be low.
Vunerability Factor	0.001	Deposition zone - 11°
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.05E-11

Geohazard Detail

ID 281 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1095.82	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1096.84		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria. Evidence of past debris flow events.
Estimated Frequency	0.1	Active channel possibly subject to relatively frequent debris flows. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion expected along route which crosses the lower portion of the fan with an approximate channel gradient of 11° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.18E-08

Geohazard Detail **ID** 43 **Hoult Creek Valley**

Category	Rockfall	**KP (Rev V) Start**	1096.84	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1097.06		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located near edge of rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however, moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 27° in the immediate vicinity of the pipeline. Expect rock to be bouncing or rolling.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.00E-08

Geohazard Detail

ID 282 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1096.84	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1097.06		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep upslope valley walls with potential for erosion and sediment accumulaltion. Small catchment area limits debris flow potential however events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses lower portion of fan with gradient approximately 15° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.00E-09

Geohazard Detail **ID** 504 **Hoult Creek Valley**

Category	Avulsion	**KP (Rev V) Start**	1096.84	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1097.06		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Fan with former avulsion events reviewed on LiDAR (March 2012).
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow) of upslope channel, avulsion frequency is expected to be high.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 4.54E-09

Geohazard Detail ID 44 Hoult Creek Valley

Category	Rockfall	**KP (Rev V) Start**	1097.06	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1097.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located within rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 22° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail

ID 283 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1097.06	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1097.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep upslope valley walls with potential for erosion and sediment accumulaltion. Small catchment area limits debris flow potential however events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses lower portion of fan with gradient approximately 22° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail

ID 505 **Hoult Creek Valley**

Category Avulsion

Source Assessment based on review of avai

KP (Rev V) Start 1097.06

KP (Rev V) End 1097.2

Feature

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Fan with former avulsion events reviewed on LiDAR (March 2012).

Estimated Frequency 0.1

Based on the apparent activity (sediment supply, debris flow) of upslope channel, avulsion frequency is expected to be high.

Vunerability Factor 0.001

Small stream.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail **ID** 506 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1097.22	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1097.38		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep upslope valley walls with potential for erosion and sediment accumulaltion. Small catchment area limits debris flow potential however events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses lower portion of fan with gradient approximately 17° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-09

Geohazard Detail

ID 508 **Hoult Creek Valley**

Category	Avulsion	**KP (Rev V) Start**	1097.22	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1097.38		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Fan with former avulsion events reviewed on LiDAR (March 2012).
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow) of upslope channel, avulsion frequency is expected to be high.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.25E-09

Geohazard Detail **ID** 509 **Hoult Creek Valley**

Category	Rockfall	**KP (Rev V) Start**	1097.22	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1097.38		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located within rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 17° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-09

Geohazard Detail ID 507 Hoult Creek Valley

Category	Debris Flow	**KP (Rev V) Start**	1097.38	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1097.48		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep upslope valley walls with potential for erosion and sediment accumulaltion. Small catchment area limits debris flow potential however events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses lower portion of fan with gradient approximately 19° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail

ID 510 **Hoult Creek Valley**

Category	Avulsion	**KP (Rev V) Start**	1097.38	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1097.48		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Fan with former avulsion events reviewed on LiDAR (March 2012).
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow) of upslope channel, avulsion frequency is expected to be high.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail ID 511 Hoult Creek Valley

Category	Rockfall	**KP (Rev V) Start**	1097.38	**Feature**	122
Source	Geotechnical Report	**KP (Rev V) End**	1097.48		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located within rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however moss and vegetation on rockfall debris suggest infrequent events.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 19° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail **ID** 15 **Hoult Creek Valley**

Category	Avulsion	**KP (Rev V) Start**	1097.48	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1098.04		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route crosses lower section of steep well defined fan. Very active channel upslope with debris flows and avalanches affecting drainage paths on fan. Located in incised channel.
Estimated Frequency	0.1	Based on the apparent activity (sediment supply, debris flow, avalanche) of upslope channel, avulsion frequency is expected to be high
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-03	Note that debris flow mitigation for same channel will require deep cover and heavy wall pipe.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01
Heavy wall pipe	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.82E-10

Geohazard Detail

ID 45 **Hoult Creek Valley**

Category	Rockfall	**KP (Rev V) Start**	1097.48	**Feature**	123
Source	Geotechnical Report	**KP (Rev V) End**	1098.04		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Located on colluvial/alluvial fan of active steep bedrock controlled channel subject to possible avalanches/debris flows, expect to have talus depostion and rolling rock. Route located near edge of rockfall shadow.
Estimated Frequency	0.01	Active channel with many potential source areas, however moss and vegetation on fan where crossing is located suggest infrequent rockfall.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 22° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-03	Note that debris flow mitigation for same channel will require deep cover and heavy wall pipe.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01
Heavy wall pipe	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.82E-10

Geohazard Detail **ID** 243 **Hoult Creek Valley**

Category	Avalanche	**KP (Rev V) Start**	1097.48	**Feature**	125
Source	Geotechnical Report	**KP (Rev V) End**	1098.04		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Defined avalanche track crosses route, bare slopes.
Estimated Frequency	0.01	Bare slope suggests regular occurrence, however smaller catchment may limit frequency of large avalanches.
Vunerability Factor	0.001	Deposition zone - 22°
Mitigation Options	1.00E-03	Note that debris flow mitigation for same channel will require deep cover and heavy wall pipe.

Applied Mitgations	**Standard Factor**
Deep burial	0.01
Heavy wall pipe	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.82E-11

Geohazard Detail

ID 284 **Hoult Creek Valley**

Category	Debris Flow	**KP (Rev V) Start**	1097.48	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1098.04		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria. Evidence of past debris flow events.
Estimated Frequency	0.1	Active channel possibly subject to relatively frequent debris flows. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses lower portion of fan with gradient approximately 22° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-03	Deep burial, heavy wall pipe.

Applied Mitgations	**Standard Factor**
Deep burial	0.01
Heavy wall pipe	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.82E-08

Geohazard Detail

ID 412 **Hunter Creek valley slopes**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1099.05	**Feature**	128
Source	Geotechnical Report	**KP (Rev V) End**	1104.2		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	REVU crosses 200m downstream where channel is less incised. REVR comments "Several small shallow slides in surface soils along terrace fronts (due to creek undercutting)." Avoided by routing.
Estimated Frequency	0	Avoided by routing
Vunerability Factor	0	Avoided by routing.
Mitigation Options	1.00E-03	HDD crossing proposed. Slides have been avoided by routing.

Applied Mitgations	**Standard Factor**
Deep burial below slide	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 16 Hoult Creek Valley

Category	Avulsion	**KP (Rev V) Start**	1099.06	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1099.28		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Route crosses channel at base of steeper slopes, channel is poorly confined/incided but no fan based on review of LiDAR. Conditions for occurrence are not met.
Estimated Frequency	0.01	Difficult to assess frequency. Field check needed.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.00E-10

Geohazard Detail

ID 46 **Hoult Creek Valley**

Category	Rockfall	**KP (Rev V) Start**	1099.06	**Feature**	124
Source	Geotechnical Report	**KP (Rev V) End**	1099.28		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Active rockfall source 1.3km upslope runout visible to 1.1km. Beyond rockfall shadow area - screening criteria only partially met.
Estimated Frequency	0.001	Rockfall source upslope, however, beyond rockfall shadow area.
Vunerability Factor	0.001	Route crosses fan with slope of approximately 7° in the immediate vicinity of the pipeline. No rockfall expected.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 5.00E-11

Geohazard Detail ID 285 Hoult Creek Valley

Category	Debris Flow	**KP (Rev V) Start**	1099.06	**Feature**	121
Source	Geotechnical Report	**KP (Rev V) End**	1099.28		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, moderately steep valley walls. Small catchment area limits debris flow potential however events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Vegetated at crossing. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the lower portion of the fan with an approximate channel gradient of 7° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail

ID 17 **Hunter Creek**

Category	Avulsion	**KP (Rev V) Start**	1103.86	**Feature**	126
Source	Geotechnical Report	**KP (Rev V) End**	1104.22		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route crosses apex of fan prone to avulsion based with multiple abandoned channels observed lower on the fan. Defined occurrence, however, extent is limited at crossing due to confinement imposed by bedrock knob to west and valley sidewall to east.
Estimated Frequency	0.1	High frequency based on active recent (partially vegetated) abandoned distributary channels on lower parts of the fan.
Vunerability Factor	0.1	Large stream.
Mitigation Options	1.00E-04	HDD crossing proposed

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.0001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail **ID** 286 **Hunter Creek**

Category	Debris Flow	**KP (Rev V) Start**	1103.86	**Feature**	127
Source	Geotechnical Report	**KP (Rev V) End**	1104.22		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Several past occurences.
Estimated Frequency	0.1	Doccumented occurrence suggests high relative frequency.
Vunerability Factor	0.01	Deposition or erosion is expected based on an approximate channel gradient of 3° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
HDD or Aerial installation	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail

ID 488 **Hunter Creek**

Category	Scour	**KP (Rev V) Start**	1103.86	**Feature**	126
Source	Geotechnical Report	**KP (Rev V) End**	1104.22		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.86E-11

Geohazard Detail

ID 287 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1106.56	**Feature**	130
Source	Geotechnical Report	**KP (Rev V) End**	1106.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls. Small catchment area limits debris flow potential, however, events are known to occur in region.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude. Vegetated at crossing. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses near top of poorly defined fan with gradient approximately 26° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail **ID** 413 **Upper Kitimat River valley**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1106.62	**Feature**	131
Source	Geotechnical Report	**KP (Rev V) End**	1124.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Steep gullied slopes, potentially unstable. Evidence of shallow to moderately deep slides in glaciofluvial and till deposits. Groundwater blow-off failures have occurred locally during logging road construction. Considered credible potential for sliding with no defined occurrence at location.
Estimated Frequency	0.1	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0.001	
Mitigation Options	1.00E-02	Deep cover, grading, drainage and groundwater control and/or surface water control as required.

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Surface water control	0.1

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.56E-12

Geohazard Detail

ID 18 — **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1106.96	**Feature**	129
Source	Geotechnical Report	**KP (Rev V) End**	1107.42		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Crossing near apex of vegetated fan, actively eroding sediment source upslope contributes towards condition for occurrence. Former avulsed channels not visible, channel is incised. Requries field review.
Estimated Frequency	0.01	High sediment supply, however, no visible former channels. Field check needed.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail ID 47 Upper Kitimat River valley

Category	Rockfall	**KP (Rev V) Start**	1106.96	**Feature**	135
Source	Geotechnical Report	**KP (Rev V) End**	1107.42		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Source area upslope originating from very steep bedrock gully sidewalls. Route appears to be beyond the rockfall shadow, further field checks required. Screening criteria only partially met.
Estimated Frequency	0.001	Rockfall source is significant distance upslope from proposed route in much steeper terrain. Crossing is located beyond rock fall shadow, expected to be very infrequent if possible.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 9° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-09 **FLOC/m** 6.67E-12

Geohazard Detail ID 288 Upper Kitimat River valley

Category	**Debris Flow**	**KP (Rev V) Start**	1106.96	**Feature**	130
Source	Geotechnical Report	**KP (Rev V) End**	1107.42		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.1	Located in Coast Mountains with high precipitaton, vegetated at crossing. Field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expect at route location which crosses the upper portion of the fan with an approximate channel gradient of 9° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-09

Geohazard Detail

ID 19 **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1107.52	**Feature**	129
Source	Geotechnical Report	**KP (Rev V) End**	1107.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Channel is incised relative to open surrounding terrain at crossing location. An obstruction in the channel may trigger avulsion. Required conditions only partially met, needs field assessment. No fan with visible former channels identified on LiDAR (March 2012).
Estimated Frequency	0.01	No evidence of previous avulsion based on initial study, therefore low frequency. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 3.57E-11

Geohazard Detail ID 289 Upper Kitimat River valley

Category	Debris Flow	**KP (Rev V) Start**	1107.52	**Feature**	130
Source	Geotechnical Report	**KP (Rev V) End**	1107.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Documented past occurrence at crossing. "Stream channel has been subject to debris flows and erosion along the channel possibly caused by diversion of water along an old logging road higher up the slope."
Estimated Frequency	0.1	Doccumented occurrence suggests high relative frequency.
Vunerability Factor	0.01	Deposition or erosion is expect at route location which crosses the upper portion of the fan with an approximate channel gradient of 10° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-03	Deep burial, heavy wall pipe.

Applied Mitgations	**Standard Factor**
Deep burial	0.01
Heavy wall pipe	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail

ID 20 **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1110.36	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1110.44		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Crossing is located on upper portion of fan, logging activity upslope and debris flow potential may be contributing to sediment supply. Conditions for occurrence satisfied.
Estimated Frequency	0.1	Fan morphology suggest avulsion is possible, however, frequency difficult to estimate. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.25E-08

Geohazard Detail ID 290 Upper Kitimat River valley

Category Debris Flow

KP (Rev V) Start 1110.36

Feature 134

Source Geotechnical Report

KP (Rev V) End 1110.44

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.1	Located in coast mountains with high precipitaton, appears vegetated at crossing, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses near the fan apex with an approximate channel gradient of 4° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	Standard Factor
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.00E-08

Geohazard Detail ID 21 Upper Kitimat River valley

Category Avulsion **KP (Rev V) Start** 1113.38 **Feature**

Source Geotechnical Report **KP (Rev V) End** 1113.4

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01
Route crosses confined channel. Avulsion potential is considered low. Field check required.

Estimated Frequency 0.01
Morphology suggests avulsion is unlikely and therefore infrequent if possible. Field check required.

Vunerability Factor 0.001
Small stream.

Mitigation Options 1.00E-02
Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-09 **FLOC/m** 5.00E-11

Geohazard Detail ID 291 Upper Kitimat River valley

Category	Debris Flow	**KP (Rev V) Start**	1113.38	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1113.4		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria with no defined occurrence.
Estimated Frequency	0.1	Located in Coast Mountains with high precipitaton, appears vegetated at crossing, field check recommended.
Vunerability Factor	0.1	Transport Zone - Channel confined at crossing with gradient approximately 20° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.00E-07

Geohazard Detail

ID 292 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1113.7	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1113.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, small catchment area limits debris flow potential - screening criteria only partially met.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude appears vegetated at crossing. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses upper portion of fan with gradient approximately 24° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail ID 414 North Side Kitimat River

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1113.7	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1113.82		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Areas of shallow sliding and debris flows of overburden materials on sloping rock and within overburden materials aided by groundwater seepage. Documented occurence.
Estimated Frequency	1	Expected to be relatively frequent.
Vunerability Factor	0.001	
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Minor slope and crest grading	0.1
Drainage and groundwater control	0.1
Surface water control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail **ID** 22 **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1114.04	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1114.12		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Small steep gully, limited catchement and moderately well defined fan. Crossing near fan apex limits lateral extent of avulsion hazard.
Estimated Frequency	0.01	Fan morphology suggest avulsion is possible, however, frequency difficult to estimate. Field check required.
Vunerability Factor	0.001	Small stream
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.25E-10

Geohazard Detail

ID 293 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1114.04	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1114.12		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, small catchment area limits debris flow potential - screening criteria only partially met.
Estimated Frequency	0.01	Small catchment limits frequency and magnitude appears vegetated at crossing. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Crossing is located near apex of fan with gradient approximately 21° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.00E-09

Geohazard Detail ID 23 Upper Kitimat River valley

Category	Avulsion	**KP (Rev V) Start**	1114.68	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1114.74		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Small steep gully, limited catchement with moderately well defined fan, screening criteria met. Channels on both sides of the fan appear to have been active.
Estimated Frequency	0.1	Fan morphology suggest avulsion is possible, however, frequency of channel switching is difficult to estimate. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail

ID 294 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1114.68	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1114.74		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, field check recommended. Vegetated channel does not appear very active.
Vunerability Factor	0.1	Transport Zone - Channel loses some confinement upstream from crossing with gradient approximately 23° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail

ID 24 **Upper Kitimat River valley**

Category Avulsion

KP (Rev V) Start 1114.86

Feature

Source Geotechnical Report

KP (Rev V) End 1114.98

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Crossing near fan apex. Drainage has significant catchment and sediment supply with a moderately well defined fan.
Screening criteria met but difficult to determine if avulsion has occurred previously at location.

Estimated Frequency 0.01

No evidence of previous avulsion based on initial study, therefore low frequency. Field check required.

Vunerability Factor 0.001

Small stream.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.00E-10

Geohazard Detail

ID 48 **Upper Kitimat River valley**

Category	Rockfall	**KP (Rev V) Start**	1114.86	**Feature**	135
Source	Geotechnical Report	**KP (Rev V) End**	1114.98		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Apparently active rockfall located 250 m upslope with visible runout to 190 m from route. Located within the rockfall shadow. All screening criteria met, however, no obvious impact at route. Field review required.
Estimated Frequency	0.1	Active source area, expect occasional rolling rock to come down gully.
Vunerability Factor	0.01	Route crosses fan with slope of approximately 20° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.00E-07

Geohazard Detail

ID 295 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1114.86	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1114.98		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, field check recommended. Vegetated channel does appear very active.
Vunerability Factor	0.1	Transport Zone - Route crosses upper portion of fan with gradient approximately 20° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.00E-08

Geohazard Detail ID 512 Upper Kitimat River valley

Category	Debris Flow	**KP (Rev V) Start**	1115.28	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1115.32		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, moderately steep valley walls, small catchment area limits debris flow potential - screening criteria only partially met.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, field check recommended. Vegetated channel does not appear very active.
Vunerability Factor	0.1	Transport Zone - Channel confined at crossing with gradient approximately 28° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.00E-09

Geohazard Detail ID 513 Upper Kitimat River valley

Category	Debris Flow	**KP (Rev V) Start**	1115.6	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1135.64		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Headwater conditions include: steep channel gradient, moderately steep valley walls, small catchment area limits debris flow potential - screening criteria only partially met.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, field check recommended. Vegetated channel does not appear very active.
Vunerability Factor	0.1	Transport Zone - Channel confined at crossing with gradient approximately 20° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 4.98E-12

Geohazard Detail

ID 25 **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1116.28	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1116.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Route crosses mid-point of moderately well defined fan, screening criteria met, however, no evidence of occurrence at this location. Requires field review.
Estimated Frequency	0.01	Fan morphology suggest avulsion is possible, however, frequency difficult to estimate. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 4.00E-11

Geohazard Detail ID 49 Upper Kitimat River valley

Category Rockfall | **KP (Rev V) Start** 1116.28 | **Feature** 135

Source Geotechnical Report | **KP (Rev V) End** 1116.6

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Gully with some steep sidewalls which may act as potential source areas. Route located near the edge of rockfall shadow zone. Field check required.

Estimated Frequency 0.01

No evidence of previous rockfall impacting pipline corridor, expect low frequency, however, field check required.

Vunerability Factor 0.01

Route crosses fan with slope of approximately 22° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 5.00E-10

Geohazard Detail

ID 244 **Upper Kitimat River valley**

Category	Avalanche	**KP (Rev V) Start**	1116.28	**Feature**	132
Source	Geotechnical Report	**KP (Rev V) End**	1116.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.01	Bear Enterprises report notes debris path of uncertain origin terminating 400 m upslope from route. "It is unlikely to reach the alignment, but the vegetation close to it showed damage that could be due to snow avalanches, but also to logging." Imagery does not support avalanche occurrence near this location.
Estimated Frequency	0.001	Treed slope, frequency of large avalanche expected to be low.
Vunerability Factor	0.001	Deposition zone - 21°
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-10 **FLOC/m** 4.00E-13

Geohazard Detail

ID 296 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1116.28	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1116.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.1	Located in coast mountains with high precipitaton, partially vegetated at crossing. Active channel. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses upper portion of fan with gradient approximately 22° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 4.00E-08

Geohazard Detail ID 297 Upper Kitimat River valley

Category	Debris Flow	**KP (Rev V) Start**	1117.16	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1117.28		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, appears vegetated at crossing, field check required.
Vunerability Factor	0.1	Transport Zone - Route crosses upper portion of fan with gradient approximately 18° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.00E-08

Geohazard Detail ID 26 Upper Kitimat River valley

Category	Avulsion
KP (Rev V) Start	1117.94
Feature	
Source	Geotechnical Report
KP (Rev V) End	1118.36

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Route crosses mid portion of fan below active gully system expected to contribute significant sediment. Former distributary channels not observed on LiDAR (March 2012). Screening criteria met with no defined occurrence at location.
Estimated Frequency	0.01	No evidence of previous avulsion based on initial study despite fan morphology. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-11

Geohazard Detail

ID 298 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1117.94	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1118.36		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, appears vegetated at crossing, field check required.
Vunerability Factor	0.1	Transport Zone - Route crosses middle portion of fan with gradient approximately 15° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.50E-09

Geohazard Detail

ID 299 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1119.36	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1119.52		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.1	Located in Coast Mountains with high precipitaton, appears partially vegetated at crossing. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses fan with gradient approximately 15° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 5.00E-08

Geohazard Detail

ID 27 **Upper Kitimat River valley**

Category Avulsion

KP (Rev V) Start 1119.38

Feature

Source Geotechnical Report

KP (Rev V) End 1119.6

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Route crosses mid-point of moderately well defined fan. Former channel visible on LiDAR. Requires field review to confirm.

Estimated Frequency 0.1

Based on the apparent activity (sediment supply, debris flow, avalanche) of upslope channel, avulsion frequency is expected to be relatively high.

Vunerability Factor 0.001

Small stream.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail ID 50 Upper Kitimat River valley

Category Rockfall **KP (Rev V) Start** 1119.44 **Feature** 135

Source Geotechnical Report **KP (Rev V) End** 1120.24

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Steep upslope terrain. Imagery shows some gaps in vegetation which may correspond to rockfall source areas. Section bounded by gullies also potentially subject to rockfall and talus deposition. Screening criteria met, field check required.

Estimated Frequency 0.01

No evidence of previous rockfall impacting pipline corridor, expect low frequency expected however field check required.

Vunerability Factor 0.01

Route crosses fan with slope of approximately 23° in the immediate vicinity of the pipeline. Expect rock to be decelerating and rolling.

Mitigation Options 1.00E-02

Deep burial plus additional protection depending on results of field check.

Applied Mitgations	Standard Factor
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-10

Geohazard Detail ID 28 Upper Kitimat River valley

Category Avulsion

Source Geotechnical Report

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

KP (Rev V) Start 1120

KP (Rev V) End 1120.62

Feature

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Stream lacks confinement at crossing on a moderately well defined fan. Credible potential but no defined occurrence. Requires field check.

Estimated Frequency 0.01

No evidence of previous avulsion based on initial study, therefore, low frequency. Field check required.

Vunerability Factor 0.001

Small stream.

Mitigation Options 1.00E-02

Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	Standard Factor
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail

ID 300 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1120	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1120.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.1	Located in Coast Mountains with high precipitaton, appears partially vegetated at crossing. Field check recommended.
Vunerability Factor	0.1	Transport Zone - Route crosses fan with gradient approximately 15° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.67E-08

Geohazard Detail

ID 366 **Upper Kitimat River valley**

Category	Lateral Migration	**KP (Rev V) Start**	1120.9	**Feature**	136
Source	Geotechnical Report	**KP (Rev V) End**	1121.4		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	The Kitimat River is eroding laterally toward the logging road aided by groundwater piping of the sediments in the river bank. The route was previously relocated a significant distance from river.
Estimated Frequency	0.001	Route is 150m from Kitimat River (relocated in past).
Vunerability Factor	0.001	80m wide channel.
Mitigation Options	1.00E+00	Mitigated by previous reroute subject to check during detailed design.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 29 **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1121.22	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1121.34		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Crossing at upper portion of a small, moderately well-defined forested fan. Morphology suggests avulsion is possible but no defined occurrence, requires review.
Estimated Frequency	0.001	Fan morphology suggests avulsion is possible, however, frequency difficult to estimate. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-09 **FLOC/m** 1.00E-11

Geohazard Detail

ID 301 **Upper Kitimat River valley**

Category	Debris Flow	**KP (Rev V) Start**	1121.22	**Feature**	134
Source	Geotechnical Report	**KP (Rev V) End**	1121.34		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Located in coast mountains with high precipitaton, vegetated at crossing, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected along route which crosses the fan with an approximate channel gradient of 11° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 1.00E-09

Geohazard Detail

ID 30 **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1121.94	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1122.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Route crosses the middle section of a well defined, vegetated fan.
Estimated Frequency	0.1	Channel is not deeply incised with possible former channels visible on LiDAR image. Field check required.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail

ID 302 **Upper Kitimat River valley**

Category Debris Flow

KP (Rev V) Start 1121.94

Feature 134

Source Geotechnical Report

KP (Rev V) End 1122.1

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.1

Headwater conditions include: steep channel gradient, moderately steep valley walls, significant catchment area - meets screening criteria.

Estimated Frequency 0.01

Located in coast mountains with high precipitaton, vegetated at crossing, field check recommended.

Vunerability Factor 0.1

Transport Zone - Channel loses some confinement upstream from crossing with gradient approximately 19° in the immediate vicinity of the pipeline.

Mitigation Options 1.00E-02

Deep burial.

Applied Mitgations	Standard Factor
Deep burial	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-09

Geohazard Detail ID 51 Upper Kitimat River valley

Category	Rockfall
Source	Geotechnical Report
KP (Rev V) Start	1126.12
KP (Rev V) End	1128.26
Feature	135

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Steep bedrock controlled terrain upslope with exposed rockbluffs potentially subject to rockfall. No runout tracks visible crossing route. Route located near margins of rockfall shadow.
Estimated Frequency	0.01	No evidence of previous rockfall impacting pipline corridor, expect low frequency, however, field check required.
Vunerability Factor	0.01	Low relief terrain immediately surrounding route. Expect rock fragments to be decelerating and rolling.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 5.00E-10

Geohazard Detail

ID 31 | **Upper Kitimat River valley**

Category	Avulsion	**KP (Rev V) Start**	1127.48	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1127.82		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Route crosses near toe of forested alluvial fan.
Estimated Frequency	0.01	Paritially vegetated fan with no visible former channels or indications of activity/frequency, field review recommended.
Vunerability Factor	0.001	Small stream.
Mitigation Options	1.00E-02	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth along alluvial fan impact area	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.50E-11

Geohazard Detail ID 303 Upper Kitimat River valley

Category	Debris Flow	**KP (Rev V) Start**	1127.48	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1127.82		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, significant catchment area - meets screening criteria.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, vegetated at crossing, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expected on route which crosses the lower portion of the fan with an approximate channel gradient of 8° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	Deep burial.

Applied Mitgations	Standard Factor
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 2.50E-10

Geohazard Detail ID 367 Chist Creek

Category	Lateral Migration	**KP (Rev V) Start**	1128.26	**Feature**	137
Source	Geotechnical Report	**KP (Rev V) End**	1128.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided channel with active bar depostion/erosion and relocation across floodplain downstream of crossing.
Estimated Frequency	0.1	Possible lateral erosion west of bridge from bend upstream.
Vunerability Factor	0.01	40 m wide channel. High mobility increases vulnerability.
Mitigation Options	1.00E-02	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Armoured stream banks suitably designed	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.94E-08

Geohazard Detail ID 489 Chist Creek

Category	Scour	**KP (Rev V) Start**	1128.26	**Feature**	137
Source	Geotechnical Report	**KP (Rev V) End**	1128.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	40 m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 2.94E-11

Geohazard Detail

ID 514 **Cecil Creek**

Category	Scour	**KP (Rev V) Start**	1136.68	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1136.74		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	15 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.00E-10

Geohazard Detail ID 415 Eastern flank on Iron Mountain

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1140.62	**Feature**	143
Source	Geotechnical Report	**KP (Rev V) End**	1149.52		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. Considered credible potential for with no defined occurence at location. Possible static or seismic initiation.
Estimated Frequency	0.0004	An estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading. This PGA corresponds to a 1:2500 return period for the Kitimat area.
Vunerability Factor	0.1	Potential for large scale events with movement across pipeline.
Mitigation Options	1.00E+00	Reroute off areas of clay onto lower rock slopes of Iron Mountain if required. Further investigation is recommended.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 4.00E-06 **FLOC/m** 4.49E-10

Geohazard Detail

ID 429 **Eastern flank on Iron Mountain**

Category	**Lateral Spreading**	**KP (Rev V) Start**	1140.62	**Feature**	142
Source	Geotechnical Report	**KP (Rev V) End**	1149.52		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0

Hazard considered under shallow to moderately deep seated sliding.

Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. Considered credible potential for sliding with no defined occurrence at proposed pipeline location. Possible static or seismic initiation.

Estimated Frequency 0

Hazard considered under shallow to moderately deep seated sliding.

An estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading. This PGA corresponds to a 1:2500 return period for the Kitimat area.

Vunerability Factor 0

Hazard considered under shallow to moderately deep seated sliding.

Route located on eastern flank of Iron Mountain with slopes greater than 5°.

Mitigation Options 1.00E+00

Hazard considered under shallow to moderately deep seated sliding.

Design and route to avoid areas prone to lateral spreading. Possible reroute on rock of Iron Mountain flank to the west. Alternate reroute along ridge in middle of Kitimat River Valley. Additional ground and drilling investigation is required to determine if reroute necessary.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 416 **Eastern flank on Iron Mountain**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1141	**Feature**	139
Source	Geotechnical Report	**KP (Rev V) End**	1142.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0

Already considered under shallow to moderate slide hazard for overlapping KP.

Potential slope stability problems in glaciomarine clay. Further geotechnical review recommended. Considered credible potential for sliding with no defined occurrence at location. Possible static or seismic initiation.

Estimated Frequency 0

Already considered under shallow to moderate slide hazard for overlapping KP.

No indication of direct occurrence on route. Expected to be moderately frequent.

Vunerability Factor 0

Already considered under shallow to moderate slide hazard for overlapping KP.

Potential for larger scale event increases vulnerability.

Mitigation Options 1.00E+00

Reroute off marine clay deposits if required by results of further study.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 52 Eastern flank on Iron Mountain

Category	Rockfall	**KP (Rev V) Start**	1142.4	**Feature**	141
Source	Geotechnical Report	**KP (Rev V) End**	1142.52		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Documented occurrence at this location.
Estimated Frequency	0.1	Documented occurrence, considered relatively frequent.
Vunerability Factor	0.1	Route crosses area that has been subject to dicrect rockfall.
Mitigation Options	1.00E-03	Deep cover berms and/or other protection as required

Applied Mitgations	Standard Factor
Deep burial (established on max particle impact energy) and/or extra compaction	0.01
Diversion berm	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.00E-07

Geohazard Detail ID 53 Southeast flank of Iron Mountain

Category Rockfall

KP (Rev V) Start 1148.6

Feature 144

Source Geotechnical Report

KP (Rev V) End 1148.7

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Documented occurrence at this location.

Estimated Frequency 0.1

Documented occurrence, considered relatively frequent.

Vunerability Factor 0.1

Route crosses area that has been subject to dicrect rockfall.

Mitigation Options 1.00E-03

Deep cover and berms and/or additional protection as required.

Applied Mitgations	Standard Factor
Deep burial (established on max particle impact energy) and/or extra compaction	0.01
Diversion berm	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.00E-07

Geohazard Detail

ID 417 **North of Wedeene River**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1148.7	**Feature**	146
Source	Geotechnical Report	**KP (Rev V) End**	1149.1		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Possible shallow to moderately deep slides in glaciomarine clay south-east of route. Lidar hillshade maps (poor quality) suggest that there may be marine clay slides. Considered credible potential for sliding at location with no defined occurrence at location. Field check required.
Estimated Frequency	0.01	No indication of direct occurrence on route. Expected to be moderately frequent.
Vunerability Factor	0.01	Potential for larger scale event and movement across pipeline.
Mitigation Options	1.00E+00	Reroute to North and West if required. Suggest further field review to assess hazard and determine if reroute is required.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.11E-08

Geohazard Detail

ID 72 | **North of Wedeene River**

Category	Deep seated slide	**KP (Rev V) Start**	1149	**Feature**	145
Source	Geotechnical Report	**KP (Rev V) End**	1149.7		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Deep-seated slide east of route, however, route was chosen to miss area. Considered legacy record from previous route revision.
Estimated Frequency	0	Deep-seated slide east of route, however, route was chosen to miss area. Considered legacy record from previous route revision.
Vunerability Factor	0	Deep-seated slide east of route, however, route was chosen to miss area. Considered legacy record from previous route revision.
Mitigation Options	1.00E+00	Further reroute possible if required based on further investigation.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 430 **Wedeene River area**

Category	**Lateral Spreading**	**KP (Rev V) Start**	1149.52	**Feature**	147
Source	Geotechnical Report	**KP (Rev V) End**	1152.32		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. Considered credible potential for sliding with no defined occurrence at proposed pipeline location. Possible static or seismic initiation.
Estimated Frequency	0.0004	An estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading. This PGA corresponds to a 1:2500 return period for the Kitimat area.
Vunerability Factor	1	Route primarily crosses low angle slopes <5° with localized areas up to approximately 15°.
Mitigation Options	1.00E-02	Use routing and crossing design to avoid sensitive clays. Further investigation required for sensitive clays.

Applied Mitgations	**Standard Factor**
Reroute to avoid areas of sensitive clays	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 4.00E-07 **FLOC/m** 1.43E-10

Geohazard Detail ID 490 Wedeene River

Category	Scour	**KP (Rev V) Start**	1150.08	**Feature**	
Source	Assessment based on review of avai	**KP (Rev V) End**	1150.14		

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	50m wide channel.
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.86E-09

Geohazard Detail

ID 418 **Wedeene River west valley slope**

Category	**Slide - shallow/moderate deep**	**KP (Rev V) Start**	1150.18	**Feature**	146
Source	Geotechnical Report	**KP (Rev V) End**	1150.38		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Shallow to moderately deep slides on west side of Wadeene River.
Estimated Frequency	0.01	Slides may be inactive.
Vunerability Factor	0.001	
Mitigation Options	1.00E-03	HDD crossing proposed.

Applied Mitgations	**Standard Factor**
Deep burial below slide	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 1.43E-11

Geohazard Detail ID 73 Wedeene River West Approach

Category Deep seated slide
KP (Rev V) Start 1150.6
Feature 145
Source Geotechnical Report
KP (Rev V) End 1154.5

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01
Deep-seated slide approximately 100 m north-west of route.

Estimated Frequency 0.001
No slides on route, very low frequency of occurence.

Vunerability Factor 1
Slopes steeper than angle of residual friction.

Mitigation Options 1.00E+00
Reroute possible if needed, HDD crossing proposed.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-05 **FLOC/m** 2.56E-09

Geohazard Detail

ID 419 **Little Wedeene River Area**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1152.32	**Feature**	149
Source	Geotechnical Report	**KP (Rev V) End**	1155.82		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Hazard considered under Lateral Spreading
Estimated Frequency	0	Hazard considered under Lateral Spreading
Vunerability Factor	0	Hazard considered under Lateral Spreading
Mitigation Options	1.00E+00	Hazard considered under Lateral Spreading

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 431 **Little Wedeene River Area**

Category	Lateral Spreading	**KP (Rev V) Start**	1152.32	**Feature**	148
Source	Geotechnical Report	**KP (Rev V) End**	1155.82		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. Considered credible potential for sliding with no defined occurrence at proposed pipeline location. Possible static or seismic initiation.
Estimated Frequency	0.0004	An estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading. This PGA corresponds to a 1:2500 return period for the Kitimat area.
Vunerability Factor	0.1	Route crosses low angle slopes <5°
Mitigation Options	1.00E-02	Use routing and crossing design to avoid areas prone to lateral spreading. Possible reroute along the rock slopes to the west. Further investigation required for sensitive clays.

Applied Mitgations	**Standard Factor**
Reroute to avoid areas of sensitive clays	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 4.00E-08 **FLOC/m** 1.14E-11

Geohazard Detail ID 420 Little Wedeene River North terrace face

Category Slide - shallow/moderate deep

KP (Rev V) Start 1153.74

Feature 150

Source Geotechnical Report

KP (Rev V) End 1153.86

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Shallow instabilities identified on terrace slopes. Review slope stability relative to the possible occurrence of glaciomarine clay.

Estimated Frequency 0.1

Expected to be relatively frequent.

Vunerability Factor 0.001

Mitigation Options 1.00E-02

Applied Mitgations	Standard Factor
Major slope and crest grading	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 9.99E-09

Geohazard Detail

ID 368 **Little Wedeene River**

Category	Lateral Migration	**KP (Rev V) Start**	1154.1	**Feature**	151
Source	Geotechnical Report	**KP (Rev V) End**	1154.86		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Braided/anastamosing channel with abandoned channel 500m to the south.
Estimated Frequency	0.01	Abandoned channel does not appear to be recently active but re-occupation appears possible based on preliminary review.
Vunerability Factor	0.1	50 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.

Applied Mitgations	**Standard Factor**
Trenchless Methods enter/exit outside extents of lateral migration	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.43E-09

Geohazard Detail ID 491 Little Wedeene River

Category	Scour	**KP (Rev V) Start**	1154.1	**Feature**	151
Source	Geotechnical Report	**KP (Rev V) End**	1154.86		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.1	50 m wide channel.
Mitigation Options	1.00E-03	Bored crossing proposed.

Applied Mitgations	**Standard Factor**
Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movement	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-06 **FLOC/m** 1.54E-09

Geohazard Detail

ID 421 **Kitimat Area**

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1155.82	**Feature**	153
Source	Geotechnical Report	**KP (Rev V) End**	1177.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Hazard considered under Lateral Spreading
Estimated Frequency	0	Hazard considered under Lateral Spreading
Vunerability Factor	0	Hazard considered under Lateral Spreading
Mitigation Options	1.00E+00	Hazard considered under Lateral Spreading

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 432 **Kitimat Area**

Category	Lateral Spreading	**KP (Rev V) Start**	1155.82	**Feature**	152
Source	Geotechnical Report	**KP (Rev V) End**	1177.62		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.1	Potential for lateral spreading and induced sliding in sensitive clays in localized areas below about 200 m elevation. Considered credible potential for sliding with no defined occurrence at proposed pipeline location. Possible static or seismic initiation.
Estimated Frequency	0.0004	An estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading. This PGA corresponds to a 1:2500 return period for the Kitimat area.
Vunerability Factor	1	Route primarily crosses low angle slopes <5° with localized areas up to approximately 15°.
Mitigation Options	1.00E-02	Use routing to avoid areas prone to lateral spreading. Possible reroute using a ridge in the Kitimat River Valley east of the current alignment. Further investigations required for sensitive clays.

Applied Mitgations	**Standard Factor**
Reroute to avoid areas of sensitive clays	0.01

Mitigation Site-specific 1

Frequency Loss of Containment 4.00E-07 **FLOC/m** 1.83E-11

Geohazard Detail

ID 369 **West of Kitimat River**

Category	Lateral Migration	**KP (Rev V) Start**	1158.8	**Feature**	154
Source	Geotechnical Report	**KP (Rev V) End**	1160		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Route situated on sideslope above the Kitimat River. Route closest to stream at KP1158 - lateral distance 500m, elevation is similar.
Estimated Frequency	0.01	Further review of lateral erosion conditions of adjacent Kitimat River is recommended.
Vunerability Factor	0.1	140m wide channel.
Mitigation Options	1.00E-02	Relocation if required by further study. Buried self launching riprap could also be considered.

Applied Mitgations	**Standard Factor**
River training measures suitably designed	0.01
Reroute	0.01

Mitigation Site-specific	100	Select only reroute or riprap, mitigations are not multiplicative.

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-10

Geohazard Detail

ID 370 **Kitimat River near gravel pit**

Category	Lateral Migration
KP (Rev V) Start	1164
Feature	155
Source	Geotechnical Report
KP (Rev V) End	1164.64

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	1	Route situated beside the Kitimat River on outside bend. Section closest to stream near KP1162.5 - lateral distance 50m.
Estimated Frequency	0.01	Further review of lateral erosion conditions and existing riprap of adjacent Kitimat River is recommended.
Vunerability Factor	0.1	140m wide channel.
Mitigation Options	1.00E-02	River training measures if required by further study. Possible relocation.

Applied Mitgations	**Standard Factor**
River training measures suitably designed	0.01
Reroute	0.01

Mitigation Site-specific	100	Select only reroute or river training, mitigations are not multiplicative.

Frequency Loss of Containment 1.00E-05 **FLOC/m** 1.11E-08

Geohazard Detail ID 371 Anderson Creek

Category	Lateral Migration	**KP (Rev V) Start**	1169.1	**Feature**	156
Source	Geotechnical Report	**KP (Rev V) End**	1169.26		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Failure of existing dikes and stream training installations to be further considered –might result in lateral erosion
Estimated Frequency	0.01	Frequency dependent on the design, condition and maintenance of stream training structures.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E+00	Relocation or augmentation of existing structures if required.

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.67E-09

Geohazard Detail ID 492 Anderson Creek

Category	Scour	**KP (Rev V) Start**	1169.1	**Feature**	156
Source	Geotechnical Report	**KP (Rev V) End**	1169.26		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	25m wide channel.
Mitigation Options	1.00E-03	

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-08 **FLOC/m** 6.67E-11

Geohazard Detail ID 54 Moore Creek

Category	Rockfall	**KP (Rev V) Start**	1170.38	**Feature**	
Source	Geotechnical Report	**KP (Rev V) End**	1170.5		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Rockfall from steep canyon walls. Aerial crossing above rockfall hazard.
Estimated Frequency	0.01	Rockfall from steep canyon walls. Aerial crossing above rockfall hazard.
Vunerability Factor	0	Rockfall from steep canyon walls. Aerial crossing above rockfall hazard.
Mitigation Options	1.00E+00	Aerial crossing above rockfall hazard.

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail ID 304 Moore Creek

Category	Debris Flow	**KP (Rev V) Start**	1170.38	**Feature**	159
Source	Geotechnical Report	**KP (Rev V) End**	1170.5		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Aerial crossing above debris flow.
Estimated Frequency	0.01	Aerial crossing above debris flow.
Vunerability Factor	0	Aerial crossing above debris flow.
Mitigation Options	1.00E-03	Aerial crossing proposed.

Applied Mitgations	**Standard Factor**
Aerial crossing	0.001

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 55 **West side of Kitimat Arm**

Category	Rockfall	**KP (Rev V) Start**	1171.92	**Feature**	161
Source	Geotechnical Report	**KP (Rev V) End**	1173.64		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Steep till slopes above route subject to weathering and release of boulders (rockfall). Route located within rockfall shadow. Loosening of boulders in cuts will also need to be considered. Field check required.
Estimated Frequency	0.1	Documented release of boulders from tills from source area below route. Potential source areas above route require assessment, frequency considered moderate.
Vunerability Factor	0.1	Route crosses slopes of approximately 25-27° in the immediate vicinity of the pipeline. Expect rock to be rolling or bouncing.
Mitigation Options	1.00E-04	Mitigative options to be finalized based on detailed terrain conditions.

Applied Mitgations	**Standard Factor**
Deep burial (established on max particle impact energy) and/or extra compaction	0.01
Concrete coating or protection	0.1
Diversion berm	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 6.25E-10

Geohazard Detail ID 422 West side of Kitimat Arm

Category Slide - shallow/moderate deep

KP (Rev V) Start 1172.52

Feature 160

Source Geotechnical Report

KP (Rev V) End 1176.72

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 1

Steeply sloping terrain, bedrock-controlled, numerous small gullies or ravines and occasional shallow surface slides.

Estimated Frequency 1

Vunerability Factor 0.001

Mitigation Options 1.00E-03

Applied Mitgations	Standard Factor
Major slope and crest grading	0.01
Drainage and groundwater control	0.1

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-06 **FLOC/m** 2.38E-10

Geohazard Detail

ID 305 **West side of Kitimat Arm**

Category	Debris Flow	**KP (Rev V) Start**	1174.48	**Feature**	162
Source	Geotechnical Report	**KP (Rev V) End**	1174.66		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0.1	Headwater conditions include: steep channel gradient, steep valley walls with potential for shallow sliding and sediment accumulation in channel, small chatchment area limits debris flow potential - partially meets screening criteria.
Estimated Frequency	0.01	Located in Coast Mountains with high precipitaton, discontinuous forested channel, field check recommended.
Vunerability Factor	0.01	Deposition or erosion is expect on route which crosses bedrock controlled channel with gradient approximately 11° in the immediate vicinity of the pipeline.
Mitigation Options	1.00E-02	

Applied Mitgations	**Standard Factor**
Deep burial	0.01

Mitigation Site-specific	1	

Frequency Loss of Containment 1.00E-07 **FLOC/m** 9.99E-10

Geohazard Detail **ID** 372 **West side of Kitimat Arm**

Category Lateral Migration

KP (Rev V) Start 1174.48

Feature 163

Source Geotechnical Report

KP (Rev V) End 1174.66

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01

Channel is well incised and does not show evidence of previous significant lateral erosion.

Estimated Frequency 0.001

Channel is well incised and does not show evidence of previous significant lateral erosion. Frequency expected to be very low.

Vunerability Factor 0.001

10 m wide channel.

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 9.99E-11

Geohazard Detail ID 57 West side of Kitimat Arm

Category	Rockfall	**KP (Rev V) Start**	1175.4	**Feature**	161
Source	Geotechnical Report	**KP (Rev V) End**	1175.8		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Pipeline route is upslope of possibe rockfall source.
Estimated Frequency	0	Pipeline route is upslope of possibe rockfall source.
Vunerability Factor	0	Pipeline route is upslope of possibe rockfall source.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m** 0.00E+00

Geohazard Detail

ID 493 **West side of Kitimat Arm**

Category	Scour	**KP (Rev V) Start**	1175.48	**Feature**	163
Source	Geotechnical Report	**KP (Rev V) End**	1174.66		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	1	Unconsolidated river bed material expected at crossing location.
Estimated Frequency	0.01	Frequency of significant scour events correspond to high runoff events typically 25 to 200 year return period.
Vunerability Factor	0.001	10m wide channel.
Mitigation Options	1.00E-03	Note that debris flow mitigation for same channel will require deep cover.

Applied Mitgations	**Standard Factor**
Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	0.001

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-08 **FLOC/m** 9.99E-11

Geohazard Detail

ID 56 | **West side of Kitimat Arm**

Category Rockfall

KP (Rev V) Start 1175.76

Feature 161

Source Geotechnical Report

KP (Rev V) End 1177.3

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0.01

Moderately steep till slopes east of route however no realease zones steeper than 40 degrees. Route is not within rockfall shadow. Rockfall from cuts will require consideration during detailed design - screening criteria only partially met.

Estimated Frequency 0.001

Frequency considered very low.

Vunerability Factor 0.01

Low to moderate relief terrain immediately upslope from route. Expect rock fragments to be decelerating and rolling if occurrence is possible.

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 1.00E-07 **FLOC/m** 7.69E-11

Geohazard Detail **ID** 58 **Kitimat Terminal**

Category	Rockfall	**KP (Rev V) Start**	1177.6	**Feature**	170
Source	Geotechnical Report	**KP (Rev V) End**	1177.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	Gentle relief in nearby area to KP, rockfall would only be an issue in cuts.
Estimated Frequency	0	Gentle relief in nearby area to KP, rockfall would only be an issue in cuts.
Vunerability Factor	0	Gentle relief in nearby area to KP, rockfall would only be an issue in cuts.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail

ID 74 **Kitimat Terminal**

Category	Deep seated slide	**KP (Rev V) Start**	1177.6	**Feature**	166
Source	Geotechnical Report	**KP (Rev V) End**	1177.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	No deep-seated slide at end of pipeline.
Estimated Frequency	0	No deep-seated slide at end of pipeline.
Vunerability Factor	0	No deep-seated slide at end of pipeline.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail ID 306 Kitimat Terminal

Category	Debris Flow	**KP (Rev V) Start**	1177.6	**Feature**	169
Source	Geotechnical Report	**KP (Rev V) End**	1177.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor 0

Estimated Frequency 0

Vunerability Factor 0

Mitigation Options 1.00E+00

Applied Mitgations **Standard Factor**

Mitigation Site-specific 1

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail ID 423 Kitimat Terminal

Category	Slide - shallow/moderate deep	**KP (Rev V) Start**	1177.6	**Feature**	165
Source	Geotechnical Report	**KP (Rev V) End**	1177.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☑ **Reroute** ☐ **Google Earth Filename**

Occurrence Factor	0	No shallow to moderately deep seated slides are present at route.
Estimated Frequency	0	No shallow to moderately deep seated slides are present at route.
Vunerability Factor	0	No shallow to moderately deep seated slides are present at route.
Mitigation Options	1.00E+00	

Applied Mitgations **Standard Factor**

Mitigation Site-specific	1	

Frequency Loss of Containment 0.00E+00 **FLOC/m**

Geohazard Detail

ID 433 **Kitimat Terminal**

Category	Lateral Spreading	**KP (Rev V) Start**	1177.6	**Feature**	167
Source	Geotechnical Report	**KP (Rev V) End**	1177.6		

Overall Geotechnical Report on the Pipeline Route Rev. R for the Enbridge Northern Gateway Project Bruderheim, Alberta to Kitimat, BC. March 2010

Legacy ☐ **Reroute** ☑ **Google Earth Filename**

Occurrence Factor	0.01	Facilities to be located outside of extents of significant fine-grained soils. Detailed investigations have been done to facilitate detailed design.
Estimated Frequency	0.0004	An estimated 12% peak ground acceleration (PGA) is considered necessary to trigger lateral spreading. This PGA corresponds to a 1:2500 return period for the Kitimat area.
Vunerability Factor	1	Slopes near KP1177.6 approximately 5-7°.
Mitigation Options	1.00E-02	Facilities to be located outside of extents of significant fine-grained soils. Detailed investigations have been done to facilitate detailed design.

Applied Mitgations	**Standard Factor**
Reroute to avoid areas of sensitive clays	0.01

Mitigation Site-specific 1

363 Records

Frequency Loss of Containment 4.00E-08 **FLOC/m**

APPENDIX C

Mitigation Summary

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
2.58	3	434	**North Saskatchewan River**	
			Scour	1.00E-06
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
62.8	62.96	326	**Riviere Qui Barre**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Design should address meander bend east of crossing.	
130.78	131.06	436	**Pembina River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			HDD crossing proposed.	
137.18	137.48	516	**Paddle River East valley slope**	
			Slide - shallow/moderate deep	1.00E-06
			Monitoring of slope stability conditions	
			Major slope and crest grading	
137.4	137.66	437	**Paddle River**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
162.82	163.18	329	**Little Paddle River**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Route crosses meander bend at KP 162.9. Reroute to avoid this meander bend should be evaluated.	
177.52	183.94	59	**Swan Hills southeast of Whitecourt**	
			Deep seated slide	1.00E-06
			Monitoring of slope stability conditions	
			Surface water and/or groundwater control	
183.5	183.8	530	**Swan Hills Area East of Whitecourt**	
			Slide - shallow/moderate deep	1.00E-08
			Reroute	
			Proposed reroute to the east beyond retrogression limits.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
186.18	187.02	439	**Athabasca River**	
			Scour	1.00E-06

Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements

Trenchless Methods enter/exit outside extents of lateral migration

HDD crossing proposed.

KP Start	KP End	ID	Location	FLOC
187	187.14	374	**North approach to Athabasca River**	
			Slide - shallow/moderate deep	1.00E-06

Deep burial below slide

HDD crossing proposed entering below north valley slope.

KP Start	KP End	ID	Location	FLOC
198.75	199.1	527	**East approach slope to Sakwatamau River**	
			Deep seated slide	1.00E-05

Major slope and crest grading

Reroute

Although slides appear to be prevalent in the area, it may be possible to micro-route through stable ground between slides. Grading and/or surface/groundwater control is also recommended.

KP Start	KP End	ID	Location	FLOC
199.06	200.16	331	**Sakwatamau River**	
			Lateral Migration	1.00E-08

Sag bends beyond long-term hydrotechnical design limits

Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows

KP Start	KP End	ID	Location	FLOC
200.16	202.26	375	**Narrow corridor near Sakwatamau River**	
			Slide - shallow/moderate deep	1.00E-06

Reroute

Reroute recommended subject to check that Alliance RoW boundary is at the crest of slides.
Possible reroute across and to the west side of Alliance. Tight area between RoW and highway, room for reroute is dependant on further checks.

KP Start	KP End	ID	Location	FLOC
215.16	215.56	376	**Tributary to Chickadee Creek valley slopes**	
			Slide - shallow/moderate deep	1.00E-07

Drainage and groundwater control

Minor slope and crest grading

Minor slope grading and drainage/groundwater control recommended.

KP Start	KP End	ID	Location	FLOC
218.46	218.62	441	**Chickadee Creek**	
			Scour	1.00E-08

Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows

Sag bends beyond long-term hydrotechnical design limits

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
241.2	242.4	442	Two Creek	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
241.5	241.65	528	East of Two Creek	
			Slide - shallow/moderate deep	0.00E+00
			Reroute	
			Requires re-route beyond the depletion zone.	
241.65	241.85	529	East approach slopes of Two Creek	
			Slide - shallow/moderate deep	0.00E+00
			Minor slope and crest grading	
			Drainage and groundwater control	
			grading, surface/groundwater control and possible riprap	
257.96	258.2	377	East approach slope to Iosegun River	
			Slide - shallow/moderate deep	1.00E-07
			Minor slope and crest grading	
			Drainage and groundwater control	
			Minor slope grading and drainage/groundwater control recommended.	
258.2	258.48	334	Iosegun River	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
258.48	259.06	426	West approach slope to Iosegun River	
			Slide - shallow/moderate deep	1.00E-08
			Minor slope and crest grading	
			Drainage and groundwater control	
			Surface water control	
			Grading and groundwater/surface water control. Route crosses small diameter pipeline which must be considered. Relocation of route may be required.	
289.7	290.1	61	East Approach to Little Smoky River	
			Deep seated slide	1.00E-06
			Surface water and/or groundwater control	
			Monitoring of slope stability conditions	
			River training and/or riprap	
			Monitoring of stability conditions and rip rap or stream training subject to detailed studies. Ground and surface water control.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
289.72	**290.02**	378	**East Approach slope to Little Smoky River**	
			Slide - shallow/moderate deep	1.00E-07

Reroute

Drainage and groundwater control

Monitoring of slope stability conditions

Surface water control

Reroute may be required either driven by this, or other nearby geohazards. Further investigations and monitoring are recommended to check movement status of slopes. Further consideration of design and mitigative methods relative to stability conditions is anticipated during detailed design. Comprehensive ground and surface water control will be required. Vulnerable to undercutting by lateral erosion.

FLOC calculated based on either reroute or combination of water control and monitoring.

KP Start	KP End	ID	Location	FLOC
290.02	**290.56**	444	**Little Smoky River crossing**	
			Scour	1.00E-06

Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements or reroute

Trenchless Methods enter/exit outside extents of lateral migration or reroute

Trenchless crossing preferred to mitigate deep seated slide. Trenchless crossing should start near toe of east approach slope extending under river and west approach slope.

KP Start	KP End	ID	Location	FLOC
290.6	**291.1**	62	**West Approach Slope to Little Smoky River**	
			Deep seated slide	1.00E-05

Surface water and/or groundwater control

Deep burial below slide or reroute

Trenchless crossing preferred to mitigate deep seated slide. Trenchless crossing should start near toe of east approach slope extending under river and west approach slope.

KP Start	KP End	ID	Location	FLOC
317.1	**317.9**	445	**Waskahigan River**	
			Scour	1.00E-08

Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows

Sag bends beyond long-term hydrotechnical design limits

KP Start	KP End	ID	Location	FLOC
331.64	**331.76**	446	**Incised creek valley draining to north**	
			Scour	1.00E-08

Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows

Streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

KP Start	KP End	ID	Location	FLOC
334.5	**334.58**	447	**Incised creek valley draining to north**	
			Scour	1.00E-08

Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows

Streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
337.9	**338.36**	337	**Deep Valley Creek**	
			Lateral Migration	1.00E-07
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
338.78	**339.42**	517	**Deep Valley Creek West valley slopes**	
			Deep seated slide	1.00E-05
			Deep burial below slide or reroute	
			Monitoring of slope stability conditions	
			Recommend reroute or trenchless crossing. Route should parallel existing pipelines which climb the valley slope just to the east of the slide margins.	
339.86	**340.06**	518	**Tributary to Deep Valley Creek East valley slopes**	
			Slide - shallow/moderate deep	1.00E-05
			Drainage and groundwater control	
			Monitoring of slope stability conditions	
			Monitoring and drainage. Recommend field reconnaisance and drill program to install instrumentation summer 2012. May require trenchless crossing (HDD).	
340.06	**340.22**	449	**Tributary to Deep Valley Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
340.06	**340.222**	338	**Tributary to Deep Valley Creek**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
340.22	**340.34**	519	**Tributary to Deep Valley Creek West valley slopes**	
			Slide - shallow/moderate deep	1.00E-05
			Drainage and groundwater control	
			Monitoring of slope stability conditions	
			Monitoring and drainage. Recommend field reconnaisance and drill program to install instrumentation summer 2012. Monitoring and drainage. Recommend that field reconnaisance and drill program to install instrumentation summer 2012. May require trenchless crossing (HDD).	
340.34	**341**	520	**West of Tributary to Deep Valley Creek**	
			Slide - shallow/moderate deep	1.00E-07
			Reroute	
			Requires reroute further back from crest of valley slopes.	
			Reroute beyond possible retrogression limits of slides. Nearby slides have failed to 6°.	
341	**341.42**	521	**Creek crossing west of tributary to Deep Valley Creek**	
			Slide - shallow/moderate deep	1.00E-06
			Reroute	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Recommend reroute approximately 700 m upstream where valley is much smaller and any potential instabilities can be graded out.	
			Recommend reroute approximately 700 m upstream where valley is much smaller and any potential instabilities can be graded out.	
341.32	**341.34**	522	**Creek crossing west of tributary to Deep Valley Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
353.56	**353.58**	450	**Tributaries to Simonette**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.	
354.58	**354.62**	451	**Tributaries to Simonette**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.	
355.18	**355.22**	452	**Tributaries to Simonette**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.	
356.38	**356.4**	453	**Tributaries to Simonette**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.	
357.26	**357.32**	454	**Tributaries to Simonette**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Tributary streams have relatively steep gradients. Pipeline cover should consider further potential scour and downcutting conditions during detailed design.	
358.94	**359.46**	455	**Simonette River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			Bored crossing proposed.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
370.94	371.28	63	East valley slope of Latornell River	
			Deep seated slide	1.00E-06
			Deep burial below slide or reroute	
			Recommend reroute to avoid slide hazard or trenchless crossing.	
			Recommend reroute to avoid slide hazard or trenchless crossing.	
371.26	371.3	340	Latornell River	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long term hydrotechnical limits. Reroute may be required to mitigate slides on approach slopes.	
371.3	372	495	West valley slope of Latornell River	
			Deep seated slide	1.00E-06
			Deep burial below slide or reroute	
			Recommend reroute or HDD.	
			Recommend reroute or HDD.	
372.1	374	64	West of Latornell River	
			Deep seated slide	1.00E-05
			Reroute	
			Subject to further work, reroute is assumed, crossing over to the west side of Alliance.	
395.02	395.22	380	Tributary to Smoky River valley slopes	
			Slide - shallow/moderate deep	1.00E-06
			Drainage and groundwater control	
			Minor slope and crest grading	
			Minor slope grading and drainage/groundwater control.	
395.1	395.12	457	Tributary to Smoky River	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
403.58	403.96	381	Tributary to Smoky River valley slopes	
			Slide - shallow/moderate deep	1.00E-09
			Minor slope and crest grading	
			Drainage and groundwater control	
			Minor slope grading and drainage/groundwater control recommended.	
419.4	419.9	382	East valley slope of Smoky River	
			Slide - shallow/moderate deep	1.00E-08
			Drainage and groundwater control	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Minor slope and crest grading	
			Minor slope grading and drainage/groundwater control recommended.	
419.5	**419.9**	65	**East valley slope of Smoky River**	
			Deep seated slide	1.00E-06
			Reroute	
			Reroute. There appears to be about 150 m setback from the existing pipeline to the north, providing room to shift the alignment at least 50 m farther away from the slide scarp. The route should parallel the south side of the existing RoW except at the crest where the route will deviate around a lease.	
420.18	**421.74**	458	**Smoky River floodplain**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Armoured stream banks suitably designed	
			Trenchless Methods enter/exit outside extents of lateral migration	
			HDD crossing proposed.	
421.7	**422.28**	66	**West valley slope of Smoky River**	
			Deep seated slide	1.00E-05
			Reroute	
			Monitoring of slope stability conditions	
			Requires reroute to north close to road. Monitoring of stability conditions recommended.	
428.16	**429.52**	384	**Big Mountain Creek valley slopes**	
			Slide - shallow/moderate deep	1.00E-05
			Reroute or HDD	
			Recommend reroute or HDD.	
428.92	**429.28**	460	**Big Mountain Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
446.4	**446.76**	385	**Bald Mountain Creek west valley slopes**	
			Slide - shallow/moderate deep	1.00E-08
			Surface water control	
			Drainage and groundwater control	
			Minor slope and crest grading	
			Ground and surface water control. Grading will reduce the potential for occurrence.	
446.64	**446.72**	461	**Bald Mountain Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
453.66	**453.86**	346	**Wilson Creek**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
458.76	**459**	386	**Tributary to Iroquois Creek valley slopes**	
			Slide - shallow/moderate deep	1.00E-05
			Drainage and groundwater control	
			Minor slope and crest grading	
			Minor slope grading and drainage/groundwater control recommended.	
470.84	**471.08**	387	**Pinto Creek meander bend 1**	
			Slide - shallow/moderate deep	1.00E-05
			Reroute	
			Reroute from south side to north of existing RoW.	
473	**473.5**	424	**Pinto Creek meander bend 2**	
			Slide - shallow/moderate deep	1.00E-05
			Reroute or HDD	
			Recommend reroute to North side of existing RoW or HDD.	
474.02	**474.12**	68	**Pinto Creek East valley slope**	
			Slide - shallow/moderate deep	1.00E-06
			Reroute or HDD	
			Recommend reroute or HDD. Requires further investigation for trenchless crossing. Possible microtunnelling or HDD. Other option is to replace existing pipeline and perform extensive grading.	
474.2	**474.28**	463	**Pinto Creek**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements or reroute	
			Requires further investigation for trenchless crossing to mitigate scour potential. Recommend HDD or reroute.	
474.34	**474.44**	427	**Pinto Creek West valley slope**	
			Slide - shallow/moderate deep	1.00E-05
			Reroute or HDD	
			Recommend reroute or HDD. Requires further investigation for trenchless crossing. Possible microtunnelling or HDD. Other option is to replace existing pipeline and perform extensive grading.	
494.94	**495.6**	464	**Wapiti River**	
			Scour	1.00E-07
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			HDD crossing proposed.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
496.3	**497**	388	**Ridge on West Side of Wapiti River**	
			Slide - shallow/moderate deep	1.00E-06
			Monitoring of slope stability conditions	
			Surface water control	
			Drainage and groundwater control	
			Potential mitigative measures if there is an issue include routing, surface and ground water control and (in the event of major problems), consideration of deep grading, directional drilling or other methods.	
534.12	**534.18**	465	**South Redwillow River**	
			Scour	1.00E-09
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
568.2	**568.26**	466	**Kinuseo Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
568.4	**581.78**	389	**Quintette Mountain area rock cuts**	
			Slide - shallow/moderate deep	1.00E-06
			Minor slope and crest grading	
			Suitable design for rock cuts includes grading and possible anchoring.	
577.3	**577.46**	4	**Quintette Creek**	
			Avulsion	1.00E-06
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
579.94	**580.04**	245	**Tributary to Kinuseo Creek**	
			Debris Flow	1.00E-08
			Deep burial	
582.16	**583.1**	246	**Five Cabin Creek**	
			Debris Flow	1.00E-05
			Deep burial	
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial.	
587.74	**587.74**	349	**Kinuseo Creek near alignment**	
			Lateral Migration	1.00E-06
			Reroute	
			Recommend reroute further to the north.	
588.86	**589.6**	497	**Tributary to Kinuseo**	
			Avulsion	1.00E-06
			Pipeline below maximum predicted scour depth along alluvial fan impact area	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
590.3	**590.68**	428	**Kinuseo Creek**	
			Lateral Migration	1.00E-07
			Trenchless Methods enter/exit outside extents of lateral migration	
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Bored crossing proposed. Reroute to shorten length exposed to lateral erosion and scour should be evaluated.	
598.82	**598.98**	390	**Tributary of Murray River**	
			Slide - shallow/moderate deep	1.00E-05
			Reroute	
			Reroute to the north-east and away from crest of blow-off failure is assumed. Grading to consider stability conditions.	
600.8	**600.92**	350	**Murray River**	
			Lateral Migration	1.00E-06
			Armoured stream banks suitably designed	
			Aerial crossing	
			Riprap of foundations and adjacent pipeline. Design of foundations.	
			Riprap of foundations and adjacent pipeline - 0.1. Foundation design - 0.01	
604.6	**604.64**	392	**Hook Creek east approach slopes**	
			Slide - shallow/moderate deep	1.00E-06
			Deep burial below slide	
			HDD crossing proposed.	
604.64	**604.76**	469	**Hook Creek**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			HDD crossing proposed.	
604.76	**604.8**	545	**Hook Creek west approach slope**	
			Slide - shallow/moderate deep	1.00E-06
			Deep burial below slide	
			HDD below sliding surface	
623.55	**623.7**	33	**Pass through Rockies**	
			Rockfall	1.00E-06
			Diversion berm	
			Diversion berms to be installed where required.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
633.92	633.96	251	**Tributary to Missinka River** Debris Flow **Deep burial**	1.00E-08
635.06	635.12	252	**Tributary to Missinka River** Debris Flow **Deep burial**	1.00E-07
637.14	637.2	253	**Tributary to Missinka River** Debris Flow **Deep burial**	1.00E-07
638.48	638.64	7	**Tributary to Missinka River** Avulsion **Pipeline below maximum predicted scour depth along alluvial fan impact area** **Deep burial** Deep cover mitigation to be applied if required based on further review. Debris flow potential on fan may also necessitate deep cover.	1.00E-08
639.58	639.6	257	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial	1.00E-08
643.38	643.46	470	**Missinka River** Scour **Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements** Bored crossing proposed.	1.00E-08
645.94	645.96	258	**Tributary to Missinka River** Debris Flow **Deep burial**	1.00E-08
646.7	647.24	259	**Tributary to Missinka River** Debris Flow **Deep burial**	1.00E-08
648.1	648.2	471	**Missinka River** Scour **Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows**	1.00E-08

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
652.1	652.56	260	**Tributary to Missinka River** Debris Flow **Deep burial** **Pipeline below maximum predicted scour depth along alluvial fan impact area** Deep burial may be required upon further review.	1.00E-07
655.1	655.22	261	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial.	1.00E-07
656.26	656.36	262	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial.	1.00E-07
659.66	659.76	263	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial may be required upon further review.	1.00E-08
661.36	661.46	264	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial may be required upon further review.	1.00E-07
662.02	662.26	265	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial may be required upon further review.	1.00E-07
665.22	665.3	266	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial may be required upon further review.	1.00E-07
666.46	666.54	267	**Tributary to Missinka River** Debris Flow **Deep burial** Deep burial may be required upon further review.	1.00E-07

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
673.6	**674.14**	472	**Parsnip River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			HDD crossing proposed.	
705.66	**705.86**	494	**Tributary to Chuchinka Creek**	
			Lateral Migration	1.00E-07
			Sag bends beyond long-term hydrotechnical design limits	
712.66	**713.16**	401	**Angusmac Creek East Valley Slope**	
			Slide - shallow/moderate deep	1.00E-06
			Drainage and groundwater control	
			Major slope and crest grading	
			May require major grading and drainage/groundwater control.	
713.16	**713.44**	354	**Angusmac Creek**	
			Lateral Migration	1.00E-06
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
713.55	**713.9**	499	**Angusmac Creek West Valley Slopes**	
			Slide - shallow/moderate deep	1.00E-06
			Major slope and crest grading	
			Drainage and groundwater control	
			May require major grading and drainage/groundwater control.	
720.88	**721.36**	474	**Crooked River**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			Bored crossing proposed.	
750.8	**750.9**	475	**Muskeg River**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			Bored crossing proposed.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
765.44	**765.9**	476	**Salmon River**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			Bored crossing proposed.	
765.9	**766.14**	402	**West valley slope of Salmon River**	
			Slide - shallow/moderate deep	1.00E-06
			Major slope and crest grading	
			Drainage and groundwater control	
			Requires major grading and drainage/groundwater control.	
782.38	**782.58**	523	**Tributary to Beaver Lake**	
			Slide - shallow/moderate deep	1.00E-08
			Reroute	
			Recommend reroute around meander within corridor.	
818.92	**819.32**	403	**Necoslie River valley slopes**	
			Slide - shallow/moderate deep	1.00E-06
			Major slope and crest grading	
			Drainage and groundwater control	
			May require major grading and drainage/groundwater control.	
819.32	**819.46**	477	**Necoslie River**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Bored crossing proposed.	
824.3	**824.6**	70	**Stuart River East valley slope**	
			Deep seated slide	1.00E-08
			Major slope and crest grading	
			Monitoring of slope stability conditions	
			HDD crossing proposed (won't mitigate). Monitoring of stability conditions and major slope and crest grading.	
824.76	**825.08**	478	**Stuart River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			HDD crossing proposed.	
825	**825.5**	71	**Stuart River West valley slope**	
			Deep seated slide	1.00E-07
			Monitoring of slope stability conditions	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			HDD crossing proposed (won't mitigate). Monitoring of stability conditions and major slope and crest grading.	
825.02	825.08	404	**Stuart River West valley slope**	
			Slide - shallow/moderate deep	1.00E-05
			Deep burial below slide	
			HDD crossing proposed.Trenchless crossing method to avoid shallow to moderately deep slide on west side. HDD expected to be significantly below area of potential sliding.	
859.24	859.4	524	**Sutherland River East valley slope**	
			Slide - shallow/moderate deep	1.00E-06
			Reroute	
			Possible reroute to the north or south beyond extents of the slide.	
859.4	859.48	500	**Sutherland River**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
951.2	951.58	515	**Maxan Creek**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
977.34	977.96	405	**Klo Creek East valley slopes**	
			Slide - shallow/moderate deep	1.00E-07
			Major slope and crest grading	
			Drainage and groundwater control	
			Major grading and drainage/groundwater control.	
978.3	978.44	546	**Klo Creek east approach Lower slopes**	
			Slide - shallow/moderate deep	1.00E-07
			Major slope and crest grading	
			Drainage and groundwater control	
978.44	978.68	479	**Klo Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
978.68	978.72	501	**Klo Creek West valley slopes**	
			Slide - shallow/moderate deep	1.00E-07
			Drainage and groundwater control	
			Major slope and crest grading	
			Major grading and drainage/groundwater control.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
989.78	**990.16**	480	**Buck Creek**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			Bored crossing proposed.	
1005.2	**1005.4**	481	**Owen Creek**	
			Scour	0.00E+00
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Bored crossing proposed.	
1006.58	**1006.7**	541	**Owen Creek East Approach Slopes**	
			Slide - shallow/moderate deep	1.00E-08
			Minor slope and crest grading	
			Surface water control	
			Drainage and groundwater control	
			For trench crossing grade slope and implement surface and groundwater controls. For trenchless crossing install pipe below maximum possible slide depth.	
1006.7	**1006.72**	532	**Owen Creek**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Deep burial across floodplain for trench crossing. Proposed bored crossing to extend below/beyond potential erosion limits.	
1006.7	**1007.1**	323	**West of Owen Creek**	
			Deep seated slide	0.00E+00
			Reroute	
			Reroute has been implemented	
1006.72	**1006.8**	543	**Owen Creek West Approach Slopes**	
			Slide - shallow/moderate deep	1.00E-08
			Minor slope and crest grading	
			Drainage and groundwater control	
			Consider grading and ground/surface water controls as required.	
1012.74	**1012.78**	534	**Fenton Creek East Approach Slope**	
			Slide - shallow/moderate deep	1.00E-09
			Surface water control	
			Minor slope and crest grading	
			Drainage and groundwater control	
			Grading and groundwater/surface water control. Deep burial.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
1012.78	1012.8	482	**Fenton Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
1012.8	1012.86	542	**Fenton Creek West Approach Slope**	
			Slide - shallow/moderate deep	1.00E-09
			Minor slope and crest grading	
			Surface water control	
			Drainage and groundwater control	
			Grading, ground and surface water control. Set pipe below rupture surface.	
1018.36	1018.4	540	**24.5 Mile Creek East approach slope**	
			Slide - shallow/moderate deep	1.00E-08
			Minor slope and crest grading	
			Drainage and groundwater control	
			Surface water control	
			Grade slope, ground and surface water control.	
1018.4	1018.42	539	**24.5 Mile Creek**	
			Lateral Migration	1.00E-09
			Sag bends beyond long-term hydrotechnical design limits	
			Grade east slope to setback sagbend.	
1021	1022	406	**Lamprey Creek East valley slopes**	
			Slide - shallow/moderate deep	0.00E+00
			Drainage and groundwater control	
			Major slope and crest grading	
			May require major grading and drainage/groundwater control.	
1024.36	1024.66	537	**Lamprey Creek East approach slope**	
			Slide - shallow/moderate deep	1.00E-09
			Drainage and groundwater control	
			Major slope and crest grading	
			Surface water control	
			Major grading with surface and groundwater control. Route has been selected to avoid steepest ground located north (downstream) of the proposed crossing towards the confluence with the Morice River.	
1024.66	1024.84	483	**Lamprey Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Sag bends beyond long-term hydrotechnical design limits	
			Burial below depth of scour.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
1028.3	1029.1	407	**Cedric Creek valley slopes**	
			Slide - shallow/moderate deep	0.00E+00
			Drainage and groundwater control	
			Major slope and crest grading	
			May require major grading and drainage/groundwater control.	
1028.45	1028.55	360	**Cedric Creek**	
			Lateral Migration	0.00E+00
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
1032.72	1032.74	538	**Cedric Creek**	
			Scour	1.00E-09
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
1035.1	1038.1	408	**Side slopes of Morice River valley**	
			Slide - shallow/moderate deep	0.00E+00
			Drainage and groundwater control	
			Major slope and crest grading	
			May require major grading and drainage/groundwater control.	
1043.06	1043.42	484	**Morice River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			HDD crossing proposed.	
1049	1049.36	269	**Crystal Creek**	
			Debris Flow	1.00E-06
			Bored crossing	
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Bored crossing proposed.	
1055.02	1055.1	270	**Tributary to Gosnell Creek**	
			Debris Flow	1.00E-07
			Deep burial	
			Deep burial.	
1057.34	1057.72	271	**Tributary to Gosnell Creek**	
			Debris Flow	1.00E-07
			Deep burial	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Deep burial.	
1058.24	**1058.7**	272	**Tributary to Gosnell Creek**	
			Debris Flow	1.00E-07
			Deep burial	
			Deep burial.	
1059.6	**1060**	273	**Tributary to Gosnell Creek**	
			Debris Flow	1.00E-08
			Deep burial	
1063.76	**1064.08**	361	**Gosnell Creek**	
			Lateral Migration	1.00E-07
			Trenchless Methods enter/exit outside extents of lateral migration	
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Bored crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area.	
1071.06	**1072.06**	274	**Tributary to Burnie River Fan**	
			Debris Flow	1.00E-07
			Deep burial	
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
1075.2	**1075.65**	409	**East approach slope to Burnie and Clore River valleys**	
			Slide - shallow/moderate deep	1.00E-08
			Major slope and crest grading	
			Drainage and groundwater control	
			Bored crossing proposed. May require major grading and drainage/groundwater control.	
1076.3	**1076.56**	526	**Tributary to Burnie River**	
			Lateral Migration	1.00E-08
			Sag bends beyond long-term hydrotechnical design limits	
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
1077.4	**1077.94**	362	**Clore River**	
			Lateral Migration	1.00E-04
			Trenchless Methods enter/exit outside extents of lateral migration	
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Reroute	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Trenchless crossing proposed. Regardless of method used, pipeline to be below depth of scour across vulnerable area. Crossing to be set back to account for conceivable lateral migration. A reroute to the south may provide feasible aerial or trenched crossing methods. FLOC calculated assuming either a trenchless method outside extents of lateral migration or a reroute south.	
1083.78	**1084.6**	410	**Tributary to Clore River and adjacent areas**	
			Slide - shallow/moderate deep	1.00E-06
			Major slope and crest grading	
1084.9	**1084.94**	275	**Tributary to Clore River crossing**	
			Debris Flow	0.00E+00
			HDD or Aerial installation	
			Aerial crossing proposed.	
1092.02	**1092.08**	363	**Hoult Creek**	
			Lateral Migration	1.00E-11
			Trenchless Methods enter/exit outside extents of lateral migration	
			HDD or Aerial installation	
			Aerial crossing.	
1092.12	**1106.42**	411	**Hoult Creek and Upper Kitimat River valley**	
			Slide - shallow/moderate deep	1.00E-07
			Drainage and groundwater control	
			Surface water control	
			Minor slope and crest grading	
			Deep cover, grading, drainage and groundwater control and/or surface water control as required.	
1093.1	**1093.12**	277	**Hoult Creek Valley**	
			Debris Flow	1.00E-06
			Concrete coating or protection	
			Deep burial	
			Deep burial concrete fill over pipe due to steep gradients.	
1094.08	**1094.1**	502	**Hoult Creek Valley**	
			Debris Flow	1.00E-06
			Deep burial	
1094.48	**1095.1**	39	**Hoult Creek Valley**	
			Rockfall	1.00E-06
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Deep burial	
			Deep burial	
			Pipeline below maximum predicted scour depth along alluvial fan impact area	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC

Note that debris flow mitigation for same channel will require deep cover.

1095.1	1095.38	279	**Hoult Creek Valley**	
			Debris Flow	1.00E-05

Deep burial

Deep burial (established on max particle impact energy) and/or extra compaction

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial

Deep burial.

1095.38	1095.78	41	**Hoult Creek Valley**	
			Rockfall	1.00E-06

Deep burial (established on max particle impact energy) and/or extra compaction

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial

Check block size. Note that debris flow mitigation for same channel will require deep cover.

1095.82	1096.84	242	**Hoult Creek Valley**	
			Avalanche	1.00E-08

Deep burial

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial (established on max particle impact energy) and/or extra compaction

Deep burial

Note that debris flow mitigation for same channel will require deep cover.

1096.84	1097.06	43	**Hoult Creek Valley**	
			Rockfall	1.00E-06

Deep burial (established on max particle impact energy) and/or extra compaction

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial

Note that debris flow mitigation for same channel will require deep cover.

1097.06	1097.2	283	**Hoult Creek Valley**	
			Debris Flow	1.00E-06

Deep burial

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial (established on max particle impact energy) and/or extra compaction

Deep burial.

1097.22	1097.38	506	**Hoult Creek Valley**	
			Debris Flow	1.00E-06

Deep burial

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial (established on max particle impact energy) and/or extra compaction

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Deep burial	
1097.38	1097.48	510	**Hoult Creek Valley**	
			Avulsion	1.00E-06
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Note that debris flow mitigation for same channel will require deep cover.	
1097.48	1098.04	45	**Hoult Creek Valley**	
			Rockfall	1.00E-07
			Heavy wall pipe	
			Heavy wall pipe	
			Deep burial	
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Heavy wall pipe	
			Heavy wall pipe	
			Deep burial	
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Note that debris flow mitigation for same channel will require deep cover and heavy wall pipe.	
1099.05	1104.2	412	**Hunter Creek valley slopes**	
			Slide - shallow/moderate deep	0.00E+00
			Deep burial below slide	
			HDD crossing proposed. Slides have been avoided by routing.	
1103.86	1104.22	488	**Hunter Creek**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			HDD or Aerial installation	
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			HDD crossing proposed.	
1106.56	1106.62	287	**Upper Kitimat River valley**	
			Debris Flow	1.00E-06
			Deep burial	
			Deep burial.	
1106.62	1124.62	413	**Upper Kitimat River valley**	
			Slide - shallow/moderate deep	1.00E-07
			Minor slope and crest grading	
			Surface water control	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC

Deep cover, grading, drainage and groundwater control and/or surface water control as required.

KP Start	KP End	ID	Location	FLOC
1106.96	**1107.42**	18	**Upper Kitimat River valley**	
			Avulsion	1.00E-08

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial

Deep burial (established on max particle impact energy) and/or extra compaction

Note that debris flow mitigation for same channel will require deep cover.

KP Start	KP End	ID	Location	FLOC
1107.52	**1107.8**	19	**Upper Kitimat River valley**	
			Avulsion	1.00E-08

Pipeline below maximum predicted scour depth along alluvial fan impact area

Heavy wall pipe

Deep burial

Note that debris flow mitigation for same channel will require deep cover.

KP Start	KP End	ID	Location	FLOC
1110.36	**1110.44**	290	**Upper Kitimat River valley**	
			Debris Flow	1.00E-06

Deep burial

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial.

KP Start	KP End	ID	Location	FLOC
1113.38	**1113.4**	21	**Upper Kitimat River valley**	
			Avulsion	1.00E-09

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial

Note that debris flow mitigation for same channel will require deep cover.

KP Start	KP End	ID	Location	FLOC
1113.7	**1113.8**	292	**Upper Kitimat River valley**	
			Debris Flow	1.00E-07

Deep burial

Deep burial

KP Start	KP End	ID	Location	FLOC
1113.7	**1113.82**	414	**North Side Kitimat River**	
			Slide - shallow/moderate deep	1.00E-06

Drainage and groundwater control

Surface water control

Minor slope and crest grading

KP Start	KP End	ID	Location	FLOC
1114.04	**1114.12**	22	**Upper Kitimat River valley**	
			Avulsion	1.00E-08

Pipeline below maximum predicted scour depth along alluvial fan impact area

Deep burial

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Note that debris flow mitigation for same channel will require deep cover.	
1114.68	**1114.74**	23	**Upper Kitimat River valley**	
			Avulsion	1.00E-06
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Note that debris flow mitigation for same channel will require deep cover.	
1114.86	**1114.98**	24	**Upper Kitimat River valley**	
			Avulsion	1.00E-08
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Note that debris flow mitigation for same channel will require deep cover.	
1115.28	**1115.32**	512	**Upper Kitimat River valley**	
			Debris Flow	1.00E-07
			Deep burial	
			Deep burial	
1115.6	**1135.64**	513	**Upper Kitimat River valley**	
			Debris Flow	1.00E-07
			Deep burial	
			Deep burial	
1116.28	**1116.6**	25	**Upper Kitimat River valley**	
			Avulsion	1.00E-08
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Deep burial	
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Note that debris flow mitigation for same channel will require deep cover.	
1117.16	**1117.28**	297	**Upper Kitimat River valley**	
			Debris Flow	1.00E-06
			Deep burial	
			Deep burial.	
1117.94	**1118.36**	26	**Upper Kitimat River valley**	
			Avulsion	1.00E-08
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Note that debris flow mitigation for same channel will require deep cover.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
1119.36	1119.52	299	**Upper Kitimat River valley**	
			Debris Flow	1.00E-05
			Deep burial	
			Deep burial.	
1119.38	1119.6	27	**Upper Kitimat River valley**	
			Avulsion	1.00E-06
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Note that debris flow mitigation for same channel will require deep cover.	
1119.44	1120.24	50	**Upper Kitimat River valley**	
			Rockfall	1.00E-07
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Deep burial plus additional protection depending on results of field check.	
1120	1120.62	300	**Upper Kitimat River valley**	
			Debris Flow	1.00E-05
			Deep burial	
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
1121.22	1121.34	29	**Upper Kitimat River valley**	
			Avulsion	1.00E-09
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Note that debris flow mitigation for same channel will require deep cover.	
1121.94	1122.1	30	**Upper Kitimat River valley**	
			Avulsion	1.00E-06
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Note that debris flow mitigation for same channel will require deep cover.	
1126.12	1128.26	51	**Upper Kitimat River valley**	
			Rockfall	1.00E-06
			Deep burial (established on max particle impact energy) and/or extra compaction	
1127.48	1127.82	31	**Upper Kitimat River valley**	
			Avulsion	1.00E-08
			Pipeline below maximum predicted scour depth along alluvial fan impact area	
			Deep burial	
			Note that debris flow mitigation for same channel will require deep cover.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
1128.26	**1128.6**	489	**Chist Creek**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Armoured stream banks suitably designed	
			HDD crossing proposed.	
1136.68	**1136.74**	514	**Cecil Creek**	
			Scour	1.00E-08
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Bored crossing proposed.	
1142.4	**1142.52**	52	**Eastern flank on Iron Mountain**	
			Rockfall	1.00E-05
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Diversion berm	
			Deep cover berms and/or other protection as required	
1148.6	**1148.7**	53	**Southeast flank of Iron Mountain**	
			Rockfall	1.00E-05
			Diversion berm	
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Deep cover and berms and/or additional protection as required.	
1149.52	**1152.32**	430	**Wedeene River area**	
			Lateral Spreading	4.00E-07
			Reroute to avoid areas of sensitive clays	
			Use routing and crossing design to avoid sensitive clays. Further investigation required for sensitive clays.	
1150.08	**1150.14**	490	**Wedeene River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			HDD crossing proposed.	
1150.18	**1150.38**	418	**Wedeene River west valley slope**	
			Slide - shallow/moderate deep	1.00E-08
			Deep burial below slide	
			HDD crossing proposed.	
1152.32	**1155.82**	431	**Little Wedeene River Area**	
			Lateral Spreading	4.00E-08
			Reroute to avoid areas of sensitive clays	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
			Use routing and crossing design to avoid areas prone to lateral spreading. Possible reroute along the rock slopes to the west. Further investigation required for sensitive clays.	
1153.74	**1153.86**	420	**Little Wedeene River North terrace face**	
			Slide - shallow/moderate deep	1.00E-06
			Major slope and crest grading	
1154.1	**1154.86**	491	**Little Wedeene River**	
			Scour	1.00E-06
			Trenchless methods with depths beyond max. theoretical scour depth and beyond limits of channel movements	
			Trenchless Methods enter/exit outside extents of lateral migration	
			Bored crossing proposed.	
1155.82	**1177.62**	432	**Kitimat Area**	
			Lateral Spreading	4.00E-07
			Reroute to avoid areas of sensitive clays	
			Use routing to avoid areas prone to lateral spreading. Possible reroute using a ridge in the Kitimat River Valley east of the current alignment. Further investigations required for sensitive clays.	
1158.8	**1160**	369	**West of Kitimat River**	
			Lateral Migration	1.00E-06
			Reroute	
			River training measures suitably designed	
			Relocation if required by further study. Buried self launching riprap could also be considered.	
			Select only reroute or riprap, mitigations are not multiplicative.	
1164	**1164.64**	370	**Kitimat River near gravel pit**	
			Lateral Migration	1.00E-05
			Reroute	
			River training measures suitably designed	
			River training measures if required by further study. Possible relocation.	
			Select only reroute or river training, mitigations are not multiplicative.	
1169.1	**1169.26**	492	**Anderson Creek**	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
1170.38	**1170.5**	304	**Moore Creek**	
			Debris Flow	0.00E+00
			Aerial crossing	
			Aerial crossing proposed.	

Mitigations vs KP

KP Start	KP End	ID	Location	FLOC
1171.92	1173.64	55	West side of Kitimat Arm	
			Rockfall	1.00E-06
			Concrete coating or protection	
			Diversion berm	
			Deep burial (established on max particle impact energy) and/or extra compaction	
			Mitigative options to be finalized based on detailed terrain conditions.	
1172.52	1176.72	422	West side of Kitimat Arm	
			Slide - shallow/moderate deep	1.00E-06
			Drainage and groundwater control	
			Major slope and crest grading	
1174.48	1174.66	305	West side of Kitimat Arm	
			Debris Flow	1.00E-07
			Deep burial	
1175.48	1174.66	493	West side of Kitimat Arm	
			Scour	1.00E-08
			Pipeline below maximum predicted scour depth for 1:100 or 1:200 peak flows	
			Note that debris flow mitigation for same channel will require deep cover.	
1177.6	1177.6	433	Kitimat Terminal	
			Lateral Spreading	4.00E-08
			Reroute to avoid areas of sensitive clays	
			Facilities to be located outside of extents of significant fine-grained soils. Detailed investigations have been done to facilitate detailed design.	

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