RESPONSE TO WORKING GROUP AND PUBLIC COMMENTS ON THE SITE C CLEAN ENERGY PROJECT ENVIRONMENTAL IMPACT STATEMENT

Technical Memo

RESERVOIR IMPACT LINES

MAY 8, 2013

Subject: Reservoir Impact Lines

1. Purpose

This technical memo addresses questions raised during the comment period on the EIS about potential slope instability, erosion and flooding around the shoreline of the proposed reservoir.

The information contained in the following sections of this technical memo is taken from EIS Section 11.2.3 and Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines, unless stated otherwise.

This technical memo:

- Describes the development of the impact lines approach to characterize the potential changes to flooding, erosion, landslides, and landslide-generated wave hazards around the proposed reservoir shoreline as a result of the impoundment and operation of the reservoir
- Summarizes some of the results of the impact lines study that are contained in the EIS
- Addresses information requests received during the comment period

2. Impact Lines Approach

2.1 The Historical Safeline

The operating parameters for the proposed reservoir have changed little since the initial designs for the dam were prepared by BC Hydro in 1981. Numerous reservoir shoreline geotechnical investigations were undertaken by BC Hydro and its consultants in the 1970s and early 1980s.

Results of the historical shoreline geotechnical investigations and analyses were used to establish a ‘residential safeline’ around parts of the proposed reservoir. The safeline was defined as “a conservatively located line beyond which the security of residents and residential improvements can be reasonably assured”. The safeline took into consideration the combined potential spatial extent of flooding, erosion, landslides and landslide-generated waves. The position of the safeline was based on the hazard that could potentially affect land furthest from the reservoir, plus a margin of safety. A shoreline stability classification was established to describe the expected degree of change to slope stability caused by the reservoir.

2.2 1983 BC Utilities Commission Recommendation

In 1983, the BC Utilities Commission issued a report in which it concluded that the approach taken by BC Hydro to characterize potential reservoir hazards, combined with commitments made for continued and ongoing investigation and monitoring, were sufficient to protect the public. However, the Commission also recommended that every effort be made to distinguish between lands that were truly hazardous and those that could be used safely for certain purposes.

2.3 Stage 2 Public Consultation

Round 1 of the Project Definition Consultation undertaken in May and June 2008 included reservoir impact lines as a topic. The Round 1 Consultation Discussion Guide[1] presented information on BC Hydro's proposal to replace the safeline approach with a series of "reservoir impact lines" based on the different physical processes that would be affected by the reservoir. The proposed approach was based on guidelines by the International Commission on Large Dams[2].

Schematic representations of the Flood, Erosion and Stability Impact Lines taken from Volume 2 Appendix B Part 2 are appended to this memo.

The Round 1 Consultation Discussion Guide:

- Summarized the history of the safeline
- Noted that studies were underway as part of Stage 2 to establish reservoir impact lines, to provide more information to land owners and residents, and to allow BC Hydro to tailor land use restrictions and property acquisitions
- Noted that the impact lines would be conservatively located based on the information available, but could be modified after some years of experience with reservoir operation, should the project proceed
- Asked for public feedback on the proposed reservoir impact lines approach

Participants in the public consultation that provided feedback were generally in agreement with the impact lines approach.

3. Environmental Impact Statement

Section 9.2.1 of the EIS Guidelines outlines the information to be included in the EIS on the characterization and classification of the reservoir shoreline including:

- Predicted changes to shoreline erosion and slope stability due to the Project
- A series of reservoir impact lines to delineate areas where limitations on residential land use or other measures may be required to manage public safety

Section 11.2.3 of the EIS presents the information required by Section 9.2.1 of the EIS Guidelines. Additional information is provided in EIS Volume 2 Appendix B Part 2.

Several IRs (gov_0010-080, gov_0010-085, gov_0010-086, gov_0010-087, gov_0010-088, gov_0010-091, gov_0010-098) questioned the level of detail provided in EIS Volume 2 Section 11.2.3, which is a summary of the results of the impact lines studies. More detail on the studies and original data are provided in EIS Volume 2 Appendix B Part 2 Preliminary Reservoir Impact lines. The appendices form part of the EIS and it is not practical or required to reproduce all the information contained within the appendices in the body of the EIS.

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[1] Peace River Site C Hydro Project, An Option to Help Meet B.C.'s Future Electricity Needs, Project Definition Consultation, Discussion Guide and Feedback Form, Round 1: May/June 2008.

[2] International Commission on Large Dams (ICOLD), 2002. Reservoir Landslides: Investigation and Management, Guidelines and Case Histories. Bulletin 124 December 2009.

Several IRs (gov_0010-080, gov_0010-084, gov_0010-086, gov_0010-091, gov_0010-606, gov_0010-607) recommended additional work to characterize geological processes that are extremely unlikely to affect the Project (for example, landslide dams and outbreak floods on tributary creeks), including the development of terrain hazard and constraint maps for such processes.

The objectives of the reservoir impact lines study were to characterize potential changes to the stability of the reservoir shoreline as a result of the impoundment and operation of the proposed Site C reservoir, and to inform land use plans to manage public safety as it relates to these potential changes. Natural landslides originating from outside the Stability Impact Line are not expected to have an impact on the project. Potential exceptions include the management of slope hazards along proposed Highway No. 29 re-alignment sections. At these locations, management of terrain hazards and risks will be carried out through ongoing monitoring of slope stability, and other means consistent with how terrain hazards are managed elsewhere along highways throughout the province.

Conservative assumptions have been used for the purpose of the EIS and the land use impacts and hazards of the project. If the project proceeds, additional hazard assessments will be conducted, as required, in final design and construction for the various Project components. It was not the objective of the study to create hazard or development constraint maps for areas within the region where the stability of natural slopes or other terrain hazards would not be altered by the project.

3.1 Impact Lines Methodology

As described in EIS Section 11.2 and Volume 2 Appendix B Part 2, the methodology used to establish the reservoir impact lines consisted of the following:

- Desktop studies, including a review of:
  - Historical air photographs, orthophotographs and satellite imagery
  - Geotechnical reports prepared for and by BC Hydro on the proposed reservoir slopes between 1978 and 1983 that document surface mapping, geotechnical drilling, slope movement and groundwater monitoring, and slope stability analyses
  - Published reports and maps on the regional bedrock and overburden geology
  - Published reports and academic research on the Cache Creek, Attachie and Halfway River landslides, a regional landslide inventory, and landslide case histories
  - Historical geotechnical site investigation results and reports prepared for the B.C. Ministry of Transportation and Infrastructure in the vicinity of Highway No. 29
  - Climate monitoring data from Fort St. John
  - High resolution topography and digital elevation models of the proposed reservoir slopes, generated from a LiDAR (light detection and ranging) survey
  - Case histories of reservoir shoreline and slope stability performance for reservoirs located in similar geological materials and environments, including Williston Reservoir (Dunlevy Section), Dinosaur Reservoir, Nechako Reservoir, Lake Roosevelt, and others
- Field studies, including:
  - Surface inspections and mapping of the proposed reservoir shoreline, with emphasis on accessible north bank slopes with existing residential development or infrastructure and south bank slopes identified as having potentially elevated landslide-generated wave initiation

potential, with the objectives to field verify the shoreline geology, collect evidence of groundwater seepage, and to field check the landslide inventory

  - Excavations of test pits at locations where old landslide deposits have been preserved on elevated river terraces, including sampling of buried organic materials for radiocarbon dating to indicate the age of the landslides
  - North bank geotechnical drilling, sampling, laboratory soil and rock testing, and groundwater monitoring, to confirm shoreline geology and to determine geotechnical parameters and groundwater levels to facilitate slope stability analyses and refinement of the reservoir impact lines
  - South bank geotechnical drilling, sampling, laboratory soil and rock testing, and groundwater and slope movement monitoring, to confirm shoreline geology and to determine geotechnical parameters and groundwater levels to facilitate slope stability analyses and refinement of the reservoir impact lines
  - Installation of a total of 65 standpipe piezometers in drill holes completed as part of the shoreline geotechnical investigations
  - Evaluation of current groundwater conditions around the proposed reservoir from records of seepage during the surface inspections, by measuring water levels in the installed standpipe piezometers using dip meters and level loggers, and by estimating hydraulic conductivity by testing
  - Installation of level loggers in selected piezometers in the south bank and the north bank
- Characterization of current shoreline conditions, including bedrock and overburden geology, and a detailed inventory and characterization of landslides and slope angles that have formed in the geological material types present throughout the Peace River valley
- Assessment of the potential flood hazard around the proposed reservoir shoreline as a result of wind-generated waves, inflows from upstream and from tributary valleys, and operation of the Project
- Development of conservative predictions of shoreline erosion over a period of 100 years of reservoir operations
- Assessment of current groundwater conditions within the proposed reservoir slopes and prediction of groundwater changes as a result of proposed reservoir impoundment and operation
- Slope stability analyses to assess the stability of slopes under current and proposed reservoir conditions
- Assessment of potential landslide-generated waves, in which slope segments susceptible to large and potentially extremely rapid landslides were investigated
- Establishment of preliminary impact lines for the proposed reservoir
- Development of a shoreline erosion and stability classification system to provide a qualitative assessment of the potential change in shoreline erosion and stability under reservoir conditions
- Additional considerations for land use and public safety around the proposed reservoir stemming from the results of the impact lines study
- Recommendations for ongoing shoreline monitoring and impact line review

The reservoir shoreline topographic and geotechnical information was compiled, reviewed and interpreted by qualified registered professional engineers and geoscientists, and interpretations of the data were reviewed by technical reviewers and a technical advisory panel convened for the Project. One IR (gov_0010-105) questioned the 100 year look-ahead period adopted for this study and suggested that the impact lines should consider the full intended life span of the reservoir. As described in Volume 2 Section 11.2.3 and Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines, the largest changes to shoreline stability and erosion are expected to occur within the first 3 to 5 years of the impoundment of the proposed reservoir. For example, erosion predictions, taking into consideration the stratigraphy of the soils around the proposed reservoir, indicate that as much as 50% of the predicted shoreline erosion over a 100 year period would occur within the first 5 years of reservoir operation. Long-term (steady state) groundwater conditions under reservoir operations scenarios, as well as rapid drawdown scenarios, have been considered in determining the position of the reservoir impact lines. Changes to groundwater conditions that could affect slope stability would largely equilibrate within the first 3 to 5 years of the impoundment of the reservoir. The positions of the reservoir impact lines, which incorporate long-term anticipated groundwater conditions and shoreline erosion predictions for a period of 100 years, appropriately reflect the potential long term changes to slope stability resulting from the impoundment and operation of the reservoir. As described in the EIS and in Section 3.6 of this technical memo, BC Hydro is committed to monitoring the stability of the reservoir shoreline for as long as the dam is in operation and the intent is, through ongoing investment in maintenance and sustaining capital, to operate the dam and reservoir in perpetuity.

One IR (gov_0014-023) requested clarification on the derivation and use of the digital elevation model that was derived from the LiDAR data. The LiDAR data was flown at a height of approximately 1,200 m using 0.75 m point spacing with an expected horizontal accuracy of 0.45 m and an expected vertical accuracy of 0.3 m. As noted in Volume 2 Appendix B Part 2 Section 4.2.1, the LiDAR data was provided in the form of a bare-earth digital elevation model with a 1 m by 1 m horizontal resolution. The LiDAR imagery was used to map terrain units, in combination with orthophotos, air photos and satellite imagery.

One IR (gov_0010-608) commented that the LiDAR data set was not provided to government reviewers. LiDAR-based digital elevation models and orthophotos were used extensively in the reservoir impact lines study. PDF copies of shaded relief imagery were used as a base map for several of the figures and drawings included in the EIS and appendices.

3.2 Summary of Results of Impact Lines Studies

Geological Model and Simplified Geological Mapping Units.

Section 11.2.3.2 of the EIS describes the grouping of select geological units for the purposes of the Impact Lines Studies. The geology of the proposed reservoir shoreline is described in detail in Volume 2 Appendix B Part 2 and was summarized in Section 11.2.2.

One IR (gov_0010_609) questioned the wide spacing of geotechnical drill holes in some areas and the potential to overestimate impacts of the Project on existing and future development. Interpreted geological sections were created at no more than 1 km intervals for both the north and south banks of the reservoir, and were used to create geological fence diagrams that illustrate interpolation of the geological model between cross sections, as detailed in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines. The cross sections were developed from historical and recent geotechnical boreholes, but also relied upon extensive surface mapping of soil and bedrock exposures in the valley walls, interpretation of LiDAR topography and orthophotos, and from literature review from prior

geological mapping work by others. Borehole locations were prioritized based on the locations of homes and other existing and proposed infrastructure that were potentially located inside the anticipated limits of the reservoir impact lines. The reservoir shoreline geological model forms the basis for the delineation of the reservoir impact lines. The geological model and suitability of investigations were reviewed by the Project team, including external reviewers comprising nationally and internationally respected geologists and geological engineers, who found it to be suitable for the purpose of establishing the reservoir impact lines and Project Environmental Assessment. The reservoir impact lines project team and review process is described in further detail in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines.

Two IRs (gov_0010-098, gov_0010-091) suggested more investigation and description of Holocene (post-glacial) geological processes. A detailed description of the evolution of the Peace River valley, including major features related to post-glacial processes, is provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 3.3. The Holocene geomorphic information most relevant to the determination of the position of the reservoir impact lines was captured in the detailed landslide inventory (including estimates of landslide frequency, volume, basal failure material, and runout behaviour), and inventory of short-term (eroded) and long-term (ultimate) slope angles that have formed in the various geological materials, as detailed in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Sections 4 and 5. It is recognized that variability in the paleoclimate has influenced the landslide record and the development of valley slope angles. The geotechnical investigations have focused on the information most relevant to the determination of the reservoir impact lines and, where required, conservative assumptions have been used to define the position of the impact lines.

Published and un-published radiocarbon dates of buried organic materials in fans and landslide deposits within the proposed reservoir area, as well as dates obtained from samples from recent BC Hydro geotechnical investigations, were taken into consideration in establishing the age of the modern Peace River valley and historic rates of landslide activity, as detailed in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Sections 3 and 4. It is believed that the frequency of landslide occurrence and reactivation has diminished since the modern Peace River valley was first formed, and again since the river was regulated with the construction of the W.A.C. Bennett Dam. It is expected that additional investigations, as suggested in the information request, would support assumptions that the rate of geomorphic activity has declined over the past several thousand years. However, the conservative assumption has been used in defining the impact lines that long-term historic rates of landslide activity also are representative of current and future rates of landslide activity.

One IR (gov_0014-024) indicated that the individual complexities and modes of failures of the individual geological units, specifically the glaciolacustrine units, could be lost in the grouping of simplified geological mapping units.

Differences between the distinct overburden units included in each simplified mapping group are acknowledged and described further in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 3.3. These differences were taken into account in assessing the susceptibility to failure and the dominant failure mechanisms of the different materials, particularly the different glaciolacustrine units, as described further in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Sections 4.1.1, 4.2.3, 8.3.1, 8.3.4, 9.2.2 and 10.2.2. Wherever the units were grouped and assigned the same parameter values, the assignments were based on the material within each group that produced the most conservative result.

Landslide Inventory

Section 11.2.3.3 of the EIS summarizes a comprehensive inventory of landslides that have occurred in the modern Peace River valley that was completed for the proposed reservoir area. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 4.

One IR (gov_0010-097) recommended further investigation and monitoring of the Cache Creek Slide (at Bear Flat) and asked about the potential for future movement of this slide to block this section of the reservoir.

Historical geotechnical investigations of the Cache Creek Slide, including geotechnical drilling and monitoring of groundwater levels and slope movements were carried out by BC Hydro and are documented in Volume 2 Appendix B Part 2 of the EIS. A detailed description of the Cache Creek Slide, including volume, mechanisms and movement rates, is provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 4.1.2.1. The proposed reservoir would be approximately 800 to 900 m wide and approximately 43 m deep at the location in question. Average movement rates at the toe of the Cache Creek Slide are slow. Therefore, unanticipated blockage of reservoir flow at this location would be extremely unlikely. To maintain operation of the powerhouse, only a small fraction of the reservoir area would be needed to safely pass flows. BC Hydro would monitor groundwater levels and the stability of the slopes in the vicinity of the Cache Creek Slide, and undertake additional geotechnical investigation to support the final design of the proposed Highway No. 29 re-alignment through Bear Flat should the Project proceed.

Two IRs (pub_0601-003 and pub_0601-008) indicated that the landslide inventory should include assessment of landslides from the Alberta region. One IR specifically referenced the Eureka River Slide of June 1990 at 50 million cubic metres of landslide material and indicated that index testing of material from this slide was within the same range found at the Attachie Slide.

As described in Volume 2 Appendix B Part 2 Section 4.1, landslide investigations in similar geological settings along tributaries of Peace River and east of the B.C.-Alberta border have been studied. A list of supplemental references is provided below. The list includes the paper on the Eureka River landslide.

Development of the preliminary impact lines is described in detail in Volume 2 Appendix B Part 2. The preliminary Stability Impact Line and Landslide-Generated Wave Impact Line were derived based on a comprehensive landslide inventory and detailed geotechnical investigations within the reservoir project activity zone. The information from within the project activity zone is considered sufficient for development of the preliminary Stability Impact Line and Landslide-Generated Wave Impact Line. In addition, however, landslide case histories for landslides originating in glaciolacustrine materials along Peace River and its major tributaries in Alberta were compiled and reviewed. The main objective of this review was to search for case histories of landslides in similar geological materials as the 1973 Attachie Slide that failed extremely rapidly; no such case histories were identified. In addition to the landslide investigations along Peace River between Hudson's Hope and the B.C.-Alberta border that are specifically referenced in Volume 2 Appendix B Part 2 Section 4.1, the following publications were studied:

Cruden, D.M., Ruel, M., Thomson, S., 1990. Landslides along the Peace River, Alberta. In Proc. 43rd Canadian Geotechnical Conference, Geotechnical Society of Canada, vol. 1, pp. 61-68.

Cruden, D.M., Keegan, T.R. and Thomson, S., 1993. The landslide dam on the Saddle River near Rycroft. Canadian Geotechnical Journal, vol. 30(6), pp. 1003-1015.

Cruden, D.M., Thomson, S., Kim, H.J., and Peterson, A.E., 1995. The Edgerton landslides. Canadian Geotechnical Journal, vol. 32(6), pp. 989–1001.

Cruden, D.M., Lu, Z.Y. and Thomson, S., 1997. The 1993 Montagneuse River landslide, Alberta. Canadian Geotechnical Journal, vol. 34(5), pp. 799-810.

Cruden, D.M., Peterson, A.E., Thomson, S. and Zabeti, P,. 2002. Thirty-five years of activity at the Lesueur Landslide, Edmonton, AB. Canadian Geotechnical Journal, vol. 39, pp. 266-278.

Dewar, D. and Cruden, D.M., 1998. The largest historic landslide in the MacKay River Valley, N.E. Alberta. Proceedings of the 51st Canadian Geotechnical Conference, vol. 1, pp.73-80.

Eshragian, A., Martin, C.D. and Cruden, D.M., 2007. Complex Earth Slides in the Thompson River Valley, Ashcroft, British Columbia. Environmental & Engineering Geoscience, vol. XIII, pp. 161–181.

Geertsema, M., 1998. Flowslides in waterlain muds of northwestern British Columbia, Canada. Proceedings 8th International IAEG Congress, vol 3, pp. 1913-1921.

Jones, F.O., Embody, D.R. and Peterson, W.L. 1961. Landslides Along the Columbia River Valley Northeastern Washington. Geological Survey Professional Paper 367.

Kim T.H., Cruden D.M., Martin C.D., and Froese C.R., 2009. The 2007 Fox Creek landslide, Peace River Lowland, Alberta, Canada. Landslides, Journal of the International Consortium on Landslides, vol. 7, pp. 89-98.

Krahn, J. and Weimer, N.F., 1984. The W.I.D. Landslide. Proceedings of the 37th Canadian Geotechnical Conference, pp. 209-215.

Lu, Z.Y., Cruden, D.M., Thomson, S., 1999. Landslides and preglacial channels in the western Peace River lowland, Alberta. In Proc. 51st Canadian Geotechnical Conference. Geotechnical Society of Canada. pp. 267-274.

Maber, C.T. and Stewart, P., 1976. The Peace River Hill Landslide; Proceedings, sponsored by the Canadian Geotechnical Society, 29th Canadian Geotechnical Conference, Vancouver, BC, pp. 33-47.

Martin, R.L., Lewycky, D.M., and Ruban, A.F., 1998. Long term movement rates in a large, translational landslide. Proceedings of the 51st Canadian Geotechnical Conference, pp. 23-30.

Miller, B.G.N. and Cruden, D.M., 2002. The Eureka River landslide and dam, Peace River Lowlands, Alberta. Canadian Geotechnical Journal, vol. 39, pp. 868-878.

Miller, B.G.N. and Cruden, D.M., 2001. Landslides, landslide dams, and the geomorphology of tributaries in the Peace River Lowland, Alberta. Proceedings of the 54th Canadian Geotechnical Conference, pp. 363-370.

Nasmith, H., 1964. Landslides and Pleistocene deposits in the Meikle River valley of northern Alberta. Canadian Geotechnical Journal, vol. 1, pp. 155-166.

Raymond, E.L., Evans, S.G. and Couture, R., 2002. Geological log of two boreholes at 2001 Cecil Lake Road landslide near Fort St. John, BC. GSC Open File 4294.

SoeMoe, K.W., Cruden, D.M., Martin, C.D., Lewycky, D., and Lach, P.R., 2009. Mechanisms and kinematics of three translational slides along the North Saskatchewan River Valley, Edmonton. Proceedings, 52nd Canadian Geotechnical Conference, September 2009, Halifax, 8p.

Thomson, S. and Hayley, D.W., 1975. The Little Smoky Landslide. Canadian Geotechnical Journal, vol. 12, pp. 379-392.

Slope Angle Inventory

Section 11.2.3.4 of the EIS summarizes the results of the slope angle inventory, which were combined with results from the geotechnical site investigations and slope stability analyses to establish predicted eroded and ultimate slope angles for each of the geological units around the proposed reservoir. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 5. IRs on this section are addressed under Stability Impact Line below.

Groundwater Flow

Section 11.2.3.5 of the EIS summarizes the predicted changes in groundwater flow that might affect slope stability as a result of proposed reservoir operations. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 8.

One IR recommended that modelling work be consistent with best practices documented in the Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities[3].

As stated on Page 3 of the guidelines, the objective of the guidelines was "to provide guidelines for groundwater modelling undertaken to identify and assess the impacts of natural resource projects in British Columbia, with specific emphasis on: hardrock mining (metal, coal), aggregate mining (gravel), and large groundwater extraction projects (> 75 L/s)." The Site C Clean Energy Project is not in a category contemplated by the guidelines. Nevertheless, the groundwater modelling completed for the Site C Clean Energy Project is consistent with the intent of the guidelines and is appropriate to meet the EA objectives.

Another IR commented that it would be useful to include maps in the EIS to show groundwater flow directions and flow rates, and potential changes caused by the Project.

The groundwater assessment presented in Sections 11.2 and 11.6 of the EIS meets the requirements described in Section 9.3.3 of the EIS Guidelines. The Technical Study Area for the groundwater regime study extends 83 km, from Peace Canyon Dam to the proposed Site C dam, and is less than 5 km wide (Figure 11.6.1 of the EIS). The cross-sectional depictions of groundwater flow conditions are appropriate to the study area geometry and observed groundwater conditions. Volume 2 Appendix B Part 2 Section 8 describes groundwater conditions. Interpreted groundwater flow regimes are described in Volume 2 Appendix B Part 2 Section 8.1 for current conditions and for proposed reservoir conditions.

[3] B.C. Ministry of Environment, 2012. Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities, April 2012.

Flood and Wind-Generated Waves

Section 11.2.3.6 of the EIS summarizes the potential for flood discharges from Peace Canyon Dam upstream of the proposed reservoir, and from tributary valleys within the proposed reservoir, combined with wind-generated waves, to temporarily inundate lands above the Maximum Normal Reservoir Level. The possible operation of the proposed Site C dam auxiliary spillway could also surcharge the reservoir is also described. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 6.

IRs on this section are addressed under Flood Impact Line below.

Reservoir Shoreline Erosion

Section 11.2.3.7 of the EIS summarizes the characterization and modelling of erosion by wind-generated waves around the proposed Site C reservoir. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 7.

IRs on this section are addressed under Erosion Impact Line below.

Slope Stability

Section 11.2.3.8 of the EIS summarizes two-dimensional limit equilibrium slope stability analyses that were carried out to refine an understanding of the effect of groundwater changes and shoreline erosion on the stability of slopes around the proposed Site C reservoir. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 9.

One IR (pub_0601-009) requested additional rationale for the selected seismic parameters used in the pseudo-static (seismic) slope stability analysis, in particular, the reason for using median ground motions for the reservoir slope analyses and mean ground motions for the dam design. Mean values from the seismic hazard assessments described in EIS Section 11.2.5 are higher than median values.

The seismic hazard for the design of the dam is based on mean values, which is consistent with the 2007 Canadian Dam Association guidelines (see EIS Section 11.2.5 Regional Seismicity and Seismic Hazard and the Technical Memo on Seismic Considerations). Median ground motions have been utilized for impact line studies that focus on the residential land use and the relocation of Highway No. 29. As described in Volume 2 Appendix B Part 2 Section 9.2.4, the methods adopted for pseudo-static stability analysis of the reservoir slopes (i.e. use of 2,475-year median PGA values) are consistent with the requirements of the National Building Code of Canada[4] and the APEGBC Guidelines for Legislated Landslide Assessments for Proposed Residential Development in B.C.[5]. It is acknowledged that ground conditions vary between sites, however, NBCC site class C (firm ground conditions - soft rock and very dense soil) is generally applicable as an average condition along potential landslide slip surfaces at all of the sites that were analyzed. The conservative use of the full PGA values is consistent with recommendations provided by APEGBC for screening level seismic slope stability analysis (i.e. to confirm that the factor of safety at the location of interest exceeds 1.0).

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[4] National Building Code of Canada (NBCC). 2010.

[5] Association of Professional Engineers and Geoscientists of British Columbia (APEGBC), 2010. Guidelines for legislated landslide assessments for proposed residential development in B.C.

Uncertainties and limitations of the reservoir slope stability analyses are described in Volume 2 Appendix B Part 2 Sections 9.1 and 9.2 and the sensitivity of the results is described in Section 9.3.

Landslide Generated Waves

Landslides with the capability of achieving extremely rapid velocities (greater than 5 m/s) have the potential to generate impulse waves if they enter the reservoir. Section 11.2.3.9 of the EIS summarizes the analysis to assess the landslide-generated wave hazard along the proposed reservoir shoreline. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 10.

IRs on this section are addressed under Landslide-Generated Wave Impact Line below.

Flood Impact Line

Section 11.2.3.10.1 of the EIS describes the Flood Impact Line. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 11.

The Flood Impact Line is the boundary beyond which land would not be expected to be affected by floods, wind-generated waves, the operation of the Site C auxiliary spillway, and/or waves caused by boats and small landslides. The Flood Impact Line is located at elevation 466 metres, or approximately four metres above the Maximum Normal Reservoir Level (elevation 461.8 metres).

One IR requested clarification of whether or not mitigation, such as dykes, could be put in place to prevent this flooding. It is not considered practical to prevent flooding from occurring within the Flood Impact Line by means of impervious dykes or other measures because of the foundation conditions, costs, and benefits. Mitigation against erosion and slope instability is considered feasible and practical along the shoreline adjacent to the community of Hudson's Hope and adjacent to re-aligned segments of Highway No. 29, but even at these locations, the construction of impervious dykes to prevent flooding within the Flood Impact Line is not proposed. Further descriptions of the probabilities associated with the Flood Impact Line are provided in Volume 2 Appendix B Part 2 Section 11.1.

One IR requested the anticipated depth and duration of the potential flooding. Further details are provided in Volume 2 Appendix B Part 2 Sections 6 and 11. The elevation of the Flood Impact Line is 466 metres, or 4.2 metres above the Maximum Normal Reservoir Level. Therefore, the potential depth of inundation within the Flood Impact Line could range from 0 to 4.2 metres, depending on the local elevation of the land and the scenario that caused the flooding. The duration could range from seconds to hours for flooding caused by wind-generated waves. The most likely cause of flooding that could reach the position of the Flood Impact Line is from wind-generated waves from a 200 year wind storm. Wave runup would vary with the local geometry of the reservoir shoreline. Additional information on predicted wave runup from a 200 year wind storm at locations around the proposed reservoir is provided in Volume 2 Appendix B Part 2 Section 6.

Several IRs (gov_0010-080, gov_0010-084, gov_0010-086) recommended additional work to characterize hazards related to landslide dam and outbreak flood potential on tributary creeks.

The characteristics of prior landslide dam events in tributary valleys (e.g. the Halfway River Slide) were reviewed and taken into consideration when establishing the elevation of the preliminary Flood Impact Line. The elevation of the Flood Impact Line is based on predicted inflows from the 1,000 year return period flood on the Halfway River combined with predicted wave run-ups from a 200 year windstorm. It

also considers potential wave run-up from smaller landslide-generated waves. The impact lines are considered adequate for managing public safety and land use potentially affected by flooding from landslide dam outburst floods in tributary creeks.

Erosion Impact Line

Section 11.2.3.10.2 of the EIS describes the Erosion Impact Line. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 11.

The Erosion Impact Line is the boundary beyond which the top of the slope adjacent to the reservoir would not be expected to regress due to erosion caused by the impoundment and operation of the reservoir over a period of 100 years. It considers both predicted shoreline erosion (to the 100-year Beach Line) and the formation of a slope above the reservoir shoreline using appropriate eroded (short term, steep) slope angles for the geological units present around the shoreline. The predicted average range of shoreline erosion by material type is shown in the table below.

Years of Operation	**Shoreline Material Type, Percent of Shoreline Length(%), and Predicted Erosion Distance (metres)**						
	ISC (8%)	**OC (15%)**	**BC (10%)**	**SG (36%)**	**SST (11%)**	**SSH (11%)**	**SH (8%)**
5	24	18 to 43	2 to 5	1 to 6	<1	<1	1
100	47	30 to 71	5 to 23	4 to 18	<1	2	3

ISC = interbedded sand, silt and clay; OC = overburden colluvium; BC = bedrock colluvium; SG = sand and gravel; SST = siltstone; SSH = silty shale; SH = shale

For example, overburden colluvium would be present along 15% of the reservoir shoreline and it is predicted that after 5 years of reservoir operation the erosion distance would be between 18 m and 43 m.

One IR suggested modelling to indicate what the valley may look like in the years shortly after reservoir filling, and discussion of the impacts to the valley and recreation.

Sedimentation studies and a visual impact assessment have been carried out looking at potential changes as a result of shoreline erosion and landslides, both in the 5-year period following impoundment of the reservoir, and over a period of 100 years of reservoir operations. As indicated in the table above, in the more erodible shoreline materials, such as interbedded sand, silt and clay deposits, as much as half of the total erosion and associated landslide activity for the 100-year period could occur within the first 5 years of reservoir operation. Examples of how the shoreline erosion predictions have been incorporated in the visual impact assessment are provided in the EIS in Volume 3 Section 27.

Another IR requested a description of the potential for beach habitats to re-form post-development. The shoreline erosion process is described in detail in Volume 2 Appendix B Part 2 Section 7. Where slopes above the Maximum Normal Reservoir Level comprise low, gentle banks in sand and gravel, gentle beaches are likely to re-form during reservoir operation. At other locations where the slopes above the Maximum Normal Reservoir Level comprise steeper and higher banks, short, steep beaches will tend to re-form during reservoir operations and a shallow (0.5 to 1.5 metre deep) wave cut platform will be created by wave erosion processes beyond the toe of the beaches.

Stability Impact Line

Section 11.2.3.10.3 of the EIS describes the Stability Impact Line. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 11.

The Stability Impact Line is the boundary beyond which land would not be expected to be affected by landslide events caused by the impoundment and operation of the reservoir. The position of this line considers extremely unlikely landslide events. It accounts for the predicted amount of shoreline erosion over a 100 year period of reservoir operation, potential changes in groundwater levels and gradual flattening of slopes above the reservoir shoreline using appropriate ultimate (long term, shallow) slope angles for the geological units present around the shoreline.

One IR commented on the straightness of the impact lines relative to the natural landscape pattern, and the potential to underestimate impacts due to sliding and slumping using such a straight line.

The exact location of future landslides is difficult to predict. The Stability Impact Line is a relatively straight line that is intended to provide a conservative envelope around potential future landslides related to reservoir impoundment and operation, wherever they may occur. This conservative approach is consistent with the definition of the Stability Impact Line provided above.

Landslide-Generated Wave Impact Line

Section 11.2.3.10.4 of the EIS describes the Landslide-Generated Wave Impact Line. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 11.

The Landslide-Generated Wave Impact Line is a boundary applied to three areas on the north bank of the proposed reservoir (Lynx Creek, Farrell Creek and Halfway River), where landslide-generated waves could temporarily flood elevations higher than the Flood Impact Line. The position of this line is based on combinations of landslide volumes and velocities that are considered extremely unlikely to occur.

One IR (gov_0010-096) requested details of the hybrid landslide-generated wave modelling approach and results. Details of the empirical and numerical modelling approach to predicting potential landslide-generated wave initiation, propagation and run-up, including validation through comparison with historical physical model tests, are documented in Volume 2, Appendix B, Part 2 Preliminary Reservoir Impact Lines, Section 10, and in Appendix H of that Appendix.

One IR (gov_0014-025) requested a quantitative value to describe the risk of landslide generated wave potential and an explanation of its derivation to clarify the actual level of risk.

The estimated likelihoods of landslides or landslide-generated waves caused by the impoundment and operation of the proposed reservoir affecting lands beyond the position of the Stability and Landslide-Generated Wave Impact Lines, respectively, are less than 1 in 10,000 per year. These likelihoods meet criteria that are being developed and used in other parts of British Columbia to guide the approval of new residential development in landslide prone terrain.

Further descriptions of the landslide-generated wave analysis, including the rationale for selected study sites, are provided in Volume 2 Appendix B Part 2 Section 10. Further descriptions of the probabilities associated with the Flood Impact Line and Landslide-Generated Wave Impact Line are provided in Volume 2 Appendix B Part 2 Section 11.1.

Shoreline Classification

The total area contained between the proposed Maximum Normal Reservoir Level and the impact lines is approximately 9,650 hectares. Of the land area encompassed by the impact lines, approximately 70% is steeper than 17°. Terrain steeper than 17° in the Peace River valley is prone to erosion and landslides under natural conditions, and is typically not considered suitable for residential use. Consequently, on their own, the impact lines do not facilitate a direct quantification of the predicted changes to slope stability or potential land use caused by the reservoir.

As described in Section 11.2.3.11, a shoreline classification system was developed to describe current conditions and the degree of potential change on slope stability caused by reservoir impoundment and operation. Further details are provided in Volume 2 Appendix B Part 2 Preliminary Reservoir Impact Lines Section 12. Shoreline segments were assigned to one or more shoreline erodibility classes based on the material type at the MNRL. Shoreline segments were also assigned to one or more landslide hazard classes.

The shoreline stability classification indicated the following changes in likelihood:

- Landslides in low bank bedrock slopes with volumes >10,000 m^3 and generally limited velocities would not generally be expected to increase under proposed reservoir conditions. Peak landslide velocities would typically be less than 13 m/month and are unlikely to exceed 1.8 m/hr, but could exceed 5 m/s where rock falls initiate on near-vertical slopes.
- Landslides in low bank overburden slopes with volumes >10,000 m^3 and possible extremely rapid velocities would be expected to increase over a length of approximately 27.9 kilometres (9%) of reservoir shoreline, primarily at locations where interbedded sand, silt and clay would be present at or below the MNRL and erosion and groundwater changes could affect slope stability. Peak landslide velocities would typically be less than 13 m/month but could exceed 5 m/s where flow slides are generated.
- Landslides in high bank bedrock slopes with volumes >100,000 m^3 and generally limited velocities would be expected to increase over a length of approximately 48.7 kilometres (16%) of reservoir shoreline, primarily downstream of Wilder Creek, where weak bedding planes associated with previous landslides, including the Tea Creek Slide, would be subject to pore water pressure changes during reservoir impoundment and operation. Peak landslide velocities would typically be less than 13 m/month and are unlikely to exceed 1.8 m/hr.
- Landslides in high bank overburden slopes with volumes >100,000 m^3 and possible extremely rapid velocities would be expected to increase over a length of approximately 66.5 kilometres (21%) of reservoir shoreline, primarily at locations where sand and gravel and interbedded sand, silt and clay would be present at or below the MNRL and erosion and groundwater changes could affect slope stability. Peak landslide velocities would typically be less than 13 m/month but could exceed 5 m/s where flow slides are generated.

Several IRs requested an estimate of the land lost to agriculture within impact lines, during the life of the project, and the future risk to farm operations within the Stability Impact Line.

Estimates of potential agricultural land loss as a result of erosion and landslides caused by the creation and operation of the reservoir assume that 100% of the land within the Erosion Impact Line will lose all agricultural value within 100 years of reservoir operation. No additional potential loss of land between the Erosion and Stability Impact Line has been accounted for, although BC Hydro would compensate

private property owners for such a loss through the acquisition of property rights. In BC Hydro's view, the approach to estimating potential agricultural land loss is appropriate for the following reasons:

- It is very conservative to assume 100% land loss within the Erosion Impact Line (the position of the line was designed to be conservative for the purpose of managing public safety)
- The probability of landslides caused by the creation and operation of the reservoir affecting land between the Erosion and Stability Impact Line is low, ranging from less than 1:100 per year at the position of the EIL to less than 1:10,000 per year at the position of the SIL
- The factor of safety against landslides caused by the creation and operation of the reservoir, based on a range of groundwater scenarios, and assuming 100 years of reservoir shoreline erosion, was calculated to be greater than 1.0 at all locations around the reservoir at the position of the EIL, indicating that such landslides are not expected.
- Where landslides do occur, their behaviour is expected to be similar to that of landslides currently present on agricultural land (movement rates will typically be slow and still suitable for some agricultural purposes).

3.3 EIS Sections that Used Information from the Impact Lines Studies

Information from the impact line studies was used and/or addressed in the following parts of the environmental assessment reported in the EIS:

- Volume 1:
  - Section 4 Project Description, for design of the dam freeboard, the Hudson's Hope shoreline protection and the Highway No. 29 realignment segments and bridges to accommodate potential landslide-generated waves
  - Section 9 Information Distribution and Consultation, listing the occasions the impact lines were discussed
  - Appendix A Vegetation, Clearing and Debris Management, to define the extent of clearing required
- Volume 2:
  - Section 11.3 Land Status, Tenure and Project Requirements, for acquisition of property rights and compensation
  - Section 11.6 Groundwater Regime, to assess the interactions between the groundwater regime and slope or terrain stability
  - Section 11.8 Fluvial Geomorphology and Sediment Transport, sediment input from reservoir shoreline
  - Section 12 Fish and Fish Habitat, sediment input from reservoir shoreline
  - Section 13 Vegetation and Ecological Communities, loss of land to erosion as well as a boundary of its local assessment area
  - Section 14 Wildlife Resources, loss of land to erosion as well as a boundary of its local assessment area

- Volume 3
  - Section 19 Current Use of Lands and Resources for Traditional Purposes, loss of land to erosion
  - Section 20 Agriculture, as a boundary of its local assessment area
  - Section 21 Forestry, as a boundary of its local assessment area
  - Section 22 Oil, Gas, and Energy, as a boundary of its local assessment area
  - Section 23 Minerals and Aggregates, as a boundary of its local assessment area
  - Section 24 Harvest of Fish and Wildlife Resources, as a boundary of its local assessment area
  - Section 25 Outdoor Recreation and Tourism, as a boundary of its local assessment area, and as consideration for the location of new recreational boat launches and day use areas proposed as mitigation measures
  - Section 26 Navigation, bank stability was considered a potential effect on navigation during operations
  - Section 27 Visual Resources, to assess the visual landscape and provide a visual simulation of what the reservoir slopes would look like over the near and long term
- Volume 4:
  - Section 30 Community Infrastructure and Services, impact lines may affect municipal infrastructure, such as sewer and water systems, along the shoreline, and they will be considered in the final engineering assessment and, where required, in design of any relocation or remediation measures
  - Section 32 Heritage Resources, as a boundary of its local assessment area
  - Section 33 Human Health, sediment input from the reservoir shoreline was taken into account in considering the potential effect of changes to water quality on human health
- Volume 5:
  - Section 35 Summary of Environmental Management Plans, in the development of monitoring and reporting plans to manage public safety
  - Section 37 Requirements for the Federal EA, effects of the environment on the Project including the potential for landslide-generated waves affecting dam safety

3.4 Public Safety

3.4.1 Public Safety Management Plans

As described in EIS Section 35.2 and Section 35.3, public safety management plans would be put in place to minimize and manage public safety risks near Project activity zones during construction and operations. Specific procedures and protocols for managing public safety risks would be developed prior to construction or operation phases. The plan would define the communication requirements, communication methods, timing, and information distribution methods to ensure that the public is aware of ongoing project activities as well as of specific activities that may directly affect them, such as

reservoir filling near the end of the construction phase. The plan would describe relevant management practices such as the Canadian Dam Association guidelines for public safety around dams[6].

A key component of the public safety management plan would be the reservoir shoreline monitoring, as described in Section 11.2.3.14 of the EIS. The objective of this plan would be to identify the requirements for regular monitoring of shoreline conditions, including groundwater levels, shoreline erosion rates and landslide activity.

3.4.2 Waterborne Debris Removal

BC Hydro has considerable experience managing waterborne woody debris in reservoirs, using catchment booms and natural shoreline collection points. The erosion of the shoreline, particularly in the early years of operations, would cause woody material to fall into the reservoir. BC Hydro has proposed to clear vegetation above the Maximum Normal Reservoir Level to the 5-year Beach Line, to reduce the amount of post-inundation debris entering the reservoir. The 5-year Beach Line was identified through the reservoir impact line mapping study, and added approximately 180 hectares to the clearing area. The 5-year Beach Line delineates the predicted shoreline erosion after 5 years of reservoir operation.

3.4.3 Around the Shoreline

BC Hydro has developed the following approach to land use on private property within the impact lines that focuses on public safety, maximizing flexibility for land owners, and minimizing the amount of land required by the Project:

- No new residential structures would be permitted within the impact lines
- Non-residential structures could remain within the impact lines, pending site-specific geotechnical assessment. To protect public safety, existing residential structures within the Flood, Erosion, and Landslide-Generated Wave Impact Lines would not be permitted to remain.
- Within the Stability Impact Line, and outside the Flood, Erosion and Landslide-Generated Wave Impact Lines, existing residential structures could remain for a period of time, at the owner's request, and provided a site-specific geotechnical assessment determines that it is safe to do so

The proposed approach to land use within the reservoir impact lines is consistent with criteria that are being developed and used in other parts of B.C. to manage new and existing residential development in landslide-prone terrain[7].

Several IRs (gov_0010-611, gov_0010-612, gov_0010-613) requested clarification on when sufficient information would be made available to make site-specific decisions about whether or not a structure could remain within the impact lines, how long structures might be permitted to remain, and who would be responsible for the cost of these assessments. Determination on whether or not it is safe for specific structures to remain for a period of time within the impact lines would be made, at the request of property owners, should the Project proceed. A determination whether it is safe for residential structures to remain would be conditional upon positive confirmation that it would be safe to remain for a period of at least 20 years based on current predictions of shoreline erosion rates and changes in

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[6] Canadian Dam Association (CDA). 2011. Guidelines for Public Safety Around Dams. Toronto, ON.

[7] Association of Professional Engineers and Geoscientists of British Columbia (APEGBC). 2010. Guidelines for legislated landslide assessments for proposed residential development in B.C.

groundwater levels. The actual period that it would be safe to remain would be verified through ongoing monitoring and review. BC Hydro would be responsible for the costs of geotechnical assessments, where appropriate, to determine if existing residential structures could remain, for a period of time, within the reservoir impact lines.

Shoreline protection adjacent to part of the community of Hudson's Hope would be constructed prior to impoundment of the reservoir. Erosion and Stability Impact Lines have not been established along this section because the proposed shoreline protection would offset the predicted changes to erosion and slope stability caused by the reservoir. However, natural erosion and slope stability hazards along the upper portion of the slopes protected by the berm would not be mitigated by the proposed shoreline protection, and enforcement of development setbacks from the crest of the slope would continue to be required to manage these hazards.

One IR (gov_0010-614) requested clarification that the proposed berm adjacent to Hudson's Hope would fully offset the adverse effects of the reservoir on global stability. The proposed berm and slope re-contouring more than fully compensates for the effects of the proposed reservoir on global slope stability. Proposed designs and slope stability calculations are documented in Project design reports that are on file with BC Hydro. Should the Project proceed, the final design would be completed and the shoreline protection would be constructed to meet these criteria.

One IR (gov_0010-615) asked if the applicability of the existing development guidelines in the District of Hudson's Hope has been confirmed by the District should the Project proceed and a berm is constructed. The berm and slope re-contouring sections of the propose Hudson's Hope shoreline protection measures would be designed to offset the effects of the reservoir on slope stability and would increase the overall stability of the slope. Because no negative change on stability is predicted, BC Hydro does not consider it to be the responsibility of the Project to determine if the existing residential development guidelines are appropriate. BC Hydro would consult with the community of Hudson's Hope on the final design of the shoreline protection. With the shoreline protection measures in place, it may be possible to adopt less stringent development guidelines in some locations, but this would be a decision made by the community of Hudson's Hope, and not BC Hydro.

The proposed realigned segments of Highway No. 29 have been located outside of the impact lines, where practical. The proposed highway realignment at the Halfway River crossing is situated inside of the Landslide-Generated Wave Impact Line. The potential for landslide generated waves has been considered in determining the proposed realigned highway embankment elevation, bridge elevation, and bridge design parameters. The proposed highway and bridge designs at Halfway River have been reviewed by the Ministry of Transportation and Infrastructure and satisfy provincial design codes and safety guidelines.

Some existing segments of Highway No. 29 are currently situated on marginally stable slopes inside the Stability Impact Line. Each of these segments has been reviewed by the Ministry of Transportation and Infrastructure. The potential changes to the stability of these highway segments as a result of the reservoir would be small and a proposed approach to ongoing highway monitoring and maintenance has been established in collaboration with the Ministry of Transportation and Infrastructure to manage the residual risks.

One IR (gov_0010-616) asked if the presence of the reservoir would result in an adverse effect on global stability for the section of Highway No. 29 located within the Stability Impact Line between Halfway Hill and Watson Hill, and if so, what measures would be put in place to mitigate these effects. The results of seepage and slope stability analyses completed for the Project (Volume 2 Appendix B

Part 2 Preliminary Reservoir Impact Lines Sections 8 and 9) suggest that the existing global factor of safety along this section of Highway No. 29 is relatively high and that impoundment and operation of the reservoir would not have a large effect on slope stability at the location of the highway. However, this section of highway is subject to ongoing local instability of Glacial Lake Peace sediments that are located well above the proposed reservoir level. Monitoring of groundwater levels and slope stability would be carried out by BC Hydro and MOTI. If slope movements (regardless of cause) necessitate remedial action, options would likely include upslope drainage improvements, construction of retaining structures or toe berms, and/or adjustment of the highway centreline location.

A reservoir shoreline monitoring and management plan would be developed for the Project. As part of this plan, BC Hydro would regularly monitor of shoreline conditions, including groundwater levels, shoreline erosion rates and landslide activity. The results of this monitoring would be used to facilitate a detailed review and update of the impact lines following approximately 5 years of reservoir operations.

3.4.4 On the Reservoir

EIS Section 26.4.8 describes the navigational restrictions that would be in place due to anticipated shoreline erosion and landslide potential. In the first year following reservoir impoundment, specific areas that would be restricted include the mouths of Lynx Creek, Farrell Creek and the Halfway River. After the second year, reservoir navigation access is anticipated in most areas, with the exception of areas downstream of Wilder Creek and at the Moberly River embayment which may be restricted slightly longer due to anticipated ongoing debris management activities in these areas.

3.5 Reservoir Infilling

As described in EIS Section 11.8.5:

- The estimated annual input of fine sediment to the reservoir due to shoreline erosion is 1.1 million t/year in Year 1 of reservoir operation, dropping to 0.55 million t/year by Year 10 as beach platforms develop, reducing the energy of wave impact
- In the first 10 years of reservoir life, the average annual outflow of suspended sediment at the dam site is estimated to be about 30% of the total sediment input into the reservoir from both tributary and shoreline sources. The sediment outflow would comprise 98% clay and 2% silt on average.
- The remainder of the tributary and shoreline sediment is predicted to be deposited within the reservoir. The estimated thickness of sediment deposition in the reservoir after 10 years would be variable with more deposition near tributary confluences and highly erodible shoreline segments. It is estimated that the deposition thicknesses would range from about 0.1 m in the main reservoir to over 2 m at the Halfway confluence and adjacent to some shoreline segments.
- After 50 years of operation, the estimated thickness of reservoir sediment deposition under average sediment load conditions would range from about 0.3 to about 0.5 m in the main reservoir and 3 m to 4 m near some shoreline sections. In the Halfway River embayment, a deposition thickness of 3 m to 4 m is expected throughout the embayment, with up to 8 m near some shoreline segments.
- The initial volume of the entire reservoir is 2,310 million m^3. The modelled sediment deposition volume for the entire reservoir after the first decade is approximately 12 million m^3, or 0.5% of the initial reservoir volume. The modelled deposition volume for the entire reservoir after 50 years is approximately 58 million m^3, or 2.5% of the initial reservoir volume, assuming average sediment input conditions. For the 5th and 95th percentile sediment input conditions for Halfway River, the

50-year deposition volumes in the reservoir would be 46 million m^3 (2.0% of reservoir volume) and 68 million m^3 (3.0% of reservoir volume), respectively.

- The initial water volume of the Halfway River embayment at the start of reservoir operations would be approximately 90 million m^3. The sediment deposition volume after the first decade is estimated at 4 million m^3, or less than 5% of the initial embayment water volume. Depending on the sediment input rate, it is estimated that the Halfway embayment would infill by 22% to 35% after 50 years and would infill completely in 150 to 220 years. Once the embayment had infilled, the Halfway River would likely flow in a gravel-bed channel with a meandering or braided pattern within a valley bottom floodplain, and would have a delta slope extending out into the main body of the reservoir.

3.6 Monitoring

In EIS Volume 2, Section 11.2.3.14 BC Hydro commits to regular monitoring of shoreline conditions, including groundwater levels, shoreline erosion rates and landslide activity.

An operational monitoring plan would be developed for the Project to provide regular monitoring of shoreline conditions, including groundwater levels, shoreline erosion rates and landslide activity. The results of this monitoring would be used to facilitate a review and update of the impact lines following approximately 5 years of reservoir operations.

It is BC Hydro's intent that instrumentation monitoring and visual inspection program would be integrated into BC Hydro’s system-wide operational surveillance and dam safety programs which would continue as long as the dam is in operation. The long-term frequency of instrumentation monitoring and visual inspection should be adjusted based on the nature of the changes in instrumentation data and shoreline conditions that are observed.

These monitoring programs, in conjunction with application of BC Hydro's proposed guidelines for land use on private property within the impact lines, will manage landslide risk to public safety in a way that is consistent with how landslides are managed in other parts of British Columbia.

Several IRs requested the EIS address the uncertainty in the impact lines and the recommendation to review and potentially update them in the future.

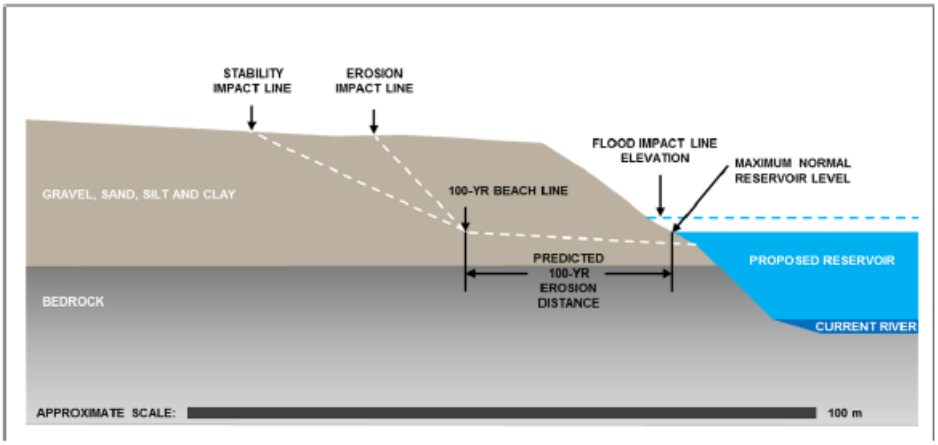
Parameter uncertainty is addressed in Volume 2 Appendix B Part 2. Where areas of uncertainty were identified, conservative assumptions were used in the analyses to develop the preliminary impact lines. Therefore, it is expected that the influence of the reservoir on flooding, erosion, landslides and landslide-generated waves will fall inside the preliminary impact lines.

One IR (gov_0010-093) requested clarification of the extent and scope of the geotechnical investigations that are still to be completed.

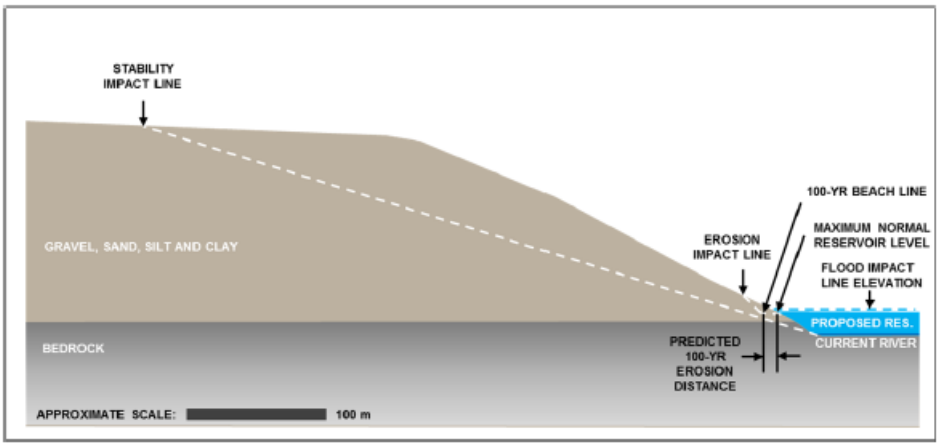
Additional geotechnical investigations are proposed to support the final designs for the Project, should it proceed. Within the reservoir area, these additional investigations would include, but are not necessarily limited to:

- Additional geotechnical drilling, surface mapping, bathymetric surveys and slope stability analyses to support optimization of the berm and slope flattening designs for the Hudson’s Hope shoreline protection

- Additional geotechnical drilling, test pitting, surface mapping and slope stability analyses, and wave erosion protection design to support final design of proposed Highway No. 29 realignment segments
- Expanding the geotechnical and slope stability monitoring program at locations where highway infrastructure is located on high bank slopes within the preliminary reservoir impact lines, and at other landslide areas including the Cache Creek Slide and near the confluence of the Peace and Moberly River
- Additional surface mapping and slope stability analyses at locations where property owners have requested that a determination be made if it is safe for residential structures to remain within the reservoir impact lines for a period of time



Schematic illustration of the Flood, Erosion and Stability Impact Lines for a typical low bank slope (<75 metres high).



Schematic illustration of the Flood, Erosion and Stability Impact Lines for a typical high bank slope (>75 metres high).

Related Comments / Information Requests:

This technical memo provides information related to the following Information Requests:

form_0004-021	gov_0002-004	gov_0010-079	gov_0010-080	gov_0010-084
gov_0010-085	gov_0010-086	gov_0010-087	gov_0010-088	gov_0010-089
gov_0010-091	gov_0010-093	gov_0010-096	gov_0010-097	gov_0010-606
gov_0010-098	gov_0010-099	gov_0010-105	gov_0010-114	gov_0010-611
gov_0010-607	gov_0010-608	gov_0010-609	gov_0010-610	gov_0010-616
gov_0010-612	gov_0010-613	gov_0010-614	gov_0010-615	gov_0010-665
gov_0010-618	gov_0010-625	gov_0010-662	gov_0010-663	gov_0014-025
gov_0010-666	gov_0010-899	gov_0014-023	gov_0014-024	pub_0062-001
pub_0004-001	pub_0011-001	pub_0014-001	pub_0044-001	pub_0223-002
pub_0115-001	pub_0194-001	pub_0202-001	pub_0218-001	pub_0250-003
pub_0225-001	pub_0229-001	pub_0241-003	pub_0242-001	pub_0448-ag-071
pub_0257-001	pub_0438-021	pub_0448-ag-029	pub_0448-ag-070	pub_0519-001
pub_0448-ag-126	pub_0448-ag-127	pub_0448-ag-128	pub_0457-005	pub_0550-001
pub_0535-011	pub_0536-001	pub_0545-002	pub_0547-001	pub_0407-001
pub_0563-001	pub_0565-001	pub_0592-001	pub_0593-001	pub_0605-028
pub_0599-001	pub_0601-003	pub_0601-008	pub_0601-009	ab_0001-205
pub_0861-001	pub_0989-001	pub_1018-001	pub_1021-001	ab_0003-040
ab_0001-578	ab_0003-034	ab_0003-037	ab_0003-038	ab_0003-040
ab_0007-002	Response to Wilderness Committee Standard Letters			