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Site C Downstream Flow and Ice Monitoring and Analysis Plan

Revision 2

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Prepared for the Impact Assessment Agency of Canada

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Revisions

Rev	Date	Description
0	February 13, 2023	Draft regulatory submission to Impact Assessment Agency of Canada
1	May 8, 2023	Final regulatory submission to Impact Assessment Agency of Canada
2	January 3, 2024	Revised to reflect updated reporting schedule, based on reservoir filling in Fall 2024

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1 Introduction

1.1 Objective

The Site C Clean Energy Project (the Project) will be the third dam and generating station on the Peace River in northeast BC. The Project will provide 1,100 megawatts (MW) of capacity and about 5,100 gigawatt hours of energy each year to the province's integrated electricity system. Appendix A shows the location of the Project.

The Project is authorized under the Site C Environmental Assessment Certificate (EAC) and federal Decision Statement (FDS), which were issued in 2014 respectively by the provincial Ministers of Environment and of Forests, Lands and Natural Resource Operations and the federal Minister of Environment.[1] Construction and operation of the Project must be undertaken in accordance with the conditions set out in the EAC and FDS.

The purpose of the Downstream Flow and Ice Monitoring and Analysis Plan ("the Plan") is to fulfil Condition 6 of the FDS which requires BC Hydro to "analyze the accuracy of predictions made during the environmental assessment on the effects of the Designated Project on downstream water flow, water level and ice (e.g., freeze-up levels, freeze-up and break-up dates and ice thickness)". Specifically, Condition 6 requires BC Hydro to undertake an analysis that includes:

> 6.2.1. assembly of the necessary water flow, water levels and ice monitoring data from existing monitoring stations; and
>
> 6.2.2. a comparison of the monitoring data with the predictions made during the environmental assessment, including predicted effects from climate change, to assess the accuracy of those predictions.

This Plan has been developed in consultation with Athabasca Chipewyan First Nation (ACFN) and Mikisew Cree First Nation (MCFN) in accordance with the Site C Settlement Agreement BC Hydro holds with these Nations. As required by the FDS Condition 6 and in consultation with ACFN and MCFN, BC Hydro submitted a draft plan to the Impact Assessment Agency of Canada, ACFN and MCFN at least 90 days prior to reservoir filling. This final plan is being submitted at least 30 days prior to reservoir filling. Future potential updates to the Plan will be completed in accordance with the requirements set out in Section 6.0 of the Plan - Reporting and Plan Updates.

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[1] Now the provincial Ministry of Environment and Climate Change Strategy and Ministry of Forests and federal Ministry of Environment and Climate Change Canada.

1.2 Consultation

BC Hydro undertook consultation on the potential effects of the Project on downstream flow during operation of the Site C Project between 2007 and 2014 during the planning and environmental assessment stages of the Project. During this period, BC Hydro received input from Indigenous Nations, including ACFN and MCFN, on the potential effects of the Project on downstream water flow and water levels as far as the Peace Athabasca Delta (PAD). ACFN and MCFN concerns included but were not limited to potential effects of the Project on downstream ice flow, ice formation, ice jamming and breakups, ice bridges and ice flow, as well as related potential impacts of flow changes on human transportation, navigation, and fish and wildlife habitat (e.g., water quality, animal migration, wintering habitat availability).[2] ACFN and MCFN particularly expressed concern regarding the potential impacts of the Project on the drying of the PAD.

The Environmental Impact Statement (EIS) found that the downstream effects of the Project do not extend beyond the Town of Peace River and the Independent Joint Review Panel constituted as part of the environmental assessment concluded "there would be no effects from the Project on any aspect of the environment in the Peace Athabasca Delta".[3] While the EAC and FDS do not require BC Hydro to implement any mitigation or downstream monitoring programs within the PAD, BC Hydro is engaging with provincial and federal agencies and ACFN,MCFN and other Indigenous Nations on issues related to the PAD through Canada's Wood Buffalo National Park World Heritage Site Action Plan and related Environmental Flow Hydrology Working Group, the development of the Strategic Flow Release Protocol , and the PAD Breakup Monitoring Operations (PAD-BMO) group.

In accordance with the terms of the Site C Settlement Agreement, BC Hydro's consultation with ACFN and MCFN specific to the Downstream Flow and Ice Monitoring and Analysis Plan commenced in 2022. BC Hydro met with ACFN and MCFN respectively on October 31, 2022 and November 25, 2022 to develop an approach to on the Plan. On February 13, 2023, BC Hydro shared a draft Plan with ACFN and MCFN for review, receiving comments from the Nations on March 15, 2023 and March 21, 2023 respectively. This revision of the Plan reflects the comments received from the Nations, and includes:

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[2] A summary of ACFN and MCFN concerns provided during the environmental assessment is provided in Environmental Impact Statement (EIS) Volume 1, Section 9, Appendix H Aboriginal Information Distribution and Consultation Supporting Documentation; Volume 3, Section 19 Current Use of Lands and Resources for Traditional Purposes; and Volume 5, Appendix A1 and A18 Supporting Information for ACFN and MCFN respectively.

[3] Joint Review Panel Report for Site C, May 2014, p. 42 located at: https://www.ceaa-acee.gc.ca/050/documents/p63919/99173E.pdf

- Information from the EIS provided by ACFN and MCFN regarding traditional use of downstream areas of the Project, as well as a summary of concerns regarding the potential effect of the Project on downstream flows, downstream ice flow, ice formation, ice jamming and breakups, ice bridges and ice flow
- BC Hydro's commitment to add additional monitoring in areas identified as important to Indigenous Nations in the EIS, such as documenting the timing of freeze-up and breakup at Garden River
- BC Hydro's commitment to further engage on community-based monitoring to support Indigenous interests

BC Hydro is committed to ongoing engagement with ACFN and MCFN on the Plan and will consider comments and feedback regarding potential future updates to the Plan.

2 Plan Scope

The scope of the Downstream Flow and Ice Monitoring and Analysis Plan has been defined by the requirements of FDS Condition 6 with additional monitoring incorporated to respond to input from MCFN and ACFN in accordance with BC Hydro and ACFN/MCFN Site C Settlement Agreement. The Scope of the Plan is focused on surface water and downstream ice regimes. Related monitoring programs are described in the Fish and Aquatic Habitat Monitoring and Follow-Up Program[4] (including the Peace River Riparian Vegetation Monitoring Program, Peace River Water and Sediment Quality Monitoring Program, Site C Fish Stranding Monitoring Program, Site C Small Fish Species Translocation Monitoring Program, Peace River Water Level Fluctuation Monitoring Program) and the Vegetation and Wildlife Mitigation and Monitoring Plan.[5]

The geographic scope of the Downstream Flow and Ice Monitoring and Analysis Plan extends from the Site C dam to Peace Point, Alberta (AB). The Plan describes:

- EIS surface water and downstream ice regime studies – namely Volume 2, Appendix D (Surface Water Regime) and Volume 2, Appendix G (Downstream Ice Regime). These studies predicted how the Project would result in relative changes to the surface water and downstream ice regime

[4] Available at: https://www.sitecproject.com/sites/default/files/Fisheries-and-Aquatic-Habitat-Monitoring-and-Follow-up-Program.pdf
[5] Available at: https://www.sitecproject.com/sites/default/files/Veg_and_Wildlife_Mit_and_Mon_Plan.pdf

- Future data collection on downstream water flow, water levels and ice monitoring from existing monitoring sites as well as sites of Indigenous cultural importance or interest
- Method of future data analysis, comparing monitoring data with information described in the EIS, including predicted effects on downstream flow, water levels and ice from climate change
- Reporting and information sharing with regulators, ACFN and MCFN and other Indigenous Nations
- BC Hydro's commitment to engage with ACFN and MCFN on community-based monitoring

Updates to the Plan scope, including additional monitoring sites or information on the community-based monitoring program, may be made in future revisions.

3 EIS Predictions Regarding Project Effects on Downstream Flows and the Downstream Ice Regime

This section describes the results from the EIS technical studies on the downstream open water and ice regimes as well as a summary of ACFN and MCFN inputs into the EIS. This information will help inform the monitoring and analysis needed to assess the accuracy of downstream water flow, water level and ice that was described in the EIS. A map of current and proposed future sampling locations – based on input from ACFN and MCFN -- is attached in Appendix A.

Note that the EIS technical studies were based on historical weather sequences. The EIS studies did not therefore provide absolute "predictions" under future Site C operations but instead predicted "relative" changes due to Site C. Under actual Site C operation, future weather sequences are sure to be different, including from the effects of climate change. Therefore, potential differences between the predicted results in the EIS and those monitored under Site C operations do not mean there were errors in the EIS modelling or analysis. These differences will need to be accounted for in the analysis of the data and may require some modelling to parse out the effects of Site C and climate.

3.1 ACFN and MCFN – EIS Assessment

ACFN and MCFN comments, issues, and concerns regarding the potential effects of the Project downstream are summarized in EIS:

- Volume 1, Section 9, Appendix H, Aboriginal Information, Distribution and Consultation Supporting Documentation
- Volume 3 Section 19 and Appendix F Current Use of Lands and Resources for Traditional Purposes Summary, and
- Volume 5, Appendix A1 (ACFN) and Appendix A18 (MCFN) Supporting documentation including consultation summary, Aboriginal Land and Resource Summary, Aboriginal Interests, and Information Requirements

Concerns provided by ACFN and MCFN in the EIS as related to FDS Condition 6 include the need to:

- Monitor potential downstream impacts of the Project on water flow and water levels in the Peace River and other locations
- Monitor potential downstream impacts of the Project on ice flow, ice formation, ice break-up and ice bridges at Shaftesbury, Dunvegan and Carcajou. (BC Hydro notes that there is no longer a bridge at Shaftesbury and that Dunvegan has a steel bridge)
- Consider climate change in the monitoring and analysis plan

The EIS includes ACFN and MCFN concerns regarding the potential effects of the Project on the PAD or areas beyond Peace Point, AB, including along the Peace River at Rocky Point, Lake Athabasca, Lake Claire, Lake Mamawi, Quatre Fourche, Coupe River, Fort Smith, and Revillon Coupe channel. As indicated previously, these areas are beyond the scope of the Downstream Flow and Ice Monitoring and Analysis Plan. BC Hydro continues to engage on the PAD through Canada's Wood Buffalo National World Heritage Site Action Plan and related sub-groups.

As part of the EIS, ACFN and MCFN also submitted a joint Desktop Knowledge and Use Report. In this public report, ACFN and MCFN identified the following locations (downstream from the dam site to Peace Point) as having subsistence, transportation, habitation, environmental, and/or cultural/spiritual importance:

- MCFN Reserve Lands at Peace Point
- ACFN/MCFN Permanent habitation areas at Peace Point
- Upstream of Peace Point – Peace River sandbars, rocks and navigational hazards
- Garden River, Permanent habitation along the Peace River near the western boundary of Wood Buffalo National Park

These locations have been incorporated into the downstream monitoring flow and ice monitoring and analysis plan.

3.2 Technical Studies - EIS Volume 2 Appendix D (Surface Water Regime Technical Memo)

The Surface Water Regime analysis in the EIS was undertaken in two parts. Part 1 consisted of a Site C operations study to obtain a 60-year hourly flow release record sequence from Site C. This study included modelling of the entire BC Hydro system, including energy import/export to neighbouring systems in the United States and Alberta. The study summarised these results to get a sense of the frequency distribution (i.e., how often certain flow volumes would occur) from future Site C flow releases. Part 2 of the analysis used the hourly flow information from Part 1 and hydraulically routed these flows downstream to understand how water level and flow variations would change due to the Project. Part 2 of the analysis included the effects of flow attenuation and tributary inflows.

3.2.1 Part 1 - Site C Operations Study

This study provided simulated hourly reservoir releases to the Peace River for the two operating scenarios, with and without Site C, over a 60-year inflow sequence. Figure 3-1 shows the frequency distribution of flow releases from this data on an annual and seasonal basis that includes Site C operations. The “probability of exceedance” shown on the figure indicates the likelihood a given flow would be exceeded during actual operations. For example, using the annual curve (purple), a flow release out of Site C would be greater than 1000 m^3/s about 63% of the time. Once a sufficient number of years pass with Site C in place, measured flow releases can be summarised and compared to the EIS study results in a similar figure.

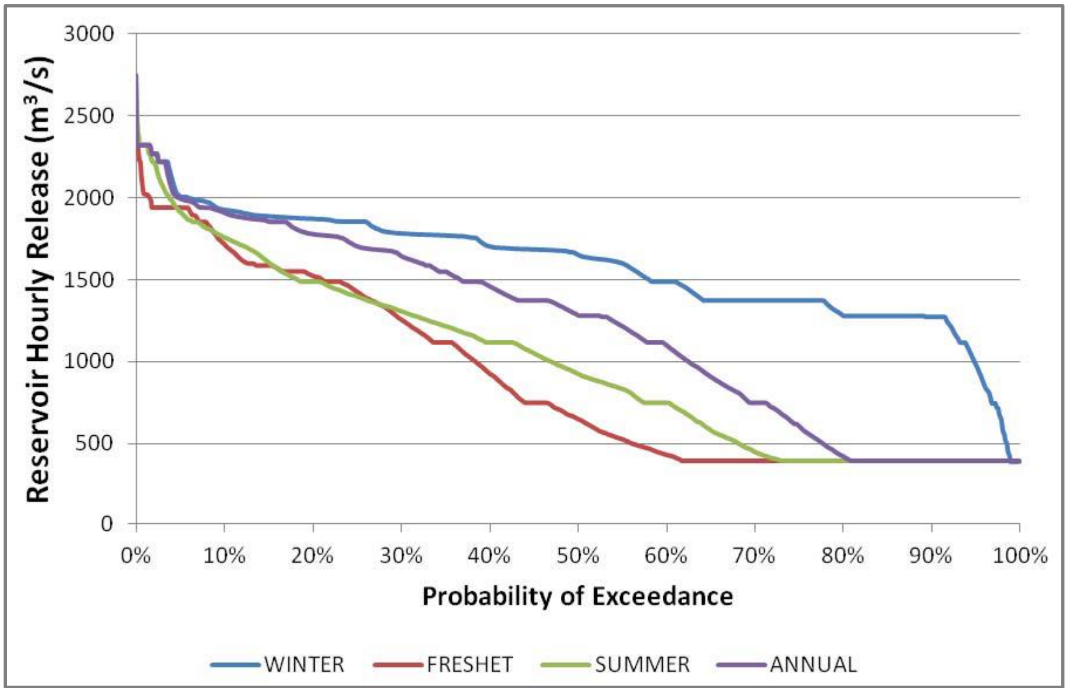

Figure 3-1: Annual and Seasonal Site C Reservoir Release Duration Curve (60-year GOM[6] Model) – Source: Site C EIS Appendix D.

Another portion of this study looked at the frequency, duration, and magnitude of spills. The study found that spills from the Site C dam would occur five times over the 60-year simulation, which means that in any given year, there would be an 8% chance that a spill could occur. The magnitude and duration of these spills are shown in Figure 3-2. It is worth noting that these spills are likely slightly underrepresented as the GOM model used for this analysis assumed a 1-month perfect insight of inflows.

[6] Generalized Optimization Model

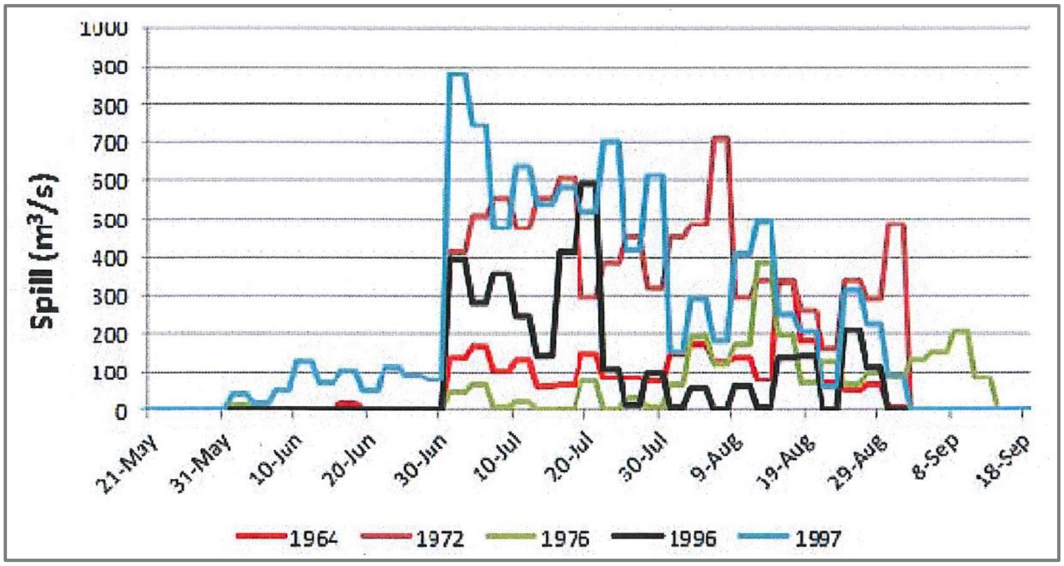

Figure 3-2: Site C spills modelled using GOM (re-operated to limit inflow foresight to one month) – Source: Site C EIS Appendix D.

3.2.2 Part 2 - Downstream Flow Modelling

Hydraulic flow routing using the MIKE 11 model (1D hydraulic flow modelling) was conducted all the way downstream to Peace Point, Alberta in this study. The purpose of this study was to assess the effects of Site C on downstream flows and water levels through relative comparisons of operational scenarios with Site C in place (Case B) and without Site C (Case A). The model output from Case A and B were compared as:

- Time series hydrographs
- Flow and water duration curves
- Hourly changes in water levels
- Daily water level range
- Hourly wetted width
- Hourly average cross-sectional velocity

In addition to the 1D hydraulic flow modelling, two-dimensional (2D) modelling was carried out for four specific side-channel areas downstream of the Site C dam thought to provide valuable fish habitat. The follow-up monitoring program for this 2D modelling is described separately in the Fisheries and Aquatic Habitat Monitoring and Follow-up Program.[7]

3.2.2.1 Time series hydrographs

In the EIS, hydraulic model results were compiled as hourly time series plots of discharge and water level with and without Site C for the Site C tailrace, Taylor, Alces, Town of Peace River and Peace Point. The EIS described that with Site C:

- Operational changes would be noticed 10 to 12 hours earlier, on average, at downstream locations compared to without Site C
- Flow oscillations would be greater in magnitude but attenuate with further distance downstream compared to without Site C (See Section 3.2.2.3 and 3.2.2.4).

3.2.2.2 Flow and water level duration curves

In the EIS, water level duration curves were presented for the 1964-1974 period with and without Site C for the Site C tailrace, Taylor, Alces near the BC/AB border, Dunvegan, Town of Peace River, Fort Vermilion and Peace Point. The largest differences in these curves occurred at the Site C tailrace and diminished further downstream. The plots were divided into Full Year, Freshet Period, High Operations Period and Low Flow Period. The curves are presented in Sub-Appendix D of Site C EIS in Volume 2 Appendices D. Two examples of these curves are shown in Figures 3-3 and 3-4. The analysis did not consider ice effects on water levels; therefore, measured water levels for only the open water season will be compared to model results.

[7] This modelling was conducted to analyze the influence of the Project on water levels and wetted areas within the channels. The four areas analyzed include an 18 km reach between the Site C dam location and the Highway 97 bridge at Taylor as well as 7 to 13 km long reaches at Pallings Flat, Raspberry Island, and Many Islands in Alberta. The Fisheries and Aquatic Habitat Monitoring and Follow-up Program provides additional information and is available on the Site C Project website at: https://www.sitecproject.com/sites/default/files/Fisheries-and-Aquatic-Habitat-Monitoring-and-Follow-up-Program.pdf

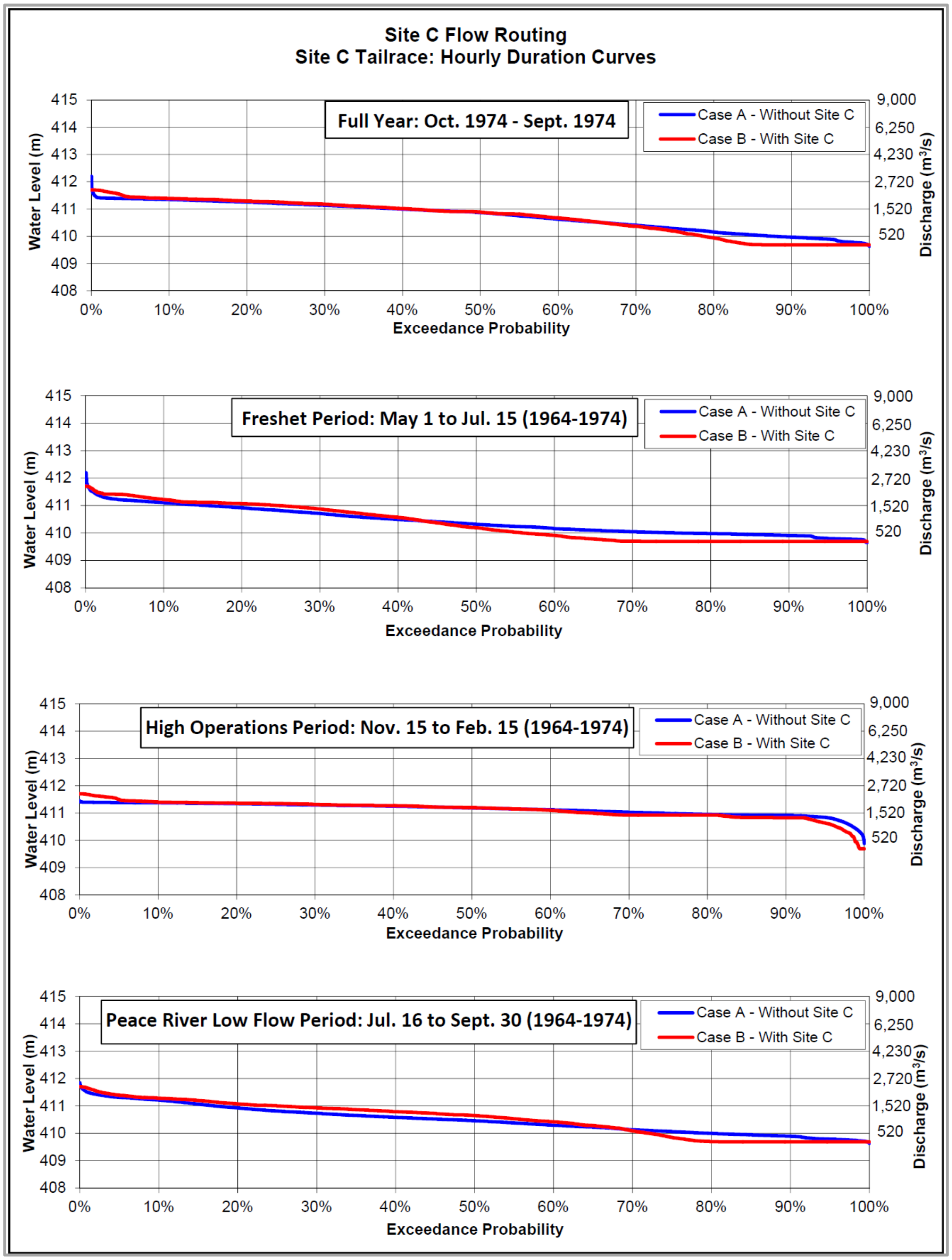

Figure 3-3: Water level and flow duration curves for with and without Site C for the Site C tailrace – Source: Site C EIS Appendix D, Sub-Appendix D.

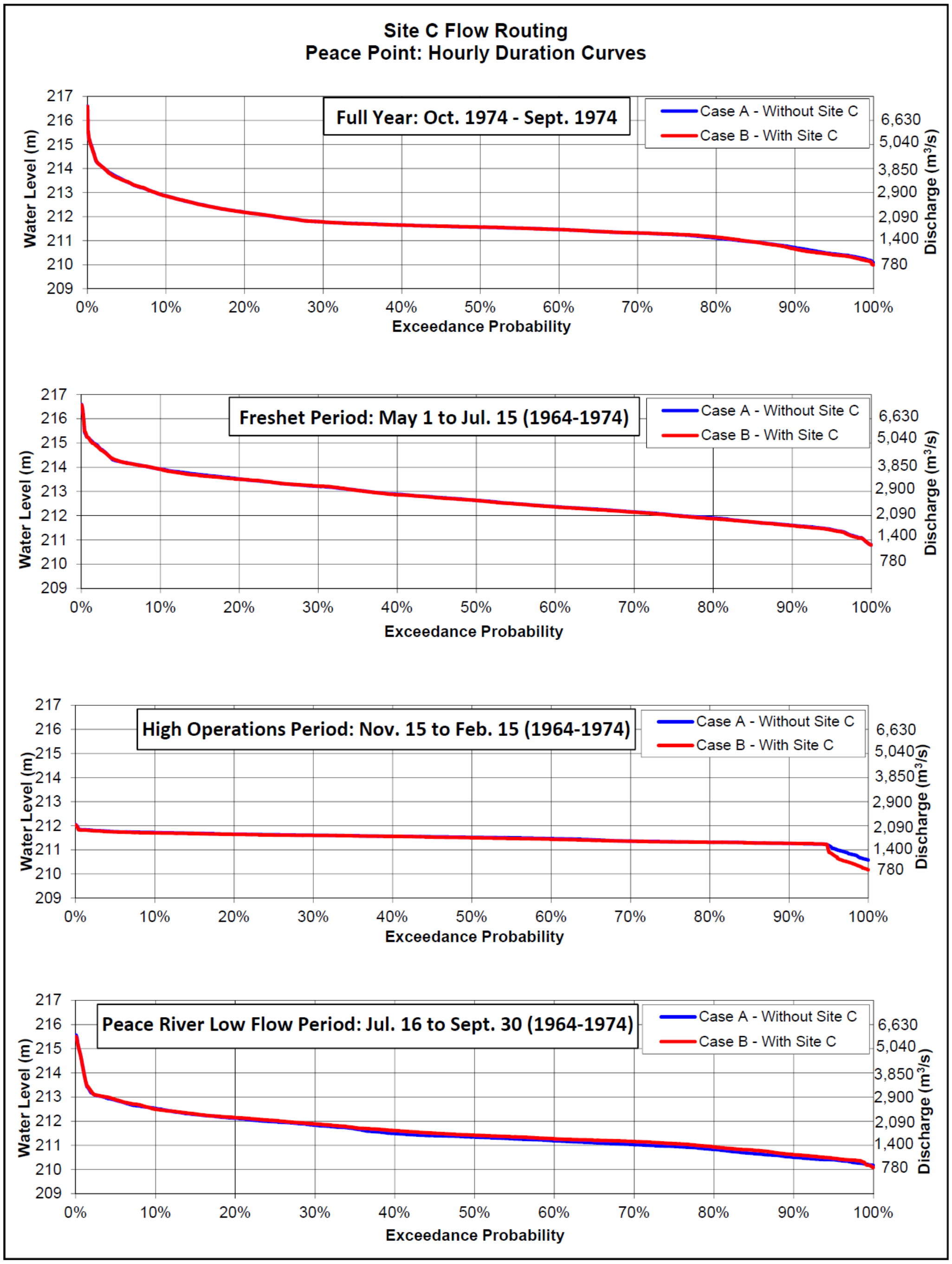

Figure 3-4: Water level and flow duration curves with and without Site C for Peace Point – Source: Site C EIS Appendix D, Sub-Appendix D.

3.2.2.3 Hourly changes in water levels

In the EIS, hourly changes in water level curves were presented for the 1964-1974 period with and without Site C for the Site C tailrace, Taylor, Alces near the BC/AB border, Dunvegan, Town of Peace River, Fort Vermilion and Peace Point. The largest differences in these curves occurred at the Site C tailrace and diminish further downstream. The curves are presented in Sub-Appendix E of Site C EIS in Volume 2 Appendix D. Two examples of these curves are shown in Figures 3-5 and 3-6.

The analysis did not consider ice effects on water levels, so measured water levels for only the open water season will be compared to model results.

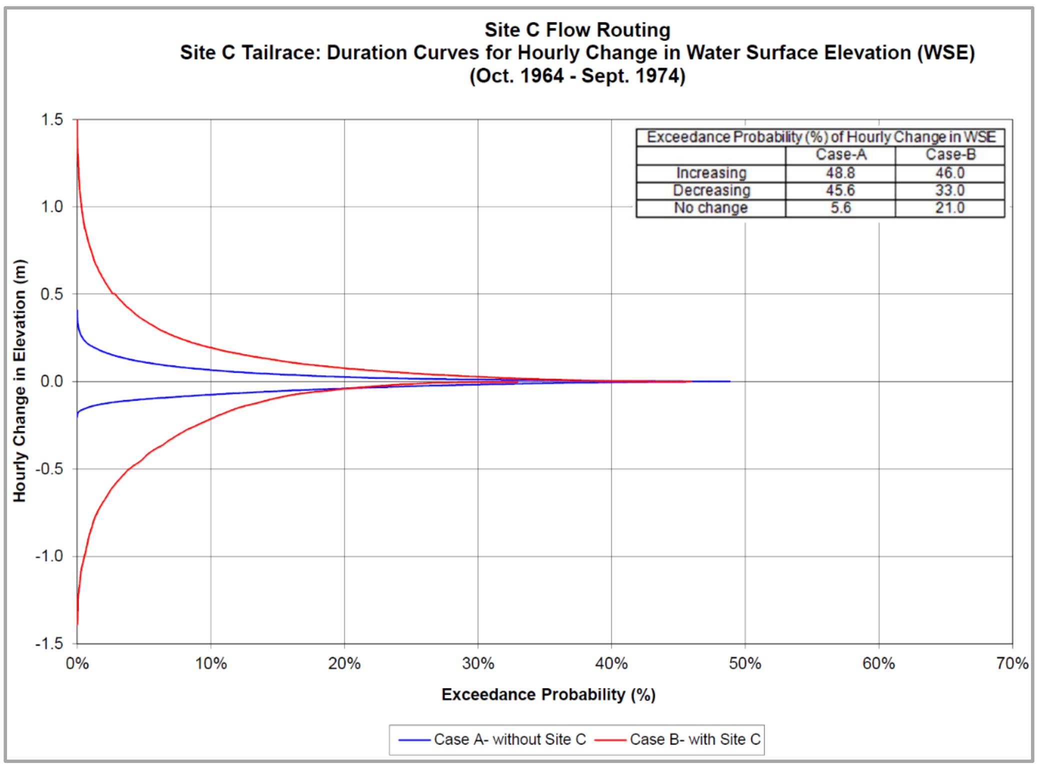

Figure 3-5: Hourly water level change curves with and without Site C for the Site C tailrace Source: Site C EIS Appendix D, Sub-Appendix E.

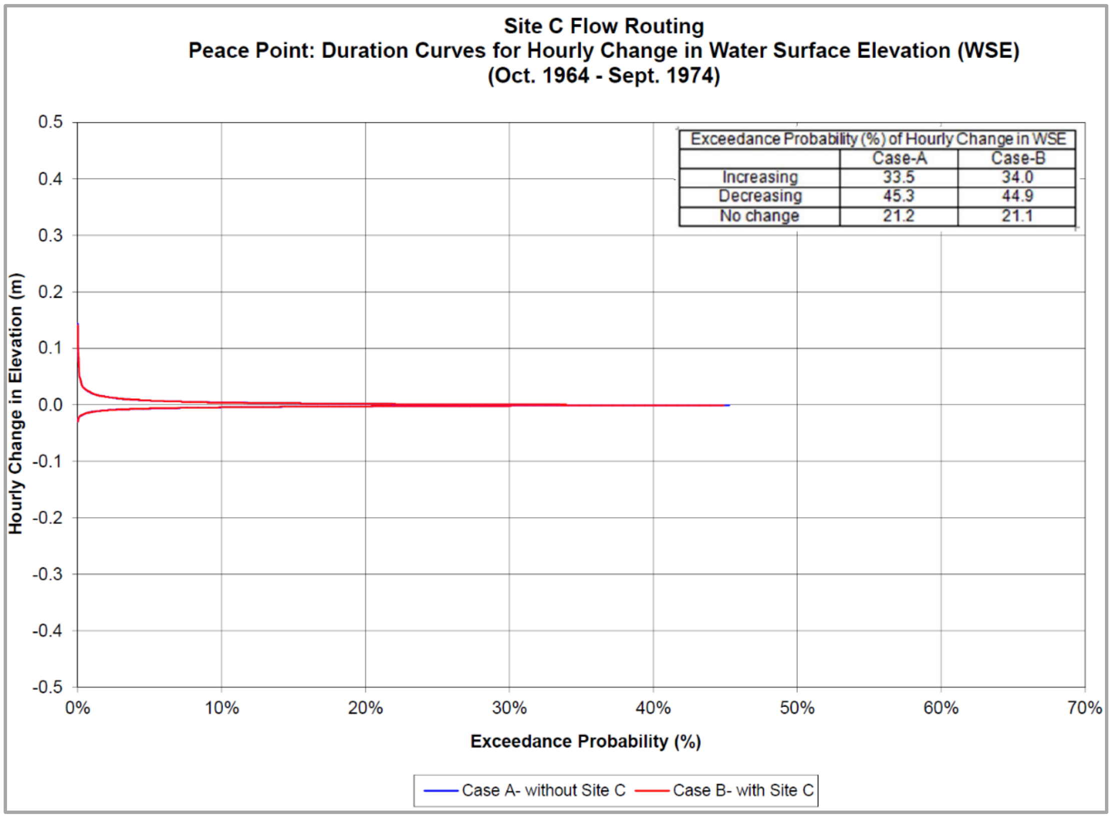

Figure 3-6: Hourly water level change curves with and without Site C for Peace Point
Source: Site C EIS Appendix D, Sub-Appendix E.

3.2.2.4 Daily average water level range

In the EIS, the average daily range of water level (i.e., the average difference between the maximum and minimum water level over each day) in the 10-year period (1964-1974) was summarized as shown Table 3-1 below. Estimates are shown for the open water periods for case A and B for Site C Tailrace, Taylor, Town of Peace River and Peace Point (Source Table 3 in Site C EIS Appendix D). The average daily range of water level was shown to be higher in case B than case A by approximately 0.5 m at Site C tailrace. Results suggested no difference at Peace Point. The analysis did not consider ice effects on water levels; therefore, measured water levels for only the open water season will be compared to model results.

Table 3-1: Daily Range of Water Levels for regulated simulated years (1964-1974) without Site C (Case A) and with Site C (Case B) for various downstream locations. – Source: Site C EIS Appendix D, Section 4.4, Table 3

Period	**Average Daily Range of Water Level (m)**							
	Site C Tailrace		**Taylor**		**Town of Peace River**		**Peace Point**	
	Case A	**Case B**	**Case A**	**Case B**	**Case A**	**Case B**	**Case A**	**Case B**
Typical Freshet Operations	0.4	1.2	0.4	0.8	0.2	0.2	0.1	0.1
Typical Summer Operations	0.6	1.1	0.5	0.9	0.2	0.2	0.1	0.1

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3.2.2.5 Hourly wetted width and average cross-sectional velocity

Hourly wetted width and average cross-sectional velocity curves with and without Site C for the Site C Tailrace, Taylor, Alces, Town of Peace River and Peace Point are presented in Site C EIS Appendix D, sub-Appendices F and G. The results were based on the hourly water levels discussed in Section 3.2.2.2 and followed the same trends with the largest differences at the Site C tailrace and diminishing effects down to Peace Point.

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3.3 Site C EIS Volume 2 Appendix G (Downstream Ice Regime Technical Data Report) – Relative Changes

3.3.1 Maximum upstream extent of ice cover

The study simulated 16 winters that represented the range of variability of winter severity at the time of the EIS study (winters 1995-1996 to 2010-2011). Figure 3-7 reproduced here from the EIS shows the maximum extent of the ice cover probabilities for pre-Site C (yellow line) and with Site C (blue line) based on these winters. The simulations show that the maximum upstream extent of the ice cover shifts downstream by about 50 km as a result of Site C.

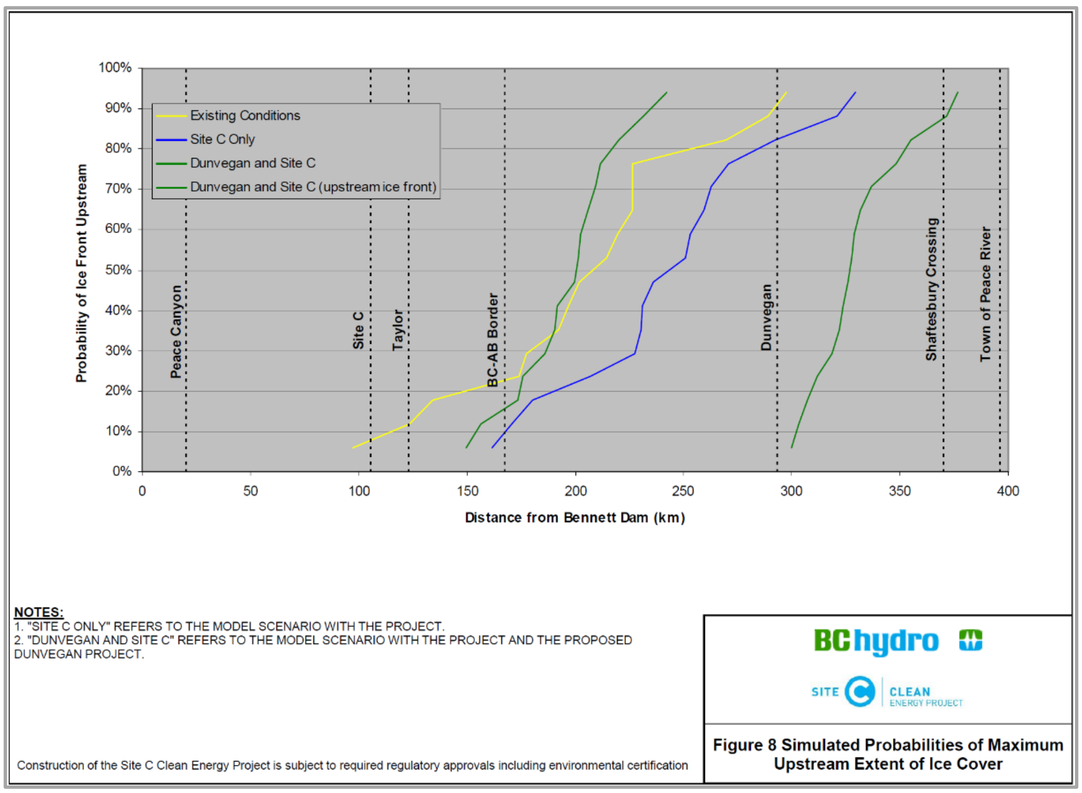


Figure 3-7: Simulated probabilities of maximum upstream extent of the ice cover based on simulated winters 1995-1996 to 2010-2011 for without Site C (yellow line) and with Site C (blue line). Green lines for Dunvegan Project can be ignored as this is no longer a viable project Source: Site C EIS Appendix G, Section 4.1, Figure 8.

The simulated years in the Site C EIS were selected to cover the observed range of winter severity based on Degree-Days of Freezing (DDF) at the Town of Peace River Airport. The minimum, average and maximum DDF were 1167, 1695 and 2436 °C – Days respectively.

3.3.2 Timing of freeze-up and break-up at the Town of Peace River

Due to the potential for flooding at freeze-up and break-up at the Town of Peace River, and the fact that a large portion of Joint Task Force guidelines[8] are based on the timing of the arrival and departure of the ice cover in the vicinity of the Town, the timing of the freeze-up and break-up of the ice cover at this location was examined in the EIS. Tables 3-2 and 3-3 shows the simulated freeze-up and break-up dates respectively at the Town of Peace River for the 16 winters simulated.

Table 3-2: Simulated dates of freeze-up at the Town of Peace River. Source: Site C EIS Appendix G, Section 4.2.

				Delay (days)	
Winter	Existing	With the Project	With the Project + Dunvegan	With the Project vs. Existing Conditions	With the Project + Dunvegan vs. Existing Conditions
1995-1996	10-Dec-95	14-Dec-95	18-Dec-95	4	8
1996-1997	21-Dec-96	24-Dec-96	24-Dec-96	3	3
1997-1998	13-Jan-98	15-Jan-98	27-Jan-98	2	14
1998-1999	6-Jan-99	09-Jan-99	18-Jan-99	3	12
1999-2000	14-Jan-00	17-Jan-00	02-Feb-00	3	19
2000-2001	10-Feb-01	13-Feb-01	18-Feb-01	3	8
2001-2002	17-Jan-02	23-Jan-02	25-Jan-02	6	8
2002-2003	29-Jan-03	4-Feb-03	16-Feb-03	6	18
2003-2004	11-Jan-04	16-Jan-04	24-Jan-04	5	13
2004-2005	5-Jan-05	7-Jan-05	12-Jan-05	2	7
2005-2006	26-Feb-06	1-Mar-06	14-Mar-06	3	16
2006-2007	13-Jan-07	14-Jan-07	22-Jan-07	1	9
2007-2008	8-Jan-08	11-Jan-08	15-Jan-08	3	7
2008-2009	27-Dec-08	29-Dec-08	2-Jan-09	2	6
2009-2010	30-Dec-09	2-Jan-10	5-Jan-10	3	6
2010-2011	26-Dec-10	29-Dec-10	4-Jan-11	3	9
Average	11-Jan	14-Jan	21-Jan	3	10

[8] Alberta - British Columbia Joint Task Force on Peace River Ice (2019). Operating procedures for influencing the freeze-up and break-up of the Peace River at the Town of Peace River, Fifth Edition, Ver. 5.1).

The simulations show that the freeze-up date is at the Town would be about 3 days earlier on average with a range of 1 to 6 days. This is much less than the natural variation of freeze-up dates that has been observed that spans about 3 months.

Table 3-3: Simulated dates of break-up at the Town of Peace River.
Source: Site C EIS Appendix G, Section 4.2.

				Delay (days)	
Winter	Existing	With the Project	With the Project + Dunvegan	With the Project vs. Existing Conditions	With the Project + Dunvegan vs. Existing Conditions
1995-1996	21-Apr-96	23-Apr-96	22-Apr-96	2	1
1996-1997	19-Apr-97	22-Apr-97	22-Apr-97	3	3
1997-1998	27-Mar-98	28-Mar-98	29-Mar-98	1	2
1998-1999	3-Apr-99	03-Apr-99	03-Apr-99	0	0
1999-2000	30-Mar-00	31-Mar-00	30-Mar-00	1	0
2000-2001	15-Mar-01	13-Mar-01	14-Mar-01	-2	-1
2001-2002	26-Apr-02	26-Apr-02	25-Apr-02	0	-1
2002-2003	15-Apr-03	13-Apr-03	13-Apr-03	-2	-2
2003-2004	3-Apr-04	4-Apr-04	4-Apr-04	1	1
2004-2005	29-Mar-05	29-Mar-05	29-Mar-05	0	0
2005-2006	5-Apr-06	3-Apr-06	31-Mar-06	-2	-5
2006-2007	22-Apr-07	22-Apr-07	20-Apr-07	0	-2
2007-2008	1-Apr-08	5-Apr-08	4-Apr-08	4	3
2008-2009	17-Apr-09	16-Apr-09	16-Apr-09	-1	-1
2009-2010	30-Mar-10	31-Mar-10	29-Mar-10	1	-1
2010-2011	20-Apr-11	19-Apr-11	19-Apr-11	-1	-1
Average	08-Apr	08-Apr	08-Apr	0	0

The simulations for break-up dates shows virtually no change and therefore no increased risk of the Smoky River breaking up into an intact Peace River ice cover due to Site C. An intact ice cover on the Peace River when the Smoky River break-up dynamically can pose an increased risk to the flooding for the Town of Peace River, AB.

3.3.3 Freeze-up and break-up water levels at the Town of Peace River

Simulations in the EIS indicate that there would be no systematic change to the freeze-up and break-up water levels due to Site C.

3.3.4 Ice control flows for the Town of Peace River

Simulations in the EIS indicate that there would be no systematic change to the duration of ice control but a slight delay of 5 days on average to the start of ice control due to Site C.

3.3.5 Ice bridge and ferry at Shaftesbury Crossing

The Site C EIS shows a detailed analysis of ice bridge and ferry operations at Shaftesbury Crossing for 16 simulated winters with and without Site C. Rather than reproduce the many tables here the reader is referred to Section 4.5 of the Site C EIS Appendix G. This analysis indicates that there would be on average 3 more days of ferry operations and 4 days less crossing days by ice bridge with the net change being one day less due to Site C. The year-to-year variability is large.

3.3.6 Ice regime changes downstream of the Town of Peace River

The EIS studies indicated that there would be no changes to the ice regime because of Site C downstream of Carcajou, which is 250 km downstream from the Town of Peace River and River and 540 km upstream of the Peace-Athabasca Delta. This is because any heat in the water released from the Site C reservoir is released to the atmosphere upstream of this point and therefore not affecting the ice generation/melting downstream of this location (Figure 3-8).

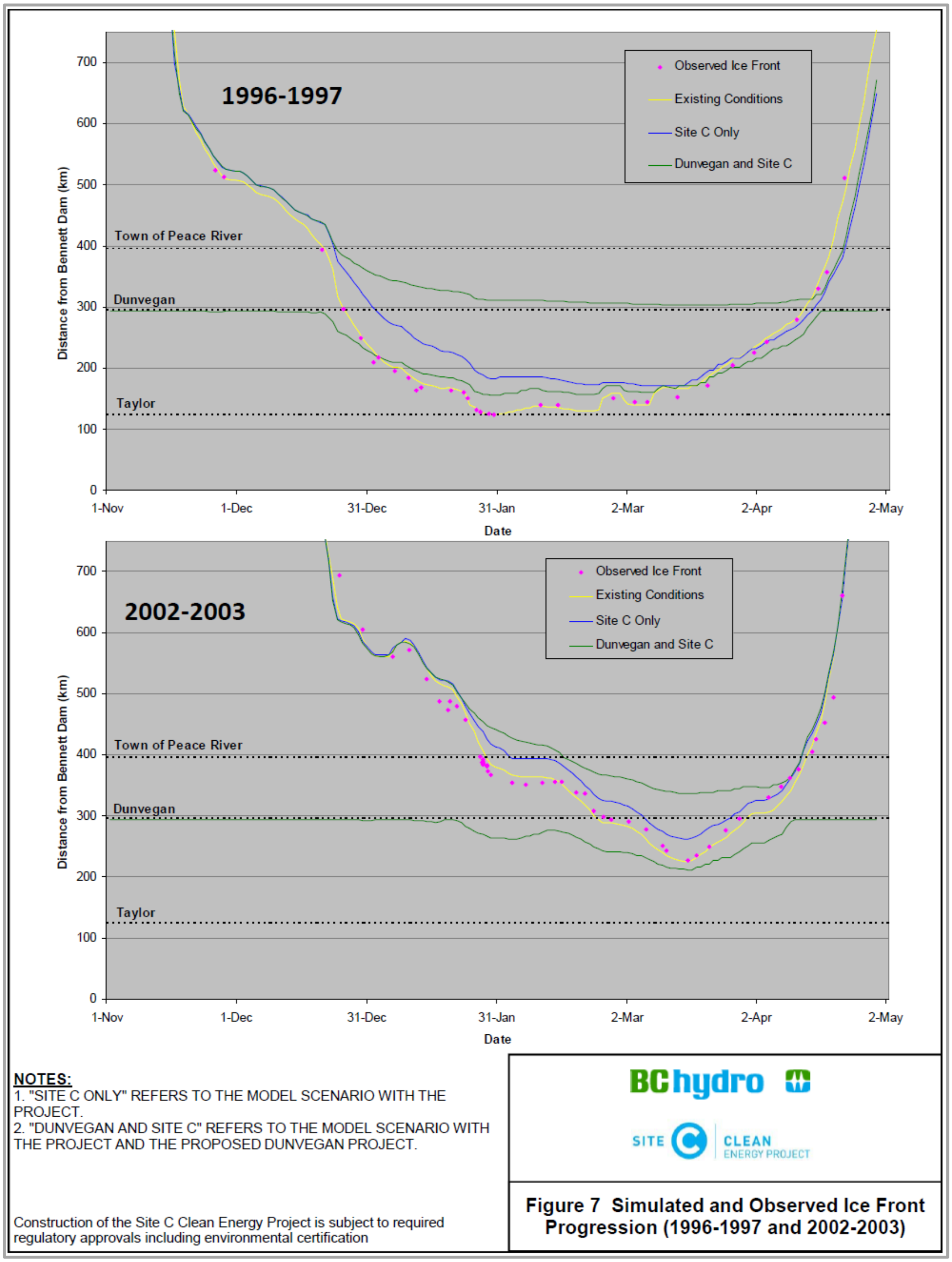


Figure 3-8: Simulated ice fronts from Site C EIS showing that the effect of Site C on the ice regime does not reach downstream past Carcajou at km 650. Source: Site C EIS Appendix G, Section 4.6.

3.3.7 Ice Thickness

The EIS study stated that the thermal ice thickness for supporting small loads would not change as a result of Site C.

3.3.8 Changes to the ice regime under a future climate

Changes to the ice regime under a future climate for the 2050s and 2080s was conducted in the EIS. The maximum ice front extent probabilities from this study for the 2050s is presented in Figure 3-9 and shows a shift of approximately 50 to 100 km further downstream.

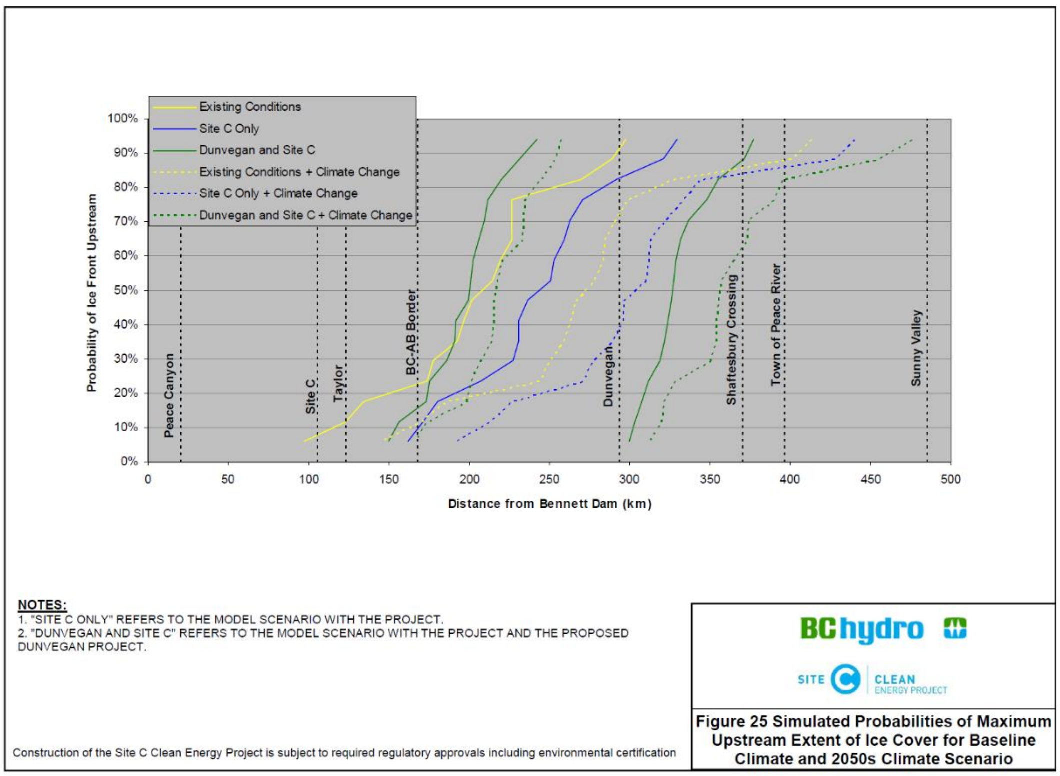


Figure 3-9: Simulated maximum upstream extent of the ice cover under 2050s and 2080s climate change scenarios analysed in the Site C EIS. Source: Site C EIS Appendix G, Section 6.

4 Site C monitoring and analysis plan to assess accuracy of relative changes in the EIS

This section describes the monitoring and analysis necessary to compare the EIS effects of the Project on downstream water flow, water level and ice with actual effects during Project operations. Table 4-2 (p. 26) describes the parameters of the monitoring and analysis.

In accordance with the requirements of Decision Statement Condition 6, BC Hydro will commence collection of data on downstream flows on an annual basis from the initiation of reservoir filling. However, the relative effects of the Project on downstream flows described in the EIS assumed that all six generating units at Site C had been installed and commissioned. Therefore, the comparative analysis of data in the monitoring plan will commence once at least five units of the generating station are operational. BC Hydro anticipates that at least five units will be operational by end of 2024 or end of 2025. However, this is subject to change.

Table 4-1 identifies monitoring and data collection locations. These locations are also shown in the Appendix A. Discharge and water level data from Water Survey of Canada (WSC) long-term stations at Taylor, Town of Peace River and Peace Point will be used to compare the actual surface water regime with the EIS estimates. Water levels measured at the Site C tailrace will also be included in future comparisons. These stations will also provide flow information on areas that AFCN and MCFN have identified in the EIS as important – namely, MCFN reserve lands at Peace Point, and permanent habitation areas at Peace Point, traditional use of the Peace River upstream of Peace Point.

BC Hydro will also collect data on Peace River freeze-up and breakup dates at locations as shown in Table 4-1. BC Hydro has added monitoring locations at Garden River and Peace Point in response to ACFN and MCFN input on these areas.

Table 4-1.Monitoring Locations and Data Collection

Data Collection/Monitoring	Location
Water levels, water flows	Site C Tailrace (WSC 07FA004)
	Taylor, BC (WSC 07FD002)
	Town of Peace River, AB (WSC 07HA001)
	Peace Point, AB (WSC 07KC001)
Ice front (freeze-up and break-up dates)	Dunvegan, AB
	Shaftesbury Crossing, AB
	Town of Peace River, AB
	Carcajou, AB
	Tompkins Landing, AB
	Fort Vermillion, AB
	Fox Lake Crossing, AB

Data Collection/Monitoring	Location
	Garden River, AB
	Peace Point, AB

5 Indigenous Community-based Monitoring

BC Hydro will work with ACFN and MCFN to develop a framework to support community-based monitoring. This framework may include, but not be limited to:

- Development of community-based monitoring plans
- Community led observation and collection of field data
- Community engagement and communications

This framework may also include other activities as agreed to by BC Hydro and ACFN and MCFN.

6 Reporting and Plan Updates

As previously noted, the relative effects of the Project on downstream flows described in the EIS assumed that all six generating units at Site C had been installed and commissioned. Until at least five units of the generating station are operation, annual reports will include downstream flow and ice data for information purposes only.

Reservoir fill is currently planned for fall 2024. The first annual report will provide downstream flow and ice data collected during the 2024-2025 water year, covering October 1, 2024 to September 30, 2025. This report will be provided by March 31, 2025. This schedule is subject to change should the schedule for reservoir filling change.

Once five generating units have been brought online (currently planned for end of 2024), annual reporting will compare monitoring data against EIS data. This analysis will include downstream flow and ice data collected during the water year. An analysis of each parameter will be performed by either graphic comparison against predicted data and/or by using the appropriate statistical test to result in three possible outcomes:

1) inside the expected range
2) outside the expected range, or
3) inconclusive (if statistically insignificant due to not enough years of data).

Additional analysis and reporting on the accuracy of results on the effects of Site C on the ice regime will occur after more years of data have been collected. These additional reports will be provided on a 5, 10 and 20 year interval with the first report submitted by March 30, 2031 or March 30, 2032 depending on schedule for generating unit operations.

Findings from the annual reports will support any necessary amendments to the collection or analysis of data if necessary. BC Hydro will share all annual and additional reports with MCFN and ACFN and other Indigenous Nations and post the reports to the Site C Project website. BC Hydro will seek feedback from ACFN and MCFN if any material changes to the Downstream Flow and Ice Monitoring and Analysis Plan are proposed.

An example of the annual Site C downstream flow and ice monitoring report is shown in Appendix B.

Table 4-2. Site C monitoring and analysis plan to assess accuracy of relative changes in the EIS.

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
3.2.1 (Water)	Figure 3-1 that shows the annual and seasonal flow duration curves from Site C based on 60-Year GOM runs.	Hourly water level data at Site C tailrace and releases from CRO Flocal.	Excel files with hourly flows. Develop flow duration curves from the observed hourly Peace above Pine gauge data (or other nearby gauge or data source) similar to Figure 3-1 and compare. Explain differences.	N/A	N/A
3.2.1 (Water)	Figure 3-2 that shows spill duration and magnitudes based on GOM runs that shows an annual probability of spills of 8%.	Record spill quantities as part of normal data acquisition	Excel files with hourly spill discharges. Compare observed spill duration, magnitudes, and frequencies to Figure 3-2 and	N/A	N/A

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
			explain differences.		
3.2.2.1 (Water)	Operational changes would be noticed 10 to 12 hours earlier, on average, at downstream locations.	Compare flows and water levels measured at Peace Canyon Dam tailrace, Site C tailrace and WSC gauges to assess travel times for operational changes.	Excel files with hourly flows and water levels (exclude ice affected water levels). Compare flow travel times between Peace Canyon Dam, Site C and WSC gauges for similar changes in pre- and post-Site C turbine releases and explain the differences. Analysis and reporting after one year of operation that includes five Site C generation units installed and	N/A	N/A

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
			available for operation. This analysis only needs to be done once since the travel times will not change for similar operational flow changes in the future.		
3.2.2.2 (Water)	Flow and water level duration curves for the Site C tailrace and several downstream locations show the largest differences between with and without Site C scenarios occur at the Site C tailrace and diminish further downstream.	Water levels at Site C tailrace and water levels and discharges at Taylor, Town of Peace River and Peace Point.	Excel files with hourly flows and water levels (exclude ice affected water levels). Compute flow and water level duration curves based on observed data at these stations and	N/A	N/A

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
			compare to EIS model results and explain differences. Also present percentile tables.		
3.2.2.3 (Water)	Hourly changes in water level curves for the Site C tailrace and several downstream locations show the largest differences would occur at the Site C tailrace and diminish further downstream.	Water levels at Site C tailrace, Taylor, Town of Peace River and Peace Point.	Excel files for hourly water levels (exclude ice affected water levels). Compute hourly changes in water level curves based on observed data at these stations and compare to EIS model results and explain differences.	N/A	N/A
3.2.2.4 (Water)	Daily average water level range at Site C tailrace and several downstream locations show that the average daily range would	Water levels at Site C tailrace, Taylor, Town of Peace River and Peace Point.	Excel files for hourly water levels (exclude ice affected water levels).	N/A	N/A

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
	be higher with Site C by approximately 0.5 m at Site C tailrace. Results suggest no difference at Peace Point		Compute daily average water level range based on observed data at these stations and compare to Site C EIS model results and explain differences.		
3.2.2.5 (Water)	Hourly wetted width and average cross-sectional velocities for Site C tailrace and downstream locations were based on the hourly water levels discussed in Section 3.1.2.2 and follow the same trends with the largest differences at the Site C tailrace and diminishing effects down to Peace Point.	These quantities are not directly measured in the field. For the Site C EIS, these quantities were computed using the MIKE 11 hydraulic model.	N/A	If 3.1.2.2 shows substantial differences from information submitted in the EIS, use MIKE 11 model cross-sections (or the most currently available cross-section information) at Taylor, Town of Peace River and Peace Point to compute hourly wetted width and average cross-	If 3.1.2.2 shows substantial differences from information submitted in the EIS then after five Site C generation units are installed and available for operation and reporting after 10 and 20 years of operation.

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
				sectional velocities based on measured water levels and compare to the EIS model results.	
3.3.1 (Ice)	Maximum upstream extent of ice cover shows a shift of about 50 km downstream due to Site C.	Routine ice front monitoring by Alberta Environment and Protected Areas and BC Hydro in the Peace River every winter.	Provide maximum upstream extent of the ice cover (river km) for that winter. Report DDF for Town of Peace River Airport and compare to simulated range in EIS to put maximum upstream extent into a climatic context. Analysis: Perform the appropriate statistical test to determine if parameter outside	The data will be plotted on Figure 3.7 and compared. Any differences between that line will be explained in view of climate to account for different winter severity than the years used in the Site C EIS.	Analysis starting after one year of operation that includes five Site C generation units installed and available for operation, and reporting after 5, 10, and 20 years.

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
			of expected range.		
3.3.2 (Ice)	Timing of freeze-up and break-up at the Town of Peace River. Freeze-up would be delayed by 3 days on average and there would be no delay on the break-up date on average.	Routine ice front monitoring by AEPA and BC Hydro at the Town of Peace River every winter.	Provide freeze-up and break-up dates at TPR for the water year. Analysis: Perform the appropriate statistical test to determine if parameter outside of expected range.	After 10 years with Site C in place and obtaining a good statistical sample of the freeze-up and break-up dates at TPR, the data will be compared to relative changes. Any differences between that line should be explained in view of climate to account for different winter severity than the years used in the Site C EIS.	To obtain a good statistical sample of the freeze-up and break-up dates at TPR analysis and reporting will occur after 5, 10 and 20 years of operation.
3.3.3 (Ice)	Freeze-up and break-up water levels at the Town of Peace River would not change as a result of Site C. The modelling predicted a 0.1 m increase in freeze-up level but this would be undetectable in	Water level gauge at the Town of Peace River with possible follow-up surveys in case of sensor shifts or gauge malfunctions.	Provide maximum instantaneous and daily average freeze-up and breakup water levels for the water year.	The freeze-up elevation at TPR will be assessed annually and compared to the historical range. If outside the historical range, then it will be	After 5, 10 years and 20 years of operation, the data will be compared to the historical distribution of freeze-up levels to determine if there is

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
	the +/- 0.5 m variability of most freeze-up elevations and within measurement error of the freeze-up elevation. Break-up elevations at the Town of Peace River would remain unchanged as they are dominated by the unregulated Smoky River.		Analysis: Perform the appropriate statistical test to determine if parameter outside of expected range.	reported and the reason for this will be investigated to determine if it is an anomaly or a systematic difference. Also examine break-up water levels and determine if above historical range. If above then investigate the reason.	a systematic shift due to Site C. Break-up elevation will only be reported and investigated if above the historical range.
3.3.4 (Ice)	Ice control flows for the Town of Peace River would be initiated 5 days later on average with Site C but have similar historical range between late November and late February as historical.	Ice control timing and duration is routinely documented in a spreadsheet by the BC Hydro Operations Planning Engineer.	Provide ice control start date(s) for the water year. Analysis: Perform the appropriate statistical test to determine if parameter outside of expected range.	After 10 years with Site C in place and obtaining a good statistical sample of control flow start date and duration, the data will be compared to relative changes. A frequency plot of ice control start dates.	Analysis and reporting will occur after 5, 10 and 20 years of operation.

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
3.3.5 (Ice)	The study showed that there would be on average 3 more days of Shaftesbury ferry operations and 4 days less crossing days by ice bridge with the net change being one day less. The year-to-year variability is large.	Ice front positions, air temperatures, ice concentrations (observed or modelled), thermal ice thickness (modelled). Actual ferry crossing and ice bridge in service dates will not be monitored because other non-ice related factors affect those quiet often as was the case in the EIS. Data will be collected to determine the maximum number of days available for crossings even if not taken full advantage of operationally.	Use river ice model results to report date when ice concentration will be too high for ferry operations. Use thermal ice modelling when ice bridge will be viable and report that date. Analysis: Perform the appropriate statistical test to determine if parameter outside of expected range.	Determine the maximum possible number of crossing days by ferry and ice bridge by the same measures used in the relative changes. Compare to EIS relative changes after enough years of data is collected for a statistically meaningful sample. Explain differences and put into context with climate compared to the historical weather sequences used in the relative changes.	Analysis and reporting will occur after 5, 10 and 20 years of operation.
3.3.6 (Ice)	There would be no change to the ice regime as a result of Site C downstream of Carcajou. Carcajou is about 250 km downstream of the Town of Peace River and 540	Ice front positions downstream and upstream of Carcajou will be collected. From these ice front data, freeze-up dates and breakup dates will be	Report ice front positions from Site C to Peace Point for the water year and extract freeze-up and breakup dates f	Once a number of years have passed with Site C in place to obtain a good statistical sample of the freeze-up and break-up timings	Analysis and reporting will occur after 5, 10 and 20 years of operation.

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
	km upstream of the Peace-Athabasca Delta.	determined for the following: Dunvegan Shaftesbury Crossing Carcajou Tompkins Landing Fort Vermilion Fox Lake Crossing Garden River Peace Point *Note: there is limited historical data for freeze-up and breakup dates for Fox Lake Crossing, Garden River and Peace Point for comparison*.	for the locations listed Analysis: Perform the appropriate statistical test to determine if parameter outside of expected range.	downstream and upstream of Carcajou, the data can be compared to ice front information without Site C and determine if statistically different after accounting for climate differences.	
3.3.7 (Ice)	The growth of thermal ice thickness for supporting small loads would not change as a result of Site C. The timing of the start of the growth may change at some locations (upstream of Carcajou).	The same physics apply for the growth of the thermal ice pre and post Site C. Thermal ice starts growing when freeze-up occurs so potential changes are linked to	Monitor freeze-up dates at various locations of interest. See freeze-up dates monitoring in sections 3.2.2 and 3.2.6.	N/A	N/A

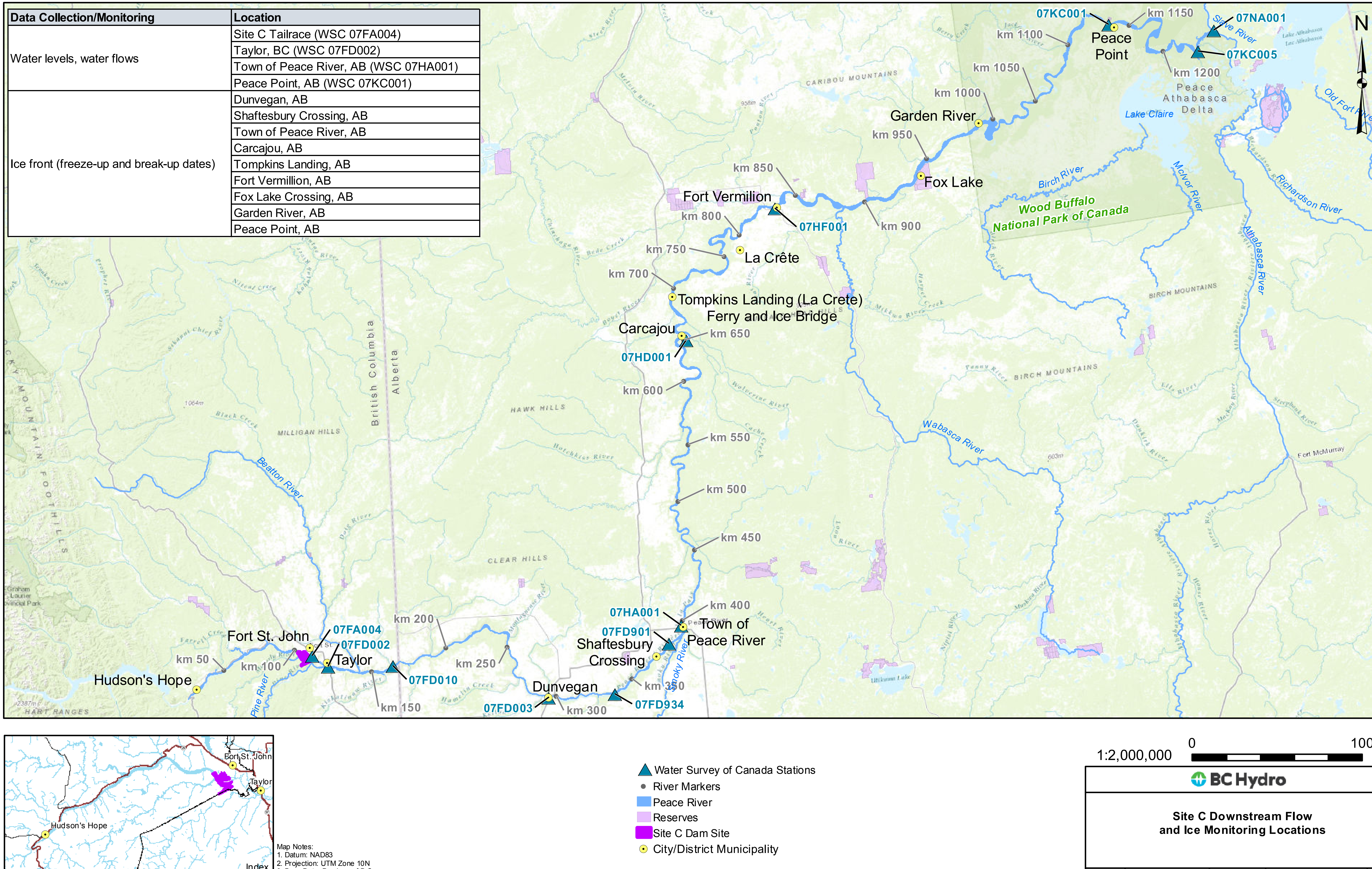
Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
		ice front arrival (freeze-up dates). This is being monitored and reported in the plan at various locations. Changes in freeze-up dates would be an indicator of the change in timing for the ability of humans and animals to travel on the ice cover.			
3.3.8 (Ice)	Changes to the ice regime under a future climate for the 2050s and 2080s was conducted in the EIS. Note: The post-Site C 20-year monitoring program would run from about 2025 to 2045 with the midpoint being about 15 years prior to 2050. Results indicated that there would be no affect on the ice regime by Site C under future climate	Ice front positions, air temperatures at long term stations at Fort St. John, Town of Peace River and High Level Airports.	Report Degree-Days of Freezing (DDF) for each water year and compare to historical and climate change winters used in the EIS. Report DDF for all three stations and compare to historical.	Compare observed maximum upstream ice cover extent with climate change prediction figure in the EIS. Compare winter temperatures to those used in the EIS to simulate winters under climate change for the 2050s. Determine the frequency of the ice front reaching Taylor, BC-AB border,	Analysis and reporting will occur after 5, 10 and 20 years of operation to obtain statically meaningful results.

Section	EIS Assessment	Monitoring	Annual Reporting and Analysis	Additional Analysis	Timing of Additional Analysis
	scenarios downstream of Carcajou.		Report maximum upstream extent of ice front for the water year (already done in 3.2.1). Analysis: Perform the appropriate statistical test to determine if parameter outside of expected range.	Shaftesbury Crossing, Town of Peace River and compare to pre–Site C frequencies.	

Appendix A

Figure: Site C and Downstream Monitoring Area

Data Collection/Monitoring	Location
Water levels, water flows	Site C Tailrace (WSC 07FA004)
	Taylor, BC (WSC 07FD002)
	Town of Peace River, AB (WSC 07HA001)
	Peace Point, AB (WSC 07KC001)
Ice front (freeze-up and break-up dates)	Dunvegan, AB
	Shaftesbury Crossing, AB
	Town of Peace River, AB
	Carcajou, AB
	Tompkins Landing, AB
	Fort Vermillion, AB
	Fox Lake Crossing, AB
	Garden River, AB
	Peace Point, AB



Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.

Water Survey of Canada Stations
River Markers
Peace River
Reserves
Site C Dam Site
City/District Municipality

1:2,000,000
0 100 km

BC Hydro

Site C Downstream Flow and Ice Monitoring Locations

Date	February 21, 2023	DWG NO	1016-N11-01783	R 1

Path: X:\ArcGIS\Projects\Regulatory\PeaceRiver_STCtoPAD_1016_N11_01783.mxd

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Appendix B

Sample Annual Monitoring Report

Sample Annual Report to fulfill Site C downstream flow and ice monitoring plan based on 2021-2022 data

Introduction

Text

Site C EIS Volume 2 Appendix D (Surface Water Regime Technical Memo)

Text

Part 1 - Site C Operations Study

The Site C operational study took a 60-year simulation (water years 1941 to 2000, i.e., Oct 1940 to Sep 2000) using GOM model to produce flow frequency distribution curves for four annual periods: Winter (Nov 15 – Feb 15), Freshet (May 1 – Jul 15), Summer (Jul 16 – Sep 30) and annual. These are plotted as dotted lines in Figure 1. The Solid lines in Figure 1 are cumulative years of data for Site C operations *(Example is based on one year of Peace Canyon operations).*

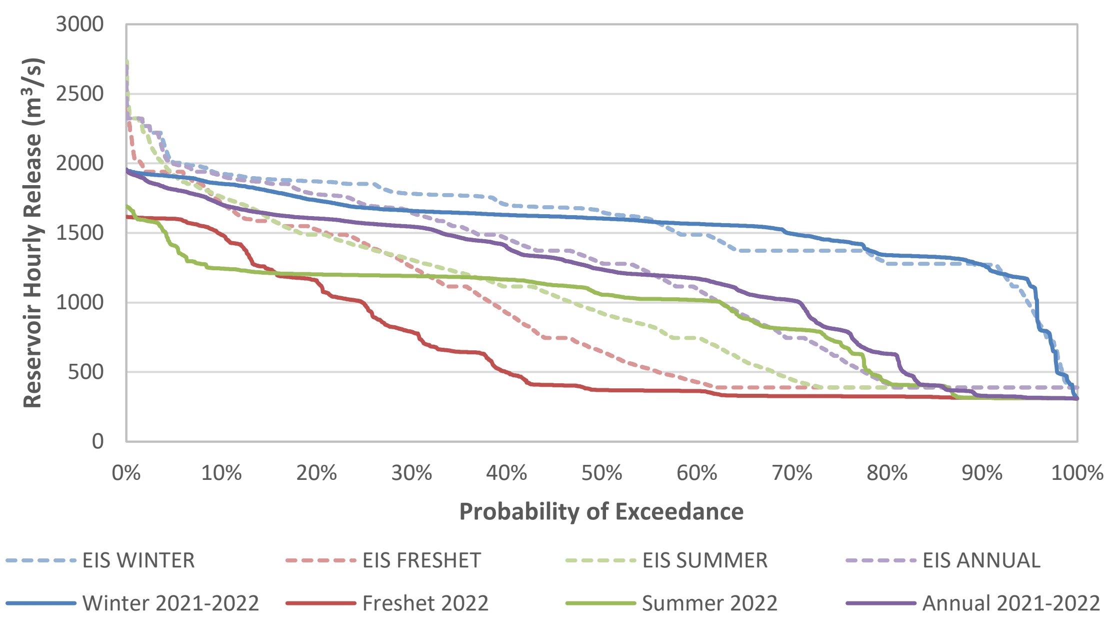


Figure 1. Annual and Seasonal Site C Reservoir Release Duration Curve.

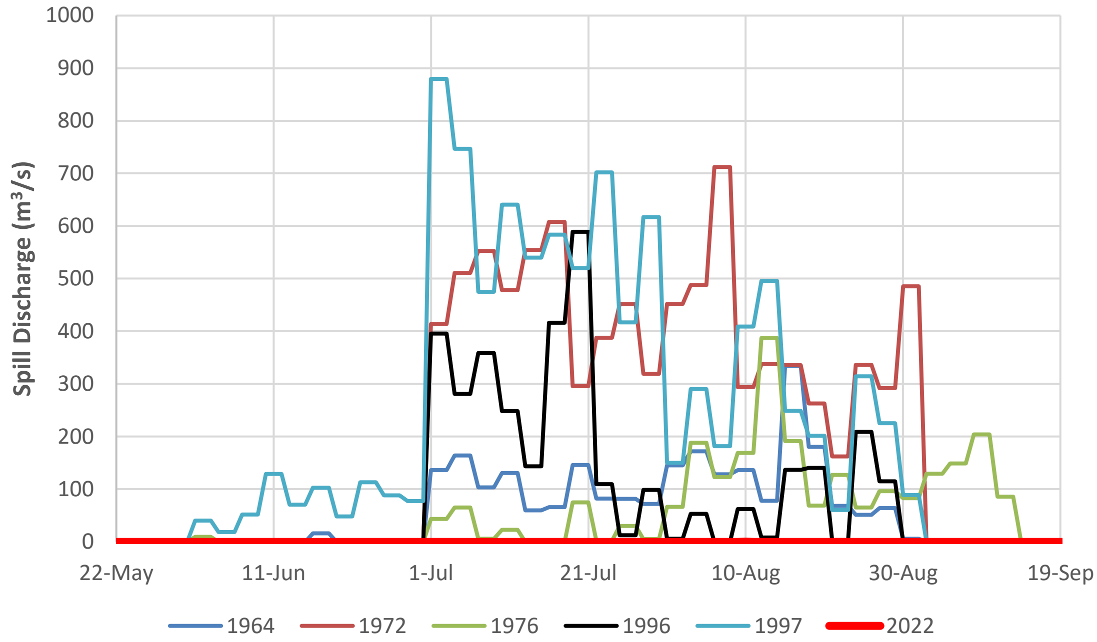


Figure 2. Traces 1964 to 1997 are all spills from 60 years of GOM runs in the Site C EIS. The 2022 year is a sample from Peace Canyon. There was no spill in 2022.

Part 2 - Downstream Flow Modelling

In the EIS, hydraulic flow routing using the MIKE 11 model was conducted to Peace Point, AB with and without Site C in place. The key characteristics of the surface water regime noted in the Site C Downstream Flow and Ice Monitoring and Analysis Plan from the EIS analysis are presented below.

In future Annual Reports, comparisons will be made with water level and discharge data from Water Survey of Canada (WSC) long-term stations at Taylor, Town of Peace River and Peace Point. Water levels measured at the Site C tailrace will also be included in future comparisons. These gauges are considered sufficient for the monitoring program. Excel files with hourly water levels and discharges measured at Site C tailrace and at the WSC gauges will be included with future Annual Reports.

Flow travel time

Hydraulic modelling performed for the EIS indicates that operational flows from Peace Canyon would take between 5 and 15 hours to reach the location of Site C, depending on the flow scenario, with an average travel time of 10 to 12 hours. Therefore, operational changes would be noticed at downstream locations 10-12 hours earlier, on average, with Site C.

In the first Annual Report, flows and water levels measured at Peace Canyon Dam tailrace, Site C tailrace and downstream WSC gauges will be compared to assess travel times for operational changes.

Flow and water level duration curves

The 10, 50 and 90% exceedance values from the hourly water level and discharge duration curves with Site C presented in the EIS are shown in Tables x to x.

Present plots similar to Figure 3-3 and 3-4 in Monitoring Plan and the tables below.

Table x. Site C tailrace hourly duration curves (water levels and discharges for 10, 50, 90% exceedance probabilities)

	Typical Freshet Period: May 1 to Jul.15			Typical Summer Period: Jul.16 to Sep.30		
	10%	50%	90%	10%	50%	90%
EIS with Site C	411.2 m / 1,700 m^3/s	410.2 m / 730 m^3/s	409.7 m / 390 m^3/s	411.3 m / 1,810 m^3/s	410.7 m / 1,090 m^3/s	409.7 m / 390 m^3/s
Future Years						

Table x. Taylor hourly duration curves (water level / discharge for 10, 50, 90% exceedance probabilities)

	Typical Freshet Period: May 1 to Jul.15			Typical Summer Period: Jul.16 to Sep.30		
	10%	50%	90%	10%	50%	90%
EIS with Site C	404.1 m / 2,410 m^3/s	403.3 m / 1,440 m^3/s	402.6 m / 760 m^3/s	403.7 m / 1,900 m^3/s	403.1 m / 1,230 m^3/s	402.2 m / 430 m^3/s
Future Years						

Table x. Town of Peace River hourly duration curves (water level / discharge for 10, 50, 90% exceedance probabilities)

	Typical Freshet Period: May 1 to Jul.15			Typical Summer Period: Jul.16 to Sep.30		
	10%	50%	90%	10%	50%	90%
EIS with Site C	313.6 m / 5,030 m^3/s	312.7 m / 3,270 m^3/s	312.0 m / 2,080 m^3/s	312.6 m / 3,090 m^3/s	311.9 m / 1,920 m^3/s	311.2 m / 940 m^3/s
Future Years						

Table x. Peace Point hourly duration curves (water level / discharge for 10, 50, 90% exceedance probabilities)

	Typical Freshet Period: May 1 to Jul.15			Typical Summer Period: Jul.16 to Sep.30		
	10%	50%	90%	10%	50%	90%
EIS with Site C	213.9 m / 3,730 m^3/s	212.6 m / 2,460 m^3/s	211.6 m / 1,720 m^3/s	212.5 m / 2,380 m^3/s	211.4 m / 1,590 m^3/s	210.6 m / 1,120 m^3/s
Future Years						

Hourly changes in water levels

Present plots similar to Figure 3-5 and 3-6 in Monitoring Plan and the tables below.

The 10 and 30% exceedance values from the hourly water level change duration curves with Site C presented in the EIS are shown in Tables x to x.

Table x. Site C tailrace hourly water level change duration curves (water level changes for 10 and 30% exceedance probabilities)

	10%	30%
EIS with Site C	±0.2 m	less than ±0.1 m
Future Years		

Table x. Taylor hourly water level change duration curves (water level changes for 10 and 30% exceedance probabilities)

	10%	30%
EIS with Site C	less than ±0.2 m	less than ±0.1 m
Future Years		

Table x. Town of Peace River hourly water level change duration curves (water level changes for 10 and 30% exceedance probabilities)

	10%	30%
EIS with Site C	less than ±0.1 m	less than ±0.1 m
Future Years		

Table x. Peace Point hourly water level change duration curves (water level changes for 10 and 30% exceedance probabilities)

	10%	30%
EIS with Site C	less than ±0.1 m	less than ±0.1 m
Future Years		

Daily average water level range

The daily average water level range (i.e. average difference between the maximum and minimum water level over each day) at Site C tailrace, Taylor, Town of Peace River and Peace Point from the EIS analysis with Site C are shown in Tables x to x.

Table x. Daily average water level range for typical freshet operations period (May 1 – Jul.15)

	Site C tailrace	Taylor	Town of Peace River	Peace Point
EIS with Site C	1.2 m	0.8 m	0.2 m	0.1 m
Future Years				

Table x. Daily average water level range for typical summer operations period (Jul.16 – Sep.30)

	Site C tailrace	Taylor	Town of Peace River	Peace Point
EIS with Site C	1.1 m	0.9 m	0.2 m	0.1 m

Future Years				

Site C EIS Volume 2 Appendix G (Downstream Ice Regime Technical Data Report) – Predictions

The following winter ice regime indicators were observed in the 2021 – 2022 water year. Where possible, these were compared to ranges from the years used in the Site C EIS.

Maximum upstream extent of ice cover and DDF at TPR

In order to compare the observed ice regime to that predicted in the EIS, it is helpful to place the coldness of the winter in context of the range of years simulated in the EIS. A convenient parameter to use for this comparison is the degree-days of freezing. Note: All ice front locations for the latest water year are tabulated in Appendix A.

Table 1. Degree-Days of Freezing at the Town of Peace River Airport

DDF (°C-days)	400-600	600-800	800-1000	1000-1200	1200-1400	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600	2600-2800
EIS Analysed (Min, Avg, Max)				1167			1695				2436	
2021-2022							1667					
Future Years …												

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 2. Maximum upstream extent of the ice front (minimum distance from Bennett Dam)

km location	375-400	350-375	325-350	300-325	275-300	250-275	225-250	200-225	175-200	150-175	125-150	100-125
EIS Prediction (Min, Avg, Max)			330				243			162		
2021-2022								211				
Future Years …												

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Timing of freeze-up and break-up at the Town of Peace River

Text

Table 3. Timing of freeze-up at the Town of Peace River.

	<=Nov 30	Dec 1 - 15	Dec 16 - 31	Jan 1 - 15	Jan 16 - 31	Feb 1 - 14	Feb 15 - 29	Mar 1 - 10	>= Mar 11
EIS Prediction (Earliest, Average, Latest)		Dec 14		Jan 14				Mar 1	
2021-2022			Dec 28						
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 4. Timing of breakup at the Town of Peace River.

	<= Feb 29	Mar 1 - 10	Mar 11 - 20	Mar 21 - 31	Apr 1 - 9	Apr 10 - 20	Apr 21 - 30	>=May 1
EIS Prediction (Earliest, Average, Latest)			Mar 13		Apr 8		Apr 26	
2021-2022				Mar 28				
Future Years ...								

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Freeze-up and break-up water levels at the Town of Peace River

Text T

Table 5. Freeze-up water levels

	< 314.0 m	314.0 – 314.5 m	314.5 – 315.0 m	315.0 – 315.5 m	315.5 – 316.0 m	316.0 – 316.5 m	316.5 – 317.0 m	317.0 – 317.5 m	317.5 – 318.0 m	> 318.0 m
Historical Max, Median, Min Site C EIS		314.21		315.03				317.06		
Historical Simulated Max, Median, Min in Site C EIS			314.63	315.33	315.99					
Simulated with Site C Max, Median, Min in Site C EIS			314.52	315.22	315.60					
2021 - 2022				315.02						
Future Years ...										

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

There were no predictions made in the Site C EIS for the breakup water level at TPR because peak breakup water levels are a function of the overwhelming discharge from downstream unregulated tributaries like the Smoky River. Breakup water levels are generally lower than freeze-up water levels. However, breakup water levels will be reported here and if they are above the freeze-up water level a description for the reason will be described in the report here. Some things that would be examined are the relative contributions of Site C releases to natural inflows to the Town of Peace River.

Table 6. Break-up water levels.

	< 314.0 m	314.0 – 315 m	315 - 316 m	316 – 317 m	317 - 318 m	318 – 319 m	319 – 320 m	320 – 321 m	> 321
Historical Max	< 314 m							~ 320 (1997 flood)	
2021 - 2022	313.7								
Future Years …									

Analysis will include what fraction of the Site C discharge of total flow contributed to the peak breakup water level if it was abnormally high.

Ice control flows for the Town of Peace River

In the Site C EIS 15 climatic years were simulated to calculate a range of ice controls for Site C operations. There has been a lot of subsequent simulations performed during operations (ice control ensemble forecasting) that shows a wider range of ice control timing and durations, including climate change studies that indicate that there is a 1 to 2% chance of no ice control occurring from 2020 to 2040 because the ice front does not make it close enough to the Town of Peace River. The Site C EIS indicated an ice control start and duration ranges as indicated in Table 7 and 8 below but the additional simulations mentioned indicate that ice control start dates can occur between Nov 30 and Mar 3 and durations can range from 8 to 91 days (although without Site C and not including the no ice control scenario). Since the EIS indicated that freeze-up and breakup dates are not predicted to change substantially at TPR, and these are linked to ice control, it is possible that some of these more extreme starts and durations could occur under Site C operations.

Table 7. Timing of the start of ice control for the Town of Peace River.

	<=Nov 30	Dec 1 - 15	Dec 16 - 31	Jan 1 - 15	Jan 16 - 31	Feb 1 - 14	Feb 15 - 29	Mar 1 - 10	>= Mar 11
EIS Prediction (Earliest, Average, Latest)		Dec 10		Jan 10			Feb 24		
2021-2022			Dec 26						
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 8. Duration of ice control (days) for the Town of Peace River.

	0	< 10	11 - 20	21 - 30	31 - 40	41 - 50	51 - 60	61 - 70	> 70
EIS Prediction (Shortest, Average, Longest)		9	20		38				
2021-2022			11						
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Ice bridge and ferry at Shaftesbury Crossing

Shaftesbury crossing is located at Peace River km 370 which is about 25 km upstream of TPR. There are four dates that need to be determined to come up with the total number of crossing days (either by ferry or ice bridge) to establish the number of crossable days per year. The justifications for the criteria in selecting these dates are outlined in the EIS and just the criteria are listed below.

1. Start of ferry operations is 15 days after the ice front passes downstream of Shaftesbury crossing in the spring.
2. Ferry operations stop at the first instance of >=20% surface ice concentration in late fall or early winter. To establish the date of first 20% ice concentration first examine CRISSP model output and collaborate with remote cameras, satellite images or ground based observations.
3. The start of ice bridge operations starts when the thermal ice thickness reaches 0.25 m. To determine date that the thermal ice reached 0.25 m examine thermal ice measurements to come off ice control at 0.4 m and work backwards on calibrated thermal ice growth model for that year to determine when 0.25 m was reached.
4. Ice bridge operations stop when the ice front recedes downstream of Shaftesbury (although it would likely be sooner, but this not easily defined. However, this unknown would be climate related and not Site C flow related so using this criterion determines the latest possible date)

It is worthy noting that after the EIS study was completed, the ice front barley made it to Shaftesbury in two years which did not occur for the 15 years simulated in the EIS making it impossible for an ice bridge to operate. The ice front was within a few km and only for a few days near Shaftsbury in the 2011 – 2012 and 2015 – 2016 ice seasons. This is also possible under Site C operations if such a mild winter occurs.

Table 9. Last ice at Shaftesbury.

	<= Feb 29	Mar 1 - 10	Mar 11 - 20	Mar 21 - 31	Apr 1 - 9	Apr 10 - 20	Apr 21 - 30	>=May 1	No solid ice at Shaftesbury
EIS Prediction (Earliest, Average, Latest)		Mar 9			Apr 5		Apr 22		
2011-2012									*
2015-2016									*
2021-2022				Mar 25					
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 10. First instance of 20% ice concentration.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
EIS Prediction (Earliest, Average, Latest)			Nov 17		Dec 8		Dec 31		
2021-2022					Dec 5				
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 11. Thermal ice thickness at Shaftesbury reaches 0.25 m.

	<=Dec 15	Dec 15 -31	Jan 1 - 15	Jan 16 - 31	Feb 1 - 15	Feb 16 - 29	Mar 1 - 15	> Mar 15	Does not reach 0.25 m
EIS Prediction (Earliest, Average, Latest)		Dec 26		Jan 25				Mar 16	
2011-2012									*
2015-2016									*
2021-2022			Jan 1						
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Ice regime changes downstream of the Town of Peace River

The modelling in EIS studies indicated that there would be no changes to the ice regime because of Site C downstream of Carcajou (km 650) which is 540 km upstream of the Peace-Athabasca Delta. Therefore, subsequent monitoring should be compared to historical freeze-up and breakup dates (rather than modelled) for locations downstream of this point because there are more years of historical than modelled data available. Consistent historical freeze-up and breakup dates downstream of Carcajou are available Fort Vermilion (km 832) and Peace Point (km 1136). For Fort Vermilion freeze-up dates from the ice front position database will be used. For Peace Point the historical designation ice backwater according to ECCC “B” designation will be used except for recent years where satellite images were available to obtain more accurate freeze-up and breakup dates. See Appendix A for all ice fronts recorded for the past ice season including those located downstream of Fort Vermilion to the PAD reach and Slave River.

Table 12. Freeze-up at Dunvegan.

	<=Nov 30	Dec 1 - 15	Dec 16 - 31	Jan 1 - 15	Jan 16 - 31	Feb 1 - 14	Feb 15 - 29	Mar 1 - 10	>= Mar 11
32 historical years since 1982. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 13. Freeze-up at Shaftesbury Crossing.

	<=Nov 30	Dec 1 - 15	Dec 16 - 31	Jan 1 - 15	Jan 16 - 31	Feb 1 - 14	Feb 15 - 29	Mar 1 - 10	>= Mar 11
32 historical years since 1982. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 14. Freeze-up at Town of Peace River.

	<=Nov 30	Dec 1 - 15	Dec 16 - 31	Jan 1 - 15	Jan 16 - 31	Feb 1 - 14	Feb 15 - 29	Mar 1 - 10	>= Mar 11
32 historical years since 1982. (Earliest, Average, Latest)		Dec 14		Jan 14				Mar 1	
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 15. Freeze-up at Carcajou.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
32 historical years since 1982. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 16. Freeze-up at Tompkins Landing.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
32 historical years since 1982. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 17. Freeze-up at Fort Vermilion.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
32 historical years since 1982. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 18. Freeze-up at Fox Lake Crossing.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
Few years with Satellite data available. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 19. Freeze-up at Garden River.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
Few years with Satellite data available. (Earliest, Average, Latest)									
2021-2022									
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 20. Freeze-up at Peace Point.

	<=Nov 1	Nov 1 - 10	Nov 11 - 20	Nov 20 - 30	Dec 1 - 10	Dec 11 - 20	Dec 21 - 31	Jan 1 - 10	> Jan 10
Few years with Satellite data available. (Earliest, Average, Latest)									
2021-2022				Nov 23					
Future Years …									

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Similar tables to 12 through 20 will be presented but for break-up timing.

Ice Thickness

Thermal ice thickness for supporting small loads would not change because of Site C. Thermal ice growth starts when the ice cover initial forms and is thick enough in a day or two to support a person or a large animal. The same physics apply for the post Site C ice cover. Freeze-up dates and breakup dates can be used as a proxy for this parameter (See previous section).

Changes to the ice regime under a future climate

To assess climate change the DDF for Fort St. John Airport, Town of Peace River, Town of Peace River Airport, High Level Airport can be compared to DDF analysis years and those from the 2050s climate change scenario in the Site C EIS. *Note: Below only the Peace River Airport Table 14 is filled in with values in this example report.*

Table 13. Degree-Days of Freezing at the Fort St. John River Airport.

DDF (ºC-days)	400-600	600-800	800-1000	1000-1200	1200-1400	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600	2600-2800
EIS Analysed (Min, Avg, Max)												
2021-2022												
Future Years …												
EIS 2050s												

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 14. Degree-Days of Freezing at the Town of Peace River Airport.

DDF (ºC-days)	400-600	600-800	800-1000	1000-1200	1200-1400	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600	2600-2800
EIS Analysed (Min, Avg, Max)				1167			1695				2436	
2021-2022							1667					
Future Years …												
EIS 2050s (Min, Avg, Max)		759			1220			1916				

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Table 15. Degree-Days of Freezing at the High Level Airport.

DDF (ºC-days)	400-600	600-800	800-1000	1000-1200	1200-1400	1400-1600	1600-1800	1800-2000	2000-2200	2200-2400	2400-2600	2600-2800
EIS Analysed (Min, Avg, Max)												
2021-2022												
Future Years …												
EIS 2050s (Min, Avg, Max)												

Analysis will include either an exceedance probability or Z-Score test to determine that the observations are outside the predicted range.

Appendix A – Ice Front Positions for 2021 – 2022 ice season.

Date / Time	Ice Front (km)	Source
20-Nov-2021 11:56		Sentinel 2 Running ice all the way from Fort Vermilion to Slave at Fitsgerald gauge
20-Nov-2021 17:59		Sentinel 1 Running ice all the way from Fort Vermilion to Slave at Fitsgerald gauge
		Sentinel 1 Running ice all the way from Fort Vermilion to Slave at Fitsgerald gauge
23-Nov-2021 12:07	1131.0	Sentinel 2
25-Nov-2021 18:07	1114.0	Sentinel 1
		possibly more ice front positions to be filled in here
		more positions to be filled in here
23-Nov-2021 12:07	970.0	Sentinel 2
24-Nov-2021 18:16	925.0	Sentinel 1
28-Nov-2021 12:07	916.1	
26-Nov-2021 00:00	831.5	Projection based on Fort Vermilion gauge rise on Nov 25
27-Nov-2021 12:00	801.0	MODIS
28-Nov-2021 12:07	812.0	Sentinel 2
28-Nov-2021 18:31	794.3	Sentinel 1
30-Nov-2021 07:01	773.0	Sentinel 1
30-Nov-2021 18:28	768.0	RCM
2-Dec-2021 07:14	756.4	RCM
3-Dec-2021 12:07	719.0	Sentinel 1
4-Dec-2021 18:32	681.0	Sentinel 1
6-Dec-2021 01:15	651.0	Carcajou Gauge
6-Dec-2021 07:14	634.5	RCM
6-Dec-2021 12:17	628.0	Sentinel 2
7-Dec-2021 17:00	574.5	RCM on Dec 9 showed some rough shore ice up to this point, time estimated to give reasonable consolidation rate
7-Dec-2021 21:30	651.0	Carcajou Gauge, consolidation moving downstream
7-Dec-2021 23:30	685.0	RCM on Dec 10 showed new toe, time estimated to give reasonable consolidation rate
8-Dec-2021 03:00	651.0	Carcajou Gauge, ice front moving back upstream
9-Dec-2021 07:05	608.0	RCM
10-Dec-2021 07:13	603.1	RCM
10-Dec-2021 18:31	586.0	Sentinel 1
11-Dec-2021 18:19	590.3	RCM
12-Dec-2021 07:02	588.0	Sentinel 1
13-Dec-2021 18:35	579.3	RCM

14-Dec-2021 07:14	576.0	RCM
16-Dec-2021 11:53	541.5	Landsat 8
16-Dec-2021 12:18	541.0	Sentinel 2
17-Dec-2021 18:32	532.0	Sentinel 1
18-Dec-2021 07:14	493.5	RCM, check with coloured version
18-Dec-2021 12:08	497.0	Sentinel 2
19-Dec-2021 18:20	483.0	RCM
21-Dec-2021 18:36	477.5	RCM
22-Dec-2021 07:13	475.0	RCM
22-Dec-2021 18:13	472.5	Sentinel 1
23-Dec-2021 12:08	471.5	Sentinel 2
23-Dec-2021 18:19	470.5	RCM
25-Dec-2021 11:47	458.0	Landsat 8
25-Dec-2021 19:00	453.0	RCM
25-Dec-2021 19:00	455.0	BCH Remote Camera
26-Dec-2021 07:13	444.9	RCM
26-Dec-2021 12:18	441.6	Sentinel 2
27-Dec-2021 09:20	426.5	Backwater at Berreth gauge stopped rising
27-Dec-2021 16:15	417.0	BCH Remote Camera - ice front moving u/s
27-Dec-2021 18:19	410.0	RCM
27-Dec-2021 22:15	417.0	BCH Remote Camera - ice front moving d/s
28-Dec-2021 00:15	417.0	BCH Remote Camera - ice front moving u/s
28-Dec-2021 16:55	398.8	AEP Ground Observation
28-Dec-2021 18:00	396.7	TPR gauge levelling off at 19:05 but 1 hour of data missing before that so could be ~18:00 to be consistent with Sentinel 1 30 min later
28-Dec-2021 18:31	392.0	Sentinel 1
29-Dec-2021 10:10	382.2	AEP Ground Observation
29-Dec-2021 10:55	381.4	Peace Above Smoky Confluence gauge
29-Dec-2021 14:00	381.4	Peace Above Smoky Confluence gauge
29-Dec-2021 15:10	381.4	Peace Above Smoky Confluence gauge
29-Dec-2021 16:10	374.7	AEP Ground Observation
30-Dec-2021 18:43	354.0	RCM
31-Dec-2021 12:18		Sentinel 1 (check hi-res)
31-Dec-2021 18:55	336.0	Elk Island Gauge - Moving upstream
31-Dec-2021 19:25	336.0	Elk Island Gauge - Moving downstream
31-Dec-2021 19:35	336.0	Elk Island Gauge - Moving upstream
31-Dec-2021 20:55	336.0	Elk Island Gauge - Moving downstream
31-Dec-2021 22:00	336.0	Elk Island Gauge - Moving upstream
1-Jan-2022 00:50	336.0	Elk Island Gauge - Moving downstream
1-Jan-2022 01:55	336.0	Elk Island Gauge - Moving upstream

1-Jan-2022 06:10	336.0	Elk Island Gauge - Moving downstream
1-Jan-2022 08:05	336.0	Elk Island Gauge - Moving upstream
1-Jan-2022 12:20	336.0	Elk Island Gauge - Moving downstream
1-Jan-2022 14:43	345.0	AEP ground observation - consolidating downstream
1-Jan-2022 16:20	336.0	Elk Island Gauge - Moving upstream
1-Jan-2022 18:10	336.0	Elk Island Gauge - Moving downstream
1-Jan-2022 20:30	336.0	Elk Island Gauge - Moving upstream
2-Jan-2022 02:00	336.0	Elk Island Gauge - Moving downstream
2-Jan-2022 04:45	336.0	Elk Island Gauge - Moving upstream
2-Jan-2022 14:31	313.2	BCH Drone Observation
3-Jan-2022 07:14	306.5	RCM
3-Jan-2022 18:43	302.0	RCM
4-Jan-2022 08:45	**295.7**	BCH Remote Camera - moving upstream
4-Jan-2022 13:15	295.7	BCH Remote Camera - moving downstream
4-Jan-2022 15:15	295.7	BCH Remote Camera - moving upstream
6-Jan-2022 18:35	244.3	RCM
7-Jan-2022 18:48	228.0	Sentinel 1
8-Jan-2022 07:22	232.3	RCM
8-Jan-2022 11:59	231.2	Landsat 8 (Check Full Res)
10-Jan-2022 12:00	213.7	BCH Flight Observation on Jan 11 indicated maximum u/s extent, likely consolidated mid-day due to warm-up this day
10-Jan-2022 13:00	230.0	BCH Flight Observation on Jan 11 indicated a toe of a consolidation here. Time based on ~16 km/hr for a consolidation reasonable
10-Jan-2022 13:30	220.2	Assume 30 minutes for stoppage front and then subsequent advance rate of 3.7 km/day
10-Jan-2022 18:35	219.4	RCM
11-Jan-2022 15:31	216.2	BCH Flight Observation
11-Jan-2022 15:50	**216.0**	BCH Flight Observation
12-Jan-2022 07:22	215.2	RCM
12-Jan-2022 11:05	214.7	BCH Drone Observation
12-Jan-2022 18:51	214.3	RCM
13-Jan-2022 12:27	215.1	Sentinel 2
16-Jan-2022 07:22	219.0	RCM
17-Jan-2022 06:00	221.5	Estimated downstream retreat based on Jan 19 drone image, time based on 6 hours after arrival of arctic front
18-Jan-2022 18:35	220.7	RCM
19-Jan-2022 16:15	214.9	BCH Drone Observation
19-Jan-2022 18:48	**213.4**	Sentinel 1
20-Jan-2022 07:22	210.5	RCM
24-Jan-2022 07:22	219.6	RCM
24-Jan-2022 11:59	220.9	Landsat 8
25-Jan-2022 12:16	223.8	Sentinel 2, 800 m of brash ice upstream

26-Jan-2022 12:43	**227.3**	BCH Drone Observation, 300 m of brah ice upstream
27-Jan-2022 07:14	229.7	RCM
30-Jan-2022 12:16	242.0	Sentinel 2
30-Jan-2022 18:35	242.0	RCM
31-Jan-2022 00:00	243.0	Most downstream extent noted on Feb 1 drone flight, assume this time ~9 hrs after the arrival of arctic front.
1-Feb-2022 07:22	241.6	RCM
1-Feb-2022 12:06	240.6	Sentinel 2
1-Feb-2022 16:40	**239.0**	BCH Drone Observation
2-Feb-2022 11:53	235.0	Landsat 8
3-Feb-2022 18:35	226.0	RCM
5-Feb-2022 07:22	221.5	RCM
6-Feb-2022 00:00	219.5	Estimated most upstream extent from the transition from cold to much warmer weather and previous rate of advance at similar temperatures.
7-Feb-2022 18:35	221.2	RCM
8-Feb-2022 07:14	**222.9**	RCM
11-Feb-2022 16:25	244.5	BCH Drone Observation
11-Feb-2022 18:35	244.6	RCM
12-Feb-2022 12:30	247.2	BC Hydro Flight
13-Feb-2022 07:22	247.2	RCM
14-Feb-2022 18:31	253.5	Sentinel 1
15-Feb-2022 09:47	257.6	BCH Remote Camera
15-Feb-2022 10:00	257.6	BCH Remote Camera
15-Feb-2022 10:30	257.8	BCH Remote Camera
15-Feb-2022 18:30	257.8	BCH Remote Camera
15-Feb-2022 22:00	257.8	BCH Remote Camera
15-Feb-2022 23:00	257.8	BCH Remote Camera
15-Feb-2022 23:30	**259.6**	BCH Remote Camera
16-Feb-2022 00:00	259.1	BCH Remote Camera
16-Feb-2022 07:30	259.1	BCH Remote Camera
16-Feb-2022 10:00	259.1	BCH Remote Camera
16-Feb-2022 17:30	258.6	BCH Remote Camera
16-Feb-2022 18:30	258.4	BCH Remote Camera
17-Feb-2022 00:00	257.8	BCH Remote Camera
17-Feb-2022 07:30	257.7	BCH Remote Camera
17-Feb-2022 12:00	**257.6**	BCH Remote Camera
18-Feb-2022 08:30	257.6	BCH Remote Camera
18-Feb-2022 18:31	257.6	BCH Remote Camera
19-Feb-2022 01:00	257.6	BCH Remote Camera
19-Feb-2022 07:06	257.8	RCM
19-Feb-2022 08:30	257.8	BCH Remote Camera

19-Feb-2022 18:30	255.9	BCH Remote Camera km 260 US
20-Feb-2022 08:00	254.0	BCH Remote Camera km 250
20-Feb-2022 11:30	253.5	BCH Remote Camera km 250
20-Feb-2022 17:30	252.3	BCH Remote Camera km 250
20-Feb-2022 18:30	251.8	BCH Remote Camera km 250
21-Feb-2022 12:04	245.4	Sentinel 2
21-Feb-2022 18:30	244.7	BCH Remote Camera km 242
22-Feb-2022 19:00	238.4	BCH Remote Camera km 242
24-Feb-2022 12:13	232.7	Sentinel 2
24-Feb-2022 18:43	232.4	RCM
24-Feb-2022 18:48	232.4	RCM
25-Feb-2022 07:22	232.4	RCM
26-Feb-2022 11:53	235.6	Landsat 9
28-Feb-2022 07:30	241.4	BCH Remote Camera km 242
28-Feb-2022 08:30	243.0	BCH Remote Camera km 242
28-Feb-2022 16:00	243.0	BCH Remote Camera km 242
28-Feb-2022 19:00	243.0	BCH Remote Camera km 242
1-Mar-2022 07:00	243.0	BCH Remote Camera km 242
1-Mar-2022 08:30	243.2	BCH Remote Camera km 242
1-Mar-2022 12:00	243.2	BCH Remote Camera km 242
1-Mar-2022 12:14	243.2	Sentinel 2
1-Mar-2022 12:30	243.5	BCH Remote Camera km 242
1-Mar-2022 15:30	243.5	BCH Remote Camera km 242
1-Mar-2022 16:00	243.7	BCH Remote Camera km 242
1-Mar-2022 19:00	243.9	BCH Remote Camera km 242
2-Mar-2022 07:00	245.6	BCH Remote Camera km 242
2-Mar-2022 10:30	245.6	BCH Remote Camera km 242
2-Mar-2022 11:00	245.8	BCH Remote Camera km 242
2-Mar-2022 19:00	245.8	BCH Remote Camera km 242
3-Mar-2022 07:00	246.7	BCH Remote Camera km 242
3-Mar-2022 07:06	246.7	RCM
3-Mar-2022 09:00	246.7	BCH Remote Camera km 242
3-Mar-2022 09:30	246.7	BCH Remote Camera km 242
3-Mar-2022 10:00	246.9	BCH Remote Camera km 242
3-Mar-2022 14:30	246.9	BCH Remote Camera km 242
3-Mar-2022 15:00	247.9	BCH Remote Camera km 242
4-Mar-2022 07:00	251.2	BCH Remote Camera km 250.5
4-Mar-2022 09:30	251.2	BCH Remote Camera km 250.5
4-Mar-2022 10:00	252.4	BCH Remote Camera km 250.5
4-Mar-2022 17:00	252.4	BCH Remote Camera km 250.5
4-Mar-2022 17:30	254.0	BCH Remote Camera km 250.5

4-Mar-2022 19:00	254.0	BCH Remote Camera km 250.5
5-Mar-2022 07:21	254.5	RCM
5-Mar-2022 11:59	254.9	Landsat 9
5-Mar-2022 13:00	257.7	BCH Remote Camera km 260 US
5-Mar-2022 16:30	257.7	BCH Remote Camera km 260 US
5-Mar-2022 17:00	259.0	BCH Remote Camera km 260 US
5-Mar-2022 19:30	259.0	BCH Remote Camera km 260 US
6-Mar-2022 07:00	261.7	BCH Remote Camera km 260 DS
6-Mar-2022 17:30	261.7	BCH Remote Camera km 260 DS
6-Mar-2022 18:00	262.8	BCH Remote Camera km 260 DS
6-Mar-2022 19:30	262.8	BCH Remote Camera km 260 DS
8-Mar-2022 11:44	**273.6**	BCH Drone observation
8-Mar-2022 18:43	273.1	RCM
9-Mar-2022 06:31	276.1	BCH Remote Camera km 276
9-Mar-2022 19:30	276.1	BCH Remote Camera km 276
10-Mar-2022 06:30	277.6	BCH Remote Camera km 276
10-Mar-2022 18:32	277.8	Sentinel 1
10-Mar-2022 19:00	278.0	BCH Remote Camera km 276
11-Mar-2022 06:30	279.0	BCH Remote Camera km 276
11-Mar-2022 19:30	279.5	BCH Remote Camera km 276
13-Mar-2022 07:22	286.4	RCM
15-Mar-2022 18:35	283.4	RCM
16-Mar-2022 12:10	288.1	Sentinel 2, upstream end of brash is at km 286.2
17-Mar-2022 07:00	293.8	BCH Remote Camera km 296 (u/s end of brash by RCM satellite at 07:22 MST = km 292.0
17-Mar-2022 12:45	**295.9**	BCH Remote Camera km 296 (u/s end of brash is at km 294.3
18-Mar-2022 12:01	305.2	Sentinel 2, brash front at km 304
19-Mar-2022 07:06	313.2	RCM
21-Mar-2022 12:11	334.0	Sentinel 2, upstream end of brash is at km 333.3
22-Mar-2022 11:53	343.0	Landsat 8
22-Mar-2022 18:27	346.4	RCM - brash front at km 345.7
24-Mar-2022 07:31	357.7	RCM - brash front at km 357.3
25-Mar-2022 09:45	367.2	AEP ground based observation
26-Mar-2022 08:40	375.2	AEP ground based observation
26-Mar-2022 20:15	378.4	AEP ground based observation
26-Mar-2022 21:00	381.4	Peace Above Smoky Confluence gauge
27-Mar-2022 08:25	383.8	AEP ground based observation
27-Mar-2022 20:00	389.0	AEP ground based observation
28-Mar-2022 12:09	393.4	Sentinel 2
28-Mar-2022 13:10	394.0	AEP ground based observation
28-Mar-2022 15:44	395.7	BCH ground based observation
28-Mar-2022 17:27	396.3	BCH ground based observation

29-Mar-2022 07:15	402.5	BCH ground based observation
30-Mar-2022 09:00	416.3	AEP ground based observation (based on AEP photograph of ice front is inline between CN(Shell) building and Diashowa plant which is km 416.3 compared to AEP report of km 415.5
31-Mar-2022 12:09	437.5	Sentinel 2
2-Apr-2022 11:59	460.0	Sentinel 2 - upstream end of brash at km 459.2
3-Apr-2022 18:31	471.1	Sentinel 1 - upstream end of brash at km 471.4
4-Apr-2022 07:05	475.5	RCM
5-Apr-2022 10:00	486.0	AEP ground based observation
6-Apr-2022 14:00	501.0	AEP ground based observation
7-Apr-2022 11:59	520.0	Sentinel 2
10-Apr-2022 12:09	557.7	Sentinel 2 - upstream end of brash at km 555.6
12-Apr-2022 11:59	578.4	Sentinel 2 - upstream end of brash at km 577.2
15-Apr-2022 18:32	589.0	Sentinel 1
17-Apr-2022 11:59	608.0	Sentinel 2
17-Apr-2022 18:22	609.0	RCM
20-Apr-2022 07:05	625.7	RCM
20-Apr-2022 12:09	632.0	Sentinel 2
20-Apr-2022 18:36	632.2	RCM - upstream end of brash at km 630.7
21-Apr-2022 07:13	640.9	RCM
22-Apr-2022 11:59	651.3	Sentinel 2 - upstream end of brash at km 650.0
23-Apr-2022 11:52	670.1	Landsat 8
25-Apr-2022 12:09	713.8	Sentinel 2 - upstream end of brash at km 713.1 with running brash km 709.4 to 712.2.
26-Apr-2022 07:21	731.0	RCM - upstream end of brash at km 729.4
2022-04-29 17:10	831.5	Fort Vermilion gauge starts dropping
2022-05-03 10:33	929.5	BCH Flight
2022-05-03 15:04	944.3	BCH Flight
2022-05-04 13:56	975.5	BCH Flight
2022-05-04 15:09	975.5	BCH Flight
2022-05-05 9:59	1045.0	BCH Flight, running ice back to km 991
2022-05-05 11:32	1066.0	BCH Flight, running ice back to km 1034
2022-05-05 17:25	1136.1	Peace River at Peace Point gauge
2022-05-05 20:40	1227.0	Peace River below Quatre Fourches gauge
2022-05-06 10:18	1252.0	Parks Canada Flight, also photos of running ice at Rocky Point and km 1217
2022-05-07 6:40	1252.0	RCM
2022-05-08 17:47	1252.0	RCM
	Upstream end of ice jams or last	

	running ice	
2022-05-03 10:20	924.5	BCH Flight
2022-05-04 13:53	963.0	BCH Flight
2022-05-04 15:12	964.0	BCH Flight
2022-05-05 9:59	1040.0	BCH Flight
2022-05-05 11:37	1062.0	BCH Flight
2022-05-07 6:40	1230.6	RCM
2022-05-08 17:47	1230.5	RCM