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Site C Reservoir Filling

Peace River Water Level & Flow in Alberta

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1. INTRODUCTION

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 of capacity and about 5,100 gigawatt hours of energy each year to the province's integrated electricity system.

The amended Project Environmental Impact Statement (EIS) was submitted to the Joint Review Panel[1] in August 2013. In November 2014, the Federal Minister of the Environment issued a Federal Decision Statement (FDS) for the Site C Clean Energy Project ('the Project'). The FDS set out conditions under which the Project can be constructed and operated.

The purpose of this document is to fulfil Condition 4.2 of the FDS which states:

> "The Proponent shall, 90 days prior to initiating reservoir filling, provide the Agency with estimates of downstream water flows and water levels to Peace Point, Alberta for scenarios at minimum, average and maximum rates of reservoir filling and a description of how these estimates have been used to undertake reservoir filling in a manner that would minimize impacts on downstream water flows and water level conditions."

2. BACKGROUND

Volume 2, Section 11 (Environmental Background) of the EIS report considers changes to the surface water regime. The reservoir filling phase was presented in EIS Volume 1 Appendix B. Filling phase effects in upstream and downstream areas are described below.

The reservoir fill plan (EIS Volume 1, Appendix B) has been developed to manage several factors, including:

- Safe commissioning of the earthfill dam. Several reservoir surface water elevation hold points are used to monitor the performance of the dam as water levels are rising.
- Williston Reservoir levels and drawdown rates. If key reservoir elevations are exposed to winter conditions, it can contribute to adverse effects to local communities such reduced air quality.
- Downstream levels of total dissolved gas (TDG) produced during reservoir filling phases. Project discharges prior to first power will be conveyed using the spillway, which would lead to increased TDG levels. Hence the maximum discharge rate is driving by regulatory compliance to not exceed TDG levels that could pose a risk to downstream fish health[2].

[1] Includes Canadian Environmental Assessment Agency and BC Environmental Assessment Office representatives.
[2] Based on subject matter expert input during the design phase, the Project team estimated the maximum outflow from the low level outlet releases and radial gates would be 1,200 m^3/s^2. These outflow levels are expected to maintain downstream TDG that do not exceed 120% saturation.

- Downstream levels of ice are influenced by Peace River discharge levels. If releases for the Project are too low in the winter period, it can lead to ice buildup and flooding in Alberta portions of the Peace River.

The reservoir fill rate is controlled by both upstream inflow rate and the level of discharge from the Project. Upstream fill rate is largely controlled by the operations of Peace Canyon Dam, meaning BC Hydro has substantial control over the rate of infill through means unrelated to discharge from the Project. The river regulation upstream of the Project means that the rate of reservoir fill is not driving the rate of downstream river levels in Alberta as much as contributions from tributary inflows.

Given the above-listed factors and means of controlling reservoir filling rate, the Project team have provided estimates of downstream flow levels in context of the expected reservoir fill profile, and the downstream tributary contributions in dry, wet and median years. These estimates show the range of likely flows that may be experienced in river sections down to Peace Point for the low-flow period of reservoir filling. Portions of reservoir filling outside the low flow period are expected to be above thresholds for downstream infrastructure and ice control.

3. APPROACH

Building upon the factors described in Section 2.0, a reference scenario was developed to assist in understanding Peace River discharge during the filling phase. The presented scenario (Table 1) is required to understand the likely range of water levels in downstream portions of the Peace River.

Table 1. Reference scenario description of Site C outflow levels during reservoir filling.

Description of Flow Conveyance	Outflow from Site C
Flow level in days before filling Phase 1	1,000 m^3/s before Sep 2022
Filling Phase 1 (Tunnel 1 + Tunnel 2 converted)	Flow increase from 1,000 m^3/s to 2,000 m^3/s over Sep 22-27
	Flow decrease from 2,000 m^3/s to 390 m^3/s from Sep 27-29
Tunnel 2 only	Flow increase from 390 m^3/s to 600 m^3/s from Sep 29-Oct 6
Spillway via Low Level Outlets; Tunnels closed	Hold at 600 m^3/s from Oct 6-31
Spillway via Low Level Outlets & Radial Gates	Flow increase from 600 m^3/s to 1,200 m^3/s from Oct 31-Nov 3
	Hold at 1,200 m^3/s after Nov 3

Using the reference scenario, the resulting downstream flows were estimated[3] based on tributary inflow records from historic data (Table 2). The model estimation and historic inflow input approach used the method described in the EIS (Volume 3, Appendix D, Part 2). A full description of the modelling approach is provided in Appendix A.

[3] Site C Clean Energy Project, Downstream Flow Modelling During Reservoir Filling. Prepared by A. Agrawal (BCH). Prepared for M. McArthur (BCH). BCH Memo 1016-GEM-00007, July 21, 2022.

4. DOWNSTREAM FLOWS

The downstream flow levels in Alberta portions of the Peace River are shown for the following key locations:

- Dunvegan Bridge: this location is ~14 km upstream of a water intakes that supplies the Town of Fairview. There are no major tributary confluences between this location and the intake.
- Shaftesbury Ferry crossing location.
- CNRL Intake[4]. This intake is located approximately 20 km downstream of the Town of Peace River.
- La Crete Ferry crossing location at Tompkins Landing.
- Fort Vermillion.
- Peace Point.

Each of the locations upstream of Peace Point was identified[5] as an important site for downstream infrastructure. Estimates of Peace River flow are shown in Table 2 for the low flow period of reservoir filling. Flows are presented in the context of downstream infrastructure minimum flow thresholds that have been identified during discussions with Alberta government representatives.

The effects of the lows flows on downstream locations has been considered by BC Hydro in developing the reservoir filling plan. BC Hydro intends to shorten the low flow period duration as much as possible whilst balancing the factors cited in Section 2.0. There is considerable incentive to BCH to minimize the period of reduce flows so as to achieve first power for the Project in December 2023, and the associated power generation at the upper Peace generating stations.

The flow and water levels estimates presented herein are based on the best available information at the time of report submittal. These estimates are subject to changes based on construction schedule progress and unforeseen delays related to safely filling the reservoir and commissioning the Project. If the estimates provided herein found to be substantially different than the likely discharges from the Project, BC Hydro will update the Agency with revised water level and flow estimates.

[4] Formerly known as the Shell intake.
[5] Email from E. Kerkhoven (Alberta Environment) to A. Pryse-Philips (BCH), 21-Nov-2013

Table 2. Peace River minimum and average daily flow and water level at key AB infrastructure locations, for Site C (STC) reservoir filling low flow period (STC releases: Sep 29 - Oct 31). Inflow data is based on 2009-2019 records.

Infrastructure Description	Distance Downstream of WAC Bennett Dam (km)	Infrastructure River Flow Threshold (m^3/s)	Driest Inflow Year (2009 - 2019)			Median Inflow Year (2009 - 2019)			Highest Inflow Year (2009 - 2019)		
			Peace River Average Daily Dischange (m^3/s); dates of flows	Peace River Average Daily Water Level (m)	Number of Days with Average Flows Below Threshold*	Peace River Average Daily Dischange (m^3/s); dates of flows	Peace River Average Daily Water Level (m)	Number of Days with Average Flows Below Threshold*	Peace River Average Daily Dischange (m^3/s); dates of flows	Peace River Average Daily Water Level (m)	Number of Days with Average Flows Below Threshold*
Dunvegan Bridge	296	600	676 (Sep 30 - Nov 3)	338.7	5	682 (Sep 30 - Nov 3)	338.7	5	847 (Sep 30 - Nov 3)	339.1	0
Shaftesbury Ferry Crossing	371	900 +/- 100 = reduced ops; 600 = shut down	678 (Oct 1 - Nov 4)	317.8	33 (900 m^3/s); 4 (600 m^3/s)	682 (Oct 1 - Nov 4)	317.8	34 (900 m^3/s); 4 (600 m^3/s)	846 (Oct 1 - Nov 4)	318.1	29 (900 m^3/s); 0 (600 m^3/s)
CNRL (used to be Shell Canada) intake	417	750 +/- 100	809 (Oct 1 - Nov 4)	302.8	5	864 (Oct 1 - Nov 4)	302.9	0	1201 (Oct 1 - Nov 4)	303.4	0
La Crete Ferry crossing	698	900 +/- 100	815 (Oct 3 - Nov 6)	252.6	32	873 (Oct 3 - Nov 6)	252.7	26	1219 (Oct 3 - Nov 6)	253.5	0
Fort Vermilion	831	900 +/- 100	819 (Oct 4 - Nov 7)	245.5	32	880 (Oct 4 - Nov 7)	245.6	26	1223 (Oct 4 - Nov 7)	246.2	0
Peace Point	1136	N/A	851 (Oct 7 - Nov 10)	210.1	N/A	932 (Oct 7 - Nov 10)	210.3	N/A	1313 (Oct 7 - Nov 10)	211	0

*based on average daily flow estimate

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Appendix A

Downstream Flow Modelling During Reservoir Filling

BC Hydro Memo # 1016-GEM-00007

July 21, 2022

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Site C Project

Downstream Flow Modelling During Reservoir Filling

Memo Number	Revision	Information Security Classification
1016-GEM-00007	0	Confidential

To:	Michael McArthur	**Date**	2022 Jul 21
From:	Abhishek Agrawal		
Copy:			

Related Facilities	STC

Additional Metadata	WR - 1254

1 Introduction

The Site C Project team has requested downstream flow modelling of the planned flow releases from Site C discharge facilities during reservoir filling that are shown below.

- before September 22: 1,000 m^3/s
- September 22-27: flow increase from 1,000 m^3/s to 2,000 m^3/s
- September 27-29: flow decrease from 2,000 m^3/s to 390 m^3/s
- September 29 to October 6: flow increase from 390 m^3/s to 600 m^3/s
- October 6-31: 600 m^3/s
- October 31 to November 3: flow increase from 600 m^3/s to 1,200 m^3/s
- after November 3: 1,200 m^3/s

These planned flow releases during filling of Site C Reservoir were prepared by Generation System Operations (sent to Engineering by the Site C Project team on April 29, 2022). At this time, the year that reservoir filling will take place is still uncertain as construction is in progress.

For reference, Peace River chainages are based on 0 km at Bennett Dam. Site C Dam is at approximately 105 km. Peace River chainages in the remainder of this memo are shown in square brackets.

Estimated flows and water levels are requested at the following locations along the Peace River:

- ferry crossings at Shaftesbury [371 km] and La Crete [698 km]
- water intakes just downstream of the Town of Peace River [CNRL, 417 km] and at Fort Vermilion [833.5 km]

Estimated flows and water levels are also requested at the following Peace River Water Survey of Canada (WSC) gauges:

- Peace above Pine 07FA004 [111.7 km]
- Taylor 07FD002 [123 km]
- Dunvegan 07FD003 [296 km]
- Town of Peace River 07HA001 [397 km]
- Fort Vermilion 07HF001 [831 km]
- Peace Point 07KC001 [1136 km]

The estimated flows and water levels at these key downstream locations during the period of low flow releases are of particular importance.

2 Analysis

As part of the Site C Environmental Assessment, 1D hydraulic modelling using the MIKE 11 software was performed to assess the influence of Site C operations on downstream Peace River flows and water levels (Sadeque, 2012). This hydraulic model has been updated using more recently collected bathymetry and topography data in various BC Hydro studies subsequent to 2012. In addition, the model has been migrated to the MIKE HYDRO River (MHR) software platform which is the successor to MIKE 11 that has been developed by the Danish Hydraulic Institute. The calibration of the latest version of the Peace River 1D hydraulic model is similar or better than that of the 1D model used for the Site C Environmental Assessment.

For hydraulic modelling of Site C flow releases during reservoir filling, three sets of Peace River tributary daily flows between Site C and Peace Point were considered corresponding to dry, average and wet conditions between August 1 and November 15. These dates were used for the tributary flows since there was initially a different set of Site C flow releases during reservoir filling specified by the Site C Project team (McArthur, 2021) compared to the flow releases indicated in

Section 1 of this memo. The low flow periods for the initial set of scenarios started as early as August and ended as late as November. The downstream flow modelling for those initial scenarios is not documented in this memo as the Site C Project team has recently requested that the analysis focus on the planned flow releases indicated in Section 1.

The gauged tributaries of the Peace River are listed in Sadeque (2012). The two largest tributaries based on drainage area and mean annual flow between Site C and Peace Point are the Smoky and Wabasca Rivers. Since WSC did not publish any flow data for the Smoky River 07GJ001 in 2016 and 2017 and for the Wabasca River 07JD002 in 2017, the 10-year period from 2009 to 2015 and 2018 to 2020 was reviewed to identify the years that best represent dry, average, and wet conditions. The selected years are as follows:

- dry year - 2009
- average year - 2018
- wet year - 2019

The dry and wet years were selected based on the minimum and maximum daily average flows in the 10-year period considering all gauged tributaries. The average year was selected based on the year with gauged tributary flows closest to the median value in the 10-year period.

The average daily flows for the August 1 to November 15 period for the selected years for the four largest tributaries are shown in Table 1. Average daily flows for each of the other gauged tributaries for the August 1 to November 15 period were generally less than 10 m^3/s in each of the ten years.

Table 1: Average Daily Flow (m^3/s) from August 1 to November 15 for Major Tributaries

Tributary	2009 (dry year)	2018 (average year)	2019 (wet year)
Pine River 07FB001	82	100	214
Beatton River 07FC001	22	7	76
Smoky River 07GJ001	172	221	477
Wabasca River 07JD002	21	57	121

The Peace River 1D hydraulic model was run with the planned Site C flow releases shown in Section 1 and daily flows specified for the gauged tributaries between Site C and Peace Point corresponding to the dry, average and wet years.

3 Results

Tabulated results for modelled flows and water levels at the key downstream locations (listed in Section 1) are shown in Attachment A. The minimum and average modelled values are provided for the low flow period.

Table 2 shows the average of modelled daily flows during the low flow period at selected locations for the dry, average and wet tributary flow years.

Table 2: Average of Modelled Daily Flows (m^3/s) During the Low Flow Period at Selected Locations

Locations	Date Range for Low Flow Period *	2009 (dry year)	2018 (average year)	2019 (wet year)
Dunvegan	Sep.30 – Nov.3	676	682	847
Shaftesbury ferry crossing	Oct.1 – Nov.4	678	682	846
CNRL water intake	Oct.1 – Nov.4	809	864	1201
La Crete ferry crossing	Oct.3 – Nov.6	815	873	1219
Fort Vermilion water intake	Oct.4 – Nov.7	819	880	1223
Peace Point	Oct.7 – Nov.10	851	932	1313

* - Low flow period corresponds to the date range with the lowest average flow at each location. For consistency, a 35-day period is used at all locations. The period of lowest modelled flows (less than 900 m^3/s) at Site C tailrace is 35 days long from September 29 to November 2.

Due to the travel time along the Peace River, flow changes at Site C tailrace will not be observed at some of the downstream locations until a few days later.

The modelled water levels provided at ferry crossings and water intakes have higher uncertainty since the 1D model has not been locally calibrated at those locations due to a lack of available data.

The following threshold flows were provided by the Site C Project team:

- Dunvegan: 600 m^3/s
- Shaftesbury ferry crossing: 600 m^3/s and 900 m^3/s

- CNRL water intake: 750 m^3/s
- La Crete ferry crossing: 900 m^3/s
- Fort Vermilion: 900 m^3/s

The number of days during the entire simulation period when the modelled flow is below these thresholds is presented in Table 3 for the dry, average and wet years.

Table 3: Number of Days of Modelled Daily Flows Below Threshold

Threshold Flow	2009 (dry year)	2018 (average year)	2019 (wet year)
Dunvegan: 600 m^3/s	5	5	0
Shaftesbury ferry: 600 m^3/s	4	4	0
Shaftesbury ferry: 900 m^3/s	33	34	29
CNRL water intake: 750 m^3/s	5	0	0
La Crete ferry: 900 m^3/s	32	26	0
Fort Vermilion: 900 m^3/s	31	26	0

The period of planned low flow releases (390 m^3/s to 600 m^3/s) between September 29 and October 6 results in modelled flows at Dunvegan and Shaftesbury ferry to be less than 600 m^3/s for four to five days during the dry and average years. Similarly, the modelled flow at the CNRL intake is less than 750 m^3/s for five days in the dry year but remains above the threshold during the average year.

The threshold of 900 m^3/s at the Shaftesbury ferry, La Crete ferry and at Fort Vermillion is not met for most of the period between early October and early November during the dry and average years as tributaries do not provide the additional required flow during Site C reservoir filling. Also, the threshold of 900 m^3/s at the Shaftesbury ferry is not met for most of the low flow period in the wet year.

4 Conclusions

Hydraulic modelling performed for planned Site C flow releases during reservoir filling provides estimates of flows and water levels at key downstream locations.

The average of modelled daily flows during the low flow period in a dry tributary flow year is estimated to be approximately 675 m^3/s at Dunvegan and Shaftesbury ferry crossing and between

800 m^3/s and 820 m^3/s at the CNRL water intake, La Crete ferry crossing and Fort Vermilion water intake. In an average tributary flow year, the average of modelled daily flows during the low flow period will be similar at Dunvegan and Shaftesbury ferry crossing and between 860 m^3/s and 880 m^3/s at the CNRL water intake, La Crete ferry crossing and Fort Vermilion water intake.

The period of planned low flow releases (390 m^3/s to 600 m^3/s) between September 29 and October 6 results in modelled flows at Dunvegan and Shaftesbury ferry to be less than 600 m^3/s for four to five days during the dry and average years. Similarly, the modelled flow at the CNRL intake is less than 750 m^3/s for five days in the dry year but remains above the threshold during the average year.

The threshold of 900 m^3/s at the Shaftesbury ferry, La Crete ferry and at Fort Vermillion is not met for most of the period between early October and early November during the dry and average years as tributaries do not provide the additional required flow during Site C reservoir filling. Also, the threshold of 900 m^3/s at the Shaftesbury ferry is not met for most of the low flow period in the wet year.

5 References

McArthur, M., 2021. Email from Michael McArthur to Faizal Yusuf, RE: Peace River – Site C downstream flow modelling, November 23, 2021.

Sadeque, F., 2012. Site C Clean Energy Project – Downstream Flow Modelling (1D). Site C Clean Energy Project Volume 2 Appendix D Surface Water Regime Technical Memos, Part 2 Downstream Flow Modelling (1D), December 4, 2012.

Attachments

- Attachment A: Modelled Daily Flows and Daily Water Levels at Key Downstream Locations

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Attachment A
Modelled Daily Flows and Daily Water Levels at Key Downstream Locations

Minimum modelled Daily Flow values				
Location	Chainage (km)	Discharge (m^3/s)		
		Tributary Flow Assumptions		
		Dry	Avg	Wet
Site C tailrace	106	403	403	403
Old Fort - WSC 07FA004	111.7	402	402	402
Taylor - WSC 07FD002	123	472	480	579
Dunvegan Bridge - WSC 07FD003	296	510	513	693
Shaftesbury Ferry Crossing	371	498	503	688
Town of Peace River - WSC 07HA001	397	652	753	1053
CNRL Intake	417	648	751	1053
La Crete Ferry Crossing	698	674	776	1085
Fort Vermilion - WSC 07HF001	831	691	783	1096
Fort Vermilion Intake	833.5	691	783	1095
Peace Point - WSC 07KC001	1136	743	852	1210

Average of Modelled Daily Flows (m^3/s) During the Low Flow Period						
Location	Chainage (km)	Date Range for Low Flow Period*		Discharge (m^3/s)		
				Tributary Flow Assumptions		
				Dry	Avg	Wet
Site C tailrace	106	29-Sep	2-Nov	597	597	597
Old Fort - WSC 07FA004	111.7	29-Sep	2-Nov	597	597	597
Taylor - WSC 07FD002	123	29-Sep	2-Nov	664	671	779
Dunvegan Bridge - WSC 07FD003	296	30-Sep	3-Nov	676	682	847
Shaftesbury Ferry Crossing	371	1-Oct	4-Nov	678	682	846
Town of Peace River - WSC 07HA00	397	1-Oct	4-Nov	809	864	1201
CNRL Intake	417	1-Oct	4-Nov	809	864	1201
La Crete Ferry Crossing	698	3-Oct	6-Nov	815	873	1219
Fort Vermilion - WSC 07HF001	831	4-Oct	7-Nov	819	880	1223
Fort Vermilion Intake	833.5	4-Oct	7-Nov	819	880	1223
Peace Point - WSC 07KC001	1136	7-Oct	10-Nov	851	932	1313

* Low flow period corresponds to the date range with the lowest average flow at each location. For consistency, a 35-day period is used at all locations. The period of lowest modelled flows (less than 900 m3/s) at Site C tailrace is 35 days long from September 29 to November 2.

Minimum modelled Daily Water Level values (m)				
Location	Chainage (km)	Water Level (m)		
		Tributary Flow Assumptions		
		Dry	Avg	Wet
Site C tailrace	106	410.3	410.3	410.3
Old Fort - WSC 07FA004	111.7	406.1	406.1	406.1
Taylor - WSC 07FD002	123	402.1	402.1	402.3
Dunvegan Bridge - WSC 07FD003	296	338.3	338.3	338.8
Shaftesbury Ferry Crossing	371	317.4	317.5	317.8
Town of Peace River - WSC 07HA001	397	310.8	310.9	311.3
CNRL Intake	417	302.5	302.7	303.2
La Crete Ferry Crossing	698	252.2	252.5	253.2
Fort Vermilion - WSC 07HF001	831	245.3	245.5	246.0
Fort Vermilion Intake	833.5	245.3	245.4	246.0
Peace Point - WSC 07KC001	1136	209.9	210.1	210.9

Average of Modelled Daily Water Level values (m) During the Low Flow Period						
Location	Chainage (km)	Date Range for Low Flow Period*		Water Level (m)		
				Tributary Flow Assumptions		
				Dry	Avg	Wet
Site C tailrace	106	29-Sep	2-Nov	410.6	410.6	410.6
Old Fort - WSC 07FA004	111.7	29-Sep	2-Nov	406.6	406.6	406.6
Taylor - WSC 07FD002	123	29-Sep	2-Nov	402.4	402.4	402.6
Dunvegan Bridge - WSC 07FD003	296	30-Sep	3-Nov	338.7	338.7	339.1
Shaftesbury Ferry Crossing	371	1-Oct	4-Nov	317.8	317.8	318.1
Town of Peace River - WSC 07HA00	397	1-Oct	4-Nov	311.0	311.0	311.4
CNRL Intake	417	1-Oct	4-Nov	302.8	302.9	303.4
La Crete Ferry Crossing	698	3-Oct	6-Nov	252.6	252.7	253.5
Fort Vermilion - WSC 07HF001	831	4-Oct	7-Nov	245.5	245.6	246.2
Fort Vermilion Intake	833.5	4-Oct	7-Nov	245.5	245.6	246.1
Peace Point - WSC 07KC001	1136	7-Oct	10-Nov	210.1	210.3	211.0