Peace River Site C Hydro Project

Stage 2

Review of Potential Downstream Changes from Site C Operations

Preliminary Findings

BC Hydro

October 2009

EXECUTIVE SUMMARY

As part of Stage 2, BC Hydro sought to gain a preliminary understanding of the potential downstream effects associated with the potential Site C project, as it is currently designed. This involved preparing sample water management scenarios in order to inform preliminary studies. Overall, preliminary studies associated with downstream flows, water elevations, sediment transport and geomorphology (riverbed forms and processes that shape them) suggest there would be relatively few notable changes beyond those within a few kilometres downstream of the dam. Further study of potential changes would be required should the project proceed to future stages of development.

Flows

Flows on the Peace River upstream of the BC-Alberta border are driven by local hydrology and the operation of the W.A.C. Bennett Dam. As Site C is not expected to have significant levels of water storage, normal downstream flows are expected to change very little if Site C is constructed. Near to the dam, there may be some changes to the timing and magnitude of river level fluctuations. However, due to the significant volumes of water flowing into the Peace River downstream of the potential Site C location and the natural attenuation of flow variability, these changes are not expected to be significant at or beyond the Town of Peace River approximately 300 km downstream of the potential project. Further work on this topic would be required should the project proceed.

Sediment

Similar to water volumes, the majority of Peace River sediment loads reaching the Alberta border come from tributaries downstream of the potential Site C location. Thus, relatively speaking, changes to the sediment load would be modest and not expected to have a significant effect downstream.

Ice Conditions

Preliminary studies of downstream river ice conditions were also conducted. Hydroelectric facilities on rivers can change ice conditions as a dam creates a barrier that gathers ice on the upstream side, facilitating an ice front upstream of the dam. A dam may also change the temperature of the water flowing downstream which reduces or promotes downstream ice formation depending on whether the water is warmer or cooler during the winter months.

Both the Site C dam and Alberta's proposed Dunvegan Hydroelectric Project are expected to change ice formation in the Peace River if either (or both) were to proceed to construction. If winter water temperatures are warmer than current conditions at the proposed Site C location, the ice formation changes could cause a reduced frequency of spring ice jamming associated with the Smoky River breakup. If the winter water temperatures are cooler, ice break-up may occur later in the year. There may also be an effect on the formation and use of ice bridges downstream of the project. Further study on this topic is required.

Further Study

At this time, no decision has been made to build Site C. The findings summarized in this paper are preliminary and based on the design for Site C as historically conceived. Additional studies of potential downstream impacts and their effects would be required if the Site C Project were to proceed to future stages. These studies would be required as part of an independent provincial and federal environmental assessment to better define the potential impacts of the project. These studies would be defined based on requirements identified by the applicable regulatory agencies and guided by data gaps, discussions with regulatory agencies, First Nations and stakeholder concerns.

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1.0 INTRODUCTION

As part of Stage 2, BC Hydro looked at sample water management scenarios to provide a preliminary understanding of the potential downstream impacts associated with Site C. Preliminary studies associated with downstream flows, water elevations, sediment transport and geomorphology (riverbed forms and processes that shape them), and downstream ice conditions were conducted and the findings are discussed further in this report.

At this time, no decision has been made to build Site C. The findings summarized in this paper are all preliminary, and additional studies of potential downstream impacts and their effects would be required if the Site C Project were to proceed to future stages. These studies would be required as part of an independent provincial and federal environmental assessment in order to better define the potential impacts of the project on downstream issues. These studies would be defined based on requirements identified by the applicable regulatory agencies and guided by current data gaps as well as discussions with regulatory agencies, First Nations and stakeholder concerns.

2.0 OVERVIEW OF PEACE RIVER OPERATIONS

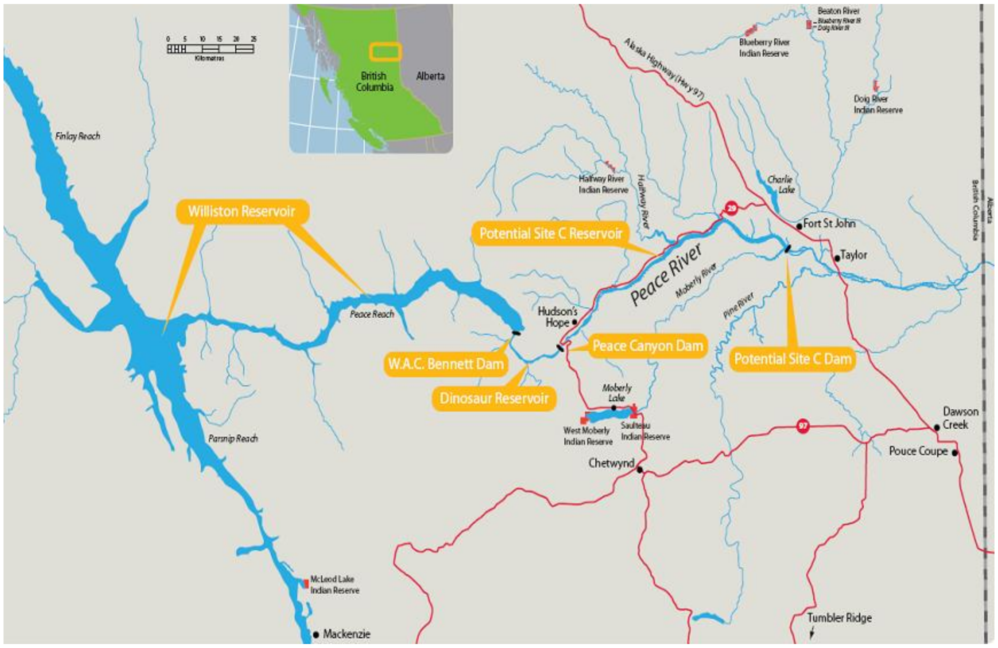
2.1 FACILITIES

The GM Shrum generating station (GMS), located at the W.A.C. Bennett Dam, and the Peace Canyon dam and generating station (PCN) play a key role in British Columbia's integrated electrical system, providing approximately one-third of BC Hydro's annual energy production.

The W.A.C. Bennett Dam impounds Williston Reservoir, which provides the reservoir storage and regulation for GMS and PCN. Located 23 kilometres downstream of GM Shrum, the PCN Generating Station was designed to have the same discharge capacity as GMS when all generating units are in service. Peace Canyon Dam impounds Dinosaur Reservoir.

Site C represents a potential third dam and hydroelectric generating station, located downstream of GMS and PCN, on BC's portion of the Peace River.

Figure 1: BC Hydro Facilities on the Peace River



2.1.1 W.A.C. Bennett Dam

The W.A.C. Bennett Dam is 183 metres high and regulates the Peace River and upstream tributaries to form the Williston Reservoir. With a surface area of 177,000 hectares, Williston Reservoir is among the largest hydroelectric reservoirs in North America. It is a multiyear storage reservoir, which means that it can be drawn down from full pool to its minimum level over several years to provide power to BC Hydro customers in the event of exceptionally low flow conditions in B.C. Within any given day, the facility may release water for generation to meet instantaneous electricity demands. When these releases exceed inflow, storage from the reservoir is used. As part of its annual operating cycle, the facility stores water when the Pacific Northwest and/or Alberta has surplus hydroelectric energy during periods of high river runoff (typically during late April to early July due to melting snow) and inflows exceed generation demands at GMS and PCN. This reservoir storage is then used during subsequent high electricity demand periods (typically late summer, fall, and winter) and when generation demands exceed inflow.

G.M. Shrum Generating Station, adjacent to W.A.C. Bennett Dam, houses 10 generating units with a maximum continuous generating capacity of 2,730 MW. In Fiscal 2009, G.M. Shrum generated approximately 15,287 GWh of energy, which was roughly 30 per cent of BC Hydro's annual energy production. BC Hydro is continuing to improve this generation facility, with a project to expand the capacity of G.M. Shrum by 90 MW now in the development stages and expected to be online by 2011.

2.1.2 Peace Canyon Dam

The 61-metre-high Peace Canyon Dam impounds the Peace River to form Dinosaur Reservoir, which extends upstream towards W.A.C Bennett Dam. It is a narrow reservoir with a surface area of 890 hectares (less than 1% of the surface area for Williston) and is generally confined within the steep rocky slopes of the Peace River canyon.

The Peace Canyon Generating Station is a four-unit power plant with maximum generating capacity of 694 MW. In Fiscal 2009, it generated 3,801 GWh of energy. Unlike Williston, with its multi-year reservoir storage capability and the ability to draft almost 100 feet, Peace Canyon's reservoir storage is only 10 feet. Subsequently, generation at PCN is effectively limited to water that has already been used upstream to generate power at G.M. Shrum. The limited storage available at Dinosaur Reservoir, however, remains very important. The 10 ft operating range is used to coordinate the operation of the GMS and PCN powerplants over the daily cycle, managing short-term flow imbalances between GM Shrum and Peace Canyon associated with maintenance activities, downstream ice conditions, and/or minor variations in the system electricity demand.

Peace Canyon, like the potential Site C project, benefits from the reservoir storage and regulation of the Peace River at W.A.C. Bennett without having a large storage reservoir of its own. While the same amount of water is used at both G.M. Shrum and Peace Canyon under normal conditions over the day, Peace Canyon has a lower generation output because its dam has a lower head (less elevation between the reservoir and generating station) than does G.M. Shrum. For every 4 MW of power produced at GMS, PCN produces approximately 1 MW with the same amount of water.

BC Hydro is currently upgrading all four turbines at the Peace Canyon Generating Station to address design deficiencies, reduce the risk of forced outages and make the plant safer for employees. The work is expected to be completed in 2010.

2.2 GENERATION PROFILE

Generation from the Peace River projects is a crucial swing resource to meet changes in the provincial integrated electricity system demands. The flexibility offered by Williston Reservoir's multi-year reservoir storage is used to match generation to overall electricity demand over periods ranging from minutes to multiple years to provide low-cost, reliable energy. BC Hydro has an existing water license that provides the right to vary flows between 283 and 1,982 cms[1] (10,000 – 70,000 cfs). The operation of these facilities within this range is at BC Hydro's discretion and will depend on system requirements.

G.M. Shrum and Peace Canyon generating stations are typically operated over the day in hydraulic balance, each plant using a similar amount of water for generation. As mentioned previously, the limited storage at Dinosaur Reservoir may be drafted or filled within the day to allow the combined operation of G.M. Shrum and Peace Canyon to be

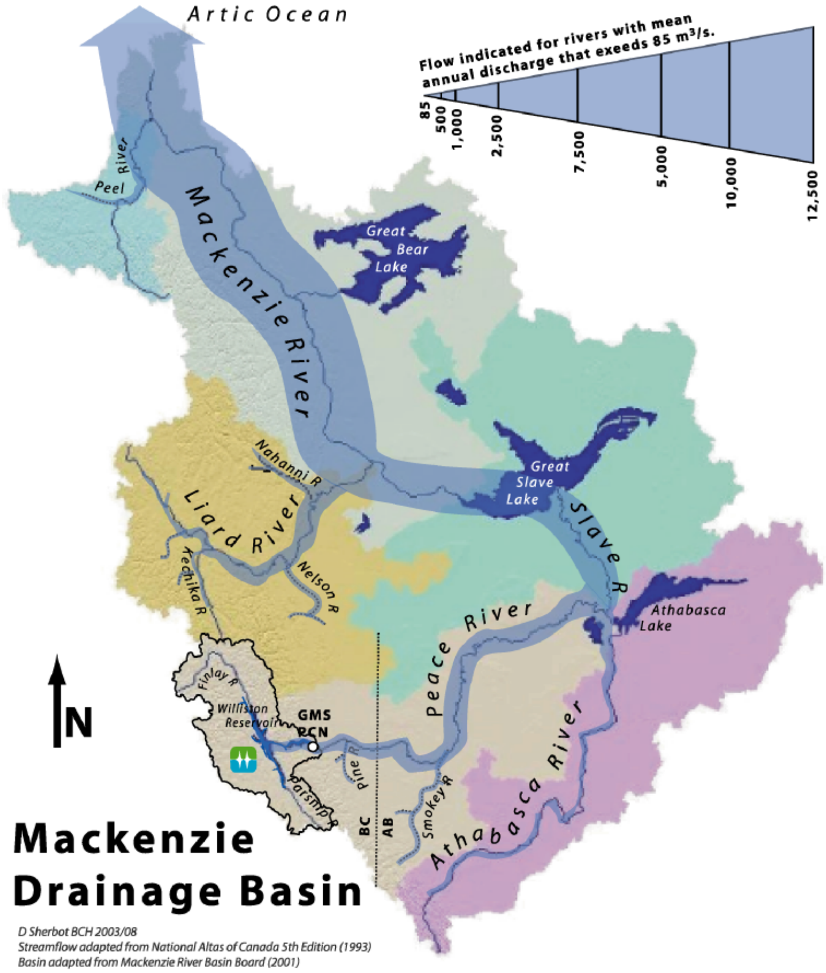
[1] cms = cubic meters per second, cfs = cubic feet per second;

coordinated and optimized to meet peak loads, respond to market opportunities, create smoother flows for favourable ice formation downstream and/or manage maintenance activities. Under these scenarios, the generation profiles for G.M. Shrum and Peace Canyon may have different within-day shapes.

2.3 PEACE RIVER HYDROLOGY

The Peace River originates in the Rocky Mountain Trench at the confluence of the Finlay and Parsnip rivers. The Peace River flows east through B.C., then northeast through Alberta where it meets the Riviere des Rochers, the main discharge from the Peace-Athabasca Delta and Lake Athabasca. Riviere des Rochers flows north into the Slave River, which then flows into the Great Slave Lake in the Northwest Territories. From the Great Slave Lake, the Mackenzie River flows northwest into the Arctic Ocean. At approximately 4,200 kilometres long, the Finlay-Peace-Slave-Mackenzie system is the second longest continuous stream in North America. Figure 2 illustrates the Mackenzie River Basin and the relative volume in the river as it flows downstream from the W.A.C. Bennett Dam to Slave River and out to the Arctic Ocean.

Figure 2: Peace River Flows and the Mackenzie River Basin



Mean annual inflow into Williston Reservoir is approximately 1,075 cms (38,000 cfs). A small contribution, 9 cms (320 cfs), is associated with local tributary inflow into Dinosaur Reservoir downstream of W.A.C. Bennett Dam. Flows into Williston are composed of, on average, equal parts snowmelt and rainfall. There are no significant glaciers feeding the Williston reservoir and glacial melt is not ever expected to be a significant component of the inflows. The yearly runoff pattern into Williston Reservoir is characterized by low inflows during the December through April period and much higher inflows when the snow melts in late April through July. Heavy summer rains can create high inflows in June through July. Moderate inflows due to rainfall are expected in August through November. Approximately 63 per cent of the inflow into Williston Reservoir occurs in the May through July period, with the peak inflow typically occurring due to snowmelt between mid-May and mid-June.

Because Williston Reservoir has multi-year storage capability, annual outflow volumes will vary and may not be directly related to annual inflows. For example, in years of high inflows, extra water may be stored to refill the reservoir. This additional reservoir storage enables BC Hydro to release additional water in years of low inflows to keep costs low and maintain reliable energy. At full pool (e.g. maximum storage) Williston Reservoir can store approximately 114% of the Peace River's annual inflow.

2.4 POTENTIAL SITE C PROJECT

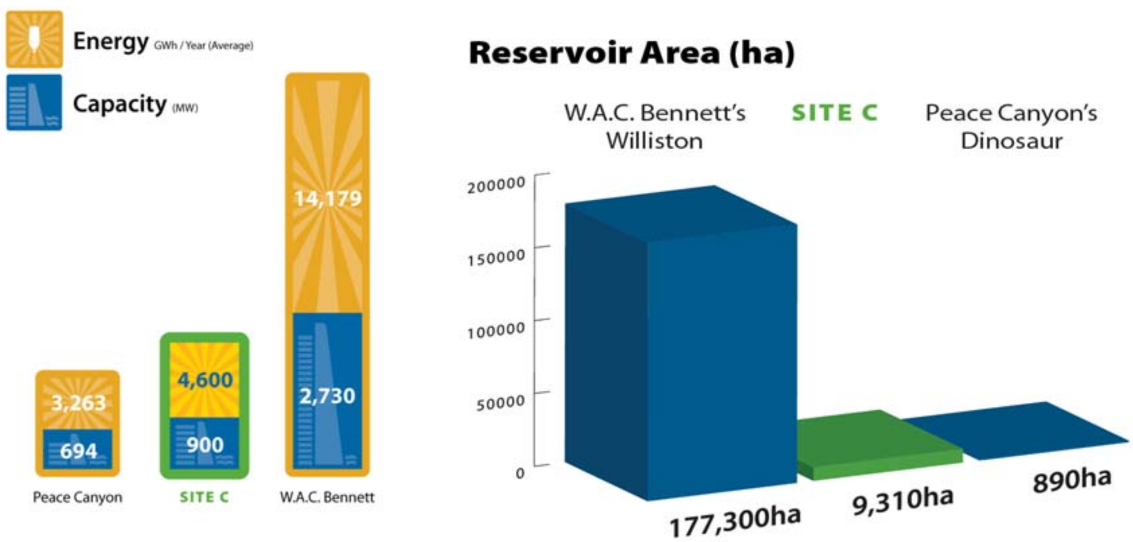
The Site C hydroelectric project would be the third hydroelectric facility on the Peace River in British Columbia. As currently conceived, the project would consist of a 60-metre dam and a powerhouse containing six generating units with a total capacity of 900 MW. The project would contribute an average of 4,600 GWh of electricity annually with 4,000 GWh of generation in a critical water year (i.e. the driest year likely to occur based on the historical record). The facility would be 83 kilometres downstream of Peace Canyon and seven kilometres southwest of Fort St. John, immediately downstream of the confluence of the Moberly River and the Peace River. The reservoir, with a surface area of approximately 9,310 hectares (~5% Williston), would extend back towards the base of the Peace Canyon dam.

Like the Peace Canyon Dam, Site C would take advantage of the regulation of the Peace River by the W.A.C. Bennett Dam, generating additional electricity from water that has already flowed through the two upstream generating stations. Most of the inflow into the reservoir would come from Peace Canyon, but the Halfway River and, to a lesser extent, the Moberly River, would also contribute some flows. Similar to Peace Canyon, Site C as currently conceived would have a relatively stable reservoir with limited daily storage and would typically operate in approximate hydraulic balance over any given day, meaning that water flowing into the project would be approximately equal to the water flowing out of the project.

2.4.1 Comparison of Site C to Existing Peace Projects

Figure 3 provides a comparison between Site C and other BC Hydro hydroelectric facilities on the Peace River. System-wide, Site C would be characterized as a mid-size hydro generating facility in terms of generating capability, well behind G.M. Shrum, Revelstoke and Mica.

Figure 3: Site C in Comparison to Other BC Hydro Facilities on the Peace River



3.0 DOWNSTREAM FLOWS

3.1 CURRENT CHARACTERISTICS

BC Hydro's current provincial water licenses for the Peace River allow for generation discharges up to 1,982 cms[2] (~70,000 cfs[3]) at PCN. Additional requirements under a provincial Water Act order contain provisions for a minimum fisheries flow of 283 cms (10,000 cfs). This means that BC Hydro regularly operates Peace Canyon within a discharge range of 283 – 1,982 cms (10,000 - 70,000 cfs), as per its water license and as driven by the requirements of the BC electricity system. Within this range and when managing unavoidable operations above this range, there are a number of factors that BC Hydro considers as part of the Peace River operations. Some key considerations are listed in Table 1.

Table 1: Some of BC Hydro's operating considerations for Peace River facilities

- Dam safety
- Erosion and sloughing
- Fish and fish habitat
- Flood management (upstream / downstream)
- Ice management (downstream)
- Effluent dilution
- Low cost, reliable energy
- Maintenance and capital projects
- Recreation and tourism
- Reservoir levels
- Transportation and navigation
- Water quality
- Water supply (industrial / domestic)
- Wildlife and terrestrial habitat

While infrequent, it can be expected that, as part of normal operations, BC Hydro may discharge flows in excess of 1,982 cms to manage water when inflows exceed the available storage of Williston and/or Dinosaur reservoirs. Operations during these events are managed with additional due diligence associated with dam and facility safety, public safety, and environmental concerns. These events are discussed further in the following section.

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[2] cms = cubic meters per second
[3] cfs = cubic feet per second

While BC Hydro has a license to operate Peace Canyon flows within the 283 to 1,982 cms range, operations of Peace River facilities generally follow a similar pattern to that of domestic electricity use, with high generation (and flows) in the winter and lower generation (and flows) in the spring. Flows out of the Peace River projects are similarly higher in the daytime and lower at night-time. Figures 4 and 5 show the relationship between the demand for electricity and flows out of the Peace Canyon generation facility. These are, however, long-term patterns – for any particular day there may be operational constraints or other issues that drive Peace River operations. These long-term patterns may change at BC Hydro's discretion as long as they are within licensed ranges.

Figure 4: Annual Electricity Demand and Peace River Flows at Peace Canyon Dam

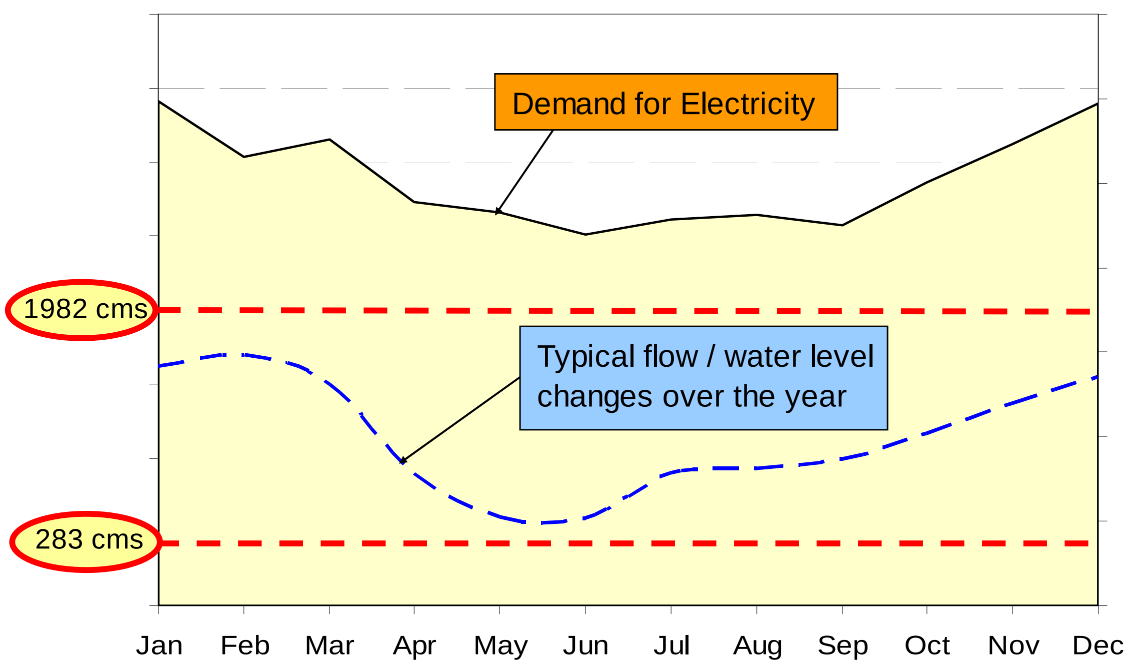
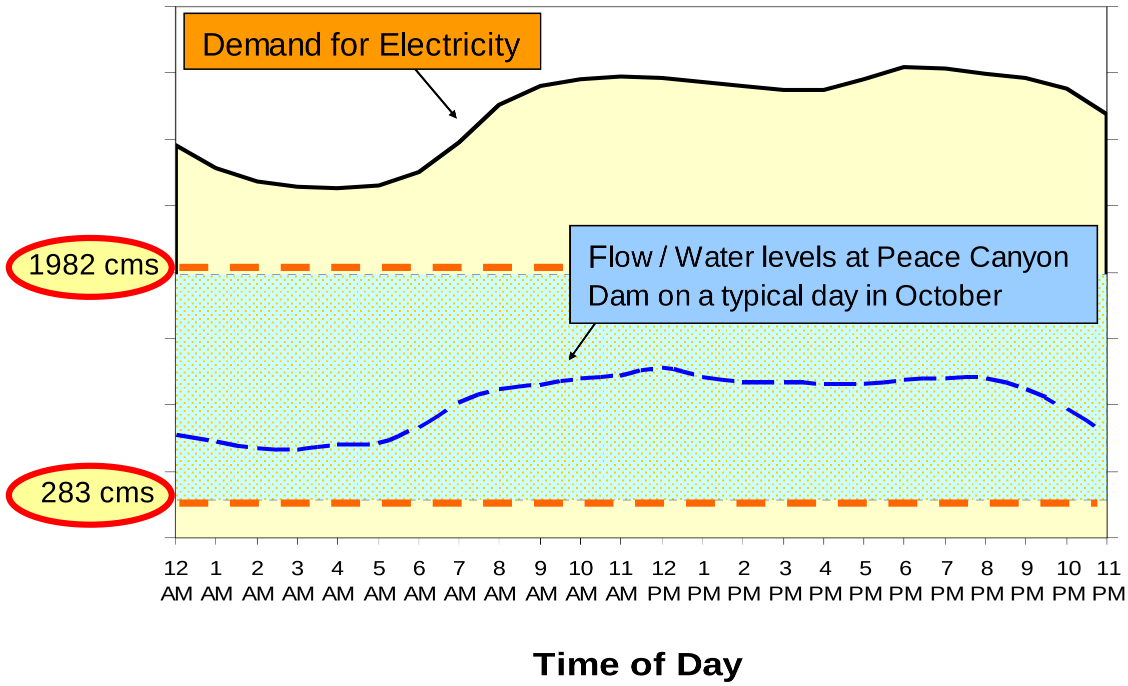


Figure 5: Daily Electricity Demand and Peace River Flows at Peace Canyon Dam



3.1.1 Spilling and Water Routing

The design of the G.M. Shrum and Peace Canyon generation facilities is intended to utilize all available water inflow for power generation in most years. There are, however, operational scenarios when inflows cannot be managed within the available storage or generation capacity of either facility. When this occurs the affected facility will have to spill (release) the surplus water in order to preserve dam safety.

Both Peace Canyon (PCN) and WAC Bennett (GMS) hydroelectric facilities are designed to spill. Spill releases can be part of normal and/or emergency operations and do not conflict with any licence requirements. On other river systems with upstream and downstream projects (e.g. Seven Mile Dam) spilling to pass high inflow events or manage imbalances between upstream and downstream generation capacity is routine. Similar spills at GMS and/or PCN are less frequent, but are still expected under normal operations.

Small spills may occur to meet environmental fisheries flows during plant outages, to manage hydraulic imbalances between GMS and PCN to meet energy demands, or to accommodate routine maintenance such as gate testing. Larger spills, while less frequent, will be expected when storage at Williston is near full and the reservoir levels are being managed within licenced storage limits. The risk of spill is a very important consideration in BC Hydro's operations planning process since spill represents water (e.g. energy) that cannot be used for generation.

Over the past forty years, there have been eight significant spill events on the Peace River system. There have only been two spill events in the past twenty years of operations on the Peace River. The impacts of small spills (i.e. spills where the total discharge remains less than the total possible discharge from generation) on interests other than energy production has no significant downstream effects. Impacts of larger spills (i.e. spills where total discharge exceed normal generation discharge of 70,000 cfs) may have impacts with both positive and negative effects in the vicinity of discharging dam.

Communication about spill events at W.A.C. Bennett Dam or Peace Canyon Dam and the environmental monitoring and reporting is conducted in accordance with the Peace Spill Protocol outlined in the Peace Water Use Plan (September 2003).

3.1.2 Progression of Variations in Downstream Water Levels

Downstream water levels at any particular point in the Peace River are dependent on the flow volume of the Peace River, as well as on the size and shape of the channel in which the flows pass, the slope at that point, and to a lesser extent, the surface the water flows over. While the flows out of Peace Canyon may fluctuate within the water license limits throughout the day, during normal operations the variations in downstream flows are dampened progressively downstream (similar to motorboat generated waves getting smaller as they travel further). The variations are also lessened as the contribution of downstream tributaries to the Peace River becomes increasingly significant to the overall flow. In addition, any change in flows at Peace Canyon will take time to travel to points downstream. Figure 6 illustrates the reduction in the variability of water levels from a sample two week period in October, 2008. Figure 7 illustrates the travel time for a change in flows at Peace Canyon Dam to be noticed downstream during a three week period in October 2007.

Figure 6: Example of the Dampening of Water Levels Downstream, October 2008

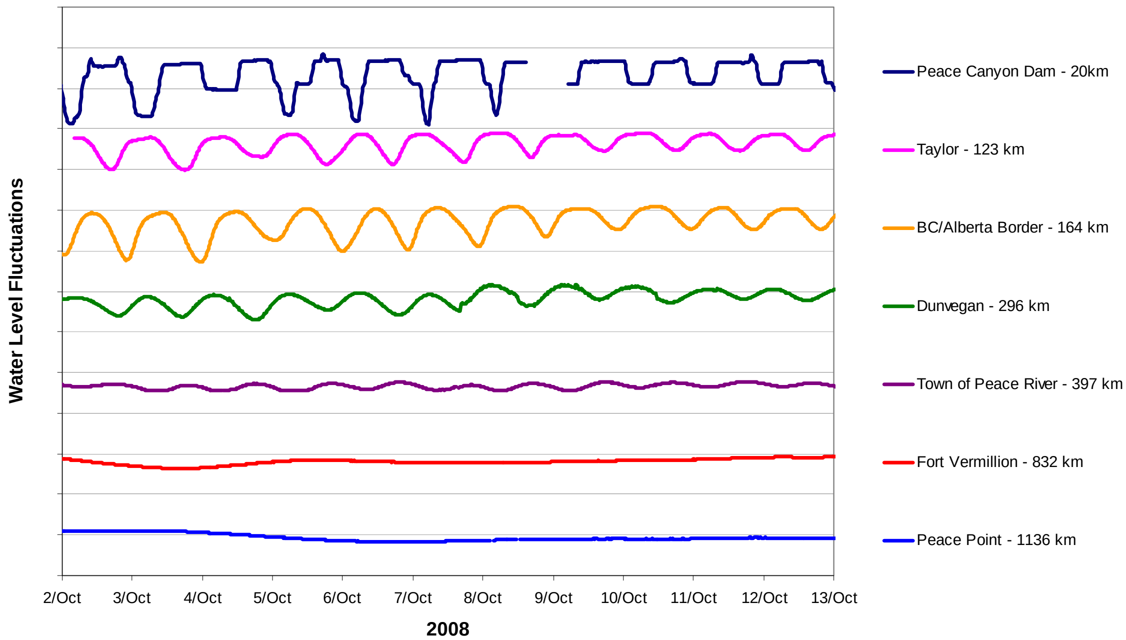
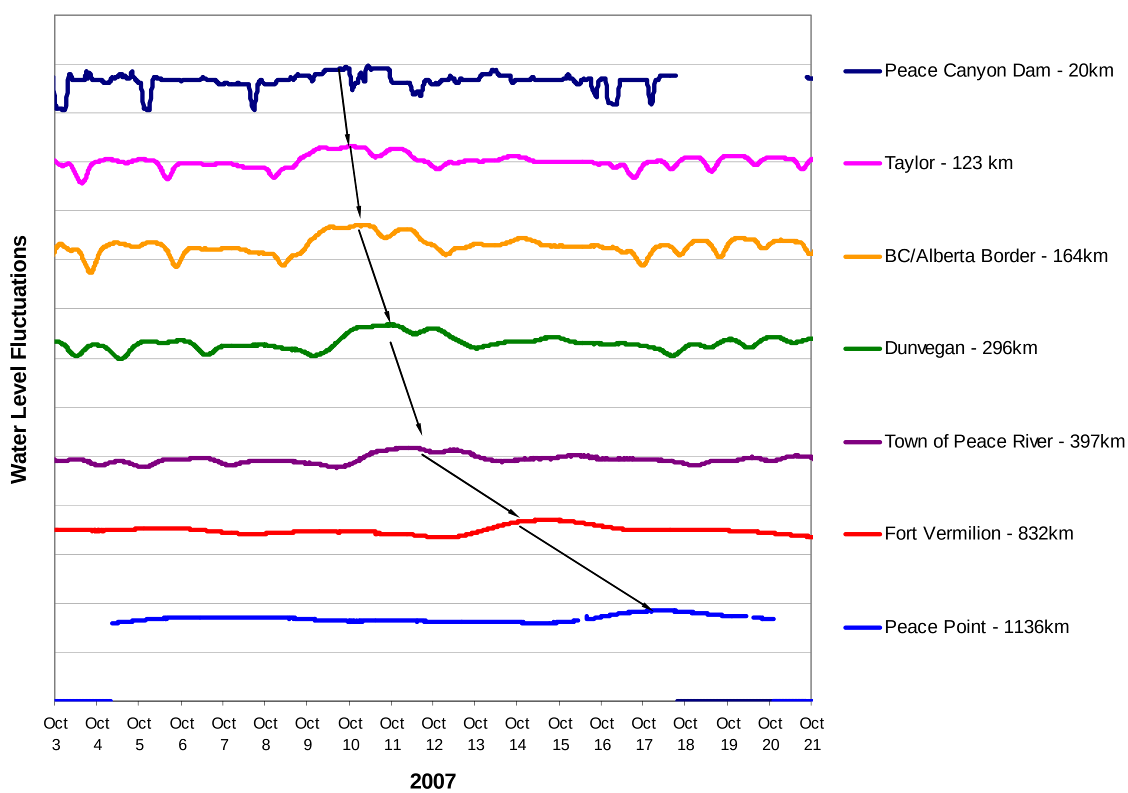


Figure 7: Example of the Travel Time of Water Level Changes Downstream, October 2007



In general, the manner in which downstream river levels change due to a change in BC Hydro operations will be different at different points downstream of Peace Canyon Dam. In considering the potential water level changes associated with a hypothetical extreme change in river flows (specifically a sustained step-change increase in flow by 1,000 cms over a few minutes), the rate of water level increase is lessened with distance from Peace Canyon (the water level would take several hours or days to rise in response to the change in flow at distances further downstream (Table 2). The amount of water level rise at any point along the river is dependent on many factors including the depth, width and slope of the river. Generally the river gets flatter and wider with distances downstream. The two have opposite effects: a flatter river increases the water level change, and a wider river decreases it. From Peace Canyon to the Town of Peace River, the widening of the river dominates this effect and the water level step change decreases with distance downstream. Downstream of Town of Peace River at about Carcajou and continuing on through Ft. Vermilion and Peace Point the river slope flattens considerably which causes the step change in increase (Table 2). At the Slave River the water level decreases again since the river is wider and also moves faster over the steep bedrock than the Peace River at Peace Point and it does not have to rise as much to accommodate the same flow (Table 2).

Table 2: Downstream Changes in Water Levels from a Change in Flow of 1,000cms at Peace Canyon Dam

Location	Average River Width (m)	River Slope (m/km)	Contribution from downstream tributaries to total annual flow (%)	Annual regulated flow (%)	Mean Annual flow (m^3/s)	Change in Water Level (m)	Time for Water Level to Rise
Hudson's Hope	200	0.65	0%	100%	1075	1.5	Full rise in less than an hour
District of Taylor	450	0.47	27%	73%	1470	1.0	Full rise in hours
Town of Peace River	700	0.27	44%	56%	1930	0.7	Full rise in less than a day
Fort Vermilion	800	0.05	49%	51%	2090	1.3	Full rise over 1 day
Peace Point	800	0.04	49%	51%	2120	1.6	Full rise over 2 days
Slave at Fitzgerald	1100	1.27	68%	32%	3400	0.4	Full rise over 2 days or more days

3.2 POTENTIAL CHANGES FROM SITE C

As part of Stage 2 activities, a preliminary assessment of the effects of Site C operations on downstream Peace River flows and water levels was conducted by using a model to predict flows as far downstream as the Town of Peace River. Based on this study, normal downstream flows are expected to change very little if Site C is constructed as currently conceived.

Two flow scenarios were considered for downstream flows to the Town of Peace River:

- Reference case (no Site C)
- Scenario including Site C as currently conceived (Optimizes energy production within publicly committed constraints, i.e. reservoir operating range +/- 0.9 m (6 feet total fluctuation).

The Reference case discharges were based on Peace Canyon Dam outflows combined with the assumed daily local inflows from tributaries between Peace Canyon Dam and Site C. To study the potential operational effects of a range of flow scenarios, three years were selected which corresponded to a typical water discharge year, a high water discharge year, and a low water discharge year. Peace River operations and resulting downstream flows were modeled for all three water discharge scenarios, with and without Site C.

The preliminary results indicate that the downstream discharges for the Site C operating scenario are generally very similar to the reference case without Site C. Directly downstream of the potential Site C dam, changes to flows will be more pronounced, whereas further downstream at the Town of Peace River, flow fluctuations will have been almost completely attenuated and dampened. Based on the preliminary modelling results, it is expected that with Site C, the high water level at the District of Taylor would be larger than the current high water level conditions by 40 cm roughly 0.8% of the time (Table 3). Similarly, the change in high water level at Taylor with Site C would be less than 5 cm from current conditions 61.5% of the time. At the Town of Peace River, the change in high water levels with Site C would never be more than 40 cm and would be less than 5 cm 87% of the time. Table 4 presents the preliminary model results for predicted changes in low water levels.

Table 3: Changes in 24-hr Maximum Water Level as a Percentage of Exceedance*

	Freq. Change from Current 24hr High Water Level*			
Location	**> 0.4 m**	**> 0.2 m**	**> 0.1 m**	**> 0.05 m**
Taylor	0.8%	11.2%	24.1%	38.5%
Alces	1.0%	14.8%	27.7%	42.9%
Town of Peace River	0%	0.2%	3.5%	13.0%

* - Note: Based on three years of data

Table 4: Changes in 24-hr Minimum Water Level as a Percentage of Exceedance*

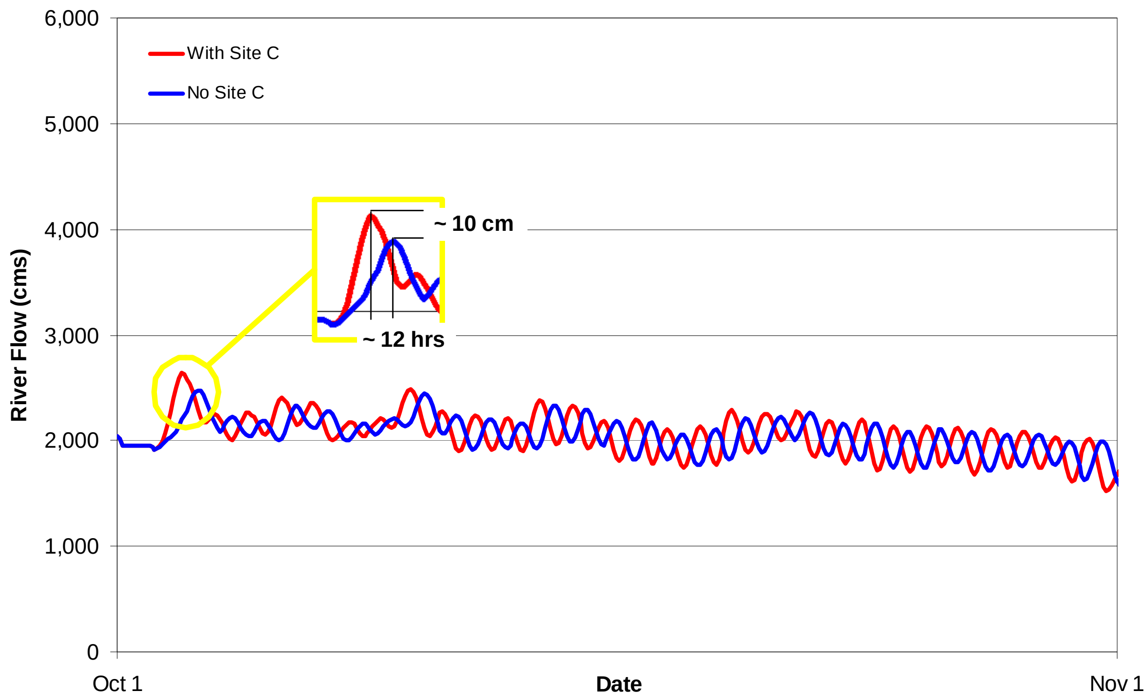
	Freq. Change from Current 24hr Low Water Level*			
Location	**> 0.4 m**	**> 0.2 m**	**> 0.1 m**	**> 0.05 m**
Taylor	1.9%	14.9%	31.5%	46.9%
Alces	4.2%	23.2%	43.5%	60.1%
Town of Peace River	0%	0.4%	1.9%	7.8%

* - Note: Based on three years of data

Figure 8 shows an example of a potential change in high water level within a 24-hour period at the Town of Peace River in a typical October scenario. As per Table 3, the difference in the high water level between the scenarios with and without Site C is generally expected to be less than 10cm roughly 96 % of the time.

With Site C, the minimum and maximum flows would occur approximately 10 to 12 hours sooner than the current conditions. This is because the water releases would follow the daily load fluctuations and be released at the Site C location rather than the current situation at the Peace Canyon Dam which is 10 to 12 hours water travel time upstream. For example, an increase in the water flowing out of the Peace Canyon powerhouse at 5 am would flow through the potential Site C location between 3 pm and 5pm (10 to 12 hours later). If Site C was operated similarly to Peace Canyon, this increase would occur at 5am instead of 3pm to 5pm.

Figure 8: Preliminary Results – Changes to downstream water levels due to Site C (Town of Peace River, October – Typical water discharge year)



NOTE: Modelled flow is represented. Figure is based on an optimization model scenario for an average discharge year with constraints (i.e. min/max flows at Site C of 283 – 1,982 cms combined with the daily local inflows). Actual flows may vary based on load and operational constraints.

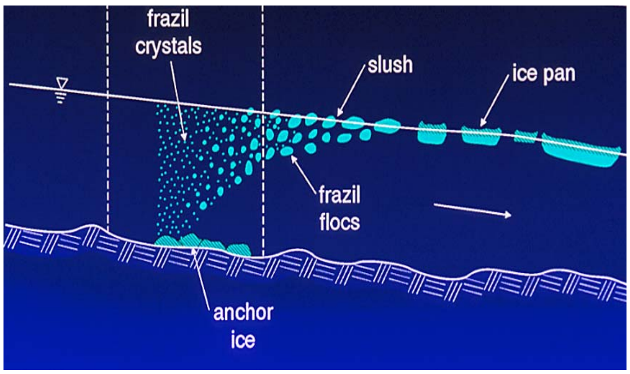
If the project were to proceed to future stages of development, additional studies would be performed to better understand the potential water level impacts downstream associated with the Site C project. BC Hydro would also consult with regulatory agencies, local governments, stakeholders and first nations to identify any specific 'areas of interest' or operations downstream where the relatively small changes to flows could potentially have an impact.

4.0 WATER TEMPERATURE AND ICE COVER

4.1 CURRENT CHARACTERISTICS

The Peace River flows northwards to the Arctic Ocean, and thus water released from the Bennett and Peace Canyon dams cools as it travels downstream in the winter. As the temperature approaches the freezing point of water, small ice crystals ("frazil ice") combine to form slush and then larger ice pans that group together at a constriction in the river and form an ice front. The ice front then moves upstream as more ice pans are added (Figure 9).

Figure 9: How ice fronts are formed **Ice front formation**



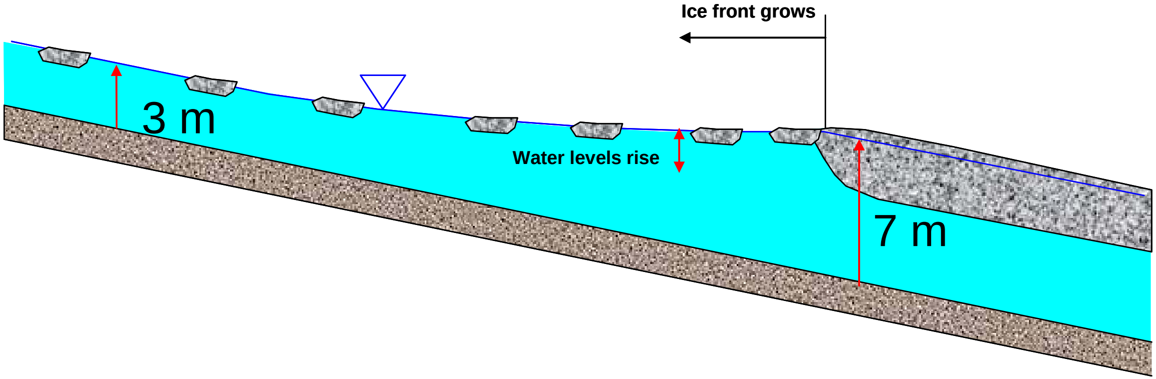
The speed the ice front grows depends on:

- air temperature - lower air temperature will create more frazil ice and, therefore, a faster-moving ice front,
- river flow / velocity - higher flows slow down the ice front progression but cause higher water levels at freeze-up,
- riverbed slope - steeper slopes slow down the ice front and cause water level increases due to the need for a thicker ice cover for stability.

The ice front creates a cover on the water surface that changes the characteristics of water flows compared to an open river. When the ice cover is newly formed it is irregular and rough, and the underside of the cover creates additional friction for the water flows. This slows the water down, and the river water levels must rise to accommodate the same amount of flow. For this reason, it is possible to see the water levels rise upstream of an ice front without ever seeing the ice front reach that same location. As the underside of the ice cover is smoothed by the river flowing beneath it, this friction is reduced and water levels fall part way back to their open-water level.

An ice consolidation event occurs when the ice cover breaks in an area of the river, and the sections of the cover move downstream. During a consolidation these chunks of ice often pile up significantly at a constriction in the river, islands or shallow areas, resulting in a heavier, rougher ice cover with corresponding significant increases in water levels. In some cases, ice consolidation events are the driving force behind changes to water levels downstream (Figure 10).

Figure 10: Example of the effect of ice fronts on river levels.



4.2 BC-ALBERTA JOINT-TASK FORCE ON ICE

In 1975, the Alberta-British Columbia Joint Task Force on Peace River Ice (JTF) was formed with membership from BC Hydro, the BC Ministry of Environment, and Alberta Environment. The JTF jointly monitors and manages flows on the Peace River to influence freeze-up and break-up in an attempt to reduce the risk of ice jam flooding. The Town of Peace River in Alberta is the largest community that can be most affected by ice jams, so freeze-up operating procedures are focused on establishing a relatively constant flow regime at the Town of Peace River during the period when the ice cover advances upstream through the town, and when the ice cover is stabilizing at the town. Prior to resuming normal operations of the upstream power facilities, the ice cover must be strong enough to resist ice jams. For this reason, ice thickness is measured regularly at several upstream points to ensure ice stability prior to resuming normal power facility operations.

4.3 POTENTIAL CHANGES FROM SITE C

Both Site C and Glacier Power Ltd.'s proposed Dunvegan hydroelectric project[4] in Alberta would change ice formation in the Peace River if either or both these projects were to proceed to construction.

As part of Stage 2, BC Hydro used an industry leading model to develop preliminary predictions of the Peace River ice front based on simulated weather scenarios both with current operations (no Site C or Dunvegan) and with Site C and Dunvegan. The predictions were based on the assumption that water temperature released from the Site C reservoir would be the same as is currently released from Peace Canyon. This was considered a reasonable assumption as the reservoir may stratify much like Dinosaur Lake upstream of Peace Canyon which is of a similar depth (This would be confirmed with the completion of water temperature modeling of the Site C reservoir if the project proceeds).

Preliminary calculations indicate that currently, in any given year, there is approximately a 50 per cent chance that the ice front would cross the B.C. Alberta border. It would extend up as far as the District of Taylor roughly 20 per cent of the time[5].

If both the Dunvegan Hydroelectric Project (as outlined in Glacier Power's November 2006 application to regulatory agencies) and Site C were constructed, water temperatures downstream of the projects would be expected to increase by a small amount – due to warmer water being released from lower depths of the reservoirs.

If there were no change in water temperature from Peace Canyon to Site C, current modelling estimates that in B.C., the net effect would be a shift of the ice front

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[4] The Dunvegan Hydroelectric Project is a low head (6 metres) facility that is proposed on the Peace River located approximately two kilometres upstream of the Highway 2 Bridge at Dunvegan, Alberta.

[5] It is noteworthy, however, that the ice front has not been to Taylor since 1996 due to the lack of severe winters.

downstream from current conditions on an average year. The ice front would rarely, if ever, reach the District of Taylor and is estimated to reach the B.C.-Alberta Border in about 25 per cent of years.

In general, with no change in water temperature between Peace Canyon and Site C, the construction of the Site C project is expected to slightly reduce the risk of ice-related flooding at the Town of Peace River. Thermal break-up of Peace River ice at the Town of Peace River is generally expected to be earlier with Site C in place. Since ice-related flooding at the Town of Peace River is typically associated with ice on the Smoky River breaking up before that on the Peace, the frequency of ice-jam related flooding at TPR should decrease.

Any changes to water temperatures as a result of the Dunvegan and Site C projects become significantly smaller as the Peace River progresses downstream due to greater influence of flows from tributaries. Modelling currently estimates no significant differences between freeze-up and break-up dates 750 km downstream of the Bennett Dam should both hydroelectric projects be constructed. Therefore there is not expected to be any effect by either one or both of these projects on ice formation at the Peace-Athabasca Delta which lies 1200 to 1243 km from the Bennett Dam.

If water temperature modelling results suggest winter temperatures could be cooler than current conditions, ice break-up may occur later in the year. There may also be an effect on the formation and use of ice bridges downstream of the project. If the Site C project were to proceed to future stages, additional temperature and ice modelling will be done for the Site C reservoir to refine these estimates based on Site C reservoir temperature modelling.

5.0 SEDIMENT MOVEMENT

If the Site C project were to proceed to construction, the sediment currently contributed to the Peace River from the newly regulated area (between Peace Canyon Dam and Site C) and related tributaries would be trapped in the reservoir (~3 million tonnes/year). Relatively speaking, changes to the sediment load would be modest and not expected to have a significant effect downstream. For example, nearly 58% of the estimated British Columbia yield at the Alberta border is delivered by Beatton River, downstream of the Site C location. Further downstream at Carcajou, Alberta, the suspended sediment load is, on average, approximately 38 million tonnes/a. As such, the loss of the contribution from the Site C area (~3 million tones/a) is not expected to have a significant effect at the Peace-Athabasca Delta (PAD) downstream or beyond.

If the project proceeds to future evaluation and planning, additional studies regarding sediment transport would be performed to further define these processes in the project area.

6.0 CLIMATE CHANGE

The majority of British Columbia's power comes from clean and renewable hydroelectricity. As such, the electricity system is very much dependent on the climate and natural water cycle. For this reason, BC Hydro's Runoff Forecasting Team is investigating the potential long-term impacts to the hydroelectric system that could result from a changing climate. For example, BC Hydro hydrologists study the rate of glacial recession in the province as part of a forecasting picture that goes as far as 2080. BC Hydro also works with other groups such as the Western Canadian Cryospheric Network and the Pacific Climate Impacts Consortium to study how glacial recession is going to affect bodies of water used for hydroelectric production across our system.

In the case of the Peace River system, glacial melt is not a contributor to run-off flows in the region and thus glacial recession is not expected to have an effect on Peace River inflows. Further future study of climate change will provide information on potential changes to annual snowfall and rainfall, and how that may affect the Peace River system. In addition, if the Site C Project were to proceed to future stages, the potential for climate change impacts associated with this facility would be considered as part of an environmental assessment.

7.0 CONCLUSION

In general, no major changes to current hydrological or geomorphological conditions downstream would be expected should the Site C project be constructed as currently conceived. While minor downstream changes are expected close to the Site C project, preliminary studies suggest Peace River flows and the associated water levels would not be significant relative to current conditions.

Both Site C and Glacier Power Ltd.'s proposed Dunvegan hydroelectric project in Alberta would change ice formation in the Peace River if either or both these projects were to proceed to construction. If winter water temperatures are warmer than current conditions at the proposed Site C location, the ice formation changes would be beneficial to the town of Peace River due to a reduced frequency of spring ice jamming associated with the Smoky River breakup. If the winter water temperatures are cooler, ice break-up may occur later in the year. There may also be an effect on the formation and use of ice bridges downstream of the project

If the project were to proceed to future stages, additional temperature and ice modelling will be done for the Site C reservoir to refine these estimates based on Site C reservoir temperature modelling, and more studies will be performed to better understand the potential hydrological and geomorphological impacts downstream.