Peace River Water Use Plan

Peace River Spill Total Dissolved Gas Pressure Monitoring Program – June/July 2021

Reference: GMSMON-11

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PEACE RIVER WATER USE PLAN

PEACE RIVER SPILL TOTAL DISSOLVED GAS PRESSURE MONITORING PROGRAM – June/July 2021

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EXECUTIVE SUMMARY

Long-term monitoring of baseline water temperature and total dissolved gas pressure (TDGP) in the vicinity of the WAC Bennett and Peace Canyon dams has been identified as an essential component of the Peace Spill Protocol (PSP) and the Peace River Flood Pulse Plan as set out by the Peace River Water Use Plan Consultative Committee and the Peace River Water Use Plan (WUP). The Plan provides for the collection of TDGP and water temperature data under the GMSMON-11 monitoring program, during spill events which exceed spill discharge and duration thresholds. The objectives of the GMSMON-11 monitoring program are to record TDGP levels during and immediately after a qualifying spill event and assess TDGP levels in terms of potential impacts on fish populations in Dinosaur Reservoir and the Peace River downstream of the Peace Canyon Dam.

In June 2021, BC Hydro determined it was necessary to release water from the WAC Bennett and Peace Canyon dam spillways in order to slow the rising elevation of Williston Reservoir. Spills were initiated at both dams on the afternoon of June 29, 2021 and continued for 7 days. The Peace Canyon spillway operated continuously for all 7 days at an average discharge rate of 230 cms. During the same 7 days, water was released from the WAC Bennett Dam spillway through a series of irregular daily pulse spills each consisting of a 600 cms release approximately 16 hours in duration followed by a pause averaging nine hours in length. The GMSMON-11 monitoring protocol was triggered at the WAC Bennett Dam spillway when the daily average spill rate during the first 2 days exceeded 205 cms.

As in previous years, monitoring results indicated supersaturated TDGP background levels in Williston Reservoir near the entrance gates to the WAC Bennett Dam spillway. Background gas saturation levels in the forebay reached 117% at 1 metre depth as a result of dramatic surface warming immediately prior to the spill, with ambient air temperatures breaking all-time records on each day between June 25 and June 30.

Gas saturation levels recorded for the left and right bank GMS turbine outflow, suggested lower background saturation values of 108% and 104%, at their respective penstock intake depths in the forebay. This resulted in an average background gas saturation level of approximately 106% from the WAC Bennett tailrace downstream through Dinosaur Reservoir and into the Peace River, before and after the spill.

Consistent with previous monitoring events, it was observed that atmospheric gases were readily introduced into Dinosaur Reservoir inflow by the Bennett Dam spillway due to a combination spillway design and plunge pool depth. The incremental increase in TDGP associated with the Bennett Dam spillway operation in 2021 was approximately 17% (106%-123%). This value was higher than the 13% incremental increase recorded in 2020, presumably due to higher forebay surface supersaturation resulting from the 2021 heat wave. Gas saturation levels downstream at the Peace Canyon forebay increased from background (106%) to approximately 116% within 24-36 hours of the start of spilling at the Bennett Dam.

Despite higher saturation levels below the Bennett Dam spillway in 2021, values recorded at the Peace Canyon forebay were slightly lower than in 2020. This was potentially due to the mitigating affect of the daily pulse spill pattern adopted at GMS in 2021.

During simultaneous operation of both the Bennett Dam and Peace Canyon spillways, gas saturation levels in the Peace River downstream of the Peace Canyon Dam increased from background (106%) to approximately 114%, with some evidence of a mitigating affect whereby excess dissolved gas introduced at the Bennett Dam spillway is released from solution by the Peace Canyon spillway. Gas saturation levels in the Peace Canyon tailrace and in the Peace River 10 km downstream returned to background levels averaging 106% within approximately 3 days of termination of the spill at both facilities.

Based solely on the results of the 2021 TDGP monitoring program, no definite determination could be made as to the potential impacts of gas supersaturation on downstream fish populations in the Peace River. However, given the relatively short 7-day duration of the 2021 spill and the relatively low incremental increase in gas supersaturation downstream of Peace Canyon (106% to 114%), acute and chronic affects of Gas Bubble Trauma seem unlikely. It can be noted that no symptoms of Gas Bubble Trauma were noted during the visual examination of 2,841 fish captured in the Peace River immediately after 32 days of spilling at comparable volumes in 2020 (DES 2021).

Total dissolved gas pressure monitoring results in 2021 suggest that fish in Dinosaur Reservoir residing in water deeper than 1.7 m and fish in the Peace River residing in water deeper than 0.8 m could have theoretically avoided the effects of incremental gas supersaturation through depth compensation.

It is recommended that the Bennett Dam daily pulse spill configuration used in 2021, be given future consideration as a mitigative tool in reducing incremental increases in TDGP downstream of Dinosaur Reservoir.

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1.0 INTRODUCTION

Long-term monitoring of baseline water temperature and total dissolved gas pressure (TDGP) in the vicinity of the WAC Bennett and Peace Canyon dams has been identified as an essential component of the Peace Spill Protocol (PSP) and the Peace River Flood Pulse Plan as set out by the Peace River Water Use Plan Consultative Committee and the Peace River Water Use Plan (WUP).

The Plan provided for the collection of TDGP and water temperature data, during spill events from Peace River generating stations, under the GMSMON-11 monitoring program for a 10-years period between 2008 and 2019. Monitoring stations included the WAC Bennett Dam forebay, WAC Bennett Dam tailrace, Peace Canyon Dam forebay, Peace Canyon Dam tailrace, Peace River at Hudson's Hope, Peace River downstream of the Halfway River, and Peace River downstream of the Pine River.

In June 2019, the Peace River Water Use Plan Monitoring Program Terms of Reference Addendum 2 extended the GMSMON-11 spill monitoring program beyond 2019 and discontinued the use of monitoring sites within and below the proposed Site C inundation zone, limiting spill monitoring sites to the forebays and tailraces of the WAC Bennett and Peace Canyon dams (Fig.1).

Triggering of the GMSMON-11 spill monitoring program is conditional on the occurrence of a spill where discharge from:

- the WAC Bennett Dam spillway exceeds a daily average of 205 cms for 2 days or more,
- the Peace Canyon Dam spillway exceeds a daily average of 1,500 cms for 2 days or more,
- the Peace Canyon Dam spillway exceeds a daily average of 500 cms for 7 days or more, or
- the total discharge from the Peace Canyon Spillway and generating station exceeds 2,000 cms for 2 days or more.

TDGP monitoring is to begin immediately prior to a triggering spill event and continue for up to 2 weeks after the spill.

The objectives of the GMSMON-11 monitoring program are to record TDGP levels during and immediately after a qualifying spill event and assess TDGP levels in terms of potential impacts on fish populations in Dinosaur Reservoir and the Peace River downstream of the Peace Canyon Dam.

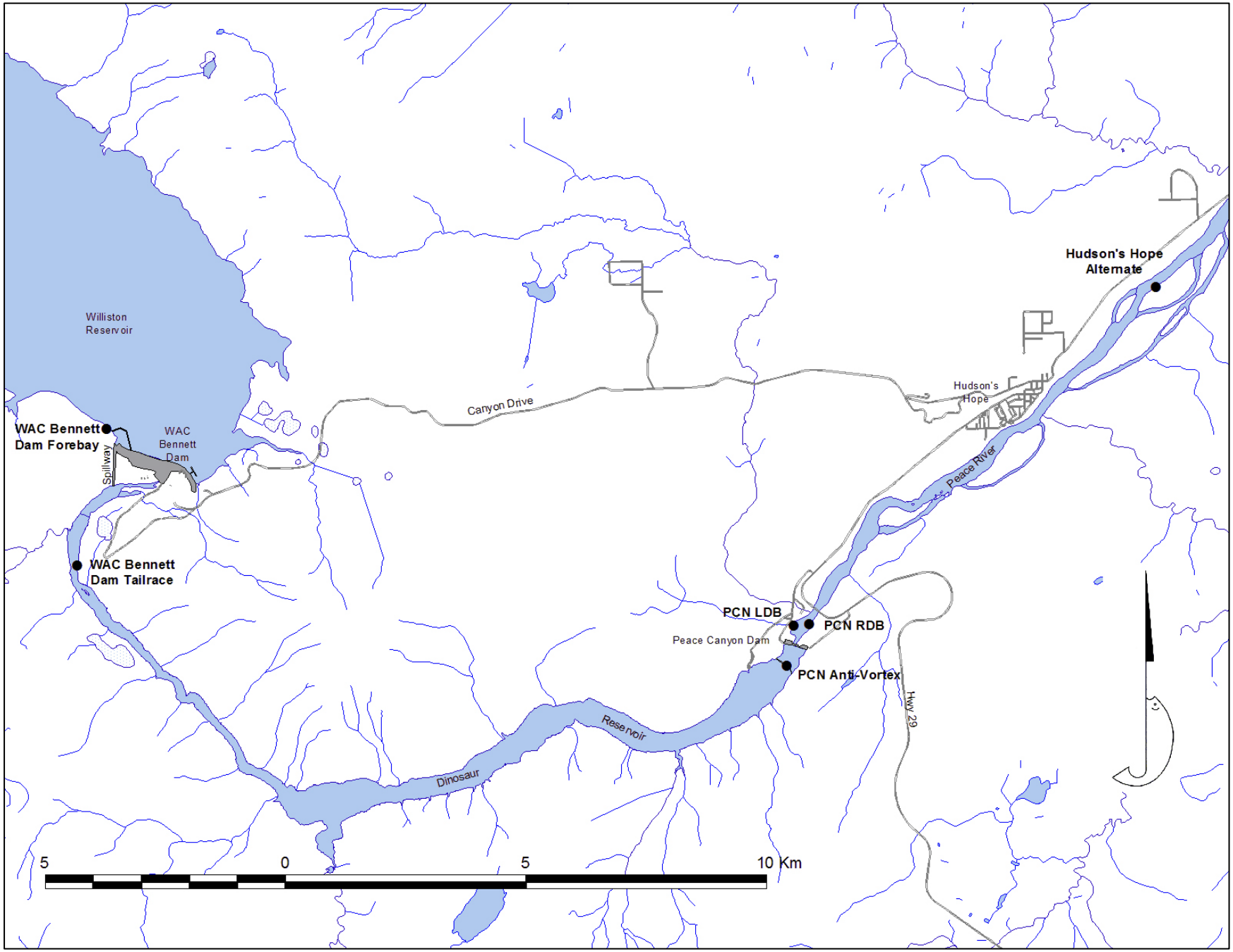

Figure 1. Location of 2021 TDGP monitoring sites.

Background

Total dissolved gas (TDG) supersaturation is a condition where the cumulative partial pressures of atmospheric gases dissolved in water exceed atmospheric pressure. Total dissolved gas pressure in a body of water is often quantified as the difference between the TDG pressure of the water and the ambient barometric pressure and can be expressed as a percentage of the barometric pressure. Thus, TDG pressures that exceed equilibrium with barometric pressure are expressed as values greater than 100% and denote supersaturation.

Excessive levels of TDGP are known to have adverse effects on aquatic organisms, including fish. When excess dissolved gas in supersaturated water escapes from solution in the tissues or circulatory systems of fish, physiological impairment, or death may occur. Common visible indications may include the presence of gas bubbles under the skin, along the lateral line, within fin membranes, behind the eyes, and in the gills. These symptoms are suggestive of a condition referred to as Gas Bubble Trauma (GBT) or Gas Bubble Disease (GBD).

In order for gas to escape solution and form bubbles in the tissues or body fluids of fish, the TDG pressure in the fish must overcome the combined effects of both barometric pressure and hydrostatic pressure. Since hydrostatic pressure increases by 0.1 atmosphere (10% saturation) for each metre of water depth, fish living in deeper water require a higher level of supersaturation before feeling the effects of GBT. For example, a fish at 2 m depth will experience gas equilibrium in a water body with a TDGP of 120% at surface. As a result, reservoir-dwelling fish populations are generally believed to be less susceptible to GBT than those living in shallow rivers.

The air supersaturation of water generally occurs when the pressure gradient between the air and the water exceeds the equilibrium of normal atmospheric conditions. This situation is most commonly created when air bubbles are suddenly forced deep into the water column and subjected to rapidly increased hydrostatic pressure. The resulting pressure gradient forces air from each compressed bubble to dissolve into the surrounding water. This mechanism occurs naturally in waterfall plunge pools, a situation often mimicked at manmade dam spillways. The degree of supersaturation is typically dependent on the density of air bubbles within the water, the depth to which the air bubbles are carried, and the amount of time the bubbles are forced to remain at depth.

A second mechanism by which water can become naturally supersaturated involves the surface warming of thermally stratified reservoirs and lakes by solar radiation. Since the gas solubility of water decreases with rising temperature, and dissolved gas dissipates from water at a relatively slow rate, excess dissolved gas can become trapped near the surface of a water body when the temperature of the epilimnion increases rapidly in mid-summer, resulting in supersaturated conditions.

The design of the WAC Bennett spillway appears to be particularly conducive to the entrainment of air bubbles within the spillway discharge stream after it leaves the deflection bucket and prior to its contact with the plunge pool below (Fig. 2). Additionally, a prominent scour hole has developed below the spillway over the 50-year life of the facility. Sounding of the plunge pool during the 2021 spill monitoring program indicated a maximum scour depth of approximately 40 m.

Figure 2. WAC Bennett Dam Spillway, July 17, 2020; 570 cms.

In contrast, the Peace Canyon Dam spillway discharge descends the downstream face of the dam in a more laminar fashion before being directed horizontally at tailrace elevation. This design allows the spillway discharge to enter the tail waters parallel to the surface of the river channel with the aim of preventing the formation of a scour pool.

2.0 METHODS

In April 2021, BC Hydro purchased five new HydroLab Model MS5 TGP meters to be dedicated to Peace Basin spill monitoring. These meters replaced much older Common Sensing Model DL6 and Point Four Model PT4 meters, which had proven relatively unreliable during previous spills due to their obsolescence.

The new Model MS5 TGP meters were deployed at the 5 mandatory monitoring sites on June 19, 2021, approximately 10 days prior to the commencement of spills at the G.M Shrum (GMS) and Peace Canyon (PCN) generating stations (Fig. 1). These locations included:

1. WAC Bennett Dam Forebay – near the south shoreline anchor point of the spillway log boom approximately 500 m upstream of the spillway entrance gates (UTM 10.548579.6208989);
2. WAC Bennett Dam Tailrace - right downstream bank approximately 1,500 m downstream of spillway plunge pool (UTM 10.547953.6206169);
3. Peace Canyon Dam Forebay – anti-vortex dam log boom approximately 450 m upstream of spillway entrance gates (UTM 10.562692.6204070);
4. Peace Canyon Tailrace LDB – north shoreline approximately 340 m downstream of dam face (turbine outlet side) (UTM 10. 562834.6204935);
5. Peace Canyon Tailrace RDB – south shoreline approximately 450 m downstream of dam face (spillway side) (UTM 10.563164.6204945).

All five Model MS5 meters were temporarily removed from service over-night on July 8 (two days after completion of the spill) to allow for replacement of pressure sensor cartridges, and then permanently removed on July 22, sixteen days after the completion spill operations.

The HydroLab Model MS5 units consist of temperature and TDGP sensors, data storage hardware, and battery pack, integrated into a single submersible sonde and were programmed to record water temperature (°C), battery voltage (volts), and total dissolved gas pressure (mmHg) at 15 minute intervals. Each unit was fastened inside the lower end of a 3.65 m length of 50.8 mm ABS plastic pipe which extended from the shoreline to approximately 1 m depth. The lower end of the pipe assembly was held in place with a metal anchor and the upper end was secured to the shoreline with nylon rope. Since no components of the Model MS5 units are above water, they are not equipped to record real time barometric pressure and were instead programmed with a standard sea level atmosphere value of 760 mmHg, to be later corrected with local hourly barometric pressure values to calculate percent saturation values. The Model MS5 sondes were launched and downloaded using HydroLab's Hydras3LT communication software loaded onto a laptop computer.

In addition to the five Model MS5 meters, three older Point Four Model PT4 metres were deployed on June 29, immediately prior to the spill, in order to collect additional data at three optional sites. These included 2 sites in the GMS tailrace located upstream of the spillway plunge pool and one site in the Peace River approximately 10 km downstream of the PCN tailrace.

The 2 additional GMS tailrace sites were located on the right and left downstream banks approximately 750 m below the turbine outflow manifolds and 150 m above the spillway plunge pool (UTM 10.

548831.6207839 and 10.548883.6207762). The collection of these data was requested by BC Hydro staff in order to confirm the saturation level of turbine outflow prior to its mixing with spillway discharge.

The additional downstream Peace River meter was deployed pursuant to a recommendation from the 2020 spill monitoring program (DES 2021) and was intended to confirm saturation levels in the Peace River after complete mixing of PCN turbine outflow and PCN spillway inputs. This monitoring site was historically located at the Hudson's Hope town site but had to be moved 3.5 km further downstream due to Site C reservoir protection berm construction (UTM 10.570373.6211957).

The Model PT4 meters were programmed to record ambient barometric pressure (mmHg), water temperature (°C), and total dissolved gas pressure (mmHg), and automatically calculate per cent gas saturation at 15 minute intervals. The Model PT4 probes were also fastened inside the lower end of a 3.65 m length of 50.8 mm ABS plastic pipe at approximately 1 m depth and were launched and downloaded using the communications software HyperTerminal® loaded onto a laptop computer.

At the end of the monitoring period, downloaded data for each recorder model were assembled into continuous data sets for each monitoring site in Microsoft Excel™. Fifteen minute interval readings were converted to hourly average values to be consistent with spillway and turbine output hourly average values. Default barometric pressure values of one standard atmosphere (760 mmHg) for the Model MS5 sondes were replaced with corrected local barometric pressure values using the following method. Hourly station pressure readings recorded at the Environment Canada Fort St. John weather station were downloaded in Excel (https://climate.weather.gc.ca/climate_data) and corrected for elevation at each monitoring site by adding 0.0847 mmHg per metre elevation drop (Table 1).

Table 1. Barometric pressure correction values for 2021 spill monitoring site elevations.

	Elevation (ASL)	Elevation change	BP correction
EnvCan FSJ weather station	695 m	-	-
Williston Reservoir	670 m	-25 m	+2.1 mmHg
Dinosaur Reservoir	502 m	-193 m	+16.3 mmHg
Peace Canyon tailrace	460 m	-235 m	+19.9 mmHg

Data sets were then reviewed for obvious corrupted or unreasonable values and these were removed.

3.0 RESULTS AND DISCUSSION

3.1 Operational Parameters/Spill Characteristics

In June 2021, BC Hydro determined it was necessary to release water from the WAC Bennett and Peace Canyon dam spillways in order to offset low turbine discharge and slow the rising elevation of Williston Reservoir. Spills were initiated at both dams on the afternoon of June 29, 2021 and continued for 7 days until the afternoon of July 6, 2021 (Fig. 3). The Peace Canyon spillway operated continuously for all 7 days at an average discharge rate of 230 cms (maximum 242 cms). During the same 7 days, water was released from the Bennett Dam spillway through a series of irregular daily pulse spills each consisting of a 600 cms release approximately 16 hours in duration followed by a pause averaging nine hours in length (Fig. 3). Turbine output volumes from both generating stations remained relatively stable at approximately 1,500 cms throughout the spill period (Fig. 3).

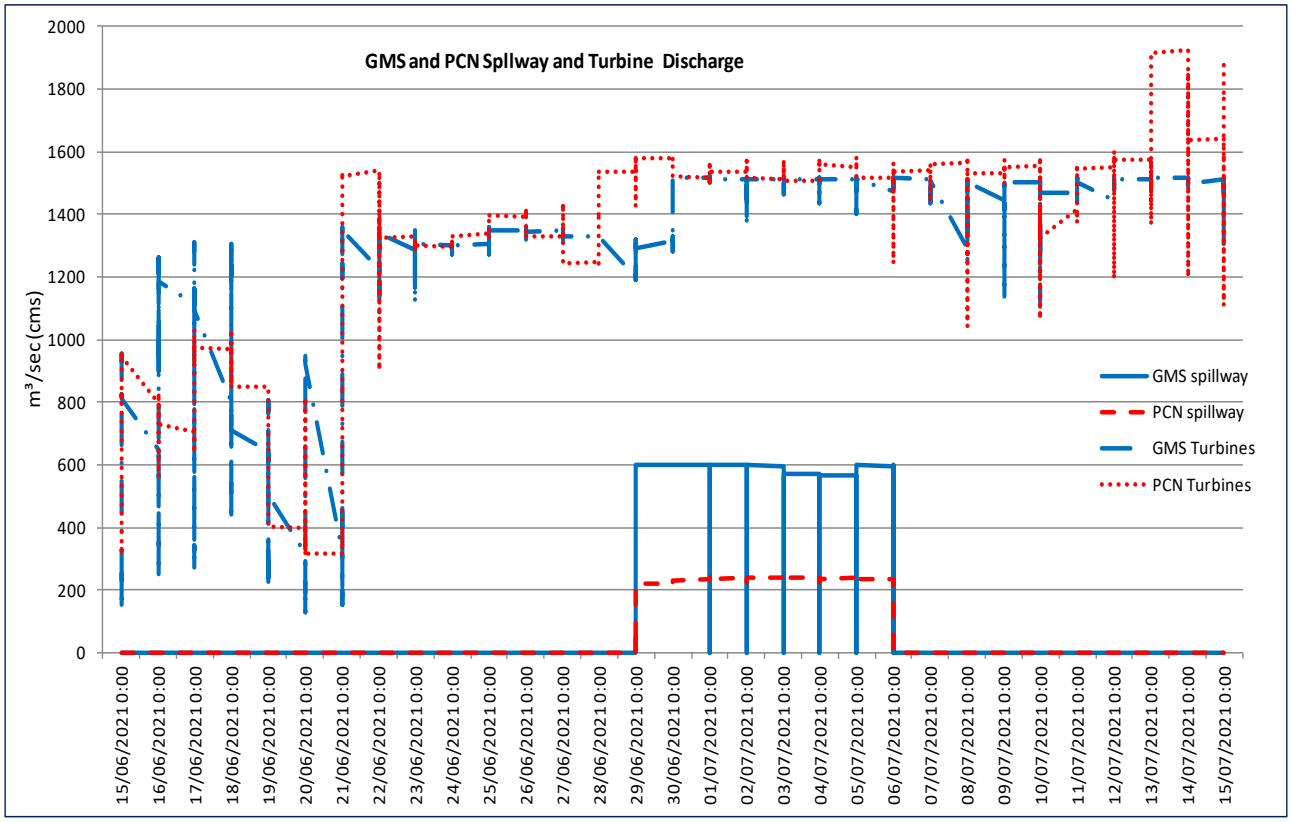

Figure 3. Spillway and turbine discharge from GMS and PCN generating stations during the 2021 spill event, June 15 – July 15, 2021.

The GMSMON-11 monitoring protocol was triggered at the Bennett Dam spillway when the daily average spill rate during the first 2 days exceeded 205 cms. None of the three monitoring criteria thresholds for the Peace Canyon Dam spillway were exceeded during the spill period.

3.2 Total Dissolved Gas Pressure Monitoring

3.2.1 WAC Bennett Dam Forebay

Total dissolved gas pressure was recorded in the Bennett Dam forebay approximately 500 m upstream of the spillway gates between June 19 and July 22, using a HydroLab Model MS5 TPG meter. Interim data downloads and battery replacements occurred on June 29 and July 8. Data recorded at the Bennett Dam forebay site indicated significant supersaturation of forebay surface waters prior to entry into the spillway (Fig. 4). Forebay saturation levels recorded during the June 19 to July 22 monitoring period ranged from 103% to 117%, peaking on June 28, one day prior to the spill then declining to 108% by the end of the 7-day spill. Forebay saturation levels were noticeably higher than in 2020 when July forebay saturation levels peaked at 111% (DES 2021). Figure 4 also includes TDGP levels recorded for left bank and right bank turbine outflow upstream of the spillway between June 29 and July 8. These values are assumed to approximate saturation levels in the forebay at the respective depths of the left and right bank penstocks intakes, with the shallower left bank intake averaging 108% and the deeper right bank intake averaging 104%.

A comparison of forebay water temperature at 1 m and 10 m depths recorded by the GMSWORKS-2 temperature monitoring program, and ambient air temperature recorded by Environment Canada at the Fort St. John Airport are represented in Figure 5. Maximum daily air temperatures recorded at the Fort St. John Airport broke all-time Environment Canada records each day between June 25 and June 30, peaking at 38.1°C on June 29, which was coincidently the first day of the 7-day spill. Localized air temperatures on Dinosaur Reservoir exceeded 40°C on the same day (B. Culling; pers. obs.). As illustrated in Figure 5, the record air temperatures resulted in rapid surface heating of Williston Reservoir immediately prior to the commencement of the 2021 spill. Water temperature at the 1-metre depth rose from 9.0°C to 17.5°C in the 48-hour period before the spill began on June 29. The 5-6 degree disparity in temperature between the 1-metre and 10-metre depths, which formed the day before spill, suggests the entrapment of excess dissolved gas in the upper layer of the forebay and seems consistent with usually high surface saturation levels in the forebay during the 7-day spill.

It should be noted that although Williston Reservoir typically becomes strongly thermally stratified in the summer, late summer temperature profiles recorded in the Peace Reach during unrelated work in 2017 and 2018 indicated that the seasonal thermocline normally develops below the 20-metre depth (B. Culling, pers. obs.).

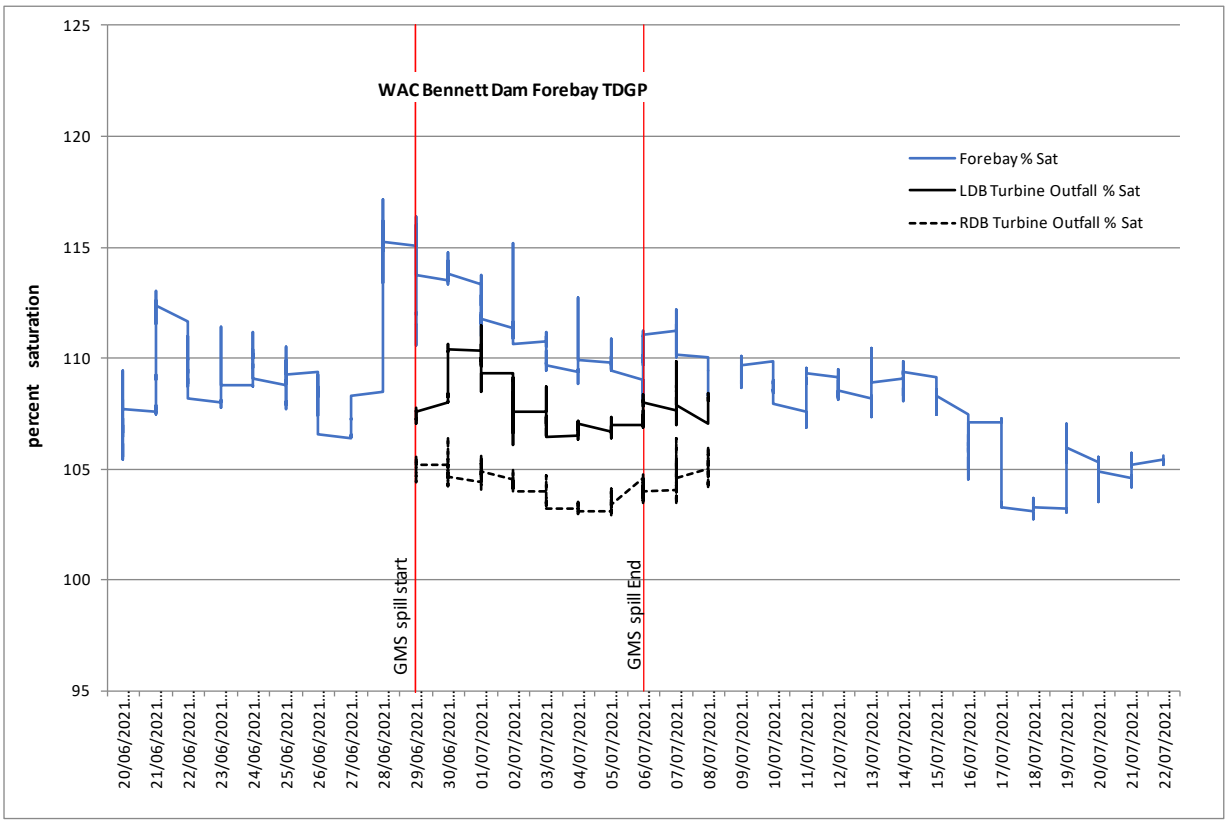

Figure 4. Percent gas saturation levels (TDGP) recorded in the WAC Bennett Dam forebay and GMS turbine outflow, June 19 – July 22, 2021.

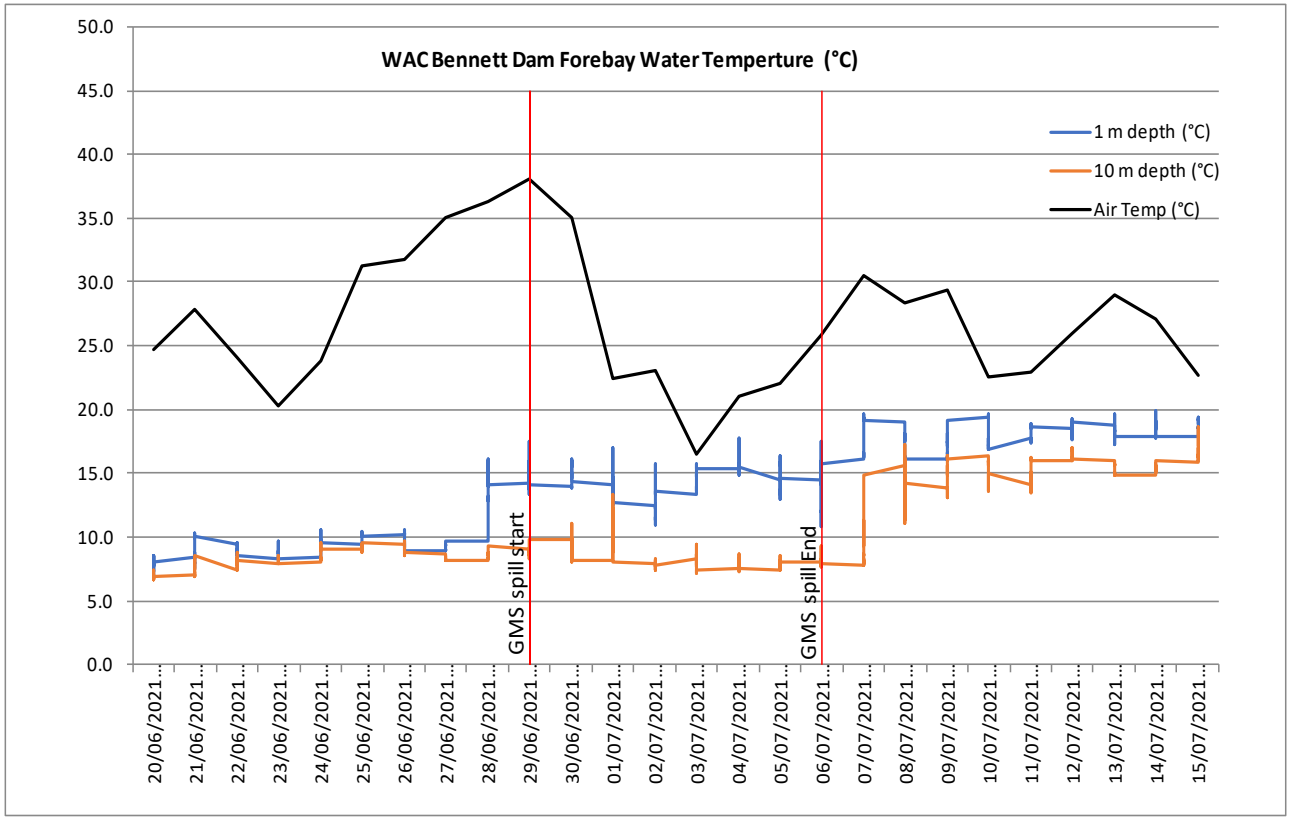

Figure 5. Water temperature recorded in the Bennett Dam forebay (1 m and 10 m depth) and ambient air temperature recorded at the Fort St. John Airport (Env Can) - June 19 – July 15, 2021.

3.2.2 WAC Bennett Dam Tailrace

Total dissolved gas pressure was monitored in the Bennett Dam tailrace, at the left downstream bank (LDB) approximately 1,500 m downstream of the spillway plunge pool (Fig. 1) between June 19 and July 22 using a HydroLab Model MS5 meter. This meter location was moved 1,000 m downstream to this site during the 2020 spill due to difficulty in accessing the original monitoring site by boat during spill operations. Use of the lower site also ensured total mixing of spillway discharge and turbine outflow due to extensive upwelling of flow within the constriction created by the Gething Creek alluvial deposit located between the plunge pool and the revised station.

Total dissolved gas pressure values recorded downstream of the spillway before, during, and after the spill are summarized in Figure 6, which also includes data from the left and right bank turbine outflow. Tailrace saturation levels during periods of normal operation fall within the range of variation between left bank and right bank turbine outflow saturation levels (108-104%). This includes periods before and after the spill as well as periods of normal operation between the daily pulse spills when TDGP values quickly returned to the mid-point between the left and right bank turbine outflow values (Fig. 6). Saturation levels of water entering Dinosaur Reservoir past the tailrace station averaged 106% during non operation of the spillway and increased to approximately 123% during spillway operation.

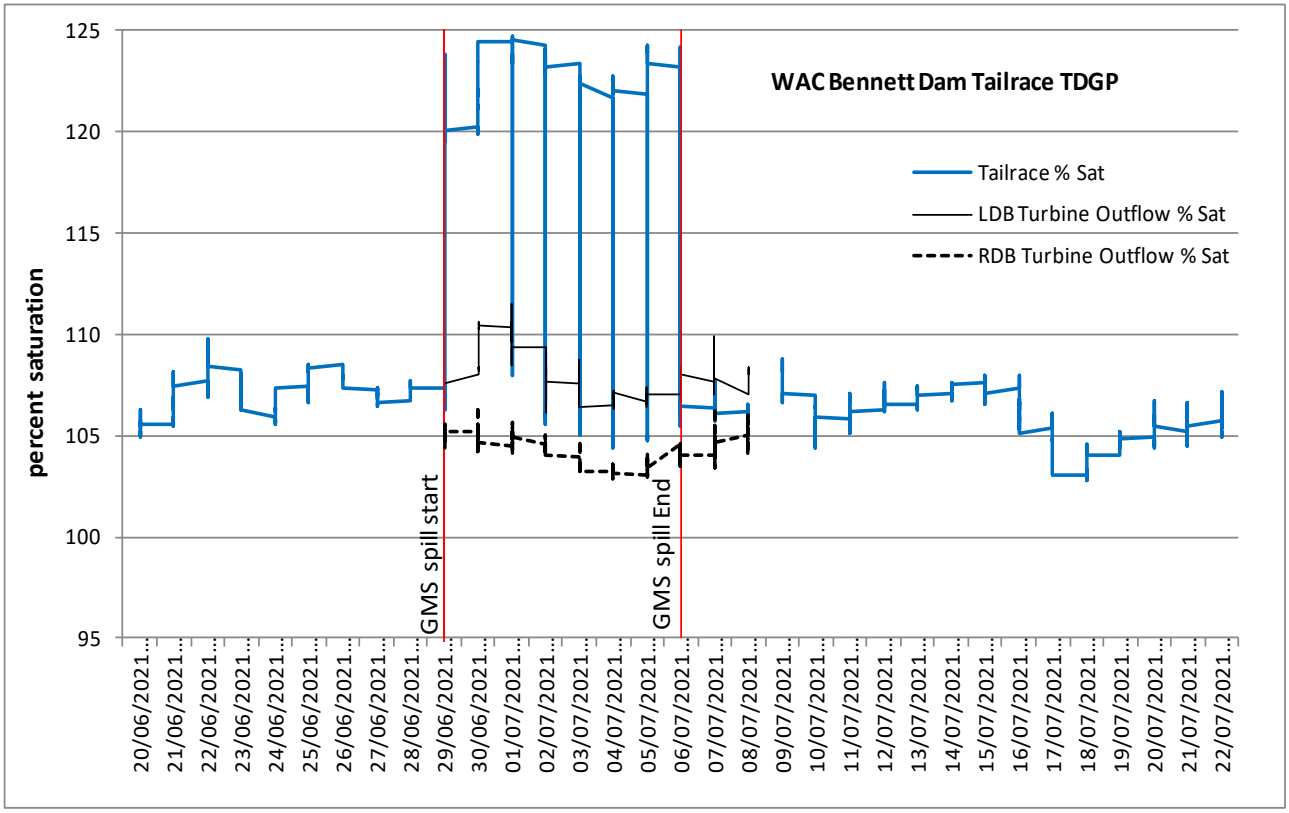

Figure 6. Percent gas saturation (TDGP) levels recorded in the WAC Bennett Dam tailrace 1,500 m downstream of spillway plunge pool and 150 m upstream of the spillway plunge pool, June 19 – July 22, 2021.

This incremental increase of 17% during spillway operation was greater than the 13% increase documented during the 2020 spill despite a comparable spill discharge rate. It was assumed that the higher 2021 value was partially due to higher forebay surface saturation levels caused by the 2021 heat wave; i.e., higher degree of background supersaturation of water entering the spillway.

3.2.3 Peace Canyon Dam Forebay

Total dissolved gas pressure was monitored in the Peace Canyon Dam forebay, at the anti-vortex dam log boom, approximately 450 m upstream of the spillway gates between June 19 and July 22, 2021, using a HydroLab Model MS5 meter. Problems with the positioning of this meter were encountered during the monitoring period due to larger than normal fluctuations in the elevation of Dinosaur Reservoir. Temperature recordings indicate that the sonde became exposed to air on July 8 and may also have been affected by shallow water and silt and debris accumulation on the sensor cartridge.

The PCN forebay meter appeared to have collected reasonable data until July 12, six days after the spill, when TDG pressure values unexpectedly spiked, and remained high for the remainder of the monitoring period. Readings after July 12 were inconsistent with values recorded upstream at the GMS tailrace and downstream in the PCN tailrace and were considered erroneous.

Figure 7 summarizes saturation levels recorded in the PCN forebay and compares them with Bennett Dam tailrace values recorded at the upstream end of Dinosaur Reservoir. As expected, PCN forebay values recorded prior to the spill matched background levels recorded at the Bennett Dam tailrace station during the corresponding pre-spill period. Upon opening the Bennett Dam spillway a delay of 24-36 hours was evident before PCN forebay values began to rise (Fig. 7). During the 7-day Bennett Dam spill, gas saturation levels at the PCN forebay averaged 116%. These levels were comparable to the levels recorded at the same station in 2020 despite higher saturation levels in water entering the reservoir through the Bennett Dam tailrace in 2021. In 2020, saturation levels at the PCN forebay during the Bennett Dam spill were 3 percentage points lower than water entering the reservoir (120% vs 117%). The decline in saturation levels over the length of the reservoir increased to 7 percentage points during the 2021 spill (123% vs 116%). This may be partially due to the daily pulse configuration used in 2021, whereby spill operations at GMS were suspended for approximately 9 hours each day.

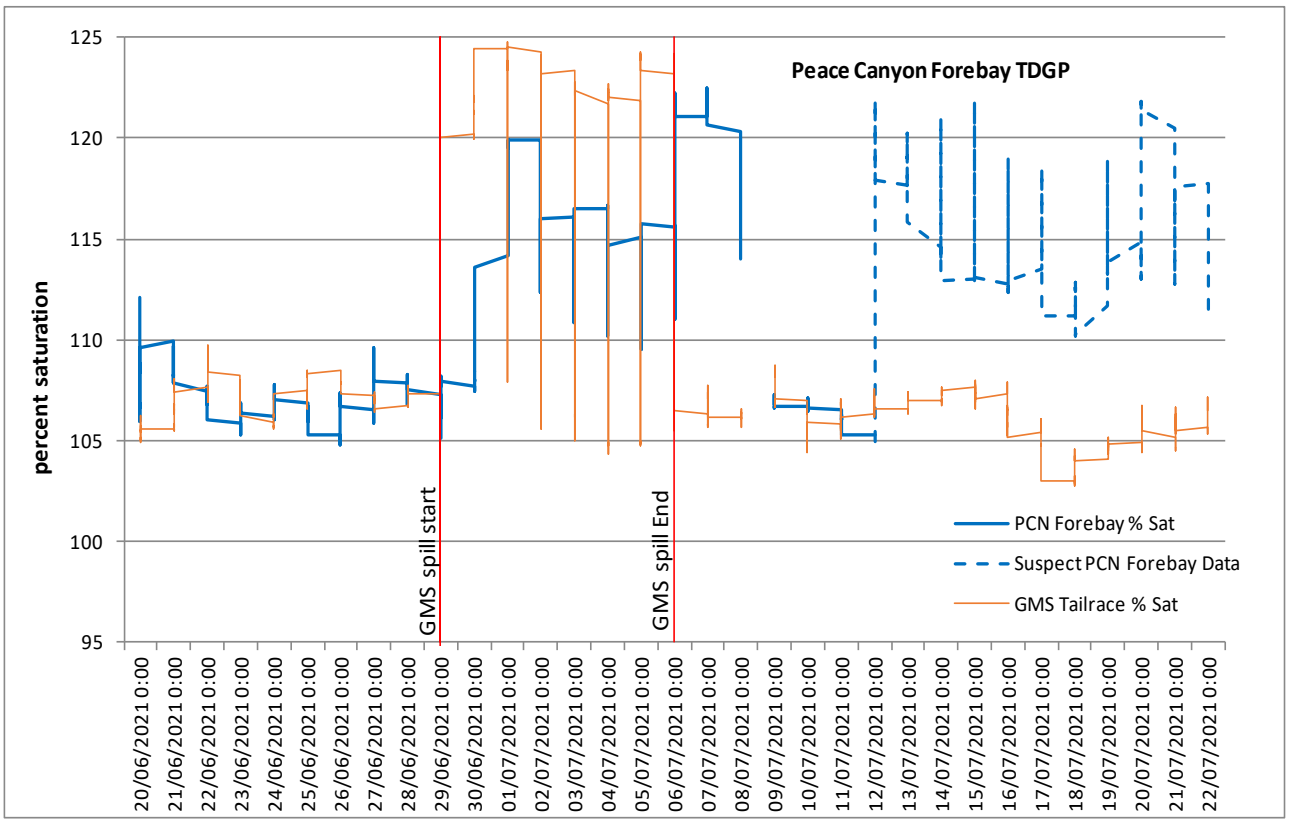

Figure 7. Percent gas saturation (TDGP) levels recorded in the Peace Canyon forebay, June 19 – July 22, 2021; (GMS tailrace TDGP added for reference).

3.2.4 Peace Canyon Dam Tailrace

Total dissolved gas pressure in the Peace Canyon Dam tailrace was measured on both the left and right banks between June 19 and July 22, 2021 using 2 HydroLab Model MS5 meters. In addition, one Point Four Systems Model PT4 meter was deployed at a site in the Peace River approximately 10 km downstream of the PCN tailrace. The downstream site was located on a mid-stream island in order to further ensure complete mixing of PCN spillway discharge and turbine outflow.

The PCN tailrace LDB meter (turbine side) appeared to record consistent data throughout the monitoring period. The right downstream bank (RDB) meter (spillway side), however, was found dislodged by current during the June 29 download, immediately prior to the spill, and did not record usable data prior to the commencement of the spill. The Hudson's Hope downstream meter was installed on June 29, immediately prior to the spill. Upon downloading this meter, it was discovered that the unit had failed after logging one record on June 29. Usable data was recorded during the post spill period beginning July 8.

Unlike the Bennett Dam tailrace, where spillway discharge enters the approximate centre of the channel, spillway discharge at PCN enters along the right downstream bank while turbine outflow

enters along the left downstream bank (Figure 8). During spillway operation, the LDB meter is assumed to sample water from turbine outflow and the RDB meter is assumed to sample primarily spillway discharge. However, it is suspected that these flows are not necessarily laminar and that circulation currents, which vary with discharge volume, may be a confounding factor.

Figure 8. Satellite image of Peace Canyon dam and tailrace during 2021 spillway operation, 2021; (GoogleEarth).

Salvageable gas saturation data from the Peace Canyon tailrace LDB and RDB, respectively, and the Hudson's Hope downstream station are summarized in Figures 9 and 10. Percent saturation levels recorded by the LDB meter closely tracked those recorded at the PCN Forebay before and during the PCN spill supporting the assumption that turbine outflow passing this station is relatively unmixed with spillway discharge. Although post-spill data from the PCN forebay is limited, LDB saturation levels tracked those from the Hudson's Hope downstream station post-spill. In addition to a 24-36 hour delay in the increase of saturation levels at the PCN forebay, Figure 9 also suggests an approximate 3 day delay in the return to background levels post-spill as spill-induced dissolved gas is flushed from Dinosaur Reservoir. During the PCN spill, saturation levels recorded by the RDB meter (Fig. 10), which was assumed to receive primarily PCN spillway discharge, averaged 4 percentage points lower than corresponding readings from the LDB and forebay, but returned to background levels matching the LDB and Hudson's Hope downstream stations at the end of the spill. This decline

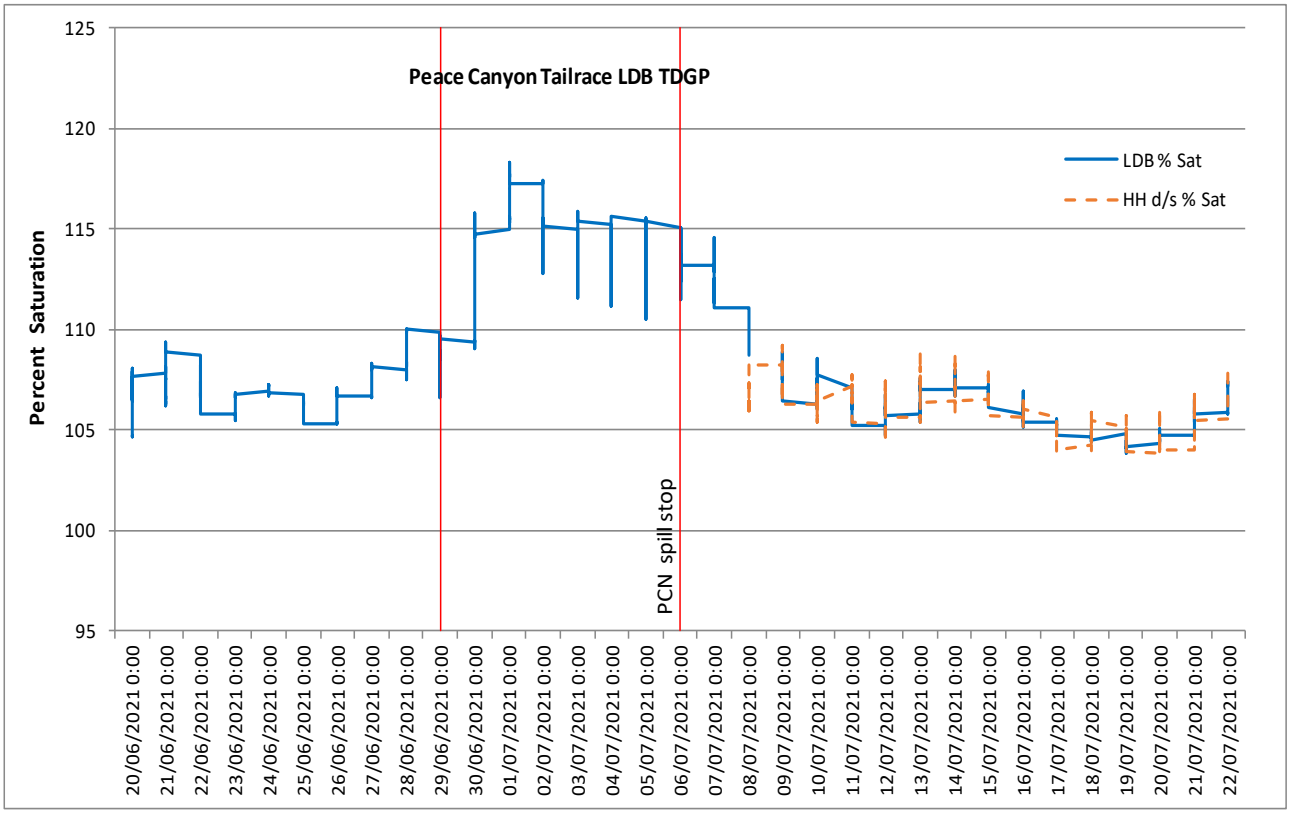

Figure 9. Percent gas saturation levels (TDGP) recorded at the Peace Canyon tailrace LDB and Hudson's Hope downstream station, June 19 – July 22, 2021.

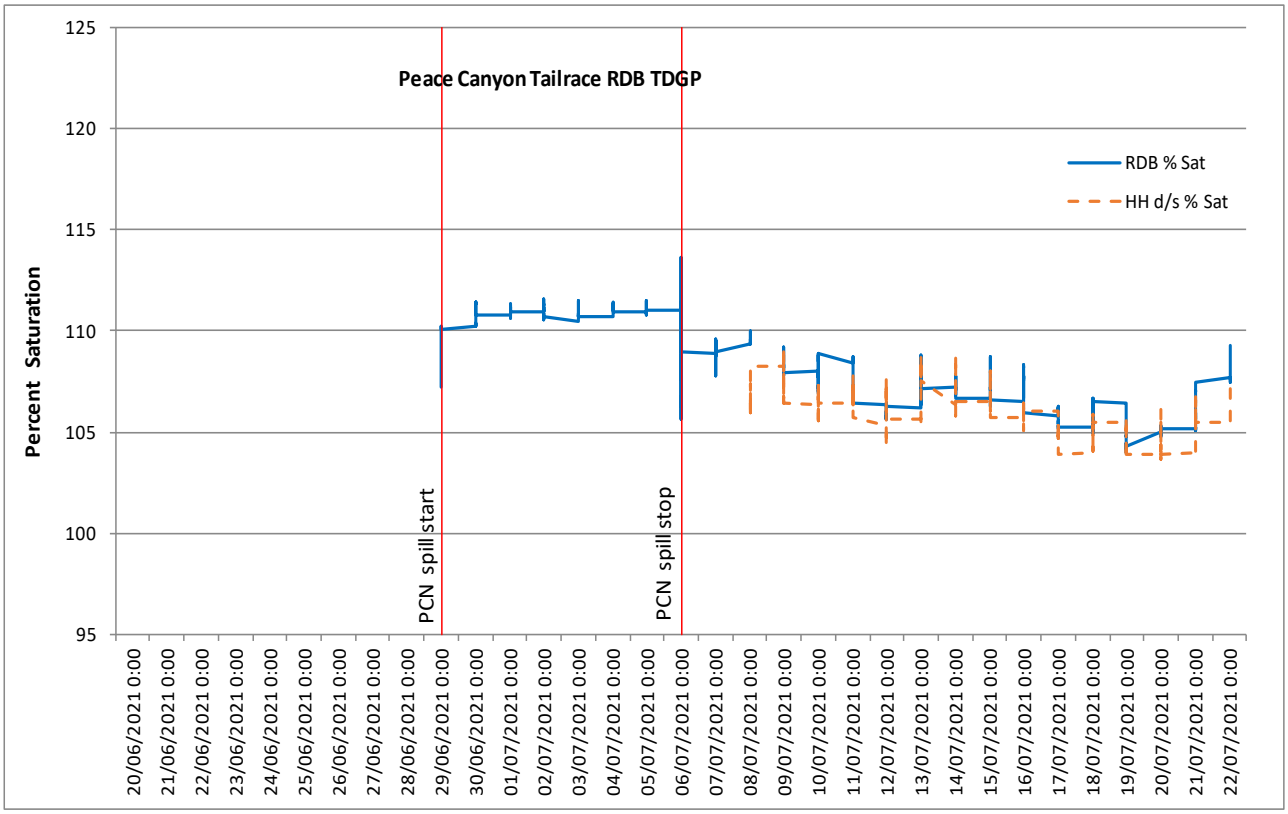

Figure 10. Percent gas saturation levels (TDGP) recorded at the Peace Canyon tailrace RDB and Hudson's Hope downstream station, June 19 – July 22, 2021.

in saturation levels during the spill supports the assertion that the Peace Canyon spillway may partially mitigate high TDGP levels entering the Peace River during simultaneous operation of the Bennett Dam spillway by "flashing off" gas when total pressure is relatively high. The failure of the Hudson's Hope downstream meter during the spill precluded the collection of further evidence of this phenomenon.

During simultaneous operation of both spillways, gas saturation levels of water entering the Peace River through the PCN turbines averaged approximately 116%. Assuming the attenuation effect of the PCN spillway and given that spillway discharge accounted for less than 15% of total volume, the gas saturation level of combined outflow into the Peace River was estimated to be approximately 114%.

Based solely on the results of the 2021 TDGP monitoring program, no definite determination could be made as to the potential impacts of gas supersaturation on downstream fish populations in the Peace River. However, given the relatively short 7-day duration of the 2021 spill and the relatively low incremental increase in gas supersaturation downstream of Peace Canyon (106% to 114%), acute and chronic affects of Gas Bubble Trauma seem unlikely. It can be noted that no symptoms of Gas Bubble Trauma were noted during the visual examination of 2,841 fish captured in the Peace River immediately after 32 days of spilling at comparable volumes in 2020, when saturation levels of flow entering the Peace River were slightly higher than in 2021 (DES 2021).

Total dissolved gas pressure monitoring results in 2021 suggest that fish in Dinosaur Reservoir residing in water deeper than 1.7 m and fish in the Peace River residing in water deeper than 0.8 m could have theoretically avoided the effects of incremental gas supersaturation through depth compensation.

4.0 RECOMMENDATIONS

The daily pulse spill configuration employed at the WAC Bennett Dam in 2021, should be further investigated as a mitigative tool in potentially reducing incremental increases in TDGP in the lower portion of Dinosaur Reservoir and the Peace River downstream of the Peace Canyon Dam. Monitoring during past spills suggests that incremental increases in TDGP at the Bennett Dam spillway are not necessarily proportional to spill rate, with increases in spill volume beyond approximately 500 cms resulting in only small increases in TDGP. Thus it may be possible to spill at higher rates during the daily pulse to maintain overall spill volumes while reducing average downstream saturation levels with daily pauses. Additional factors such as operational considerations and potential increases in fish entrainment rates would need to be considered.

TDGP meters deployed in the Peace Canyon Tailrace have been subjected to strong currents and shifting substrate that are suspected to have impacted data quality and consistency in 2020 and 2021. Consideration should be given to moving these stations up to 1,000 m further downstream if stable and secure sites can be located. In addition, the practice of deploying an optional meter further downstream should continue until sufficient data can be obtained from beyond the mixing zone of PCN spillway discharge and turbine outflow. This temporary measure would be conditional on the timing of inundation of the proposed Site C reservoir. In the meantime, these data may provide information about the potential mitigating affect of the PCN spillway on high gas saturation levels.

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Diversified Environmental Services. 2021. Peace River Water Use Plan Peace River Spill Total Dissolved Gas Pressure/Temperature Monitoring Program – June/July 2021. Prepared for BC Hydro, 6911 Southpoint Drive, Burnaby, BC