Peace River Water Use Plan

Monitoring Program

- **Peace River Spill Total Gas Pressure/Temperature**

WUP Implementation Year 5

Reference: GMSMON-11

Study Period: June – August 2012

Final Report

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Peace River Water Use Plan Monitoring Program: GMSMON-11 Peace River Spill Total Gas Pressure/Temperature

Executive Summary

The monitoring study triggers defined in the Peace Project Water Use Plan (WUP) were met in the fifth implementation year of the WUP, during the June 26th – August 2nd period in 2012. The WUP's Total Gas Pressure/Temperature monitoring study (GMSMON-11) was conducted for the first time, measuring Peace River total gas pressure and temperature levels before, during and after the 2012 spillway operations at the W.AC. Bennett (GMS) and Peace Canyon Dams (PCN). River sampling stations were placed upstream of the dams, as well as downstream for a total of 5 sites. The results of the 2 key monitoring periods (June 25th – July 13th; July 26th – August 8th) showed the median levels of Total Gas Pressure saturation in the PCN forebay were 118 and 121% during GMS spillway operations at 581 and 1490cms (median discharge). The median spillway discharges at Peace Canyon Dam were 1160 and 311cms during the two monitoring periods and its tailrace TDG levels were similar to its forebay TDG. The GMS spills were associated with a modest rise in TDG levels (12-15%) in the PCN forebay as well as gas bubble trauma in fish captured in reaches downstream of the tailrace. The PCN spills were not associated with a substantial change in TDG levels above and beyond those elevated saturation levels found in its forebay as a result of GMS spills. When the PCN generation discharge dropped but spills held constant, there was a corresponding decline in tailrace % TDG (left and right bank.

The study management question is:

> During a spill event at GMS, do dissolved supersaturated gases in the Dinosaur Reservoir and the Peace River reach a level that negatively impacts fish populations?

Based on the 2012 study results, as well as data from concurrent fisheries studies, there can be no determination of population-level impacts. The Ecological Hypothesis for the study is:

> H_A: TDG levels downstream at GMS during a spill are at levels that are known to cause mortality or sub-lethal effects to fish.

This hypothesis was accepted due to anecdotal observation of fish showing gas bubble trauma as well as published accounts of trout (Antcliffe et al. 2002) and whitefish response (Fickeisne and Montgomery 1978) to TDG saturation levels similar or less than those recorded in 2012. The extent of the effects cannot be extrapolated beyond the individual fish observed based on the available data.

Mitigation measures for future spills are recommended where operational changes are thought to affect TDG saturation levels. When GMS is spilling, reduced levels of PCN generation or increases in PCN spill levels are a recommended means to pass a comparable volume of water while creating lesser downstream TDG saturation levels than passing all water via the PCN turbines.

1.0 Study Description

1.1 Background

The Peace Project Water Use Plan Committee (the 'Committee') recommended monitoring of downstream water quality effects of spill through the WUP's Spill Protocol (PSP) (BC Hydro 2003). The supersaturation of dissolved gas in areas downstream of the W.A.C. Bennett and Peace Canyon Dams can occur around spill events (Wilby 1997). High concentration of total dissolved gas pressure (TDG), measured as percent TDG saturation, can lead to acute physiological stress in fish (i.e. Gas Bubble Trauma (GBT) (Antcliffe et al. 2002) hence it was the key water quality parameter the Committee recommended monitoring during spills.

The aim of the monitoring program (GMSMON#11) was to gather information related to TGP generated by dam operations during high rates of spill. By comparing known information on fish GBD rates with the TDG levels recorded during a Peace spill, this study Terms of Reference (ToR) infers the potential implications for fish populations downstream of the spill(s). BC Hydro also subsequently developed its TDG Strategy (the Strategy, Anon 2013) which outlines a series of thresholds for which monitoring, impact assessment and mitigation activities are employed to assess and manage TGP impacts. This study is intended to both align its activities with those in the Strategy while addressing the key questions raised in the WUP.

The PSP would combine the results of the TDG monitoring program with the results of other monitoring programs s to help evaluate the overall effects of spills. For example, the results of this study are to inform the Peace WUP's Flood Pulse Management Plans as it strives to quantify the ecological merit of high flows (i.e. >1,982cms) on the Peace River habitat.

The PSP definition of a 'spill' as a trigger for TDG monitoring is (BC Hydro 2003):

- Peace Canyon Dam spillway discharge of $\geq$1,500cms for $\geq$ 2 days;
- Peace Canyon Dam spillway discharge of 500cms for $\geq$ 7 days;
- 205cms discharge from the W.A.C. Bennett Dam spillway for $\geq$ 2 days; or,
- 2,000cms total discharge from Peace Canyon Dam Spillway and Generating Station.

This report describes the Peace Project facility operations in 2012 as well as the associated TDG monitoring and recommendations for future study to fulfill the study's objectives set by the original WUP CC and Spill Protocol as well as to meet BC Hydro's TDG Strategy requirements.

1.2 Management Question

The following sections (1.2-1.4) are excerpts from the GMSMON#11 Monitoring Terms of Reference.

The study management question is:

During a spill event at GMS, do dissolved supersaturated gases in the Dinosaur Reservoir and the Peace River reach a level that negatively impacts fish populations?

The approved ToR does not explicitly define the level of effect that is considered a negative impact at the population level. The Peace WUP Committee report examined spill effects to fish in two sections of the report: 1) Flood Pulse Plan (FPP) and, 2) Pease Spill Protocol. The PSP defines when to start the monitoring of TDG based on the level of discharge, and the FPP section looks to weigh the effects of spill in contrast to gains that may result from planned spills that target ecological benefits in the downsteam reaches. This means that negative impacts to fish populations would need to consider the net changes estimated in the FPP and PSP monitoring studies ahead of determining the overall population effect.

This monitoring study represents one component of the suite of information that will be required to address the management question. Specifically, this study aims to address a specific hypothesis related to TDG levels during a spill (see below) and known information on fish sensitivity.

1.3 Impact Hypothesis about TDG and Temperature Effects

The sole study hypothesis stated in the ToR was:

H_A: TDG levels downstream at GMS during a spill are at levels that are known to cause mortality or sub-lethal effects to fish.

This hypothesis examines TDG levels as well as the time period over which the levels occur to assess whether fish are expected to suffer lethal or sub-lethal effects from dissolved supersaturated gases based on accepted values within scientific literature.

The approved ToR does not have any specific management questions or impact hypotheses in regard to water temperature, however it is measured as it is known to be a factor in determining TDG as well as having a potential effect on fish habitat. The temperature regime outside the spill event must be described ahead of interpreting the spill effects, and hence the continuous multi-year monitor, GMSWORKS-2 which contains the historic PCR temperature dataset will address temperature changes in its 2012 report.

2.0 Monitoring Program Approach

2.1 Objective and Scope

The monitoring program Terms of Reference lists the following 2 objectives and scope for the GMSMON-11 study program:

1) Measure total gas pressure for the duration of a spill and immediately after;

2) Assess total gas pressure levels in terms of impact on fish populations in the Dinosaur Reservoir and the Peace River downstream of the Peace Canyon Dam.

Subsequent to the development of ToR objectives, a BCH facility-wide TDG Implementation Strategy (BCH 2013) was developed as a systematic approach for addressing high TDG situations. The Implementation Strategy builds on the *in situ* data collected under the original GMSMON-11 ToR (Objective #1) and used the collected information to determine the best management actions. Specifically, the Strategy uses the following information as a basis for decision on next steps:

a) Does air supersaturation occur at the facility?

b) If so, under what conditions does it occur?

c) How frequent do those conditions arise?

d) When it does occur, what is the magnitude and duration of the event?

e) Does the magnitude and duration of the event exceed the threshold for harm?

f) If potentially harmful events occur repeatedly, is there sufficient time between events for full recovery? If not, are successive impacts additive or multiplicative?

The Strategy is further described as a series of steps (Figure 1) that guide management decisions.

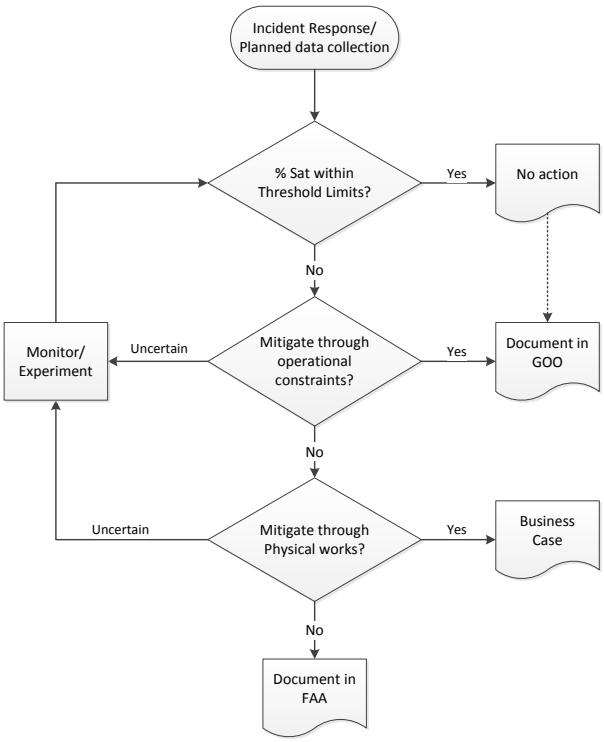

Figure 1. TDG Strategy decision tree showing how TDG data are used to guide management decisions.

The Strategy considers mitigating factors (e.g. gas composition, water depth, exposure duration) as well as threshold levels as a starting point for assessing the

risks to fish. The % TDG saturation threshold levels are defined as 1) Up to 110%; 2) Up to 115%, and 3) Up to 120%. When the results are combined, a response is specified (Table 1).

Table 1. Summary of TDG management thresholds, modifying factors, corresponding mitigation response, and need for agency notification.

TDG Measurement	Downstream Water Depth	Exposure Duration	Response	Agency Notification
TDG < 110% [1]	Any	Any	None	
110%< TDG <115%	> 0.5 m	Any	None	
	≤ 0.5 m	≤ 10 days	None	
	≤ 0.5 m	> 10 days	Low Effort Monitoring	Yes
115%< TDG <120%	> 1.0 m	≤ 2 days	None	
	> 1.0 m	> 2 days	Low Effort Monitoring	Yes
	≤ 1.0 m	Any	High Effort Monitoring	Yes
TDG > 120%	> 1.0 m	Any	High Effort Monitoring	Yes
	≤ 1.0m	Any	Impact Assessment	Yes

[1] threshold when gas ratios are significantly different from normal atmosheric conditions or are unknown

The study area includes the forebay of GMS to the Peace River immediately downstream of Pine River. The Peace Spill Protocol specifies monitoring is triggered during spill events where spill discharge (Q_{SDI}) at:

- GMS exceeds a daily average of 7,240 cfs (205 cms) for two or more days;
- Peace Canyon Dam exceeds a daily average of 17,657 cfs (500 cms) for seven or more days;
- Peace Canyon Dam exceeds a daily average of 52,972 cfs (1,500 cms) for two or more days.

Monitoring is also triggered when total discharge from the Peace Canyon facility exceeds a total discharge of 70,629 cfs (2,000 cms) for two or more days.

TDG monitoring before, during and after the 2012 spill is described in Section 2.5

2.2 Sampling Approach

TDG meters were installed to provide the average hourly gas saturation and temperature based on measurement being recorded every 15 minutes. Temperature measurements before, during and after the PSP spill trigger was met in 2012 via sensor built into the TDG meters as well as the loggers installed under the GMSWORKS-2 program. The near-continuous, *in situ*, measurement was considered key to understanding how the river and reservoir TDG varies with changing generation and spillway discharges. Downstream meter locations were established to help understand the influence of Peace River tributary inflow and

general patterns of mixing and dissipation of dissolved gas saturation levels over time.

2.3 Methods

2.3.1 Installation of TDG meters

TDG meters (Common Sensing Model #DL6) were installed by Diversified Environmental Services ahead of the spill being triggered and are described in Table 1 and Figure 2. Sensors were positioned so that they were accessible from shore and to record gas saturation and temperature levels within 50cm of water surface. The meters were maintained & calibrated by Diversified as part of the WLR Project GMSWORKS#2 (Peace River Baseline TDG/Temp) in the period preceding and during the spill. In addition, a river temperature monitoring program (GMSWORKS#2) has been implemented at Peace River sites to determine the spatial and temporal variation in the temperature regime on an ongoing basis. Sites used for ongoing temperature monitoring were also used during the GMSMON#11 spill TDG monitoring as described in Table 1.

Table 1. TDG monitoring locations and descriptions.

Location	Meter #	TDG Measurement Period(s)	Site Description	Location Used in GMSWORKS#2 Temp	Notes
Bennett Dam Forebay	1	July 26 - August 7	Northern portion of spillway debris boom	Y	Data QC checks show the meter was not reliably measuring TGP. Looks at ambient gas saturation level of surface water.
Peace Canyon Dam Forebay	2	June 25 - July 3; July 26 - August 7	East End of Anti-Vortex Dyke	Y	~450m upstream of dam face. Records TGP level generated upstream of PCD.
Peace Canyon Dam Tailrace Right Bank	3	June 25 - July 3; July 26 - August 7	Right bank of the river	N	~200m downstream of dam. Targets measurement of incrimental TGP generation cause by PCD spillway operations.
Peace Canyon Dam Tailrace Left Bank	4	June 25 - July 3; July 26 - August 7	Left bank of the river	Y	~200m downstream of dam. Aims to record the TGP entrained through turbines at PCD.
Hudson's Hope Pumphouse	5	June 25 - July 3; July 26 - July 30	Adjacent to municipal pump house, left bank.	Y	Aims to record levels mixing of left & right tailrace TGP from PCD. Beaver chewed through TGP sensor cable 30 July 2012.
Peace River, upsteam of Pine	6	June 25 - July 3	Right bank of the river	Y	~2km upstream of Pine R. confluence. Data not considered reliable. Meter malfunctioned during all sampling periods.

The GMSMON#11 program had access to 6 TGP meters that were maintained & calibrated under the GMSWORKS#2 monitor. During the June 25 deployment, BCH staff opted to install 5 meters, *in situ*, for continuous logging, and to keep the 6th meter for spot checks to verify the installed meter reading and as a backup.

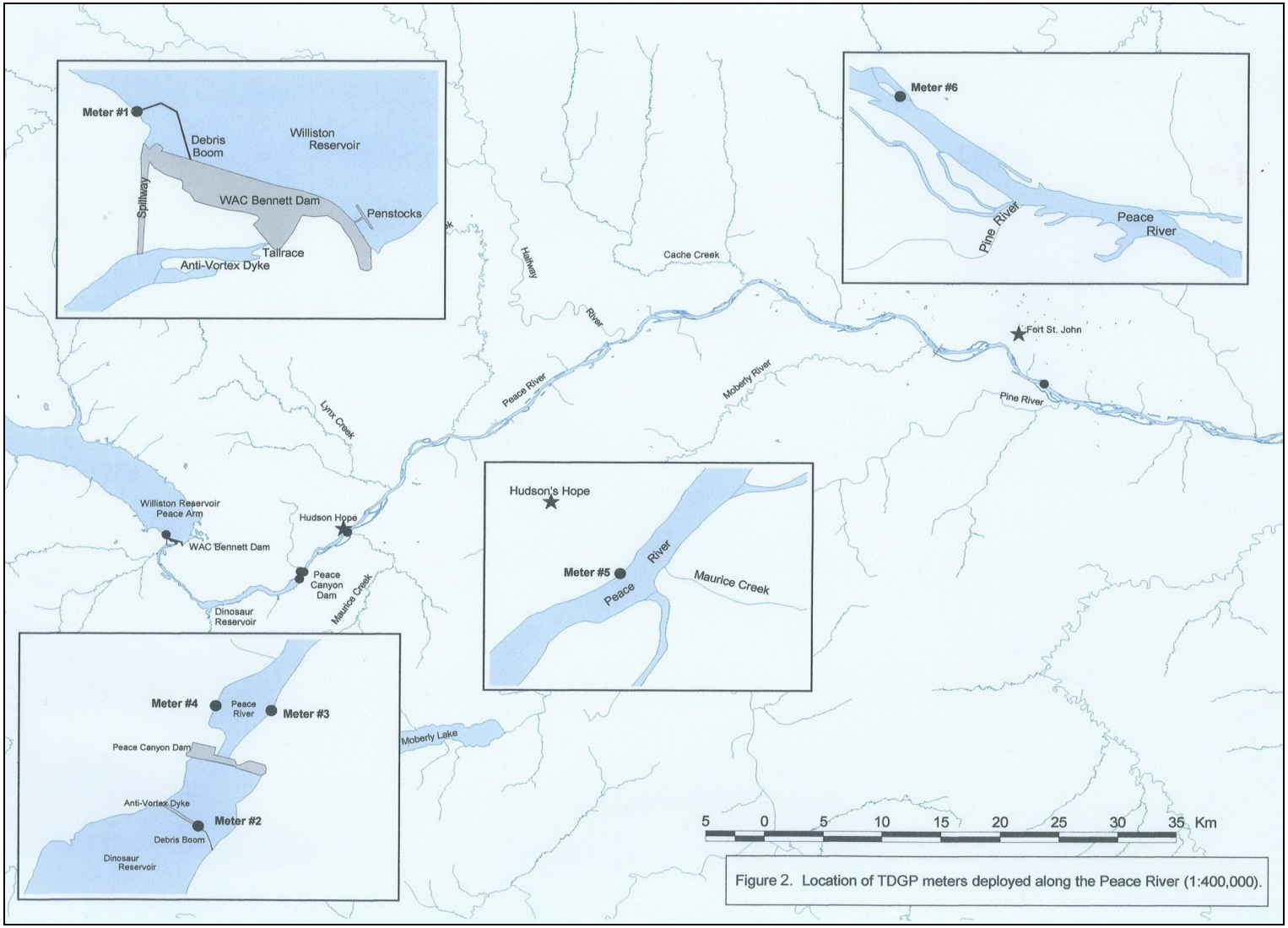

Figure 2. Map of TDG/Temperature metering locations.

2.3.2 Data Collection and Quality Assurance/Quality Control

Data uploads from each of the fixed monitoring sites were conducted manually, on site, using a laptop computer. Flow release data was provided by the BCH Commercial Resource Operations (CRO), Flocal data access tool. The CRO tool collects the operations data from the spillway gates and turbines and converts that information into discharge estimates using established rating curves.

Quality checks done by BCH staff after the July 3rd fixed station data downloads found that several of the TGP meters installed on June 25th had ongoing errors in the recorded data as evidenced by fact that the total gas saturation calculations automatically computed in the TGP meters did not, in some cases, resemble patterns in the oxygen saturation readings. Once the errors were detected, recording was stopped on July 13th and all meters were sent to the manufacturer for repair and recalibration, then re-installed on July 26th. Upon re-installation, the meter located upstream of the Pine River was found to again malfunction due to installation issues, resulting in no further data being collected from this location for the 2012 spills. Subsequent the July 26th installation, the GSM forebay meter later became clogged with debris and its data records are not considered to accurate.

2.3.3 Data Entry and Analysis

Data from the TDG meters was recorded and operation is collected every 15 minutes by their respective sensors, and the data records were later converted into average hourly data to synchronize with operations data. Operations and TDG data summaries and plots were analyzed using MS Excel.

2.5 Results

There were two distinct operations periods monitored for TDG: June 26th – July 13th and July 26th – August 8th, 2012. The appendix contains tabular records for the operations and TDG parameters. The PSP spill trigger was met on June 27th when the daily average spill at W.A.C. Bennett Dam (GMS) became > 205cms. The spill at GMS was concluded on July 11th, and started again on July 24th and continued until August 2nd. The PSP trigger for TDG monitoring was also met for the spill at Peace Canyon Dam (PCN) when spillway discharge was >500 cms for 7+ days as of July 2nd. The spillway operations and PCN were stopped on July 11th, and restarted for 5 hours on July 13th and again for the July 24th – July 28th period.

<u>June 26th – July 13th</u>

The median spillway discharge in this period was 1,490 and 1,160cms for GMS and PCN, respectively. The peak spillway discharge levels for 2012 were observed for ~4hr period on June 28th when the Bennett Dam average hourly spills were 1,950 – 2,865cms and PCN spill discharge (hourly average) rose to 1,757cms (Figure 3).

The peak and median TDG levels at the Peace Canyon forebay during the spills at GMS were 125.5 and 121.5%, respectively. The average hourly TDGmeasured at the Hudson's Hope Pumphouse was 120% for ~12 days in this period, with the peak level being 121% on June 29th.

July 26th – August 8th

The median spill level in this period was 581 (7/26 - 8/8) and 311cms (7/24 - 7/28) for GMS and PCN, respectively. Peak spill levels were <10cms greater than the median spills values.

The peak and median TDGlevels at the Peace Canyon forebay were 120% and 118%, respectively. The average hourly TDG measure at the Hudson's Hope gauge was not examined due to a Beaver severing the sensor cable, however the left bank of the PCN tailrace show peak and median TDG of 119% and 114%, respectively.

Figure 3. Spillway discharge (~1,477 cms) from the W.A.C. Bennett Dam, June 28th. Photo credit: Kim Hawkins, BC Hydro.

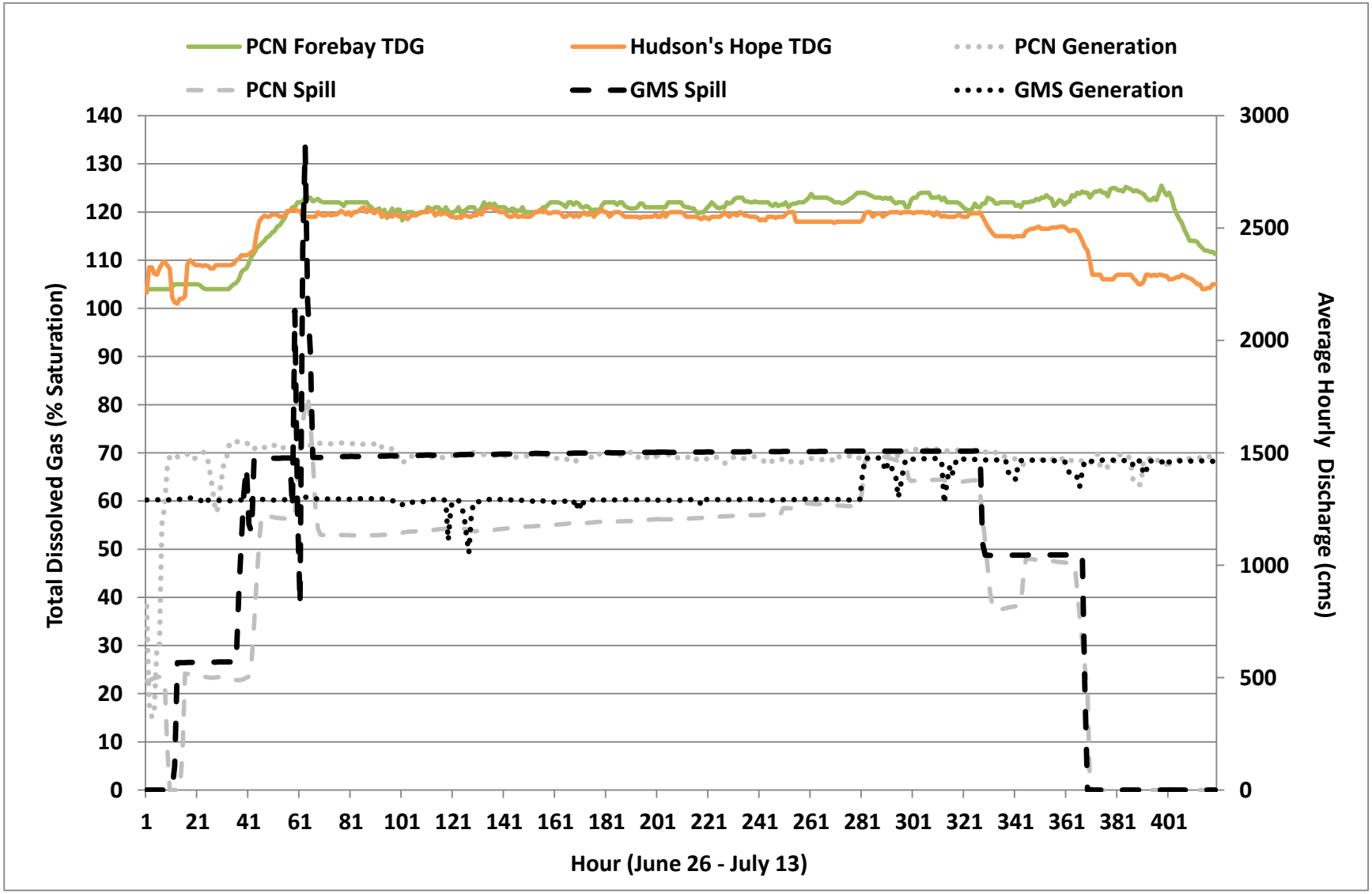

Figure 4. Hourly total dissolved gas concentration (%TDG saturation) and dam operations levels for June 26 - July 13, 2012.

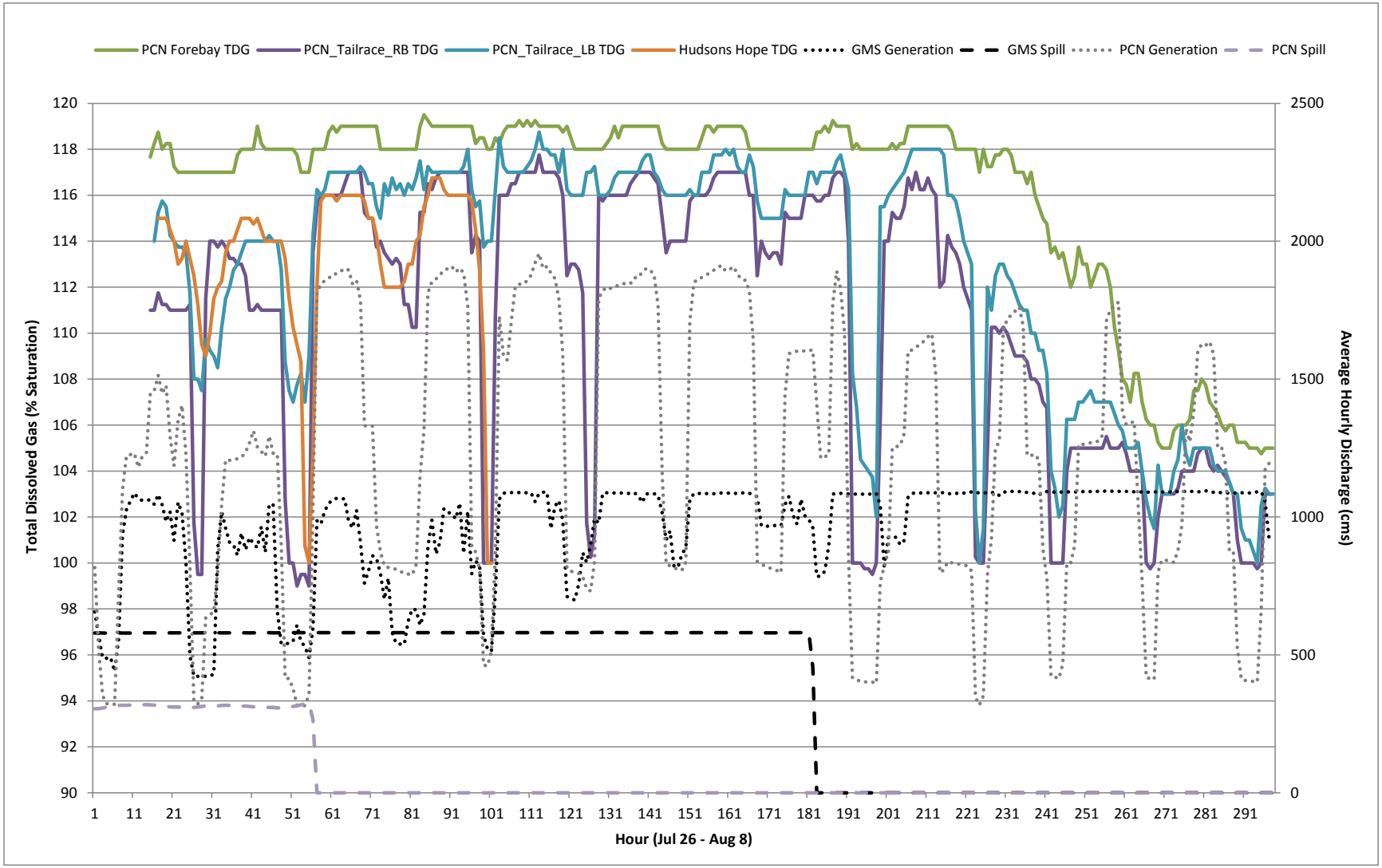

Figure 5. Hourly total dissolved gas concentration (measured as % TDG saturation) and Operations data for July 26 - August 8, 2012.

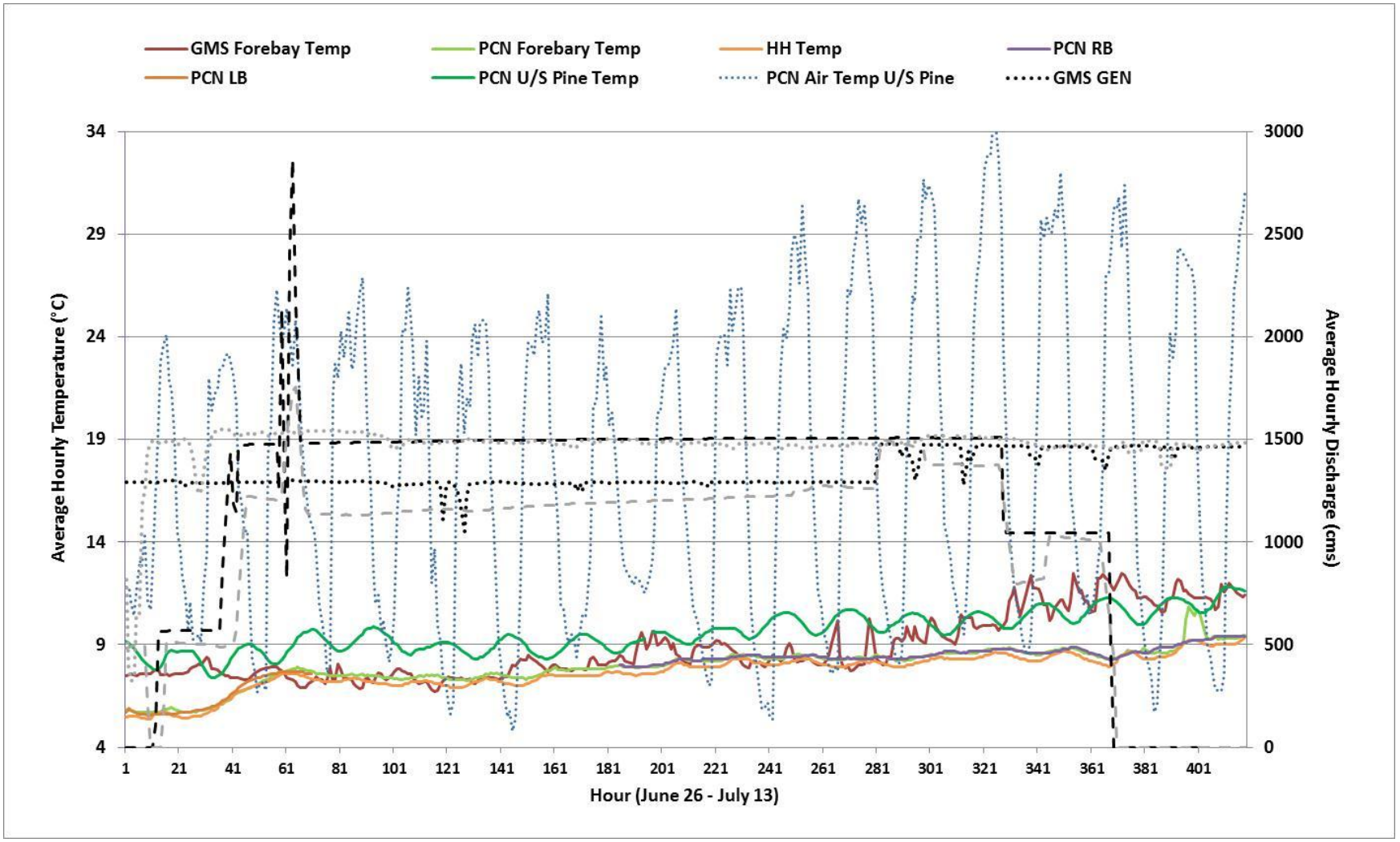

Figure 6. Hourly surface water temperature and facility operations, June 26-July 13, 2012.

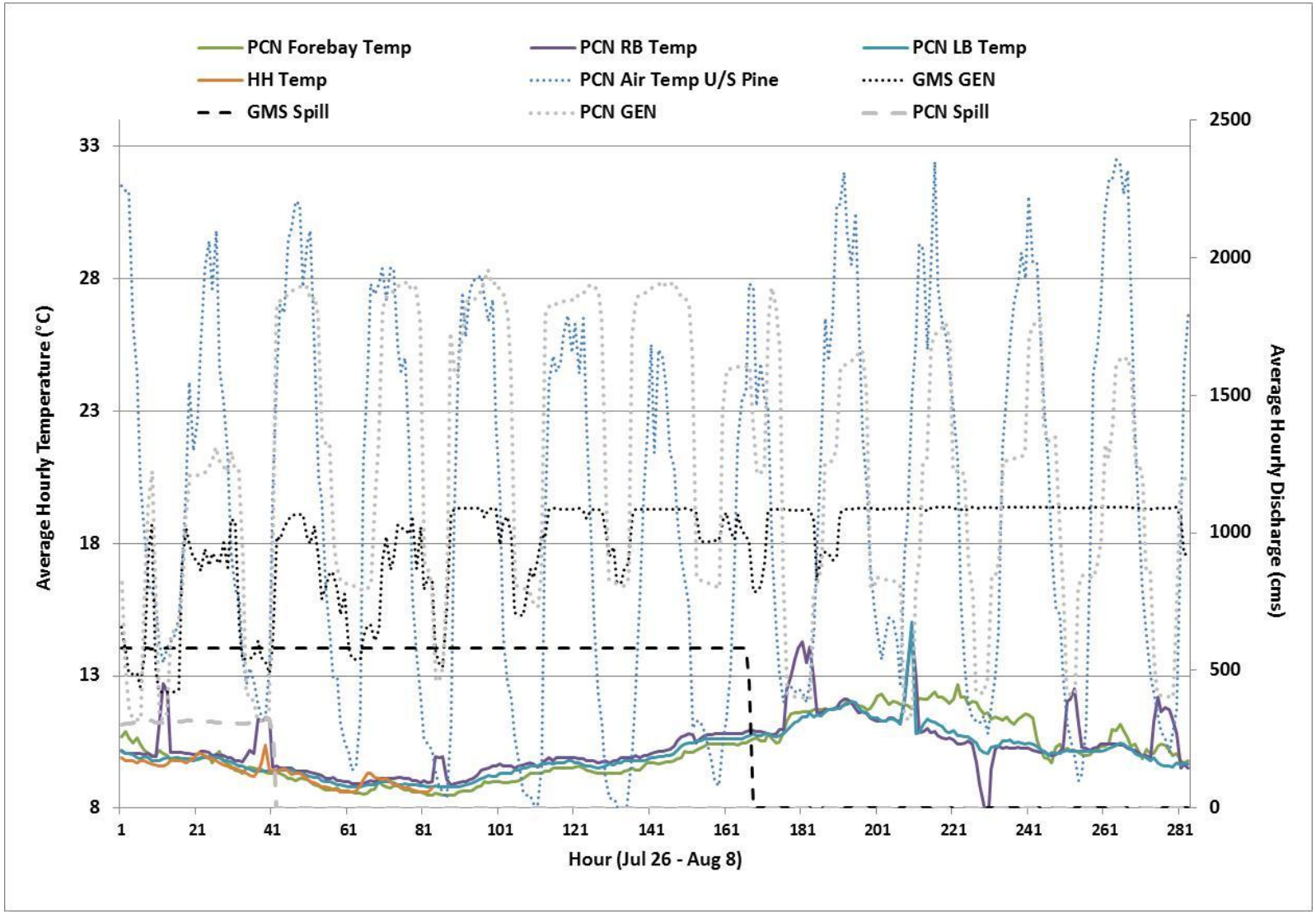

Figure 7. Hourly surface water temperature and facility operations, July 26 - August 8, 2012.

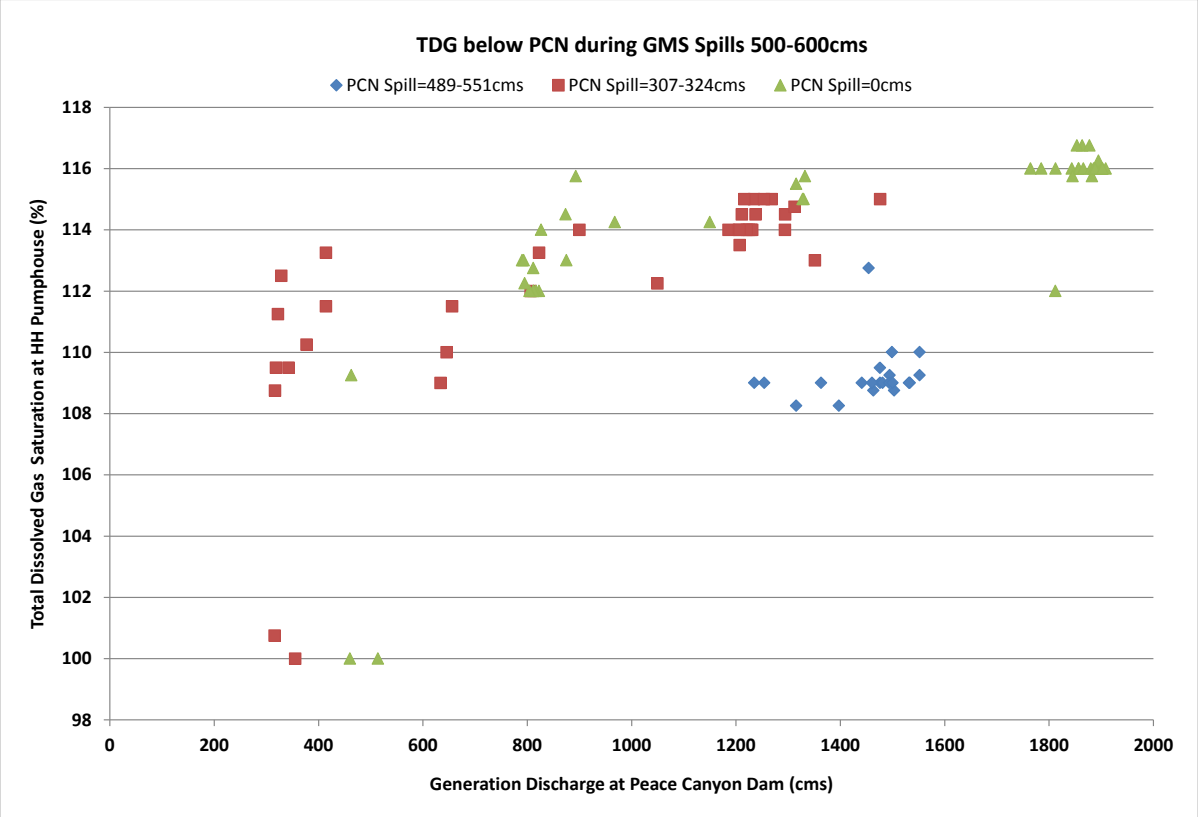

Figure 8. Average hourly TDG saturation in the Peace River at Hudson's Hope plotted against Peace Canyon Dam (PCN) generation discharge for the 2012 spill period while spillway discharge at Bennett Dam (GMS) was 500-600cms.

2.6 Interpretation of Monitoring Program Results

The GMSMON-11 Management Question and associated ecological hypothesis do not make reference to temperature effects, hence interpretation of the water temperature results will be done as part of the WLR study, GMSWORKS#2 which contains the historical temperature trends information for the Peace River and hence is better suited to contextualizing the influence of the spill. Temperature has been incorporated, automatically, by each the TDG meters so as to provide concurrent instrument correction for the influence of temperate on TDG readings.

2.6.1 Relationship between TGP and 2012 Peace Project Operations

G.M. Shrum Generating Station & W.A.C. Bennett Dam

There were two GMS spill levels (median=1,490 and 581cms) monitored (via PCN forebay) for a prolonged period (ie., over several days) during the 2012 spill study. During the 1,490cms spill discharge, the PCN forebay showed TGP levels at ~121% whereas 581cms was correlated with ~118% forebay TDG. In contrast, the PCN forebay TGP before the spills began was ~105%, mean that there was a 12% increase in % TDG associated with the 581cms, and a 15% increase during the 1,490cms spill period. This result shows there is little incremental increase in TDG

concentration (measured at PCN forebay) between 581cms and 1,490cms discharge from the GMS spillway.

After spill discharge at GMS was eliminated there was a reduction in PCN forebay TGP approximately 3.5 days later (spill stop August 2nd; 15:00; TGP= 105% at 04:00 August 6th).

Peace Canyon Dam & Generating Station

The June 26 – July 13th monitoring results showed very similar TDG in the PCN forebay and Hudson's Hope (HH, left bank) during concurrent spillway use across GMS and PCN, hence raising the question as to whether the incremental increases in TDG concentration from the PCN spillway (median Q=1,160cms) was: a) measurably higher than water entrained through the generation units, or b) poorly mixed in the Peace River at Hudson's Hope (i.e., higher concentration on the right bank than left bank).

The GMS spillway discharges at the ~1,500cms level (June 28th – July 7th) were associated with Peace Canyon forebay % TDG saturation levels at ~121%. The concurrent spill at Peace Canyon Dam (mean=1,280cms) was associated with HH %TGP level that closely resembled the Peace Canyon forebay levels. This result means that %TGP generated by the Peace Canyon spillway operations at 1,280cms does not behave in a simple, additive concentration to the %TGP levels recorded at the surface of the PCN forebay when measured at Hudson's Hope.

There was a brief spike in GMS spillway discharge on the afternoon of June 28th which saw 2,407 and 2,865cms as the hourly average spill at hour 14 and 15, respectively (Figure 4). The %TDG saturation level increased from 122 to 123% at the Peace Canyon forebay over the same period.

The July 26 – August 8th results (Figure 5) show evidence that the Hudson's Hope Pumphouse section of the Peace River has %TDG levels that reflect mixing of left and right bank tailrace water. On the morning of July 29th (hours 73-81), there was a drop from 116 to 112% drop in HH %TDG while the PCN tailrace LB site remained at ~116%. The apparent reason for the LB tailrace data departing from the HH data (also LB) is that the drop in the PCN RB levels loosely tracked the HH values. The influence of PCN RB levels of %TDG at HH shows mixing after a relatively short distance from Peace Canyon Dam. The pattern was repeated on the morning of July 30th (hours 99-102, Figure 5).

The effects of increasing PCN spill level combined with reduced generation was shown to be a reduction in downstream %TDG at HH when under steady spill conditions at GMS (500-600cms) (Figure 8). The scenario of PCN generation/spill discharge being ~1500/500cms was associated with 109% TDG saturation whereas ~1300/320cms had 114-115% saturation (Figure 8). This result was most importing findings of the study as it presents a possible mitigation tool for future operations.

Trends in the lag in %TDG concentration at the Pine River location with changing operations were not available due to the faults in the equipment before and after the recalibration by Point Four Systems.

Overall, the 2012 program provides strong evidence that spills at GMS of 1,500cms are sufficient to create relatively high, surface water %TDG levels (~120%). Similarly, the GMS 570cms spill level at GMS was shown to produce Peace Canyon forebay levels to stay at or above 118%. The mixing and dissipation of background and super-saturated water in Dinosaur Reservoir was shown to result in a 3.5 day lag in the reduction of TDG levels in the PCN forebay subsequent to spill stopping at GMS. Downstream of Peace Canyon Dam, there appears to be mixing of left and right bank TDG as soon as the Hudson's Hope section of the Peace River. Reductions in PCN generation flows during periods of elevated PCN forebay TDG were found to be associated with a reduction in tailrace TDG levels (left and right banks), and may point to a dilution effect from subsurface water inputs. The reduction in tailrace TDG concentration through reduced generation suggests a means of Operational change for mitigating TDG levels during a spill. Furthermore, reductions in PCN generation flow that require an offset by increased PCN spill may also mitigate the downstream TDG saturation levels.

2.6.2 Management Question & Hypothesis Discussion

The GMSMON-11 ToR management question (MQ) is:

> During a spill event at GMS, do dissolved supersaturated gases in the Dinosaur Reservoir and the Peace River reach a level that negatively impacts fish populations?

The Impact Hypothesis associated with the MQ is:

> H_A: TDG levels downstream at GMS during a spill are at levels that are known to cause mortality or sub-lethal effects to fish.

The discussion first addresses the Hypothesis, followed by discussion of the management question.

The results of the 2012 spill monitoring program showed prolonged periods of TDG levels at or slightly above 120%, a level that is known to cause sub-lethal and lethal effects in individual fish (Antcliffe et al. 2002), hence the H_1 hypothesis is accepted. Anecdotal observations of fish collected during the spill for the Site C baseline study work (July 4-12th, 2012) revealed fish showing gas bubbles in their fin rays (>10% in fish captured upstream of Halfway River)(Figure 9). Of the 2,231 fish (Rainbow Trout, Mountain Whitefish, White Sucker, Longnose Sucker and Kokanee) sampled July 4 - 12th by the Site C fisheries contractor, 11% showed evidence of gas bubble trauma (e.g., subcutaneous bubbles, skin sloughing etc.). These fish could have experienced ~120% TDG levels for up to 17 days, depending on their distribution in the mainstem water column.

In considering the elevated TGP effects to the fish community, the key considerations reported by the literature include: a) compensation by depth of fish, b) length of exposure; c) % saturation of TDG in the water column, d) species and e) past exposure to elevate TDG level (Weitkamp 2009). In the Peace River, the frequency of spill is rare such that the 2012 fish community would not have had prior experience with TDG saturation levels comparable to the 2012 spill. There was a 15% increase in the ambient % TDG saturation at <1m depth, which is considered a

'modest' (0-25%) increase in the literature. The Peace River fish at 1m depth would have experienced 116-118% TDG saturation during the 10 day period when GMS was spilling at a rate of 1,490cms, according to the relationships published by Weitcamp et al. (2003). A review of the digital elevation model data for the Peace River, between PCN and Pine River, showed that 85.5% of the wetted habitat was >1m deep while 14.5% was ≤1m during 2,850cms outflow (spill + generation) from PCN, which closely resemble the mean flow of the June 28th – July 7th period (2,724cms). In terms of fish response, the work from Antcliffe et al. (2002) showed 42% of Rainbow Trout experiencing 116% TDG levels had died after 9 days. Fickeisen and Montgomery (1978) found 100% mortality in Mountain Whitefish experiencing 120% TDG levels for 2-4 days, and noted that they are more sensitive than Rainbow Trout.

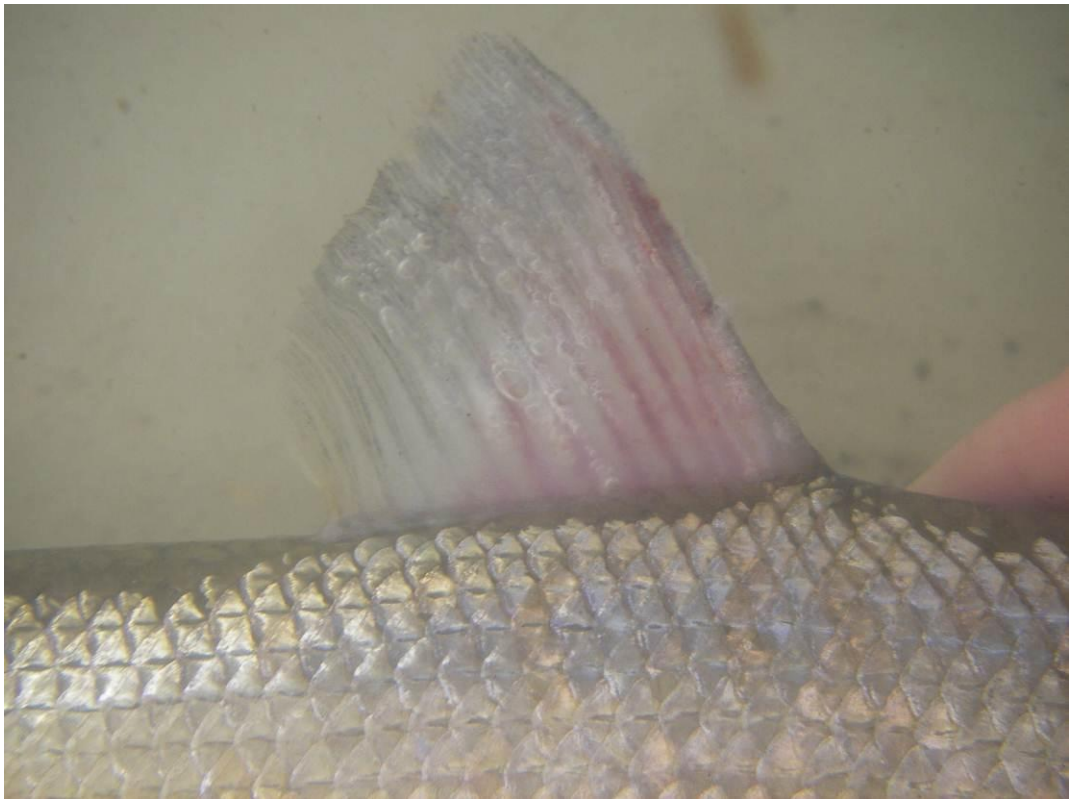

Figure 9. Mountain Whitefish, dorsal fin ray showing subcutaneous bubbles. Photo was taken of a fish captured in the July 4-7th, 2012 period in the Peace River, upstream of the Halfway River confluence. Photo credit: Mainstream Aquatic Consultants.

Results of the annual Peace River Fish Index program (Pattenden 2013) are presented however it is not expected that they be considered as a direct response to the spill, but rather a function of all factors affecting the index fish (adult Mountain Whitefish, Arctic Grayling and Rainbow Trout) in the September 2011 – July 2012 period. Furthermore, the spill-related effects to sub-adults would not be recorded in the 2012 index program results, but rather would be measured in future years of the index study.

The index study results showed the Bull Trout population health and structure were stable across sampling years. Whitefish length-at-age and body condition-at-age

measured in 2012 were below the 2008-2011 mean for most ages and the younger and older fish were less numerous in 2012. Arctic grayling abundance was relatively low in 2012, resulting in them being considered scarce across of sections of the Peace River between Peace Canyon Dam and the Pine River confluence. The changing Arctic graying abundance has been hypothesized to be a result of diminished recruitment from the Moberly River assemblage which makes up the majority of Peace main stem individuals sampled (Pattenden 2013).

The largest risk of TDG effects in 2012 is expected to have come from the June 28th – July 7th spills at GMS (average=1,500cms) and PCN (average=1,280cms) which saw consistent TGP levels at ~120%. This spill level is roughly 16% of the GMS spill capacity and 29% of the 1996 spill (June 24 – August 17). The 1996 spill (BCH 1999) indicated that GMS tailrace TDG saturation level increases leveled off once spillway discharge went higher than roughly 3,400cms.

Impact Assessment

The April draft TGP strategy (Anon 2013) explains than an impact assessment for TGP-related effects in fish is not required for Peace River habitat >1m deep, meaning that effects assessment should be limited to fish community using the portions of the river ≤ 1m in depth at the time of the spill. There was at least 14.5% of the wetted habitat located at <1m depth during the 2012 spills, however the relative abundance of fish in this zone is unknown.

The results of 2012 *in situ* measurements do not provide sufficient information to explain the extent of exposure to TDG saturation levels that were A) measured and B) known to be harmful to fish. Without information on the fish distribution and the greater detail on the spatial variation in TDG saturation levels in the Peace River during the spill, there can be no reliable estimate of population impacts in 2012 as per the Management Question.

The annual fish index program (GMSMON-2) provided some anomalous results in the fall 2013 sampling program, whereby a ~20% reduction in body condition factor was observed in older Mountain Whitefish captured from Sections 3 and 5 (Mainstream, 2014). Liver samples from the affected fish were examined in October 2104 by a provincial fish pathology expert (G. Marty, BC Ministry of Agriculture). The results were not conclusive; however the etiology did not match published accounts of fish with acute exposure to elevated TDG saturation levels (Pauley et al. 1967). While the pathologist indicated that these fish had stress related to poor nutrition, the stomachs of the affected fish were shown to be comparably full as compare to fish with average body condition (R. Pattenden, pers. comm., 29/10/2013). Furthermore, the relatively dark colour of liver tissue in affected fish was attributed to elevated lipofuscin, a conditions known to result from a variety of 'insults', including exposure to organic contaminants. The conclusion drawn from the pathology investigation was that the liver results would be unprecedented if related to TDG exposure, and that fish would more likely have succumbed in the winter of 2012/2013 if effects were related to spillway operations. Further investigation into the root cause of this body condition change are beyond the scope of this monitor, but will be tracked in the annual fish index program.

Flood Pulse Program

Part of the rationale for monitoring the TDG saturation levels was to understand the overall merit of implementing any Flood Pulse program. The possible benefits were explored in the Side Channel Response program (GMSMON-8, NHC 2013) in terms of side channel substrate mobilization and fish access improvements. The MON-8 result show little substrate movements or evidence of habitat improvements as a result of the high discharges during 2012 spills. The results of the riparian vegetation flooding program (GMSMON-6) are to be studied in WUP implementation years 9-10 with the intention of determining possible benefits of the 2012 spills and any subsequent flows that meet the PSP triggers. Hence the results of the Flood Pulse Plan are to be considered in aggregate ahead of effects determination, however there is no early evidence suggesting there are net benefits to Peace River habitat that result from operations levels similar to those in 2012.

Mitigation

A key component of the TDG Strategy is to examine opportunities for mitigation where possible. The mitigation opportunity exploration is outside the Management Question and Ecological Hypothesis but is considered to be the focus of this monitoring study in light of the overall Strategy. The 2012 monitoring provide 2 key observations and represent future mitigation opportunities.

Mitigation via Reduced PCN Generation

The July 26 – August 8 period provided a chance to observe the Peace Canyon Dam tailrace % TDG levels under varying generation and spill levels. When the generation discharge dropped but spills held constant, there was a corresponding decline in tailrace % TDG (left and right bank, Figure 7). One explanation for this reduction in tailrace levels is that there is a local input of water containing lower % TDG levels in the tailrace area (e.g. sub-surface flows from the river bank) that performs a dissolved gas dilution function in the tailrace water column. While the exact mechanism of reduced generation discharge leading to lower PCN tailrace level remains unclear, there is an opportunity for abatement of % TDG levels in operations that select storage over generation under constant spill level.

Mitigation via Increased Spill at PCN

The %TDG recorded at the Peace River station near Hudson's Hope (left bank) was found to decrease from ~114-115% to 109% under higher spills at PCN (307-324cms vs. 489-551cm) when the GMS spill level was held relatively constant (500-600cms). For comparison, the variation of generation flows was found to have a lesser mitigation effect on downstream TGP than changes to PCN spill levels when considered on a per-unit-volume perspective (Figure 8).

2.6.3 Recommendations to address uncertainties

The following recommendations are intended to meet the TDG strategy response requirements as it was released subsequent to the GMSMON-11 Terms of Reference.

Future TDG Monitoring
The monitoring equipment issues during the 2012 program combined with the fisheries risks of relatively small spills at Bennett Dam results in the recommendation of the current GMSMON-11 study design being repeated in future years. Future studies would be expected to better explain the mixing downstream of Hudson's Hope and how it reacts to changing operations.

Mitigation via Operations
Operations during future spills should focus on the ratio spill vs. generation vs. storage options available. When there is a spill at GMS, a trial which includes a greater amount of the water being passed via the spillway than the generators should be undertaken. Should this trial show the TDG measured in the PCN forebay remain consistently higher (eg., 120 vs. 115%) than the Hudson's Hope station, it would be considered successful as compared to passing all the water via the PCN

The recommendations for operational mitigation are not likely to have a measureable effect on the total discharge from Peace Canyon Dam. The Peace WUP Flood Pulse Plan studies on riparian flooding (GMSMON-6) and substrate mobilization (GMSMON-8) would only be influenced by operational changes affecting total discharge, and hence are not considered in the mitigation recommendation listed in herein.

In the event that future GMS spillway operations are likely to be substantially greater than 1,500cms for several days, there would likely be a need for an effects assessment under the TDG strategy. The fisheries studies that could accompany such as effects assessment should be discussed with Peace WUP technical committee to ensure the efforts are effective and target the priority fish assemblages in the Peace River.

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