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Technical Memorandum

Prepared for: Biota Pacific, Ochoco Irrigation District, and the City of Prineville

Prepared by: Mount Hood Environmental

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Re: Total Dissolved Gas Monitoring in the Crooked River, Oregon, 2019

A large run-off event occurred in the Crooked River watershed beginning on April 3rd, 2019 and managers began spilling water at Bowman Dam. Spill events at Bowman Dam are known to increase the amount of total dissolved gases (TDG) downstream, which has been shown elsewhere in the region to increase the prevalence of gas bubble disease (GBD) in fish. GBD typically occurs when TDG levels exceed 110% saturation for prolonged periods. On the Crooked River, studies conducted by BOR (2008), Nesbit (2010), and Sharpe (2012) documented TDG levels greater than 110% when flows exceeded approximately 600 cfs. At 1,200 cfs, Nesbit (2010) measured TDG at or exceeding 120% and BOR (2008) observed similar TDG levels at 2,600 cfs. High TDG levels were documented by Nesbit (2010) 12 rkm downstream of Bowman Dam, indicating the problem persists downstream of the tailrace through the Wild and Scenic reach of the Crooked River.

To monitor TDG changes in response to Bowman Dam discharge, Mount Hood Environmental (MHE) deployed a Hydrolab MS5 TDG probe (Table 1) downstream of the stilling basin from April 9th through May 2nd, 2019. The probe, which was suspended beneath two buoys and positioned near the main channel at a depth of approximately 1 meter, collected total gas pressure (TGP) data in 30-minute intervals. In addition to the continuous monitoring at the dam, a hand held Pentair Tracker 4 Total Gas Pressure meter was used on April 23rd to take measurements downstream in the Wild and Scenic reach and around the City of Prineville. Similarly, on the final day of monitoring, downstream measurements were recorded using the Hydrolab MS5 probe to further document the extent of elevated TDG conditions (Table 2).

TGP data collected by the probes was then converted to TDG saturation by dividing TGP by local barometric pressure (mmHg). Local barometric pressure was obtained from a weather station at Prineville airport (Station KS39 - https://mesowest.utah.edu/). Each week when data was downloaded from the TGP probe, barometric pressure was also measured using a YSI Professional Plus hand held water quality probe to ensure measurements at the airport did not differ substantially from the actual conditions on site. Total dissolved gas saturation was then paired with Bowman Dam discharge data provided by BOR and time series plots were generated to demonstrate how TDG changed over time in response to discharge at Bowman Dam. Finally, a linear regression model was fit to the data to relate TDG to discharge.

Discharge out of Bowman Dam during the TDG monitoring period ranged from 406 cfs up to 3,100 cfs (Figure 2). TDG ranged from approximately 109% up to nearly 124% during the same period. TDG remained at elevated levels (>120%) until flows dropped below

approximately 1,000 cfs on April 18th and remained above 108% for the duration of the monitoring period. A strong log-linear relationship was documented between discharge and TDG (Figure 3), which unlike previous monitoring efforts (BOR 2008, Nesbit 2010, and Sharpe 2012), suggests that there is an upper limit of gas supersaturation once discharge reaches approximately 1,500 to 2,000 cfs. Monitoring efforts in the Wild and Scenic reach and City of Prineville sections of the Crooked River also revealed elevated TDG levels between 108 and 111%, even after flows dropped below 500 cfs (Table 2). These observations suggest that elevated TDG levels persist much further downstream than previously observed.

This effort was useful for refining the functional relationship between Bowman Dam discharge and TDG. Reported TDG levels immediately downstream of Bowman Dam were similar to previous studies, and the relationships observed between flow and TDG were compatible except that our data show an upper TDG limit at about 1,500 to 2,000 cfs. We also found elevated TDG levels further downstream than previously reported.

Multiple factors can influence TDG, only one of which is the amount of water released from the reservoir. Other factors can include depth of the stilling basin, water temperature, and downstream hydraulic conditions. The extent to which these other factors may have been influencing total TDG and the rate of TDG attenuation in late April and early May 2019 is unknown, and this subject warrants further investigation. If managers decide to reduce the potential for elevated TDG in the Crooked River, it will be important to know the exact cause of the elevation.

It may also be helpful to evaluate fish for evidence of GBD during and after high flow events. While the cause and effect relationship between elevated TDG and GBD has been well documented in the region (Maynard 2008), the relationship between TDG level and GBD incidence has not been documented in the Crooked River. Moreover, the potential for fish to avoid GBD by sounding (moving to deep water) in the Crooked River is not known.

Table 1. Parameters measured downstream of Bowman Dam and instruments used to collect data.

Parameter	Instrument	Resolution and Accuracy
Total Dissolved Gas (mmHg)	Hydrolab MS5 multi-parameter mini sonde	1.0 mmHg; ±1.5 mmHg
	Pentair Point Four Tracker TGP meter	1.0 mmHg
Barometric Pressure	YSI Professional Plus	0.1 mmHg; ±1.5 mmHg
Water Temperature (^{o}C)	Hydrolab MS5 multi-parameter mini sonde	0.01 ^{o}C; ± 0.10 ^{o}C
Depth (m)	Hydrolab MS5 multi-parameter mini sonde	0.1m; ±0.05m

Table 2. Results from downstream total dissolved gas monitoring efforts.

Date	Sampling Location	Distance D/S	Probe	Total Gas Pressure (mmHg)	Barometric Pressure (mmHg)	TDG Saturation (%)	Depth (m)	Bowman Discharge (cfs)
4/23	Stilling Basin	200 m	Pentair Tracker 4	761	685	111.1	1	706
4/23	Big Bend C.G	872 m	Pentair Tracker 4	757	685	110.5	1	702
4/23	Cobble Rock C.G.	4.61 km	Pentair Tracker 4	759	685	110.8	0.7	706
4/23	Greenwood C.G.	9.3 km	Pentair Tracker 4	759	685	110.8	0.7	706
4/23	Castle Rock C.G	12.44 km	Pentair Tracker 4	759	685	110.8	1.1	706
4/23	Les Schwab Park	34.50 km	Pentair Tracker 4	753	685	109.9	1.2	706
5/2	Les Schwab Park	34.50 km	Hydrolab MS5	731	678	107.7	0.86	418
5/2	Castle Rock C.G	12.44 km	Hydrolab MS5	743	678	109.6	0.96	418

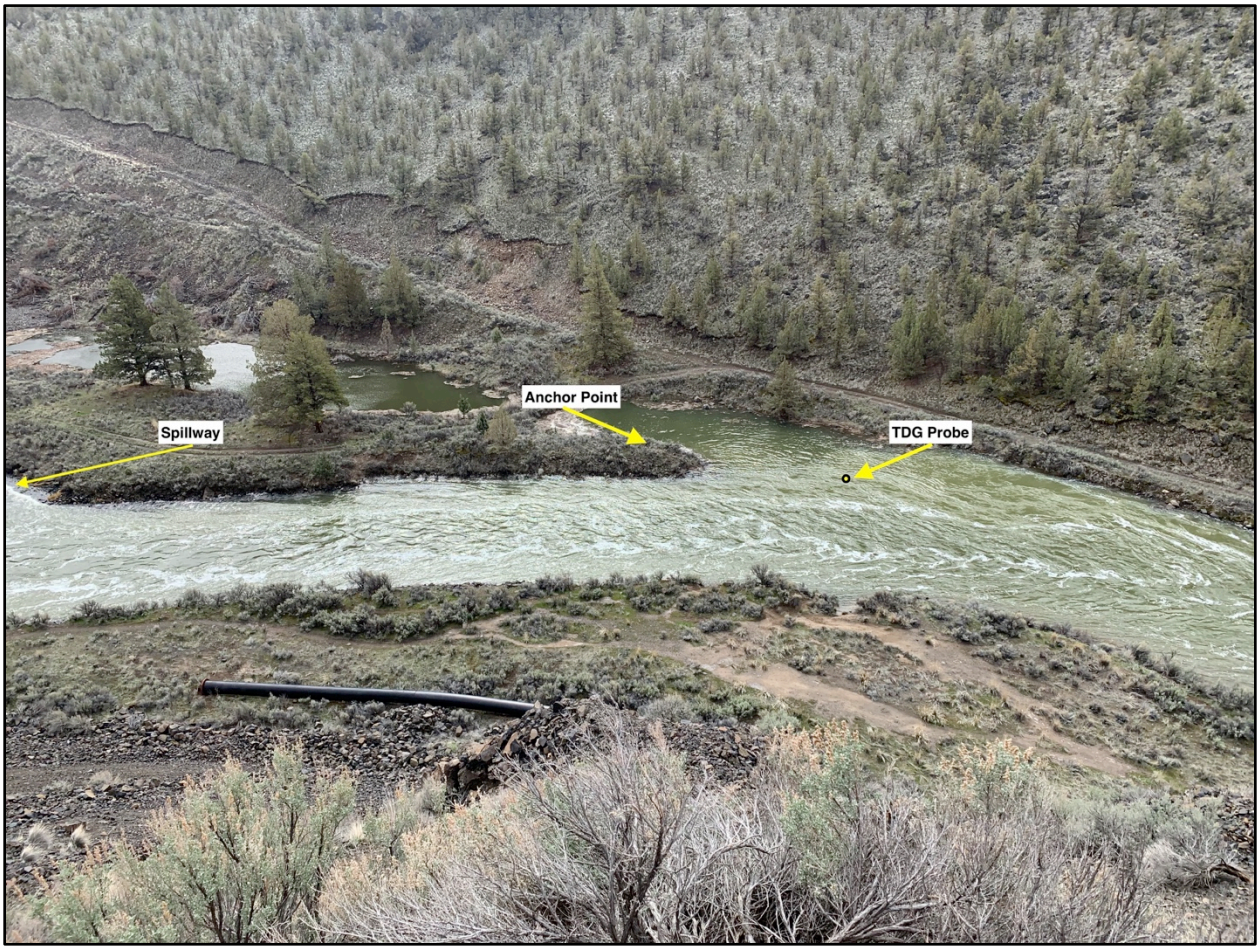

Figure 1. TDG sampling location near Bowman Dam on April 9, 2019 when the flow was 2,900 cfs.

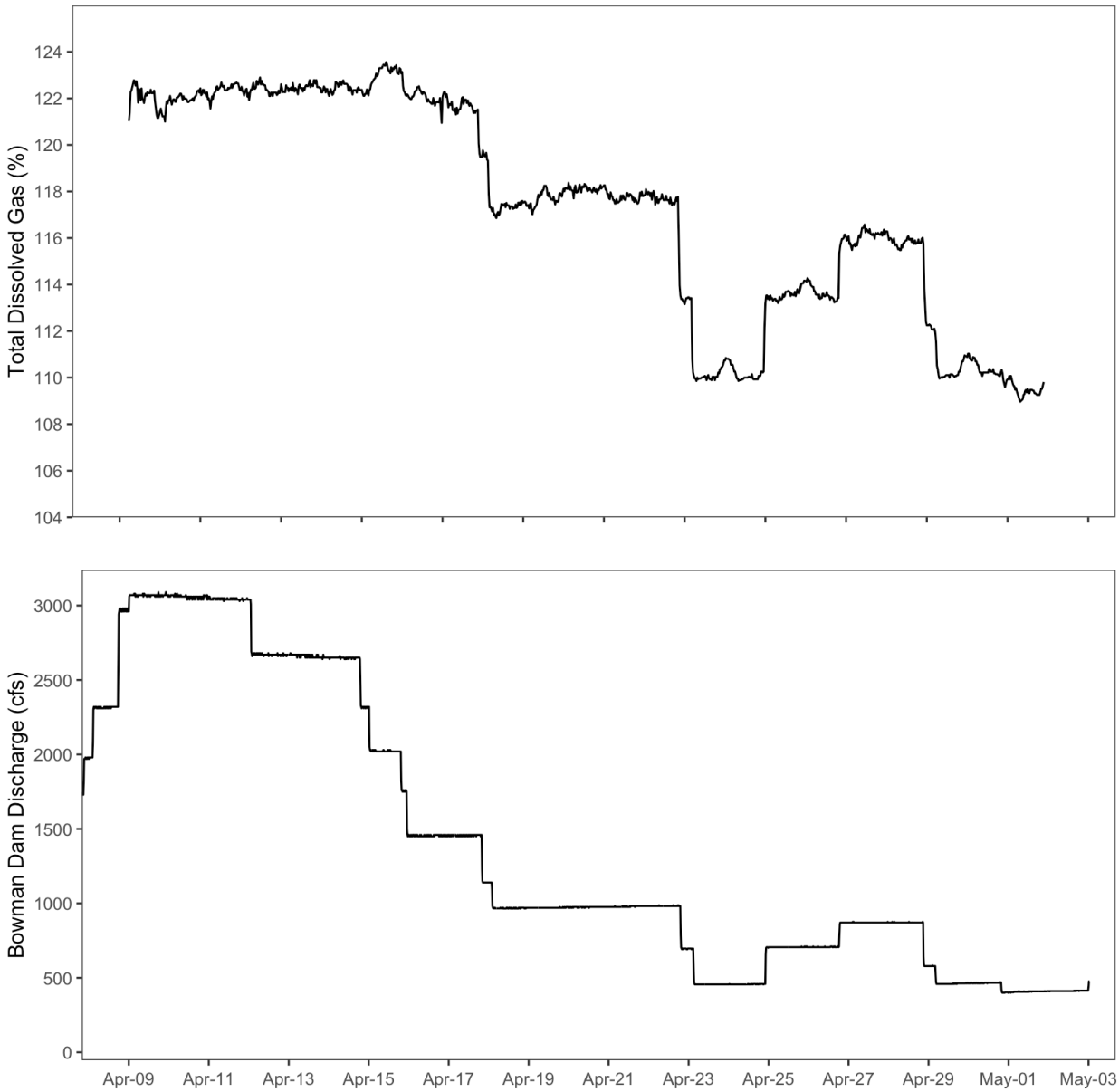

Figure 2. Time series of total dissolved gas and discharge measured at Bowman Dam from April 9th through May 2nd, 2019.

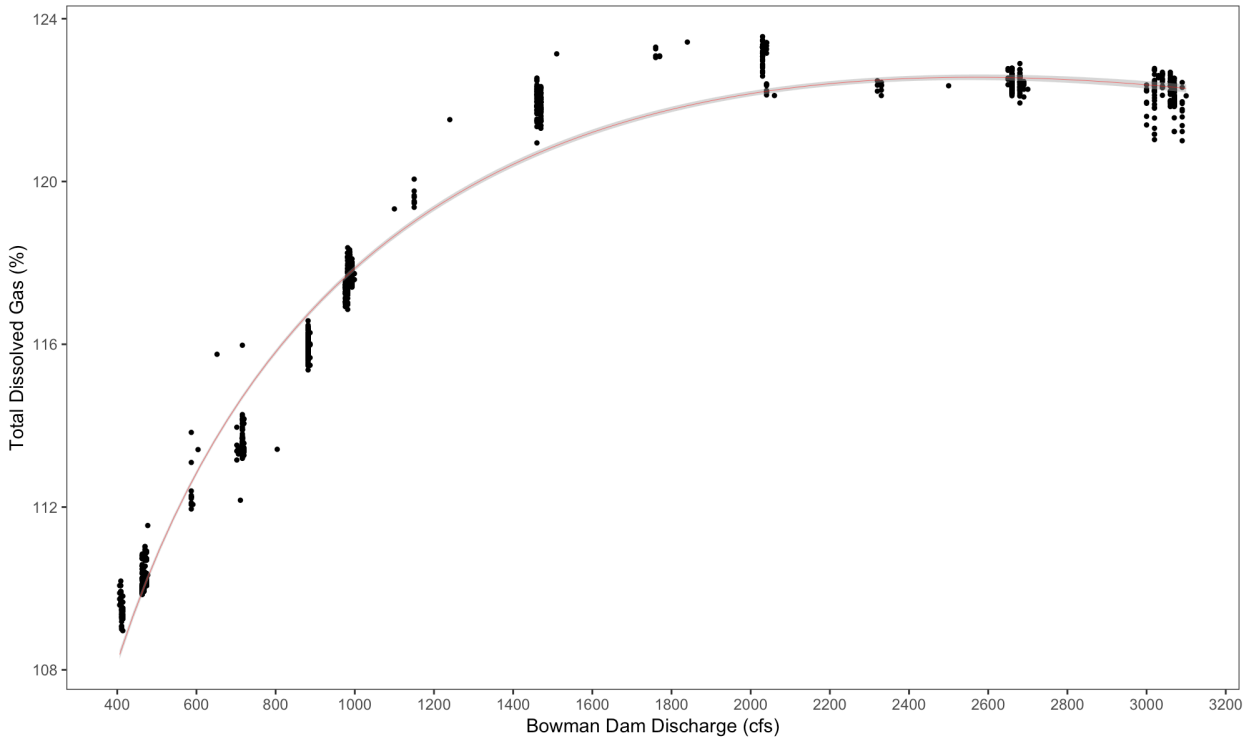

Figure 3. Relationship between discharge at Bowman Dam and total dissolved gas measured downstream of Bowman Dam. ($R^2 = 0.98$, *p-value* < 0.001).

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