Final
Bevan Avenue Groundwater Supply Development Project

Year 10 Environmental Monitoring Report

Prepared for:

City of Abbotsford
32315 South Fraser Way,
Abbotsford, BC
V2T 1W7

Prepared by:

ENKON ENVIRONMENTAL LIMITED
Surrey, BC
V3S 5J9
Phone: 604-574-4477
Fax: 604-574-4353
E-mail: enkon@enkonenv.com
Web Page: http://enkonenvironmental.com/

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Executive Summary

The City of Abbotsford was granted approval under a BC Environmental Certificate (EAC) #W11-01 to increase the withdrawal of water from the Abbotsford – Sumas Aquifer (the Aquifer) to meet seasonal peak drinking water demands. The Bevan Wells Groundwater Supply Development Project (The Project) was initially intended to extract water at an increased rate from a maximum 74.9 liters per second (L/s) to 290 L/s during times of seasonal peak usage (May to September) until such time as an additional surface water supply was constructed. The original EAC expired December 31, 2015 but was extended to the end of 2016 to allow sufficient time to prepare a comprehensive amendment application to operate the wells indefinitely. The amendment allowing indefinite operation of the wells was granted on June 12, 2017.

Schedule B of the EAC outlines the City of Abbotsford's commitments with respect to the project. Condition #4 stipulates that the City must implement a monitoring program for the duration of operation of the project. The program includes monitoring surface water flows, surface water levels, and surface water quality. Conditions added in the 2017 Amendment include implementation of a monitoring and mitigation plan (Condition #22), which includes vegetation monitoring (Condition # 23), and inviting Matsqui First Nation to continue participation in existing fish habitat monitoring programs and participate in the new and expanded vegetation and fish habitat monitoring programs (Condition #27). If any unanticipated adverse effects are identified in the monitoring reports, then the City of Abbotsford must develop and implement appropriate mitigation measures to the satisfaction of the EAO.

As per Conditions #4 and #27, annual reporting is to be completed and submitted to the Environmental Assessment Office and Matsqui First Nation. This report summarizes the Year 10 (May 2020 to April 2021) monitoring data. The expanded monitoring programs were implemented in 2018 and continued in 2019-2021. Matsqui First Nation were invited to participate in the summer 2020 fish habitat and indicator plant monitoring events. They participated in the fish habitat monitoring in August, September, and October but did not respond to the invitation to participate in the July monitoring event. They declined to participate in the indicator plant monitoring because it took place at the same time as the September mesohabitat monitoring.

Year 10 monitoring did not identify changes in stream flow or the water levels of Laxton and Judson Lakes that can be directly attributed to operation of the Bevan wells.

Year 10 of the water quality monitoring showed that the use of the Bevan wells has not affected the surface water quality relative to baseline conditions. However, that the baseline condition is affected by agricultural and urban activities, so the baseline quality ranged from marginal to good in Year 1. There were no statistically significant decreases in the WQI at any of the monitoring sites. However, there was a significant improvement in the WQI at H-01.

Over the ten years of monitoring there were statistically significant decreasing trends in dissolved oxygen at B-01 (Boa Brook) and H-02 (Horn Creek) during the summer period and annually. However, these trends were not observed at the other monitoring sites in Boa Brook and Horn Creek, and there was no corresponding increase in water temperature in Boa Brook, which would be expected if the lower dissolved oxygen were associated with decreasing stream flows. Thus, the lower dissolved oxygen at B-01 and H-02 is not attributable to operation of the Bevan Wells.

Prior to Year 8, water quality in Downes Creek (D-01) and Fishtrap Creek (F-01 and F-02) was monitored in April, September, October, and January. Therefore, the available data were insufficient to analyze seasonal or annual trends. However, trends during each of the four months were analyzed. No water quality trends were statistically significant in these watercourses.

Groundwater quality monitoring was conducted to compare the quality of augmentation flows relative to surface water quality guidelines. Water quality in the Garibaldi Park mitigation well (which discharges to Horn Creek) was good. The Allen Park mitigation well had consistently elevated arsenic concentrations, over three times the water quality guideline. However, a risk assessment completed in 2018 found that risks related to arsenic exposure would not be expected even if receptors in Boa Brook were exposed to undiluted groundwater In addition, annual average phosphorus concentrations in the Allen Park well were above the water quality objective for the Sumas River. The new Fishtrap Creek mitigation well also had an average phosphorus concentration above the objective for the Sumas River, but all other parameters were below guidelines to protect aquatic life.

The drinking water wells had generally good water quality. The average concentrations of arsenic, fluoride and iron were below the maximum guidelines for protection of aquatic life. However, concentrations of nitrate and copper were higher in the drinking water wells than in the mitigation wells.

The fish habitat monitoring program for Horn Creek and Boa Brook did not identify any changes over time that appeared to be associated with operation of the Bevan Wells. Over the ten years of monitoring there were no statistically significant decreasing trends in bankfull width, wetted width, or bankfull depth.

Groundwater level monitoring in Year 10 showed that aquifer levels were generally consistent on a year-over-year basis in terms of the magnitude and seasonal variation.

There was no evidence of a progressive year-over-year decline in water levels in any of the observation wells.

The third full year of stream flow, water quality, and mesohabitat monitoring was completed at the expanded monitoring sites in Fishtrap Creek and Downes Creek from May 2020 to April 2021. The third year of shallow groundwater monitoring and fourth year of vegetation monitoring were also completed during this time period. The results of these monitoring programs are presented in the current report.

No unanticipated adverse effects were identified in Year 10 monitoring. The three to four years of mesohabitat, shallow groundwater, and vegetation data are not sufficient to draw conclusions, but there were no changes that would suggest an immediate need for a mitigation well for Downes Creek (Condition #25). Monitoring is continuing for Year 11 (May 2021 to April 2022), and results will be presented in a separate annual monitoring report.

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1.0 INTRODUCTION

1.1 Background

The Bevan Avenue Wells Groundwater Supply Development Project (the Project) was proposed in response to increasing summer water use demand in the City of Abbotsford (the City) and the District of Mission (Mission). The Bevan Avenue Wells are operated by the City on behalf of the Abbotsford Mission Water & Sewer Commission (AMWSC). In October 2010, the City submitted an *Application for an Environmental Assessment Certificate* (the *Application,* (Hemmera, 2010) for the Project in accordance with the requirements and guidance of the British Columbia Environmental Assessment Office (EAO), and as required under the British Columbia *Environmental Assessment Act S.B.C. 2002* (BC EAA) and the *Canadian Environmental Assessment Act* (CEAA). An Environmental Assessment Certificate (EAC) was awarded on May 10, 2011 (EAC number: W11-01) and allowed for the operation of the Bevan Wells for five years under prescribed conditions. The EAC was amended on June 12, 2017 to allow for the wells to operate indefinitely, with additional conditions.

Potential environmental effects of the Project are related to drawdown of water levels in the Abbotsford – Sumas Aquifer (the Aquifer), which may affect surface water flows and in turn fish and fish habitat. The original *Application* predicted that changes in surface flows would be below acceptable thresholds in the reaches of all evaluated watercourses except Horn Creek and its tributary, Boa Brook (Hemmera, 2010). A decrease in flow could change the quantity and potentially affect the quality of available habitat for fish. In particular, a decrease in flow could result in elevated water temperatures and a decrease in dissolved oxygen, which could directly affect fish. The most critical period for fish is mid-July to end of October, when base flow is at or near seasonal lows.

The subsequent *Amendment Application* (ENKON 2016) addressed long-term operation of the Project, including operation during extended (5 year) unusually dry periods. This assessment identified a potential for the Project to affect surface flows in Fishtrap Creek and Downes Creek and shallow groundwater that sustains wetlands, particularly in the Downes Creek watershed.

In order to mitigate potential effects to fish and fish habitat and in accordance with the terms and conditions of the EAC, the City installed and operates mitigation wells. Two wells, located in the headwaters of Horn Creek and Boa Brook, are intended to supplement predicted low flows to pre-Project levels. Both wells pump water to their respective creeks when measured flows at the Horn Creek station are below 25.2 L/s (equivalent to 90% of the minimum base flow of 28 L/s) and the Bevan Wells have pumped more than 175 ML during the preceding 30 days. A third mitigation well was installed in Fishtrap Creek in 2019.

In 2011, an Operational Environmental Management Plan (OEMP) was prepared for the Project by Hemmera. The intent of the mitigation measures described in the OEMP was to meet a standard of no negative change in water quality and stream flow as a result of the Project. The OEMP included a monitoring program, the purpose of which was to compare conditions in Horn Creek and Boa Brook during operation of the Bevan Avenue Wells and mitigation wells to baseline conditions.

The OEMP was updated in July 2018 (ENKON *et al*., 2018) to address the new conditions in the amended EAC. This update expanded the aquatic monitoring program in Fishtrap Creek and Downes Creek and added vegetation and shallow groundwater monitoring programs. New monitoring sites and/or monitoring programs were established in the fall of 2017, and routine monitoring began in May 2018.

The goals of the monitoring program in the current OEMP are to:

- Assess the efficiency of the mitigation measures in protecting fish and fish habitat;
- Compare baseline conditions to conditions during operation of the Bevan Wells and, if applicable, the mitigation wells;
- Assess the ability of the mitigation measures to sufficiently supplement groundwater inputs to affected watercourses;
- Determine the need (if any) for further mitigation measures to protect instream fish habitat and riparian/wetland vegetation, especially in Downes Creek; and
- Verify the assessments presented in the original Application and the Amendment Application regarding potential residual effects of the Project on water quality, stream flows, riparian vegetation, and shallow groundwater.

This report presents the results of the Year 10 monitoring program, which began in May 2020 and concluded in April 2021. It includes comparisons of all years of the Project for which multi-year data are available. A summary and schedule of the Year 10 monitoring activities for groundwater, surface water, and fish habitat is presented in Table 1-1. Shallow groundwater monitoring sites are monitored continuously. Vegetation monitoring occurs annually in late summer.

Table 1-1 Monitoring Activities and Schedule (2020-2021) for the Bevan Wells Project

Component & Site	**2020** May	**2020** June	**2020** July	**2020** August	**2020** September	**2020** October	**2020** November	**2020** December	**2021** January	**2021** February	**2021** March	**2021** April
Water Quality Samples & *In-Situ* Water Quality												
Boa Brook (B-01)	x	x	x	x	x	x	x	x	x	x	x	x
Boa Brook (B-02)	x	x	x	x	x	x	x	x	x	x	x	x
Horn Creek (H-01)	x	x	x	x	x	x	x	x	x	x	x	x
Horn Creek (H-02)	x	x	x	x	x	x	x	x	x	x	x	x
Horn Creek (H-03)	x	x	x	x	x	x	x	x	x	x	x	x
Willband Creek (W-01)	x	x	x	x	x	x	x	x	x	x	x	x
Downes Creek (D-01)	x	x	x	x	x	x	x	x	x	x	x	x
Downes Creek (D-02)	x	x	x	x	x	x	x	x	x	x	x	x
Fishtrap Creek (F-01)	x	x	x	x	x	x	x	x	x	x	x	x
Fishtrap Creek (F-02)	x	x	x	x	x	x	x	x	x	x	x	x
Fishtrat Creek (FOF)	x	x	x	x	x	x	x	x	x	x	x	x
Fishtrap Creek (F-03)	-	-	x	x	x	x	-	-	-	-	-	-
Fishtrap Creek (F-04)	-	-	x	x	x	x	-	-	-	-	-	-
Duplicate	F-01	F-02	W-01	H-01	D-01	H-02	H-03	B-01	B-02	H-01	H-02	H-03
Number of sites	10	10	12	12	12	12	10	10	10	10	10	10
Manual Streamflow and Water Level												
Boa Brook (B-01)	x	x	x	x	x	x	-	-	x	-	-	x
Boa Brook (B-02)	x	-	x	-	x	-	-	-	x	-	-	-
Horn Creek (H-01)	x	x	x	x	x	x	-	-	x	-	-	x
Horn Creek (H-02)	x	x	x	x	x	x	-	-	x	-	-	x
Horn Creek (H-03)	x	x	x	x	x	x	-	-	x	-	-	x
Willband Creek (W-01)	x	x	x	x	x	x	-	-	x	-	-	x
Downes Creek (D-01)	x	x	x	x	x	x	-	-	x	-	-	x
Downes Creek (D-02)	x	-	x	-	x	-	-	-	x	-	-	-
Downes Creek (D-03)	x	-	x	-	x	-	-	-	x	-	-	-
Downes Creek (D-04)	x	-	x	-	x	-	-	-	x	-	-	-
Fishtrap Creek (F-01)	x	-	x	-	x	-	-	-	x	-	-	-
Fishtrap Creek (F-02)	x	-	x	-	x	-	-	-	x	-	-	-
Waechter (WT-01) +	x	-	x	-	x	-	-	-	x	-	-	-
Fishtrap Creek (F-04)	x	-	x	-	x	-	-	-	x	-	-	-
Judson Lake	x	x	x	x	x	x	x	x	x	x	x	x
Laxton Lake	x	x	x	x	x	x	x	x	x	x	x	x
Number of stream flow sites	14	6	14	6	14	6	0	0	14	0	0	6

Component & Site	2020 May	2020 June	2020 July	2020 August	2020 September	2020 October	2020 November	2020 December	2021 January	2021 February	2021 March	2021 April
Fish & Fish Habitat Monitoring												
Site 1 (Mesohabitat A, B, C)	-	-	x	x	x	x	-	-	-	-	-	-
Site 2 (Mesohabitat A, B)	-	-	x	x	x	x	-	-	-	-	-	-
Site 3 (Mesohabitat A, B, C)	-	-	x	x	x	x	-	-	-	-	-	-
Site 4 (Mesohabitat A, B)	-	-	x	x	x	x	-	-	-	-	-	-
Site 5 (Mesohabitat A, B, C, D)	-	-	x	x	x	x	-	-	-	-	-	-
Site 6 (Mesohabitat A, B)	-	-	x	x	x	x	-	-	-	-	-	-
Downes Creek (D-01) (pool & riffle)	-	-	-	-	-	-	-	-	-	-	-	-
Downes Creek (D-02) (pool & riffle)	-	-	x	x	x	x	-	-	-	-	-	-
Downes Creek (D-03) (pool & riffle)	-	-	x	x	x	x	-	-	-	-	-	-
Downes Creek (D-04) (pool & riffle)	-	-	x	x	x	x	-	-	-	-	-	-
Fishtrap Creek (F-01) (pool & riffle)	-	-	x	x	x	x	-	-	-	-	-	-
Fishtrap Creek (F-02) (pool & riffle)	-	-	x	x	x	x	-	-	-	-	-	-
Fishtrap Creek (F-03) (pool)	-	-	x	x	x	x	-	-	-	-	-	
Fishtrap Creek (F-04) (pool & riffle)	-	-	x	x	x	x	-	-	-	-	-	-
Number of sites	0	0	13	13	13	13	0	0	0	0	0	0
TEM, Indicator Plants, Snail Habitat												
Downes Creek TEM Sites (11 plots)	-	-	-	-	x *		-	-	-	-	-	-
Downes Creek Indicator Plants (8 Plots)	-	-	-	-	x **	-	-	-	-	-	-	-
Downes Creek Oregon Forestsnail Habitat	-	-	-	-	x	-	-	-	-	-	-	-
Fishtrap Creek TEM Sites (6 plots)	-	-	-	-	x *		-	-	-	-	-	-
Horn/Boa TEM Sites (4 plots)	-	-	-	-	x *		-	-	-	-	-	-
Horn/Boa Indicator Plants (2 Plots)	-	-	-	-	x **	-	-	-	-	-	-	-
Number of sites	0	0	0	0	22	10	0	0	0	0	0	0
Shallow Groundwater Well Monitoring												
Downes Creek (8 wells)	-	-	-	-	-	x	-	-	-	-	-	x
Control Wetland A (3 wells)	-	-	-	-	-	x	-	-	-	-	-	x
Control Wetland B (3 wells)	-	-	-	-	-	x	-	-	-	-	-	x
Control Wetland C (3 wells)	-	-	-	-	-	x	-	-	-	-	-	x
Fishtrap Creek (3 wells)	-	-	-	-	-	x	-	-	-	-	-	x
Horn Creek/Boa Brook (2 wells)	-	-	-	-	-	x	-	-	-	-	-	x
Number of sites	0	0	0	0	0	22	0	0	0	0	0	22
Groundwater Quality Monitoring												
Allen Park Mitigation Well	x	x	x	x	x	x	x	x	x	x	x	x
Garibaldi Park Mitigation Well	x	x	x	x	x	x	x	x	x	x	x	x
AMWSC Drinking Water Wells	x	x	x	x	x	x	x	x	x	x	x	x
Number of sites	3	3	3	3	3	3	3	3	3	3	3	3

Component & Site	2020 May	2020 June	2020 July	2020 August	2020 September	2020 October	2020 November	2020 December	2021 January	2021 February	2021 March	2021 April
Groundwater Level Monitoring												
Exhibition Park	x	x	x	x	x	x	x	x	x	x	x	x
Columbia Bible College	x	x	x	x	x	x	x	x	x	x	x	x
DND South Townline	x	x	x	x	x	x	x	x	x	x	x	x
Heritage RV	x	x	x	x	x	x	x	x	x	x	x	x
TW06-2 Bevan	x	x	x	x	x	x	x	x	x	x	x	x
TW06-3 Courthouse	x	x	x	x	x	x	x	x	x	x	x	x
Number of sites	6	6	6	6	6	6	6	6	6	6	6	6

+ Substituted for station F-03

*TEM Plots to be assessed between September 15 and October 15

**Indicator plant plots to be completed after 1065 degree-days above 10 degrees Celsius (approximately September 20th). Surveys should take place no later than October 1st.

1.2 Year 10 Operation

In Year 10 of the Project (May 1, 2020 to April 30, 2021) the Bevan Wells pumped 1,766 million litres per year (ML/year). This total is equivalent to 70% of the total groundwater diversion (2,505 ML/year) permitted in accordance with EA Certificate W11-01. The maximum daily pumping rate was 17.056 ML/day on July 27, which represents 68% of the 25-ML/day allowable maximum pumping rate.

The Allen Park and Garibaldi Park mitigation wells were triggered on September 9, 2020 and pumped an average of 3.02 L/s and 11.75 L/s through October 16. However, activation of the wells was due to erroneous flow readings. Subsequent review of the data by a qualified hydrologist confirmed that flows in Horn Creek had not dropped below 25 L/s during this period or at any other time during Year 10.

The Fishtrap Creek mitigation well came online on May 10, 2019. The associated flow monitoring station was not completed until January 2021 due to Ministry of Transportation and Infrastructure roadwork and culvert replacement. In the interim, manual flow measurements were taken, and monitoring at the F-02B telemetry station continued through 2021. The mitigation well was turned on as a precaution and pumped from May 15 to June 19, 2020, and from September 9 to October 14, 2020 (Appendix I).

2.0 SURFACE WATER MONITORING PROGRAM

Hydrological investigations undertaken during preparation of the *Application* determined that is potential for the Project to affect surface flows in Horn Creek and Boa Brook. Subsequent analysis undertaken for the *Amendment Application* identified the potential for effects on flows in Fishtrap Creek and Downes Creek during multi-year dry periods. Such decreases in flow have the potential to affect fish habitat and water quality through decreases in water volume, possibly resulting in increased concentrations of nutrients, elevated water temperature, and corresponding decreases in dissolved oxygen. The most critical period is late summer to early autumn, when base flows are at or near seasonal lows.

Mitigation for reduction in surface flows in Horn Creek and Boa Brook as a result of the Project operations consists of augmentation of surface flows with groundwater. This occurs when measured flows at the Horn Creek station are below 25.2 L/s (equivalent to 90% of the minimum base flow of 28 L/s) (Hemmera, 2011b). Flow augmentation for Fishtrap Creek came online in the summer of 2019 (Year 9) and was operated as a precaution in the summers of Year 9 and Year 10, as the associated flow monitoring station was not operational.

The Year 10 surface water monitoring program included the following:

- Streamflow measurements (watercourses);
- Water level measurements (water bodies);
- Collection of *in-situ* water quality measurements; and
- Collection of water quality samples for laboratory analysis.

2.1 Site Description

Water quality and/or stream flow measurements were taken at 15 sites (watercourses), and water levels were recorded at two sites (water bodies). These are described in Table 2-1 and shown in Figures 2-1 to Figure 2-3.

The monitoring sites on Horn Creek, Boa Brook, Fishtrap Creek, and Downes Creek are locations potentially impacted by the Project and/or the groundwater mitigation measures. Willband Creek was chosen as a control, as it is not expected to be affected by the Project, but is surrounded by land use (i.e., city park, urban mix of residential and commercial) similar to that around Horn Creek and Boa Brook (Hemmera, 2011).

Table 2-1 Surface Water Monitoring Sites

Water Feature	Site ID	Description	UTM Northing	UTM Easting
Watercourses				
Boa Brook	B-01	Boa Brook mitigation well outfall	5433683	550844
	B-02	Hydrometric station - Boa Brook, downstream of mitigation well outfall (monitoring station was moved in 2018 to a suitable location for level logger installation)	5434336	550671
		Water quality - Boa Brook, downstream of mitigation well outfall	5434298	550651
Downes Creek	D-01	Downes Creek (monitoring station was moved in September 2014 due to a hazardous tree)	5435965	549189
	D-02	Located 30m upstream of Downes Road	5435905	549143
	D-03	Approximately 20m downstream of headwall	5435425	549298
	D-04	Approximately 60m upstream from pedestrian bridge.	5435296	549169
Fishtrap Creek	F-01	Confluence of Enns Brook and Fishtrap Creek	5433158	546746
	F-02	Fishtrap Creek downstream from Marshall Road Extension[a]	5431962	545250
	F-03	Near previously established staff gauge (water quality only)	5430294	544294
	F-04	Flow logger installed at right bank piles under Echo Rd Bridge	5430337	544026
Horn Creek	H-01	Horn Creek headwaters, upstream of mitigation well outfall	5433951	550190
	H-02	Horn Creek, downstream of confluence with Boa Brook	5434380	550784
	H-03	Horn Creek, downstream of mitigation well outfall	5434025	550234
Waechter Creek	WT-01	Waechter Creek at 1266 Hope Road (hydrometric only; site selected because F-03 was unsuitable for installing a level logger) [b]	5430425	544487
Willband Creek	W-01	Willband Creek (control site)	5432998	551363
Water Bodies				
Judson Lake	-	Judson Lake (discussed with groundwater program)	5427980	548328
Laxton Lake	-	Laxton Lake (discussed with groundwater program)	5428820	547457

Note: UTM Coordinates are NAD83, Zone 10U

[a] Station was moved to 10U 545221 E 5431928 N in September 2018 to avoid conflict with Marshall Road widening and culvert replacement works.

[b] The flow at F-03 can be calculated by subtracting flow at WT-01 from F-04.

2.2 Schedule

2.2.1 Water Quality

In-situ water quality measurements and samples for laboratory analyses collected at 11 locations (B-01, B-02, H-01, H-02, H-03, F-01, F-02, FOF, D-01, D-02, and W-01) on a monthly basis. The remaining locations (F-03 and F-04) had water quality samples collected only in July, August, September, and October (Table 1-1).

2.2.2 Stream Flow

The hydrometric network for the Bevan Wells monitoring program included automated hydrometric stations installed on Horn Creek (H-02), Fishtrap Creek (F-01 and F-02), Downes Creek (D-01), and Willband Creek (W 01). The automated hydrometric stations were installed by Piteau in 2008. The site on Horn Creek (H-02) was vandalized and taken out of the monitoring program early in Year 3. It was replaced with a SCADA monitoring station.

The expanded monitoring program (ENKON, 2018a) included installation of level loggers at the following locations:

- H-02 on Horn Creek as a back-up to the SCADA system;
- B-02 to better characterize flows in Boa Brook on a continuous basis;
- D-02, D-03, and D-04 to characterize flows within the Downes Bowl tributaries to Downes Creek on a continuous basis; and
- WT-01 (on Waechter Creek in lieu of F-03) and F-04 to better characterize flows within Fishtrap Creek on a continuous basis.

Manual stream flow measurements were made at B-01, H-01, H-02, H-03, D-01, and W-01 monthly from May through October 2020 plus January and April 2021. These months capture the high flows in January, the early dry season in April, May and June, and summer low flows which typically extend from July to October. Manual stream flow measurements were made at the remaining stations in May, July, and September 2020, and January 2021.

2.3 Study Methods

2.3.1 Stream Flow

The stream flow and water level monitoring program included:

- Download of data from the monitoring sites where water level loggers are installed; and

Legend

- ▲ Surface water monitoring location
- Abbotsford-Sumas aquifer
- Streams
- Waterbody

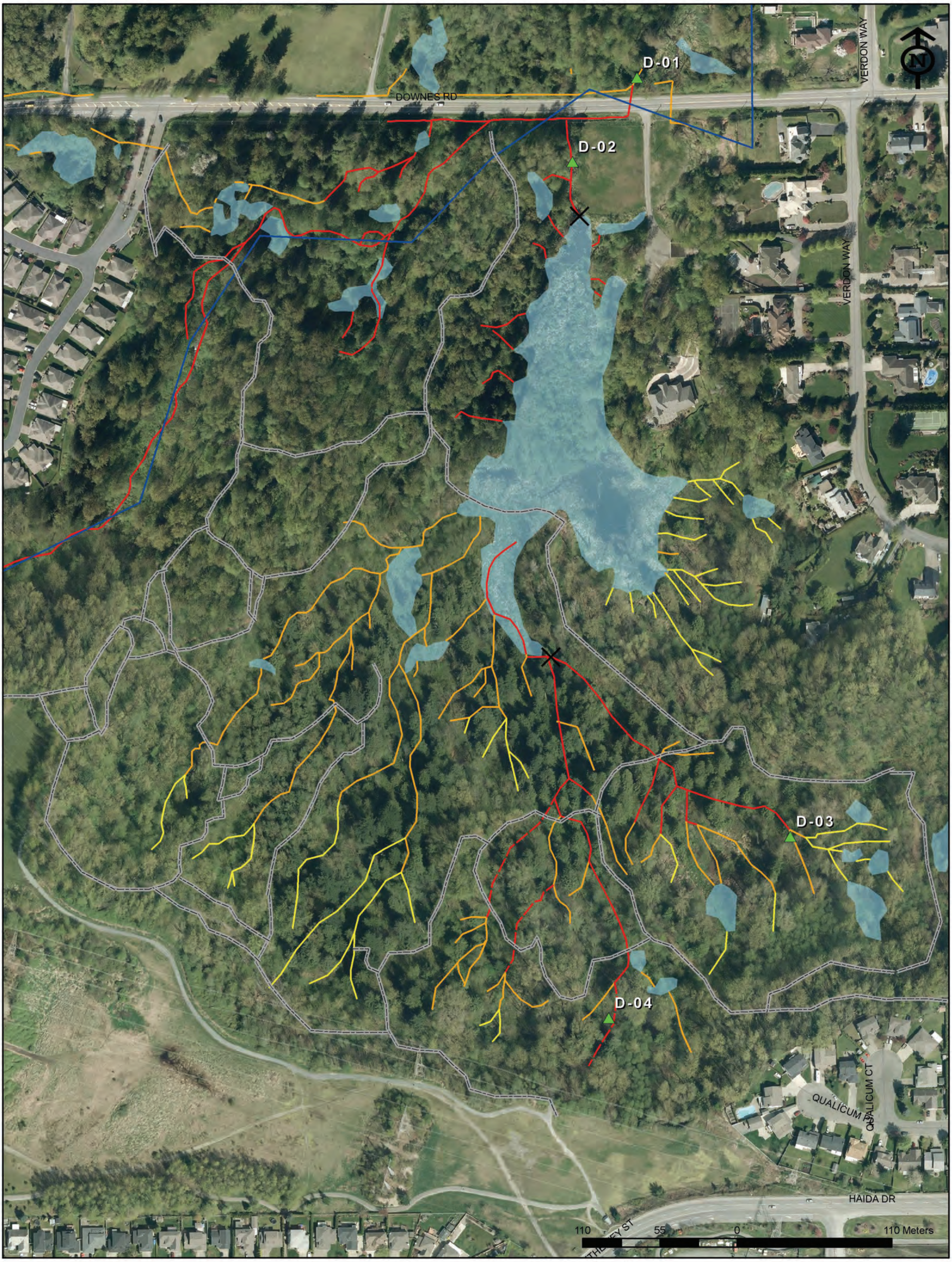
Prepared by: **ENKON** Environmental Ltd.

Horn Creek, Boa Brook & Willband Creek Surface Water Monitoring Sites

City of Abbotsford

Created: December 2019
Projection:
NAD 83 UTM Zone 10N
1:6,000

Figure 2-1



Legend

- Surface water monitoring location
- DownesTrails
- Abbotsford-Sumas aquifer
- Waterbody

Watercourses (CoA Modified)

- Class A (fish-bearing)
- Class Ao (overwintering)
- Class B (food and nutrient)
- Permanent (Unclassified)

Prepared by: ENKON Environmental Ltd.

Created: December 2019
Projection:
NAD 83 UTM Zone 10N
1:2,500

Downes Creek
Surface Water Monitoring Sites

City of Abbotsford

Figure 2-2

Legend

- Surface water monitoring location
- Abbotsford-Sumas aquifer
- Streams
- Waterbody

Prepared by: ENKON Environmental Ltd.

Fishtrap Creek
Surface Water Monitoring Sites

City of Abbotsford

Created: December 2019
Projection:
NAD 83 UTM Zone 10N
1:10,000

Figure 2-3

- Stream flow transects at each of the 14 monitoring sites listed in Table 2-1 and Table 2-2.

Table 2-2 Hydrology Stations on Streams

Site ID	Stream Flow Transect	Automated Data Logger
H-01	X	
H-02	X	X
H-03	X	
B-01	X	
B-02	X	X
D-01	X	X
D-02	X	X
D-03	X	X
D-04	X	X
F-01	X	X
F-02	X	X
WT-01	X	X
F-04	X	X
W-01	X	X

Stream transects were conducted in accordance with the methods described in *The Manual of British Columbia Hydrometric Standards* (RISC, 2009). Stream flow was measured with a SonTek FlowTracker or FlowTracker2® handheld Acoustic Doppler Velocimeter (ADV®).

Concurrent stage and flow measurements were used to establish a stage-discharge relationship for each instrumented station. These relationships were used to estimate flowrates from the hourly water level records. Equivalent water level elevations were determined by correcting the measured levels against a surveyed datum.

2.3.2 Water Quality

2.3.2.1 Parameters Monitored

The water quality monitoring program included:

- *In-situ* water quality monitoring of dissolved oxygen, pH, specific conductance, and temperature;
- Field monitoring of turbidity;
- Monitoring of nutrients (nitrate/nitrite, ammonia, and phosphorus);
- Monitoring of total metals;

- Monitoring of water hardness;
- Monitoring of total fluoride; and
- Coordination of scheduling and sampling locations with surface water flow monitoring.

Potential surface water quality effects of the Project are predicted to be from reduced flows rather than inputs of new contaminants. Watercourses and water quality in the Abbotsford area are currently affected by agricultural and urban activities. Physical and chemical analyses of water samples collected during the field program were reflective of these concerns. In addition to the monitoring of nutrients, total metals analysis was added to the analysis requirements for all surface water samples beginning in October 2012 due to the elevated background levels of arsenic and fluoride in the Abbotsford-Sumas aquifer groundwater (Hemmera, August 2011).

The selected water quality attributes are described below:

- **Turbidity –** A measure of the optical properties of a water sample induced mostly by suspended particulate matter which results in a scattering of light as it passes through water. High levels are commonly the result of suspended solids and can reduce biological productivity of the water or prey capture success by visual predators such as trout and salmon. Turbidity guidelines primarily deal with induced increases above background level. The City of Abbotsford’s Erosion and Sediment Control Bylaw specifies 25 NTUs as the maximum limit. This is meant to be measured at point of release rather than above background. Turbidity below 8 NTU is used to define “clear” flow (Singleton, 2001).
- **Dissolved Oxygen –** A measure of the amount of oxygen dissolved in water, essential to the survival and health of most aquatic organisms. Turbulent water contains more dissolved oxygen than stagnant water. Water also contains more oxygen at saturation at colder temperatures. Anthropogenic inputs such as agricultural runoff and other organic materials use oxygen as they decompose, reducing dissolved oxygen levels.
- **Temperature –** Aquatic organisms have an optimal temperature range outside of which they become stressed, more susceptible to disease, and grow more slowly. Increased temperature contributes to algal growth and is a contributing factor toward eutrophication of a watercourse. Temperature also affects the toxicities of a range of other substances, including ammonia.
- **pH –** Aquatic organisms have an optimal pH range outside of which they become stressed, more susceptible to disease, and grow more slowly. pH is a factor in the toxicities of numerous pollutants, including ammonia. Eutrophication may cause a slight rise in pH in watercourses during the daytime due to photosynthesis.

- **Nitrate and Nitrite –** Nitrate and nitrite occur naturally but also can be introduced by anthropogenic sources such as agricultural and urban run-off. Both nitrate and nitrite are useable by plants. Nitrite is an intermediate step in the nitrification of ammonia. It is unstable in surface waters and rapidly degrades to nitrate, the most oxidized and stable form of nitrogen in a water body. Nitrate can contribute to the eutrophication of water bodies, and nitrite can be toxic to aquatic organisms.
- **Ammonia –** The most reduced inorganic form of nitrogen in water, and an essential plant nutrient. Excess ammonia contributes to eutrophication of water bodies and is toxic to aquatic life at high concentrations. Ammonia occurs naturally at low concentrations but similarly to nitrate can be introduced by anthropogenic sources such as agricultural and urban run-off.
- **Total Phosphorus –** Both inorganic and organic forms of phosphorus can be present as dissolved or particulate matter. Phosphorus is generally the limiting nutrient to plant growth in fresh water and is found in very low concentrations in natural waters. Anthropogenic inputs of phosphorus include agricultural and urban run-off and industrial effluents. Such inputs are often responsible for eutrophication of freshwater systems.
- **Total Metals** – As noted in the *Surface Water and Mitigation Well Groundwater Quality Report* (Hemmera, August 2011), no metals concentrations of potential concern were detected in the single sampling event; however, the report recommended further sampling due to high detection limits for arsenic, cadmium, chromium, and zinc in historical surface water samples.
- **Total Fluoride –** The *Surface Water and Mitigation Well Groundwater Quality Report* (Hemmera, August 2011) recommended that additional groundwater samples from the drinking water and mitigation wells should be taken to determine the range of fluoride (and arsenic) concentrations in the aquifer.

2.3.2.2 Sampling Methods

Water quality sampling was done in accordance with the *BC Field Sampling Manual* (Ministry of Environment, 2013) and Resources Information Standards Committee (RISC) guidelines (Cavanagh, 1994; RISC, 1998). Sampling containers and preservatives were obtained from ALS Environmental (ALS) or Bureau Veritas (BV). *In-situ* parameters (pH, temperature, dissolved oxygen, and conductivity) were measured with a YSI Professional Plus multi-parameter meter with the probe placed directly into the stream flows. Field turbidity was measured using a LaMotte 2020e turbidity meter. Sample containers were filled directly from the stream. Water samples were sent to ALS (2020) or BV (2021) for chemical analyses.

2.3.2.3 Quality Assurance and Quality Control

Quality assurance (QA) procedures during field sampling included:

- Proper maintenance and calibration of field equipment;
- Labelling sample containers prior to collection with company information, project identification, station identification, sample date and time;
- Keeping samples cool and dark, and preserving as specified for the type of sample;
- Delivering samples to the laboratory within specific holding times; and
- Keeping accurate records for sample chain-of-custody.

The following quality control samples were collected during each sampling event:

- **Duplicate samples –** two samples collected at the same location and time;
- **Travel blanks** - a bottle of deionized water filled and preserved at the analytical laboratory, then taken into the field in the sample cooler and returned unopened to the laboratory; and
- **Field blanks –** prepared by filling the sample bottles with deionized water in the field and then preserving the samples, if appropriate.

Analyses were completed by an analytical laboratory accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL). Internal laboratory QA/QC procedures are consistent with the *BC Environmental Laboratory Manual* (Ministry of Environment and Climate Change Strategy, 2020) and include the use of quality control samples such as blanks, duplicates, and reference materials (standards, spikes, etc.). Values exceeding set standards or control limits undergo an internal review process.

2.3.2.4 Data Analysis

Results of laboratory analyses were entered into the CCME Water Quality Index (WQI) Calculator 2.0 (CCME, 2017). The CCME water quality index summarizes the results of a number of water quality variables in comparison to established criteria in order to describe water bodies as “poor”, “marginal”, “fair”, “good” or “excellent”[1]. This approach was used

[1] **Excellent (E):** (CCME WQI Value 95-100) – water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.

Good (G): (CCME WQI Value 80-94) – water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.

both here and during the environmental assessment, as the streams under study are not in pristine condition and on some occasions, do not meet federal and provincial water quality guidelines for selected parameters. The water quality index allows for a comparison of overall changes in stream quality over time, which is a more meaningful analysis in the context of potential impacts of the Project than comparison to set criteria.

Annual reports for Year 1 to Year 7 used the CCME Water Quality Index Calculator 1.2 (CCME, 2011a). The Year 8 annual report (ENKON 2020) used Version 2 of the WQI Calculator and the 19 parameters and associated guidelines listed in Table 2-3. The WQI values for Years 2 through 7 were updated using the same calculations in order to make the data for these years comparable. [2] The Year 10 WQI values also have been determined using WQI Calculator Version 2 and the 19 parameters listed in Table 2-3.

2.4 Results

2.4.1 Stream Flow

2.4.1.1 Original Hydrometric Monitoring Program Sites

The original hydrometric monitoring sites include Horn Creek 2 (H-02), Fishtrap Creek 1 (F-01) Fishtrap Creek 2 (F-02B, which replaces station F-02), Downes Creek D-01), and Willband Creek (W-01). Water levels are graphed in Figure 2-4, and flows are shown in Figure 2-5. Total daily precipitation at the Abbotsford Airport (recorded by Environment Canada) is included on Figure 2-4. The graphs and discussion of stream flow data for these stations extends to October 2020.

Flows measured in the creeks during 2020-21 were within range of previous measurements and did not exhibit any long-term declining trends. The seasonal low flows measured in Downes Creek remained above the 27.9 L/s threshold that represents a 10% reduction from the lowest flow measured in this creek in September 2008 (prior to commissioning of the Bevan Wells). Creek flows below this amount may trigger further assessment and/or mitigation if due to the operation of the Bevan Wells.

Fair (F): (CCME WQI Value 65-79) – water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.

Marginal (M): (CCME WQI Value 45-64) – water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.

Poor (P): (CCME WQI Value 0-44) – water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

[2] The Year 1 WQI was not recalculated because the raw water quality data were unavailable.

Table 2-3 Water Quality Criteria Used in the Water Quality Index Calculation

Parameter	Source	Criteria
Nitrate as N (mg/L as N)	CCME	2.9 mg/L as N
Nitrite as N (mg/L as N)	CCME	0.06 mg/L as N
Ammonia (mg/L as N)	CCME	Temperature and pH dependent.
Phosphorus (mg/L)	SSWQG	0.03 mg/L
Dissolved Oxygen (mg/L)	BCWQG	Species and life stage dependent. In study area streams, July 1 to October 31: ≥8 mg/L November 1 to June 30: ≥11 mg/L
Temperature (°C)	BCWQG	Species and life stage dependent. In study area streams, July 1 to October 31: ≤15°C November 1 to June 30: ≤13°C
pH	BCWQG	Between 6.5 and 9
Fluoride	CCME	0.12 mg/L (interim guideline)
Total Metals	CCME	
Arsenic		5 µg/L
Cadmium		$10^{(0.083(\log[\text{hardness}])-2.46)}$
Chromium VI		1 µg/L
Copper		$0.2 * e^{0.8545[\ln(hardness)]-1.465}$
Iron		300 µg/L
Lead		$e^{1.273[\ln(hardness)]-4.705}$
Mercury (inorganic)		0.026
Nickel		$e^{0.76[\ln(hardness)]+1.06}$
Selenium		1 µg/L
Silver		0.1 µg/L
Zinc		30 µg/L

CCME – Canadian Council of Ministers of the Environment; BCWQG – British Columbia Water Quality Guideline; SSWQG - Site-Specific Water Quality Guidelines (for the Sumas River)

The low flows in Downes Creek in 2018 were attributed to lower-than-average precipitation during the spring and summer, as indicated by the steepness of the cusum[3] line between April and September and were thus not due to pumping of the Bevan Wells. Short term excursions of the calculated flow below the 27.9 L/s threshold occurred in 2019, but were not substantiated by actual flow measurements and have not been repeated since. The occurrence of calculated values below the 27.9 L/s threshold likely reflects the difficulty in achieving a reliable stage-discharge relationship for this monitoring station, and the high sensitivity of calculated flows to changes in the apparent water level in the creek (i.e., stage).

The low flows in Fishtrap Creek at 0 Ave in 2018 likely reflect withdrawals from the creek, as low flows measured in the upper reaches of Fishtrap Creek (F-01) were greater. A similar low flow trend was reported for this monitoring station in September 2019 and may also have been caused by creek withdrawals. Based on the absence of lower water levels in the majority of water level monitoring stations (Section 4.2.4), it is unlikely to be associated with operation of the Bevan Wells. Due to the occurrence of erratic and unreliable trends in the data reported for Fishtrap Creek at 0 Avenue that occurred in mid-August 2020 and from June 2021 onwards, the relevant data record has been omitted, and the low-flows were not recorded.

Although calculated flows at Fishtrap Creek stations F-01 prior to July 2018 are unreliable, more recent calculated flows at this location correlate well with measured flows and are within the range indicated by measured flows prior to 2018. Flows measured at station F-02B on Fishtrap Creek are within the range indicated by measured flows at nearby station F-02 that was discontinued in 2018. Calculated flows at F-02B based on water levels measured after a period of no-data between approximately mid-August to late-September 2020 are erratic and appear unreliable. Low flows measured in July and August 2021 are within the historical range, and are attributed to the declining cusum trend.

Observed and calculated flows in Willband Creek reflect a slight decreasing trend that is attributed to less than average precipitation, as indicated by the declining cusum line. Willband Creek is the reference station that is outside the influence of the Bevan Wells.

2.4.1.2 Expanded Hydrometric Monitoring Program Sites

Year 10 represents the third year of monitoring at new hydrometric stations established at Boa Brook (B-02), Downes Creek (D-02, D-03 and D-04), Fishtrap Creek (F-04) and Waechter Creek (WT-01); thus, no year-over-year trend analysis was completed. Water levels at these sites are shown in Figure 2-6.

[3] cumulative deviation from the monthly mean of precipitation

Stream flows at F-03 and F-04 on Fishtrap Creek are presented in Figure 2-7. The flows at F-03 on Fishtrap Creek were derived by subtracting flows at WT-01 from F-04. The F-04 logger failed sometime during the fall or winter of 2020-21. It could not be downloaded in April 2021, and data after September 28, 2020 could not be recovered. As a result, it was not possible to calculate F-03 flows for the period from the end of September 2020 through April 2021.

Flows could not be calculated from the water level data recorded at the three Downes Creek hydrometric stations and the B-02 station on Boa Brook as stage-discharged rating curves could not be established. Based on the manual streamflow measurements recorded in Year 10 (Appendix A), flows at B-02 ranged from 8.9 L/s (July 22) to 21.3 L/s (January 21). Streamflow at D-03 and D-04 ranged from 0.7 L/s (July 21) to 9.1 L/s (May 25) and 2.1 L/s (May 22) to 11.7 L/s (January 21), respectively.

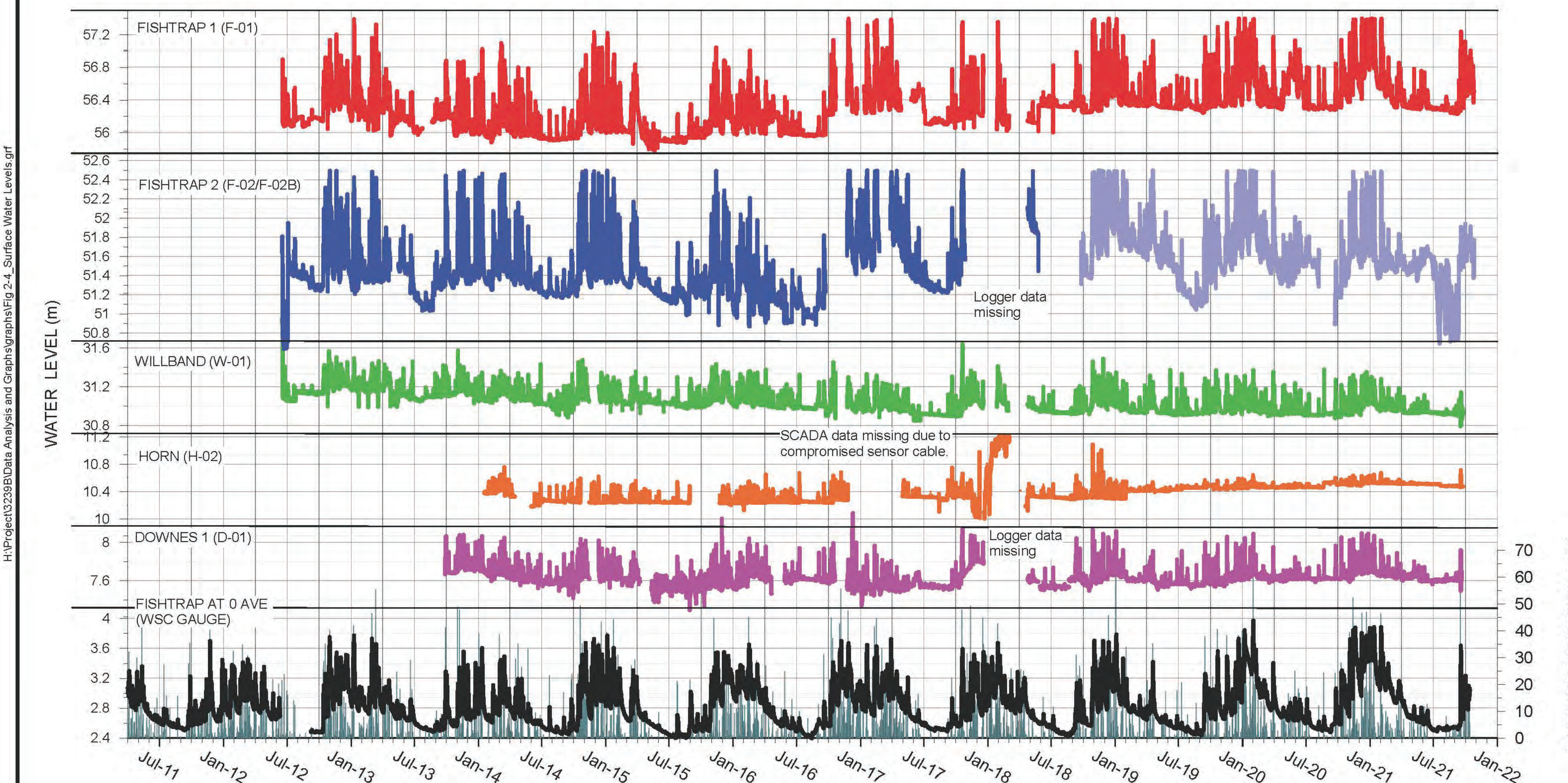
In 2018 and 2019, the D-02 hydrometric station was frequently inundated by a beaver dam, which influenced the water levels recorded by the pressure transducer. Large variations in flows, especially very low flow in May 2019, are attributed to beaver dam removal and reconstruction. The beaver dam was not present in August 2019 or subsequently. Flows and staff gauge readings (stages) measured from May 2020 to January 2021 produced a weak stage-discharge relationship ($R^2 = 0.61$), which suggests that with additional data it may be possible to develop a usable stage-discharge curve. Flows measured at D-02 in Year 10 ranged from 21.9 L/s (January 20) to 80.7 L/s (May 25).

2.4.2 Water Quality

2.4.2.1 Background

A major purpose of the water quality monitoring program is to compare conditions during operation of the Bevan Avenue Wells, and, potentially, during operation of the mitigation wells, to baseline conditions. The intent of project mitigation measures is to meet a standard of no negative change in water quality as a result of the Project. The CCME Water Quality Index (WQI) summarized overall water quality based the extent to which multiple parameters meet federal and provincial guidelines. Thus, the data analysis includes comparing CCME WQI ratings from year to year over the life of the Project. In addition, as the number of years of monitoring increases it becomes possible to conduct statistical analysis of temporal trends in both the WQI and in parameters of particular concern.

Comparison of water quality data to provincial and federal guidelines for freshwater aquatic life should be performed with care when assessing project effects or mitigation effectiveness, as the streams in the monitoring program area are impacted by urban influences and in some cases already exceed various guidelines. However, a discussion of the results in relation to these guidelines is provided to add detail to the CCME WQI ratings and to establish baseline conditions and subsequent changes in these streams. Table 2-3



Fishtrap 1 (F-01)
Fishtrap 2 (F-02)
Fishtrap 2 (F-02B)
Willband (W-01)
Horn (H-02)
Downes (D-01)
Fishtrap at 0 Ave (WSC gauge)
Precipitation

Water levels shown as elevations for all except Fishtrap at 0 Ave

All precipitation data from Environment Canada station at Abbotsford Airport.

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HYDROGRAPHS OF 2011 TO 2021
SURFACE WATER LEVEL TRENDS

BY:	DATE:
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APPROVED:	FIG:
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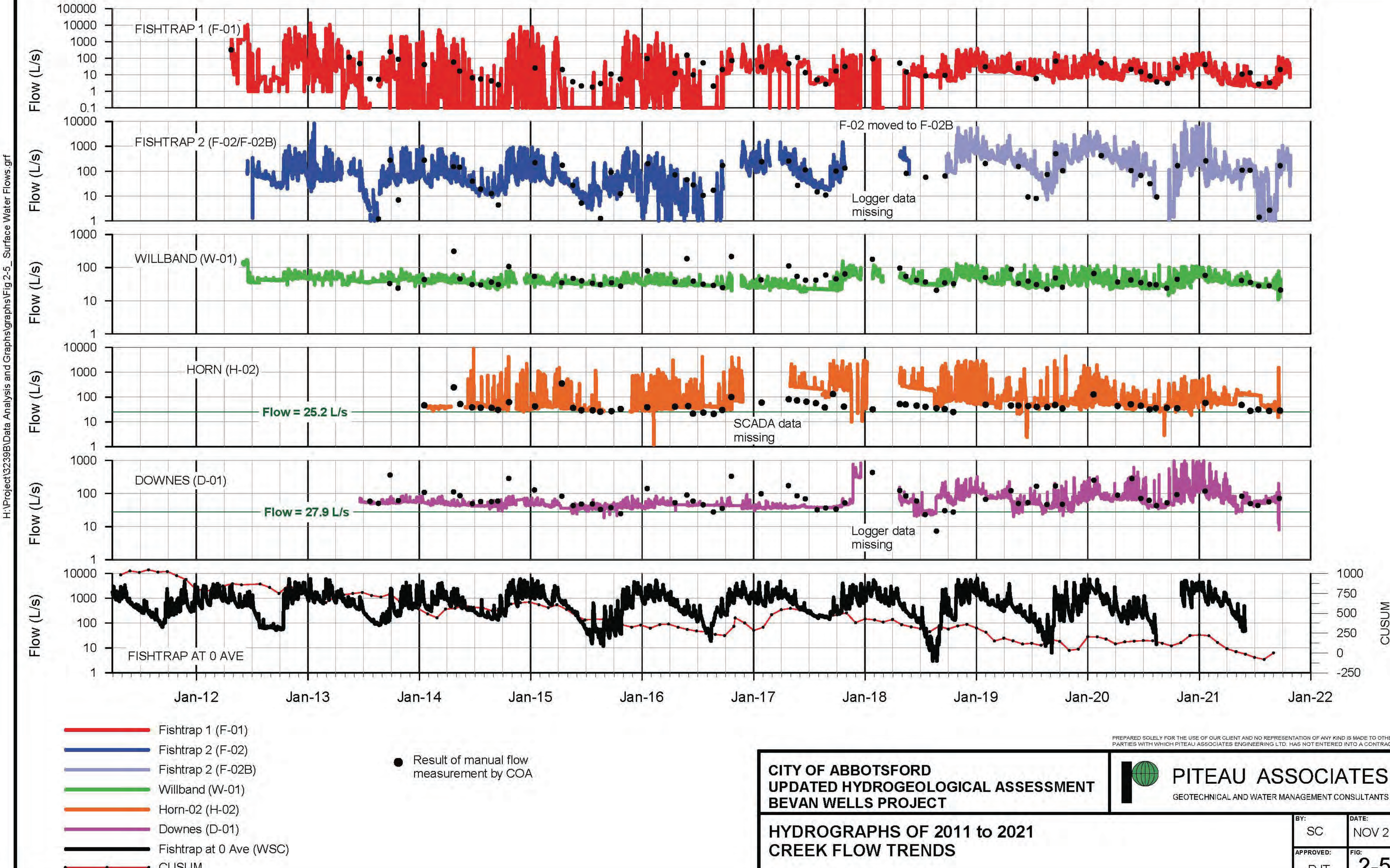

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HYDROGRAPHS OF 2011 to 2021
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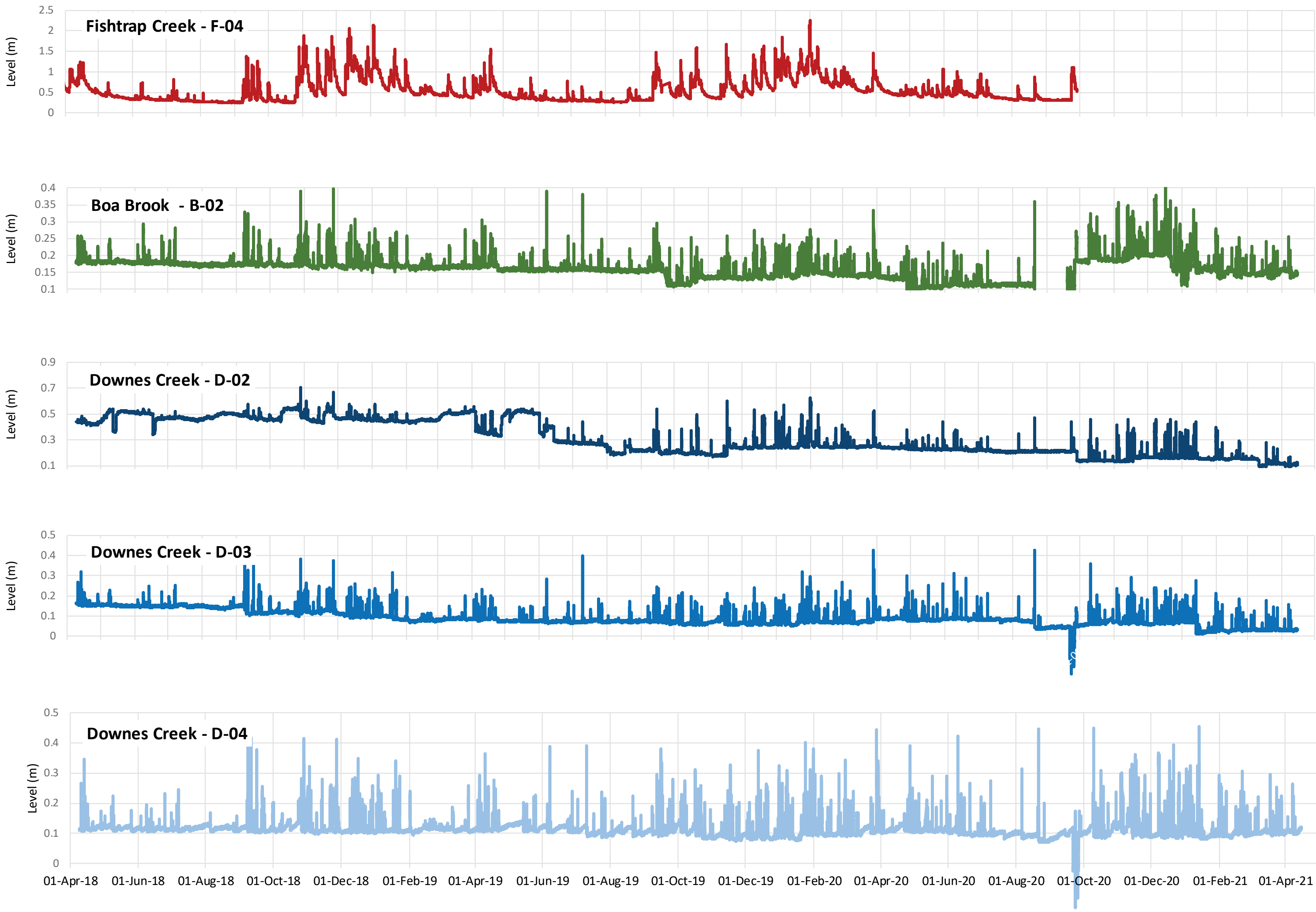


Figure 2-6 Surface Water Levels at Expanded Hydrometric Monitoring Sites

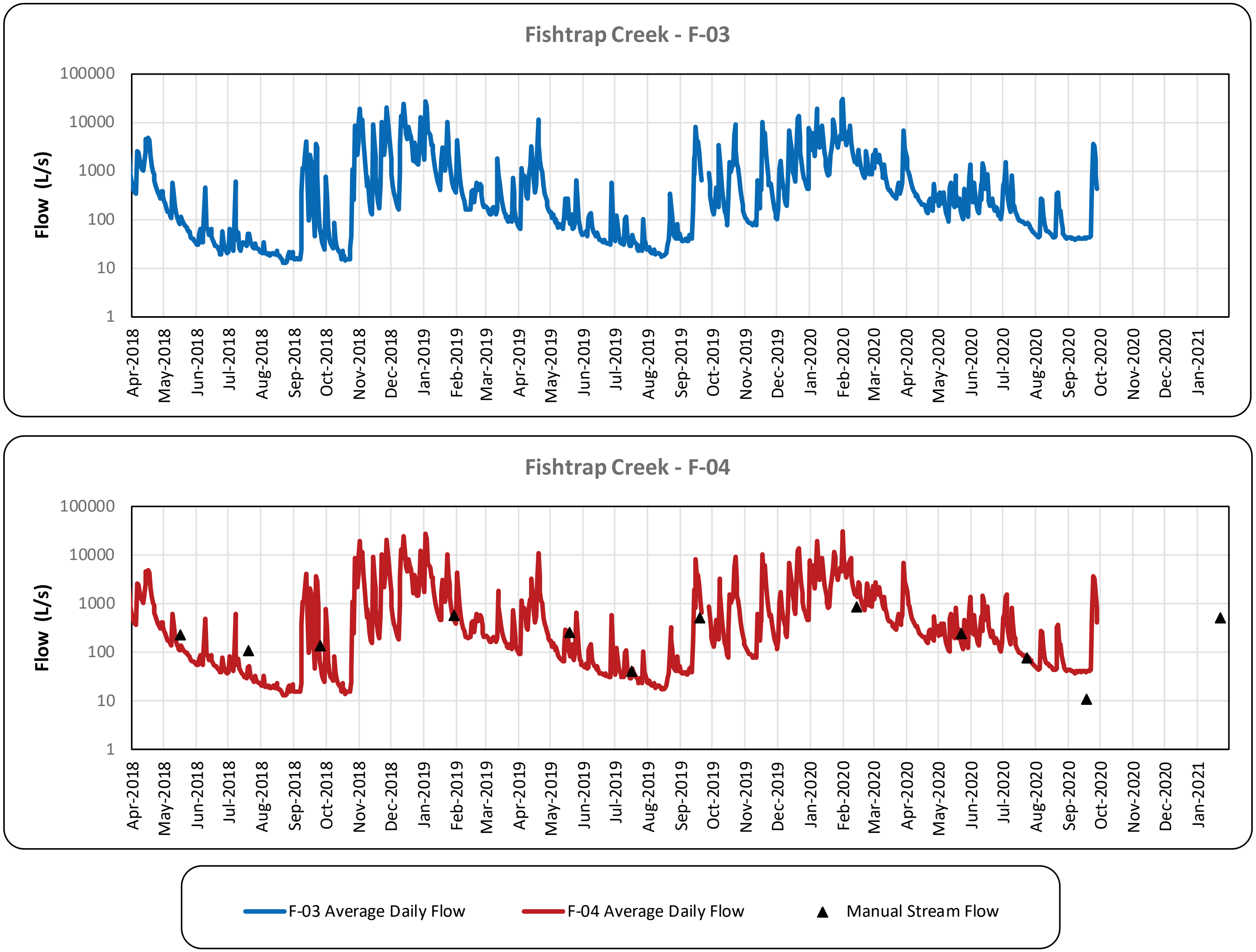


Figure 2-7 Flows at Expanded Hydrometric Monitoring Sites at Fishtrap Creek

describes the guidelines used in calculating the CCME WQI ratings and referred to in the discussion of results below. Raw surface water quality results are located in Appendix C (tables) and D (laboratory reports). Temporal graphs of Years 1 through 9 surface water quality data are located in Appendix E.

2.4.2.2 CCME Water Quality Index Results

Table 2-4 contains the results of the CCME WQI calculations for Year 10. According to the WQI, water quality at most sites was good or fair, with only B-01 rated "marginal." The Year 10 results are consistent with or slightly better than the baseline results from Year 1 and reflect the fact that water quality in the Abbotsford area is affected by agricultural and urban activities. Potential surface water quality effects of the Project would result from reduced flows producing higher temperatures, lower dissolved oxygen, and lower dilutions rather than inputs of new contaminants.

WQI results for Years 2 through 10 showed some variability but no apparent downward trends (Figure 2-8), suggesting that the use of the Bevan wells has not significantly affected the water quality in Boa Brook, Horn Creek, Downes Creek, or Fishtrap Creek. Year-to-year variability included upward or downward changes of one category, but differences in the absolute value of the WQI generally were small (Table 2-5).

The mean frequencies of water quality parameters not meeting applicable guidelines from Year 2 to Year 10 are summarized in Figure 2-9. Dissolved oxygen, temperature, phosphorus, fluoride, and a variety of metals did not consistently meet their respective guidelines at any monitoring site. Dissolved oxygen was particularly problematic in the headwaters of Boa Brook and Horn Creek with on average 91.7% and 91.3% of the samples at B-01 and H-01, respectively, having concentrations below the minimum guideline. In addition, over 50% of the samples from H-03, F-01, F-02, and W-01 (the reference site) did not meet the guideline for dissolved oxygen.

Historically, between 26.7% and 29.1% of the samples from Fishtrap Creek (F-01 and F-02, respectively) have not met the seasonal guidelines for temperature. These incidences occurred most frequently in May. However, in 2018 and 2019 the temperatures in Fishtrap Creek were elevated from May through August, and in 2020 they were elevated from April or May through September. Among the other monitoring sites the frequencies of temperature exceedances ranged from 8.7% at D-01 to 20.4% at H-01. Exceedances at all sites occurred most commonly in May and June, when the winter temperature guideline applies, but there were occasional exceedances in July, August, or September, when the summer guideline applies. In particular, temperatures at most sites were elevated in August 2019.

On average, phosphorus did not meet its guideline in over 50% of the samples from B-01, F-01, and F-02, while exceedances occurred in 17.6% to 31.5% of samples from the remaining monitoring sites. The metals most frequently not meeting guidelines were chromium, copper, and iron (Figure 2-9, Appendix F). The metals data suggest an impact from urban sources.

Table 2-4 CCME Water Quality Index Results for Year 10

Station	F1	F2	F3	CCME WQI	Sum of Failed Tests	Normalized Sum of Excursion	Total Samples	Number of Variables Tested	Total Tests	Number of Failed Tests	Number of Passed Tests	Number of Tests Below Detection	WQI Category
B-01	57.9	24.6	14.7	62.7	39.3	0.2	12	19	228	56	172	35	M
B-02	36.8	10.1	6.9	77.6	16.8	0.1	12	19	228	23	205	50	F
D-01	31.6	7.5	2.9	81.2	6.8	0.0	12	19	228	17	211	68	G
D-02	36.8	13.2	12.5	76.3	32.5	0.1	12	19	228	30	198	67	F
F-01	31.6	14.0	7.4	79.6	18.2	0.1	12	19	228	32	196	53	F
F-02	31.6	16.2	24.8	75.0	75.2	0.3	12	19	228	37	191	61	F
F-03	15.8	11.8	15.6	85.5	14.0	0.2	4	19	76	9	67	14	G
F-04	10.5	7.9	7.5	91.3	6.2	0.1	4	19	76	6	70	17	G
FOF	47.4	19.3	25.3	67.1	77.1	0.3	12	19	228	44	184	46	F
H-01	52.6	14.9	15.2	67.2	40.8	0.2	12	19	228	34	194	55	F
H-02	26.3	6.6	2.6	84.3	6.2	0.0	12	19	228	15	213	56	G
H-03	36.8	9.2	5.3	77.9	12.9	0.1	12	19	228	21	207	50	F
W-01	26.3	9.6	3.7	83.7	8.7	0.0	12	19	228	22	206	63	G

F1 (Scope) – Percent of parameters not meeting guidelines

F2 (Frequency) – Percent of individual tests not meeting guidelines

F3 (Amplitude) – Amount by which failed test values do not meet their guidelines

WQI – Water Quality Index

WQI Categories: G – Good (80-94), F – Fair (65-79), M – Marginal (45-64)

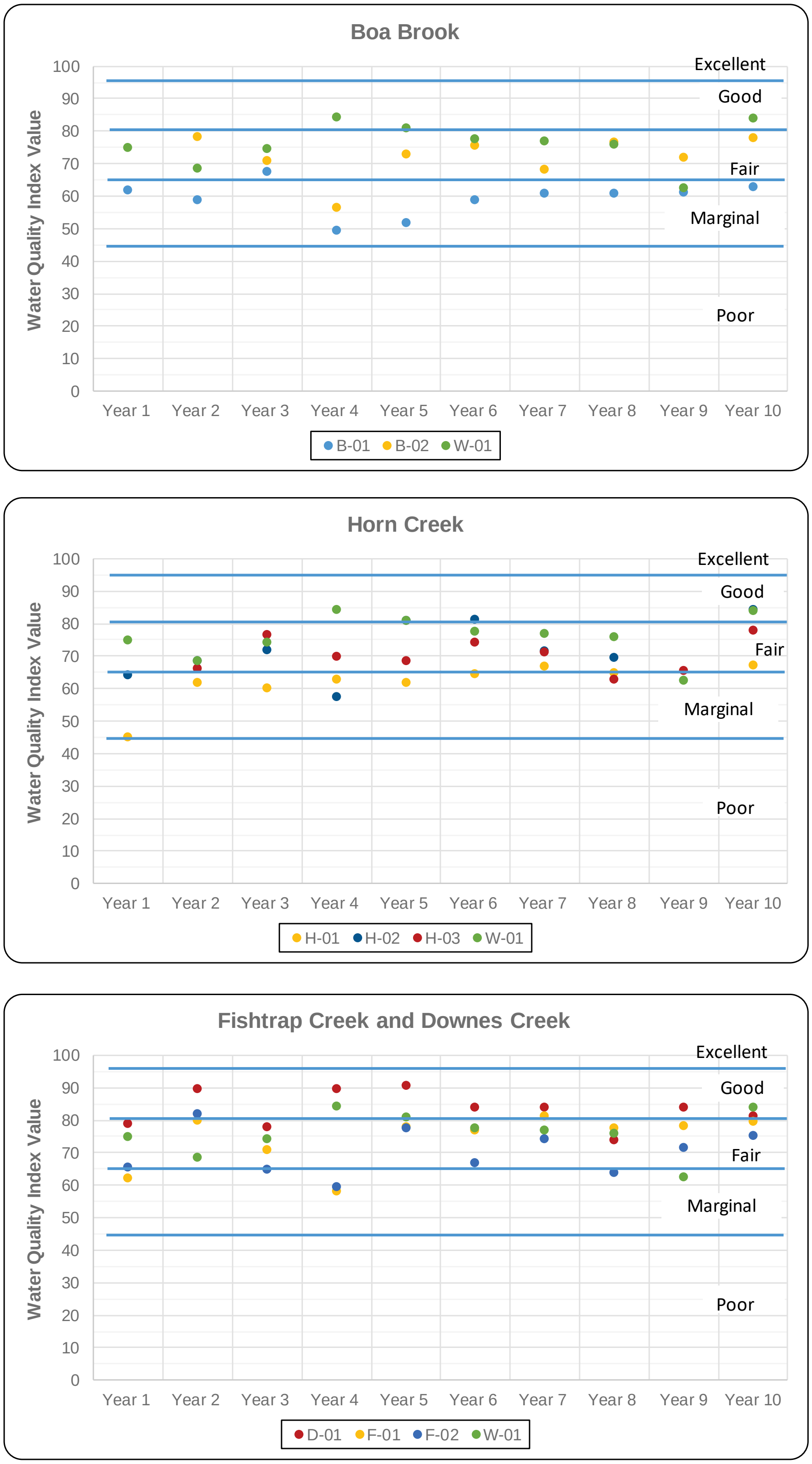


Figure 2-8 Variability in the CCME Water Quality Index, Year 1 to Year 10

Table 2-5 Comparison of the CCME Water Quality Index Results for Year 1 to Year 10

Station	Year 10 WQI	Rating	Year 9 WQI	Rating	Year 8 WQI	Rating	Year 7 WQI	Rating	Year 6 WQI	Rating	Year 5 WQI	Rating	Year 4 WQI	Rating	Year 3 WQI	Rating	Year 2 WQI	Rating	Year 1 WQI	Rating
B-01	62.7	M	61.1	M	60.8	M	60.7	M	58.5	M	51.6	M	49.4	M	67.3	F	58.7	M	61.6	M
B-02	77.6	F	71.8	F	76.3	F	68.1	F	75.4	F	72.7	F	56.2	M	70.8	F	78.1	F	--	--
D-01	81.2	G	84.0	G	73.9	F	84.0	G	83.7	G	90.5	G	89.7	G	77.9	F	89.5	G	78.9	F
F-01	79.6	F	78.3	F	77.5	F	81.2	G	76.9	F	77.9	F	58.2	M	70.8	F	79.7	F	62.2	M
F-02	75.0	F	71.5	F	63.7	M	74.0	F	66.7	F	77.5	F	59.3	M	64.7	M	81.8	G	65.4	F
H-01	67.2	F	55.2	M	64.6	M	66.7	F	64.4	M	61.9	M	62.7	M	60.1	M	61.9	M	45.0	M
H-02	84.3	G	53.1	M	69.3	F	71.4	F	81.3	G	80.9	G	57.5	M	71.7	F	68.5	F	64.2	M
H-03	77.9	F	65.3	F	62.9	M	71.0	F	74.3	F	68.5	F	69.7	F	76.6	F	66.2	F	--	--
W-01	83.7	G	62.4	M	75.7	F	76.9	F	77.4	F	80.7	G	84.2	G	74.3	F	68.3	F	74.8	F

WQI – Water Quality Index

WQI Categories: G – Good (80-94), F – Fair (65-79), M – Marginal (45-64)

Note that the Downes Creek location was moved in September 2014 due to hazardous trees in the area. Thus, Year 4 represents baseline conditions for the current monitoring location.

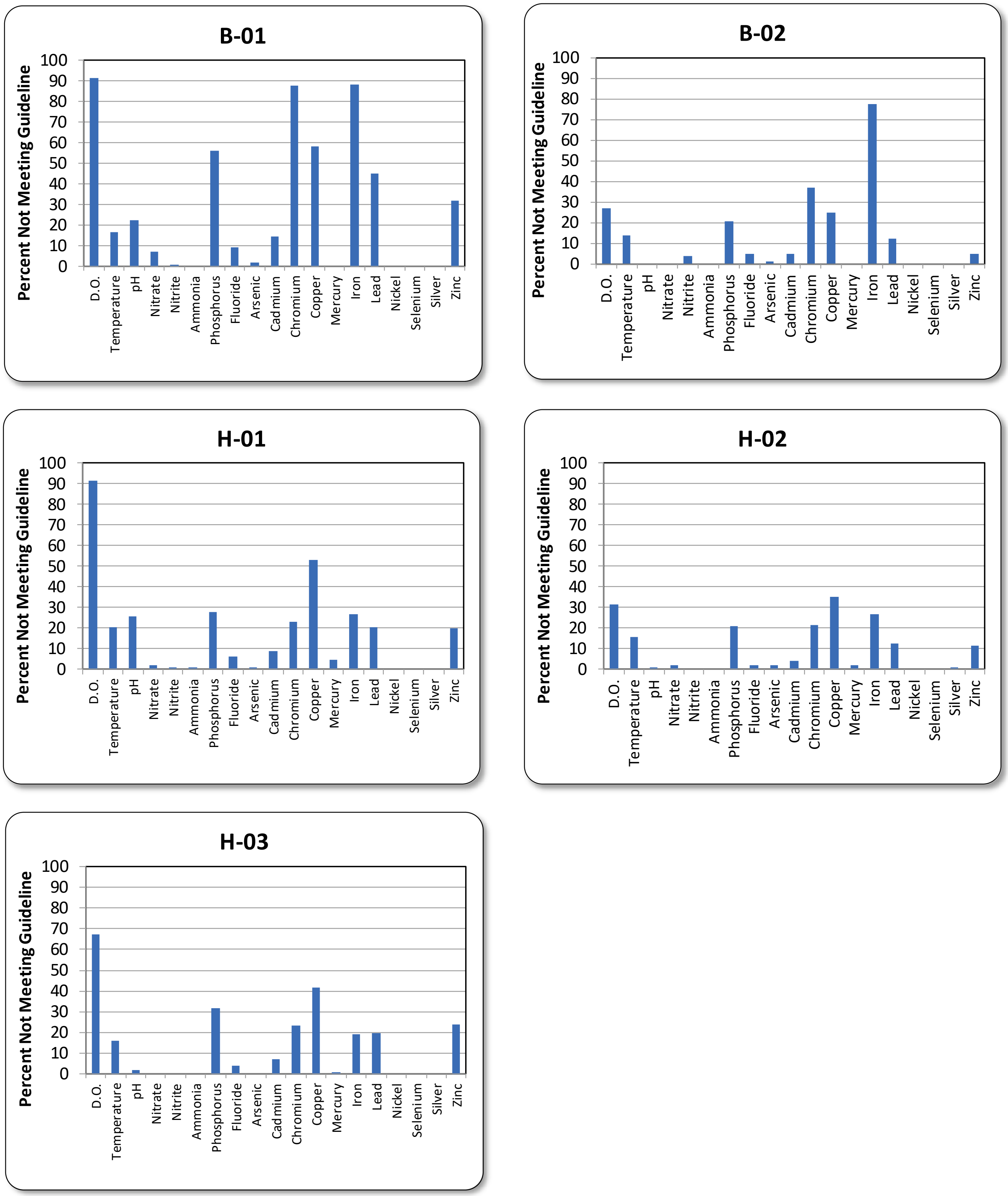


Figure 2-9 Mean Frequencies of Water Quality Parameters Not Meeting Guidelines, 2012-2020

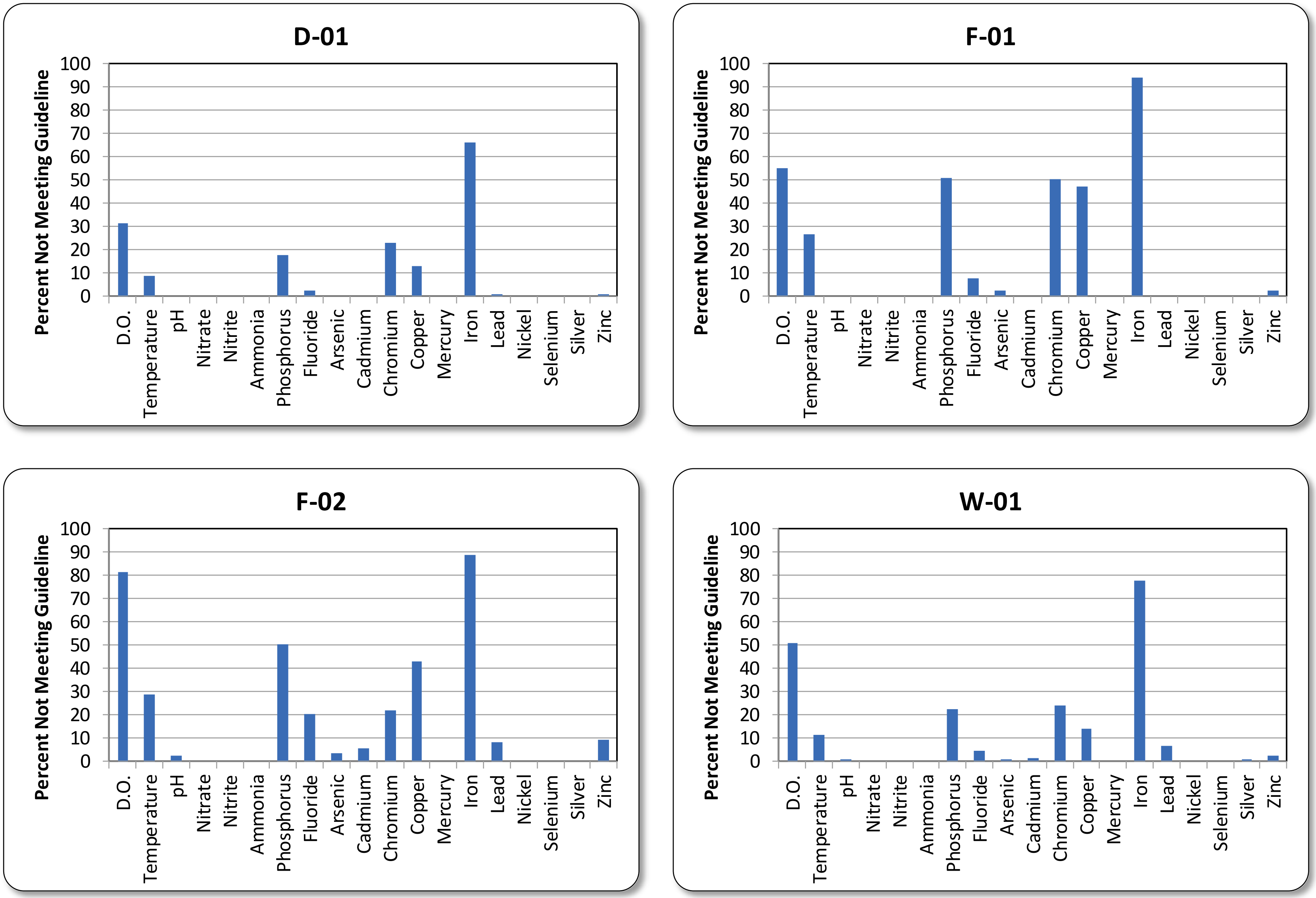


Figure 2-9 Mean Frequencies of Water Quality Parameters Not Meeting Guidelines, 2012-2020 (Continued)

2.4.2.3 Temporal Trend Analysis

Mann-Kendall non-parametric trend tests were performed using the MAKESENS application for Excel (Salmi *et al*. 2002). Trends were assessed on an annual basis and on a seasonal (July-October) basis. Only sites that had at least eight data points for annual and seasonal means were assessed. Parameters tested included the WQI (annual basis only) plus *in-situ* dissolved oxygen and temperature (annual and seasonal basis). Dissolved oxygen and temperature are parameters of particular interest because of their importance for fish habitat quality and because decreases in stream flow can result in higher summer water temperatures and resulting decreases in dissolved oxygen.

The Mann-Kendall test showed no statistically significant decrease in the WQI at any of monitoring sites. However, there was a significant improvement in the WQI at H-01 (Table 2-6).

Table 2-6 Statistical Significance of Mann-Kendall Trends in the CCME Water Quality Index at the Bevan Wells Monitoring Sites

Site	First Year	Last Year	n	Mann-Kendall Z or S	Significance
B-01	Year 1	Year 10	10	0.89	
B-02	Year 2	Year 10	9	6	
D-01	Year 1	Year 10	10	-0.27	
F-01	Year 1	Year 10	10	1.43	
F-02	Year 1	Year 10	10	0.18	
H-01	Year 1	Year 10	10	2.07	**p <0.05**
H-02	Year 1	Year 10	10	0.72	
H-03	Year 2	Year 10	9	0	
W-01	Year 1	Year 10	10	0.18	

MAKESENS calculates the Z approximation to the Mann-Kendall S-statistic for $n \geq 10$.
Negative values of Z or S represent downward trends; positive values represent upward trends.
Blank – Probability (p) >0.1. Significance set at $p < 0.05$.

The tests showed significant negative (downward) trends in dissolved oxygen concentrations in the summer (July to October) time period and annually at B-01 and H-02 (Table 2-7). The was a corresponding increase in the annual temperature at H-02 but not a B-01. There were no corresponding increases in the summer temperatures at B-01 and B-02, which suggests that the use of the Bevan Wells was not responsible for the decreases in dissolved oxygen. There were no significant trends in dissolved oxygen at the other monitoring sites on Boa Brook and Horn Creek or at the Willband Creek reference site.

Table 2-7 Statistical Significance of Mann-Kendall Trends in Dissolved Oxygen and Temperature at the Monitoring Sites in Boa Brook, Horn Creek, and Willband Creek

Parameter	Site	Time Series	First Year	Last Year	n	S or Z	Significance
Dissolved Oxygen	B-01	Annual	Year 1	Year 10	10	-2.68	**p <0.01**
		Jul - Oct	Year 1	Year 10	10	-2.15	**p <0.05**
	B-02	Annual	Year 3	Year 10	8	-4	
		Jul - Oct	Year 3	Year 10	8	-2	
	H-01	Annual	Year 1	Year 10	10	-0.537	
		Jul - Oct	Year 1	Year 10	10	-0.358	
	H-02	Annual	Year 1	Year 10	10	-2.50	**p <0.05**
		Jul - Oct	Year 1	Year 10	10	-2.33	**p <0.05**
	H-03	Annual	Year 1	Year 10	10	-1.09	
		Jul - Oct	Year 1	Year 10	10	-1.61	
	W-01	Annual	Year 1	Year 10	10	-1.43	
		Jul - Oct	Year 1	Year 10	10	-0.89	
Temperature	B-01	Annual	Year 1	Year 10	10	1.61	
		Jul - Oct	Year 1	Year 10	10	0.179	
	B-02	Annual	Year 3	Year 10	8	12	
		Jul - Oct	Year 3	Year 10	8	8	
	H-01	Annual	Year 1	Year 10	10	1.43	
		Jul - Oct	Year 1	Year 10	10	0.716	
	H-02	Annual	Year 1	Year 10	10	2.33	**p <0.05**
		Jul - Oct	Year 1	Year 10	10	0.000	
	H-03	Annual	Year 1	Year 10	10	0.934	
		Jul - Oct	Year 1	Year 10	10	0.179	
	W-01	Annual	Year 1	Year 10	10	1.25	
		Jul - Oct	Year 1	Year 10	10	0.894	

MAKESENS calculates the Z approximation to the Mann-Kendall S-statistic for $n \geq 10$.
Negative values of Z or S represent downward trends; positive values represent upward trends.
p – probability. Blank indicates $p > 0.1$. Significance set at $p < 0.05$.

Prior to Year 8, water quality in Downes Creek (D-01) and Fishtrap Creek (F-01 and F-02) was monitored in April, September, October, and January. Therefore, the available data were insufficient to analyze seasonal or annual trends. However, trends during each of the four months were analyzed. No trends were statistically significant in these watercourses (Table 2-8).

2.4.2.4 Quality Control Results for Surface Water Samples

<u>Laboratory QC</u>

Appendix D contains the full report of ALS's and BV's QC samples and results. Overall, the laboratory's QC results were good with most samples meeting the laboratory's data quality objectives (DQO). Several spike recoveries did plus one method blank and one duplicate analysis did not meet the DQO for all parameters. These tests and parameters are listed in Table 2-9.

Total calcium was detected in one ALS method blank for September 2020. A second method blank run with the same sample batch did not contain detectable calcium.

The relative percent difference (RPD) for total copper in the duplicate associated with the August 2020 samples was above ALS's DQO. The duplicate analysis was run on an anonymous sample and therefore might not reflect variability in the Bevan samples.

Spike recoveries[4] for several metals were outside ALS's or BV's DQO. However, both laboratories noted in all cases that the results of the multi-element scans met acceptability criteria.

<u>Field QC</u>

Field QC included one travel blank, one field blank, and one duplicate sample per month. Complete field QC results are presented in Appendix C.

Except in December 2020, the results of the travel blanks were excellent with no analytes detected. However, the December 2020 travel blank contained hardness, total ammonia, nitrate, and total phosphorus at concentrations >10 times the detection limits and nitrite at a concentration >7 times the detection limit. These substances were not detected in the December 2020 field blank, and their concentrations in the associated water samples were not elevated by comparison with the concentrations measured in other months. Thus, contamination in the travel blank does not appear to have affected the sample results.

[4] Called "laboratory control samples" (LCS) by ALS and "matrix spike" by BV

Table 2-8 Statistical Significance of Mann-Kendall Trends in Dissolved Oxygen and Temperature at the Monitoring Sites in Downes Creek and Fishtrap Creek

Parameter	Site	Time Series	First Year	Last Year	n	Z or S	Significance
Dissolved Oxygen	D-01	May	2013	2021	9	-2	
		September	2012	2021	9	12	
		October	2013	2021	9	4	
		January	2012	2021	8	-2	
	F-01	May	2013	2021	8	-4	
		September	2012	2021	10	0.894	
		October	2013	2021	9	4	
		January	2012	2021	8	2	
	F-02	May	2013	2021	9	-18	p<0.1
		September	2014	2021	8	-10	
		October	2013	2021	9	-7	
		January	2013	2021	9	-8	
Temperature	D-01	May	2013	2021	9	0	
		September	2012	2021	9	8	
		October	2013	2021	9	2	
		January	2012	2021	10	1.252	
	F-01	May	2013	2021	9	-6	
		September	2012	2021	10	1.073	
		October	2013	2021	9	1	
		January	2012	2021	10	1.167	
	F-02	May	2013	2021	9	-4	
		September	2014	2021	8	12	
		October	2013	2021	9	0	
		January	2013	2021	9	5	

MAKESENS calculates the Z approximation to the Mann-Kendall S-statistic for n ≥10.
Negative values of Z or S represent downward trends; positive values represent upward trends.
p – probability. Blank indicates p >0.1. Significance set at p <0.05.

Table 2-9 Parameters Not Meeting the Laboratory Quality Control Limits

Parameter	Lab.	Sample Batch	QC Test and Units	Result	DQO
Total Calcium	ALS	Sep. 29	Method Blank (mg/L)	0.094	<0.05
Total Copper	ALS	Aug. 11	Duplicate (RPD)	54.7%	20
Total Sodium	ALS	Aug. 11	Spike Recovery (%)	129%	80-120
Total Bismuth	ALS	Aug. 11	Spike Recovery (%)	121%	80-120
Total Bismuth	BV	Jan. 20	Spike Recovery (%)	24%	80-120
Total Molybdenum	BV	Jan. 20	Spike Recovery (%)	72%	80-120
Total Phosphorus	BV	Jan. 20	Spike Recovery (%)	-0.088%	80-120
Total Mercury	BV	Jan. 20	Spike Recovery (%)	121%	80-120
Total Phosphorus	BV	Mar. 17	Spike Recovery (%)	60%	80-120

Results of the field blanks were good for most parameters. However, barium, lead, molybdenum, and zinc each were detected in one blank. The concentrations of barium (June 2020) and molybdenum (December 2020) were <5 times the applicable detection limits, while the concentration of lead (July 2020) was about nine times the detection limit. The concentration of zinc in the June 2020 field blank was extremely elevated at 80 µg/L (almost 27 times the detection limit).

The Resource Inventory Standards Committee (RISC, 1998) recommends that concentrations of parameters detected in blanks not exceed 10% of the applicable water quality guideline(s) or 10% of the sample concentrations. The concentrations of barium and molybdenum in the field blanks were <0.1% of the British Columbia guidelines (1000 µg/L for both metals). However, the concentration of lead in the blank was 47% of the most restrictive CCME guideline (1 µg/L for hardness <60 mg/L as $CaCO_3$), and the zinc concentration was 267% of the 30-µg/L CCME guideline. [5] None of the July 2020 samples contained lead at concentrations >1 µg/L, but the June 2020 sample from F-02 had a zinc concentration of 36.7 µg/L. Sample contamination might have contributed to apparent zinc exceedance at F-02, but no other guideline comparisons were compromised.

The concentration of barium in the field blank was <4% of the sample concentrations, but the concentrations of lead and molybdenum in the blanks were >10% of and often greater than the sample concentrations. The zinc concentration in the field blank was higher than the concentration in any sample. In theory, the contamination suggested by the field blanks

[5] The BC guidelines for barium and molybdenum were not used in the WQI calculation but the CCME guidelines for lead and zinc were (Section 2.3.2.4).

might have biased the concentrations of lead, molybdenum, and zinc in the associated samples. However, the concentrations of lead and molybdenum in the associated samples were within the ranges measured throughout the Year 10 monitoring program. The June 2020 zinc concentrations at sites D-01, D-02, F-01, and F-02 were the highest recorded at those sites during Year 10 and might have been elevated due to sample contamination.

Results of the most duplicate samples were excellent with relative percent differences (RPD) rarely exceeding the 25% recommended by RISC (1998) for field duplicates in which one or both concentrations are ≥5 times the detection limit. Exceptions were phosphorus and zinc in the June 2020 total metals duplicate; aluminum in the July 2020 duplicate; hardness, ammonia, and nitrate in the December 2020 duplicate; and turbidity in the October 2020 field measurement duplicate. The June 2020 duplicate was taken and F-02, and the high variability for zinc (values 36.7 μg/L and 3.2 μg/L) is consistent with sample contamination as observed in the corresponding field blank.

2.5 Successes, Challenges and Suggested Changes

A storm event on August 21, 2020, caused sedimentation that impacted the H-02 staff gauge. The streambed remained unstable into October but had mostly stabilized by December 1, 2020. The changes caused shifts in the baseflow stage, which required several calculations of the rating curve.

A new flow monitoring station to be connected to SCADA was installed at F-02 on January 7, 2020. However, it was not possible to produce a reliable stage-discharge curve from the January 2020 – April 2021 data. The location of the monitoring station is being reevaluated.

The Hobo logger at F-04 failed during the 2020-2021 fall/winter period. As a result, no water level data for this period were recovered.

The manual stream flow data recorded at B-02, D-02, D-03 and D-04 were insufficient to establish a stage-discharge rating curve. Causes included frequent inundation of the D-02 hydrometric station by a beaver dam, and low flows at B-02, D-03, and D-04, which may have affected the accuracy of streamflow measurements. Beaver dam removal at D-02 was completed in 2019, and no evidence of dam reconstruction was observed during the Year 10 monitoring. During Year 10 the low flows were measured using a Hach FH950, which is more suitable for low flow conditions than the ADV meter previously employed. The changes appear to have improved the stage-discharge relationship at D-02, but the measured flows did not correspond well with the stream flows calculated using this curve. The stage-discharge relationships at B-02, D-03, and D-02 did not improve in Year 10.

Low water depths were also a problem at WT-01. As a result, the Hach FH950 meter was used at this site. In July 2020, the location of the manual stream flow measurements was moved downstream of the staff gauge to a point where the channel depth was greater. Nevertheless, the channel at the new measurement point was dry in August 2020.

3.0 FISH HABITAT PROGRAM

3.1 Background

The following section describes the fish habitat monitoring program that was conducted as per the requirements of the OEMP (ENKON, 2018) and the Fish Habitat Characterization Work Plan (Hemmera, 2011a). The objectives of the monitoring program are to assess the effectiveness of mitigation in minimizing effects to fish and fish habitat if flows in Horn Creek, Boa Brook, Fishtrap Creek and/or Downes Creek are reduced by use of the Bevan Wells.

Although fish species lists for Horn Creek and Boa Brook are not available, these streams form part of the Willband Creek watershed, which does have a list of identified species (MoE, 2012). Based on the fish species list for Willband Creek, fish species assumed to be present within headwater areas including tributary streams such as Horn Creek and Boa Brook include Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*), Coho Salmon (*O. kisutch*) and Threespine Stickleback (*Gasterosteus aculeatus*) (Hemmera, 2010). Golder Associates (Golder) biologists conducted fish salvage activities in the headwaters reach of Horn Creek in August 2011 prior to in stream works; species caught during this work included Rainbow Trout (*O. mykiss*), Cutthroat Trout and Coho Salmon (personal communication, Rob Hoogendor, Golder, 2011).

Fish sampling conducted by ENKON (2016) documented Coho Salmon and Cutthroat Trout within Downes Creek headwaters. Fish were found to be well distributed within the Downes Bowl stream network, often far upstream and in proximity to the immediate channel headwaters. Fishtrap Creek supports populations of Salish sucker (*Catostomus sp.)* and Nooksack Dace (*Rhinichthys cataractae*) which are listed as endangered under Schedule 1 of the federal *Species at Risk Act* (SARA). Salmonids species present in Fishtrap Creek include Coho, Cutthroat Trout, and Rainbow Trout.

3.2 Monitoring Sites

During Year 1 of the monitoring program, six representative sites for the assessment of fish habitat (approximately 50 m long, one per reach) were chosen (two on Boa Brook and four on Horn Creek) based on aerial photographs and topographic maps. Sites were chosen to coincide with water quality/stream flow sites, where possible. These site locations were confirmed during the sampling event in July 2011. Mesohabitats within each reach were identified (e.g., pools, glides, runs, riffles, cascades, etc.), and one site per mesohabitat type present was then chosen at random and georeferenced to establish a transect.

In fall 2017, additional fish habitat monitoring sites were established at Downes Creek and Fishtrap Creek, as required by the Mitigation Plan (ENKON 2017), which was developed as part of the 2017 EAC amendment. Seven sites were selected (three on Downes Creek and four on Fishtrap Creek). Mesohabitat sites were set up consistent with the pre-existing mesohabitat sites at Boa Brook and Horn Creek. Monitoring of these sites commenced in summer 2018. Mesohabitat site locations are described in Table 3-1 and shown on Figure 3-1, 3-2 and 3-3.

3.3 Schedule

The period where base flows are most likely to be affected in the subject streams is during the summer and early fall. This occurs after salmonid fry emergence (spring) and before adult chum (mid-October to November) and coho spawning migrations (November to December). Fish habitat monitoring was carried out once a month beginning in July and ending in October. In accordance with Condition #27 of the amended EA certificate, a representative from Matsqui First Nations accompanied ENKON monitoring staff on August 13; September 21, 28, 29; and October 19, 20, 21, 22, 28, 2020. The Matsqui First Nations representative assisted with data collection and input, along with equipment coordination. The Matsqui First Nation did not respond to the invitation to participate in July.

3.4 Methods

The methods for fish habitat monitoring are described below and were adapted from Lewis et al.(2004). During the Year 1 to Year 7 monitoring, general characteristics that were assessed over each 50 m site reach included:

- Mesohabitat Types;
- Channel type: confinement, channel pattern, islands/bars;
- D95 Particle Diameter;
- Gradient;
- Substrate Type: % of each size class;
- Cover: presence of deep pools, boulders, in stream vegetation, overhanging vegetation, large woody debris (LWD) and/or canopy closure; and

During the Year 8 through 10 monitoring program substrate, D95 particle diameter and cover were assessed at each mesohabitat within a site, rather than at the reach level as was done in previous monitoring years.

Table 3-1 Fish Mesohabitat Sites

Watercourse	Site	Mesohabitat Site	Northing	Easting	Mesohabitat Type
Horn Creek	1	1A	5434383	550784	Riffle
		1B			Run
	2	2A	5434420	550482	Pool
		2B			Riffle
		2C			Run
	3	3A	5434412	550693	Run
		3B			Riffle
		3C			Pool
	6	6A	5434032	550243	Run
		6B			Riffle
Boa Brook	4	4A	5434288	550643	Run
		4B			Pool
	5	5A	5433794	550812	Pool
		5B			Riffle
		5C			Run
		5D			Pool
Downes Creek	D-02	D-02 riffle	5435914	549145	Riffle
		D-02 pool	5435897	549141	Pool
	D-03	D-03 riffle	5435429	549298	Riffle
		D-03 pool	5435450	549280	Pool
	D-04	D-04 riffle	5435292	549174	Riffle
		D-04 pool	5435333	549181	Pool
Fishtrap Creek	F-01	F-01 riffle	5433414	546387	Riffle
		F-01 pool	5433389	546388	Pool
	F-02	F-02 riffle	5431957	545249	Riffle
		F-02 pool	5432145	545274	Pool
	F-03	F-03 pool	5430294	544039	Pool
	F-04	F-04 riffle	5430325	544016	Riffle
		F-04 pool	5430354	544039	Pool

Note: UTM Coordinates are NAD83, Zone 10U

At each selected mesohabitat site within the reach, physical characteristics (i.e., channel width, bankfull depth and wetted width) were assessed. A transect was established and marked with flagging tape and coordinates were established with a Garmin GPS unit.

All information was recorded in the field on RISC site cards. Photo documentation of each transect and site sampled was taken following protocols in the *British Columbia Photo Documentation Guidelines for Aquatic Inventory* (RISC, 1996).

3.5 Results

3.5.1 Biophysical Characteristics

Biophysical habitat characteristics measured at the 13 sites at Horn Creek, Boa Brook, Downes Creek and Fishtrap Creek are described below. A summary of biophysical data is presented in Appendix G.

3.5.1.1 Horn Creek

Biophysical habitat characteristics were measured at three sites within the project area along Horn Creek (Figure 3-1).

<u>Site 1 – Horn Creek</u>

Site 1 is located downstream of the confluence of Horn Creek and Boa Brook. This site was chosen to coincide with water quality monitoring site H-02 and to represent the reach of Horn Creek between Boa Brook and Maclure Road. Two mesohabitat types were identified here: a riffle (Mesohabitat Site 1A) and a run (Mesohabitat Site 1B).

Channel morphology at Site 1 was straight, unconfined, and had a low gradient (1-2%). The reach has undercut banks, over hanging vegetation and trace amounts of instream vegetation and small woody debris (SWD). One piece of suspended large woody debris (LWD) upstream from Site 1A was swept downstream between the August 2020 and September 2020 monitoring visits. Deep pools were only observed at Site 1A.

In Year 10, The substrate at Site 1A shifted from a fines (40%) and gravel (55%) mix to primarily fines (83%) in September 2020. Minimal cobbles (5%) were present. D95 ranged from 9 cm to 14 cm for both sites. Embeddedness for the reach remained consistent throughout the four monitoring visits averaging 27.5%. Canopy closure was moderate for both sites, averaging 35% and 48% for Site 1A and Site 1B, respectively.

Legend

- Mesohabitat site
- Abbotsford-Sumas aquifer
- Streams
- Waterbody

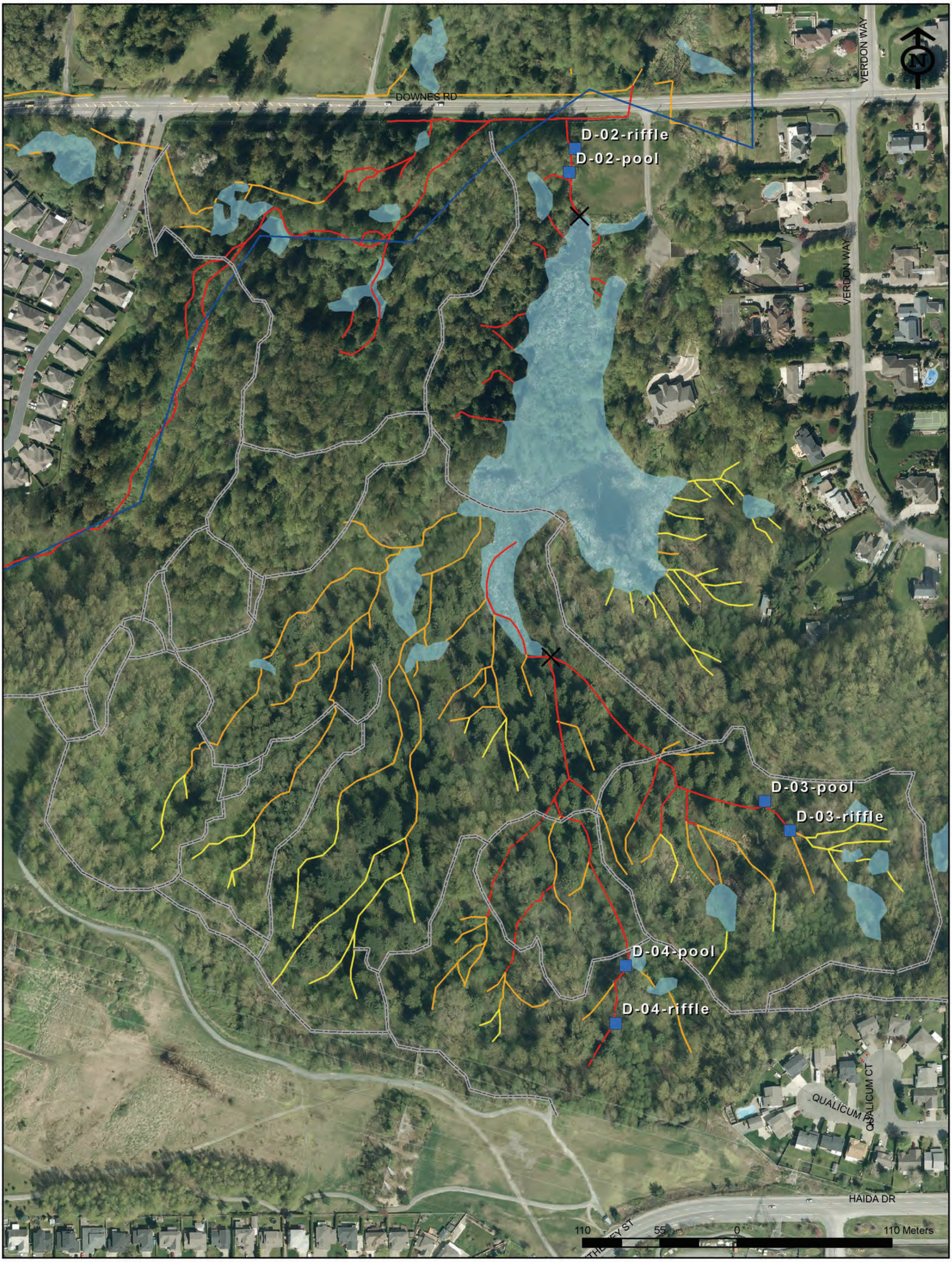
Prepared by: ENKON Environmental Ltd.

Horn Creek and Boa Brook Mesohabitat Monitoring Sites

City of Abbotsford

Created: December 2019
Projection:
NAD 83 UTM Zone 10N
1:3,000

Figure 3-1



Legend

- Mesohabitat site
- DownesTrails
- Abbotsford-Sumas aquifer
- Waterbody

Watercourses (CoA Modified)

- Class A (fish-bearing)
- Class Ao (overwintering)
- Class B (food and nutrient)
- Permanent (Unclassified)

Prepared by: ENKON Environmental Ltd.

Created: December 2019
Projection:
NAD 83 UTM Zone 10N
1:2,500

Downes Creek
Mesohabitat Monitoring Sites

City of Abbotsford

Figure 3-2

Legend

- Mesohabitat site
- Abbotsford-Sumas aquifer
- Streams
- Waterbody

Prepared by: ENKON Environmental Ltd.

Created: December 2019
Projection:
NAD 83 UTM Zone 10N
1:10,000

Fishtrap Creek Mesohabitat Monitoring Sites

City of Abbotsford

Figure 3-3

Photographs 3-1 Site 1 (Horn Creek) – August 2020 (top) and September 2020 (bottom)

1A Facing upstream

1B Facing downstream

1A Facing upstream

1B Facing downstream

Site 2 – Horn Creek

Site 2 is located upstream of Trafalgar Road and between two unnamed tributaries to Horn Creek. Three mesohabitat types were identified here: a pool (Mesohabitat Site 2A), a run (Mesohabitat Site 2B), and a riffle (Mesohabitat Site 2C).

Site 2 had a confined sinuous and straight channel and gradient of 2%. Sand and gravel side bars were observed during all monitoring events. This site had good salmonid rearing habitat values, along with moderate values for overwintering and spawning habitat. During the August 2020 visit, soap suds were observed in the water coming from an unknown upstream source.

The pool mesohabitat (2A) substrate was dominated by gravel (65%) until the October 2020 monitoring site visit. The proportion of fines increased from 10% to 50% between the September 2020 and October 2020 monitoring visits. Cobble and boulders remained consistent throughout the monitoring season averaging at 11% and 20%, respectively. Embeddedness increased to 40% in October 2020 from 10-15%.

The dominant cover type was boulders with deep pools as the subdominant cover type. Trace amounts of overhanging vegetation, instream vegetation, SWD and LWD were also present. Crown closure averaged at 75% throughout the monitoring season.

The run mesohabitat (2B) had predominately gravel substrate (average 52%), with lesser amounts of cobble (20%), fines (18%), and boulders (10%). Cover within the site was dominated by boulders with overhanging vegetation, SWD and LWD being the subdominant cover. A small section of undercut bank and trace amounts of instream vegetation were also available for cover. Crown closure dropped from 50% in July 2020 to 5-15% in the later months. D95 averaged at 14 cm.

Site 2C (riffle) had substrate composition similar to Site 2B. Gravels dominated (59%) with lesser amounts of cobble (16%), fines (14%), and boulders (11%). Boulders were also the dominant cover type but had subdominant components of undercut bank and overhanging vegetation. Additional cover included SWD, LWD, and instream vegetation. Crown closure also dropped after the August 2020 site visit from 50% to 0-5%. Site 2C had an average D95 of 14.5 cm

The average substrate embeddedness for this reach ranged from 15% at Site 2A and 2B to 20% at Site 2C in Year 10.

Photographs 3-2 Site 2 (Horn Creek) – September 2020

2A Facing upstream

2B Facing upstream

2C Facing downstream

Site 3 – Horn Creek

Site 3 is located between the Trafalgar Street culvert and the confluence of Horn Creek and its tributary Boa Brook. Three mesohabitat types were identified here: a run (Mesohabitat Site 3A), a riffle (Mesohabitat Site 3B) and a pool (Mesohabitat Site 3C).

Photographs 3-3 Site 3 (Horn Creek) – September 2020

3A Facing upstream

3B Facing downstream

3C Facing downstream

3C Facing downstream (August 2020)

Channel morphology at Site 3 was straight and frequently confined with a gradient of 1%. Sand and gravel side bars were observed during all monitoring events. Site 3 had good rearing and overwintering habitat values, along with moderate spawning habitat values for salmonids.

The dominant substrate material at Site 3A (run mesohabitat) was gravel (63%). Fines served as the subdominant material (24%), with trace amounts of cobble (9%) and boulders (5%). The dominant cover type was undercut banks with overhanging vegetation and deep pools as the subdominant cover type. Trace amounts of instream vegetation, LWD, SWD, and boulders were also present as potential cover. Crown closure was moderate at 40%.

Site 3B had a substrate composition of gravels (56%), cobble (25%), and fines (19%). The dominant cover type was undercut banks with overhanging vegetation as the subdominant cover. Trace amounts of instream vegetation, SWD and LWD were also present. Crown closure was less than site 3A at 25%.

From July 2020 to August 2020, Site 3C substrate consisted of gravels (55%), cobbles (25%), and fines (20%). The substrate composition changed to 85% fines, 10% gravel and 5% cobble, on average, for the September to October 2020 monitoring visits. Dominant cover type included deep pools with a subdominant cover type of under cut bank and overhanging vegetation. Instream vegetation and SWD were also present in trace amounts. There was 0% crown closure at Site 3C.

Embeddedness across all three mesohabitat sites ranged from 19% (3C) to 25% (3A). Site 3A had the smallest D95 (9.5 cm) while Sites 3B and 3C had similar D95 values (13 cm), on average.

<u>Site 6 – Horn Creek</u>

Site 6 represents the headwaters reach of Horn Creek and overlaps with water quality monitoring site H-03. Two mesohabitat types were identified here: a run (Mesohabitat Site 6A) and a riffle (Mesohabitat Site 6B). This reach of Horn Creek is almost entirely fed by urban storm water and may see more variable flows than reaches farther downstream (Piteau, 2010).

Photographs 3-4 Site 6 (Horn Creek) – September 2020

6A facing downstream

6B facing upstream

The channel pattern at Site 6 was straight and sinuous. The site had a confined channel, with an average gradient of 1.5%. Site 6 had good rearing and moderate overwintering habitat values, but limited spawning habitat potential for salmonids. Soap suds from an unknown source were also observed at this site during the August 2020 monitoring site visit.

At the pool mesohabitat site (6A), substrate consisted of gravel (69%), fines (30%), and cobbles (9%). The amount of fines increased slightly after the August 2020 site visit. Monitors noted that sediment deposition had occurred between the August 2020 and September 2020 site visits. Deep pools were the dominant cover type for this site with overhanging vegetation and LWD being the subdominant. Other cover types were present in trace amounts; they included instream vegetation, undercut banks, and SWD. Crown closure was high at 80%, much higher than the riffle site (6B).

Site 6B had a substrate composition of gravel (45%), cobbles (29%), fines (19%), and boulders (7%). The dominant cover type for 6B was boulders. Overhanging vegetation was the subdominant cover with instream vegetation, undercut banks, and SWD were present in trace amounts. Crown closure averaged at 14%.

On average, the D95 and embeddedness were very similar between the two mesohabitat sites. D95 ranged from 14-15 cm for Site 6B and 6A, respectively. Embeddedness was slightly lower at 6B (5%) than at Site 6B (6%).

Boa Brook

<u>Site 4 – Boa Brook</u>

Site 4 is situated as close to surface water monitoring site B-01 as possible while still representing a reach where meaningful measurements of stream flow and other habitat characteristics are possible. It represents the headwater reach of Boa Brook, delineated at its downstream end by a steeper gradient section of the stream. One mesohabitat site, a run (Mesohabitat Site 4A), was identified at this location in 2011, and in 2012 a pool was added (Site 4B).

Photographs 3-5 Site 4 (Boa Brook) – August 2020

4A Facing upstream

4B Facing downstream

Site 4 had a confined, sinuous channel with a gradient of 1.5%. Side bars consisting of fines were present during most monitoring visits. Crown closure was high, ranging between 75-90%. The substrate at both Site 4 mesohabitat sites was entirely fines. Cover at the run mesohabitat (4A) site was dominated by LWD and SWD with some trace amount of overhanging vegetation. Dominant cover at the pool mesohabitat (4B) was undercut banks with subdominant deep pool habitat. Trace amounts of small and large woody debris were also present. Overall fish habitat quality at Site 4 was poor due the location in the upper headwaters of Boa Brook, along with the lack of spawning habitat, overwintering habitat, and limited cover for salmonids.

Site 5 – Boa Brook

Site 5 represents the reach between the confluence with Horn Creek and a steeper gradient section of Boa Brook as identified by online mapping (MoE, 2011). The location of Site 5 was somewhat constrained by access concerns, as most of this reach of Boa Brook can only be accessed through private property. Three mesohabitat types were identified here: two pools (Mesohabitat Site 5A and 5D), a riffle (Mesohabitat Site 5B); and a run (Mesohabitat Site 5C).

The channel at Site 5 was meandering and frequently confined by steep ravine slopes. The average gradient was 2%, although this measurement may not be accurate due to the short lines of sight at Site 5. Side sand and gravel bars were recorded for Sites 5B, 5C, and 5D.

The dominant cover type for the four mesohabitat sites was undercut banks, some extending as far as 70 cm. The subdominant cover of overhanging vegetation was also consistent across all four sites. Site 5A also had a subdominant cover of LWD. In general, all sites had trace amounts of SWD. All sites except 5C had instream vegetation. Field staff also recorded a few boulders at Sites 5C and 5D. Crown closure was fairly consistent among the four sites, ranging between 72% and 79% on average.

In general, a decrease in gravels and cobbles and an increase of fines was the overlying trend at Site 5 from July 2020 to October 2020. All but one mesohabitat site consisted of 100% fines in October 2020 (5B had 95% fines). Site 5B was the only site that was dominated by gravels at the start of the sampling season. On average, Site 5A was dominated by fines (93%) with minimal gravel (7%). The riffle mesohabitat 5B had nearly equal parts gravel (50%) and fines (48%) with minimal cobble (2%). Site 5C was comprised of fines (83%), gravel (14%), and cobble (4%). The second pool mesohabitat site (5D) had a similar substrate composition with fines (67%), gravel (25%), cobble (4%), and boulder (4%). Average embeddedness ranged from 13% (5B) to 40% (5A). Average D95 was similar across all four sites ranging from 7 cm (5A) to 12 cm (5C). Site 5 had moderate quality habitat values for salmonid rearing and overwintering, but only relatively low spawning habitat values due to the shallowness of the stream and low amounts of spawning gravel.

Photographs 3-6 Site 5 (Boa Brook) – August 2020 and September 2020

5A Facing downstream (August)

5A Facing downstream (September)

5B Facing upstream (August)

5B Facing upstream (September)

5C Facing upstream (August)

5C Facing upstream (September)

5D Facing downstream (August)

5D Facing downstream (September)

Downes Creek

Year 10 represents the third year of fish habitat monitoring at Downes Creek. Three sites were established within the headwater tributaries of Downes Creek.

D-02

Site D-02 is located approximately 30 m upstream from Downes Road (Figure 3-2). D-02 is located on a tributary that drains the Downes Creek headwaters and overlaps with water quality monitoring site D-02. It represents the lower reach of the stream, between the Downes wetland and the confluence with Downes Creek. Two mesohabitats were identified here: a pool (D-02-pool) and a riffle (D-02-riffle).

D-02 is a low gradient (2%) stream with a straight and confined channel. No islands or bars were present during any site assessments. Substrate at the D-02 pool mesohabitat site consisted entirely of entirely fines. Cover for fish was predominately overhanging vegetation with trace amounts of instream vegetation.

On average, substrate at the D-02 riffle site consisted of gravel (70%) and fines (30%). An increase in the fines component was noted in October 2020. The dominant cover type at the riffle was overhanging vegetation with subdominant instream vegetation. Crown closure was high, averaging at 90%. D95 equated to 5 cm with embeddedness averaging at 14%. The pool mesohabitat substrate was 100% fines. Cover types at the pool site were similar to those at the riffle site with trace amounts of undercut banks and SWD. Crown closure was less than at the riffle site ranging from 15-30%.

Photographs 3-7 D-02 (Downes Creek) – August 2020

Site D-02-pool Facing upstream

Site D-02-riffle Facing downstream

D-03

D-03 is located at a potentially fish-bearing headwater tributary within Downes Creek Bowl (Figure 3-2). Two mesohabitats were identified here: a pool (D-03-pool) and a riffle (D-03-riffle). D-03-riffle and D-03-pool are located immediately downstream and approximately 30 m downstream of the hydrometric station, respectively. D-03 is characterized as a frequently confined to confined stream with a straight channel. The pool mesohabitat site had a gravel and sand side bar present for all monitoring visits. Orange precipitate was prominent throughout the watercourse.

Substrate at the riffle mesohabitat was predominately gravel (78%), followed by cobble (11%) and fines (11%). Cover for fish was predominately overhanging vegetation and undercut banks, with trace SWD and instream vegetation. The pool mesohabitat substrate was predominately gravel (60%) and fines (31%) with lesser amounts of cobble (9%). The average substrate embeddedness at the riffle and pool mesohabitat was 20% and 36%, respectively. D95 ranged from 8 cm to 9 cm, on average, at D-03. Crown closure was similar at both mesohabitat sites, being 23% at the pool site and 29% at the riffle site.

Photographs 3-8 D-03 (Downes Creek) – September 2020

D-03-pool Facing upstream **D-03-riffle Facing downstream**

D-04

D-04 is located at a potentially fish bearing headwater tributary within Downes Creek Bowl (Figure 3-2). Two mesohabitats were identified here: a pool (D-04-pool) and a riffle (D-04-riffle). The D-04-riffle mesohabitat site is located immediately upstream of the hydrometric station. The D-04-pool mesohabitat site is located approximately 30 m downstream from the hydrometric station at a scour pool with confirmed fish presence. D-04 is classified as an occasionally confined, sinuous channel with some straight sections and an average gradient of 5.5%. Orange precipitate was prominent throughout the watercourse. The pool mesohabitat had a sand and gravel side bar during all monitoring visits. In August 2020, an active wasp nest within the vicinity of the site prevented the field crew from accessing the site safely.

The riffle mesohabitat was dominated by gravel (62%), followed by fines (33%), and lesser amounts of cobble (5%). The substrate had an average embeddedness of 23%. D95 averaged 10.1 cm. Average crown closure ranged from 65% to 70%. Cover for fish was predominantly undercut banks with overhanging vegetation and trace amounts of SWD.

Substrate at the pool mesohabitat site was dominated by gravel (60%), followed by fines (30%), and lesser amounts of cobble (7%) and boulders (3%). Embeddedness was 40% on average with an average D95 of 9.6 cm. Crown closure was moderate at 43%. Cover for fish was dominated by overhanging vegetation, SWD, and undercut banks, with trace amounts of instream vegetation and LWD.

Photographs 3-9 D-04 (Downes Creek) – July 2020

D-04-pool Facing upstream

D-04-riffle Facing upstream

Fishtrap Creek

F-01

F-01 is located at the headwaters of Fishtrap Creek north of Highway 1 at Gardner Park off Livingstone Avenue. It overlaps with water quality monitoring site F-01. Two mesohabitat sites were established here: a pool (F-01-pool) located 11 m north of the hydrometric station and a riffle (F-01-riffle) located 20 m downstream from the station.

F-01 is characterized as a low gradient (approximately 1-2%), straight channel with a riffle-pool morphology. The reach has been channelized and is confined on both banks. The substrate at the riffle mesohabitat site was dominated by gravel (83%), with minimal amounts of fines (7%), cobble (5%), and boulders (5%). The substrate was embedded by an average 23%. Average D95 was 11 cm. Cover at this mesohabitat site included overhanging vegetation (dominant), boulders (subdominant), and trace amounts of undercut banks, instream vegetation, and SWD. Canopy closure was, on average, 16% during the monitoring visits.

The pool site substrate was entirely fines. The dominant cover type was deep pool with overhanging/instream vegetation and SWD as the subdominant types. Trace amounts of undercut banks and LWD were also present. Canopy closure was estimated to be 30%.

Photographs 3-10 F-01 (Fishtrap Creek) – July 2020

F-01-pool Facing upstream

F-01-riffle Facing downstream

F-02

F-02 is located on Fishtrap Creek at the Marshall Road Extension and overlaps with water quality monitoring site F-02. Two mesohabitats were established here: a pool (F-02-pool) located 35 m upstream of Mt Lehman Road and a riffle (F-02-riffle) located 30 m downstream of the Marshall Road extension. F-02 is a low gradient (average 1%), confined to frequently confined, riffle-pool channel located within an agricultural area. It has no bars or islands. Beaver activity was recorded throughout the monitoring season.

The riffle mesohabitat site was dominated by entirely fines. Beaver activity has backwatered the site and slowed flows. Small woody debris was the dominant cover type at this site with subdominant overhanging vegetation and instream vegetation. Trace amounts of LWD were also present. Crown closure was estimated to be between 50% and 60%.

The pool mesohabitat was dominated by fines (57%) with some gravel (25%) and cobble (18%). A trend of increasing gravel and decreasing fines was noted through the monitoring season. Average D95 was 8.75 cm with an average embeddedness of 15%. Cover for fish consisted of deep pool (dominant), with subdominant overhanging and instream vegetation, and undercut banks. Trace amounts of SWD and LWD were also present. There was 0% crown closure at the pool mesohabitat site.

Photographs 3-11 F-02 (Fishtrap Creek) – July 2020

F-02-pool Facing downstream

F-02-riffle Facing upstream

F-03

F-03 is located near the existing F-03 staff gauge, approximately 115 m upstream from the confluence with Waechter Creek. The site overlaps with the F-03 water quality monitoring site. One mesohabitat (F-03-pool) was established at F-03. The mesohabitat represents pool habitat, as the reach is a continuous sequence of beaver dam impoundments. No riffle habitat was present at the F-03 site.

F-03 lies within an agricultural area and is characterized as a low gradient (<1%), frequently confined, sinuous channel. Substrate was dominated by fines (75%), followed by gravel (20%), and cobble (5%). No canopy cover was present at the site. Cover was primarily deep pool with trace levels of undercut banks, overhanging vegetation and instream vegetation. Water depth and clarity limited the visual assessment of substrate composition; therefore, estimates were made by probing channel bottom with a wading staff where possible.

Photographs 3-12 F-03 (Fishtrap Creek) – August 2020

F-03-pool Facing upstream

F-03-pool Facing downstream

F-04

F-04 is the downstream-most station on Fishtrap Creek. The site overlaps with the F-04 water quality monitoring station. Two mesohabitats were identified here: one pool (F-04-pool) and one riffle (F-04-riffle). The pool and riffle mesohabitats are located 15 m upstream and 15 m downstream of the Echo Road bridge, respectively. F-04 is a low gradient (0-1%) stream with a linear, confined channel and lies within an agricultural area. The canopy at F-04 was open (0% closure).

Substrate at the riffle mesohabitat consisted of a mix of gravel (57%) and fines (40%) with minimal cobble (3%). The substrate was embedded by 35% on average. The average D95 for the riffle site was 9.6 cm. Cover for the site consisted of overhanging vegetation with subdominant instream vegetation and undercut banks.

Water depth and clarity limited the visual assessment of substrate composition at the pool mesohabitat; therefore, estimates were made by probing across the channel. Substrate for the pool mesohabitat is approximately 90% fines, 6% gravel and 4% cobble on average. Cover was primarily deep pools with undercut banks and overhanging and instream vegetation as the subdominant cover. Trace amounts of SWD were present.

Photographs 3-13 F-04 (Fishtrap Creek) – July 2019

F-04-pool Facing upstream

F-04-riffle Facing downstream

3.5.2 Changes in Biophysical Parameters over Time

Year 1 (2011) through to Year 10 (2020) physical measurement data collected at the Horn Creek and Boa Brook mesohabitat sites were analysed to determine whether adverse effects on aquatic habitat have occurred subsequent to increased extraction from the aquifer by the Bevan Wells. The Downes Creek and Fishtrap Creek mesohabitat sites were not included in the statistical analysis, as only three years of mesohabitat monitoring has been conducted in these streams, but results were graphed for illustrative purposes.

The physical measurement data, including wetted width, bankfull width and bankfull depth, were statistically analysed using a Mann-Kendall non-parametric trend analysis. Substrate monitoring data was not analyzed because the Year 8 to Year 10 substrate data was collected using a different method compared to previous monitoring years and is not directly comparable to the Year 1 to Year 7 data.

3.5.2.1 Physical Measurements

Wetted Width

Wetted width can be used as an indicator of habitat area for fish and benthic invertebrates. It is sensitive to changes in flow volumes. A reduction in wetted width from reductions in flow typically results in a reduction in benthic invertebrate production, which in turn may result in reduced food sources for fish and other aquatic organisms.

In an urban setting, wetted width can be variable; as even a small rain event can result in high flows and increased wetted widths. Furthermore, results may be hard to interpret between years as high flow events (especially in the fall and winter months) may alter the channel geometry. Figure 3-4 to Figure 3-7 show the results of the wetted width monitoring at all mesohabitats monitoring sites through 2020.