Table 2-4 CCME Water Quality Index Results for Year 12

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	52.6	34.4	31.1	59.5	102.3	0.5	12	19	227	78	149	43	M
B-02	42.1	10.6	9.9	74.3	24.8	0.1	12	19	226	24	202	76	F
D-01	26.3	5.3	1.5	84.5	3.6	0	12	19	227	12	215	97	G
D-02	47.4	13.9	20.5	69.1	53.6	0.3	11	19	208	29	179	87	F
F-01	31.6	13.7	7.5	79.7	18.4	0.1	12	19	227	31	196	73	F
F-02	31.6	12.7	20.4	77.1	58.3	0.3	12	19	228	29	199	88	F
FOF	36.8	18.4	24.8	72.2	75.3	0.3	12	19	228	42	186	77	F
H-01	73.7	28.6	56.8	43.8	298	1.3	12	19	227	65	162	51	P
H-02	42.1	7.9	5.6	75.1	13.4	0.1	12	19	227	18	209	76	F
H-03	57.9	16.8	31	60.9	101.6	0.4	12	19	226	38	188	62	M
W-01	42.1	14.5	14.2	73	37.6	0.2	12	19	228	33	195	69	F

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 12

Table 2-5 Comparison of the CCME Water Quality Index Results for Year 1 to Year 12

Station	Year 12 WQI	Rating	Year 11 WQI	Rating	Year 10 WQI	Rating	Year 9 WQI	Rating	Year 8 WQI	Rating	Year 7 WQI	Rating
B-01	59.5	M	65.6	F	62.7	M	61.1	M	60.8	M	60.7	M
B-02	74.3	F	73.9	F	77.6	F	71.8	F	76.3	F	68.1	F
D-01*	84.5	G	83.9	G	81.2	G	84	G	73.9	F	84	G
F-01	79.7	F	75.9	F	79.6	F	78.3	F	77.5	F	81.2	G
F-02	77.1	F	77.9	F	75	F	71.5	F	63.7	M	74	F
H-01	43.8	P	70.8	F	67.2	F	55.2	M	64.6	M	66.7	F
H-02	75.1	F	87.4	G	84.3	G	53.1	M	69.3	F	71.4	F
H-03	60.9	M	77.9	F	77.9	F	65.3	F	62.9	M	71	F
W-01	73.0	F	80.4	G	83.7	G	62.4	M	75.7	F	76.9	F
Station	**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	58.5	M	51.6	M	49.4	M	67.3	F	58.7	M	61.6	M
B-02	75.4	F	72.7	F	56.2	M	70.8	F	78.1	F	--	--
D-01*	83.7	G	90.5	G	89.7	G	77.9	F	89.5	G	78.9	F
F-01	76.9	F	77.9	F	58.2	M	70.8	F	79.7	F	62.2	M
F-02	66.7	F	77.5	F	59.3	M	64.7	M	81.8	G	65.4	F
H-01	64.4	M	61.9	M	62.7	M	60.1	M	61.9	M	45.0	M
H-02	81.3	G	80.9	G	57.5	M	71.7	F	68.5	F	64.2	M
H-03	74.3	F	68.5	F	69.7	F	76.6	F	66.2	F	--	--
W-01	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.

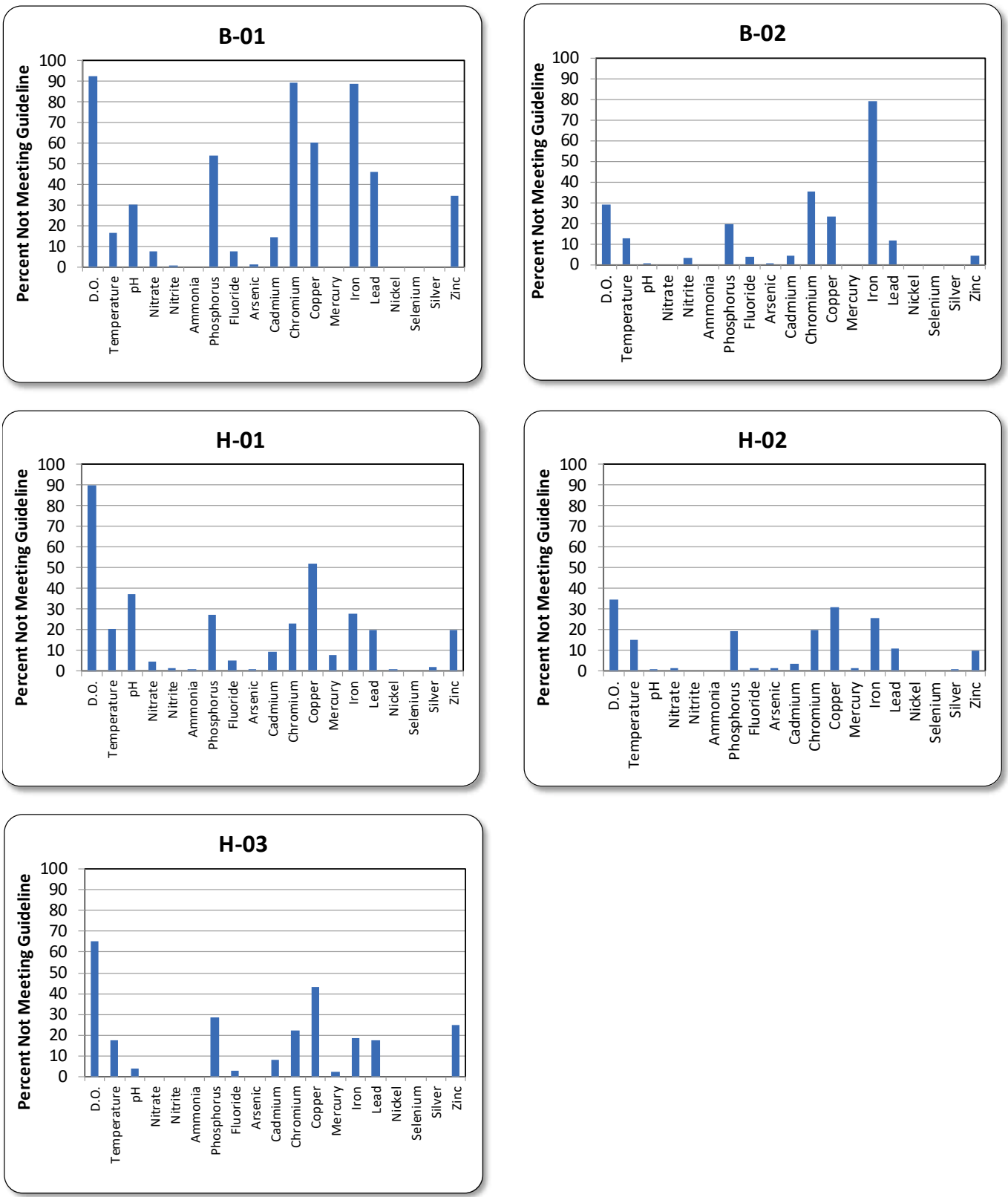


Figure 2-9 Mean Frequencies of Water Quality Parameters Not Meeting Guidelines, 2012-2023

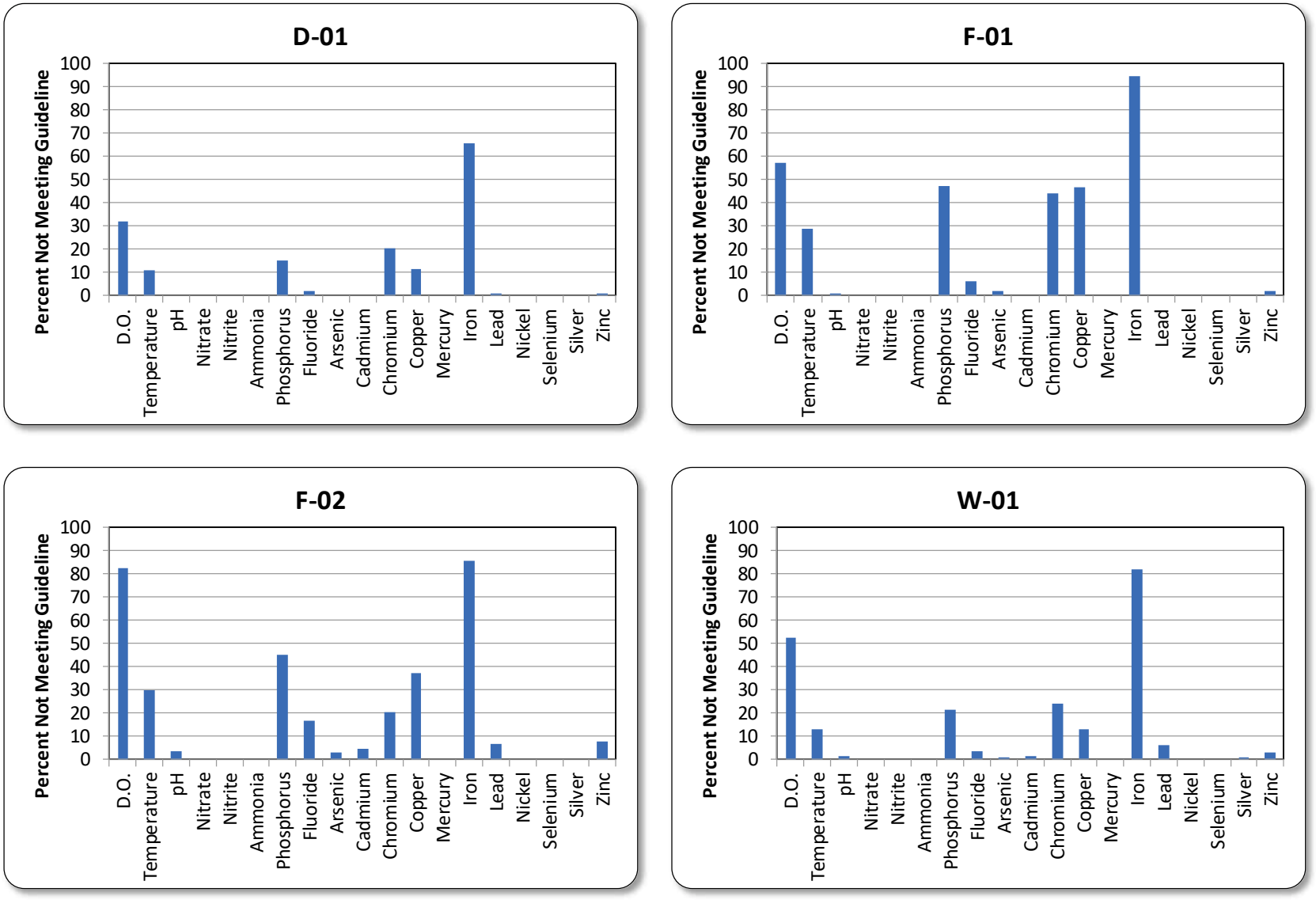


Figure 2-9 Mean Frequencies of Water Quality Parameters Not Meeting Guidelines, 2012-2023 (Continued)

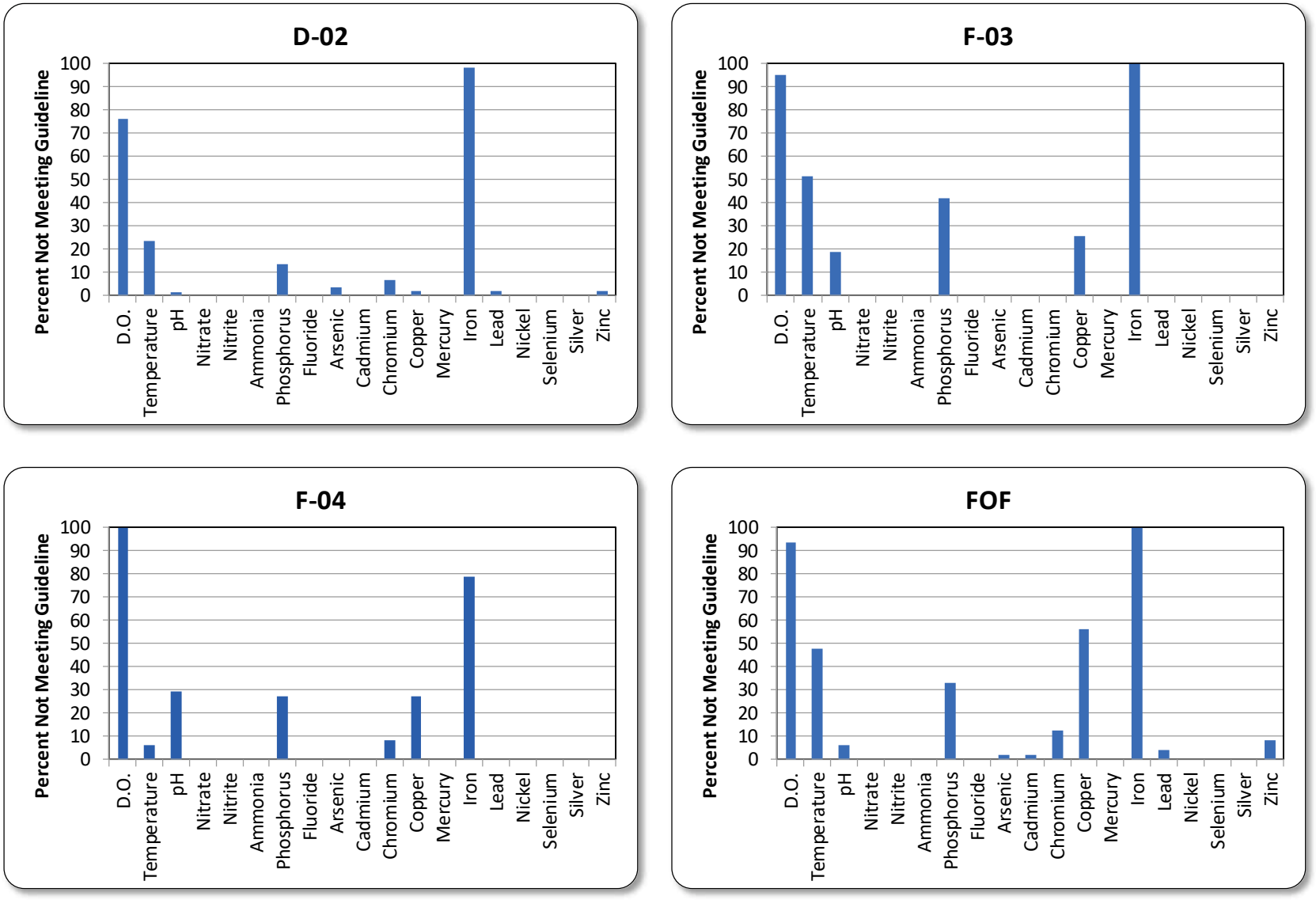


Figure 2-9 Mean Frequencies of Water Quality Parameters Not Meeting Guidelines, 2018-2023 (Continued)

Among the other monitoring sites the frequencies of temperature exceedances ranged from 10.9% at D-01 to 20.5% 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. Temperatures in Fishtrap Creek were elevated from May or June through August or September from 2019 to 2022.

On average, phosphorus did not meet its guideline in over 50% of the samples from B-01 and ≥45% of the samples from F-01 and F-02, while exceedances occurred in 15.1% to 28.8% of samples from the remaining long-term monitoring sites. The metals most frequently not meeting guidelines were chromium, copper, and iron (Figure 2-9, Appendix G). The metals data suggest an impact from urban sources.

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 (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	Z	Significance
B-01	Year 1	Year 12	12	1.03	NS
B-02	Year 2	Year 12	11	0.623	NS
D-01	Year 1	Year 12	12	0.00	NS
F-01	Year 1	Year 12	12	1.37	NS
F-02	Year 1	Year 12	12	1.03	NS
H-01	Year 1	Year 12	12	1.51	NS
H-02	Year 1	Year 12	12	1.44	NS
H-03	Year 2	Year 12	11	-0.078	NS
W-01	Year 1	Year 12	12	0.00	NS

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.
NS – Not significant. Significance set at $p < 0.05$.

The tests showed significant negative (downward) trends in annual mean dissolved oxygen concentrations at B-01 and H-02 (Table 2-7). In addition, there was a significant decreasing trend at H-02 during the summer (July to October) time period. There were no corresponding significant increases in the summer or annual temperatures, 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.

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	Z	Significance
Dissolved Oxygen	B-01	Annual	Year 1	Year 12	12	-3.09	**p <0.01**
		Jul - Oct	Year 1	Year 12	12	-1.58	
	B-02	Annual	Year 3	Year 12	10	-1.43	
		Jul - Oct	Year 3	Year 12	10	-1.43	
	H-01	Annual	Year 1	Year 12	12	0.069	
		Jul - Oct	Year 1	Year 12	12	-0.617	
	H-02	Annual	Year 1	Year 12	12	-3.09	**p <0.01**
		Jul - Oct	Year 1	Year 12	12	-2.81	**p <0.01**
	H-03	Annual	Year 3	Year 12	10	-0.358	
		Jul - Oct	Year 3	Year 12	10	-0.716	
	W-01	Annual	Year 1	Year 12	12	-1.44	
		Jul - Oct	Year 1	Year 12	12	-1.58	
Temperature	B-01	Annual	Year 1	Year 12	12	0.891	
		Jul - Oct	Year 1	Year 12	12	-0.069	
	B-02	Annual	Year 3	Year 12	10	0.000	
		Jul - Oct	Year 3	Year 12	10	0.716	
	H-01	Annual	Year 1	Year 12	12	0.480	
		Jul - Oct	Year 1	Year 12	12	0.000	
	H-02	Annual	Year 1	Year 12	12	1.58	
		Jul - Oct	Year 1	Year 12	12	0.206	
	H-03	Annual	Year 3	Year 12	10	0.000	
		Jul - Oct	Year 3	Year 12	10	0.537	
	W-01	Annual	Year 1	Year 12	12	0.000	
		Jul - Oct	Year 1	Year 12	12	0.412	

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 (indicated by **bold**) 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. The only statistically significant trend in these watercourses was a decreased in dissolved oxygen in May at F-02 (Table 2-8).

2.4.2.4 Quality Control Results for Surface Water Samples

Laboratory QC

Appendix E contains the full report of 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 not meet the DQO for all analytes. These tests and parameters are listed in Table 2-9. However, BV noted in all cases that the results of the multi-element scans met acceptability criteria.

Field QC

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

The results of the travel blanks were excellent with no analytes detected in 10 of the 12 blanks. The May 2022 travel blank contained nitrate, while the August 2022 sample contained total cobalt. The concentrations of both substances were <2 times the detection limit. Neither analyte was detected in the corresponding field blanks. Thus, contamination in the travel blanks apparently did not affect the sample results.

Results of the field blanks also were excellent overall. The only substances detected were total copper in the April 2023 field blank, total uranium in the November 2022 field blank, and nitrate in three field blanks (January, February, and April 2023). The concentration of uranium and the highest nitrate concentration in the blanks were <3 times the detection limits, while the copper and remaining nitrate concentrations were <2 times the detection limits.

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 nitrate concentrations in all three affected field blanks were <0.3% of the CCME guideline (2.9 mg/L as N), and the uranium concentration in the November 2022 field blank was 2% of the BC guideline.[3] The concentration of copper in the January 2022 blank was 45% of the most restrictive CCME guideline (2 µg/L for hardness <50 mg/L as $CaCO_3$) and might have contributed to a guideline exceedance at FOF.

[3] Uranium is not included in the WQI.

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	Significance
Dissolved Oxygen	D-01	May	Year 2	Year 12	11	0.467	
		September	Year 1	Year 12	11	-0.156	
		October	Year 2	Year 12	11	0.00	
		January	Year 1	Year 12	10	-0.89	
	F-01	May	Year 2	Year 12	10	-0.36	
		September	Year 1	Year 12	12	1.44	
		October	Year 2	Year 12	11	0.778	
		January	Year 1	Year 12	10	-0.72	
	F-02	May	Year 2	Year 12	11	-2.34	**p <0.05**
		September	Year 3	Year 12	10	-1.25	
		October	Year 2	Year 12	11	-1.80	p <0.10
		January	Year 2	Year 12	11	-1.87	p <0.10
Temperature	D-01	May	Year 2	Year 12	11	-1.40	
		September	Year 1	Year 12	11	1.71	p <0.10
		October	Year 2	Year 12	11	-0.16	
		January	Year 1	Year 12	12	1.79	p <0.10
	F-01	May	Year 2	Year 12	11	-1.40	
		September	Year 1	Year 12	12	1.17	
		October	Year 2	Year 12	11	-0.23	
		January	Year 1	Year 12	12	1.72	p <0.10
	F-02	May	Year 2	Year 12	11	-1.02	
		September	Year 3	Year 12	10	1.35	
		October	Year 2	Year 12	11	-0.16	
		January	Year 2	Year 12	11	1.02	

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 (indicated by **bold**) set at p <0.05.

Table 2-9 Parameters Not Meeting the Laboratory Quality Control Limits (Year 12)

Parameter	Sample Batch	QC Test and Units	Result	DQO
Total Zinc	17-May	Matrix Spike Recovery (%)	133%	80-120
Total Ammonia	15-Aug	Matrix Spike Recovery (%)	122%	80-120
Total Silicon	15-Aug	Spiked Blank Recovery (%)	128%	80-120
Total Selenium	27-Oct	Matrix Spike Recovery (%)	41%	80-120
Total Mercury	01-Nov	Matrix Spike Recovery (%)	129%	80-120
Total Mercury	24-Jan	Matrix Spike Recovery (%)	78%	80-120
Total Silicon	25-Jan	Matrix Spike Recovery (%)	134%	80-120
Total Silicon	28-Feb	Matrix Spike Recovery (%)	123%	80-120
Total Titanium	28-Feb	Matrix Spike Recovery (%)	125%	80-120
Total Selenium	28-Mar	Matrix Spike Recovery (%)	54%	80-120
Total Mercury	25-Apr	Matrix Spike Recovery (%)	67%	80-120

Results of the most field 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. The exception was the August 2022 duplicate in which RPDs for total phosphorus, aluminum, arsenic, and iron were elevated.

2.5 Successes, Challenges and Suggested Changes

Flow monitoring at the new (2021) Fishtrap Creek hydrometric station continued to provide a challenge, as it proved impossible to develop a stage-discharge relationship for the site. In June 2022, KWL and City of Abbotsford agreed that going forward the monitoring site would operate as a water level station, and flow measurements would not be completed. It is recommended that the mitigation well continues to be turned on during the summer months.

Challenges also occurred at the 2019 Downes Creek hydrometric station. An apparent shift in the flow pattern occurred on December 24, 2022, triggered by a rainfall event. Although an adjustment was made to the rating curve, all reported discharge data after December 24, 2022 should be considered estimates. An additional five flow measurements encompassing a range of low, medium, and high flows are recommended to allow redevelopment of the rating curve.

Manual flow monitoring at several sites experienced challenges related to high or low water levels. The high water levels observed in Fishtrap Creek in Year 11 persisted, at least in part due to debris blocking the channel. As a result, the water at F-02 was too deep to complete flow measurements in in June 2022 and October 2022 through April 2023. Conversely, the channel was dry at both F-02 and F-04 in September 2022. Waechter Creek at the staff gauge was also dry in September 2022, and in August 2022 the flow at this point was too low to measure accurately. A similar issue occurred in Boa Brook at B-01. The staff gauge was above the water line from July through September/early October 2022.

Issues with the water level loggers in Year 12 have been discussed in Section 2.4.1.2. A programming error in the shuttle for the Hobo loggers resulted in a lack of flow data for April and May 2022. Additionally, the WT-01 and D-04 Hobo loggers failed, and no valid data were recorded at these sites during the summer of 2022.

The atmospheric river in November 2021 caused the loss of the WT-01 monitoring station. The Hobo logger, PVC pipe, and staff gauge were recovered in May 2022 and reinstalled 70 m downstream of the previous location. However, the recovered logger failed to function properly, and no valid data were collected in the summer of 2022. Thus, logger data are unavailable from November 15, 2021 to October 31, 2022, when a new logger was installed.

The expanded flow monitoring stations have continued to be problematic. In addition to the high and low water level issues, the manual stream flow data recorded at B-02, D-02, D-03 and D-04 have been too variable to establish a stage-discharge rating curve.

ENKON recommends that a qualified professional hydrologist in consultation with a qualified professional fisheries biologist re-evaluate the expanded flow monitoring sites to determine whether:

- monitoring at these sites can provide sufficiently accurate flows to determine temporal trends in summer low flows;
- sufficiently accurate flow monitoring can be achieved without significant channel configuration (e.g., weir installation) and if not, whether the flow data is valuable enough to warrant the disturbance to fish habitat; and
- whether the program objectives (identification of negative effects on fish habitat) can be achieved through seasonal flow monitoring (manual measurements) in conjunction with the current mesohabitat monitoring program.

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 was invited to accompany ENKON monitoring staff on these visits. A Matsqui First Nations representative accompanied ENKON in July and October. The Matsqui representative assisted with data collection and input and equipment coordination. The Matsqui First Nation did not respond to the invitation to participate in September. In October, the Matsqui elected to participate in mesohabitat monitoring rather than the vegetation monitoring.

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.

During the Year 8 through Year 11 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, wetted width, and depths and velocities across the channel) 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 H.

3.5.1.1 Horn Creek

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

Site 1 – Horn Creek

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 over the 2022 season, ranging from straight and confined in July, August, and October to straight and frequently confined in September. The reach had a gradient of 2- 4%. Observations of small woody debris (SWD) and large woody debris (LWD) varied between monitoring visits. In July and October 2022, trace amounts of SWD were observed, and LWD was subdominant. In August, trace amounts of LWD and SWD were observed, however, in September, LWD was largely absent from the sample area.

The substrate at Site 1A had shifted from a fines (60%) and gravel (40%) mix in October 2021 (Year 11) to 50% fines, 25% gravel and 25% cobbles mix in July 2022. Over the summer, the proportion of fines decreased to 30% in August, 33% in September, and 10% in October. Gravel and cobble levels fluctuated in proportion to the decrease in fines over the course of the monitoring duration; in August, gravel decreased to 20% and cobbles also decreased to %20; in September, gravels and cobbles increased to 33%, and in October, gravel decreased slightly to 30% and cobbles increased to 50%. Boulders, , which were not observed during the preceding months, comprised 10% of the substrate at Site 1A and Site 1B in October.

Legend

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

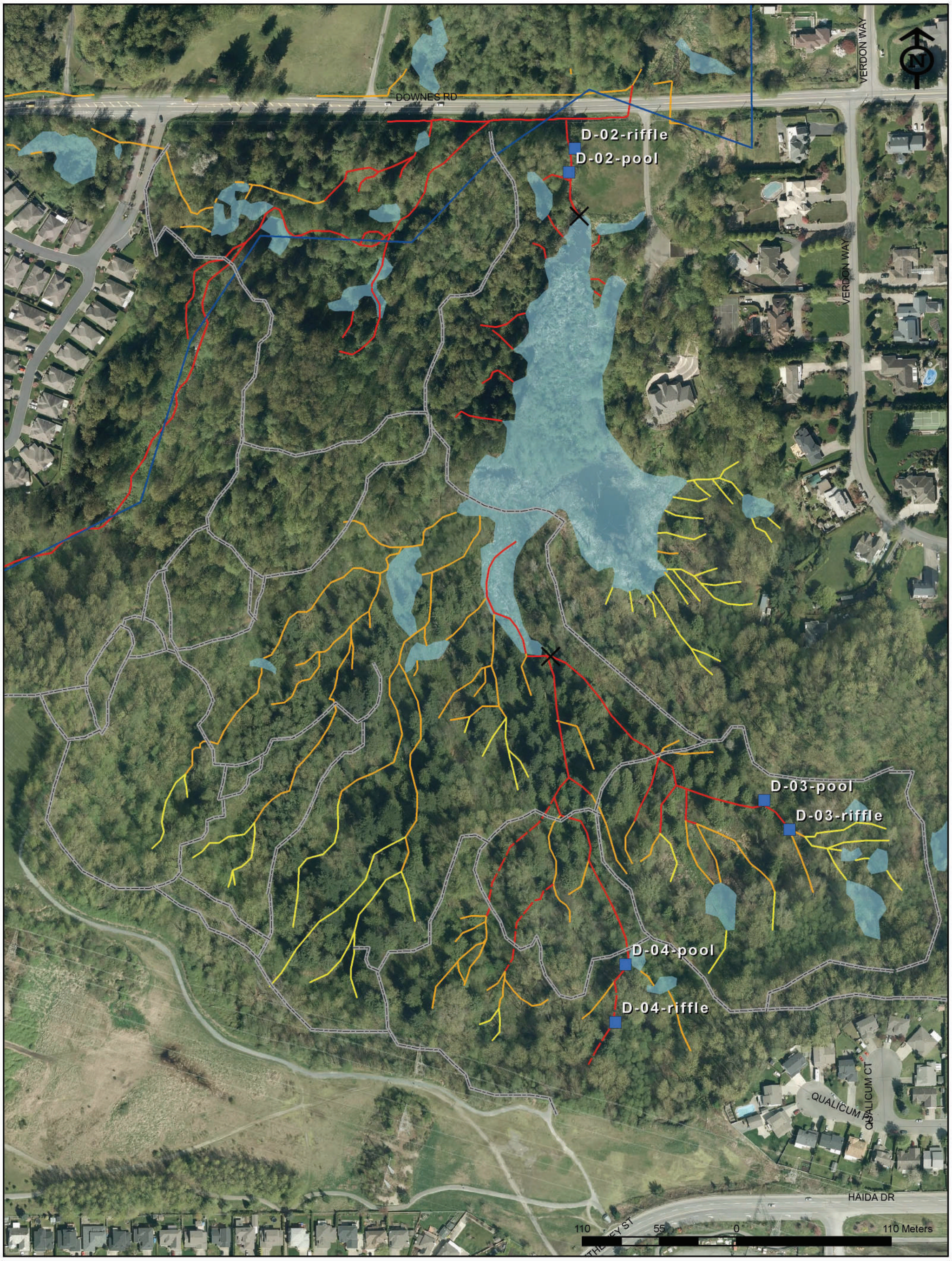
Prepared by:
ENKON Environmental Ltd.

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.

Fishtrap Creek
Mesohabitat Monitoring Sites

City of Abbotsford

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

Figure 3-3

The substrate at Site 1B fluctuated in a similar fashion but had a higher proportion of gravel (40%) in July, with 40% fines and 20% cobbles. In August, fines had increased to 50%, which correlates with the downstream movement of fines from Site 1A during this month. Gravels at this location oscillated between 25% and 40%, and cobbles ranged from 20% – 55%. At both sites, D95 ranged from 9 cm to 12 cm. The presence of undercut banks ranged from trace to dominant, and no deep pools were observed. Overhanging vegetation ranged from sub-dominant to dominant, and no instream vegetation was observed at either site. Embeddedness ranged from 20% to 40% throughout the reach during the four monitoring visits. Canopy closure was moderate to good for both sites, averaging 59% and 55% for Site 1A and Site 1B, respectively.

Photograph 3-1 Site 1 (Horn Creek) – September 2022

1A Riffle—looking upstream

1B Pool—looking 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 with a gradient of 4-5%. Sand and gravel side bars were present during all monitoring events. This site had good salmonid rearing habitat values, along with moderate values for overwintering and spawning habitat.

The substrate at Site 2A was dominated by fines (50%) in July and August, but fines fell to 40% in September and 10% in October. Gravels decreased in tandem with fines and fell from 40% in July to 10% in October. Cobbles were low in July (10%) but increased to 75% in October. Boulders were only observed in October and comprised 10% of the substrate during this month. The embeddedness at this site ranged from 5% to 45%. Deep pools were observed in July at Site 2A and in August at Site 2B but were absent during subsequent months.

The substrate at Site 2B fluctuated over the four-month period. In July, fines, gravels, and cobbles were present in equal proportions. In August, fines had increased to 50%, while cobbles and gravels had decreased to 25%. In September, substrate types again occurred in equal proportions. However, in October the fines had been washed downstream and were not present; cobbles comprised 80% and gravels and boulders each comprised 10% of the substrate at this location.

The substrate at Site 2C fluctuated in a similar fashion as Site 2A and 2B; fines decreased from 33% to 10% and were absent during the October assessment. Gravels ranged from 23% to 45% in August and September and fell to 10% in October. Cobbles ranged from 43% – 45% from July to September and rose to 80% in October. Boulders were only observed in October, comprising 10% of the substrate.

D95 at this reach ranged from 10 cm to 18 cm. Crown closure ranged from good to excellent across this reach, averaging 60%, 69%, and 70% at sites 2A, 2B, and 2C, respectively. SWD and LWD ranged from trace to dominant across this reach. Overhanging vegetation also ranged from trace to dominant, and instream vegetation was only noted in trace amounts in October at sites 2A and 2B.

Photograph 3-2 Site 2 (Horn Creek) –September 2022

2A Pool—looking downstream)

2B Run—looking upstream

2C Riffle—looking upstream

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).

Channel morphology at Site 3 was frequently confined with a gradient ranging from 2% to 5%. Sand and gravel side bars were observed during all monitoring events. LWD and SWD were present throughout the reach in trace amounts. Site 3 had good rearing and overwintering habitat values, along with moderate spawning habitat values for salmonids.

Photograph 3-3 Site 3 (Horn Creek) – August 2022

3A Run – looking upstream

3B Riffle—looking upstream

3C Pool—looking downstream

The substrate at Site 3A was variable over the 4-month observation period. Fines ranged from 5% to 33%; gravels oscillated from 33% in July to 40% in August, then reduced to 33% in September, and rose again to 40% in October. Cobbles ranged from 33% to 49%, and boulders were present in August (5%), September (20%), and October (10%).

Embeddedness for this reach ranged from 5% to 60%. D95 ranged from 11 cm to 23 cm. Overhanging vegetation cover was excellent, ranging from dominant to subdominant at each observation month. Deep pools were not present at Sites 3A and 3B and were observed at Site 3C with depths ranging from 43 cm to 55 cm. Crown closure was moderate across this reached, averaging 55%, 43.75%, and 32.5% at Sites 3A, 3B, and 3C, respectively. Overhanging vegetation was dominant to subdominant, and instream vegetation was not observed. Undercut banks ranged from nonexistent to subdominant in September at Site 3A. At Site 3B, undercut banks were subdominant in July and October, dominant in September, with only trace indications were observed in August. Undercut banks were more prevalent at Site 3C and were observed during all four assessments.

Site 6 – Horn Creek

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).

The channel pattern had shifted significantly from Year 11. In 2021, Site 6 was observed to be straight with a confined channel. In Year 12 (2022), the channel morphology had shifted to meandering at Site 6A and irregular to intermittent at 6B, with a frequently confined channel throughout. The gradient averaged 4.5%, and bars were present on either side of the stream throughout this reach. The gradient was steeper than the 2% observed in Year 11 (2021).

Photograph 3-4 Site 6 (Horn Creek) – August 2021

6A pool looking upstream

6B riffle looking downstream

The substrate at Site 6A was variable throughout the four-month observation period. Fines ranged from 20% to 33%, reaching the highest value in August at 33%. Gravel remained largely consistent, ranging from 30% to 33%. Cobble content ranged from 30% to 45%, and boulders were observed at 10% in July and September and at 5% in October. Embeddedness ranged from 3% to 35% with an average of 17.75%. Crown closure at this site averaged 38.75%, and overhanging vegetation ranged from dominant to subdominant at both sites. Trace amounts of instream vegetation were observed throughout the reach in August and October and were subdominant in August at Site 6B. Undercut banks ranged from trace to dominant in October. Deep pools were not observed at either site. Trace amounts of LWD were observed at Site 6A, while SWD ranged from dominant from July to September to negligible in October. D95 at Site 6A ranged from 10 cm to 23 cm, with an average of 18.75 cm.

The substrate at Site 6B was equally distributed among fines, gravel, cobbles, and boulders in July and September. In August, gravels, cobbles, and boulders increased to 30% each,

while fines decreased to 10% of the substrate composition. In October, fines fell to 5%, gravel to 10%, while cobbles increased to 60%, and boulders comprised the remaining 25% of the substrate. Embeddedness ranged from 10% to 70% with an average of 37.5%. Crown closure ranged from 20% - 40%, with an average of 33.75%. LWD and SWD ranged from subdominant to trace amounts. D95 was larger at Site 6B, ranging from 35 cm to 49 cm, with an average of 44.5%.

Overall, Site 6 had moderate rearing habitat due to the consistent presence of gravels and cobbles. It was rated lower for spawning habitat due to the low proportion of gravel in comparison to fines.

Boa Brook

Site 4 – Boa Brook

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 (Site 4A), was identified at this location in 2011, and in 2012 a pool (Site 4B) was added.

Photograph 3-5 Site 4 (Boa Brook) – August 2022

4A looking upstream

4B looking downstream

The channel morphology at Site 4 had shifted from confined and sinuous in 2021 to frequently confined, irregular, and intermittent in 2022 with an average gradient of 2.75%. Bars were present throughout this reach during all observation months, and crown closure remained high with an average of 70% across both sites. Islands were not present, and no instream vegetation was observed. Overhanging vegetation at both sites ranged from trace to non-existent. The substrate for both sites consisted of 100% fines during all observation months, therefore no D95 measurements were taken as no boulders were present.

Overall fish habitat quality at Site 4 was poor due its location in the upper headwaters of Boa Brook. The site lacked spawning habitat, overwintering habitat, and deep pools for refugia. There was 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 pattern was variable across this reach; Site 5A had a pattern that ranged from straight to irregular; and Sites 5B, 5C and 5D had a pattern that ranged from meandering to irregular. Channel morphology across the reach ranged from confined to frequently confined by steep ravine slopes. Bars were present at all sites during all observation months, except in September at Site 5A. Islands were not observed at any point along this reach. The gradient ranged from 2%-4%, with an average of 3.5%. Deep pools were not observed at sites 5A through 5C but were noted at 5D in August, September, and October. Undercut banks were evident, ranging from trace to subdominant at Sites 5A, 5B, and 5D, but dominated at Site 5C with one that undermined the west bank by approximately 30 cm. Overhanging vegetation ranged from dominant to trace, and was least dominant at site 5C. No instream vegetation was observed. SWD was present in trace amounts at Sites 5A, 5B, and 5C, but was subdominant to dominant at Site 5D from July through September; LWD was not present at Site 5A or 5B but occurred in trace to subdominant amounts at Sites 5C and 5D.

The substrate at Site 5 was variable. At 5A fines ranged from 5% to 55%, with the lowest percentage observed in September. Gravel ranged from 20% to 60%, and cobbles ranged from 13% to 45%. Boulders were only observed in October, comprising 5% of the substrate. Embeddedness ranged from 2% - 35% with an average of 21.25%. D95 sizes ranged from 14 cm to 26 cm, averaging 18.75%. Crown closure was high at this location, ranging from 65% to 70% in July, August and October, but fell to 20% in September. While this may have been due to the prolonged drought during the growing season, it is not consistent with increased leaf drop that generally begins near the end of September.

The substrate at Site 5B in July was comprised of 35% fines, 45% gravel, and 20% cobbles. In August, the substrate had shifted to a lower percentage of fines (20%) with 50% gravel and 30% cobble. In September, fines had decreased to 5%. In October, substrate composition had again shifted: fines had increased to 35%; gravel had decreased to 45%; cobbles had decreased to 25%; and boulders were present. Embeddedness ranged from 2% to 35%, averaging 18%. Crown closure ranged from 20% to 30%, with an average of 25%.

The substrate at Site 5C had a high proportion of fines throughout the four months, comprising 70% of the substrate in July, September, and October, and 50% in August. In July, the remainder of the substrate was comprised of 5% gravel, 5% cobbles and 5% boulders. In August, gravel was 20%; cobbles were 20%, and boulders remained at 10%. In September and October, gravel, cobble, and boulders each comprised 10% of the substrate. Embeddedness ranged from 15% to 40%, averaging 30%. Crown closure remained high, ranging from 60% to 80%, with an average of 68%.

The substrate at Site 5D also had a high proportion of fines, ranging from 80% to 90%. In July and August, the remainder of the substrate consisted of 5% gravel, 5% cobbles and 5% boulders. In September, gravel was absent from this site, and the remainder was comprised of 2% cobble and 8% boulders. In October, gravel had increased to 10% and cobble to 5%. Boulders were absent. Embeddedness ranged from 3% to 35%, with an average of 17.75 %. Crown closure ranged from 30% to 45%, averaging 38.75%. Overall, this reach had poor spawning and rearing habitat for salmonids, due to the high percentage of fines that were consistently observed over the four months.

Photograph 3-6 Site 5 (Boa Brook) – September 2022

At 5B, looking downstream to 5C and 5D

5A looking upstream

Downes Creek

Year 12 represents the fifth year of fish habitat monitoring at Downes Creek. Three sites were established within the headwater tributaries of this watercourse.

D-02

Site D-02 is located approximately 30 m upstream from Downes Road (Figure 3-2) 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 its confluence with Downes Creek. Two mesohabitats were identified here: a pool (D-02-pool) and a riffle (D-02-riffle).

D-02 is an extremely low gradient (0.6%) stream with a straight and confined channel. The gradient differs from Year 11, when the gradient was reported as 2%. Side bars were noted at D-02 pool in August and at D-02 riffle in August and September but were not observed at any other time. No islands were observed. Instream vegetation was present in trace amounts at both sites, while overhanging vegetation was consistently dominant. No deep pools were observed. Slight undercutting was noted at D-02 pool in August and October and at D-02 riffle in August and September. There was no LWD at either site, while SWD was present at D-02 pool in July, September, and October. SWD ranged from subdominant to trace at D-02 riffle.

The substrate at D-02 pool consisted entirely of fines and is not consistent with suitable salmonid habitat. The substrate at D-02 riffle was more variable, but fines comprised the highest proportion during all four months, ranging from 35% to 95% of the substrate. Proportions of gravel ranged from 5% in July to 45% in September. Cobbles comprised up to 10% of the substrate but were not observed in October. Boulders were not present along this reach. Embeddedness occurred only in September (5%) and October (25%).

Due to the high percentage of fines, this reach does not supply high quality spawning or rearing habitat for salmonids. However, during the October monitoring, two adult salmonids were observed swimming upstream but not passing through the culvert under Downes Road.

Photograph 3-7 D-02 (Downes Creek) – September 2022

Site D-02-Pool Facing Downstream

Site D-02-Riffle Facing Upstream

D-03

D-03 is located in 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 sinuous to irregular morphology. This differed from Year 11 (2021), when the channel morphology was straight. Gravel and sand side bars were present at both mesohabitat sites. Overhanging vegetation was dominant during all observation periods, but no instream vegetation was observed. No deep pools were present, but undercut banks occurred at D-03 pool in August, September, and October and at D-03 riffle in August and September. The gradient at this site was higher than at D-02, with a range of 4% to 5%. Crown closure ranged from 20% to 40% across the reach, with an average of 32.5% at both sites.

The substrate at the pool mesohabitat was comprised of fines ranging from 20 % to 60% and gravel ranging from 15% to 45%. Cobbles ranged from 10% to 35%, and boulders ranged from 5% to 10%. The substrate at the riffle mesohabitat included fines ranging from 10% to 30% and gravel ranging from 20% to 60%. Cobbles ranged from 15% to 65% and boulders ranged from 5% to 25%. Embeddedness ranged from 5% to 35%, averaging 21.25%. D95 ranged from 7cm to 49cm, with the largest being observed at D-03 riffle in July and August.

Instream features included SWD, which dominated at D-03 pool and riffle sites. LWD was present only in trace amounts.

Photograph 3-8 D-03 (Downes Creek) – August and September 2022

D-03 Riffle Facing Upstream (August 2022)

D-03 Pool—looking 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 a confined, sinuous channel with an average gradient of 5%. The pool mesohabitat had a sand and gravel side bar during all monitoring visits, while the riffle had a sidebar only in September. Overhanging vegetation was dominant through both sites, and no instream vegetation was present. Crown closure ranged from 45% to 75%, averaging 65.6%. Sand and gravel islands were present at the pool mesohabitat during all monitoring visits.

The pool mesohabitat substrate was dominated by fines ranging from 45% to 70%. Gravel ranged from 15% to 35%, and cobbles ranged from 15% to 20%. Boulders were not observed. Embeddedness ranged from 5% to 15%. The riffle mesohabitat substrate had a lower percentage of fines throughout the monitoring period, ranging from 15% to 50%. Cobbles ranged from 10% to 55%, and gravel ranged from 15% to 50%. Boulders comprised 10% to 20% of the substrate. D95 ranged from 7cm to 15 cm, with an average of 11.6 cm.

Photograph 3-9 D-04 (Downes Creek) – August 2022

D-04 Pool Facing Upstream

D-04 Riffle Facing Upstream

Fishtrap Creek

F-01

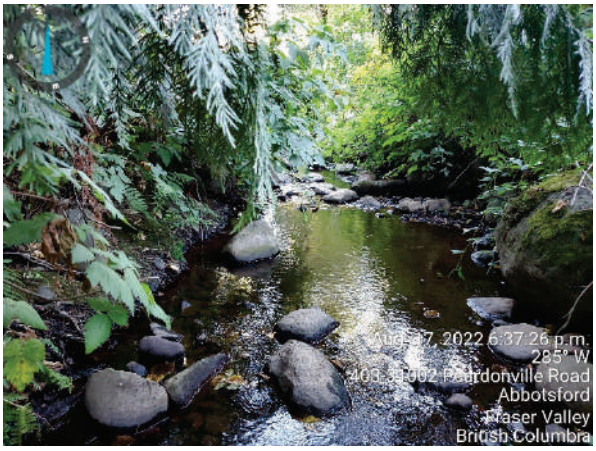
F-01 is located at the headwaters of Fishtrap Creek north of Highway 1 at Gardner Park off Livingstone Avenue. It overlaps with water quality monitoring site F-01. Two mesohabitat sites were established here: a pool (F-01-pool) located 11 m north of the hydrometric station and a riffle (F-01-riffle)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

F-01 is characterized as a low to moderate gradient (1% – 5%) stream with a sinuous channel that is straight in some sections. The reach ranges from confined at the pool mesohabitat, becoming largely unconfined at the riffle mesohabitat with the channel appearing entrenched during the August assessment. Instream vegetation was not evident except in trace amounts at the riffle site. Overhanging vegetation dominated throughout this reach, and SWD ranged from trace to subdominant. Crown closure throughout the reach ranged from 0% (at the pool) to 75% and had the highest range (30% to 75%) at the riffle habitat.

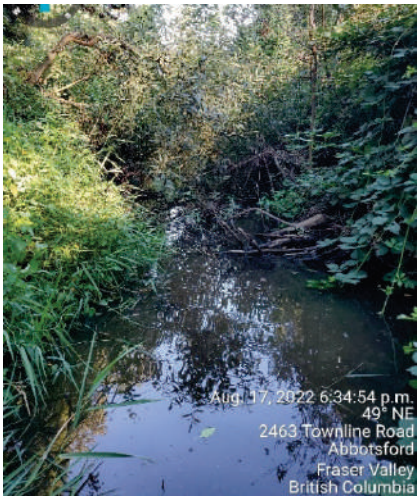
The substrate at the pool mesohabitat site was largely consistent throughout the monitoring period; fines remained 40% before an increase to 100% in September. Cobbles were observed in only October when they comprised 10% of the substrate. The proportion of boulders ranged from 10% to 20%. Embeddedness ranged from 5% to 10%, and D95 ranged from 28 cm to 33 cm at this site.

The substrate at the riffle mesohabitat site was slightly variable, with percentages of fines ranging from 0% to 50% and gravel ranging from 5% to 33.3%. Cobbles ranged from 25% to 33%, and boulders ranged from 20% to 35%. Embeddedness ranged from 15% to 30%, averaging 21.25%. D95 ranged from 11 cm to 34 cm, with an average size of 32.25cm.

Photograph 3-10 F-01 (Fishtrap Creek) – August 2022



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 (1% - 3%), riffle-pool channel that oscillated between confined to frequently confined, to unconfined at F-02 riffle in July, August, and October. It had a straight to sinuous pattern. No islands or bars were present. Undercut banks were present throughout this reach, dominating in August and September at the pool mesohabitat. Undercut banks were not present at the riffle mesohabitat in September. Beaver dams were noted upstream and downstream of the site in August 2022.

The pool mesohabitat was dominated by fines and gravel throughout the four-month assessment period. No cobbles or gravel were present. The substrate composition consisted of 40% fines and 60% gravel in July, 20% fines and 80% gravel in August, 100% fines in September, and 40% fines and 60% gravel in October. Embeddedness ranged from 4% to 30%, except with 0% observed in August. SWD was present in trace amounts in August and October, and LWD was absent from the pool mesohabitat.

Overhanging and instream vegetation at the pool mesohabitat ranged from subdominant to dominant. Crown closure was 5% in July and August, increasing to 30% in September and returning to 5% in October. The increase in crown closure in September was due to a partially fallen cedar bough that was hanging over the site; it had fallen onto an adjacent bank in October. Deep pools dominated in July and October but were non-existent in August and September. During this two-month period water levels dropped by approximately 1.2 m from August to September due to extremely dry conditions. By October water levels had risen substantially, and mesohabitat was assessed 6 m upstream due to the unsafe depth for wading at the monitoring site.

The substrate composition at the riffle mesohabitat consisted of 100% fines from July through to October. The presence of fines was inferred in August based on previous observations, as the bottom of the stream was not visible through the deep water. Embeddedness was 0% during all months. SWD and LWD dominated during all months except September, when only trace amounts were evident. These may have been washed downstream due to frequent fluctuating water levels (i.e., entire site was flooded in August, then water levels dropped by approximately 1.2 m in September).

Crown closure ranged from 15% to 100%, with the highest cover observed in August when the entire site was flooded. This apparent increase in cover is somewhat misleading, as the stream occupied a larger are while it was flooded, necessitating that mesohabitat measurements incorporate a wider area. However, it is also likely that canopy cover during August was overestimated. Deep pools were dominant in July, August, and October, and

but were reduced to trace amounts in September due to the lower water level. Overhanging and instream vegetation dominated from July to October.

Based on the observations collected during the four-month period from July to October 2022, this site provides moderate rearing and overwintering habitat and refugia for salmonids in the summer months, due to the presence of deep pools throughout the year and the robust overhanging and instream vegetation. However, due to the lack of cobbles and gravel, this location is rated as poor for spawning habitat.

Photograph 3-11 F-02 (Fishtrap Creek) – August and September 2022

F-02 Pool Facing Upstream

F-02 Riffle—looking downstream

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, meandering to intermittent channel type. The channel characteristics had changed from 2021, when channel morphology was straight. No bars or islands were present along this section of the stream, and undercut banks were observed only in August (dominant) and September (trace). Substrate was inferred to be dominated by fines (100%) in July, August, and October, as the water depth was unsafe for a thorough assessment; however, water was clear in July and August, and the substrate was visible. In October, the water was too turbid for a proper substrate assessment. In September, fines had reduced to 45%, gravel occupied 45% of the substrate, and boulders made up the remaining 10%.

No overhanging vegetation was evident at this site, except for trace amounts observed in September. Crown closure was non-existent. Instream vegetation dominated throughout the observation period. SWD occurred in trace amounts, and LWD was absent except for trace amounts observed in August. Deep pools dominated throughout the observation period and would provide substantial refugia for salmonids and other aquatic species.

Photograph 3-12 F-03 (Fishtrap Creek) – August 2022

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 to meandering, frequently confined channel. It lies within an agricultural area. The canopy at F-04 was open to moderately covered (0% closure at the riffle site and 20%-55% closure at the pool site). Overhanging vegetation largely dominated throughout this reach but at the riffle site it was present only in trace amounts in August and October. Instream vegetation usually dominated at both the pool and riffle sites, but it was absent from the riffle in October. No islands or bars were present along this reach, except for a side sand bar noted in September at the pool site.

Substrate at the pool mesohabitat consisted of a mix of fines and gravel, with no cobbles or boulders present. Fines ranged from 40% to 80%, with the lowest observed in September. Gravel ranged from 20% to 60%, with the highest being observed in

September. SWD dominated at the pool habitat, while LWD varied from trace amounts in July and August to dominant in October but was absent in September. Slightly undercut banks were observed in August and October, and deep pools dominated from August to October. Embeddedness was low at the pool site, ranging from 0% to 5% throughout the observation period. The highest embeddedness occurred in September when gravel made up a larger proportion of the substrate.

Substrate at the riffle mesohabitat remained largely consistent, comprised of a relatively even mix of fines (40% to 50%) and gravel (50% to 60%) throughout the observation period. The average embeddedness was 12.5%, with 20% observed in July and 5% observed in October. Crown closure was 0%, with trace to subdominant amounts of overhanging vegetation. Instream vegetation largely consisted of reed canary grass (*Phalaris arundinacea*), which was dominant from July to September but had died by October. D95 size ranged from 3.5 cm to 5 cm from July to September, excluding October.

Photograph 3-13 F-04 (Fishtrap Creek) –September and October 2022

F-04 Riffle—facing upstream

F-04 Pool—facing upstream

3.5.2 Changes in Biophysical Parameters over Time

Year 1 (2011) through to Year 12 (2022) 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 four 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 12 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 2022.

The Mann-Kendall tests showed no significant negative or positive trends in the average wetted width at the Boa Brook mesohabitat sites during the 2012 to 2022 monitoring period (Table 3-2). At Horn Creek, a significant increasing trend in the average wetted width was observed at site 1A ($p < 0.05$), and a significant decreasing trend occurred at site 3C. No significant trends (increasing or decreasing) were observed at the other Horn Creek or Boa Brook sites.

Five years of monitoring is not enough to detect trends at the Downs Creek and Fishtrap Creek with any degree of confidence. However, the data presented in Figures 3-6 and 3-7 do not show consistent changes from site to site within a watercourse, nor do they suggest potential decreases in available habitat.

Bankfull Width and Depth

The bankfull width of a stream is defined by major high flow events, typically in the fall and winter months, and may not be strongly influenced by reductions in flow in the summer period. Bankfull depth is measured from the bankfull width elevation to the elevation of the channel thalweg (deepest portion of channel cross section). In the low flow period, bankfull depth may be sensitive to flow reductions due to sediment deposition. However, once high flows occur, the sediment may be scoured away returning bankfull depth to typical levels.

Figure 3-8 to Figure 3-11 show the results of the bankfull width and depth monitoring at the mesohabitats monitoring sites through 2022. In a system where flows are decreasing, a negative trend in bankfull width and depth over time may be expected. The Mann-Kendall tests did not show statistically significant decreasing trends in bankfull width. However, there were significant increasing trends in bankfull width at mesohabitat sites 1A, 1B, 2A, and 2B on Horn Creek and 4B, 5A, 5B and 5D on Boa Brook (Table 3-3). There were no significant negative trends in bankfull depth at the Horn Creek and Boa Brook mesohabitat sites, but there were significant increases in bankfull depth at 1A, 1B, 2B, 3A and 3C on Horn Creek and 5D and 6A on Boa Brook (Table 3-3).

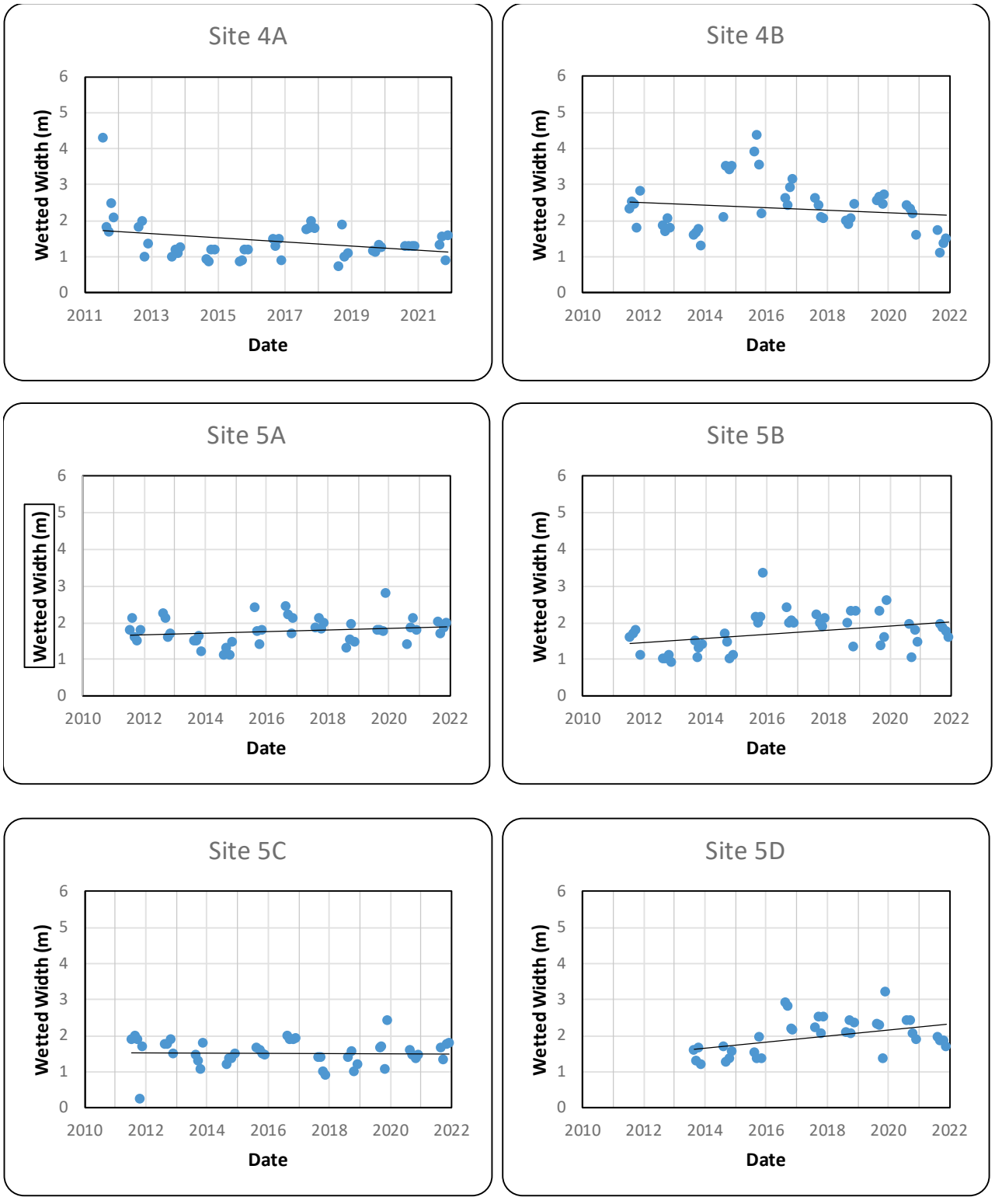


Figure 3-4 Wetted Width at Boa Brook Mesohabitat Sites (2012 to 2022)

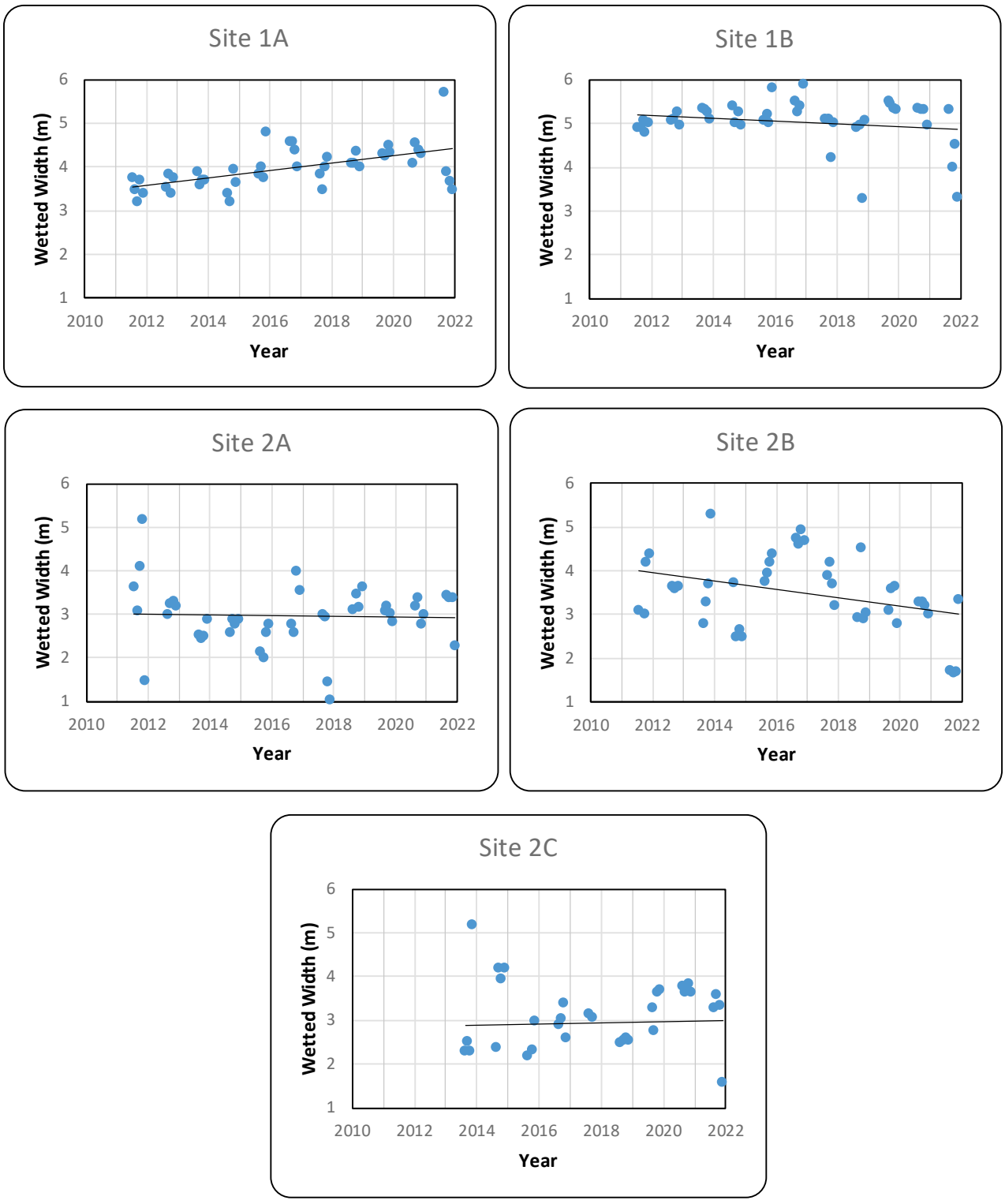


Figure 3-5 Wetted Width at Horn Creek Mesohabitat Sites (2012 to 2022)

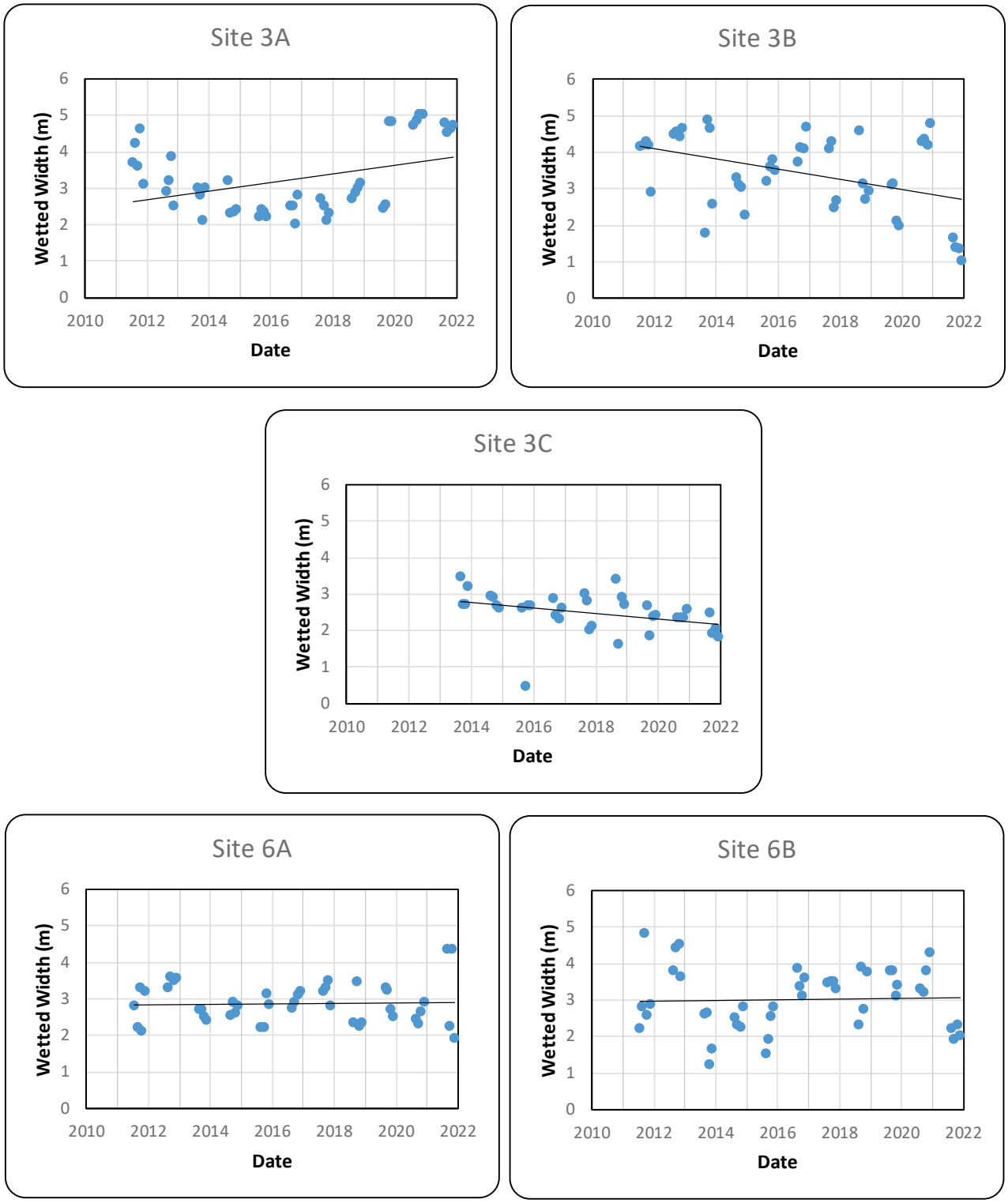


Figure 3-5 Wetted Width at Horn Creek Mesohabitat Sites (2012 to 2022) (Continued)

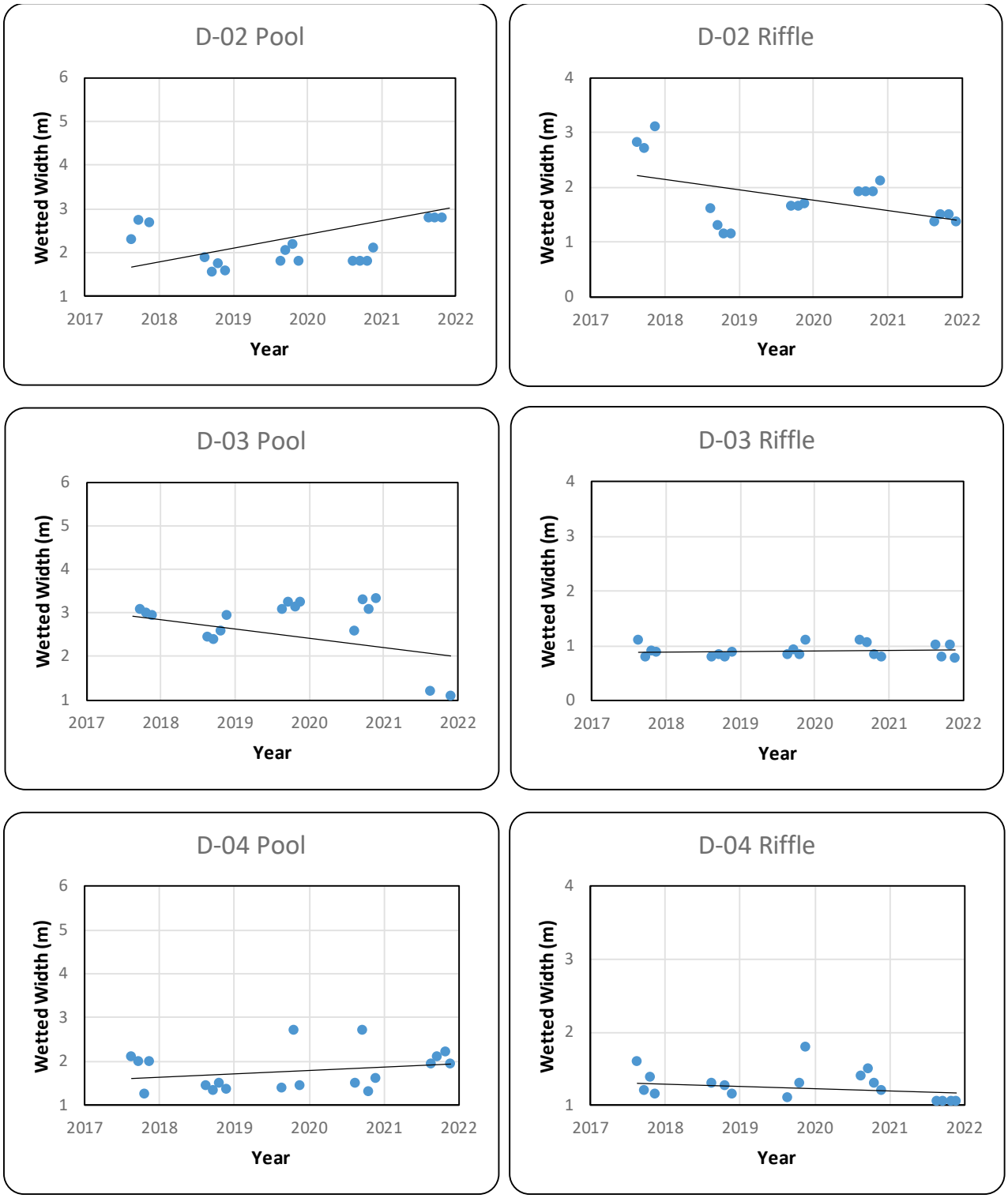


Figure 3-6 Wetted Width at Downes Creek Mesohabitat Sites (2018 to 2022)

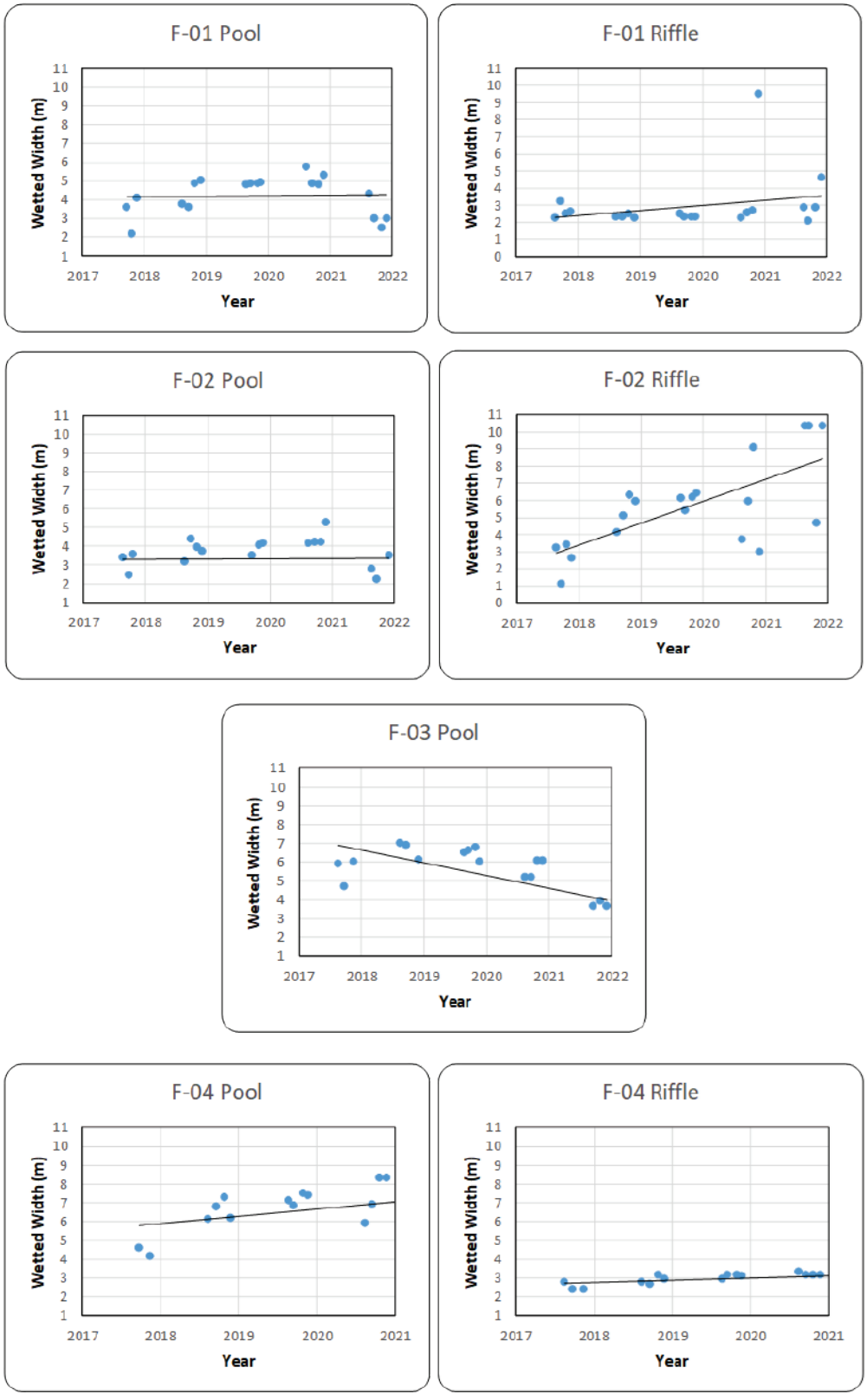


Figure 3-7 Wetted Width at Fishtrap Creek Mesohabitat Sites (2018 to 2022)

Table 3-2 Statistical Significance of Mann-Kendall Trends in Wetted Width at the Bevan Wells Mesohabitat Monitoring Sites

Mesohabitat Site	First Year	Last Year	n	Mann-Kendall S or Z	Significance
1A (Horn Creek)	2012	2022	11	2.49	**p <0.05**
1B (Horn Creek)	2012	2022	11	-0.156	
2A (Horn Creek)	2012	2022	11	-0.156	
2B (Horn Creek)	2012	2022	11	-1.87	p <0.10
2C (Horn Creek)	2014	2022	9	2	
3A (Horn Creek)	2012	2022	11	0.62	
3B (Horn Creek)	2012	2022	11	-1.557	
3C (Horn Creek)	2014	2022	9	-20	**p <0.05**
4A (Boa Brook)	2012	2022	11	0.000	
4B (Boa Brook)	2012	2022	11	-0.78	
5A (Boa Brook)	2012	2022	11	0.778	
5B (Boa Brook)	2012	2022	11	0.547	
5C (Boa Brook)	2012	2022	11	0.000	
5D (Boa Brook)	2014	2022	9	8	
6A (Horn Creek)	2012	2022	11	0.156	
6B (Horn Creek)	2012	2022	11	0.31	

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.

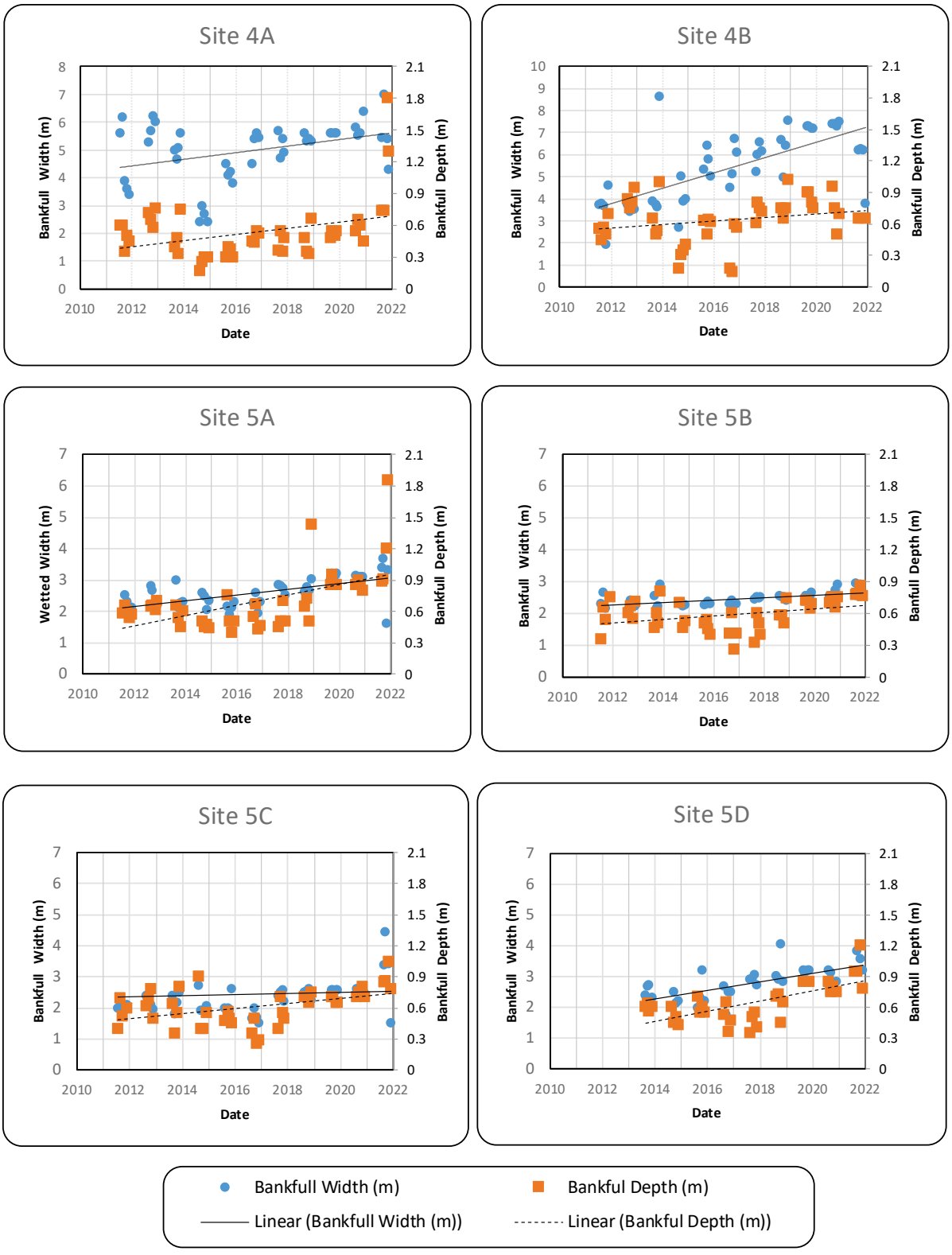


Figure 3-8 Bankfull Width and Depth at Boa Brook Mesohabitat Sites (2012 to 2022)

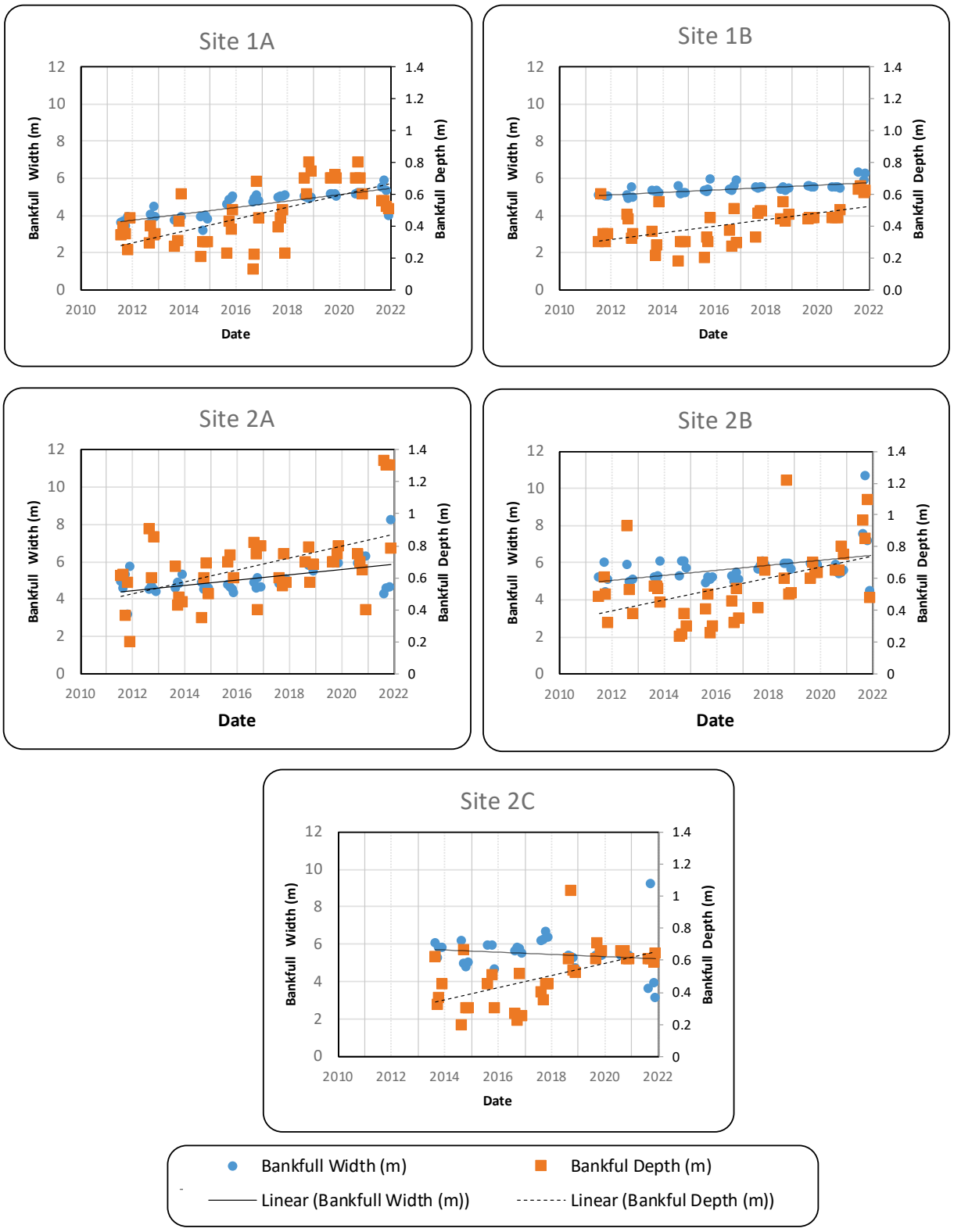


Figure 3-9 Bankfull Width and Depth at Horn Creek Mesohabitat Sites (2012 to 2022)

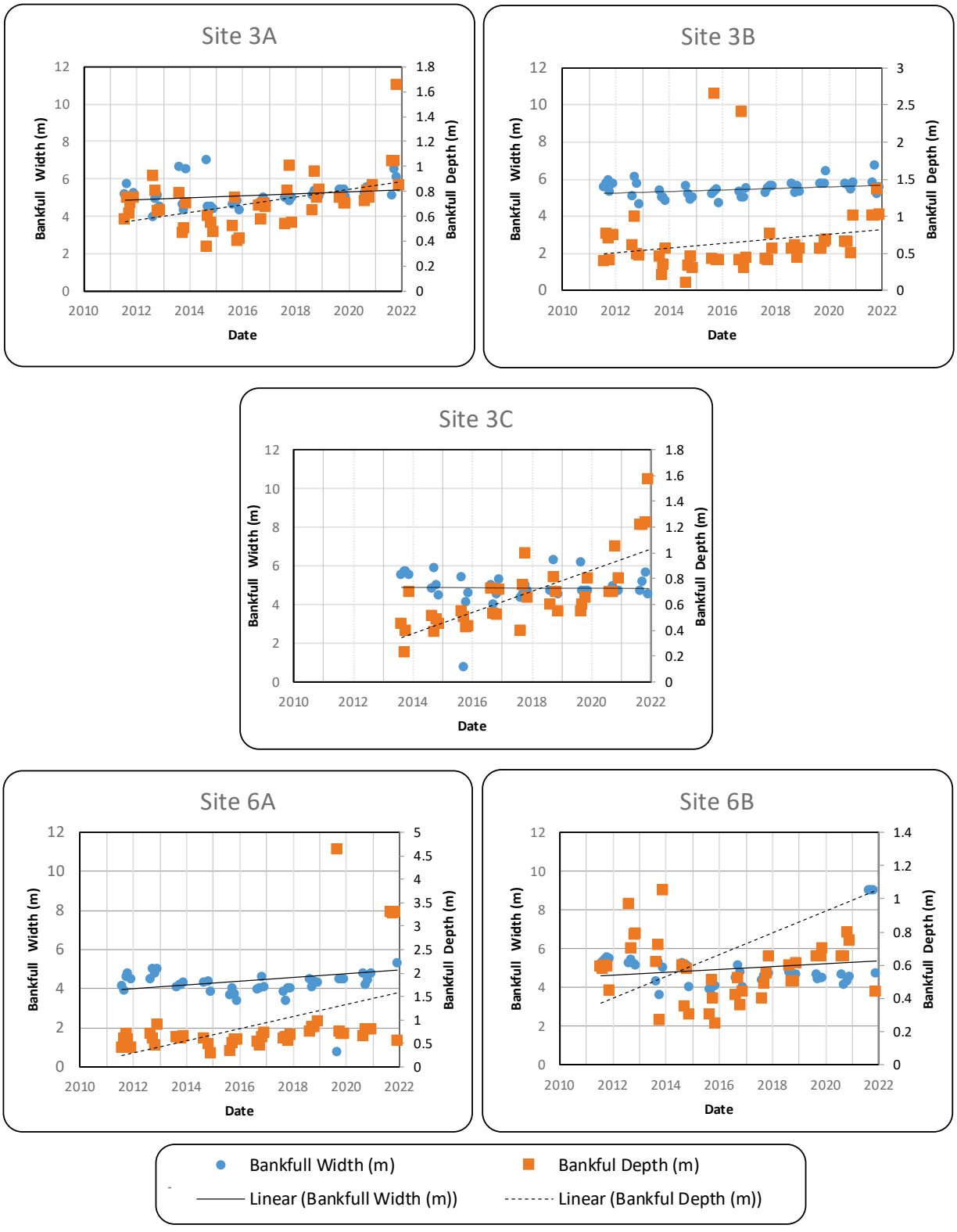


Figure 3-10 Bankfull Width and Depth at Horn Creek Mesohabitat Sites (2012 to 2022) (Continued)

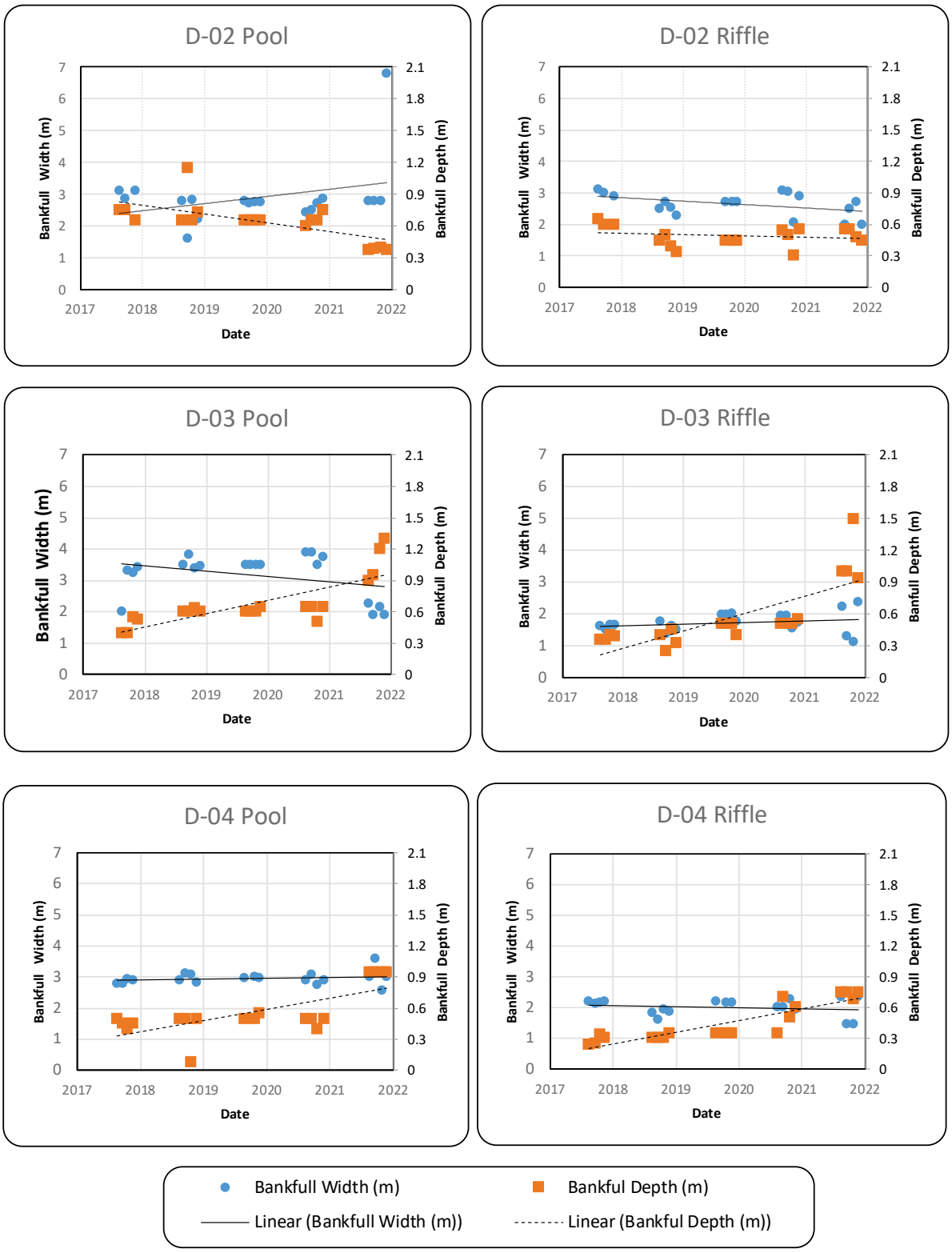


Figure 3-11 Bankfull Width and Depth at Downes Creek Mesohabitat Sites (2018 to 2022)

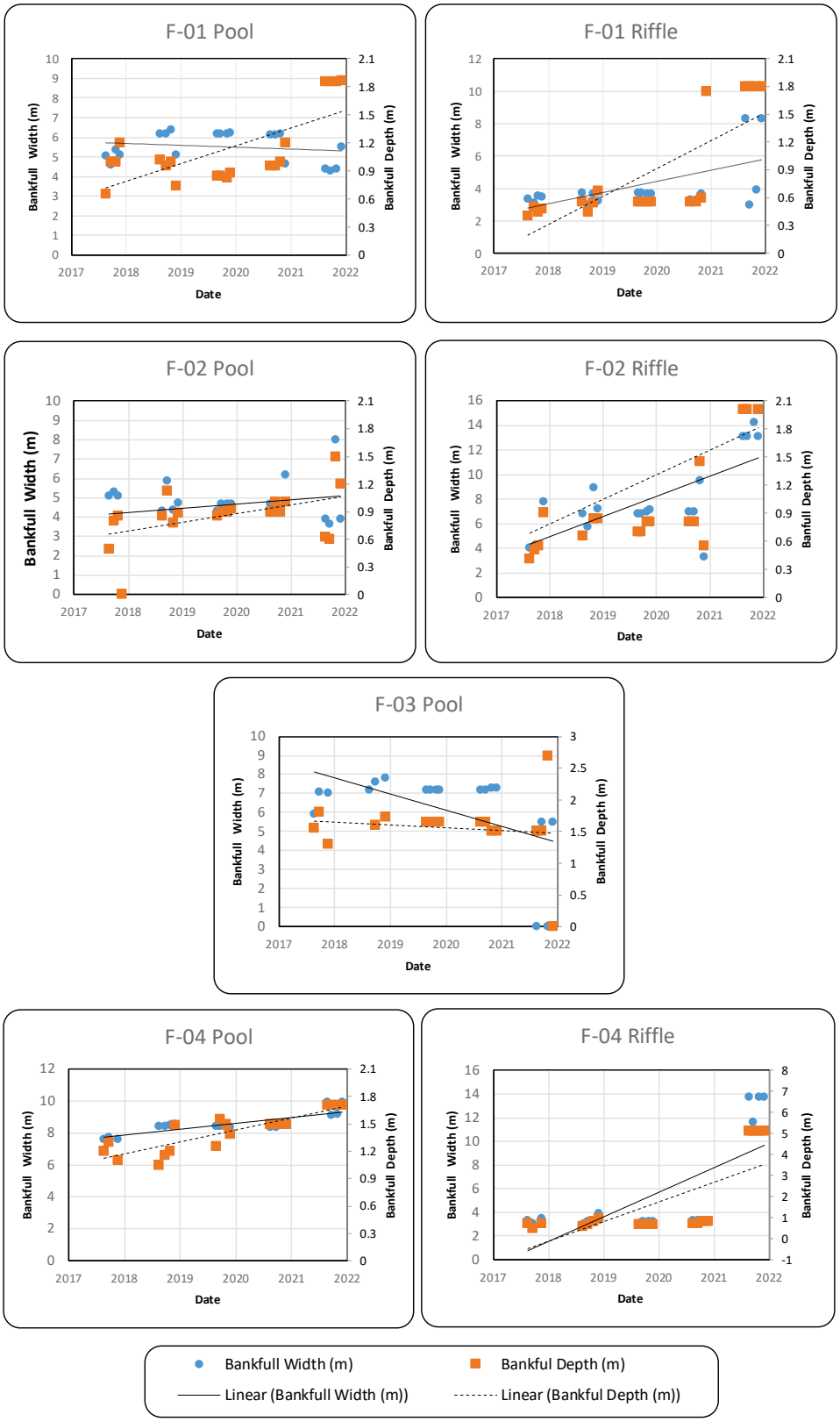


Figure 3-12 Bankfull Width and Depth at Fishtrap Creek Mesohabitat Sites (2018 to 2022)