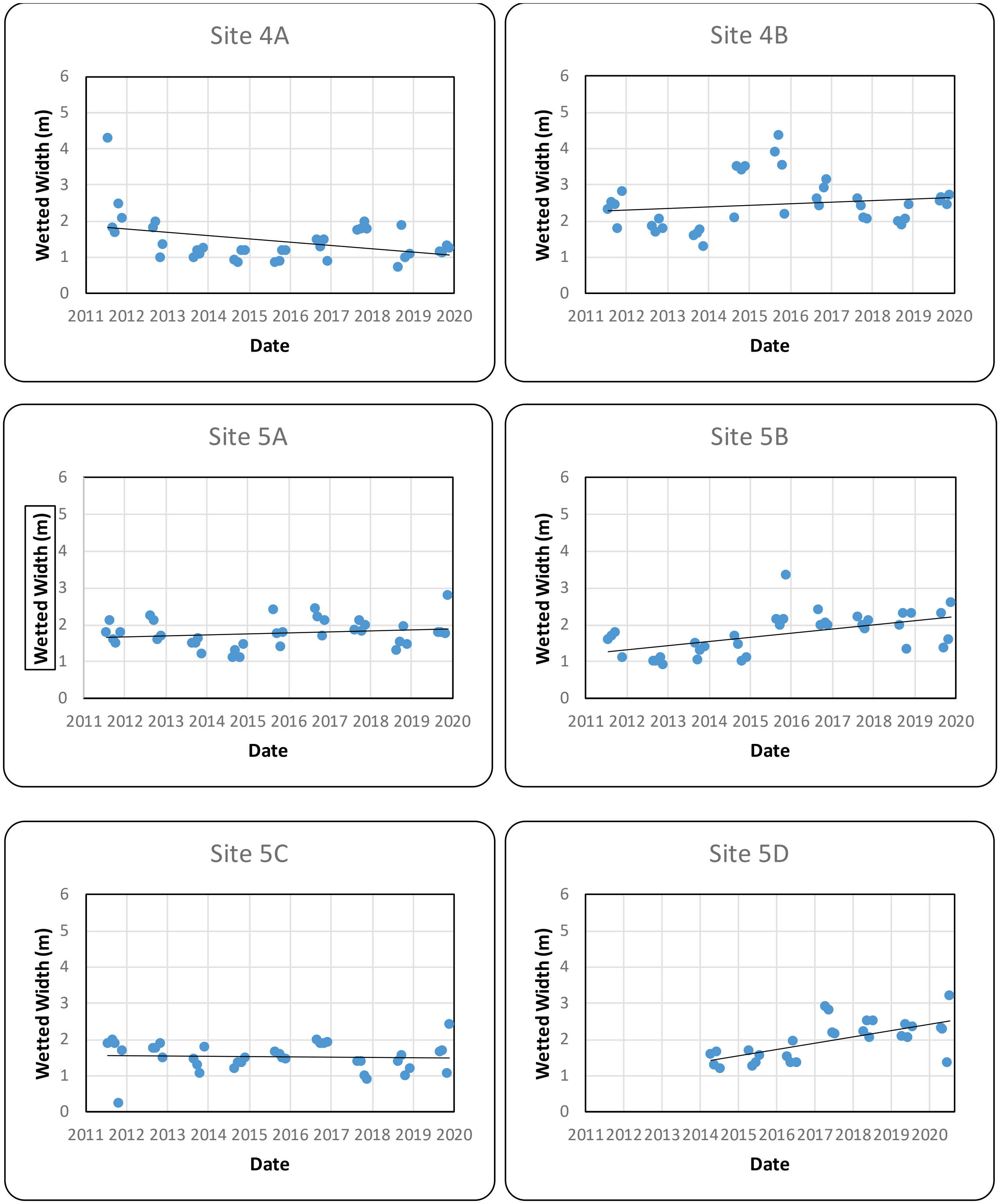


**Figure 3-4 Wetted Width at Boa Brook Mesohabitat Sites (2012 to 2020)**

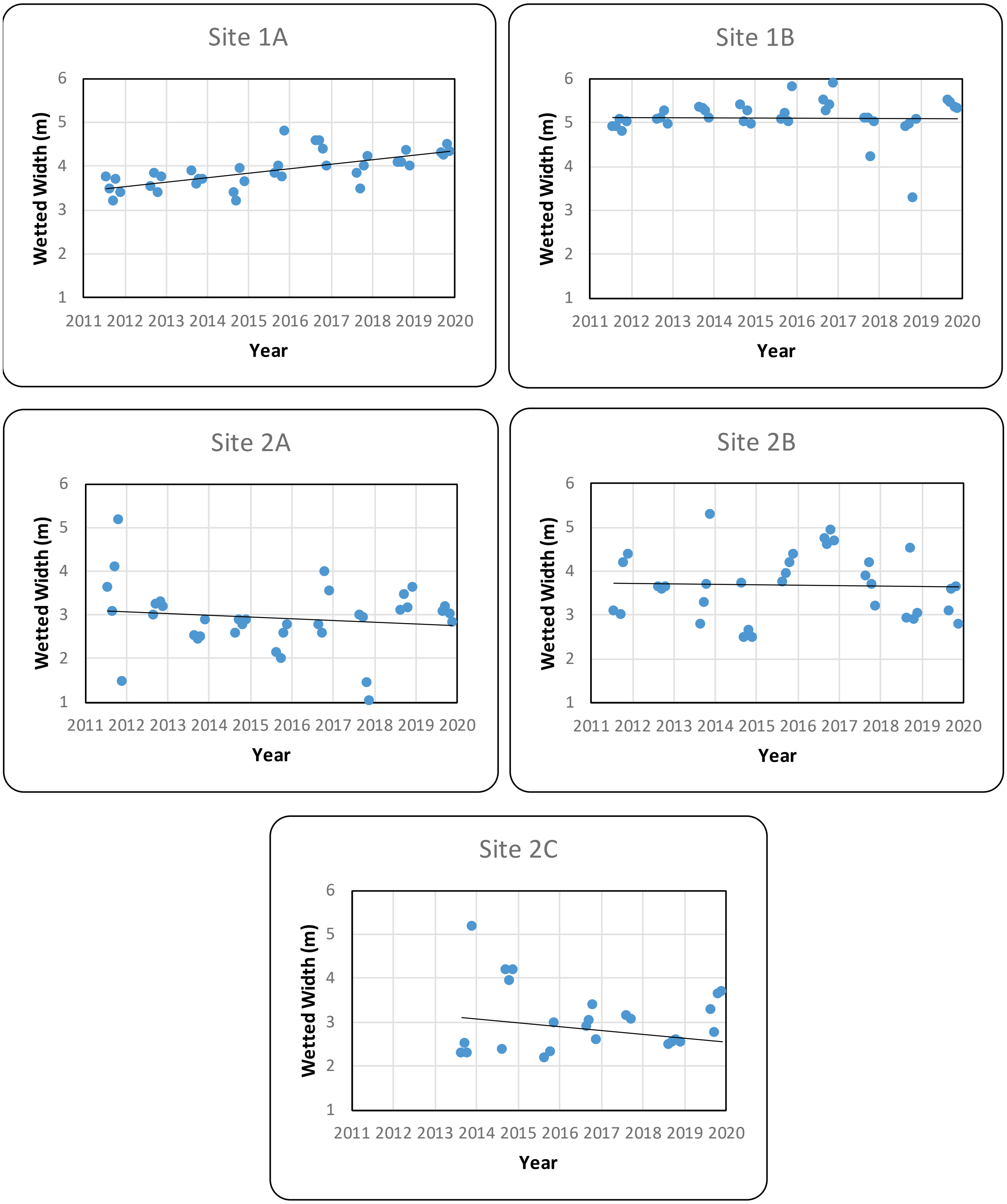


**Figure 3-5 Wetted Width at Horn Creek Mesohabitat Sites (2012 to 2020)**

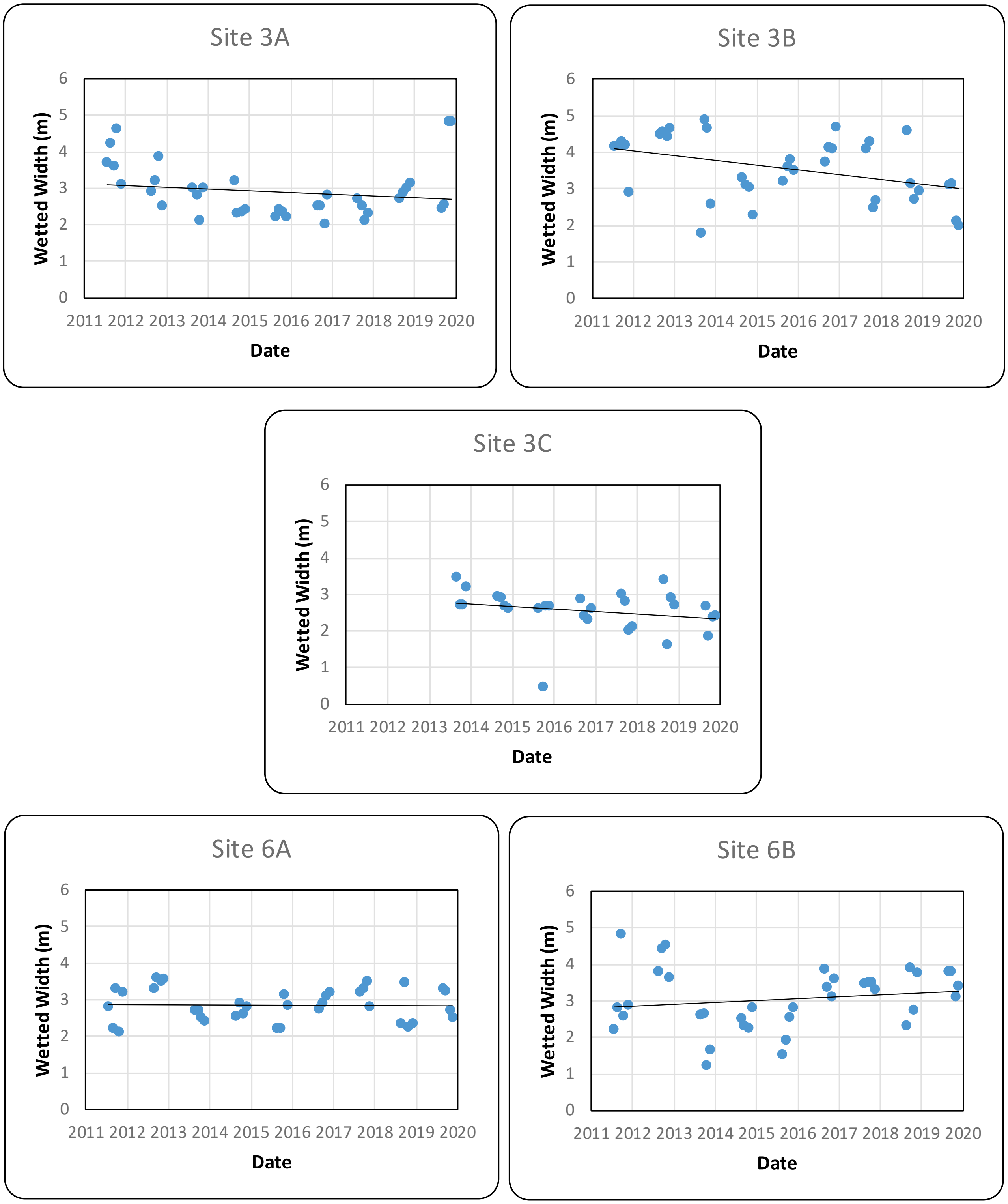


**Figure 3-5 Wetted Width at Horn Creek Mesohabitat Sites (2012 to 2020) (Continued)**

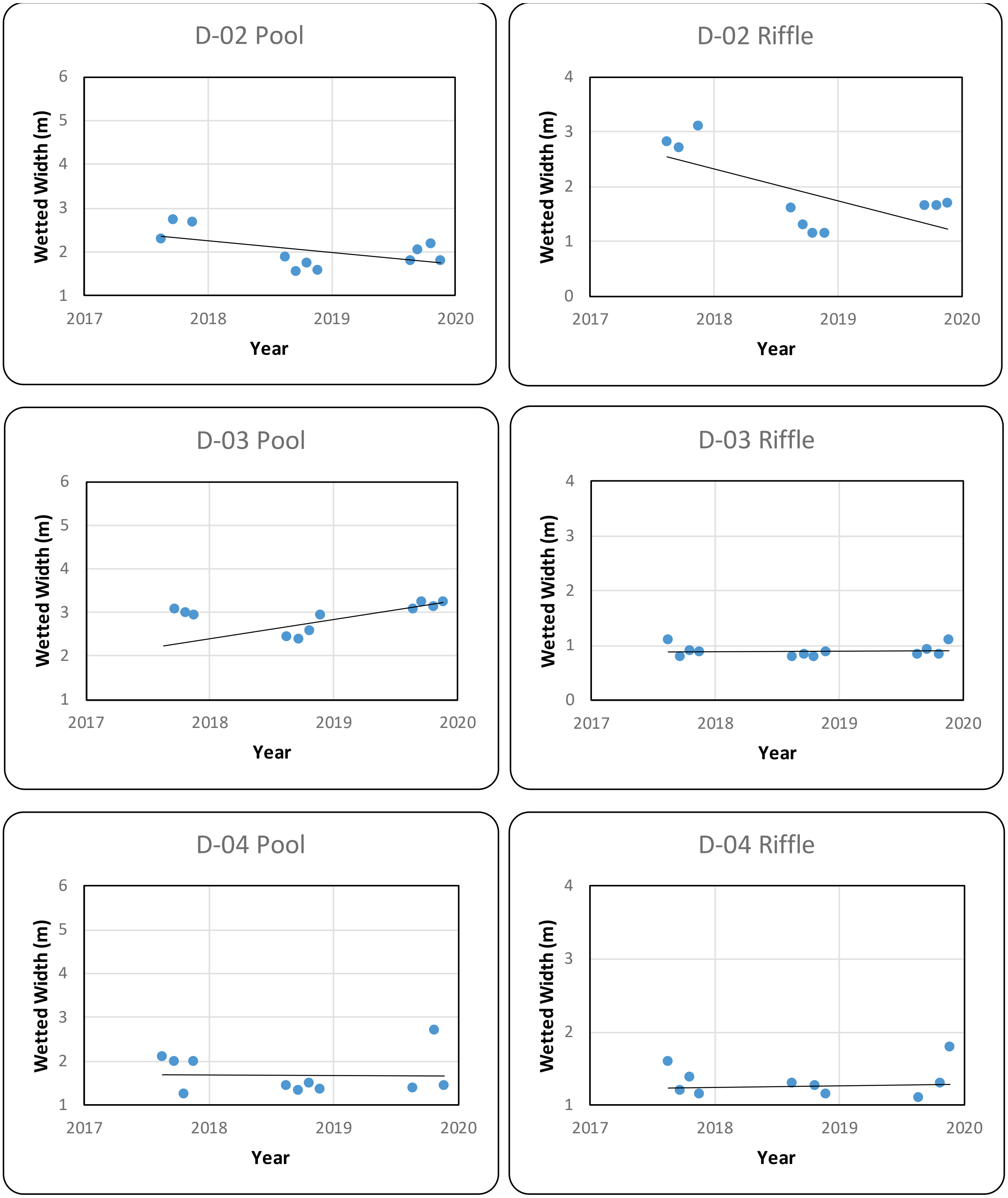


**Figure 3-6 Wetted Width at Downes Creek Mesohabitat Sites (2018 to 2020)**

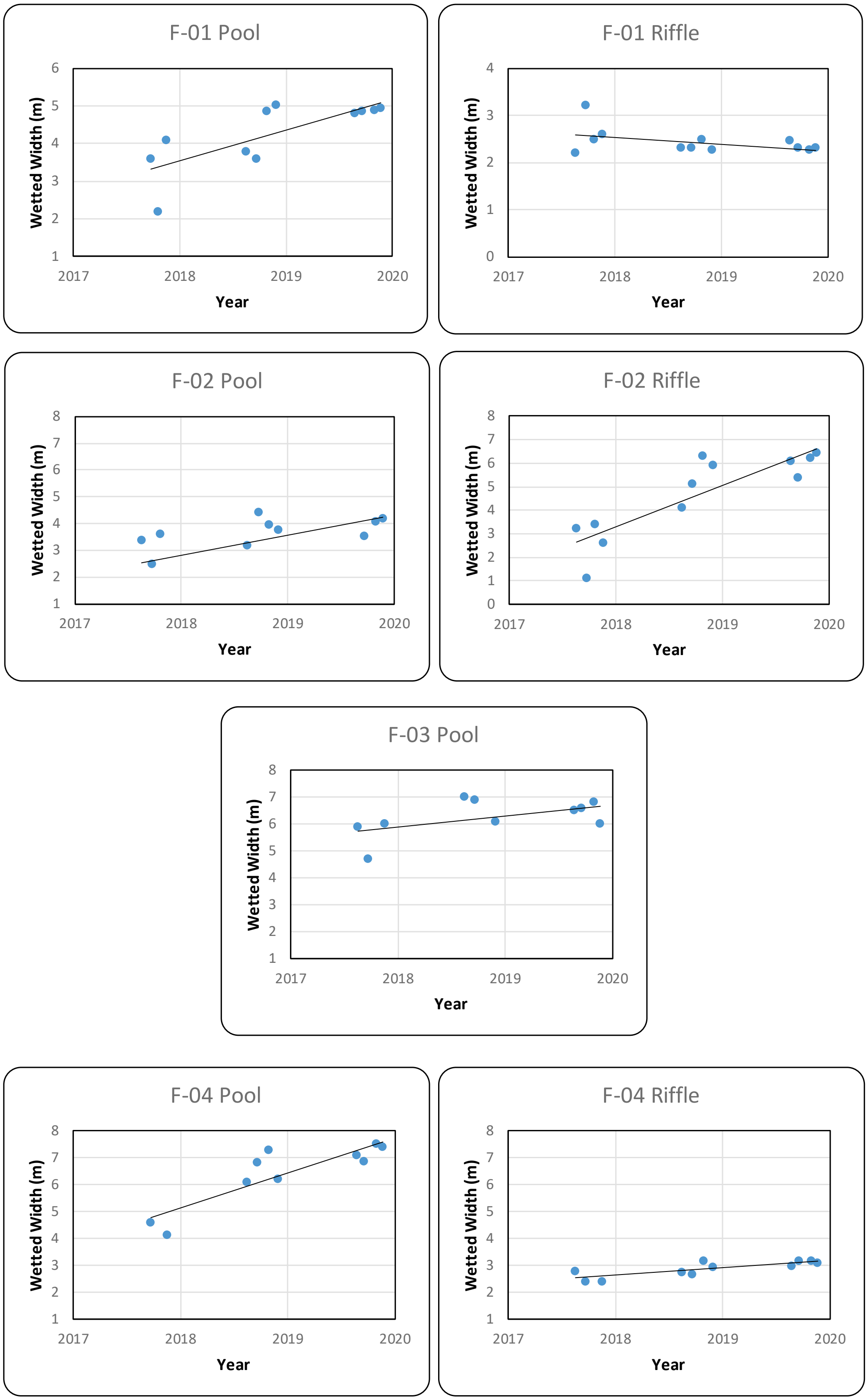


**Figure 3-7 Wetted Width at Fishtrap Creek Mesohabitat Sites (2018 to 2020)**

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 2020 monitoring period (Table 3-2). At Horn Creek, a significant increasing trend in the average wetted width was observed at site 1A ($p < 0.05$). No significant trends (increasing or decreasing) were observed at the other Horn Creek sites.

**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 | Significance |
|---|---|---|---|---|---|
| 1A (Horn Creek) | 2012 | 2020 | 9 | 24 | **p <0.05** |
| 1B (Horn Creek) | 2012 | 2020 | 9 | 6 | |
| 2A (Horn Creek) | 2012 | 2020 | 9 | -6 | |
| 2B (Horn Creek) | 2012 | 2020 | 9 | -8 | |
| 2C (Horn Creek) | 2014 | 2020 | 7 | -3 | |
| 3A (Horn Creek) | 2012 | 2020 | 9 | -8 | |
| 3B (Horn Creek) | 2012 | 2020 | 9 | -18 | P<0.1 |
| 3C (Horn Creek) | 2014 | 2020 | 7 | -9 | |
| 4A (Boa Brook) | 2012 | 2020 | 9 | -6 | |
| 4B (Boa Brook) | 2012 | 2020 | 9 | 2 | |
| 5A (Boa Brook) | 2012 | 2020 | 9 | 10 | |
| 5B (Boa Brook) | 2012 | 2020 | 9 | 9 | |
| 5C (Boa Brook) | 2012 | 2020 | 9 | -4 | |
| 5D (Boa Brook) | 2014 | 2020 | 7 | 11 | |
| 6A (Horn Creek) | 2012 | 2020 | 9 | 2 | |
| 6B (Horn Creek) | 2012 | 2020 | 9 | 6 | |

p – probability. Blank indicates $p > 0.1$. Significance set at $p < 0.05$.

Three 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 2020. In a system where flows are decreasing, a negative trend in bankfull width and depth over time may be expected. The Mann-Kendall tests showed no significant negative trends in bankfull width at the Horn Creek and Boa Brook mesohabitats over the monitoring period (Table 3-3). However, the analysis showed significant increasing trends in bankfull width at mesohabitat sites 1A and 1B ($p<0.01$) and 2A and 2B ($p <0.05$) on Horn Creek and 4B ($p <0.001$) and 5B ($p<0.05$) on Boa Brook.

**Table 3-3 Statistical Significance of Mann-Kendall Trends in Bankfull Width and Depth at the Bevan Wells Mesohabitat Monitoring Sites**

| Mesohabitat Site | First Year | Last Year | n | Bankfull Width | | Bankfull Depth | |
|---|---|---|---|---|---|---|---|
| | | | | Mann-Kendall S | Significance | Mann-Kendall S | Significance |
| 1A (Horn Creek) | 2012 | 2020 | 9 | 28 | **p<0.01** | 18 | p<0.1 |
| 1B (Horn Creek) | 2012 | 2020 | 9 | 26 | **p<0.01** | 11 | |
| 2A (Horn Creek) | 2012 | 2020 | 9 | 22 | **p<0.05** | 16 | |
| 2B (Horn Creek) | 2012 | 2020 | 9 | 20 | **p<0.05** | 12 | |
| 2C (Horn Creek) | 2014 | 2020 | 7 | -3 | | 5 | |
| 3A (Horn Creek) | 2012 | 2020 | 9 | 4 | | 10 | |
| 3B (Horn Creek) | 2012 | 2020 | 9 | 10 | | -2 | |
| 3C (Horn Creek) | 2014 | 2020 | 7 | -1 | | 15 | **p<0.05** |
| 4A (Boa Brook) | 2012 | 2020 | 9 | 12 | | 2 | |
| 4B (Boa Brook) | 2012 | 2020 | 9 | 32 | **p<0.001** | 12 | |
| 5A (Boa Brook) | 2012 | 2020 | 9 | 16 | | 5 | |
| 5B (Boa Brook) | 2012 | 2020 | 9 | 20 | **p<0.05** | -8 | |
| 5C (Boa Brook) | 2012 | 2020 | 9 | 3 | | -2 | |
| 5D (Boa Brook) | 2014 | 2020 | 7 | 11 | | 7 | |
| 6A (Horn Creek) | 2012 | 2020 | 9 | -18 | p<0.1 | 14 | |
| 6B (Horn Creek) | 2012 | 2020 | 9 | -16 | | -4 | |

As discussed for wetted width, three years of monitoring is not enough to detect trends with any degree of confidence. The data presented in Figures 3-10 and 3-11 do not show consistent changes in either bankfull width or depth from site to site within Downs Creek or Fishtrap Creek, nor do they suggest potential decreases in available habitat.

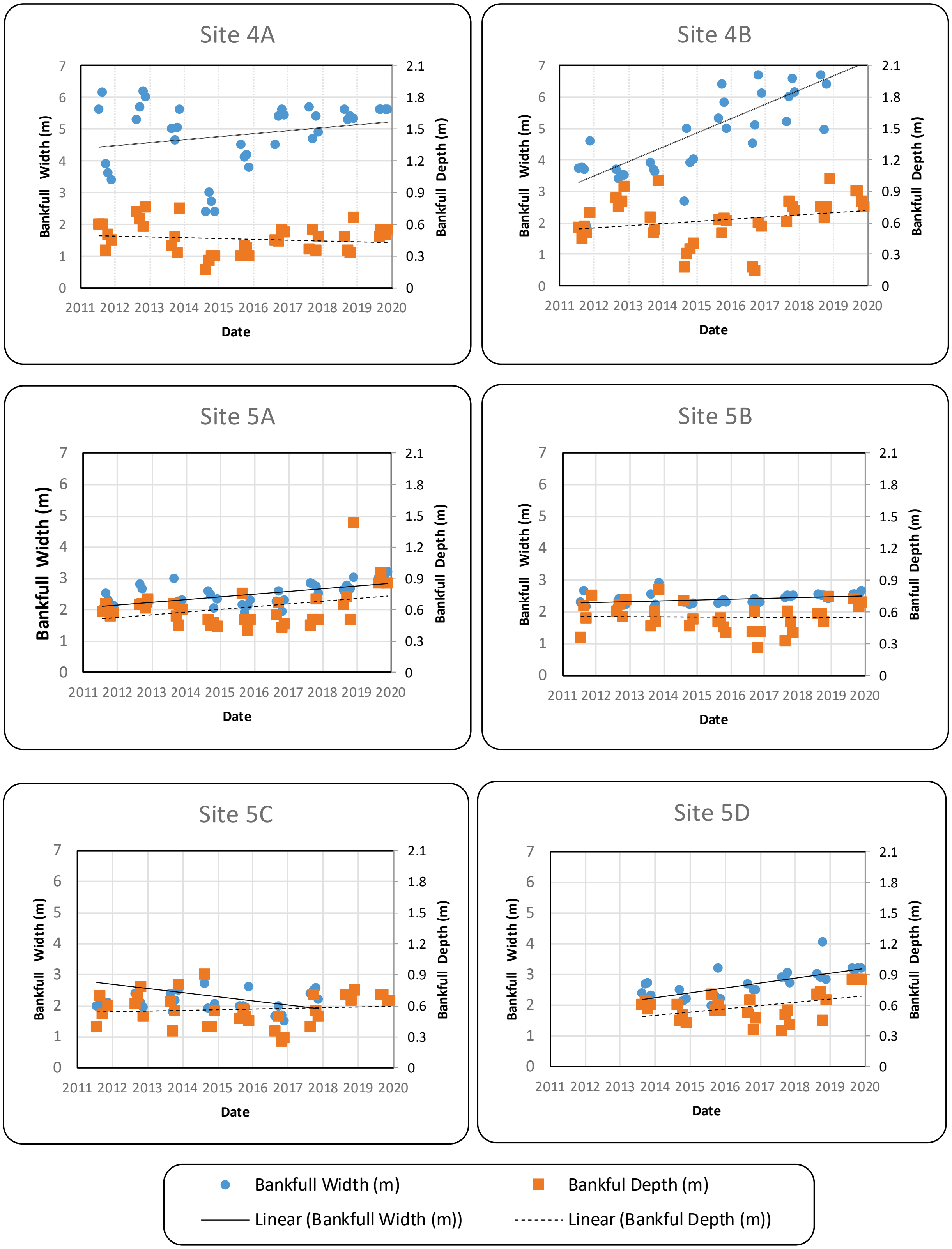


**Figure 3-8 Bankfull Width and Depth at Boa Brook Mesohabitat Sites (2012 to 2020)**

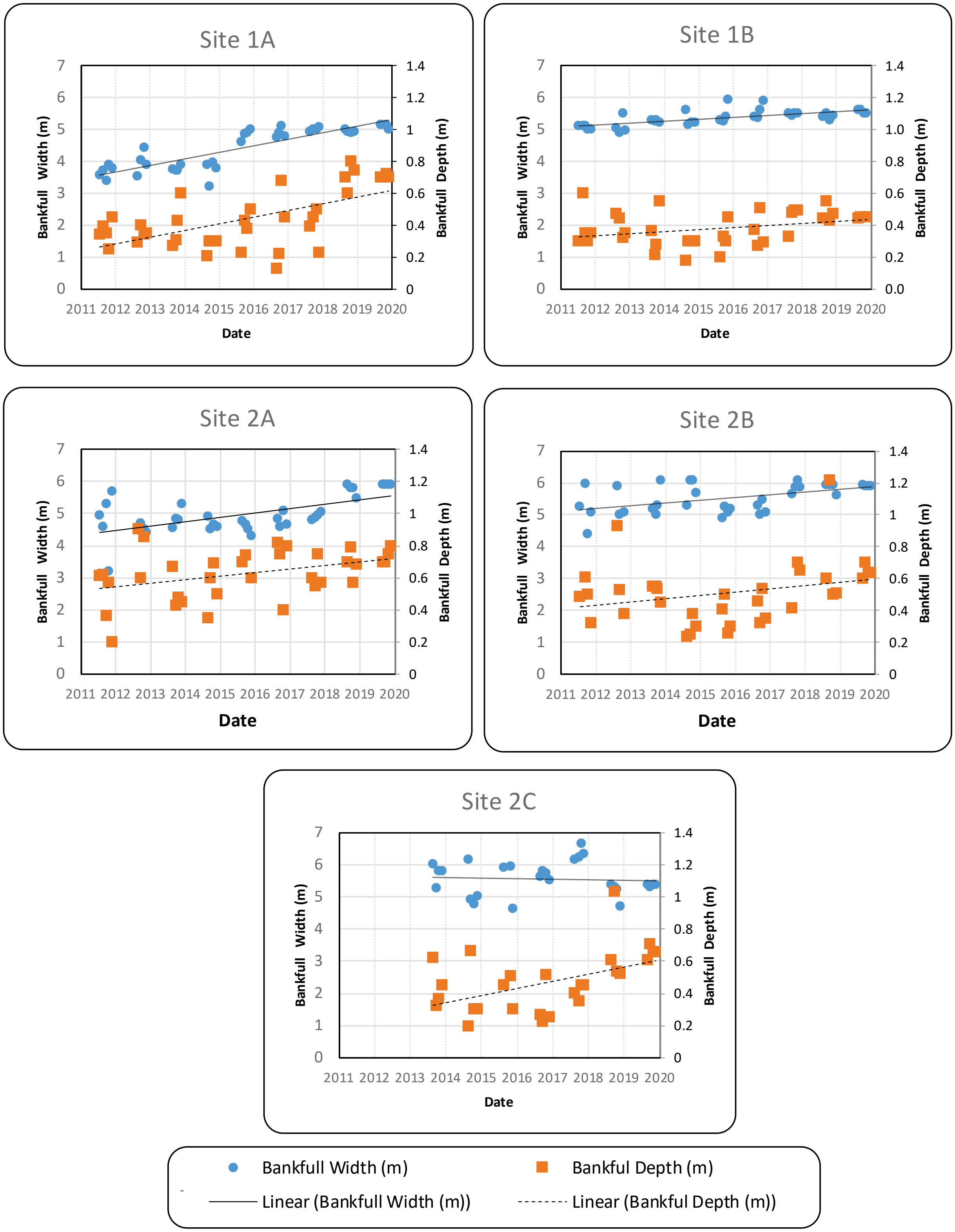


**Figure 3-9 Bankfull Width and Depth at Horn Creek Mesohabitat Sites (2012 to 2020)**

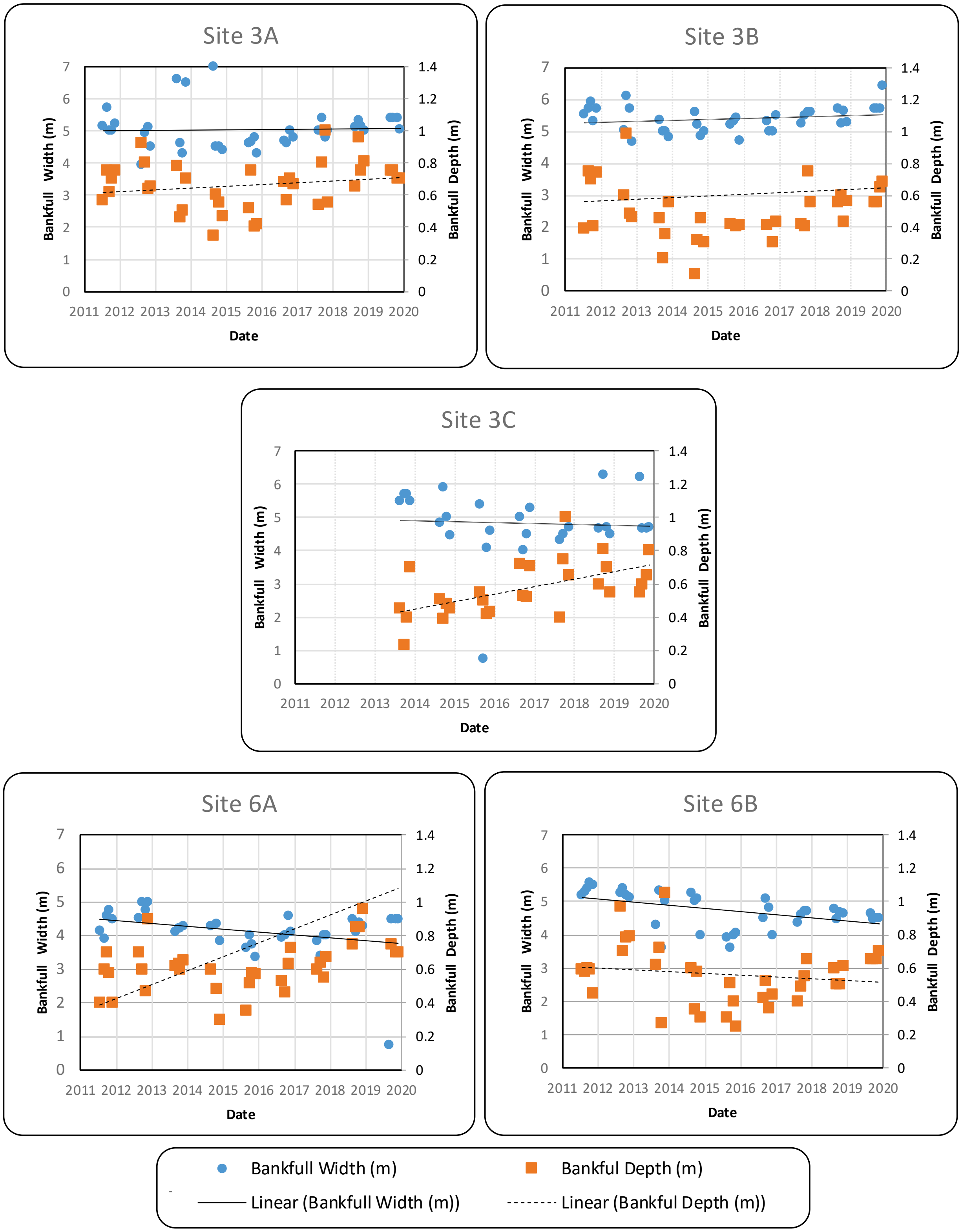


**Figure 3-10 Bankfull Width and Depth at Horn Creek Mesohabitat Sites (2012 to 2020) (Continued)**

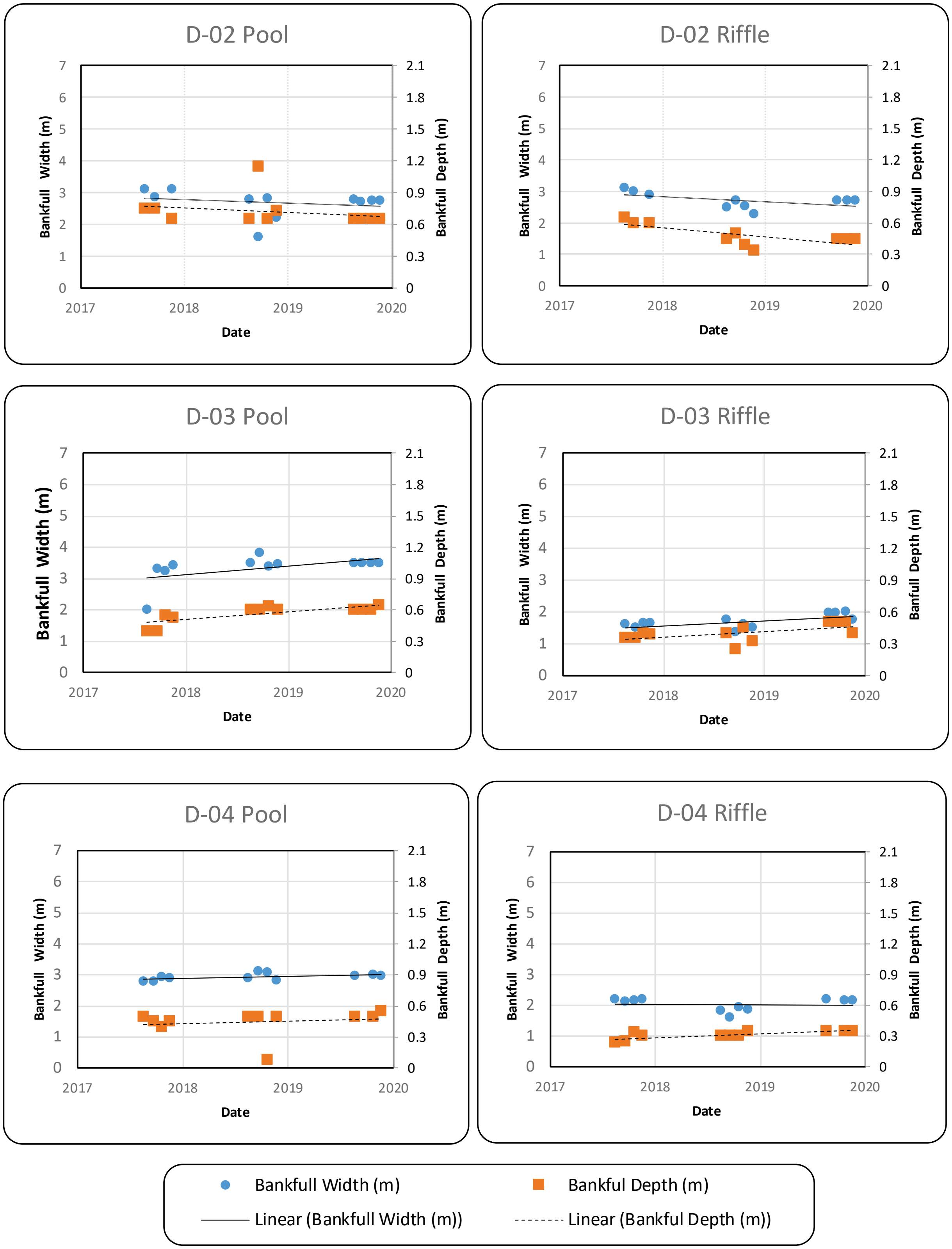


**Figure 3-10 Bankfull Width and Depth at Downes Creek Mesohabitat Sites (2018 to 2020)**

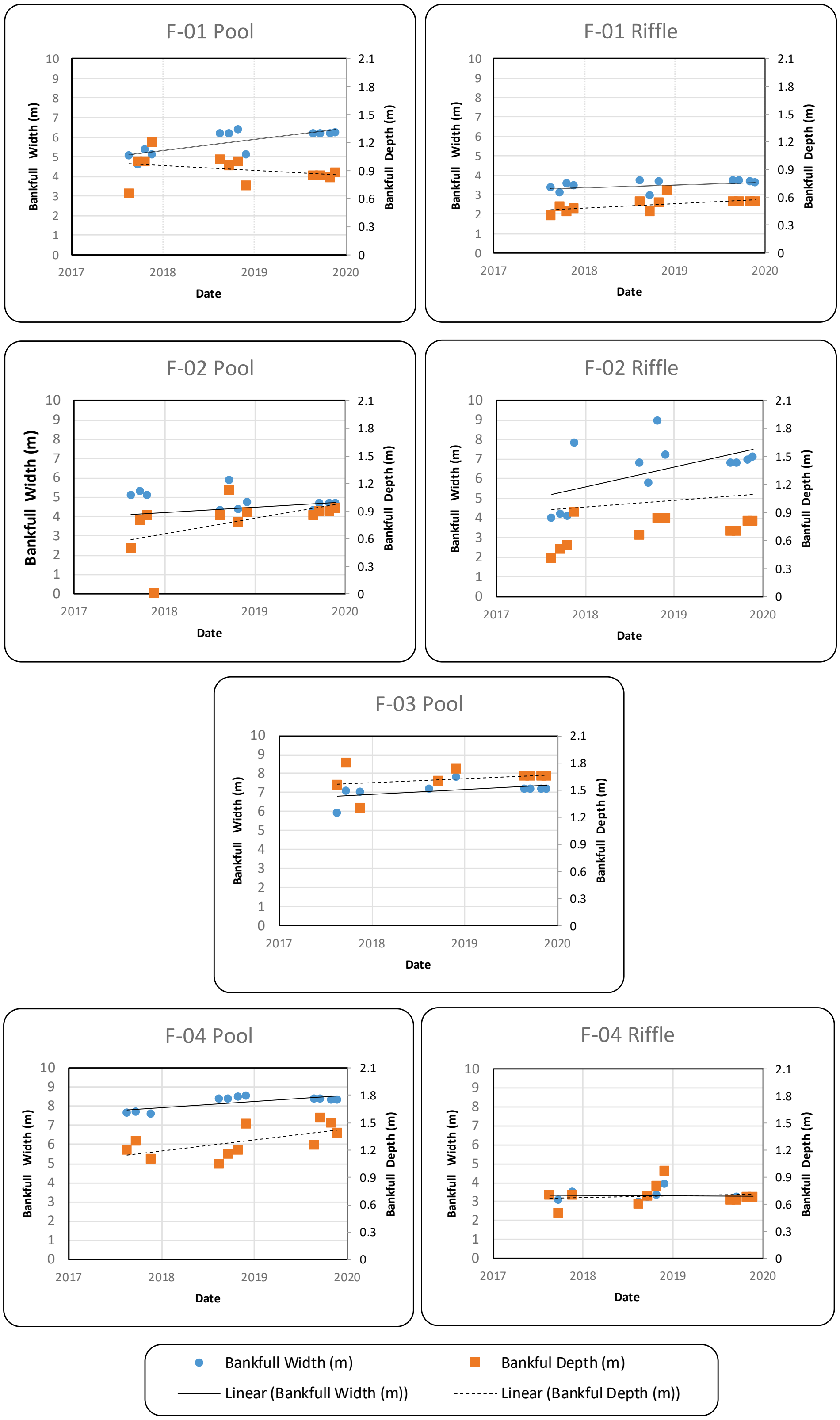


**Figure 3-11 Bankfull Width and Depth at Fishtrap Creek Mesohabitat Sites (2018 to 2020)**

## 3.6 Successes, Challenges and Suggested Changes

Mesohabitat site F-03 was influenced by beaver activity during the entirety of the 2020 monitoring period and was backwatered by downstream dams. F-03 was too deep to wade to collect physical channel measurements during all site visits. Beaver dam removals will need to be considered when comparing year to year mesohabitat measurements for this site. ENKON recommends that an F-03 riffle site be added if beaver activity stops in the area in future. Field staff will continue to monitor the status of beaver activity. Additionally, the beaver activity has made site access difficult due to bank burrowing. The resulting holes are usually obscured by overgrown reed canarygrass (*Phalaris arundinacea*) and present a potential safety hazard to site monitors.

Beaver activity also began occurring at F-02-riffle during 2020, changing the site over the monitoring season. F-02 experiences very low flow velocity and had an increased bankfull width compared with the previous monitoring seasons.

A storm event between the August 2020 and September 2020 monitoring visits changed substrate and cover composition at Site 1 (A and B), Site 2A (pool), Site 3C (pool), Site 6 (A and B), Site 5 (all sites), D-02 (riffle), and F-02 (pool). Additionally, the storm blew out the mesohabitat bank markers at Site 3C (right bank), 6A (left bank), 4B (right bank), 5D (left bank), F-02 (both markers), and F-04 (left bank). The markers were replaced but might not have been returned to the exact places where they initially were established.

Active wasp nests near the D-04 pool and riffle monitoring sites presented another challenge. Crews were unable to access the sites safely without potentially disturbing the nests. As a result, no data were collected in August 2020, but data collection resumed in September when the nests became inactive.

# 4.0 GROUNDWATER PROGRAM

## 4.1 Well Water Quality Monitoring

### 4.1.1 Background

During installation of the mitigation wells in summer 2011, Hemmera investigated groundwater quality in comparison with existing background surface water quality in the receiving waters of Horn Creek and Boa Brook. No constituents of potential concern (COPC) were identified as a result of potential groundwater inputs into Horn Creek and Boa Brook (Hemmera, 2011c). However, the report recommended that additional samples from the mitigation and other water wells within the same aquifer be taken to determine the range of arsenic and fluoride concentrations. Subsequent data analysis showed a potential concern with arsenic in Allen Park mitigation well, which discharges to Boa Brook (ENKON, 2016).

### 4.1.2 Testing Program

The mitigation wells and are tested monthly for most of the same parameters as the surface water monitoring sites. Testing of the mitigation well for Fishtrap Creek began in 2019. Abbotsford also monitors water quality in 19 drinking water wells, of which nine are considered representative for comparison with the mitigation wells. The representative wells were the four Bevan Wells plus Marshall #1, Marshall #3, McConnell, Townline #1, and Townline #2 (Figure 4-1).

### 4.1.3 Groundwater Quality Results

Table 4-1 shows average water quality in the Allen Park mitigation well for Years 2 through 10. The results are compared with water quality guidelines for protection of aquatic life to illustrate the implications of this well's discharging to Boa Brook. The Allen Park well had consistently elevated arsenic concentrations. Yearly average arsenic concentrations ranged from 15.1 µg/L to 16.9 µg/L or over 3 times the 5-µg/L water quality guideline. Fluoride concentrations in this well were consistently above the 0.12-mg/L CCME guideline but met the current BC guideline, 0.4 mg/L to >1.0 mg/L, depending upon hardness (MoE, 2017). In addition, average phosphorus concentrations in the Allen Park well have consistently been above the 0.03-mg/L water quality objective for the Sumas River.

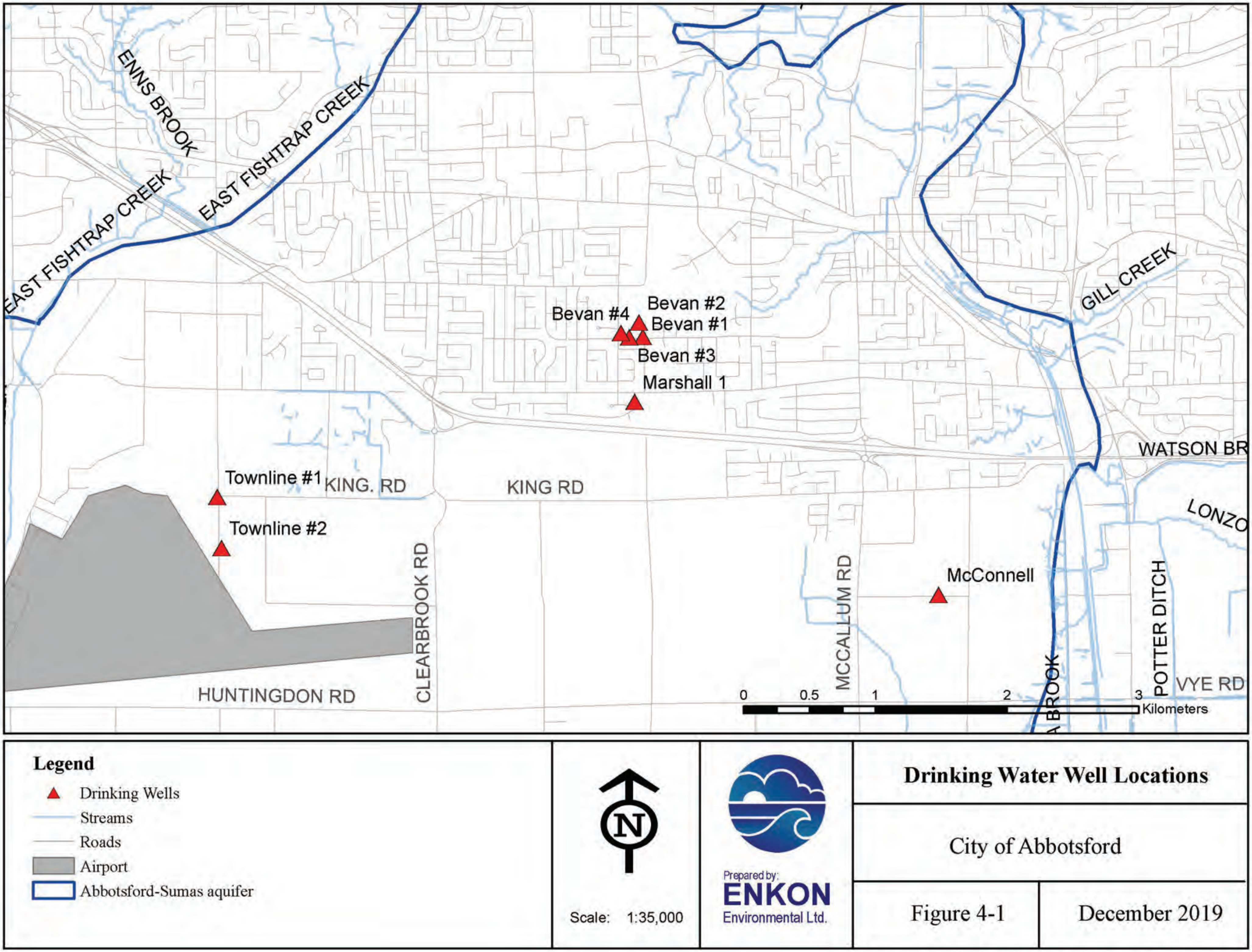


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Table 4-1 Average Water Quality of the Allen Park Mitigation Well (Year 2 – Year 10)

| Parameter | Units | Average | | | | | | | | | Guidelines for Freshwater Aquatic Life | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | CCME | BCWQG | SSWQG |
| pH | pH | 8.17 | 8.33 | 8.33 | 8.30 | 8.21 | 8.29 | 8.48 | 8.47 | 8.45 | 6.5 to 9.0 | 6.5 to 9.0 | 6.5 to 9.0 |
| Ammonia (N) | mg/L | 0.361 | 0.105 | 0.120 | 0.193 | 0.199 | 0.232 | N/A | 0.123 | 0.120 | See Appendix | | |
| Total Phosphorous (P) | mg/L | 0.182 | 0.186 | 0.175 | 0.149 | 0.149 | 0.151 | N/A | 0.195 | 0.209 | See Appendix | | 0.03 |
| Nitrate (N) | mg/L | 0.02 | 0.002 | < | < | < | 0.358 | < | < | < | 13 (long term) | 3 (long term) | 2.93 |
| Nitrite (N) | mg/L | 0.005 | 0.001 | < | < | < | < | < | < | < | 0.06 | See Appendix | 0.02 |
| Total Hardness ($CaCO_3$) | mg/L | 31.5 | 40.6 | 43.1 | 56.1 | 58.0 | 62.2 | 55.7 | 56.3 | 52.4 | | | |
| Fluoride (F) | mg/L | 0.178 | 0.178 | 0.150 | 0.147 | 0.154 | 0.189 | 0.204 | 0.207 | 0.210 | 0.12 | See Appendix | |
| Total Aluminum (Al) | µg/L | 4.00 | 2.18 | 4.03 | 1.58 | < | 4.3 | 5.1 | 4.3 | 3.4 | See Appendix | See Appendix | |
| Total Antimony (Sb) | µg/L | 0.4 | < | 0.025 | < | 0.117 | < | < | < | < | | 9 (Sb III) | |
| Total Arsenic (As) | µg/L | 15.5 | 16.1 | 16.3 | 16.6 | 16.5 | 15.1 | 16.4 | 16.6 | 16.9 | 5 | 5 | |
| Total Barium (Ba) | µg/L | 12.3 | 15.5 | 17.2 | 23.6 | 26.1 | 24.9 | 25.6 | 25.1 | 24.0 | | 1000 | |
| Total Beryllium (Be) | µg/L | 0.08 | < | < | N/A | N/A | N/A | < | < | < | | 0.13 | |
| Total Bismuth (Bi) | µg/L | 1 | < | < | N/A | N/A | N/A | < | < | < | | | |
| Total Boron (B) | µg/L | 120 | 133 | 115 | 167 | 166 | 155 | 173 | 159 | 166 | 1500 (long term) | 1200 | |
| Total Cadmium (Cd) | µg/L | 0.011 | 0.003 | 0.001 | 0.001 | 0.004 | 0.003 | 0.0053 | 0.0050 | 0.015 | See Appendix | See Appendix | |
| Total Chromium (Cr) | µg/L | 0.80 | < | < | < | 0.167 | 0.592 | 0.80 | 0.70 | 0.47 | 1 (Cr VI), 8.9 (Cr III) | | See Appendix |
| Total Cobalt (Co) | µg/L | 0.5 | < | < | N/A | N/A | N/A | < | 0.233 | 0.133 | | 110 | |
| Total Copper (Cu) | µg/L | 0.388 | 0.418 | 0.600 | 0.675 | 0.717 | 0.961 | 1.03 | 0.885 | 0.548 | See Appendix | | See Appendix |
| Total Iron (Fe) | µg/L | 20.9 | 23.9 | 32.3 | 52.5 | 35.0 | 32.2 | 26.8 | 26.1 | 20.1 | 300 | 1000 | |
| Total Lead (Pb) | µg/L | 0.464 | 0.152 | 0.078 | 0.142 | 0.175 | 0.210 | 0.423 | 0.357 | 0.187 | See Appendix | See Appendix | See Appendix |
| Total Lithium (Li) | µg/L | 5.0 | < | < | N/A | N/A | N/A | 1.0 | 1.0 | 1.4 | | | |
| Total Manganese (Mn) | µg/L | 10.2 | 13 | 15.4 | 20.3 | 21 | 18.7 | 19.4 | 19.0 | 18.0 | | See Appendix | |
| Total Mercury (Hg) | µg/L | 0.026 | < | < | < | < | < | N/A | 0.0051 | 0.0040 | 0.026 | | |
| Total Molybdenum (Mo) | µg/L | 3.46 | 4.29 | 3.83 | N/A | N/A | N/A | 7.73 | 7.54 | 7.91 | 73 | 2000 | |
| Total Nickel (Ni) | µg/L | 1 | < | 0.025 | 0.083 | 0.292 | 0.214 | 1.02 | 0.833 | 0.667 | See Appendix | See Appendix | |
| Total Selenium (Se) | µg/L | 0.08 | < | < | < | < | 0.106 | < | 0.050 | 0.067 | 1 | 1 | |
| Total Silver (Ag) | µg/L | 0.016 | < | < | < | < | < | < | < | < | 0.25 | See Appendix | |
| Total Strontium (Sr) | µg/L | 137 | 57.0 | 57.6 | N/A | N/A | N/A | 77.9 | 84.2 | 77.9 | | | |
| Total Thallium (Tl) | µg/L | 0.04 | 0.017 | < | N/A | N/A | N/A | < | < | < | 0.8 | 0.3 | |
| Total Tin (Sn) | µg/L | 5.0 | 1.7 | < | N/A | N/A | N/A | 0.4 | < | < | | | |
| Total Titanium (Ti) | µg/L | 4.0 | 1.7 | < | N/A | N/A | N/A | < | < | < | | | |
| Total Uranium (U) | µg/L | 0.08 | < | 0.01 | 0.06 | 0.07 | 0.08 | 0.165 | 0.153 | 0.073 | 15 (long term) | 8.5 | |
| Total Vanadium (V) | µg/L | 4.0 | < | < | N/A | N/A | N/A | < | < | < | | | |
| Total Zinc (Zn) | µg/L | 4.22 | < | 2.72 | 0.42 | 0.67 | 5.88 | < | 4.33 | 3.73 | 30 | See Appendix | See Appendix |
| Total Zirconium (Zr) | µg/L | 0.5 | < | < | N/A | N/A | N/A | < | < | < | | | |
| Total Calcium (Ca) | mg/L | 6.69 | 8.73 | 8.81 | 11.6 | 11.8 | 13.3 | 11.7 | 11.7 | 11.1 | | | |
| Total Magnesium (Mg) | mg/L | 3.60 | 4.52 | 5.12 | 6.58 | 6.95 | 7.02 | 6.48 | 6.55 | 5.96 | | | |
| Total Potassium (K) | mg/L | 4.60 | 5.15 | 5.23 | N/A | N/A | N/A | 6.45 | 6.36 | 6.15 | | | |
| Total Silicon (Si) | mg/L | 6.87 | 7.04 | 6.99 | N/A | N/A | N/A | 7.33 | 7.32 | 7.46 | | | |
| Total Sodium (Na) | mg/L | 43.0 | 49.1 | 41.0 | N/A | N/A | N/A | 67.2 | 66.7 | 68.1 | | | |
| Total Sulphur (S) | mg/L | 5.46 | 6.44 | 5.80 | N/A | N/A | N/A | 7.98 | 8.02 | 8.00 | | | |

< - Not detected

N/A - Not analyzed

Due to concerns about the arsenic concentrations in the Allen Park mitigation well and their potential effects on aquatic life in Boa Brook, the City commissioned a risk assessment. Based on a comparison of the maximum groundwater arsenic concentrations to selected toxicity data, the assessment concluded that risks related to arsenic exposure would not be expected even if receptors in Boa Brook were exposed to undiluted groundwater (SLR Consulting (Canada) Ltd., 2018).

Average water quality in the Garibaldi Park mitigation well is presented in Table 4-2. The water quality of this well was good with annual average arsenic concentrations ranging from 0.6 µg/L to 1.9 µg/L and fluoride concentrations ranging from <0.020 mg/L to 0.045 mg/L.

Table 4-3 shows the average water quality of the Fishtrap Creek mitigation well. The water quality in this well was generally good with an average arsenic concentration in 2020-2021 of 1.03 µg/L and an average fluoride concentration of 0.055 mg/L. All other parameters except total phosphorus had concentrations below guidelines to protect aquatic life. However, the average total phosphorus concentration, 0.048 mg/L, was above the 0.03-mg/L water quality objective for the Sumas River. The total phosphorus concentration in this well in 2019-2020 also was above the objective for the Sumas River.

The results for the nine drinking water wells are presented for comparison with water quality of the mitigation wells (Tables 4-4 and 4-5). 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 most of the drinking water wells than in the mitigation wells. This also was the case in Year 9.

## 4.2 Groundwater Level Program

The groundwater level monitoring program consisted of three components:

- Continuous (real-time through the City's Supervisory Control and Data Acquisition (SCADA) system) monitoring of water levels in the Bevan Avenue Wells and the mitigation wells;
- Measurements of water levels in seven existing[6] monitoring wells;
- Recording of water levels in Judson Lake and Laxton Lake.

### 4.2.1 Site Description

Groundwater levels were measured at seven monitoring well locations. The M14-2 (near H-02) and M14-1 (near H-03) monitoring wells were added in February 2014. The wells are described in Table 4-6 below and shown in Figure 4-2. Another groundwater well, TW05-1, located in Highland Park, was originally included in the OEMP groundwater monitoring program. This well

[6] Plus analysis of data from wells monitored by other agencies

**Table 4-2 Average Water Quality of the Garibaldi Park Mitigation Well (Year 2 – Year 10)**

| Parameter: | Units: | Average | | | | | | | | | Guidelines for Freshwater Aquatic Life | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year 2 | Year 3 | Year 4 | Year 5 | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 | CCME | BCWQG | SSWQG |
| pH | pH | 7.81 | 7.81 | 7.63 | 7.18 | 7.11 | 7.43 | 7.66 | 7.70 | 7.57 | 6.5 to 9.0 | 6.5 to 9.0 | 6.5 to 9.0 |
| Ammonia (N) | mg/L | 0.007 | 0.062 | 0.016 | 0.086 | 0.092 | 0.127 | N/A | 0.0057 | 0.0092 | See Appendix | | |
| Total Phosphorous (P) | mg/L | 0.006 | 0.006 | 0.015 | 0.036 | 0.00675 | 0.021 | N/A | 0.0073 | 0.0061 | See Appendix | | 0.03 |
| Nitrate (N) | mg/L | 2.32 | 2.25 | 2.31 | 2.24 | 2.23 | 2.17 | 2.15 | 2.13 | 2.03 | 13 (long term) | 3 (long term) | 2.93 |
| Nitrite (N) | mg/L | 0.005 | < | < | < | < | < | < | 0.0010 | 0.0013 | 0.06 | See Appendix | 0.02 |
| Total Hardness ($CaCO_3$) | mg/L | 93 | 102 | 104 | 106 | 109 | 104 | 110 | 113 | 111 | | | |
| Fluoride (F) | mg/L | 0.025 | 0.024 | 0.025 | < | < | 0.045 | 0.020 | 0.021 | 0.030 | 0.12 | See Appendix | |
| Total Aluminum (Al) | µg/L | 4.28 | 1.41 | 1.34 | 0.58 | 2.42 | 1.55 | < | 4.4 | 3.0 | See Appendix | See Appendix | |
| Total Antimony (Sb) | µg/L | 0.4 | < | 0.017 | < | 0.017 | 0.048 | < | < | < | | 9 (SbIII) | |
| Total Arsenic (As) | µg/L | 0.6 | 0.7 | 0.7 | 1.9 | 0.7 | 1.8 | 0.70 | 0.630 | 0.632 | 5 | 5 | |
| Total Barium (Ba) | µg/L | 8.3 | 8.7 | 9.3 | 10.6 | 9.8 | 11.6 | 17.5 | 16.7 | 9.63 | | 1000 | |
| Total Beryllium (Be) | µg/L | 0.08 | < | < | N/A | N/A | N/A | < | < | < | | 0.13 | |
| Total Bismuth (Bi) | µg/L | 1 | < | < | N/A | N/A | N/A | < | < | < | | | |
| Total Boron (B) | µg/L | 40 | < | 7.42 | 34.5 | 23.3 | 34.5 | 78.0 | 70.8 | 25.0 | 1500 (long term) | 1200 | |
| Total Cadmium (Cd) | µg/L | 0.023 | 0.020 | 0.019 | 0.017 | 0.043 | 0.021 | 0.022 | 0.021 | 0.020 | See Appendix | See Appendix | |
| Total Chromium (Cr) | µg/L | 0.820 | < | 0.375 | 0.933 | 1.24 | 1.23 | 1.03 | 0.953 | 0.859 | 1 (Cr VI),<br>8.9 (Cr III) | | See Appendix |
| Total Cobalt (Co) | µg/L | 0.5 | < | < | N/A | N/A | N/A | 0.26 | 0.233 | 0.133 | | 110 | |
| Total Copper (Cu) | µg/L | 2.62 | 2.69 | 2.77 | 3.33 | 2.83 | 2.98 | 2.87 | 2.99 | 2.48 | See Appendix | | See Appendix |
| Total Iron (Fe) | µg/L | 203 | 104 | 107 | 58 | 56 | 41 | 29 | 28 | 28 | 300 | 1000 | |
| Total Lead (Pb) | µg/L | 1.26 | 0.518 | 0.645 | 0.625 | 0.550 | 1.84 | 1.59 | 0.474 | 0.293 | See Appendix | See Appendix | See Appendix |
| Total Lithium (Li) | µg/L | 5.0 | < | < | N/A | N/A | N/A | 1.7 | 1.7 | 1.8 | | | |
| Total Manganese (Mn) | µg/L | 1.5 | 0.6 | 0.9 | 2.43 | 1.00 | 2.58 | <0.30 | 0.29 | 0.54 | | See Appendix | |
| Total Mercury (Hg) | µg/L | 0.026 | < | 0.002 | < | < | < | N/A | 0.0053 | 0.0040 | 0.026 | | |
| Total Molybdenum (Mo) | µg/L | 1 | < | < | N/A | N/A | N/A | <0.77 | 0.699 | 0.412 | 73 | 2000 | |
| Total Nickel (Ni) | µg/L | 1.5 | 0.708 | 1.16 | 1.07 | 1.03 | 0.79 | <1.4 | 0.85 | 0.82 | See Appendix | See Appendix | |
| Total Selenium (Se) | µg/L | 0.486 | 0.473 | 0.492 | 0.333 | 0.389 | 0.556 | 0.510 | 0.554 | 0.516 | 1 | 1 | |
| Total Silver (Ag) | µg/L | 0.016 | 0.003 | 0.004 | < | < | < | < | < | < | 0.25 | See Appendix | |
| Total Strontium (Sr) | µg/L | 110 | 120 | 123 | N/A | N/A | N/A | 135 | 140 | 138 | | | |
| Total Thallium (Tl) | µg/L | 0.04 | < | < | N/A | N/A | N/A | < | < | < | 0.8 | 0.3 | |
| Total Tin (Sn) | µg/L | 5 | < | < | N/A | N/A | N/A | 0.45 | < | < | | | |
| Total Titanium (Ti) | µg/L | 4 | < | < | N/A | N/A | N/A | < | < | < | | | |
| Total Uranium (U) | µg/L | 0.136 | 0.161 | 0.154 | 0.158 | 0.168 | 0.149 | 0.19 | 0.18 | 0.14 | 15 (long term) | 8.5 | |
| Total Vanadium (V) | µg/L | 4 | < | < | N/A | N/A | N/A | 1.26 | < | 2.46 | | | |
| Total Zinc (Zn) | µg/L | 10.8 | 12.1 | 14.5 | 17.4 | 19.6 | 16.8 | 27.5 | 14.0 | 15.3 | 30 | See Appendix | See Appendix |
| Total Zirconium (Zr) | µg/L | 0.5 | < | < | N/A | N/A | N/A | < | < | < | | | |
| Total Calcium (Ca) | mg/L | 25.4 | 28.1 | 28.6 | 28.9 | 29.7 | 28.2 | 30.2 | 31.1 | 30.5 | | | |
| Total Magnesium (Mg) | mg/L | 7.16 | 7.63 | 7.83 | 8.08 | 8.37 | 8.25 | 8.40 | 8.64 | 8.44 | | | |
| Total Potassium (K) | mg/L | 1.2 | 1.31 | 1.31 | N/A | N/A | N/A | <1.83 | 1.78 | 1.33 | | | |
| Total Silicon (Si) | mg/L | 10.7 | 11.5 | 11.6 | N/A | N/A | N/A | 11.3 | 11.2 | 11.1 | | | |
| Total Sodium (Na) | mg/L | 5.89 | 57.4 | 6.43 | N/A | N/A | N/A | 6.87 | 7.06 | 6.91 | | | |
| Total Sulphur (S) | mg/L | 4.2 | 4.59 | 4.75 | N/A | N/A | N/A | 5.02 | 4.99 | 5.07 | | | |

< - Not detected

N/A - Not analyzed

**Table 4-3 Average Water Quality of the Fishtrap Creek Mitigation Well**

| Parameter: | Units: | 2019 - 2020 | 2020 - 2021 | Guidelines for Freshwater Aquatic Life | | |
|---|---|---|---|---|---|---|
| | | | | CCME | BCWQG | SSWQG |
| pH | pH | 8.27 | 8.25 | 6.5 to 9.0 | 6.5 to 9.0 | 6.5 to 9.0 |
| Ammonia (N) | mg/L | 0.156 | 0.154 | See Appendix | | |
| Total Phosphorous (P) | mg/L | 0.060 | 0.048 | See Appendix | | 0.03 |
| Nitrate (N) - Calculated | mg/L | < | < | 13 (long term) | 3 (long term) | 2.93 |
| Nitrite (N) | mg/L | < | < | 0.06 | See Appendix | 0.02 |
| Total Hardness ($CaCO_3$) | mg/L | 108 | 113 | | | |
| Fluoride (F) | mg/L | 0.055 | 0.055 | 0.12 | See Appendix | |
| Total Aluminum (Al) | µg/L | 3.0 | 3.0 | See Appendix | See Appendix | |
| Total Antimony (Sb) | µg/L | < | < | | 9 (SbIII) | |
| Total Arsenic (As) | µg/L | 1.06 | 1.03 | 5 | 5 | |
| Total Barium (Ba) | µg/L | 20.3 | 21.1 | | 1000 | |
| Total Beryllium (Be) | µg/L | < | < | | 0.13 | |
| Total Bismuth (Bi) | µg/L | < | < | | | |
| Total Boron (B) | µg/L | 17.1 | 27.8 | 1500 (long term) | 1200 | |
| Total Cadmium (Cd) | µg/L | < | < | See Appendix | See Appendix | |
| Total Chromium (Cr) | µg/L | < | <<br>< | 1 (Cr VI),<br>8.9 (Cr III) | | See Appendix |
| Total Cobalt (Co) | µg/L | < | < | | 110 | |
| Total Copper (Cu) | µg/L | < | < | See Appendix | | See Appendix |
| Total Iron (Fe) | µg/L | 58 | 92 | 300 | 1000 | |
| Total Lead (Pb) | µg/L | 0.065 | 0.11 | See Appendix | See Appendix | See Appendix |
| Total Lithium (Li) | µg/L | 1.03 | 1.35 | | | |
| Total Manganese (Mn) | µg/L | 96.4 | 100 | | See Appendix | |
| Total Mercury (Hg) | µg/L | < | < | 0.026 | | |
| Total Molybdenum (Mo) | µg/L | 0.645 | 0.748 | 73 | 2000 | |
| Total Nickel (Ni) | µg/L | < | < | See Appendix | See Appendix | |
| Total Selenium (Se) | µg/L | < | < | 1 | 1 | |
| Total Silver (Ag) | µg/L | < | < | 0.25 | See Appendix | |
| Total Strontium (Sr) | µg/L | 106 | 122 | | | |
| Total Thallium (Tl) | µg/L | < | < | 0.8 | 0.3 | |
| Total Tin (Sn) | µg/L | < | < | | | |
| Total Titanium (Ti) | µg/L | < | 1.88 | | | |
| Total Uranium (U) | µg/L | N/A | < | 15 (long term) | 8.5 | |
| Total Vanadium (V) | µg/L | < | < | | | |
| Total Zinc (Zn) | µg/L | 5.2 | 5.4 | 30 | See Appendix | See Appendix |
| Total Zirconium (Zr) | µg/L | < | < | | | |
| Total Calcium (Ca) | mg/L | 29.5 | 31.1 | | | |
| Total Magnesium (Mg) | mg/L | 8.43 | 8.68 | | | |
| Total Potassium (K) | mg/L | 2.76 | 2.74 | | | |
| Total Silicon (Si) | mg/L | 12.1 | 12.0 | | | |
| Total Sodium (Na) | mg/L | 11.9 | 11.1 | | | |
| Total Sulphur (S) | mg/L | 4.69 | 4.85 | | | |

< - Not detected

N/A - Not analyzed

Table 4-4 Average Water Quality of Selected Drinking Water Wells (Year 10)

| Parameter | Units | Bevan #1 | Bevan #2 | Bevan #3 | Bevan #4 | Marshall #1 | Marshall #3 | Townline #1 | Townline #2 | McConnell |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | pH | 7.31 | 7.18 | N/A | 7.02 | 8.14 | 7.56 | N/A | 6.98 | 7.91 |
| Alkalinity (total, as $CaCO_3$) | mg/L | 52.4 | 54.6 | N/A | 38.4 | 105 | 99.175 | N/A | 44.1 | 76.2 |
| Conductivity | µS/cm | 228 | 248 | N/A | 217 | 349 | 357 | N/A | 182 | 339 |
| Hardness (total, as $CaCO_3$) | mg/L | 85.9 | 83.9 | 82.6 | 77.0 | 139 | 135 | 74.1 | 67.3 | 127 |
| Colour | CU | <5 | <5 | N/A | <5 | <5 | <5 | N/A | <5 | <5 |
| Fluoride | mg/L | <0.033 | <0.033 | <0.029 | <0.030 | <0.040 | <0.051 | 0.020 | <0.031 | <0.047 |
| Sulphate | mg/L | 12.6 | 22.5 | N/A | 11.6 | 26.2 | 29.7 | N/A | 14.6 | 64.1 |
| Turbidity | NTU | <0.1 | <0.1 | N/A | <0.1 | 0.2 | <0.1 | N/A | <0.1 | 0.14 |
| Nitrate (as N) | mg/L | 3.08 | 2.92 | 2.68 | 2.99 | 0.201 | 0.222 | 5.00 | 3.06 | 1.68 |
| Nitrite (as N) | mg/L | <0.001 | <0.001 | <0.001 | <0.001 | <0.002 | <0.002 | 0.001 | <0.001 | <0.037 |
| Ammonia (total, as N) | mg/L | <0.015 | <0.019 | <0.015 | <0.015 | 0.023 | <0.015 | N/A | <0.015 | <0.020 |
| Total Aluminum (Al) | µg/L | <3.0 | <3.1 | <3.1 | <3.0 | <3.2 | <5.1 | <3.0 | <3.0 | <3.1 |
| Total Antimony (Sb) | µg/L | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.1 | <0.2 | <0.3 |
| Total Arsenic (As) | µg/L | 0.24 | 0.29 | 0.25 | 0.19 | 2.18 | 1.10 | 0.56 | 0.63 | 4.89 |
| Total Barium (Ba) | µg/L | 5.76 | 6.16 | 5.89 | 5.43 | 13.1 | 9.91 | 20.9 | 5.40 | 27.0 |
| Total Beryllium (Be) | µg/L | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Total Bismuth (Bi) | µg/L | <0.37 | <0.37 | <0.24 | <0.37 | <0.24 | <0.37 | <0.50 | <0.37 | <0.37 |
| Total Boron (B) | µg/L | <26 | <26 | <19 | <25 | <25 | <29 | 21 | <32 | <33 |
| Total Cadmium (Cd) | µg/L | 0.0233 | 0.0223 | 0.0204 | 0.0240 | 0.0244 | 0.0287 | 0.0337 | 0.0234 | <0.011 |
| Total Chromium (Cr) | µg/L | <0.47 | <0.51 | <0.37 | <0.48 | <0.28 | <0.44 | 0.14 | <0.47 | <0.41 |
| Total Cobalt (Co) | µg/L | <0.13 | <0.13 | <0.12 | <0.13 | <0.12 | <0.32 | <0.1 | <0.13 | <0.13 |
| Total Copper (Cu) | µg/L | 12.8 | 13.2 | 24.5 | 20.7 | 5.59 | 1.30 | 12.1 | 8.14 | 4.48 |
| Total Iron (Fe) | µg/L | <79.0 | <37.1 | <41.6 | <21.6 | 81.9 | <26.8 | 27.3 | <37.8 | <22.8 |
| Total Lead (Pb) | µg/L | <0.155 | <0.202 | 1.19 | <0.110 | <0.240 | <0.100 | 0.437 | 0.301 | <0.215 |
| Total Lithium (Li) | µg/L | <1.3 | <1.4 | <1.2 | <1.3 | <2.0 | <1.6 | <1.0 | <1.3 | <1.7 |

**Table 4-4 Average Water Quality of Selected Drinking Water Wells (Year 10)**

| Parameter | Units | Bevan #1 | Bevan #2 | Bevan #3 | Bevan #4 | Marshall #1 | Marshall #3 | Townline #1 | Townline #2 | McConnell |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Mercury (Hg) | µg/L | <3.73 | <1.40 | 2.61 | <1.49 | 10.6 | 30.2 | 86.0 | 5.39 | 17.4 |
| Total Manganese (Mn) | µg/L | <0.0040 | <0.0040 | <0.0044 | <0.0040 | <0.0044 | <0.0040 | <0.0050 | <0.0059 | <0.0040 |
| Total Molybdenum (Mo) | µg/L | <0.42 | <0.44 | <0.29 | <0.40 | 1.55 | 1.87 | 0.25 | <0.54 | 2.10 |
| Total Nickel (Ni) | µg/L | <1.76 | <1.91 | 2.50 | <1.33 | <0.89 | <1.93 | <0.54 | <0.67 | <1.03 |
| Total Selenium (Se) | µg/L | 0.158 | 0.182 | 0.217 | 0.139 | <0.061 | <0.069 | 0.114 | 0.171 | 0.542 |
| Total Silver (Ag) | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Thallium (Tl) | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Tin (Sn) | µg/L | <2 | <2 | <1 | <2 | <1 | <2 | <0.1 | <2 | <2 |
| Total Titanium (Ti) | µg/L | <2 | <2 | <1 | <2 | <1 | <2 | <0.3 | <2 | <2 |
| Total Vanadium (V) | µg/L | <2.2 | <2.3 | <1.6 | <2.2 | <2.2 | <2.4 | <0.56 | <2.3 | <2.3 |
| Total Zinc (Zn) | µg/L | 16.5 | <7.52 | 10.1 | <13.5 | <7.69 | <4.54 | 18.5 | 15.0 | <9.68 |
| Total Zirconium (Zr) | µg/L | <0.17 | <0.17 | <0.18 | <0.17 | <0.18 | <0.17 | <0.2 | <0.17 | <0.17 |
| Total Calcium (Ca) | mg/L | 23.5 | 22.7 | 22.8 | 21.9 | 41.4 | 39.1 | 21.8 | 19.8 | 37.0 |
| Total Magnesium (Mg) | mg/L | 6.51 | 6.30 | 6.21 | 5.37 | 9.06 | 9.04 | 4.76 | 4.34 | 8.38 |
| Total Potassium (K) | mg/L | 1.10 | 1.10 | 1.12 | 1.05 | 2.68 | 2.10 | 3.31 | 1.09 | 3.02 |
| Total Silicon (Si) | mg/L | 11.2 | 11.3 | 11.1 | 11.0 | 7.15 | 7.43 | 8.94 | 9.02 | 7.62 |
| Total Sodium (Na) | mg/L | 8.03 | 7.15 | 7.64 | 7.67 | 17.0 | 14.2 | 8.38 | 7.68 | 15.5 |

Means were calculated by setting concentrations less than the detection limit to the detection limit and showing the mean as “<” the calculated value.

N/A – Not analyzed

Table 4-5 Maximum Concentrations of Water Quality of Selected Drinking Water Wells (Year 10)

| Parameter | Units | Bevan #1 | Bevan #2 | Bevan #3 | Bevan #4 | Marshall #1 | Marshall #3 | Townline #1 | Townline #2 | McConnell |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | pH | 7.31 | 7.18 | N/A | 7.02 | 8.14 | 7.73 | N/A | 6.98 | 7.91 |
| Alkalinity (total, as $CaCO_3$) | mg/L | 52.4 | 54.6 | N/A | 38.4 | 105 | 105 | N/A | 44.1 | 76.2 |
| Conductivity | µS/cm | 228 | 248 | N/A | 217 | 349 | 357 | N/A | 182 | 339 |
| Hardness (total, as $CaCO_3$) | mg/L | 99.0 | 96.8 | 89.0 | 81.3 | 159 | 147 | 78.0 | 71.7 | 133 |
| Colour | CU | <5 | <5 | N/A | <5 | <5 | <5 | N/A | <5 | <5 |
| Fluoride | mg/L | <0.050 | <0.050 | <0.050 | <0.050 | <0.050 | 0.086 | 0.021 | <0.050 | 0.053 |
| Sulphate | mg/L | 12.6 | 22.5 | N/A | 11.6 | 26.2 | 29.7 | N/A | 14.6 | 64.1 |
| Turbidity | NTU | <0.1 | <0.1 | N/A | <0.1 | 0.2 | <0.1 | N/A | <0.1 | 0.14 |
| Nitrate (as N) | mg/L | 3.93 | 3.22 | 3.36 | 3.26 | 0.517 | 0.489 | 5.09 | 3.38 | 4.9 |
| Nitrite (as N) | mg/L | <0.002 | <0.002 | <0.002 | <0.002 | 0.0054 | <0.002 | 0.0014 | <0.002 | 0.095 |
| Ammonia (total, as N) | mg/L | <0.015 | 0.022 | <0.015 | <0.015 | 0.023 | <0.015 | N/A | <0.015 | 0.024 |
| Total Aluminum (Al) | µg/L | <3.0 | 3.6 | 3.4 | <3.0 | 4.2 | 28.9 | <3.0 | <3.0 | 3.6 |
| Total Antimony (Sb) | µg/L | <0.5 | <0.5 | <0.5 | <0.5 | 0.5 | 0.5 | <0.1 | <0.5 | 0.5 |
| Total Arsenic (As) | µg/L | 0.33 | 0.36 | 0.30 | 0.23 | 3.47 | 1.33 | 0.60 | 0.76 | 6.11 |
| Total Barium (Ba) | µg/L | 6.89 | 6.88 | 6.26 | 5.92 | 18.2 | 10.9 | 22.1 | 6.14 | 29.1 |
| Total Beryllium (Be) | µg/L | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Total Bismuth (Bi) | µg/L | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <0.50 | <1.0 | <1.0 |
| Total Boron (B) | µg/L | <50 | <50 | <50 | <50 | <50 | <50 | 23 | <50 | <50 |
| Total Cadmium (Cd) | µg/L | 0.0320 | 0.0296 | 0.0221 | 0.0290 | 0.0297 | 0.0557 | 0.0374 | 0.0270 | 0.0144 |
| Total Chromium (Cr) | µg/L | 1.0 | 1.0 | 1.0 | 1.0 | <1.0 | 1.0 | 0.2 | 1.0 | 1.0 |
| Total Cobalt (Co) | µg/L | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | 1.91 | <0.1 | <0.2 | <0.2 |
| Total Copper (Cu) | µg/L | 40.7 | 54.9 | 94.9 | 102 | 32.6 | 2.17 | 14.2 | 12.2 | 6.68 |
| Total Iron (Fe) | µg/L | 528 | 142 | 125 | 64.0 | 456 | 113 | 50.0 | 188 | 96.0 |
| Total Lead (Pb) | µg/L | 0.369 | 0.956 | 5.56 | 0.200 | 0.421 | <0.20 | 0.491 | 0.887 | 0.301 |
| Total Lithium (Li) | µg/L | 2 | 2 | 2 | <2 | 2.5 | 2 | <1 | <2 | 2 |

Table 4-5 Maximum Concentrations of Water Quality of Selected Drinking Water Wells (Year 10)

| Parameter | Units | Bevan #1 | Bevan #2 | Bevan #3 | Bevan #4 | Marshall #1 | Marshall #3 | Townline #1 | Townline #2 | McConnell |
|---|---|---|---|---|---|---|---|---|---|---|
| Total Mercury (Hg) | µg/L | 13.4 | 4.64 | 8.10 | 4.60 | 40.8 | 168 | 89.7 | 11.9 | 21.1 |
| Total Manganese (Mn) | µg/L | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | 0.0286 | <0.005 |
| Total Molybdenum (Mo) | µg/L | 1.00 | 1.00 | 1.00 | 1.00 | 1.93 | 2.01 | 0.26 | 1.00 | 2.40 |
| Total Nickel (Ni) | µg/L | 4.62 | 4.29 | 4.60 | 4.30 | 1.33 | 9.93 | 0.61 | 1.00 | 1.74 |
| Total Selenium (Se) | µg/L | 0.239 | 0.263 | 0.358 | 0.211 | 0.100 | 0.100 | 0.123 | 0.223 | 1.18 |
| Total Silver (Ag) | µg/L | <0.02 | <0.02 | 0.026 | <0.02 | <0.02 | <0.02 | <0.01 | <0.02 | <0.02 |
| Total Thallium (Tl) | µg/L | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Total Tin (Sn) | µg/L | <5 | 5 | 6.7 | <5 | <5 | <5 | <0.1 | <5 | <5 |
| Total Titanium (Ti) | µg/L | <5 | <5 | <5 | <5 | <5 | <5 | <0.3 | <5 | <5 |
| Total Vanadium (V) | µg/L | <5 | <5 | <5 | <5 | <5 | <5 | 0.67 | <5 | <5 |
| Total Zinc (Zn) | µg/L | 39.2 | 15.1 | 13.3 | 32.3 | 15.6 | 8.3 | 24.8 | 29.4 | 17.5 |
| Total Zirconium (Zr) | µg/L | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| Total Calcium (Ca) | mg/L | 27.8 | 26 | 24.7 | 23.4 | 47.7 | 43.4 | 22.8 | 20.9 | 38.8 |
| Total Magnesium (Mg) | mg/L | 7.20 | 7.20 | 6.63 | 5.85 | 9.66 | 9.88 | 5.08 | 4.77 | 9.11 |
| Total Potassium (K) | mg/L | 1.21 | 1.20 | 1.16 | 1.12 | 3.43 | 2.29 | 3.52 | 1.22 | 3.40 |
| Total Silicon (Si) | mg/L | 12.0 | 12.3 | 11.5 | 11.6 | 7.92 | 8.66 | 9.27 | 9.84 | 9.76 |
| Total Sodium (Na) | mg/L | 9.21 | 8.09 | 8.14 | 8.11 | 22.3 | 15.2 | 8.65 | 9.4 | 17.4 |

**Table 4-6 Groundwater Monitoring Sites**

| Site ID | Description | Type | UTM Northing | UTM Easting |
|---|---|---|---|---|
| TW06-1 | Gladwin and Bevan Avenue, Bevan Avenue Wells site in Centennial Park. | Monitoring well | 5432370 | 549965 |
| M14-2 (H-02 Monitoring Well) | Maclure Road, in center of path where Horn Creek meets Maclure Road | Monitoring well | 5434385 | 550857 |
| M14-1 (H-03 Monitoring Well) | In path directly beside H-03 monitoring site. | Monitoring well | 5434038 | 550246 |
| Exhibition Park | Trethewey and Maclure, Exhibition Park in southeast corner of parking lot 1, near washrooms. | Monitoring well | 5434623 | 549342 |
| Columbia Bible College | 2940 Clearbrook Road, at George Ferguson Way. Well is in basement of the dormitory. | Monitoring well | 5433888 | 548408 |
| Heritage RV | 33120 Huntington Road. Well is flush-mounted in front yard. | Monitoring well | 5429553 | 550705 |
| DND | Townline and King, just inside fence in clump of trees. Well is about a 0.5 m stickup. Climate control transducer is located here as well. | Monitoring well | 5431067 | 546765 |
| Bevan Avenue Wells | Gladwin and Bevan Avenue, Bevan Avenue Wells site in Centennial Park. | SCADA | 5432370 | 549965 |
| Boa Brook mitigation well | Allan Park, George Ferguson Way and Fuller Street | SCADA | 5433505 | 550917 |
| Horn Creek mitigation well | Garibaldi Park, Gladwin and Dahlstrom Place | SCADA | 5433976 | 549978 |
| Fishtrap Creek Mitigation Well | West side of Deacon Street between 2669 and2595 and above the north bank of Fishtrap Creek. | SCADA | 5433235 | 546217 |

DWG. NUMBER: K:\3239\Cadd\3239-004.dwg (Fig 4-2)

## SURFICIAL GEOLOGY UNITS

**SALISH SEDIMENTS**

| | |
|---|---|
| SAb,c | LOWLAND PEAT<br>With organic silt loam, and silty loam. Up to 14m thick; overlies unit Fg and Fh. |
| SAe | UPLAND PEAT<br>Up to 8m or more thick. |
| SAh | STREAM DEPOSITS<br>Lowland stream channel fill, overbank sandy loam to clay loam. Also some organic deposits. Up to 8m thick. |
| SAk | STREAM DEPOSITS<br>Lowland stream channel fill sand and gravel, minor silt, and clayey silt, up to 5m thick. |
| SAm | SLOPE DEPOSITS<br>Slopewash sand, up to 4m thick. |
| SAq | LACUSTRINE DEPOSITS<br>Silt to clay, normally less than 5m thick. |
| SAr | LACUSTRINE DEPOSITS<br>Sand to sand loam; up to 5m thick. |
| SAs | LACUSTRINE DEPOSITS<br>Fine sand forming beaches and spits; up to 8m thick. |
| SAt | WIND BLOWN SAND, SILT AND SILT LOAM |

**FRASER RIVER SEDIMENTS**

| | |
|---|---|
| Fd | CHANNEL FILL AND FLOOD PLAIN DEPOSITS<br>Channel fill, clayey silt, and silty clay up the 10m thick |

**SUMAS DRIFT**

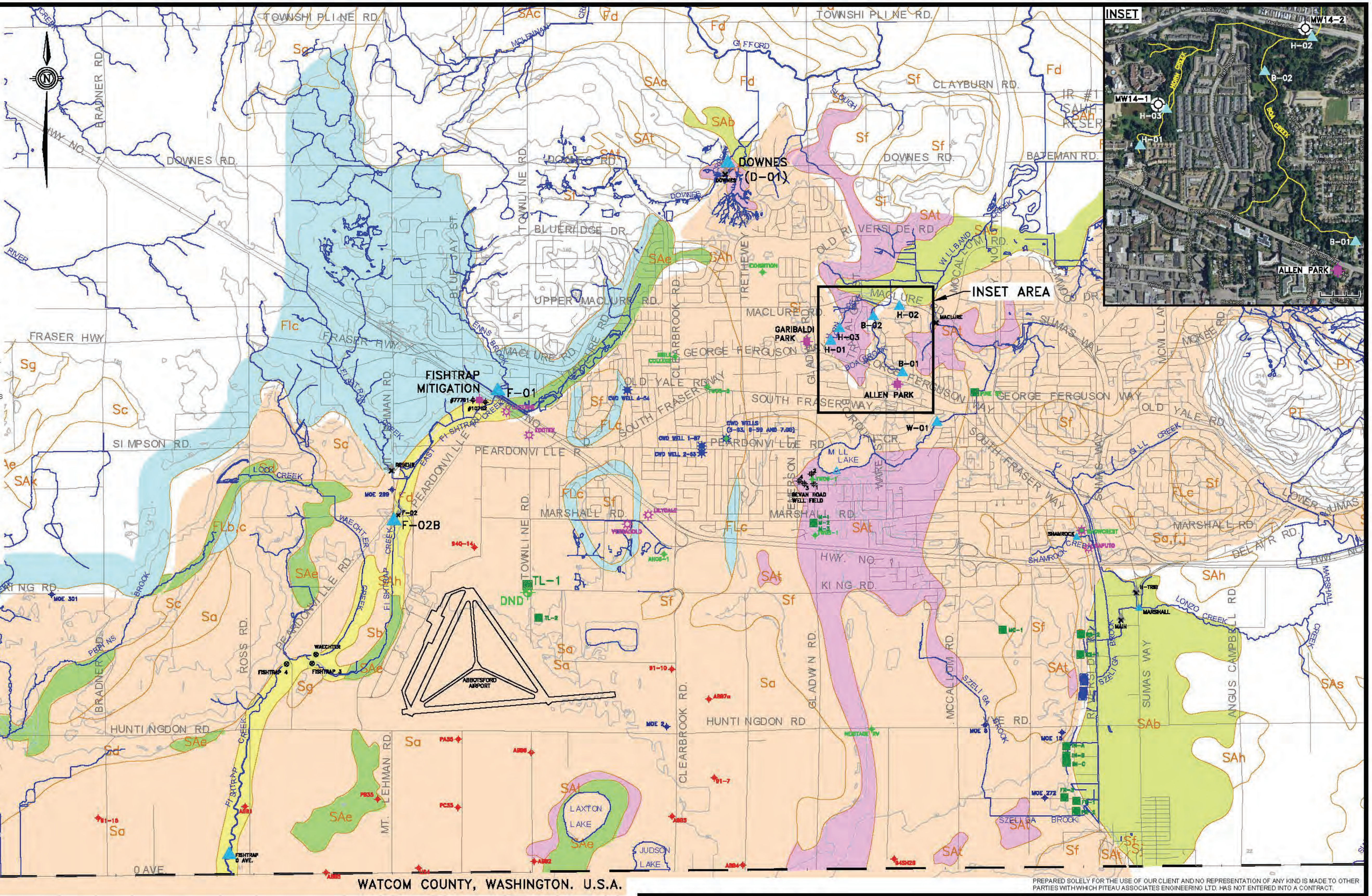
| | |
|---|---|
| Sa | RECESSIONAL CHANNEL AND FLOOD PLAIN DEPOSITS<br>Sand and gravel up to 40m thick. |
| Si | RECESSIONAL CHANNEL AND FLOOD PLAIN DEPOSITS<br>Similar to Sa except that it is pitted outwash |
| Sb,c | ICE CONTACT GRAVEL AND SAND<br>Containing till lenses, and clasts of glaciomarine stony clayey silt. |
| Sd | SUMAS DRIFT-ICE CONTACT<br>Gravel and sand with till lenses. 5 to 25m thick. |
| Sf,g | SUMAS TILL, GLACIOFLUVIAL AND ICE-CONTACT DEPOSITS<br>Sandy till and substratified drift. |
| Sj | TILL, ICE CONTACT AND ICE-CONTACT SEDIMENTS<br>Glaciofluvial gravel and sand, up to 40m thick, underlying Sf. |

**FORT LANGLEY FORMATION**

| | |
|---|---|
| FLc | GLACIOMARINE STONY SILT TO LOAMY CLAY<br>8 to 100m thick. |

**BEDROCK**

| | |
|---|---|
| PT | MESOZOIC AND UPPER PALEOZOIC BEDROCK<br>Includes sedimentary, volcanic granitic and metamorphic rocks. Where bedrock is not exposed it is overlain by thin deposits normally less than 2m thick, of glacial, colluvial and eolian sediments. |
| T | TERTIARY BEDROCK<br>Including sandstone, siltstone, shale and conglomerate, and minor volcanic rocks. Where not exposed at surface, it is overlain by 1 to 5m of glacial deposits and colluvium. |

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## LEGEND

- B.C. MINISTRY OF ENVIRONMENT OBSERVATION WELL
- MONITORING WELL MONITORED BY COA
- ENVIRONMENT CANADA MONITORING WELL
- PRIVATE WELL IDENTIFIED BY WELL TAG No.
- CITY OF ABBOTSFORD PRODUCTION WELL
- FRASER VALLEY TROUT HATCHERY WELL
- CLEARBROOK WATER DISTRICT PRODUCTION WELL
- PRIVATE INDUSTRY PRODUCTION WELL
- BEVAN ROAD WELL
- MONITORING WELL INSTALLED BY PITEAU
- MITIGATION WELL
- LOCATION OF SPOT-MEASUREMENT OF SURFACE WATER FLOWS (SEP. 2009)
- MILL LAKE MONITORING STATION
- CREEK MONITORING STATION
- HISTORICAL CREEK MONITORING STATION
- ABBOTSFORD SUMAS AQUIFER (CANADIAN PORTION)

## NOTES:

1. SURFICIAL GEOLOGY FROM ARMSTRONG ET. AL., 1976.
2. SURFICIAL GEOLOGY UNITS OUTSIDE LIMITS OF AQUIFER DEPICTED WITHOUT COLOUR.

0 400 800 1200 1600 2000m

SCALE 1:45,000

CITY OF ABBOTSFORD
UPDATED HYDROGEOLOGICAL ASSESSMENT
BEVAN WELLS PROJECT

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AQUIFER LEVEL AND SURFACE WATER MONITORING STATIONS WITH SURFICIAL GEOLOGY

| BY: | DATE: |
|---|---|
| SC/sl | FEB 21 |
| APPROVED: | FIG: |
| DJT | 4-2 |

was installed by Environment Canada as part of a broader-region water level project but was decommissioned by the City of Abbotsford in 2010. TW06-3 was added to the monitoring program in July 2013 but transferred to the Province in 2017. It is currently part of the Provincial Monitoring Network.

Continuous monitoring of groundwater via the SCADA system occurred at four additional sites, described in Table 4-6 and shown in Figure 4-2. The H-02 SCADA monitoring station was added in April 2014 and reconnected in November 2015 after a storm knocked over the station in August 2015.

### 4.2.2 Schedule

Six of the monitoring wells described in Table 4-6 are equipped with level loggers, and water level data was retrieved from the data loggers every month. Water levels were also monitored manually when the level logger data was downloaded. Water levels at one well that was not equipped with a level logger (Exhibition Park) was monitored manually on a monthly basis. This well does not have a level logger as it gets stuck on the casing. Recording of water levels also occurred at Judson Lake and Laxton Lake four times per year.

### 4.2.3 Methods

Each of the seven monitoring wells (all except Exhibition Park) contain Solinist Levelogger water level loggers (non-vented pressure transducer with an internal logger). In addition, TW06-1 contains a pressure transducer (barologger), which takes barometric readings every hour and stores them in the logger. Variations in pressure indicate a change in water depth.

The data from each of the six monitoring wells with level loggers was downloaded, and the loggers were re-launched at each visit. A manual measurement of depth from the top of casing to the water was also done at each of these monitoring wells during each visit using a Heron Dipper-T water level meter. Water level in the monitoring well that is not equipped with a data logger (Exhibition Park) was also measured during each visit.

The four SCADA stations consist of a flow meter and an analog pressure gauge, which are located within the valve chamber. Each well is outfitted with one probe for measuring water level, located within the well casing at the depth of the well pumps (Associated Engineering, 2012).

### 4.2.4 Results

*4.2.4.1 Groundwater Level Results*

Daily average water level and temperature in the monitoring wells is attached in Appendix H. Data for the three mitigation wells is attached in Appendix I. Manual water level measurements are presented in Appendix J. The Bevan Wells water levels and extraction data are presented in Appendix K.

All data were analysed and graphed by a professional hydrogeologist from Piteau Associates (Figure 4-3). The data analysis included several wells monitored by other agencies: MW6-59 (data provided by CWD) and FLNRO's Observation Wells #2, #8, #15, #272, #299, #301 and #441. Total daily precipitation at the Abbotsford Airport (recorded by Environment Canada) is included on Figure 4-3, which also includes a line denoting cumulative deviation from the monthly mean of precipitation, or "cusum". This parameter is useful for identifying long-term climate trends. Wetter-than-normal trends correspond to an upward sloping line and drier-than-normal trends correspond to a downward sloping line.

The aquifer water level data shown on Figure 4-3 indicate levels are generally consistent on a year-over-year basis in terms of the magnitude and seasonal variation. In response to dry summers in 2015 and 2016 several observation wells experienced levels between August and late October as much as 1m lower the same months during previous years. Seasonal low water levels measured in 2017 were higher than in 2015 and 2016, which is attributed to an overall increase in precipitation that occurred in 2017. Since 2018, the drying trend indicated by the cusum line on Figure 4-3 has been consistent with lower seasonal peaks and troughs, which are similar to low levels observed in 2015 and 2016.

Aquifer water levels observed in 2020-2021 were within seasonal ranges observed during previous years. There was no evidence of a progressive year-over-year decline in water levels at any of the locations monitored. Trends in most observation wells did not indicate any obvious changes relating to pumping the Bevan Wells, the CWD wells, or the Marshall Road Wells (Figure 4-4 and 4-6). Exceptions include TW06-1, which is located within the Bevan wellfield and experiences rapidly fluctuating water levels caused by cycling of the Bevan Wells, and MOE 441 and MW6-59, which are the next closest monitoring wells and exhibit some short-term influence attributed to pumping of the CWD and Bevan Wells.

Having begun in 2013, the water level record for the Allen and Garibaldi wells (Figure 4-5) is shorter than for the observation wells shown on Figure 4-3. The non-pumping levels generally reflect the pattern noted in other observation wells but are somewhat more muted. Since 2014, the wells have been pumped for short durations for maintenance purposes. The Fishtrap Creek mitigation well was installed in 2019.

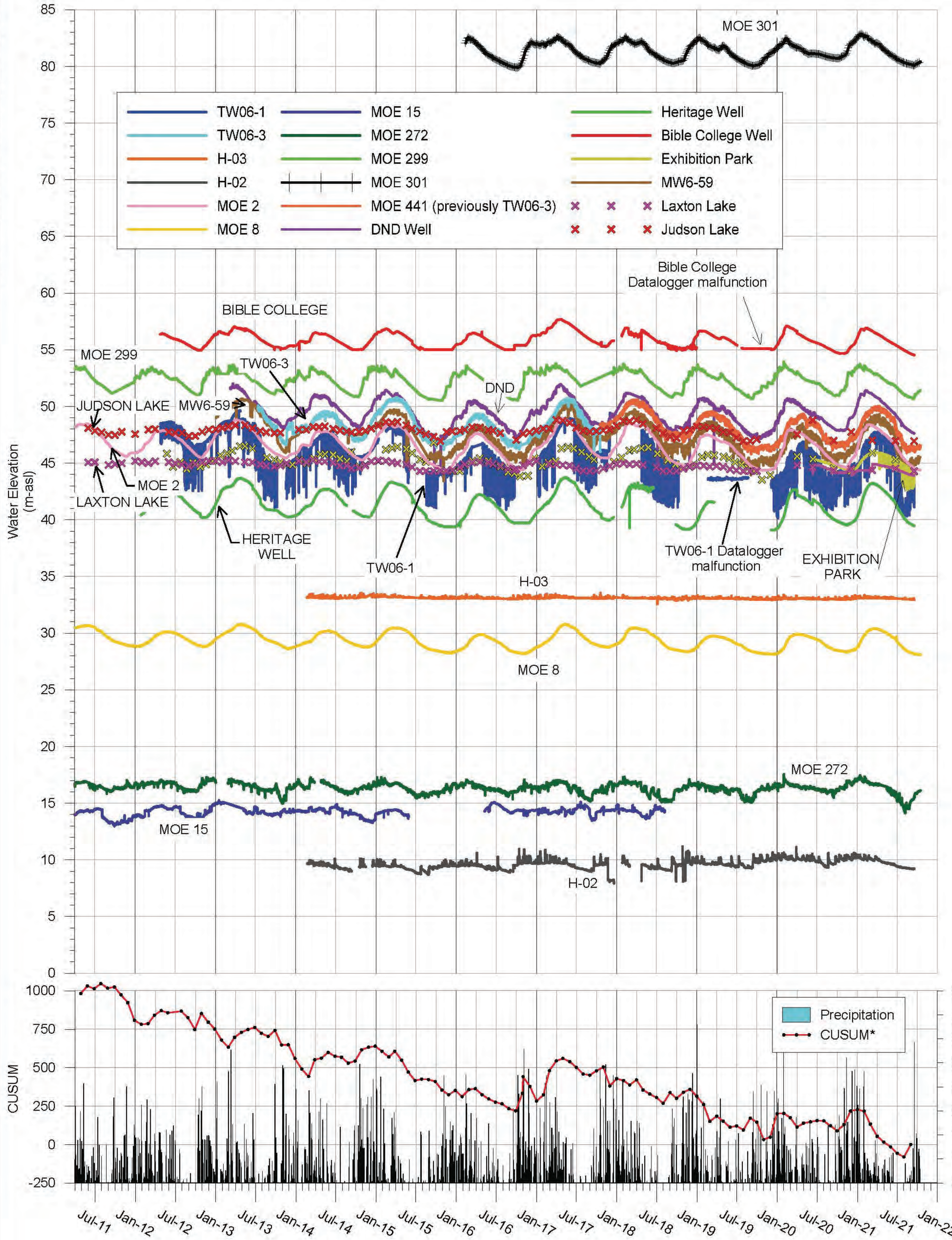
#### *4.2.4.2 Lake Level Results*

Year-over-year water level trends for Laxton Lake and Judson Lake (Table 4-7) were consistent. Laxton and Judson Lake water levels are illustrated in Figure 4-3.

## 4.3 Successes, Challenges and Suggested Changes

Well levels in Year 10 remained consistent with previous monitoring years. All data was successfully collected for the Year 10 monitoring report. There are no suggested changes for the Year 11 (2021-2022) groundwater monitoring program.

H:\Project\3239B\Data Analysis and Graphs\graphs\Fig 4-3_COA_water_levels.grf






Manual readings denoted with "✕"

* CUSUM= Cumulative sum of deviation from mean monthly precipitation based on data collected between January 1945 and September 2021. All precipitation data from Environment Canada station at Abbotsford Airport.

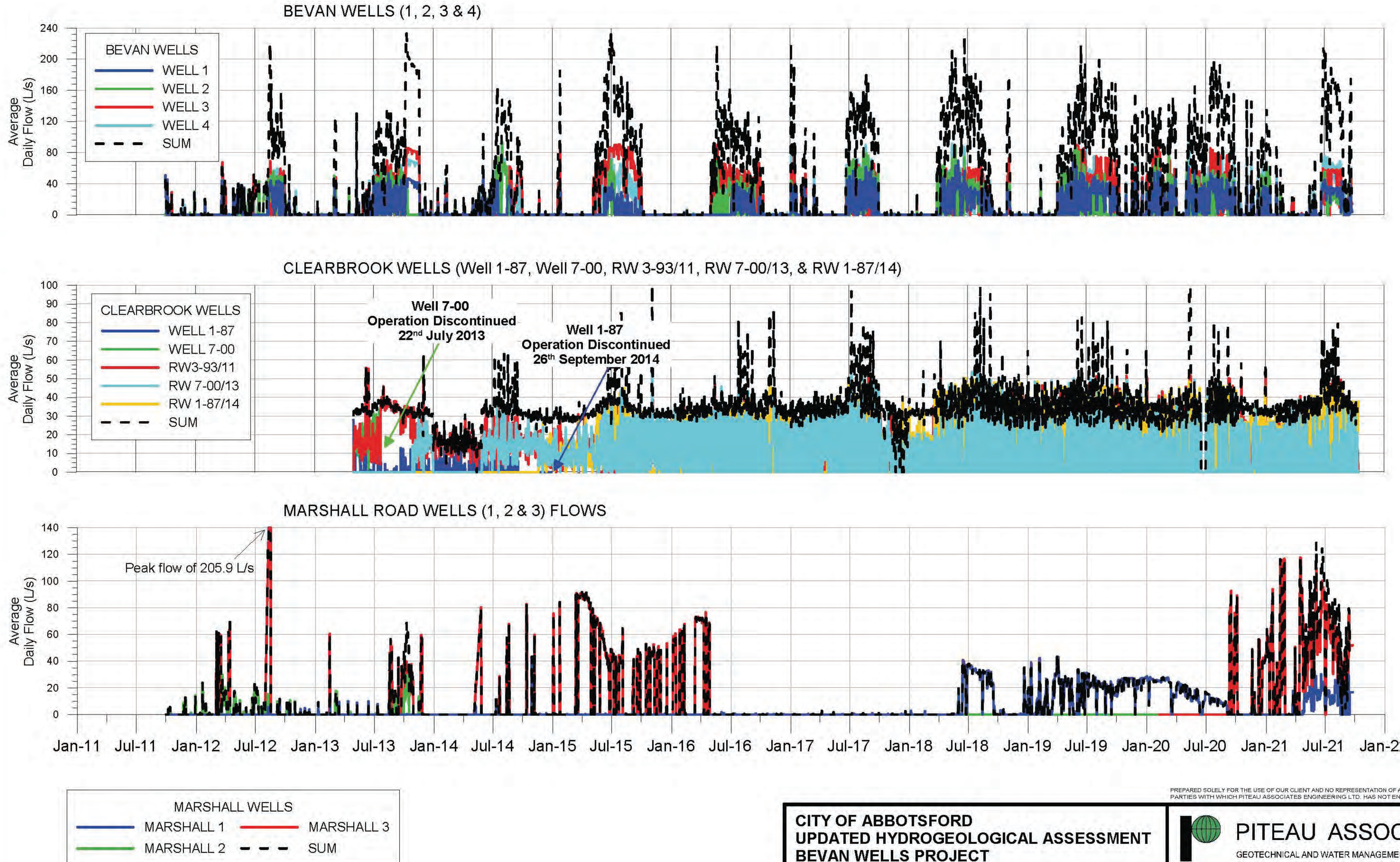
**CITY OF ABBOTSFORD**
**UPDATED HYDROGEOLOGICAL ASSESSMENT**
**BEVAN WELLS PROJECT**

PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

**HYDROGRAPHS FOR 2011 TO 2021 SURFACE AND GROUNDWATER LEVEL TRENDS**

| BY: | DATE: |
|---|---|
| SC | NOV 21 |
| APPROVED: | FIG: |
| DJT | 4-3 |

H:\Project\3239B\Data Analysis and Graphs\graphs\Fig 4-4_Flows - 24hr avgs Bevan-1.gpj






**CITY OF ABBOTSFORD**
**UPDATED HYDROGEOLOGICAL ASSESSMENT**
**BEVAN WELLS PROJECT**

PITEAU ASSOCIATES
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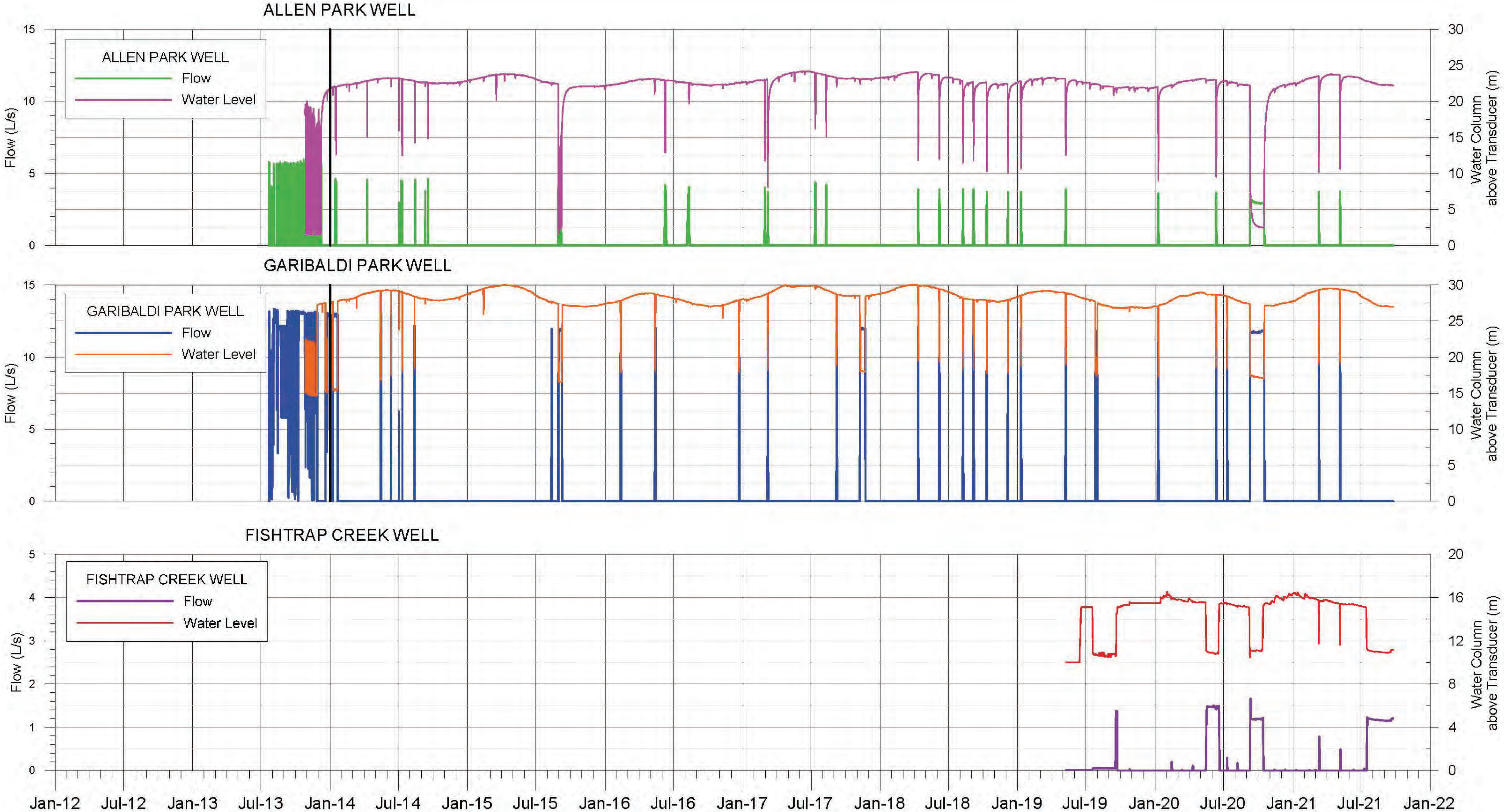
**PUMPING RATES FOR BEVAN, CLEARBROOK AND MARSHALL WELLS**

| BY: | DATE: |
|---|---|
| SC | NOV 21 |
| APPROVED: DJT | FIG: 4-4 |

H:\Project\3239B\Data Analysis and Graphs\graphs\Fig 4-5_Allen,Garibaldi, and Fishtrap Flow and Levels.gpj





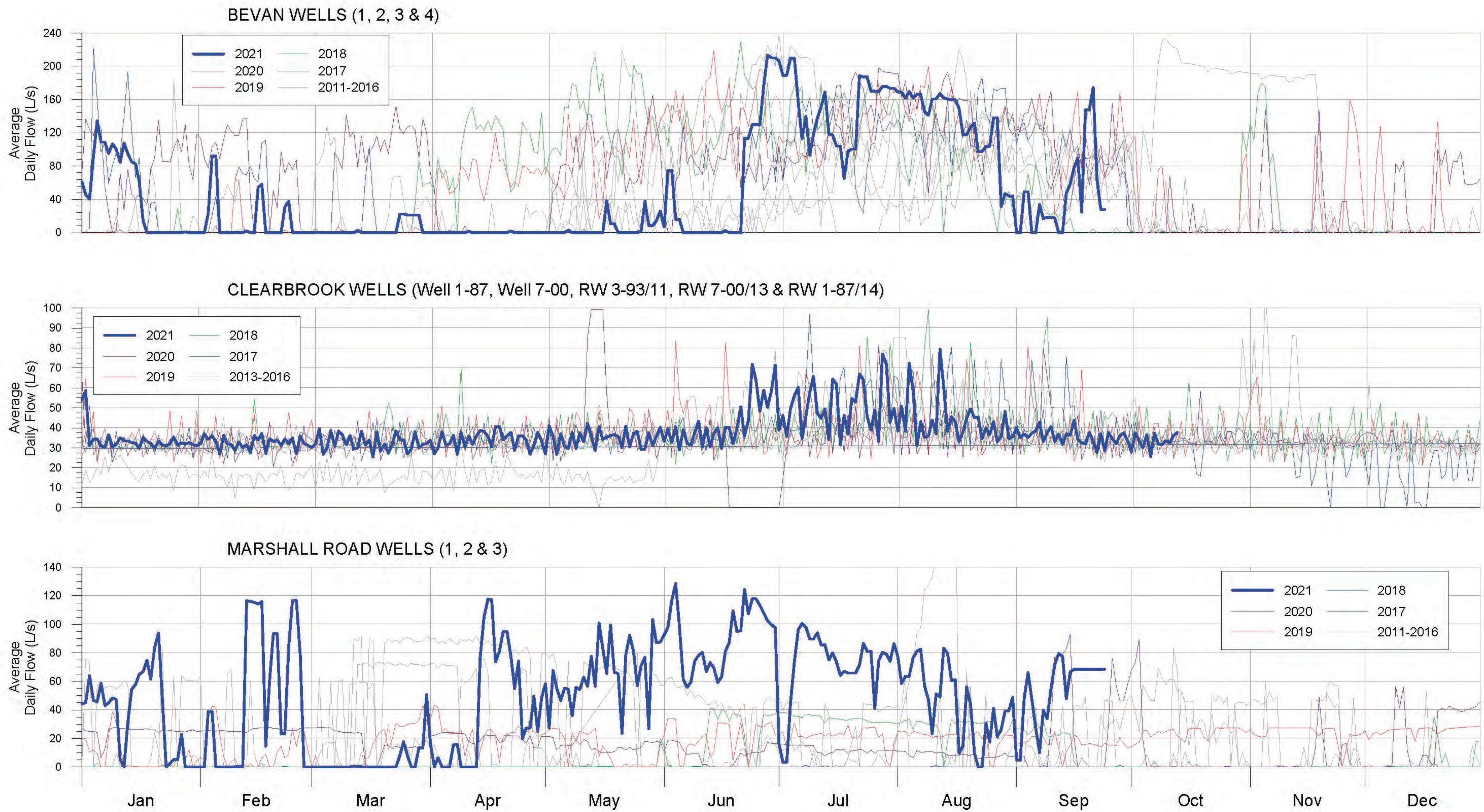

**CITY OF ABBOTSFORD**
**UPDATED HYDROGEOLOGICAL ASSESSMENT**
**BEVAN WELLS PROJECT**

PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

**GROUNDWATER LEVELS AND FLOWS IN MITIGATION WELLS AT ALLEN PARK, GARIBALDI PARK, AND FISHTRAP CREEK**

| BY: | DATE: |
|---|---|
| SC | NOV 21 |
| APPROVED: DJT | FIG: 4-5 |

H:\Project\3239B\Data Analysis and Graphs\graphs\Fig 4-6_Flows-YOY.gpi






**CITY OF ABBOTSFORD**
**UPDATED HYDROGEOLOGICAL ASSESSMENT**
**BEVAN WELLS PROJECT**

PITEAU ASSOCIATES
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**YEAR-OVER-YEAR AVERAGE DAILY PUMPING RATES FOR BEVAN, CLEARBROOK AND MARSHALL WELLS**

| BY: | DATE: |
|---|---|
| SC | NOV 21 |
| APPROVED: DJT | FIG: 4-6 |

**Table 4-7 Laxton Lake and Judson Lake Water Level Results**

| | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | | Year 6 | | Year 7 | | Year 8 | | Year 9 | | Year 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | | Water Level (depth in m) | |
| | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake | Laxton Lake | Judson Lake |
| May | N/A | N/A | 0.85 | 1.10 | 0.80 | 1.40 | 0.85 | 1.30 | 0.38 | 1.40 | 0.75 | 1.00 | 0.54 | 1.81 | 0.54 | 1.53 | 0.38 | 0.80 | N/A | N/A |
| Jun | 0.80 | 1.13 | 0.80 | 0.81 | 0.76 | 1.14 | 0.75 | 1.09 | 0.16 | 1.10 | 0.63 | 0.91 | 0.47 | 1.62 | N/A | N/A | 0.16 | 0.75 | 0.35 | 1.85 |
| Jul | 0.78 | 0.90 | 0.68 | 0.74 | 0.60 | 0.90 | 0.47 | 0.95 | 0.06 | 0.86 | 0.50 | 0.70 | 0.24 | 1.17 | 0.32 | 1.14 | 0.06 | 0.30 | N/A | N/A |
| Aug | N/A | N/A | 0.58 | 0.72 | 0.46 | 0.77 | 0.48 | 0.85 | 0.00 | 0.60 | N/A | N/A | 0.04 | 0.92 | 0.00 | 0.68 | 0.00 | 0.00 | N/A | N/A |
| Sep | 0.53 | 0.56 | 0.45 | 0.44 | 0.40 | 0.70 | 0.27 | 0.75 | 0.00 | 0.39 | 0.10 | N/A | 0.00 | 0.83 | 0.00 | 0.40 | 0.00 | 0.00 | 0.05 | 0.04 |
| Oct | 0.54 | 0.52 | 0.62 | 0.45 | 0.48 | 0.74 | 0.30 | 0.82 | 0.00 | N/A | 0.18 | 0.10 | 0.07 | 0.89 | 0.00 | 0.26 | 0.00 | 0.15 | N/A | N/A |
| Nov | N/A | N/A | 0.78 | 0.82 | 0.69 | Fallen | 0.50 | 0.92 | N/A | 0.80 | 0.51 | 0.66 | 0.23 | 0.94 | 0.20 | 0.90 | N/A | N/A | N/A | N/A |
| Dec | N/A | N/A | 0.90 | 1.00 | N/A | N/A | 0.85 | 1.10 | N/A | 0.85 | 0.73 | 0.77 | 0.43 | 1.03 | 0.40 | 1.00 | N/A | N/A | 0.172 | 0.799 |
| Jan | 0.86 | 0.62 | 0.88 | 1.05 | 0.90 | 1.00 | 0.94 | 1.36 | N/A | 0.88 | 0.89 | 0.92 | 0.62 | 1.35 | 0.49 | 1.29 | N/A | N/A | N/A | N/A |
| Feb | N/A | N/A | 0.86 | 1.17 | 0.80 | 1.00 | 0.90 | 1.68 | N/A | 1.00 | N/A | 1.10 | 0.69 | 1.78 | 0.48 | 1.26 | N/A | N/A | N/A | N/A |
| Mar | 0.70 | 1.00 | 1.00 | 1.30 | 0.98 | 1.24 | 0.80 | 1.62 | N/A | 1.23 | 0.62 | 1.10 | 0.60 | 1.75 | 0.40 | 1.19 | N/A | N/A | 0.072 | 0.073 |
| Apr | 0.87 | 1.06 | 0.88 | 1.40 | N/A | N/A | 0.70 | 1.70 | 0.53 | 1.20 | 0.59 | 1.86 | 0.64 | 1.84 | 0.46 | 1.10 | 0.53 | 0.58 | N/A | N/A |

N/A – Not Available

# 5.0 SHALLOW GROUNDWATER MONITORING

## 5.1 Background

The Bevan Wells EA Certificate Amendment Application identified three areas where the Bevan Wells project has the potential to affect the hydrology of wetlands and floodplains. The Mitigation Plans document submitted with the EA amendment application identified the installation of a network of shallow groundwater wells, which record water table depth measurements, as one strategy for detecting changes in wetland and floodplain hydrology in potentially affected areas. Potentially affected areas are located in Downes Creek, Fishtrap Creek and the Horn and Boa watersheds. In addition to installing shallow groundwater wells in potentially affected areas, the Mitigation Plans report requires wells to be installed in three control wetlands located outside of the modeled zone of influence of the Bevan Wells project but within the Abbotsford-Sumas aquifer.

In spring of 2018, shallow groundwater wells were installed in three study areas within the zone of influence and at three control wetlands (Figure 5-1). Study areas include Fishtrap Creek (3 wells; Figure 5-2), Horn Creek and Boa Brook (2 wells; Figure 5-3), and Downes Creek (8 wells; Figure 5-4). Well installation for the three study areas and the control wetlands took place in spring of 2018. Three groundwater wells were installed at each of the control wetlands (Figure 5-5). Locations of shallow groundwater wells are recorded in Appendix L.

## 5.2 Methods

### 5.2.1 Monitoring Wells

Well sites were selected to monitor for changes in water table depth over time. As such they were distributed throughout the potentially affected areas with a focus on catchment headwater areas expected to be most sensitive to aquifer changes. Wells were also distributed longitudinally in both the Downes and Fishtrap study areas to facilitate change monitoring from headwaters to downstream areas. Wells were placed in areas where the summer water table depth is expected to remain within 1m of the soil surface, as the maximum well depth is 1m. These sites are generally wet, moisture-receiving areas in toe of slope positions on gently sloping or level ground. There are few surface water inputs, and soil moisture is unlikely to be affected by downstream changes in flow (e.g., debris jams, beaver dams). The surficial soil layer at the well sites is humic organic, and these regions contain similar indicator plant species, including *Lysichiton americanus* (Western skunk cabbage), *Equisetum arvense* (common horsetail), *Salix* (willow) species, and sedge species. Within the Downes, Horn, and Boa Study Areas, all shallow groundwater wells were coupled with indicator plant plots (Section 6.2). At Fishtrap Creek, groundwater wells were installed in wet depression environments at a distance to avoid surface water inputs from a watercourse.

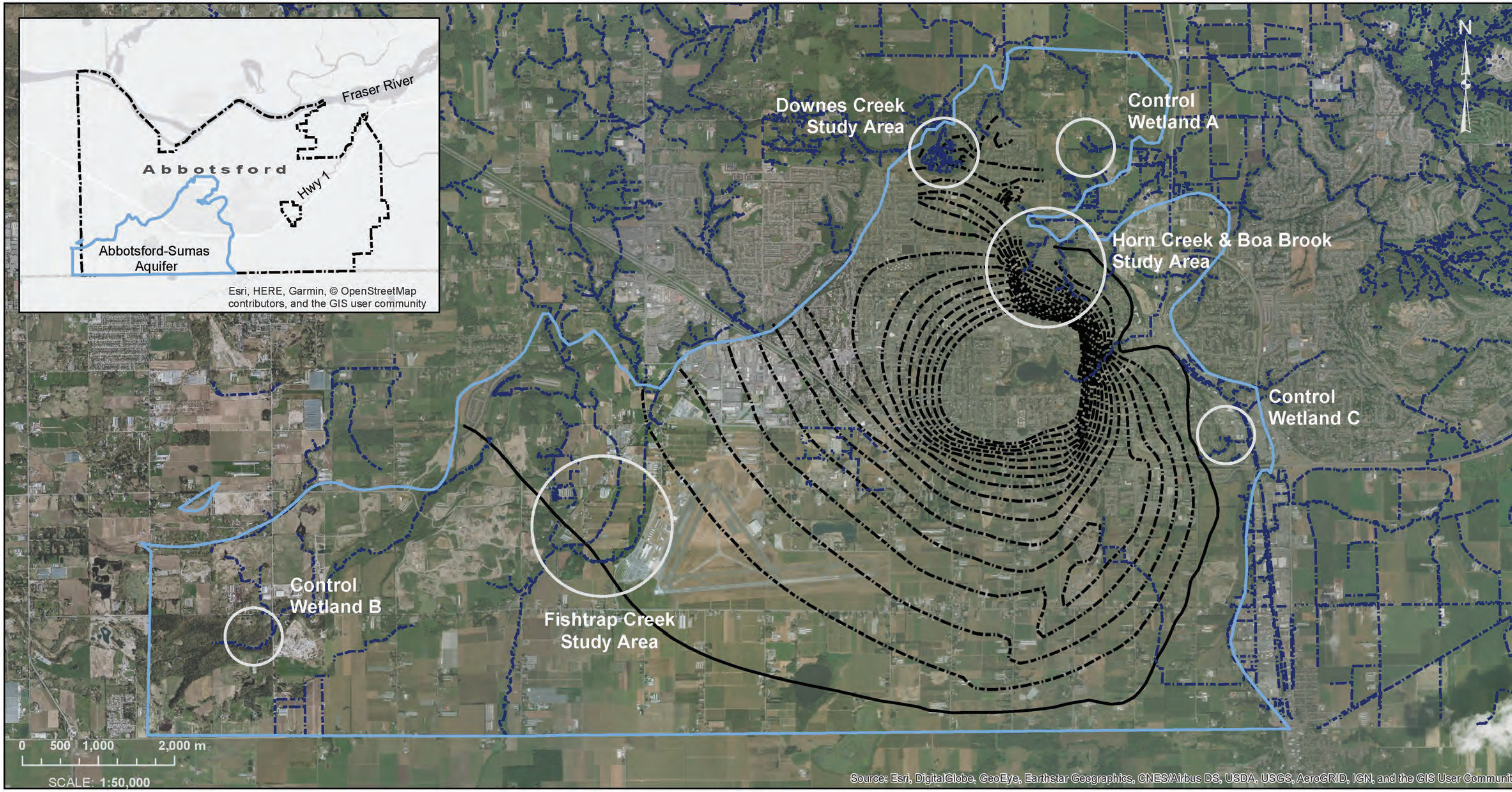
The shallow groundwater wells were installed according to the design and materials recommended in the Wetland Regulatory Assistance Program guidance document regarding installing monitoring wells and piezometers in wetlands (WRAP, 2000). Each groundwater well consists of a simple 1.25” PVC pipe with 0.10” slots. Well specifications and measures can be found in Appendix M. The pipe was installed 1.25 m into the ground, except where terrain limited the depth of the installation. Control Wetland B groundwater plots 1, 2, and 3, and Control Wetland C plots 1, 2 and 3 could not be installed to complete depth and are closer to 0.8 m in depth. An Onset U20 Hobo freshwater water level data logger was hung in each well, a minimum of 10 cm above the bottom of the pipe. The pipe was topped with a loose cap to prevent intrusion of outside materials, while still allowing for air flow around the cap.

For the annual monitoring, existing shallow groundwater plots are revisited, and the Hobo logger data downloaded. Barometric data for the region is also downloaded. Data is transferred into Hoboware software, which converts pressure and temperature data into a sensor depth below water. Ground level is measured at the time of download, based on an average of two measures from top-of-pipe to ground, taken perpendicular to the direction of the slope. This accounts for any shift of the pipe within the ground. Ground level and the top-of-pipe to sensor measures are used to calculate water depth below ground from the sensor depth measure provided by the instrument (Appendix M).

In spring of 2019, several adjustments to the original installment were made, to ensure accuracy of data into the future. To reduce the number of required measurements, a change to the hanging system was made in April of 2019, at the time of download. This allows subsequent datasets to require fewer measures to correct for the depth of sensor. Additionally, in spring of 2019, a barometric unit was installed for this project only, to prevent truncation of the datasets by barometric downloads for other projects. This bypasses a limitation of the Hoboware software.

### 5.2.2 Wetland Water Level

On May 15, 2018, a Water Survey of Canada (WSC) alloy staff gauge was installed to monitor water level in the large open-water wetland in the Downes Creek watershed. The staff gauge was read during May, July, August, September, October, and sometimes January flow or mesohabitat monitoring visits.




**LEGEND**

- Case 2 - ZOI boundary
- Case 2 - 0.1m contour
- Stream
- Abbotsford-Sumas aquifer
- Study area

| | | |
|---|---|---|
| Prepared by: ENKON Environmental Ltd. | CITY OF ABBOTSFORD<br>FOR BEVAN WELLS PROJECT | **Figure 5-1** |
| | **Bevan Wells Wetland, Floodplain and Riparian Impact Study Area** | Created by: K. Martin<br>Date: March 2018 |


**Legend**

- ▲ Shallow groundwater well
- ● TEM plot
- Watercourse

**Site Series**

- 05 - Western Redcedar - Sword Fern
- 07 - Western Redcedar - Foamflower
- 08 - Sitka Spruce - Salmonberry (high bench)
- 10 - Black Cottonwood - Willow (low bench)

Prepared by: ENKON Environmental Ltd.

Created: April 2018
Projection: NAD 83 UTM Zone 10N
Scale:1:5,000

**Fishtrap Creek TEM Mapping and Monitoring Locations**

City of Abbotsford

Figure 5-2


**Legend**

- ● TEM plot
- ▲ Indicator plant plot & shallow groundwater well
- Watercourse

**Site Series**

- 01 - Western Hemlock - Oregon Beaked-moss
- 05 - Western Redcedar - Sword Fern
- 08 - Sitka Spruce - Salmonberry (high bench)
- 09 - Black Cottonwood - Red-osier Dogwood (medium bench)
- 10 - Black Cottonwood - Willow (low bench)
- Ws51 - Sitka Willow – Pacific Willow – Skunk Cabbage (Swamp)
- Ws52 - Red Alder – Skunk Cabbage (Swamp)
- Ws53 - Western Redcedar – Sword Fern – Skunk Cabbage (Swamp)

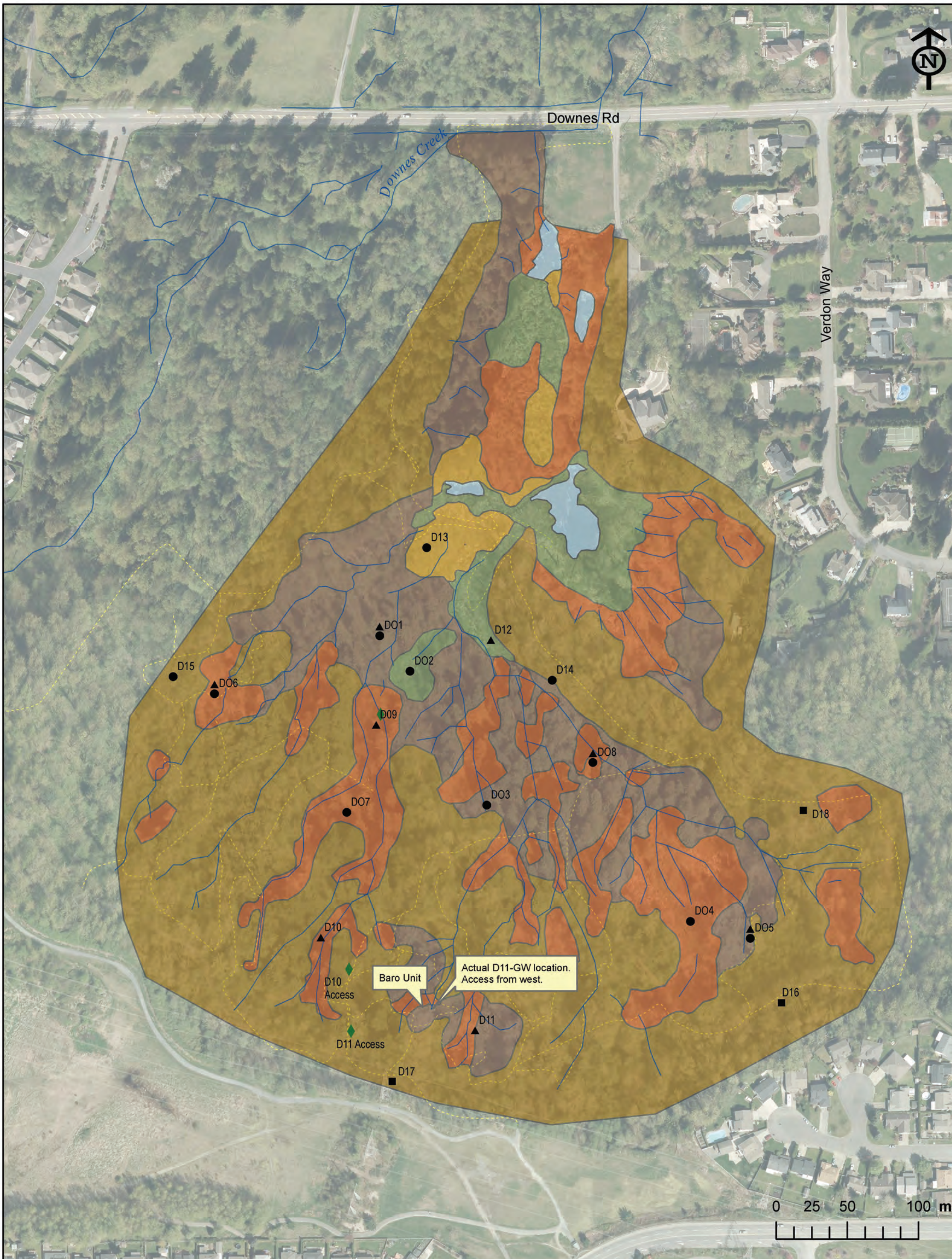
Created:
April 2018
Projection:
NAD 83 UTM
Zone 10N
1:4,000

Prepared by:
ENKON
Environmental Ltd.

**Horn Creek and Boa Brook TEM Mapping and Monitoring Locations**

City of Abbotsford

Figure 5-3




## Legend

- ● TEM Plots
- ▲ Indicator plant plot & shallow groundwater well
- ■ Snail plot
- ♦ Plot access
- Trail
- Watercourse

| | Code | Site Series | Conservation Status |
|---|---|---|---|
| | OW | Shallow open water | NA |
| | Ws51 | Sitka willow-Pacific willow-skunk cabbage | Red Listed |
| | Ws52 | Red alder- skunk cabbage swamp | Red Listed |
| | Ws53 | Western redcedar-swordfern - skunk cabbage | Blue Listed |
| | Wm05 | Cattail marsh | Blue Listed |
| | 07 | Western redcedar-foamflower | Blue Listed |

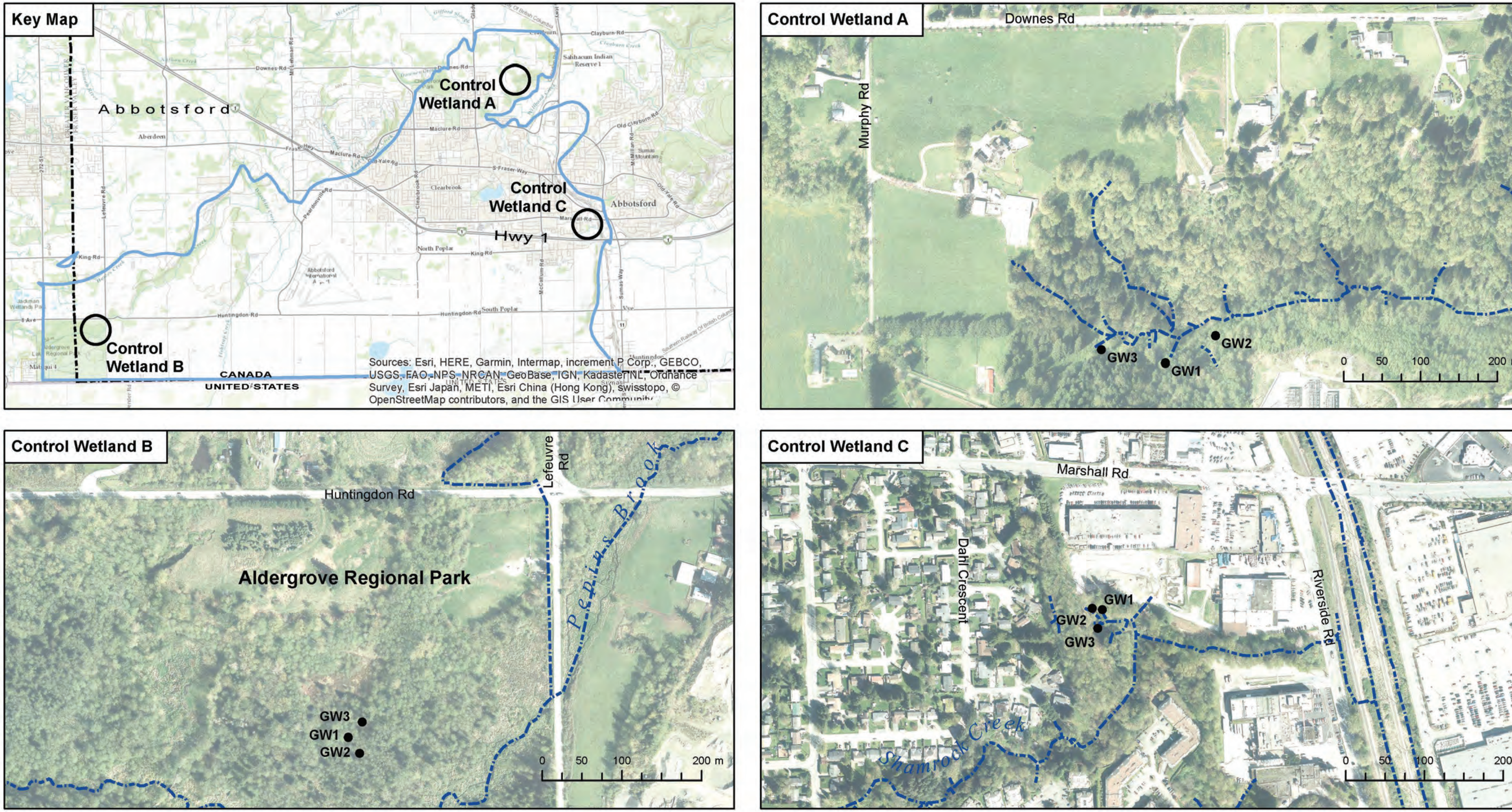
Prepared by:
ENKON Environmental Ltd.

Created: March 2018
Projection:
NAD 83 UTM Zone 10N
1:2,500

**Downes Creek Ecosystem Mapping & Monitoring Locations**

City of Abbotsford

Figure 5-4




**LEGEND**

- Shallow groundwater well
- Stream
- Abbotsford-Sumas aquifer
- Abbotsford boundary

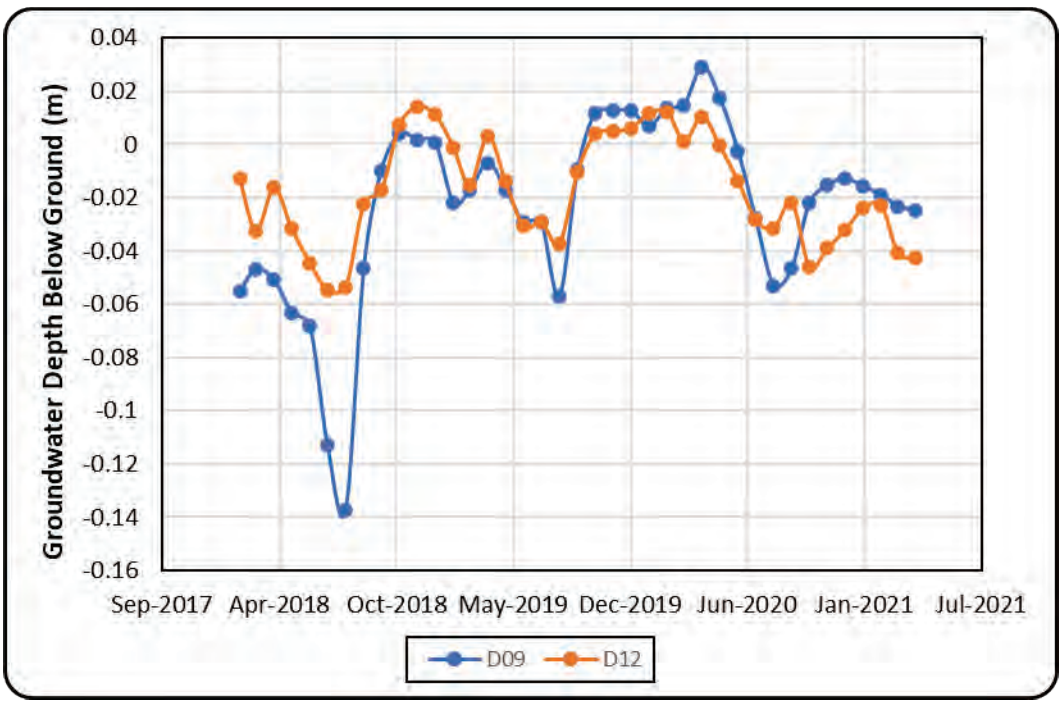
Prepared by: ENKON Environmental Ltd.

| | |
|---|---|
| CITY OF ABBOTSFORD<br>FOR BEVAN WELLS PROJECT | **Figure 5-5** |
| **Control Wetlands**<br>**Shallow Groundwater Well Locations** | Date: April 2018 |

## 5.3 Results and Discussion

### 5.3.1 Monitoring Wells

Shallow groundwater data graphs for April 2020 through to April 2021 are attached in Appendix N. Within the Bevan Wells zone of influence and at the control sites, groundwater levels in 2020 tended to be slightly higher overall than in previous years. Several exceptions within the Downes Creek basin were D11, which had lower summer water levels in 2020 than in previous years, and D09 and D12, which had lower 2020 winter water levels than in previous years (Figure 5-6). In both cases, the pattern was only present for a portion of the year. The trend of overall decline in groundwater depth during the summer (late June to late September) occurred at over half of the sites, as observed in previous years. In these cases, the groundwater reached its lowest point in September, and




a sharp increase followed in October.

**Figure 5-6 Temporal Variations in Groundwater Levels at Two Monitoring Wells in the Downes Creek Watershed**

Wells within Fishtrap Creek showed the greatest seasonal differences in groundwater levels, with drops of up to 1.2 m between the winter and summer. As in previous years, flooding was apparent at two of the three Fishtrap Creek wells, where water levels were above the top of the pipe briefly in November. Of the remaining sites, only Boa Brook showed large fluctuations with a 0.6-m range in water table depth from winter to summer. This location is fed by stormwater run off.

Half of the Downes Creek sites and the single Horn Creek site did not show signs of seasonal variations in groundwater level, and water levels remained relatively consistent. Plots 5 and 6 within Downes Creek continued to show greater seasonal variation, and Plots 9 and 10 showed less pronounced seasonal variation.

Seasonal variation was also seen in half of the Control Wetland sites. Site 2 of Control Wetland A and all three sites of Control Wetland B showed seasonal groundwater change. Groundwater levels within the remaining Control Wetland sites showed water level fluctuations up to 0.3m, but these did not appear to be associated with a change from dry season to wet season.

The trends in shallow groundwater levels after three years of monitoring illustrate seasonal changes that occurred within both the control wetlands and the Bevan Wells zone of influence. No downward trends in shallow groundwater levels occurred within the Downes Creek, Fishtrap Creek, or Horn Creek/Boa Brook study areas (e.g., Figure 5-6), nor were any changes attributable to the operation of the Bevan Wells.

### 5.3.2 Wetland Water Level

Wetland water levels recorded from May 2018 through April 2021 are illustrated in Figure 5-7. This graph shows an overall declining trend in the depth of water within the wetland. The reason for this trend is unclear. It does not appear to be related to the operation of the Bevan wells as no similar trends were observed in the flow of Downes Creek (Section 2.4.1), water levels in the (deeper) monitoring wells (Section 4.1.3), or water levels in the shallow groundwater wells (Section 5.2.1). However, a decline is consistent with the drying trend indicated by the cusum line on Figure 4-3.

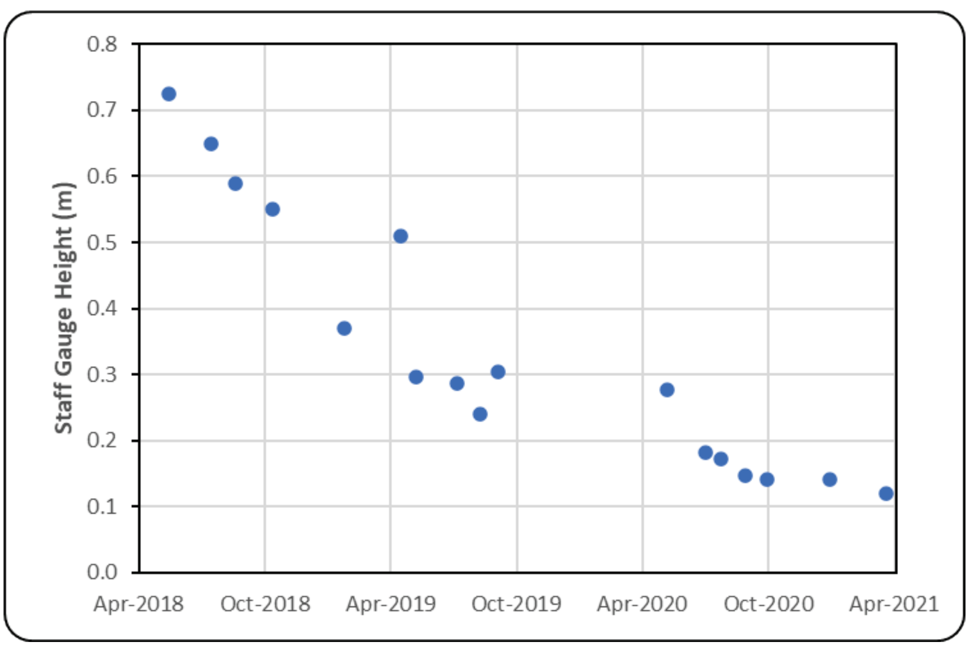



**Figure 5-7 Water Levels in the Downes Creek Open-Water Wetland, 2018-2021**

## 5.4 Successes, Challenges and Suggested Changes

The 2020 dataset is the third documentation of summer water table depths. Three data sets do not provide a robust measure of trend to identify effects, if any, of drawdown due to the Bevan Wells. With additional seasons of data at each plot in the Bevan Wells sone of influence and the control wetlands, comparison of these two areas will aim to identify the extent to which trends through time are climatic or influenced by the ongoing summer use of the Bevan Wells.

Because at each monitoring site the sensor hangs at a set height throughout the year, water depths below the sensor cannot be measured. Water levels below the sensor depth produce a constant maximum depth during the summer months, and depth variations below that level are not documented. This limitation has occurred within Fishtrap Creek Plots 1 and 3 and all three plots in Control Wetland B. Depths greater than 0.5 to 0.58 m below the surface within Control Wetland B do not appear to have been measured. It was not possible to install groundwater wells at greater depth at these locations due to a layer of gravel in the soil that prevented further excavation of the hole for the pipe. While these wells are limited in the depths they can measure, they provide other seasonal data, such as the timeline for the onset and end of the drought period.

# 6.0 VEGETATION MONITORING

## 6.1 Terrestrial Ecosystem Mapping

### 6.1.1 Background

The Bevan Wells Environmental Assessment Certificate Amendment Application (ENKON 2016) provided preliminary terrestrial ecosystem mapping (TEM) results for three study areas where adverse effects to wetland, floodplain or riparian might occur. A Mitigation Plans document (2017) submitted with the 2016 amendment application recommended that the preliminary ecosystem mapping be enhanced to provide detailed vegetation community descriptions and permanent vegetation plots for monitoring species composition change over time. In 2017, TEM was completed for the Fishtrap Creek, Horn Creek and Boa Brook, and Downes Creek watersheds (Figure 5-1) according to the Resources Inventory Committee (RIC) Standards for Terrestrial Ecosystem Mapping in British Columbia (May 1998). The 2017 TEM incorporates the results of two previous TEM projects (ENKON 2016; Hemmera 2010) and provides revised ecosystem boundaries and ecosystem classifications, where appropriate, as well as detailed ecosystem descriptions.

Wetland, floodplain, and riparian areas within the study area are classified down to the site series level. Classifications identify site potential ecosystems as mature seral stages and are based on a site's soil moisture and nutrient regime. Ecosystem information in the TEM is used as a baseline dataset against which vegetation species composition and growing condition (soil moisture and nutrient regime) changes can be measured over time. As such, in 2017 one to three permanent ground inspection plots were established in each significant wetland, floodplain or riparian site series within the study area. Subsequently, three plots were added for a total of 24 permanent ground inspection plots (Figures 5-2, 5-3, and 5-4), seven of which were also used to monitor changes in Oregon forestsnail (*Allogona townsendiana*) critical habitat (Figure 5-4). One additional plot was monitored visually. The ground inspection plots were sampled annually at the end of the dry season, when effects on riparian vegetation from groundwater withdrawal and/or decreased surface water flows should be most apparent. The fourth annual survey was completed in fall of 2020.

### 6.1.2 Methods

Ground inspection plots within each terrestrial ecosystem mapping unit were established using data collection methods outlined in the provincial Site Visit (SIVI) Standards (BC Ministry of Environment 2010). Most plots are 20 m by 20 m, but several 10 m x 10 m plots were created due to terrain restrictions at Fishtrap Creek (all plots aside from FT04), plot B01 at Boa Brook, and plot D14 at Downes Creek. The plots were marked with stakes. In 2018, a reference tree was added to improve the ability to identify each plot. The tree closest to the plot stake was marked and its species recorded along with bearing and distance.

The initial inventory collected **site feature data** (slope position, slope, and aspect), **stand attribute data** (age, height, structural stage, and successional status), **soil moisture regime**, **soil nutrient regime**, **rooting zone data** (soil drainage, texture, coarse fragment content, humus form, seepage depth and root restricting layers), and **vegetation species composition data** (percent cover by species and by layer). For the 2020 annual monitoring, existing ground inspection plots were revisited, and the vegetation species composition data was collected by a vegetation specialist and a field assistant.

The TEM plots documenting Oregon forestsnail habitat characteristics included D05. D06, D14, and D15. At these plots, critical habitat features were observed, including stinging nettle (*Urtica dioica*) presence, presence of coarse woody debris, and factors that assist in maintenance of a moist microclimate, including intact deciduous canopy, dense understory vegetation, and presence of leaf litter. In 2020, three additional 10 m by 10 m Oregon forestsnail plots were added to the survey and designated D16, D17 and D18.

### 6.1.3 Results

#### *6.1.3.1 Vegetation Changes*

Vegetation cover within the TEM plots has remained similar over the four years of monitoring, and none of the changes observed represent large shifts in the plant community. While some new species were observed within six of the plots (Appendix O), these species are not associated with a drier plant community. No signs of drought stress or recent shrub or herb layer mortality were observed at any of the TEM plots. Recently fallen trees were observed at Fishtrap Plot 4 and Horn Plot 1, but no apparent drought stress or tree disease was seen within the plots, and these trees appeared to be regenerating. No changes in ecosystem boundaries were observed in traversing the Downes Creek and Horn and Boa study areas.

As in previous years, percent cover by the dominant species varied at the sites, but no consistent patterns have been observed over the four years of data collection. Observed differences in vegetation cover were small in most cases. Larger shifts in 2020 cover as compared to 2019 are highlighted in Tables 6-1 and 6-2. Overall, decreases in cover were observed in key indicator species at 20 plots in 2020. Ten of these plots had some level of decay reported. Leaf fall and decay that was observed at some plots even in the earliest days of the inventory is attributed to variability in the timing of leaf fall among years. Variability in weather patterns among years also impacts plant growth. These factors contribute to the variability of cover estimates over time.

**Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2019 and 2020**

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| D02 | Wm05 | B | vine maple | *Acer circinatum* | 13 | 11 | 18 | 5 | Plot stake not found |
| D02 | Wm05 | B | salmonberry | *Rubus spectabilis* | 17 | 14 | 22 | 9 | Plot stake not found |
| D02 | Wm05 | C | Common cattail | *Typha latifolia* | 6 | 7 | 8 | 5 | Plot stake not found |
| D02 | Wm05 | C | lady fern | *Athyrium filix-femina* | 8 | 8 | 16 | 12 | Plot stake not found. Lady fern = 2m tall. |
| D02 | Wm05 | C | Western skunk cabbage | *Lysichiton americanus* | 15 | 10 | 8 | 6 | Plot stake not found |
| B02 | Ws51 | A | Pacific willow | *Salix lucida ssp. Lasiandra* | 15 | 9 | 4 | 3 | |
| B02 | Ws51 | B | Hardhack | *Spiraea douglasii* | 8 | 10 | 9 | 2.5 | |
| D13 | Ws51 | A | Pacific willow | *Salix lucida ssp. Lasiandra* | 8 | 8 | 12 | 2 | Partially fallen. Leaves down. |
| D13 | Ws51 | A | red alder | *Alnus rubra* | 42 | 40 | 17 | 7 | Leaves down. Thinning? |
| D13 | Ws51 | C | lady fern | *Athyrium filix-femina* | 14 | 4 | 13 | 6 | Decay |

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2019 and 2020

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| D13 | Ws51 | C | common horsetail | *Equisetum arvense* | 12 | 3 | 8 | 4 | Decay |
| B01 | Ws52 | B | salmonberry | *Rubus spectabilis* | 95 | 6 | 90 | 65 | Branch fell & cleared shrubs near plot centre. |
| D04 | Ws52 | C | lady fern | *Athyrium filix-femina* | 3 | 3 | 20 | tr | Decay |
| D04 | Ws52 | C | common horsetail | *Equisetum arvense* | 65 | 60 | 80 | 60 | Decay |
| D04 | Ws52 | C | Western skunk cabbage | *Lysichiton americanus* | 31 | 30 | 70 | 35 | Decay |
| D06 | Ws52 | C | Western skunk cabbage | *Lysichiton americanus* | 15 | 8 | 15 | 5 | Decay |
| D06 | Ws52 | C | piggy-back plant | *Tolmiea menziesii* | 47 | 25 | 14 | 8 | |
| D07 | Ws52 | C | lady fern | *Athyrium filix-femina* | 1 | 2 | 11 | 2 | Plot stake not found |
| D08 | Ws52 | B1 | salmonberry | *Rubus spectabilis* | 14 | 9 | 12 | 3 | 11% in B2 |
| D08 | Ws52 | B1 | Western redcedar | *Thuja plicata* | 5 | 15 | 6 | 4 | |
| D08 | Ws52 | C | lady fern | *Athyrium filix-femina* | 7 | 6 | 9 | 5 | |
| D08 | Ws52 | C | spiny wood fern | *Dryopteris expansa* | 11 | 5 | 11 | 7 | |
| H01 | Ws53 | A | red alder | *Alnus rubra* | 15 | 10 | 4 | 4 | |

**Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2019 and 2020**

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| H01 | Ws53 | B2 | stink currant | *Ribes bracteosum* | 0.5 | 10.5 | 0.5 | Trace | |
| D01 | Ws53 | A | Western redcedar | *Thuja plicata* | 18 | 13 | 21 | 20 | |
| D01 | Ws53 | B2 | salmonberry | *Rubus spectabilis* | 7 | 2 | 13.5 | 7.5 | 2% in B1. |
| D01 | Ws53 | C | common horsetail | *Equisetum arvense* | 33 | 7 | 18 | 16 | Some decay. |
| D01 | Ws53 | C | false lily-of-the-valley | *Maianthemum dilatatum* | 0.5 | 0.1 | 4.5 | 0.5 | Some decay. |
| D01 | Ws53 | C | fringecup | *Tellima grandiflora* | | 0.1 | 2.5 | 2 | Some decay. |
| D03 | Ws53 | B1 | vine maple | *Acer circinatum* | 11 | 11 | 19 | 12.5 | Leaves fallen. |
| D03 | Ws53 | B | salmonberry | *Rubus spectabilis* | 39 | 42 | 49 | 44 | Leaves fallen. |
| D03 | Ws53 | C | lady fern | *Athyrium filix-femina* | 0.5 | 4 | 8 | 3 | Fronds fallen. |
| D03 | Ws53 | C | Western skunk cabbage | *Lysichiton americanus* | 6 | 5 | 4 | 2 | Decay |
| D03 | Ws53 | C | spiny wood fern | *Dryopteris expansa* | 42 | 20 | 9 | 22 | |
| D05 | Ws53 | A1 | black cottonwood | *Populus balsamifera ssp. trichocarpa* | 20 | 20 | 35 | 23 | Leaves partly fallen. |
| D05 | Ws53 | B | salmonberry | *Rubus spectabilis* | 27 | 20 | 24 | 14 | |

**Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2019 and 2020**

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| D05 | Ws53 | C | Western skunk cabbage | *Lysichiton americanus* | 22 | 29 | 40 | 28 | |
| D05 | Ws53 | C | lady fern | *Athyrium filix-femina* | 10 | 7 | 17 | 7 | Very large (2.25m), but many fallen. |
| FT03 | 10 | B | Sitka willow | *Salix sitchensis* | 2 | 15 | 3 | 5 | |
| FT06 | 10 | A | black cottonwood | *Populus balsamifera ssp. trichocarpa* | 70 | 60 | 70 | 65 | Decay observed. |
| FT06 | 10 | B1 | black twinberry | *Lonicera involucrata* | | 11 | 5 | -- | Not observed |
| FT06 | 10 | | common horsetail | *Equisetum arvense* | 0.5 | 2.5 | 5 | 1 | Decay observed. |
| FT07 | 10 | B1 | baldhip rose | *Rosa gymnocarpa* | 0.5 | 1 | 15 | 5 | |
| FT01 | 08 | B1 | black twinberry | *Lonicera involucrata* | 24 | 20 | 12 | 18 | Some leaves fallen. |
| FT01 | 08 | B1 | Cascara | *Rhamnus purshiana* | | 25 | 20 | 21 | Some leaves fallen. |
| FT01 | 08 | B1 | red elderberry | *Sambucus racemosa* | 40 | 35 | 70 | 33 | Some leaves fallen. |
| FT01 | 08 | C | lady fern | *Athyrium filix-femina* | | 5 | 0.5 | 3 | Some leaves fallen. |

**Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2019 and 2020**

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| FT01 | 08 | C | spiny wood fern | *Dryopteris expansa* | 27 | 15 | 40 | 14 | Some leaves fallen. |
| D14 | 07 | A3 | Cascara | *Rhamnus purshiana* | 8 | 20 | 15 | 12 | |
| D14 | 07 | B | thimbleberry | *Rubus parviflorus* | 20 | 25 | 18 | 17 | Documented in B1 in 2019 |
| D14 | 07 | B | salmonberry | *Rubus spectabilis* | 33 | 25 | 18 | 8 | |
| D14 | 07 | C | sword fern | *Polystichum munitum* | 35 | 25 | 30 | 21 | |
| D15 | 07 | A | red alder | *Alnus rubra* | 12 | 20 | 10 | 11 | |
| D15 | 07 | B1 | red elderberry | *Sambucus racemosa* | 19 | 15 | 21 | 7 | Few leaves. |
| D15 | 07 | | spiny wood fern | *Dryopteris expansa* | 9 | 5 | 13 | 8 | |
| FT04 | 05 | A1 | Douglas-fir | *Pseudotsuga menziesii* | 9 | 8 | 14 | 12 | |
| FT04 | 05 | B | paper birch | *Betula papyrifera* | | 4 | 4 | 1 | Fallen. Mostly dead. |

**Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2019 and 2020**

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| B02 | Ws51 | C | lady fern | *Athyrium filix-femina* | 5 | 8 | 4 | 12 | |
| D06 | Ws52 | B | salmonberry | *Rubus spectabilis* | 27 | 45 | 23 | 40 | |
| D06 | Ws52 | B | red elderberry | *Sambucus racemosa* | 10 | 12 | 7 | 8 | |
| D06 | Ws52 | C | spiny wood fern | *Dryopteris expansa* | 12 | 12 | 7 | 8 | |
| D07 | Ws52 | B | salmonberry | *Rubus spectabilis* | 19 | 8 | 29 | 40 | Plot stake not found |
| D07 | Ws52 | C | spiny wood fern | *Dryopteris expansa* | 22 | 14 | 5 | 5.5 | Plot stake not found |
| D07 | Ws52 | C | common horsetail | *Equisetum arvense* | 5 | 18 | 10 | 23 | Plot stake not found |
| D07 | Ws52 | C | Western skunk cabbage | *Lysichiton americanus* | 5 | 16 | 4 | 11 | Plot stake not found |
| D07 | Ws52 | C | piggy-back plant | *Tolmiea menziesii* | 2 | 1 | 5 | 16 | Plot stake not found |
| D08 | Ws52 | B1 | vine maple | *Acer circinatum* | 11 | 12 | 32 | 33 | Vine maple leaves not fallen this time. |
| D08 | Ws52 | B1 | red alder | *Alnus rubra* | - | 10 | 5 | 10 | |
| H01 | Ws53 | A2 | paper birch | *Betula papyrifera* | 1 | 10 | 1.5 | 8 | |
| H01 | Ws53 | A | Western redcedar | *Thuja plicata* | 60 | 40 | 20 | 24 | |
| H01 | Ws53 | B | Western redcedar | *Thuja plicata* | 10 | 5 | 1 | 2.5 | |
| H01 | Ws53 | C | lady fern | *Athyrium filix-femina* | 6 | 10 | 8 | 12 | |

**Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2019 and 2020**

| Plot | Ecosystem Type | Layer | Common Name | Species Name | 2017 (%) | 2018 (%) | 2019 (%) | 2020 (%) | 2020 Notes |
|---|---|---|---|---|---|---|---|---|---|
| H01 | Ws53 | C | Western skunk cabbage | *Lysichiton americanus* | 10 | 12 | 6 | 7 | |
| H02 | Ws53 | A | black cottonwood | *Populus balsamifera ssp. trichocarpa* | 5 | 20 | 8 | 18 | Little decay observed |
| H02 | Ws53 | A | paper birch | *Betula papyrifera* | 7 | 9 | 2 | 4 | Little decay observed |
| H02 | Ws53 | B2 | salmonberry | *Rubus spectabilis* | 45 | 35 | 25 | 35 | Little decay observed |
| H02 | Ws53 | C | lady fern | *Athyrium filix-femina* | 19 | 15 | 6 | 11 | Little decay observed |
| D01 | Ws53 | C | Western skunk cabbage | *Lysichiton americanus* | 8 | 10 | 10 | 14 | Some decay. |
| D05 | Ws53 | C | common horsetail | *Equisetum arvense* | 25 | 25 | 48 | 55 | |
| FT06 | 10 | B1 | red-osier dogwood | *Cornus sericea* | 42 | 40 | 53 | 65 | Greatly expanded. Decay observed. |
| D15 | 07 | A1 | bigleaf maple | *Acer macrophyllum* | 30 | 50 | 25 | 45 | |
| D15 | 07 | B | salmonberry | *Rubus spectabilis* | 68 | 70 | 30 | 34 | |

Increased cover by some species was observed at ten plots in 2020, although in one case the increase was an artifact of relocating a plot stake. At two of the sites the cover increases were attributed to lack of decay at the time of survey. At one site, FT06, a significant community shift appeared to be taking place, with red-osier dogwood (*Cornus sericea*) expanding greatly each year. This might represent a shift from low bench to high bench floodplain vegetation.

The plot centres at D02 and D07 could not be located in 2020, which resulted in changes to percent cover at these sites. At D02, the reference tree was used to approximate the centre. At D07, the reference tree could not be located, and a new one was ultimately established.

Measurement error also might have impacted cover estimates. Potential sources of measurement error include insufficiently accounting for gaps within the canopy of a species (overestimate), insufficiently accounting for leaf layering within the canopy (underestimate), and incorrectly projecting plot boundaries for each layer (inconsistent cover estimate).

#### *6.1.3.2 Oregon Forestsnail Habitat Features*

No significant changes in overall deciduous canopy cover were observed at the Oregon forestsnail habitat plots. Leaf litter volume remained consistently deep and was comprised primarily of bigleaf maple. Plots D14 through D18 had high (55% to 85%) cover of bigleaf maple, which was reflected in depths of litter (3 cm to 6 cm). As noted during the baseline assessment, D06 contains stinging nettle (*Urtica dioica*), which the snails require for breeding. The new plots D16, D17, and D18, were selected to contain stinging nettle, allowing additional tracking of nettle cover through time. At D06, the cover of stinging nettle had increased in 2020 from 2019. Minimal coarse woody debris was found at D06, and decay was observed in the coarse woody debris at D05. The quantities of coarse woody debris at D14 and D15 remained similar to that observed previously. The 2020 monitoring showed no deterioration in the Oregon forestsnail habitat.

### 6.1.4 Successes, Challenges and Suggested Changes

After three years of data collection, neither plant mortality nor changes to ecosystem boundaries have been observed, and no major shift in species composition is taking place. Annual variability in leaf drop and decay continue to present a challenge for interpreting the data. Additional years of data will provide a better estimate of natural variability and the ability to identify unusual changes in cover or species assemblages. Completion of future surveys prior to leaf drop will provide more accurate cover metrics for species that are more sensitive to groundwater changes, such as skunk cabbage and lady fern, and for species that tend to lose their leaves quickly, such as salmonberry, red alder, and vine maple.

## 6.2 Indicator Plants

### 6.2.1 Background

Monitoring of hydric indicator plants is identified in the EA Certificate Amendment Application – Mitigation Plans document (2017) as a means to detect effects of potential changes in shallow groundwater and associated soil moisture conditions. Western skunk cabbage (*Lysichiton americanus*) is a hydric soil moisture regime indicator species common to the swamp ecosystems of the Horn Creek and Boa Brook Study Area and the Downes Creek Study Area (Figures 5-3 and 5-4), and both plant density and plant size have been observed to change in with soil moisture (Minore 1969). Indicator plant plots were established in fall 2017 to assess species presence, density, and plant phenology. Comparison of these measures through time will provide a means to assess any observed changes in shallow groundwater dynamics as detected by installed groundwater wells (Section 5). If adverse effects of the Bevan Wells operation occur, shallow ground water elevations are likely to change first, with a vegetation species composition response taking place over a longer time period. Indicator plant plots will be monitored on an annual basis for the first five years to establish typical vegetation and shallow groundwater conditions. The following constitutes data from the fourth year of monitoring as collected in fall 2020.

### 6.2.2 Methods

Ten hydric indicator plant plots have been established within the watersheds of interest: 8 plots in the Downes Creek watershed (Figure5-4) and 2 plots in the Horn Creek and Boa Brook watershed (Figure 5-3). Plot locations are distributed to capture a range of soil moisture conditions ranging from Wm05 sites in downstream confluence areas to Ws53 sites in watershed headwaters. Candidate plot sites required a minimum skunk cabbage patch size of 15m in diameter. Where possible, these plots were installed adjacent to terrestrial ecosystem mapping plots (Section 6.1.2). At Horn Creek, the terrain within the swamp wetland does not allow for a 15m transect and instead two transects of 10m in length are present.

Field work was conducted on September 28- 30, 2020 and on October 08, 2020, about a week later than the 2019 and 2018 data collection. The 2020 field work occurred three weeks earlier than the 2017 data collection due to the amount of petiole decay observed in 2017. To adjust for the amount of decay observed 2017, the 2018 Bevan Avenue Groundwater Supply Development Project Operation Environmental Management Plan (OEMP) (City of Abbotsford, 2018) specifies that sampling should occur after 1065 growing degree days (or Julian days), which is likely to occur around September 20. It also specifies that all plots must be assessed no later than October 1 each year. However, the growing degree day threshold was reached on October 5, 2020. Thus, sampling of most plots occurred before the plants were fully mature.

At each plot, line intercept transects 15-m long were marked with PVC posts at the start and finish. An eslon tape was pulled tight along the transect line. Each mature plant (minimum 6 petioles) intersecting the transect line was included in the plot and its location and longest petiole length recorded. Rules for determining whether plants petioles that intersect the transect and are included in the plot have been developed and applied and are available upon request.

### 6.2.3 Results and Discussion

Detailed plot data may be found in Appendix P. Results are summarized in Table 6-3 and Figures 6-1 to 6-6.

In 2020, average petiole length per plot ranged from 30.17 cm to 51.93 cm (Table 6-3), with an average of 40.0 cm for all plots. This value is lower than the 2019, 2018 and 2017 data, which had average petiole lengths of 47.6 cm, 48.1 cm and 48.4 cm respectively. Average petiole lengths have varied throughout the four years at each site, but there has been no consistent year-to-year trend (Figures 6-1 and 6-2). The 2020 mean petiole lengths were significantly lower than the 2017 measurements at 7 of the 11 sample sites, and in five cases the 2020 results were also significantly lower than the 2019 data.

**Table 6-3 Indicator Plant Plot Results 2017 to 2020**

| Plot # | Average of Petiole Length (cm) | | | | Density (Plants per Metre) | | | | Total Petiole length per metre (cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | 2020 | 2017 | 2018 | 2019 | 2020 | 2017 | 2018 | 2019 | 2020 |
| B02-LA1 | 52.85 | 49.89 | 43.76 | 30.17 | 0.87 | 3.13 | 1.67 | 2.40 | 45.80 | 156.33 | 72.93 | 72.40 |
| D01-LA1 | 63.47 | 60.95 | 58.62 | 51.00 | 2.27 | 2.87 | 2.27 | 2.33 | 143.87 | 174.73 | 129.53 | 119.00 |
| D05-LA1 | 55.15 | 51.88 | 54.74 | 47.83 | 1.33 | 2.20 | 1.53 | 1.20 | 73.53 | 114.13 | 83.93 | 57.40 |
| D06-LA1 | 54.29 | 50.90 | 51.35 | 41.41 | 0.93 | 2.07 | 1.73 | 1.13 | 50.67 | 105.20 | 78.73 | 46.93 |
| D08-LA1 | 35.40 | 37.11 | 33.83 | 33.00 | 0.33 | 0.60 | 0.40 | 0.40 | 11.80 | 22.27 | 13.53 | 13.20 |
| D09-LA1 | 46.58 | 49.35 | 51.50 | 34.00 | 0.80 | 1.53 | 2.00 | 1.93 | 37.27 | 75.67 | 103.00 | 65.73 |
| D10-LA1 | 43.83 | 43.92 | NA** | 48.29 | 0.40 | 0.80 | NA** | 0.93 | 17.53 | 35.13 | NA** | 45.07 |
| D11-LA1 | 38.80 | 41.55 | 44.33 | 34.91 | 0.33 | 0.67 | 0.60 | 0.73 | 12.93 | 27.70 | 26.60 | 25.60 |
| D12-LA1 | 56.98 | 58.97 | 56.84 | 51.93 | 1.73 | 2.13 | 1.67 | 1.73 | 98.77 | 125.80 | 94.73 | 96.93 |
| H01-LA1* | 41.96 | 44.96 | 44.85 | 31.71 | 0.93 | 1.53 | 1.30 | 0.93 | 39.17 | 68.93 | 58.30 | 44.40 |
| H01-LA2* | 42.67 | 39.75 | 36.35 | 35.76 | 1.80 | 2.13 | 1.70 | 1.13 | 76.80 | 84.80 | 61.80 | 60.80 |

*Measures are based on a 10m transect, rather than 15m, and the plots are the same site in parallel
**Plot could not be found due to blowdown that occurred after the 2018 sampling period. The plot was found again in 2020.

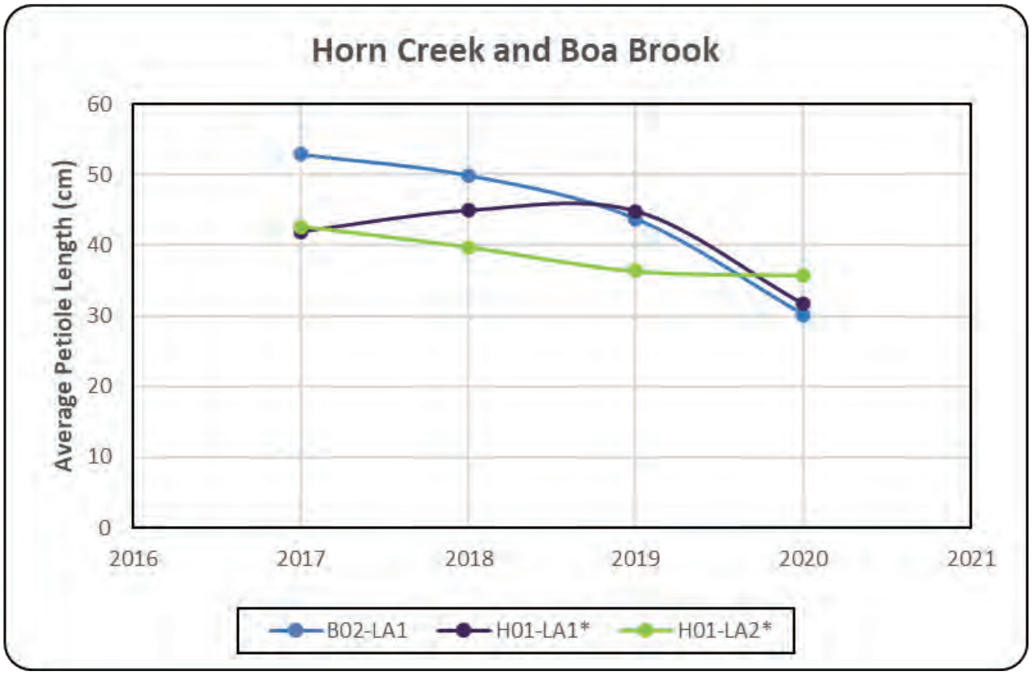



**Figure 6-1** **Comparison of the Average Petiole Length for the 2017 to 2020 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed**

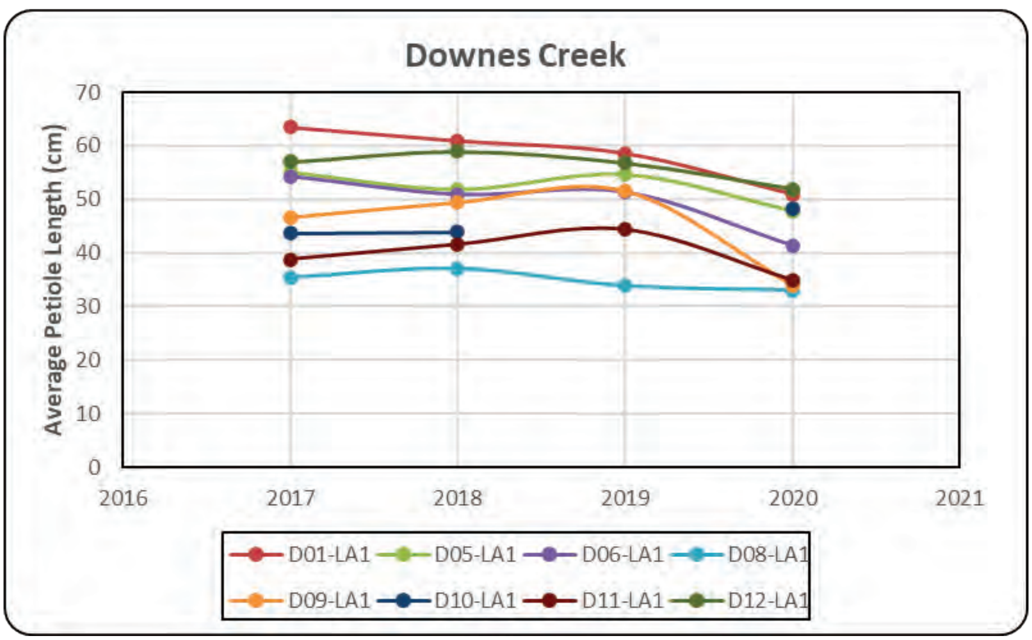



**Figure 6-2** **Comparison of the Average Petiole Length for the 2017 to 2020 Skunk Cabbage Line Intercepts in the Downes Creek Watershed**

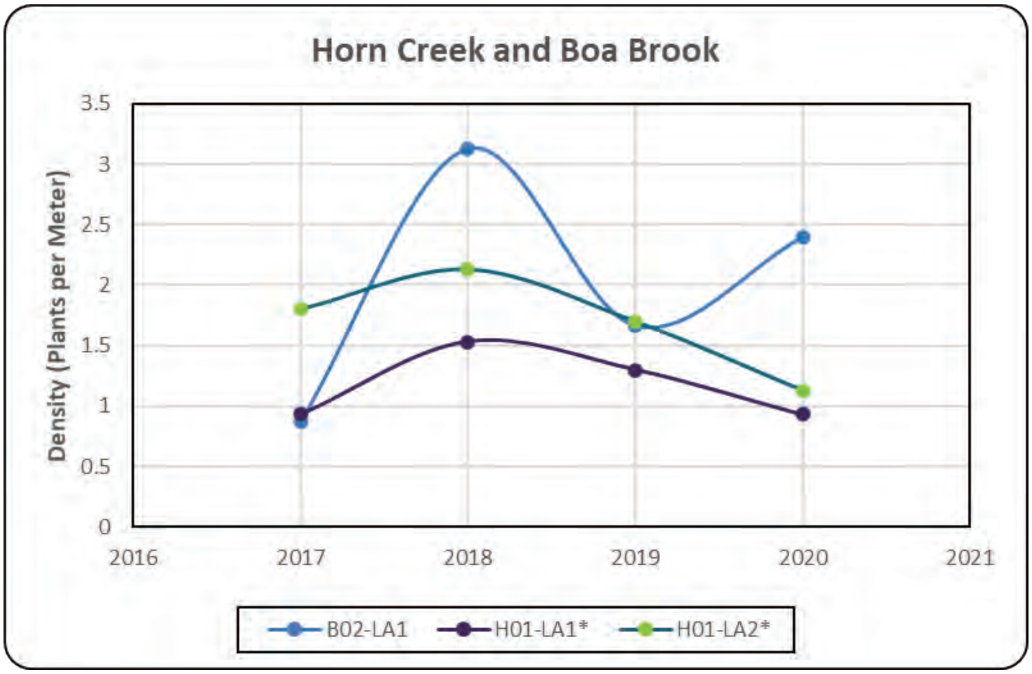



**Figure 6-3 Comparison of the Density of Plants Encountered by the2017 to 2020 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed**

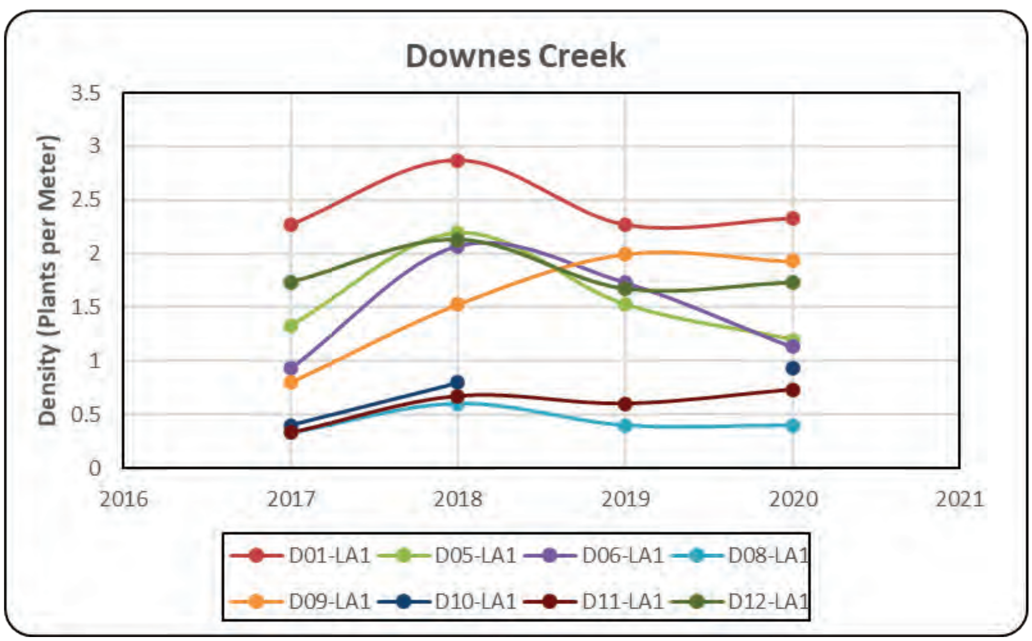



**Figure 6-4 Comparison of the Density of Plants Encountered by the 2017 to 2020 Skunk Cabbage Line Intercepts in the Downes Creek Watershed**

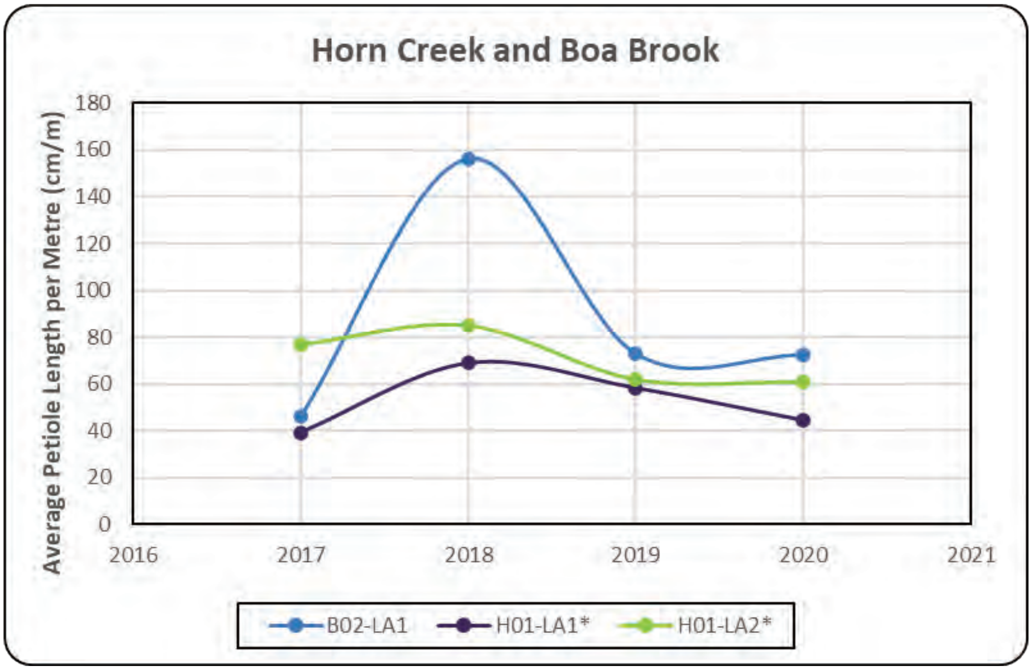



**Figure 6-5 Comparison of the Average Petiole Length Encountered per Metre for the 2017 to 2020 Skunk Cabbage Line Intercept Data in the Horn Creek/Boa Brook Watershed**

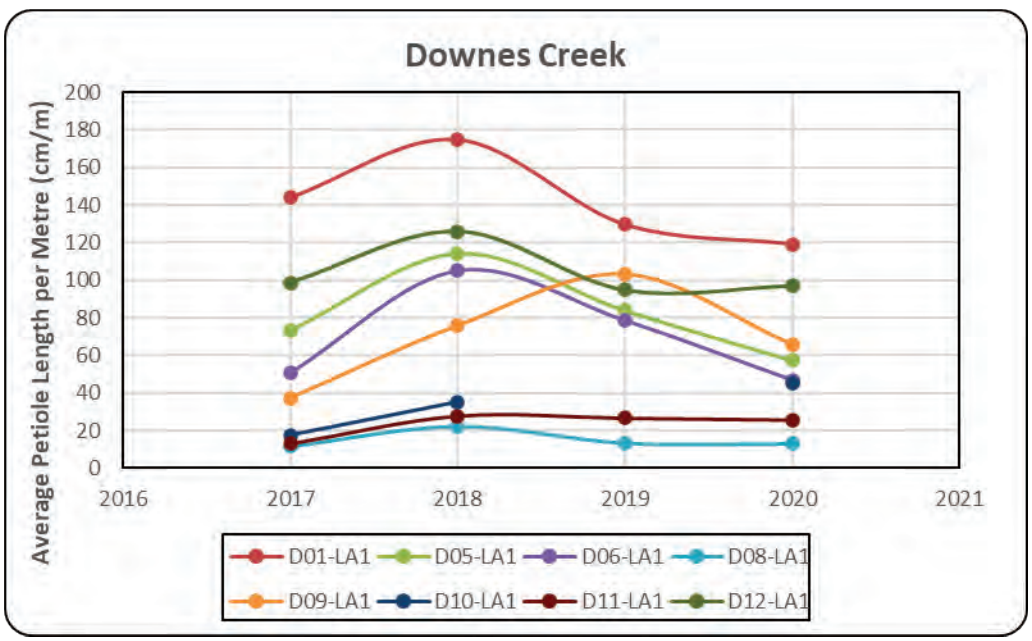



**Figure 6-6 Comparison of the Average Petiole Length Encountered per Metre for the 2017 to 2020 Skunk Cabbage Line Intercept Data in the Downes Creek Watershed**

In 2020 the plant density (as number of plants per metre) was higher than the 2017 density at 7 of the 11 sample sites (Figures 6-3 and 6-4). The 2020 density was lower than the 2019 value at five sites. Sites B02, D01, and D12 had greater plant densities in 2020 than in 2019. No consistent pattern was seen in density through time across the sites.

Petiole length per metre values decreased at four of the sites in 2020 compared with 2017; however, trends were not consistent across all sites (Figures 6-5 and 6-6). The 2020 average petiole length per metre was 58.86 cm compared to 72.31 cm in 2019, 90.06 cm in 2018, and 55.29 cm in 2017.

Overall, petiole lengths per meter and plant densities have varied greatly over the four years of monitoring, and no set pattern has been observable within the dataset. Year-to-year differences were not related to variations in water extraction by the Bevan Wells.

### 6.2.4 Successes, Challenges, and Suggested Changes

Due to the assessment timing change included in the OEMP, the 2018 to 2020 fieldwork was completed 4 to 5 weeks earlier than the 2017 baseline, with a goal of viewing plants largely prior to decay. The first two days of the 2020 survey followed the October 1 deadline laid out in the OEMP. As a result, most sites were inventoried prior to the growing degree day threshold, which was October 5, 2020. One site was inventoried on October 8, three days after the threshold. Despite the fact that the 2020 inventory was largely completed before the maturation threshold, decay was observed in all plots. Completing the survey prior to the threshold may have resulted in slightly shorter petiole lengths as plants were 7 to 8 days from the full growing season outlined by the growing degree day target.

It is clear that maturation is not the sole factor influencing encounter rate of mature skunk cabbage plants. Future surveys should expect some year-to-year changes in measurements due to weather/climatic variations, such as an earlier arrival of fall rains, which has a strong impact on plant decay.

# 7.0 CONCLUSIONS

This report summarises the findings from the Year 10 (May 2020 – April 2021) environmental monitoring of the Bevan Wells Groundwater Supply Development Project. Year 10 data have been presented in comparison with previous annual monitoring data, including the Year 2 baseline data, and Year 3 and 4 data when the mitigation wells were augmenting flows to Horn Creek and Boa Brook.

A maximum daily withdrawal of 25 ML/day is permitted under the EA Certificate. The Bevan wells were used extensively from Year 3 through Year 10. In 2020, the maximum daily withdrawal was 17.056 ML/day, and the total withdrawal was 1,766 ML or 70% of the total allowable groundwater diversion (2,505 ML/year).

Although the Bevan wells have been used extensively in Years 3 through 10, water quality data have remained generally consistent with Year 2 baseline data. The only observed change was a statistically significant decreasing trend in dissolved oxygen concentrations at B-01 and H-02. However, water temperature at H-02 did not show a corresponding increase, which suggests that the trend was unrelated to the operation of the Bevan Wells. Other data for Years 2 to 10 show that the use of the Bevan Wells has not affected water quality.

Six representative sites for the assessment of fish habitat (two on Boa Brook and four on Horn Creek) continued to be assessed as part of the annual monitoring program. There was very little change in physical habitat parameters from the previous annual monitoring results. There were no statistically significant decreasing trends in wetted width, bankfull width, or bankfull depth. Any changes over time are attributable to natural variation of physical habitat parameters or due to variations in sampling locations. Since 2018, channel measurements and wetted width measurements have been recorded at clearly defined sampling locations to reduce the latter source of variability.

Groundwater levels were measured at seven monitoring well locations. Seasonal low water levels measured in 2018 to 2020 were similar to those measured in 2015 and 2016 and lower than the levels measured in 2017. The difference is attributed to an overall higher precipitation in 2017. There was no evidence of a progressive year-over-year decline in water levels in any of the observation wells.

Year 10 was the third full year of the expanded monitoring programs required under the amended EA Certificate, although some data were collected in 2017 during establishment of the additional monitoring stations. Stream flow, water quality, fish mesohabitat, shallow groundwater, and wetland/riparian vegetation were monitored at sites in Downes Creek and Fishtrap Creek. The results are presented in the current report, but it is too early to assess trends at these sites. However, the results of Downes Creek monitoring programs showed no changes that would suggest an immediate need for a mitigation well. Future reports will consider trends, if any, in the measured parameters in relation to operation of the Bevan Wells and the potential requirement for a Downes Creek mitigation well.

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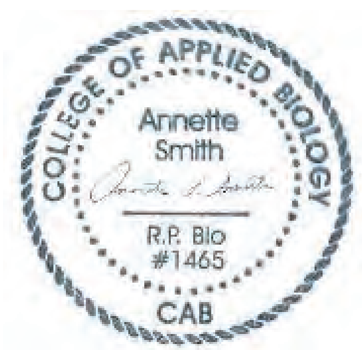

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