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 or Z	Significance	Mann-Kendall S or Z	Significance
1A (Horn Creek)	2012	2022	11	3.43	**p <0.001**	2.02	**p <0.05**
1B (Horn Creek)	2012	2022	11	2.96	**p <0.01**	2.11	**p <0.05**
2A (Horn Creek)	2012	2022	11	2.65	**p <0.01**	1.87	p <0.10
2B (Horn Creek)	2012	2022	11	2.34	**p <0.05**	2.34	**p <0.05**
2C (Horn Creek)	2014	2022	9	-12		10	
3A (Horn Creek)	2012	2022	11	1.64		2.02	**p <0.05**
3B (Horn Creek)	2012	2022	11	1.87	p <0.10	0.934	
3C (Horn Creek)	2014	2022	9	-2		30	**p <0.001**
4A (Boa Brook)	2012	2022	11	1.87	p <0.10	1.40	
4B (Boa Brook)	2012	2022	11	3.11	**p <0.01**	0.93	
5A (Boa Brook)	2012	2022	11	2.18	**p <0.05**	1.64	
5B (Boa Brook)	2012	2022	11	2.96	**p <0.01**	0.778	
5C (Boa Brook)	2012	2022	11	1.17		1.25	
5D (Boa Brook)	2014	2022	9	22	**p <0.05**	20	**p <0.05**
6A (Horn Creek)	2012	2022	11	0.000		2.18	**p <0.05**
6B (Horn Creek)	2012	2022	11	-0.934		0.934	

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

As discussed for wetted width, five 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.

Habitat Suitability for Salmonids

The methods for fish habitat monitoring described in Section 3.4 were adapted from the BC Instream Flow Methodology developed by Lewis *et al.* (2004) for assessing the effects of dams and water diversion/extraction. The assumption was that the habitat parameters would be weighted by a habitat suitability scores ranging from 0 to 1. These scores would then be combined to calculate a Habitat Suitability Index (HSI) that would quantify the loss of habitat for each fish species/life stage resulting from decreased instream flow. Lewis *et al*. (2004) stated, "HSI scores will be available on the Ministry web site for most species and life stages of interest."

HSI scores are not available on either the Ministry of Environment and Climate Change Strategy or the Ministry of Land, Water, and Resource Stewardship website.[4] However, Ptolemy (2001), with input from various professionals, developed habitat suitability curves for water use planning (WUP). An Excel spreadsheet of these curves (Wright 2003) is available. It calculates amount (in meters) and percentage of suitable habitat based on depth and velocity along a channel cross section. The spreadsheet includes suitability calculations for three salmonid species known to inhabit Horn Creek, Downes Creek, and/or Fishtrap Creek: coho salmon, cutthroat trout, and rainbow trout. The calculations for cutthroat trout and rainbow trout include suitability for two life stages: fry and parr (fingerlings).

The spreadsheet was used to evaluate changes, if any, in the amount of suitable habitat for coho, cutthroat trout fry and parr, and rainbow trout fry and parr. The assessment was based on changes in the amount of usable habitat in meters of channel width. The percent of usable habitat was not considered on the assumption that wetted channel width could decrease resulting in a higher proportion of usable width in spite of a decrease to the absolute amount of usable habitat.

Figures 3-12 to 3-14 illustrate the changes in habitat suitability in Boa Brook and Horn Creek. The evaluation of habitat suitability in these creeks was limited to mesohabitat sites where the pre-2019 channel measurements were detailed enough to calculate suitability (4A and 5B in Boa Brook and 1A, 2A, 3A, and 6A in Horn Creek). Mann-Kendall trend tests showed significant changes in habitat suitability for some species and/or life stages at some sites but no overall decrease in availability of suitable habitat (Table 3-4). Changes included statistically significant decreases in coho ($p < 0.05$) and cutthroat trout ($p < 0.01$) habitat at Horn Creek 1A. In contrast, there were significant ($p < 0.05$) increases in habitat suitability for coho and cutthroat trout parr at Boa Brook 5B and rainbow trout fry at Horn Creek 1A.

Depth and velocity were measured at the Downes Creek and Fishtrap mesohabitat sites from 2019 through 2022. The four year of data were insufficient for statistical analyses. However, the results are graphed in Figures 3-15 through 3-20. Changes in amounts of suitable habitat were not consistent from site to site, and the amount of data scatter was wide. The results did not suggest a negative impact from operation of the Bevan Wells.

[4] A report by Rempel *et al*. (2012) contains habitat suitability criteria for rainbow trout; chinook, chum, and sockeye salmon; mountain whitefish, and mountain sucker.

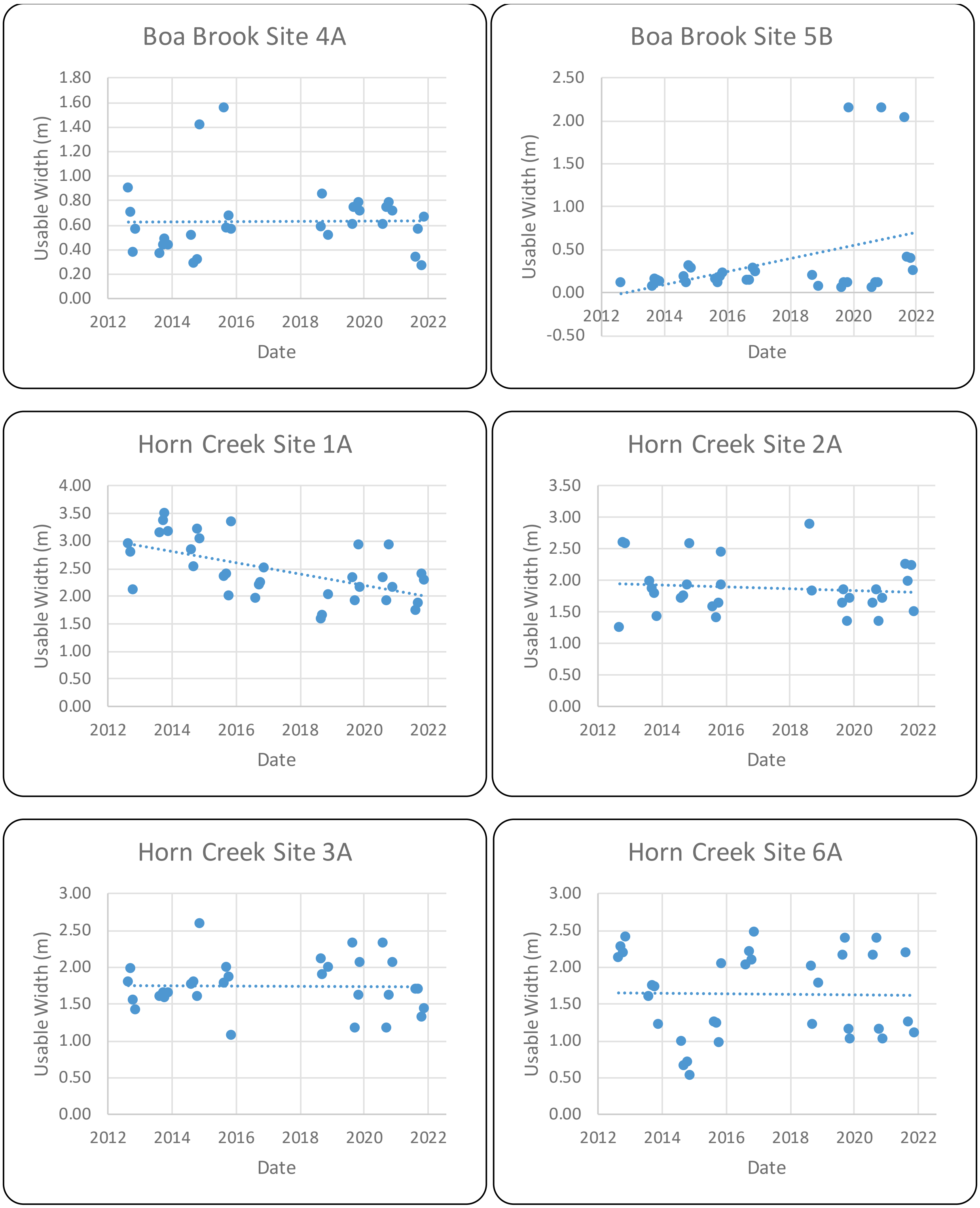


Figure 3-13 Habitat Suitability for Coho at Boa Brook and Horn Creek Mesohabitat Sites (2013 to 2022)

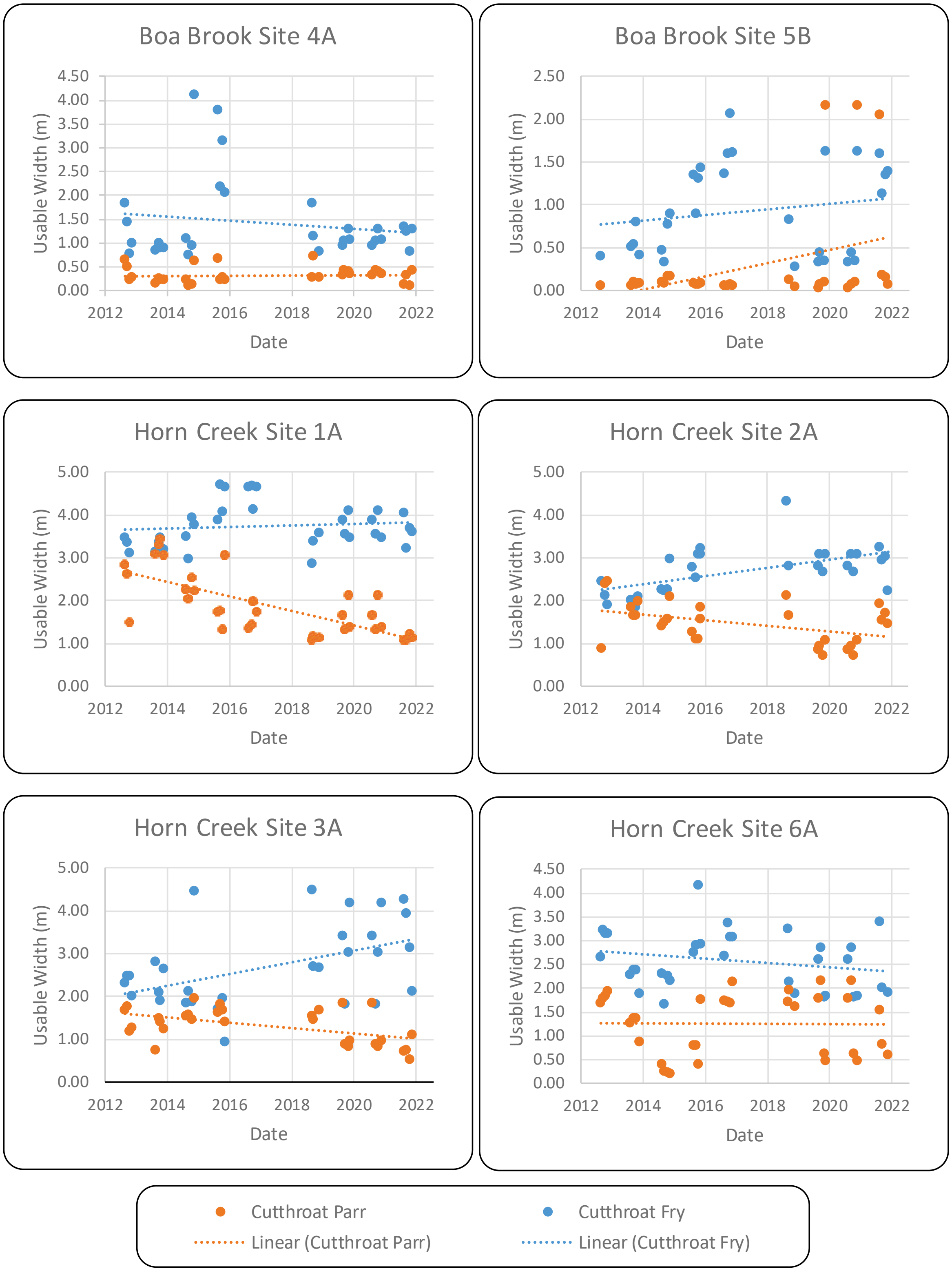


Figure 3-14 Habitat Suitability for Cutthroat Trout at Boa Brook and Horn Creek Mesohabitat Sites (2013 to 2022)

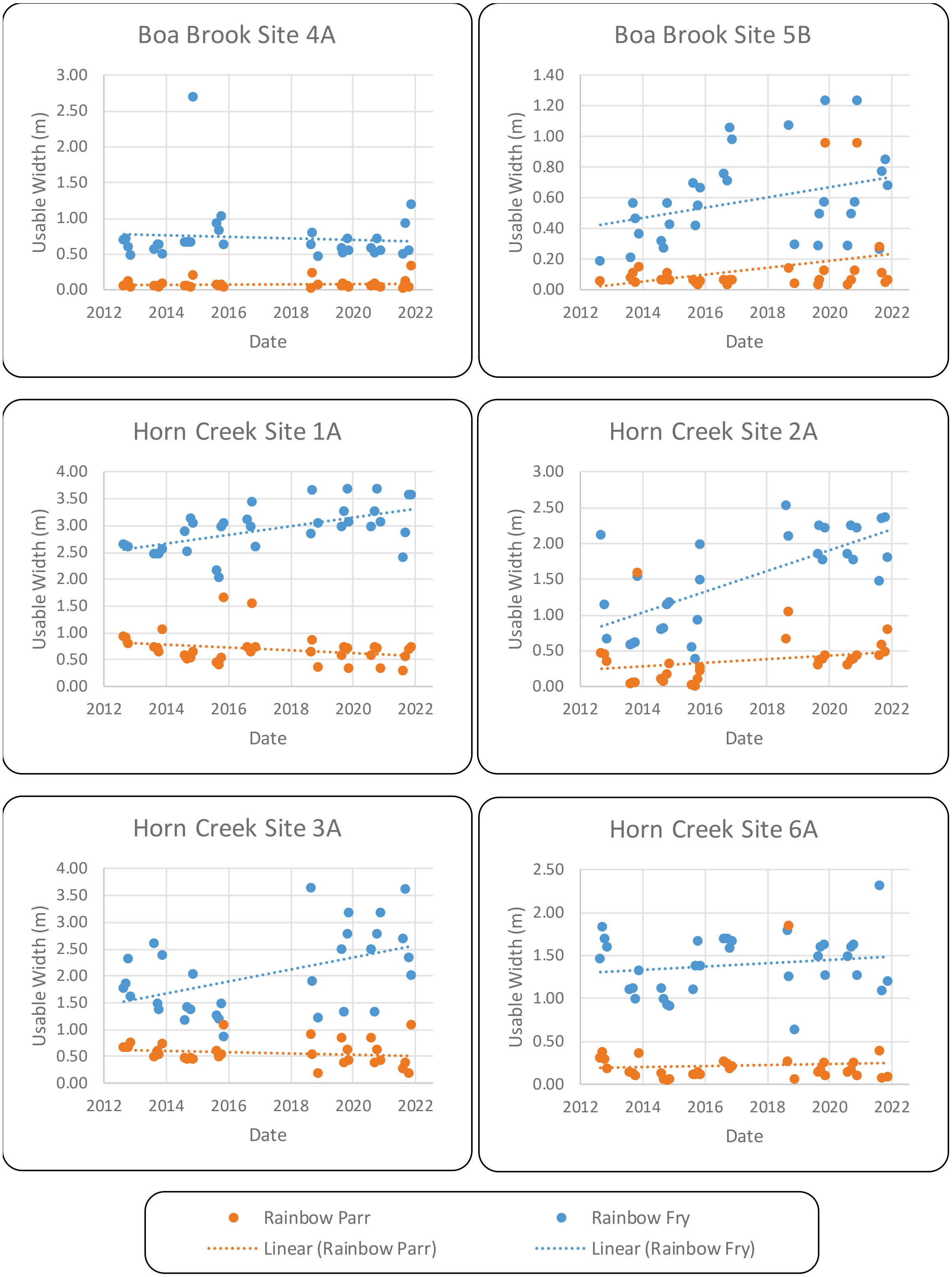


Figure 3-15 Habitat Suitability for Rainbow Trout at Boa Brook and Horn Creek Mesohabitat Sites (2013 to 2022)

Table 3-4 Statistical Significance of Mann-Kendall Trends in Availability of Suitable Fish Habitat at Selected Mesohabitat Monitoring Sites in Boa Brook and Horn Creek

Species & Life Stage	Mesohabitat Site	First Year	Last Year	n	Mann-Kendall S	Significance
Coho	4A (Boa Brook)	2013	2022	8	5	
	5B (Boa Brook)	2013	2022	9	25	**p <0.05**
	1A (Horn Creek)	2013	2022	9	-21	**p <0.05**
	2A (Horn Creek)	2013	2022	8	-5	
	3A (Horn Creek)	2013	2022	8	-1	
	6A (Horn Creek)	2013	2022	9	-1	
Cutthroat Fry	4A (Boa Brook)	2013	2022	8	-5	
	5B (Boa Brook)	2013	2022	9	17	
	1A (Horn Creek)	2013	2022	9	7	
	2A (Horn Creek)	2013	2022	8	9	
	3A (Horn Creek)	2013	2022	8	17	p <0.10
	6A (Horn Creek)	2013	2022	9	-1	
Cutthroat Parr	4A (Boa Brook)	2013	2022	8	1	
	5B (Boa Brook)	2013	2022	9	25	**p <0.05**
	1A (Horn Creek)	2013	2022	9	-29	**p <0.01**
	2A (Horn Creek)	2013	2022	8	-13	
	3A (Horn Creek)	2013	2022	8	-15	
	6A (Horn Creek)	2013	2022	9	-5	
Rainbow Fry	4A (Boa Brook)	2013	2022	8	-1	
	5B (Boa Brook)	2013	2022	9	15	
	1A (Horn Creek)	2013	2022	9	23	**p <0.05**
	2A (Horn Creek)	2013	2022	8	11	
	3A (Horn Creek)	2013	2022	8	17	p <0.10
	6A (Horn Creek)	2013	2022	9	9	
Rainbow Parr	4A (Boa Brook)	2013	2022	8	3	
	5B (Boa Brook)	2013	2022	9	17	
	1A (Horn Creek)	2013	2022	9	-19	p <0.10
	2A (Horn Creek)	2013	2022	8	3	
	3A (Horn Creek)	2013	2022	8	-11	
	6A (Horn Creek)	2013	2022	9	1	

Negative values of Z or S represent downward trends; positive values represent upward trends.
p – probability. Blank indicates p >0.1. Significance set at p <0.05.

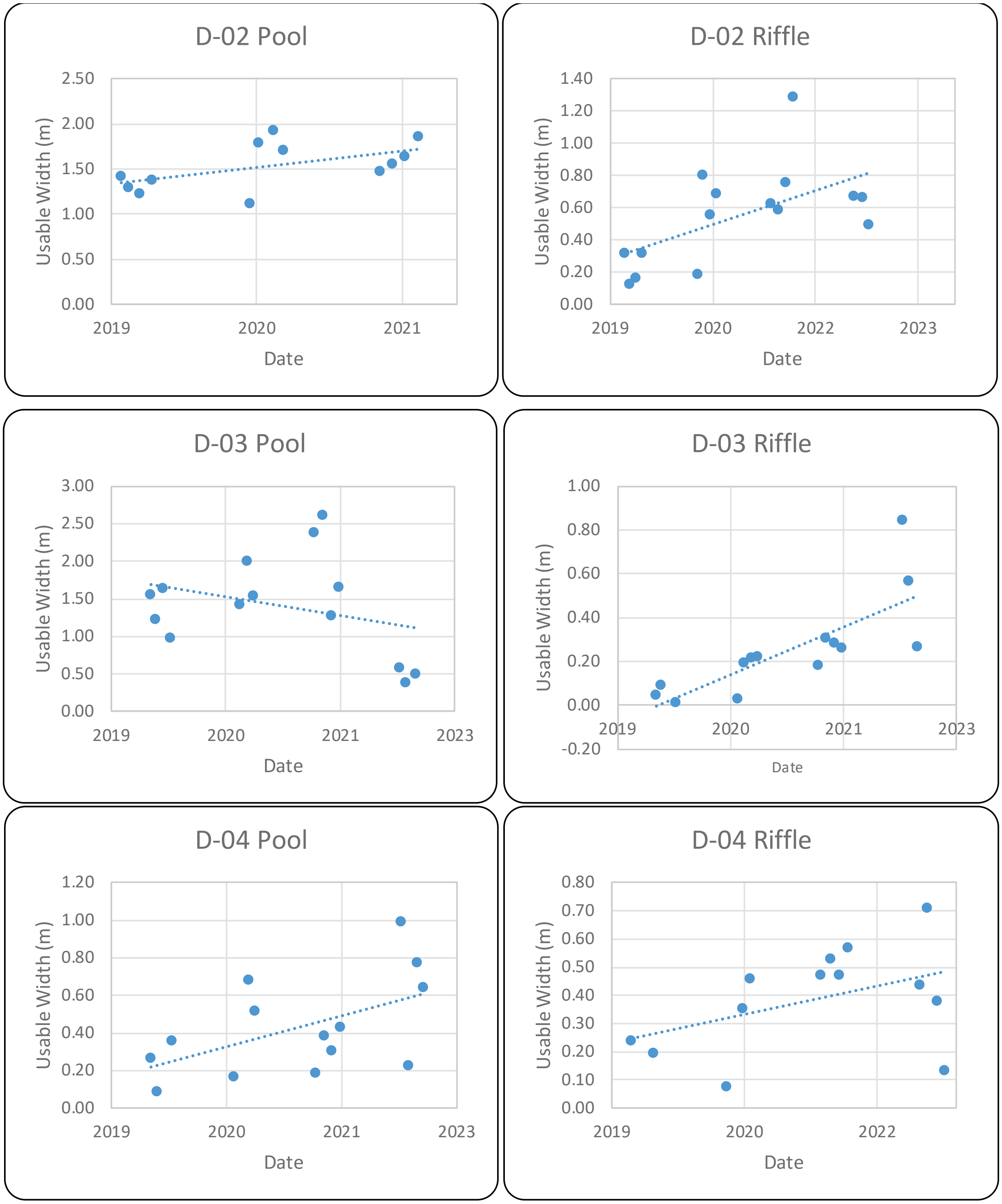


Figure 3-16 Habitat Suitability for Coho at Downes Creek Mesohabitat Sites (2019 to 2022)

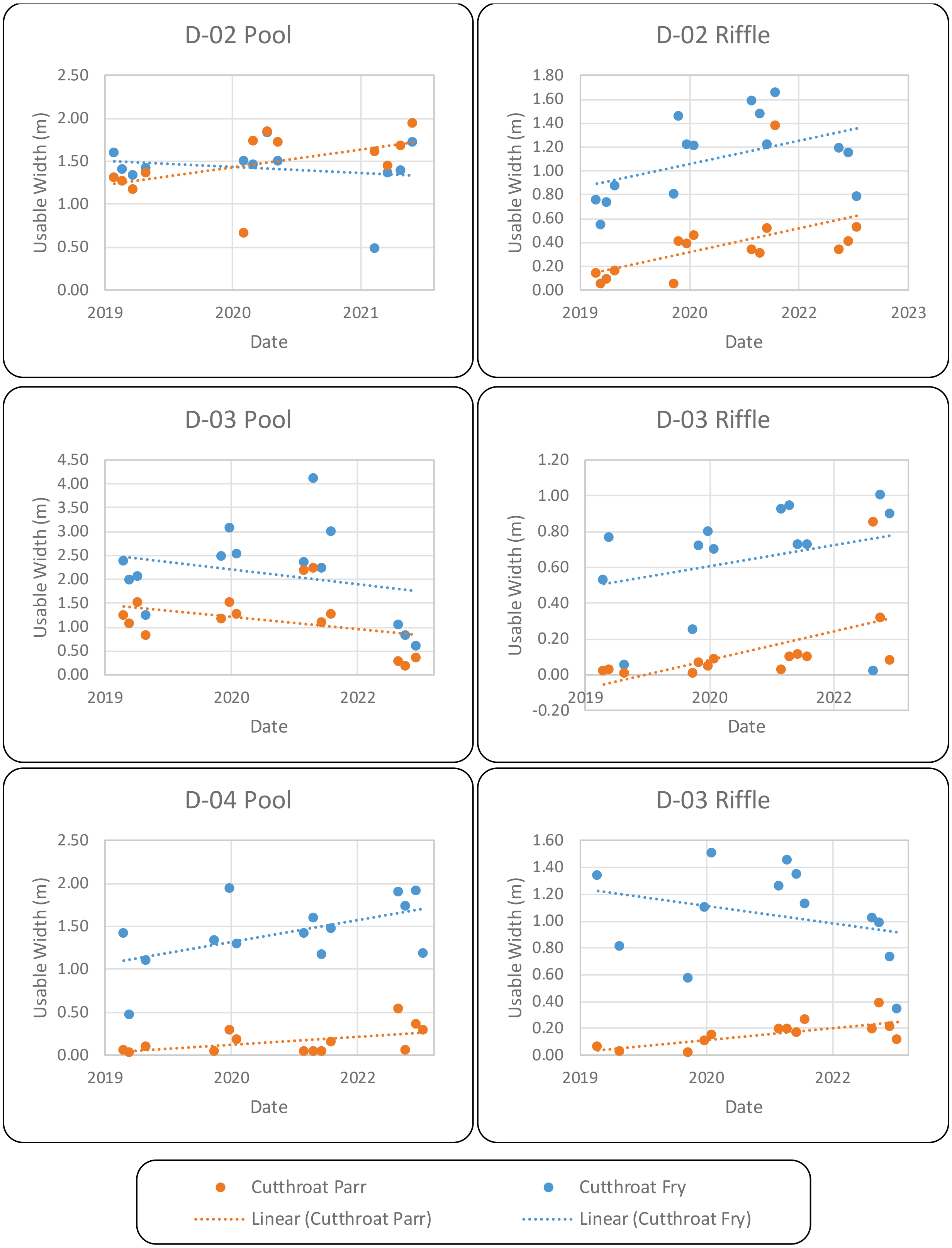


Figure 3-17 Habitat Suitability for Cutthroat Trout at Downes Creek Mesohabitat Sites (2019 to 2022)

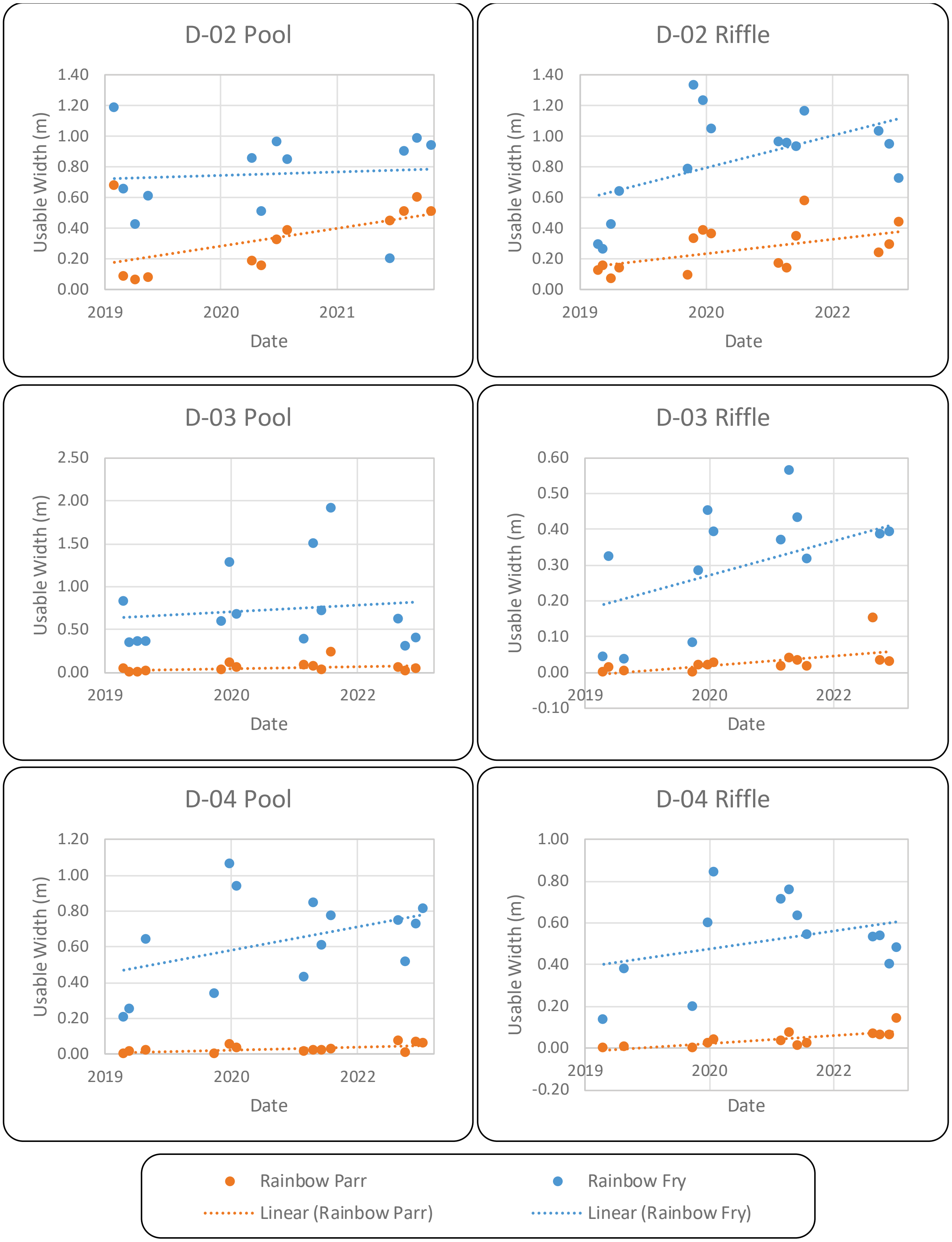


Figure 3-18 Habitat Suitability for Rainbow Trout at Downes Creek Mesohabitat Sites (2019 to 2022)

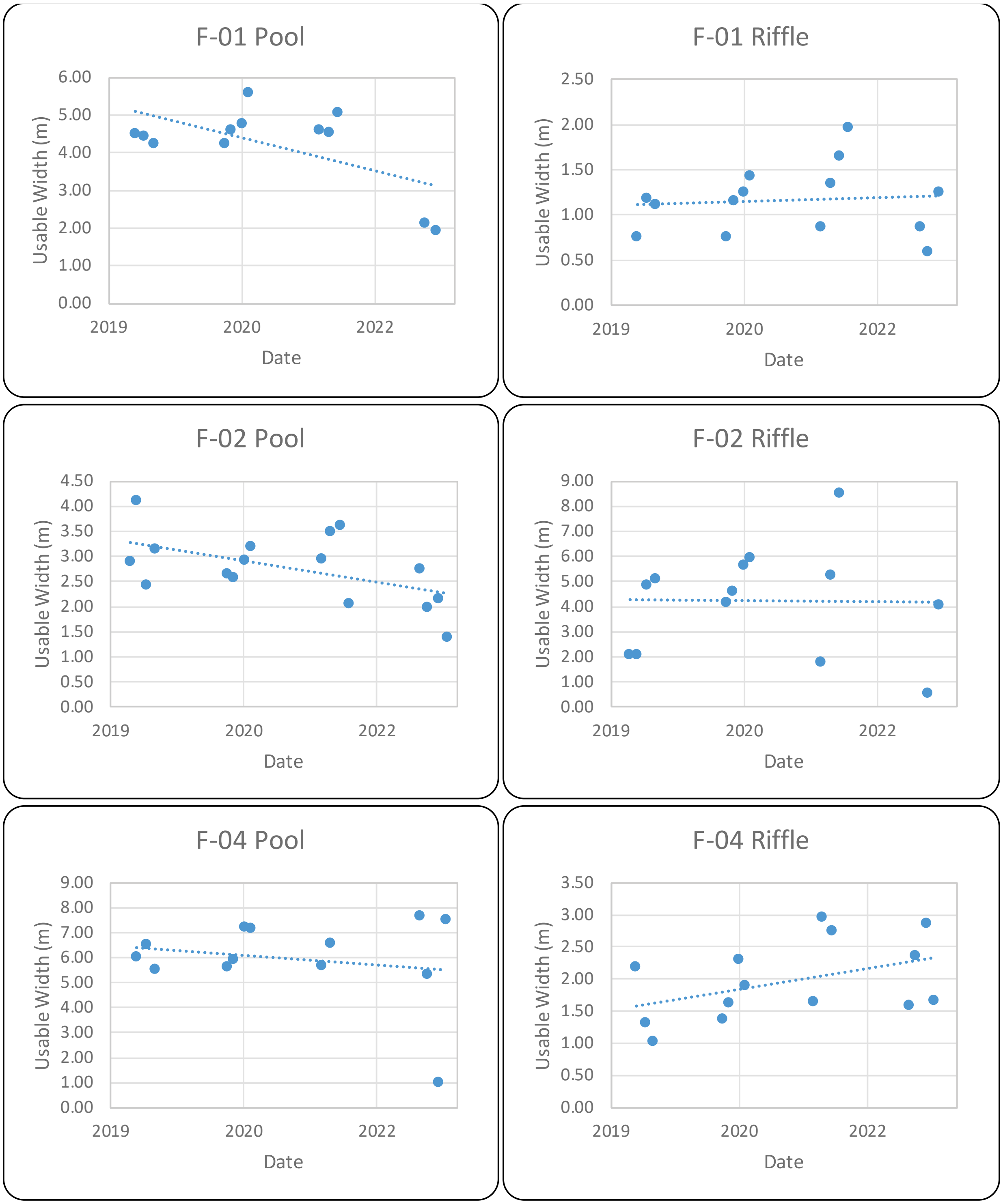


Figure 3-19 Habitat Suitability for Coho at Fishtrap Creek Mesohabitat Sites (2019 to 2022)

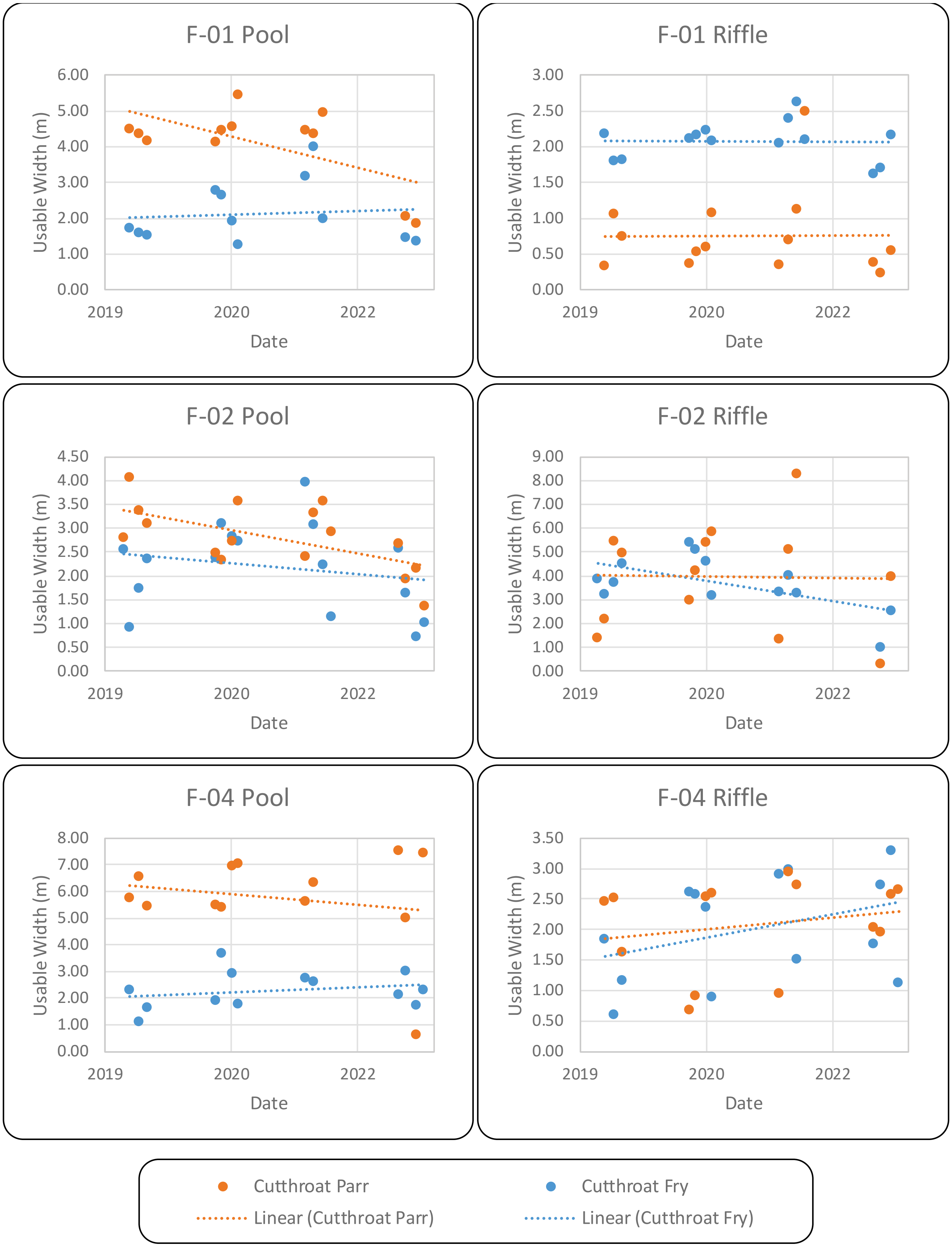


Figure 3-20 Habitat Suitability for Cutthroat Trout at Fishtrap Creek Mesohabitat Sites (2019 to 2022)

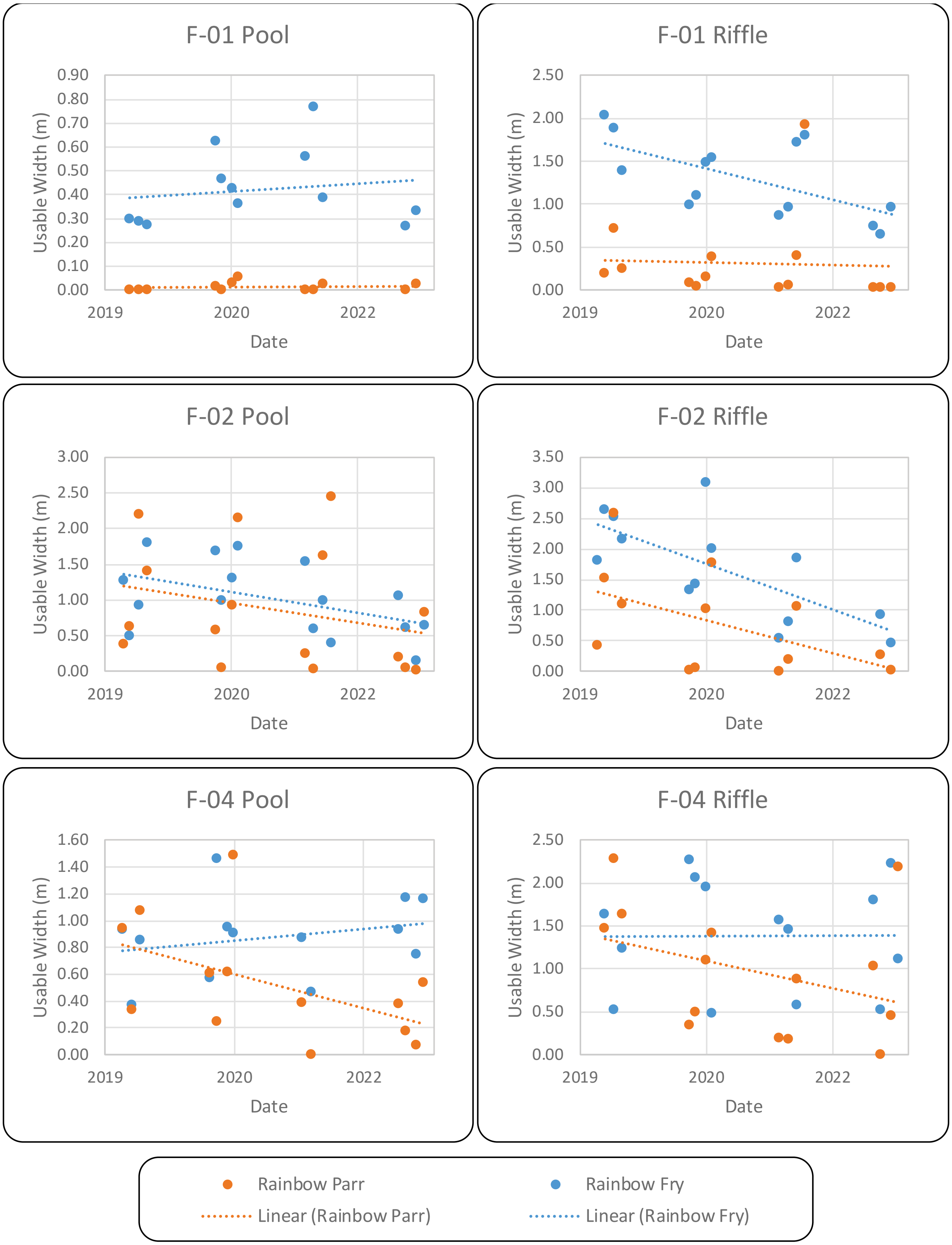


Figure 3-21 Habitat Suitability for Rainbow Trout at Fishtrap Creek Mesohabitat Sites (2019 to 2022)

3.6 Successes, Challenges and Suggested Changes

As a result of beaver dams mesohabitat site F-03 was too deep to wade to collect physical channel measurements in 2022 except during the September site visit. This was also the case for all site visits in 2021. Beaver activity affected the F-02-riffle site in 2021 and 2020, changing the site characteristics over the monitoring seasons. It will be difficult to identify effects, if any, of the Bevan Wells on fish habitat at these sites due to the confounding influence of beaver activity. A qualified fisheries biologist should assess the possibility of finding additional or alternate mesohabitat monitoring sites that are unaffected by beavers, although these sites will not likely be available in some reaches.

4.0 GROUNDWATER PROGRAM

4.1 Well Water Quality Monitoring

4.1.1 Background

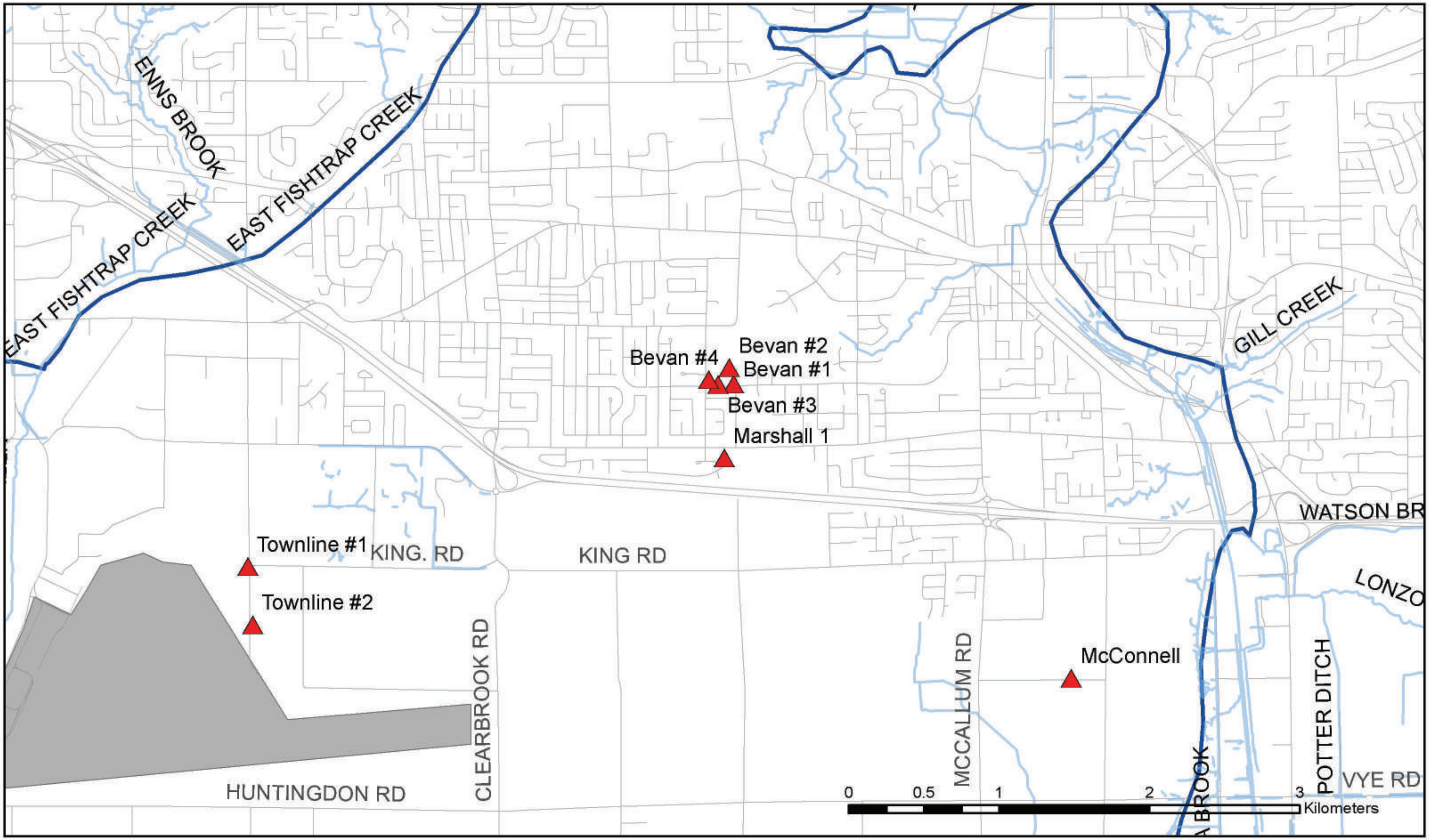
During installation of the mitigation wells in summer 2011, Hemmera investigated groundwater quality in comparison with existing background surface water quality in the receiving waters of Horn Creek and Boa Brook. No constituents of potential concern (COPC) were identified as a result of potential groundwater 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 11. 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.



Legend

- Drinking Wells
- Streams
- Roads
- Airport
- Abbotsford-Sumas aquifer

N

Scale: 1:35,000

Prepared by:
ENKON Environmental Ltd.

Drinking Water Well Locations

City of Abbotsford

Figure 4-1

December 2019

Document Path: N:\GIS_Base\1021\016_Bevan_Yr8\DrinkingWellLocations_R03.mxd

Table 4-1 Average Water Quality of the Allen Park Mitigation Well (Year 2 – Year 12)

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	Year 11	Year 12	CCME	BCWQG	SSWQG
pH	pH	8.17	8.33	8.33	8.30	8.21	8.29	8.48	8.47	8.45	8.26	8.39	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	0.13	0.14	See Appendix		
Total Phosphorus (P)	mg/L	0.182	0.186	0.175	0.149	0.149	0.151	N/A	0.195	0.209	0.19	0.19	See Appendix		0.03
Nitrate (N)	mg/L	0.02	0.002	<	<	<	0.358	<	<	<	0.0023	0.0021	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	53.8	58.2			
Fluoride (F)	mg/L	0.178	0.178	0.150	0.147	0.154	0.189	0.204	0.207	0.210	0.21	0.22	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	3.3	3.8	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	16.9	17.4	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	24.9	27.4		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	169	178	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	1.05	1.33	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	33	27	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	0.30	0.47	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	18.6	20.3		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	8.1	9.0	73	2000	
Total Nickel (Ni)	µg/L	1	<	0.025	0.083	0.292	0.214	1.02	0.833	0.667	1.1	1.2	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	80.2	90.2			
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	5.3	5.2	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	11.2	12.4			
Total Magnesium (Mg)	mg/L	3.60	4.52	5.12	6.58	6.95	7.02	6.48	6.55	5.96	6.25	6.65			
Total Potassium (K)	mg/L	4.60	5.15	5.23	N/A	N/A	N/A	6.45	6.36	6.15	6.29	6.48			
Total Silicon (Si)	mg/L	6.87	7.04	6.99	N/A	N/A	N/A	7.33	7.32	7.46	7.52	7.54			
Total Sodium (Na)	mg/L	43.0	49.1	41.0	N/A	N/A	N/A	67.2	66.7	68.1	65.8	68.1			
Total Sulphur (S)	mg/L	5.46	6.44	5.80	N/A	N/A	N/A	8.0	8.0	8.0	7.8	7.9			

< - 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 0.59 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 average arsenic concentrations ranging from 0.96 µg/L to 1.06 µg/L and average fluoride concentrations ranging from 0.055 mg/L to 0.056 mg/L. All other parameters except total phosphorus had concentrations below guidelines to protect aquatic life. However, the average total phosphorus concentrations ranged from 0.037 mg/L to 0.060 mg/L and were above the 0.03-mg/L water quality objective for the Sumas River.

The results for the eight 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 copper in most drinking water wells and nitrate in some wells were higher than in the mitigation wells. This also was the case in Years 9 through 11.

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, Marshall Road Wells, and the mitigation wells;
- Measurements of water levels in seven existing[5] 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

[5] Plus analysis of data from one well (MW6-59) monitored by the Clearbrook Water District and seven observation wells (#2, #8, #15, #272, #299, #301 & #441) monitored by the Ministry of Environment and Climate Change Strategy.

Table 4-2 Average Water Quality of the Garibaldi Park Mitigation Well (Year 2 – Year 12)

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	Year 11	Year 12	CCME	BCWQG	SSWQG
pH	pH	7.81	7.81	7.63	7.18	7.11	7.43	7.66	7.70	7.57	7.51	7.48	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	0.018	<	See Appendix		
Total Phosphorus (P)	mg/L	0.006	0.006	0.015	0.036	0.0068	0.021	N/A	0.0073	0.0061	0.0048	0.0074	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	2.09	2.16	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	113	116			
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	3.1	3.3	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	0.59	0.58	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	10.1	10.5		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	0.018	0.019	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	1.1	1.0	1 (Cr VI), 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	<	0.21		110	
Total Copper (Cu)	µg/L	2.62	2.69	2.77	3.33	2.83	2.98	2.87	2.99	2.48	1.71	1.97	See Appendix		See Appendix
Total Iron (Fe)	µg/L	203	104	107	58	56	41	29	28	28	43	67	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	0.27	0.35	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	1.0	1.3		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	<	1.4	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	0.56	0.54	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	139	143			
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	0.14	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	10.9	13.7	30	See Appendix	See Appendix
Total Zirconium (Zr)	µg/L	0.5	<	<	N/A	N/A	N/A	<	<	<	0.12	<			
Total Calcium (Ca)	mg/L	25.4	28.1	28.6	28.9	29.7	28.2	30.2	31.1	30.5	31.1	32.3			
Total Magnesium (Mg)	mg/L	7.16	7.63	7.83	8.08	8.37	8.25	8.40	8.64	8.44	8.46	8.52			
Total Potassium (K)	mg/L	1.2	1.31	1.31	N/A	N/A	N/A	<1.83	1.78	1.33	1.36	1.37			
Total Silicon (Si)	mg/L	10.7	11.5	11.6	N/A	N/A	N/A	11.3	11.2	11.1	11.5	11.7			
Total Sodium (Na)	mg/L	5.89	57.4	6.43	N/A	N/A	N/A	6.87	7.06	6.91	6.93	6.86			
Total Sulphur (S)	mg/L	4.2	4.6	4.8	N/A	N/A	N/A	5.0	5.0	5.1	4.9	4.9			

< - Not detected

N/A - Not analyzed

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

Parameter:	Units:	2019 - 2020	2020 - 2021	2021 - 2022	2022 - 2023	Guidelines for Freshwater Aquatic Life		
						CCME	BCWQG	SSWQG
pH	pH	8.27	8.25	8.12	8.20	6.5 to 9.0	6.5 to 9.0	6.5 to 9.0
Ammonia (N)	mg/L	0.156	0.154	0.15	0.17	See Appendix		
Total Phosphorus (P)	mg/L	0.060	0.048	0.037	0.039	See Appendix		0.03
Nitrate (N) - Calculated	mg/L	<	<	0.0022	0.0025	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	118	124			
Fluoride (F)	mg/L	0.055	0.055	0.056	0.055	0.12	See Appendix	
Total Aluminum (Al)	µg/L	3.0	3.0	3.1	3.2	See Appendix	See Appendix	
Total Antimony (Sb)	µg/L	<	<	<	<		9 (SbIII)	
Total Arsenic (As)	µg/L	1.06	1.03	0.96	1.0	5	5	
Total Barium (Ba)	µg/L	20.3	21.1	22.1	22.8		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	<	<	<	<	1 (Cr VI), 8.9 (Cr III)		See Appendix
Total Cobalt (Co)	µg/L	<	<	<	<		110	
Total Copper (Cu)	µg/L	<	<	0.54	<	See Appendix		See Appendix
Total Iron (Fe)	µg/L	58	92	98	120	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	104	109		See Appendix	
Total Mercury (Hg)	µg/L	<	<	<	<	0.026		
Total Molybdenum (Mo)	µg/L	0.645	0.748	1.0	<	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	115	121			
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	5.2	<	30	See Appendix	See Appendix
Total Zirconium (Zr)	µg/L	<	<	<	<			
Total Calcium (Ca)	mg/L	29.5	31.1	32.5	34.3			
Total Magnesium (Mg)	mg/L	8.43	8.68	9.01	9.18			
Total Potassium (K)	mg/L	2.76	2.74	2.83	2.81			
Total Silicon (Si)	mg/L	12.1	12.0	12.3	12.6			
Total Sodium (Na)	mg/L	11.9	11.1	11.8	10.2			
Total Sulphur (S)	mg/L	4.7	4.9	5.0	5.1			

< - Not detected

Table 4-4 Average Water Quality of Selected Drinking Water Wells (Year 12)

Parameter	Units	Bevan #1	Bevan #2	Bevan #3	Bevan #4	Marshall #1	Marshall #3	McConnell	Townline #2
pH	pH Units	7.08	7.07	7.04	6.61	8.06	7.84	n/a	6.92
Colour	TCU	<5.5	<5.5	<5.7	n/a	<6.5	<5.9	n/a	<10.1
Total Dissolved Solids	mg/L	167	160	170	n/a	243	207	n/a	135
Hardness (total, as $CaCO_3$)	mg/L	90.1	88.6	84.9	79.1	149	134	136	76.2
Chloride	mg/L	30.7	29.3	31.7	n/a	29.3	28.0	n/a	17.0
Fluoride	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Turbidity	NTU	0.20	0.45	<0.13	n/a	0.10	<0.11	n/a	<0.15
Ammonia (total, as N)	mg/L	<0.015	<0.015	n/a	<0.015	<0.123	<0.015	<0.016	<0.015
Nitrate (as N)	mg/L	3.18	3.10	3.15	3.26	<0.0072	0.633	1.84	4.07
Nitrite (as N)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.089	<0.002
Aluminum (total)	µg/L	<3.0	<3.0	<3.1	<14.1	<3.0	<3.0	<3.0	<3.0
Antimony (total)	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Arsenic (total)	µg/L	0.225	0.295	0.237	0.200	4.34	1.20	6.407	0.694
Barium (total)	µg/L	5.82	6.78	5.92	5.63	15.8	10.3	31.6	6.28
Beryllium (total)	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bismuth (total)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Boron (total)	µg/L	<50	<50	<50	<50	<50	<50	<50	<50
Cadmium (total)	µg/L	0.026	0.025	0.024	0.045	0.033	0.032	<0.013	0.029
Chromium (total)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cobalt (total)	µg/L	<0.2	<0.2	<0.2	<0.27	<0.2	<0.2	<0.2	<0.2
Copper (total)	µg/L	7.81	7.31	11.4	21.3	1.61	0.89	2.84	13.8
Iron (total)	µg/L	<8.18	<12.2	<8.47	<11.3	5.00	5.00	25.3	<40.6
Lead (total)	µg/L	0.20	0.20	<0.24	0.20	0.20	0.20	<0.22	<0.45
Manganese (total)	µg/L	<1.5	<1.0	<1.0	<5.3	13.2	13.4	45.1	15.2
Mercury (total)	µg/L	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019
Molybdenum (total)	µg/L	<1.0	<1.0	<1.0	<1.0	1.3	1.4	1.9	<1.0
Nickel (total)	µg/L	1.6	1.3	<1.7	<1.5	<1.0	<1.1	<1.0	<1.0
Selenium (total)	µg/L	0.16	0.17	0.15	0.13	<0.1	<0.1	0.34	0.16
Silicon (total, as Si)	µg/L	12033	12133	11917	11925	7932	8327	7630	9748
Silver (total)	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Table 4-4 Average Water Quality of Selected Drinking Water Wells (Year 12)

Parameter	Units	Bevan #1	Bevan #2	Bevan #3	Bevan #4	Marshall #1	Marshall #3	McConnell	Townline #2
Strontium (total)	µg/L	136	125	130	128	144	144	135	117
Thallium (total)	µg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Tin (total)	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium (total)	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Uranium (total)	µg/L	<0.1	<0.1	<0.1	<0.1	0.71	0.52	0.46	<0.1
Vanadium (total)	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Zinc (total)	µg/L	<11.8	<5.3	<5.9	9.3	<5.0	<5.2	<5.6	21.9
Zirconium (total)	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Calcium (total)	mg/L	25.2	24.5	24.0	22.7	44.9	38.9	39.8	22.7
Magnesium (total)	mg/L	6.62	6.66	6.07	5.43	8.89	8.90	8.93	4.74
Potassium (total)	mg/L	1.15	1.16	1.13	1.09	3.32	2.09	3.51	1.19
Sodium (total)	mg/L	8.23	7.28	8.11	8.17	19.3	13.1	15.5	7.99
Sulfur (total)	mg/L	4.1	<3.5	3.5	<3.3	12.9	9.8	21.1	4.8

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 Parameters in Selected Drinking Water Wells (Year 12)

Parameter	Units	Bevan #1	Bevan #2	Bevan #3	Bevan #4	Marshall #1	Marshall #3	McConnell	Townline #2
pH	pH Units	7.29	7.37	7.23	6.61	8.19	8.05	n/a	7.1
Colour	TCU	6.5	6.4	7.2	n/a	9.6	7.8	n/a	15.2
Total Dissolved Solids	mg/L	170	190	190	n/a	260	220	n/a	140
Hardness (total, as $CaCO_3$)	mg/L	99.6	93.1	90.5	81.7	153	138	139	80.4
Chloride	mg/L	34	32	33	n/a	31	29	n/a	18
Fluoride	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Turbidity	NTU	0.34	0.7	0.15	n/a	0	0.13	n/a	0.2
Ammonia (total, as N)	mg/L	<0.015	<0.015	n/a	<0.015	0.23	<0.015	0.018	<0.015
Nitrate (as N)	mg/L	3.53	3.33	3.35	3.30	0.0098	0.798	2.9	4.53
Nitrite (as N)	mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.117	<0.002
Aluminum (total)	µg/L	<3.0	<3.0	3.3	47.2	<3.0	<3.0	<3.0	<3.0
Antimony (total)	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Arsenic (total)	µg/L	0.24	0.32	0.26	0.27	4.90	1.31	6.62	1.00
Barium (total)	µg/L	6.2	7.1	6.3	5.8	16.6	10.6	32.1	6.9
Beryllium (total)	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bismuth (total)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Boron (total)	µg/L	<50	<50	<50	<50	<50	<50	<50	<50
Cadmium (total)	µg/L	0.029	0.027	0.035	0.088	0.039	0.035	0.016	0.031
Chromium (total)	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cobalt (total)	µg/L	<0.2	<0.2	<0.2	0.49	<0.2	<0.2	<0.2	<0.2
Copper (total)	µg/L	11.0	12.2	15.8	37.4	2.22	1.39	4.61	38.4
Iron (total)	µg/L	19.5	26.1	17.4	29.9	0	0	37.8	174
Lead (total)	µg/L	0	0	0.46	0	0	0	0.27	1.45
Manganese (total)	µg/L	3.1	1.0	<1.0	17.7	16.2	15.1	48.4	17.8
Mercury (total)	µg/L	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019
Molybdenum (total)	µg/L	<1.0	<1.0	<1.0	<1.0	1.4	1.7	2.1	<1.0
Nickel (total)	µg/L	2.5	1.6	3.9	2.3	<1.0	1.1	<1.0	<1.0
Selenium (total)	µg/L	0.21	0.21	0.16	0.13	<0.1	<0.1	0.44	0.17
Silicon (total, as Si)	µg/L	12300	12500	12100	12300	8300	8760	7780	10100
Silver (total)	µg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02

Table 4-5 Maximum Concentrations of Water Quality Parameters in Selected Drinking Water Wells (Year 12)

Parameter	Units	Bevan #1	Bevan #2	Bevan #3	Bevan #4	Marshall #1	Marshall #3	McConnell	Townline #2
Strontium (total)	µg/L	144	139	137	132	157	155	140	122
Thallium (total)	µg/L	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Tin (total)	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Titanium (total)	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Uranium (total)	µg/L	0	0	0	0	0.77	0.66	0.5	0
Vanadium (total)	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Zinc (total)	µg/L	19.2	6.0	7.3	12.4	<5.0	5.9	6.7	55.5
Zirconium (total)	µg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Calcium (total)	mg/L	28.6	26	26.1	23.9	46.7	41	40.5	24.1
Magnesium (total)	mg/L	6.87	7.04	6.19	5.51	9.08	9.28	9.14	4.93
Potassium (total)	mg/L	1.18	1.24	1.19	1.12	3.43	2.14	3.62	1.26
Sodium (total)	mg/L	9.14	7.59	8.29	8.27	20.5	14.4	15.6	8.43
Sulfur (total)	mg/L	4.8	3.8	3.8	3.9	14.4	10.6	22.7	5.1

n/a – Not analyzed

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: K13239\Cadd\13239-004.dwg (Fig 4-2)

SURFICIAL GEOLOGY UNITS

SALISH SEDIMENTS

- **SAb,c** — LOWLAND PEAT. With organic silt loam, and silty loam. Up to 14m thick; overlies unit Fg and Fh.
- **SAe** — UPLAND PEAT. Up to 8m or more thick.
- **SAh** — STREAM DEPOSITS. Lowland stream channel fill, overbank sandy loam to clay loam. Also some organic deposits. Up to 8m thick.
- **SAk** — STREAM DEPOSITS. Lowland stream channel fill sand and gravel, minor silt, and clayey silt, up to 6m thick.
- **SAm** — SLOPE DEPOSITS. Slopewash sand, up to 4m thick.
- **SAq** — LACUSTRINE DEPOSITS. Silt to clay, normally less than 5m thick.
- **SAr** — LACUSTRINE DEPOSITS. Sand to sand loam; up to 5m thick.
- **SAs** — LACUSTRINE DEPOSITS. Fine sand forming beaches and spits; up to 5m thick.
- **SAt** — WIND BLOWN SAND, SILT AND SILT LOAM

FRASER RIVER SEDIMENTS

- **Fd** — CHANNEL FILL AND FLOOD PLAIN DEPOSITS. Channel fill, clayey silt, and silty clay up the 10m thick

SUMAS DRIFT

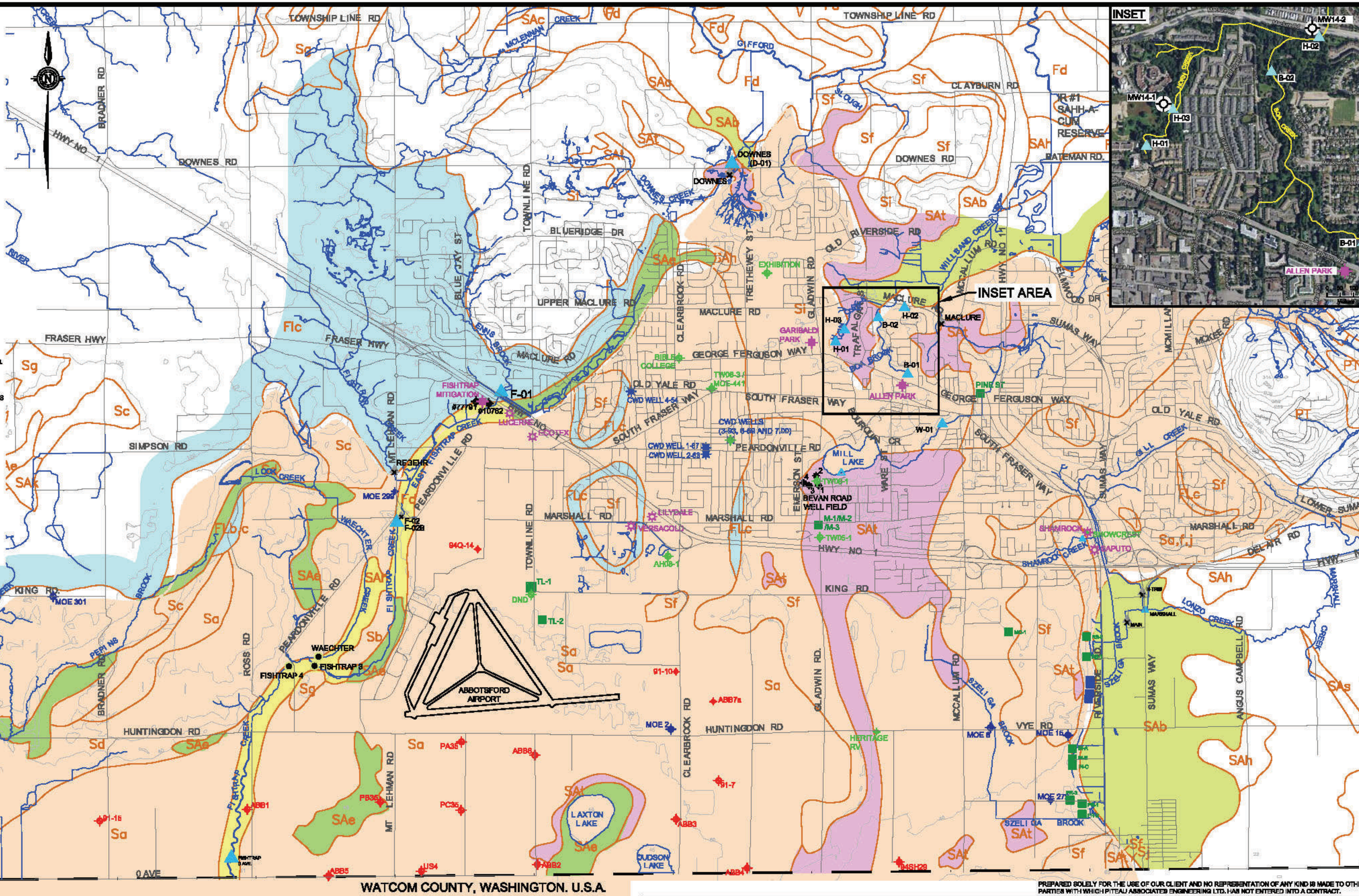
- **Sa** — RECESSIONAL CHANNEL AND FLOOD PLAIN DEPOSITS. Sand and gravel up to 40m thick.
- **Sf** — RECESSIONAL CHANNEL AND FLOOD PLAIN DEPOSITS. Similar to Sa except that it is pitted outwash
- **Sb,c** — ICE CONTACT GRAVEL AND SAND. Containing till lenses, and clasts of glaciomarine stony clayey silt.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

FORT LANGLEY FORMATION

- **FLc** — GLACIOMARINE STONY SILT TO LOAMY CLAY. 5 to 100m thick.

BEDROCK

- **PT** — MESOZOIC AND UPPER PALEOZOIC BEDROCK. 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. 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

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AQUIFER LEVEL AND SURFACE WATER MONITORING STATIONS WITH SURFICIAL GEOLOGY

BY:	DATE:
SC/sl	DEC 23
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. A pressure transducer datalogger and staff gauge were installed in Laxton Lake in 2020, and equivalent water level elevations were determined by correcting the measured levels against a surveyed datum. The staff gauge at Laxton Lake went missing in September 2021, and the installed pressure transducer datalogger went missing in April 2022. A new set of staff gauge and pressure transducer was installed in Laxton Lake in September 2022 to resume monitoring the lake water level. Water levels in Judson Lake are manually measured.

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

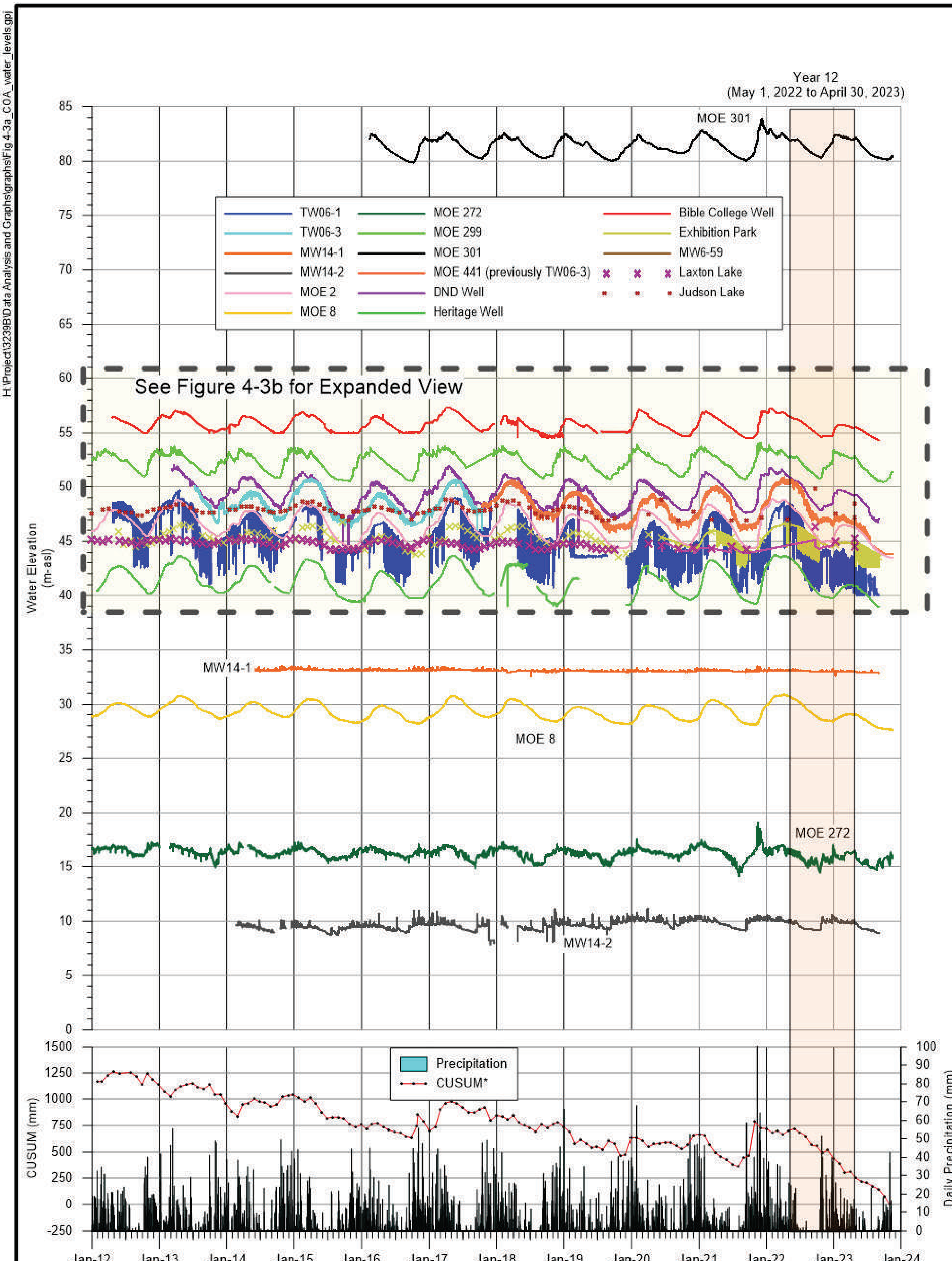
4.2.4.1 Groundwater Level Results

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

All data were analysed and graphed by a professional hydrogeologist from Piteau Associates (Figures 4-3a and 4-3b). 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 Figures 4-3a and 4-3b, which also include 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.

Figures 4-3a and 4-3b show that aquifer water levels during the first half of Year 12 (i.e., May 1, 2022 to November 30, 2022) were generally consistent with trends for the same interval during prior years in terms of elevations and the magnitude of seasonal variation. However, water levels during the second half of this interval (December 1, 2022 to April 30, 2023) were as much as about 1.5 m lower than typical levels at the same time of year at most locations throughout the aquifer. These variances are attributed to significantly lower-than-average recharge from infiltrating precipitation, as indicated by the downward slope of the CUSUM line starting in June 2022. The occurrence of similar trends at monitoring points throughout the aquifer, including those several kilometers distant from the Bevan Wells (i.e., MOE8 and MOE301), indicates that the lowered water levels observed during Year 12 result from lower long-term average precipitation.

TW06-1, which is located within the Bevan wellfield, experiences rapidly fluctuating water levels caused by cycling of the Bevan Wells. MOE 441 and MW06-59, which are the next closest monitoring wells, also exhibit some short-term influence attributed to pumping of the CWD and Bevan Wells.



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* CUSUM= Cumulative sum of deviation from mean monthly precipitation based on data collected between January 1945 and November 2022. All precipitation data from Environment Canada station at Abbotsford Airport.

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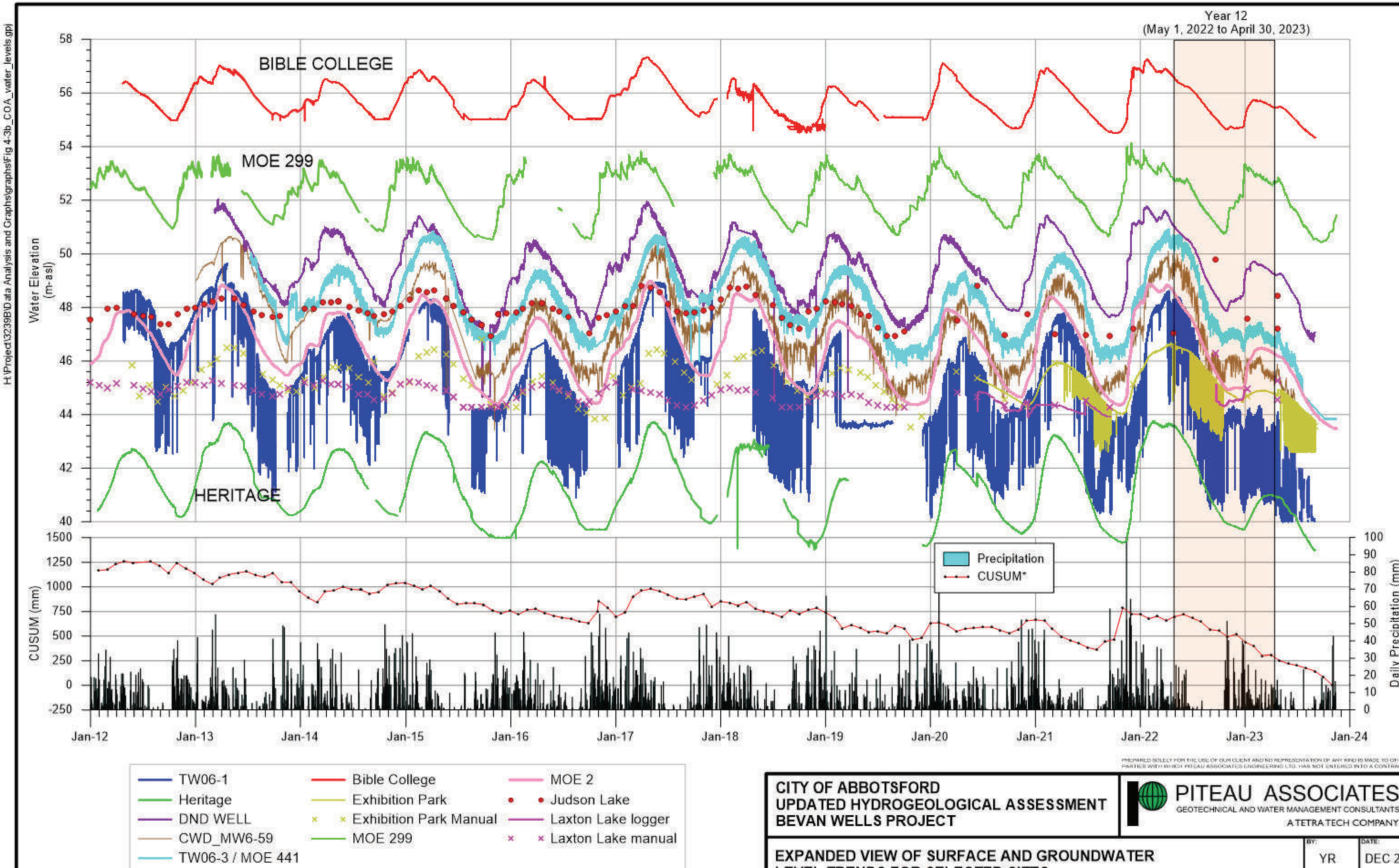
HYDROGRAPHS FOR 2011 TO 2023 SURFACE AND GROUNDWATER LEVEL TRENDS

BY: YR	DATE: DEC 23
APPROVED: DJT	FIG: 4-3a



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BEVAN WELLS PROJECT

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EXPANDED VIEW OF SURFACE AND GROUNDWATER LEVEL TRENDS FOR SELECTED SITES

BY:	DATE:
YR	DEC 23
APPROVED:	FIG:
DJT	4-3b

Figures 4-4 and 4-6 show groundwater volumes pumped at Bevan Wells along with the Clearbrook and Marshall Road Wells up to October 31, 2023. The total annual amounts pumped by the Bevan Wells were 1.971 million litres (ML) in Year 12 and 2.339 ML/year for the first 5.7 months of Year 13 (May 1 to October 18, 2023). The Year 12 total is equivalent to 79% of the allowable groundwater diversion (2,505 ML/year) in accordance with EA Certificate W11-01, and the interim Year 13 total is 93% of this amount.

Starting in 2013, the water level record for the Allen and Garibaldi wells (Figure 4-5) is shorter than for the observation wells shown on Figures 4-3a and 4-3b. The non-pumping levels in these wells generally reflect patterns noted in other observation wells. The wells were not pumped in Year 12 but were operated continuously between early July and October, 2023 (Year 13).

4.2.4.2 Lake Level Results

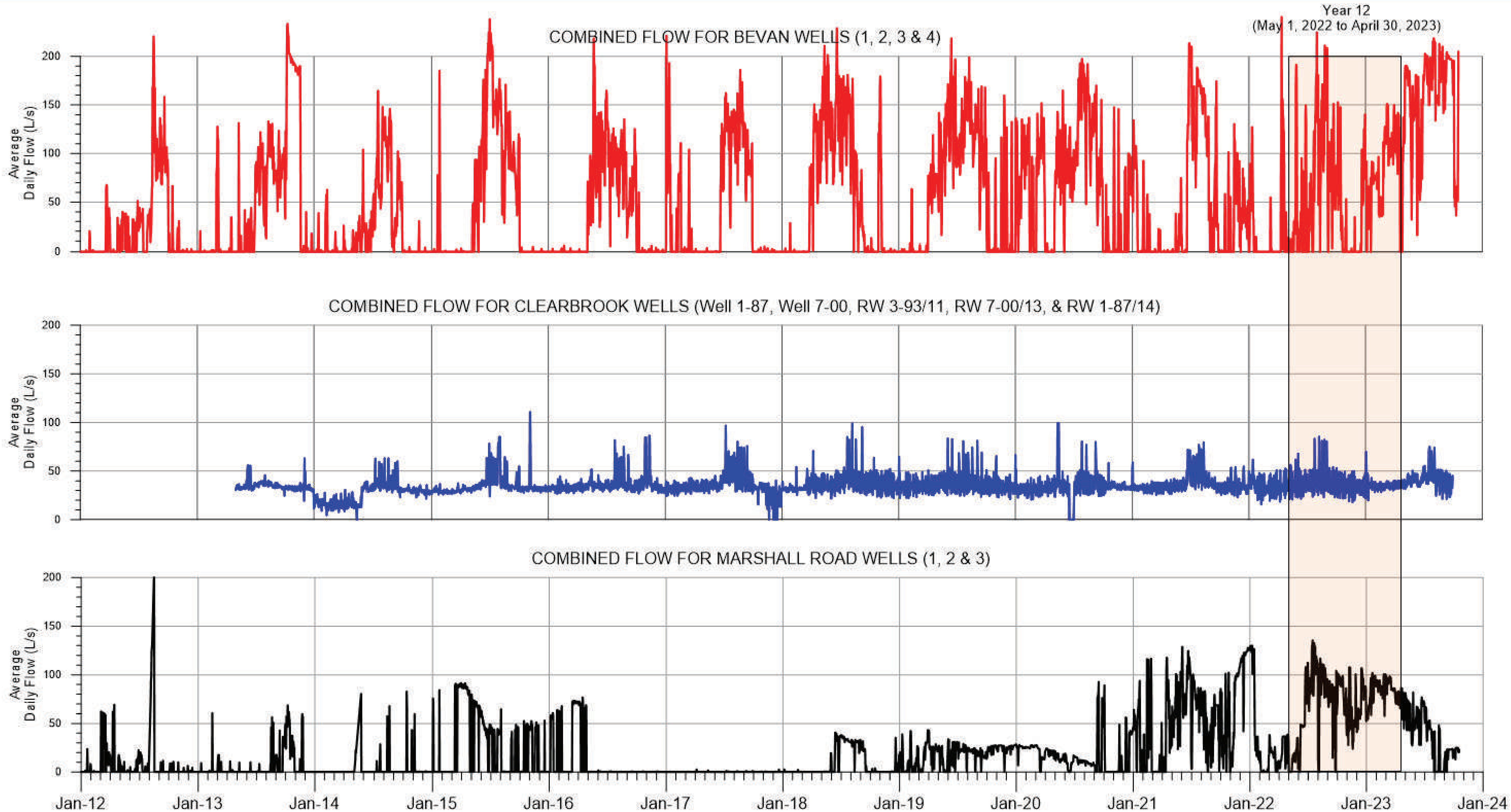
Water level trends for Laxton Lake and Judson Lake (Figure 4-3a & 4-3b, Table 4-7) for Year 12 are consistent with previously observed water levels. At 49.8 m-asl, the September 21, 2022 measurement in Judson Lake appears erroneous.

4.3 Successes, Challenges and Suggested Changes

Aquifer water levels observed in Year 12 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.

All data was successfully collected for the Year 12 monitoring report. There are no suggested changes for the Year 13 (2023-2024) groundwater monitoring program

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



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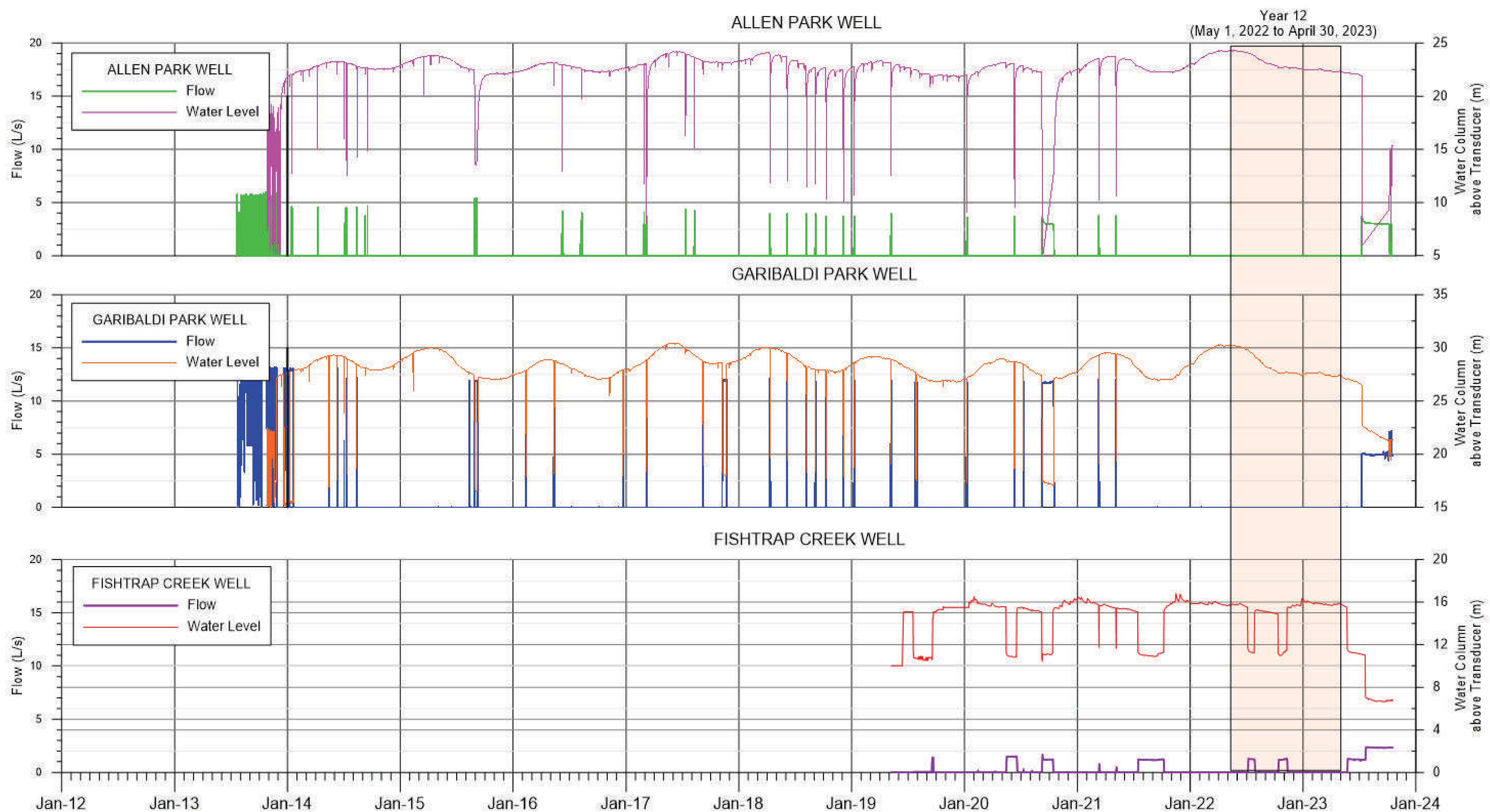
	BY:	DATE:
DAILY AVERAGE PUMPING RATES FOR BEVAN, CLEARBROOK AND MARSHALL WELLS	YR	DEC 23
	APPROVED: DJT	FIG: 4-4

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



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BEVAN WELLS PROJECT

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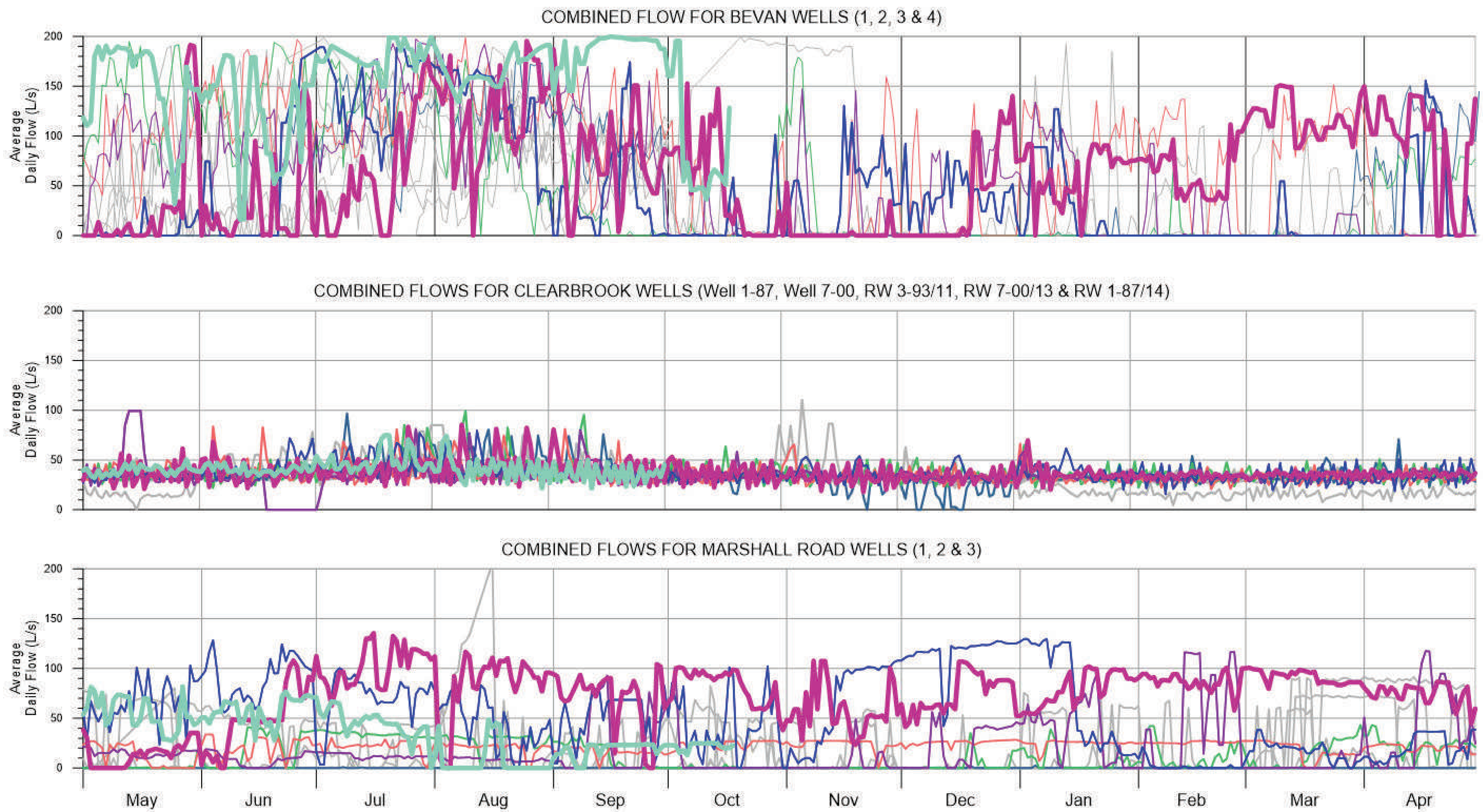
GROUNDWATER LEVELS AND FLOWS IN MITIGATION WELLS AT ALLEN PARK, GARIBALDI PARK, AND FISHTRAP CREEK

BY:	DATE:
YR	DEC 23
APPROVED: DJT	FIG: 4-5

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

Month	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Year 11		Year 12	
	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)		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	Laxton Lake	Judson Lake	Laxton Lake	Judson Lake
May	N/A	N/A	0.85	1.1	0.8	1.4	0.85	1.3	0.38	1.4	0.75	1	0.54	1.81	0.54	1.53	0.38	0.8	N/A	N/A	N/A	N/A	N/A	N/A
Jun	0.8	1.13	0.8	0.81	0.76	1.14	0.75	1.09	0.16	1.1	0.63	0.91	0.47	1.62	N/A	N/A	0.16	0.75	0.35	1.85	0.24	0.01	N/A	N/A
Jul	0.78	0.9	0.68	0.74	0.6	0.9	0.47	0.95	0.06	0.86	0.5	0.7	0.24	1.17	0.32	1.14	0.06	0.3	N/A	N/A	N/A	N/A	N/A	N/A
Aug	N/A	N/A	0.58	0.72	0.46	0.77	0.48	0.85	0	0.6	N/A	N/A	0.04	0.92	0	0.68	0	0	N/A	N/A	N/A	N/A	N/A	N/A
Sep	0.53	0.56	0.45	0.44	0.4	0.7	0.27	0.75	0	0.39	0.1	N/A	0	0.83	0	0.4	0	0	0.05	0.04	0	0	2.00	2.85
Oct	0.54	0.52	0.62	0.45	0.48	0.74	0.3	0.82	0	N/A	0.18	0.1	0.07	0.89	0	0.26	0	0.15	N/A	N/A	N/A	N/A	N/A	N/A
Nov	N/A	N/A	0.78	0.82	0.69	Fallen	0.5	0.92	N/A	0.8	0.51	0.66	0.23	0.94	0.2	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dec	N/A	N/A	0.9	1	N/A	N/A	0.85	1.1	N/A	0.85	0.73	0.77	0.43	1.03	0.4	1	N/A	N/A	0.17	0.8	N/A	0.28	N/A	N/A
Jan	0.86	0.62	0.88	1.05	0.9	1	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	N/A	N/A	0.66	0.64
Feb	N/A	N/A	0.86	1.17	0.8	1	0.9	1.68	N/A	1	N/A	1.1	0.69	1.78	0.48	1.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mar	0.7	1	1	1.3	0.98	1.24	0.8	1.62	N/A	1.23	0.62	1.1	0.6	1.75	0.4	1.19	N/A	N/A	0.07	0.07	N/A	N/A	N/A	N/A
Apr	0.87	1.06	0.88	1.4	N/A	N/A	0.7	1.7	0.53	1.2	0.59	1.86	0.64	1.84	0.46	1.1	0.53	0.58	N/A	N/A	N/A	0.09	0.96	0.25

N/A – Not Available



H:\Project\1323B\Data Analysis and Graphs\graphs\Fig 4-6_Flows-YOY.gpj

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BEVAN WELLS PROJECT

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

BY:	DATE:
YR	DEC 23
APPROVED:	FIG:
DJT	4-6

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 M.

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.

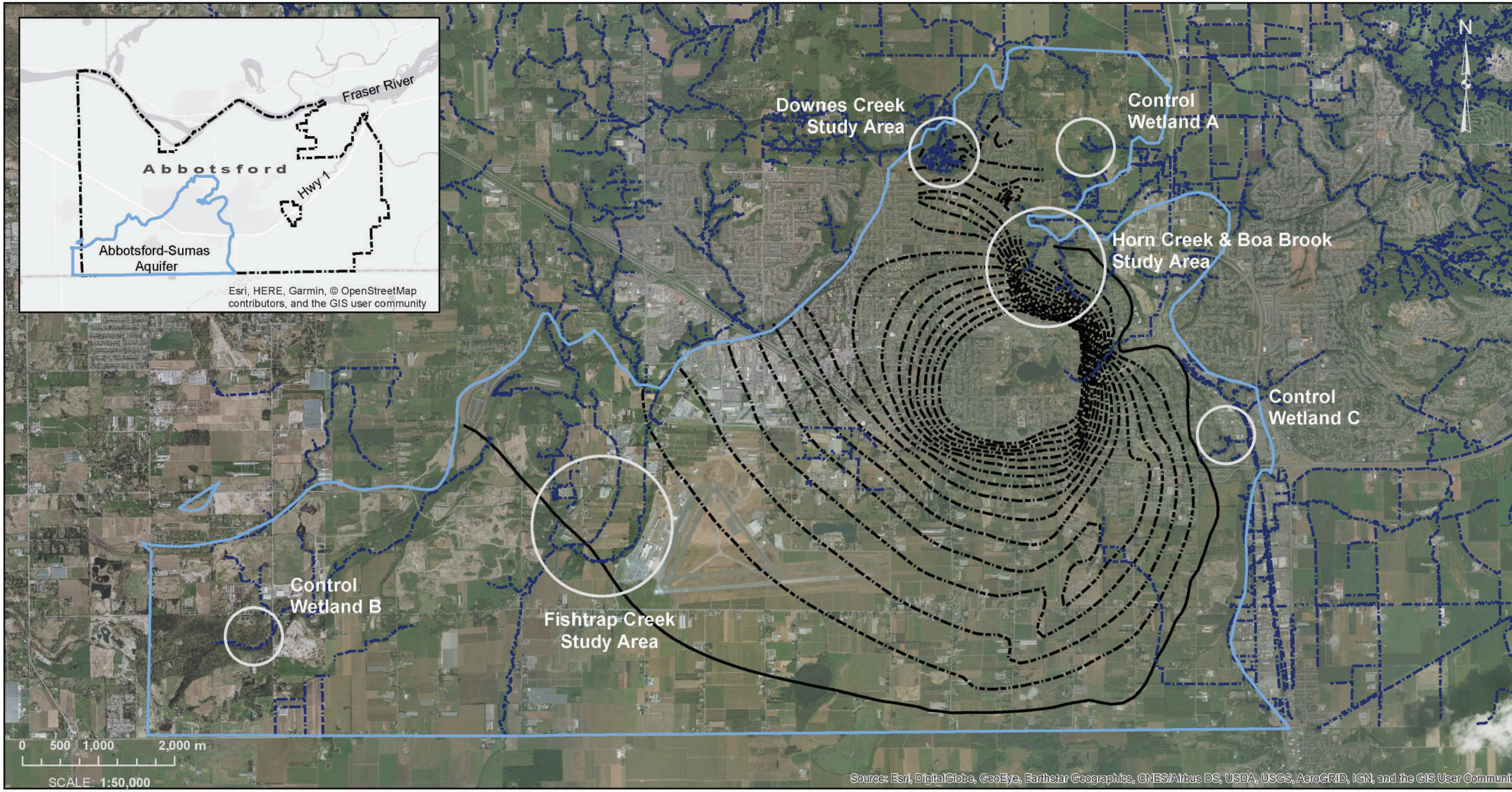
The shallow groundwater wells were installed according to the design and materials recommended in the Wetland Regulatory Assistance Program guidance document regarding installing monitoring wells and piezometers in wetlands (WRAP, 2000). Each groundwater well consists of a simple 1.25" PVC pipe with 0.10" slots. Well specifications and measures can be found in Appendix N. 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 N).

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 during January flow 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
FOR BEVAN WELLS PROJECT

Figure 5-1

Bevan Wells Wetland, Floodplain and Riparian Impact Study Area

Created by: K. Martin
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.

Fishtrap Creek TEM Mapping and Monitoring Locations

City of Abbotsford

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

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