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.

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 (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 2021-2022 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. Water level and pumping record in Fishtrap Creek mitigation well are shown on Figure 4-5.

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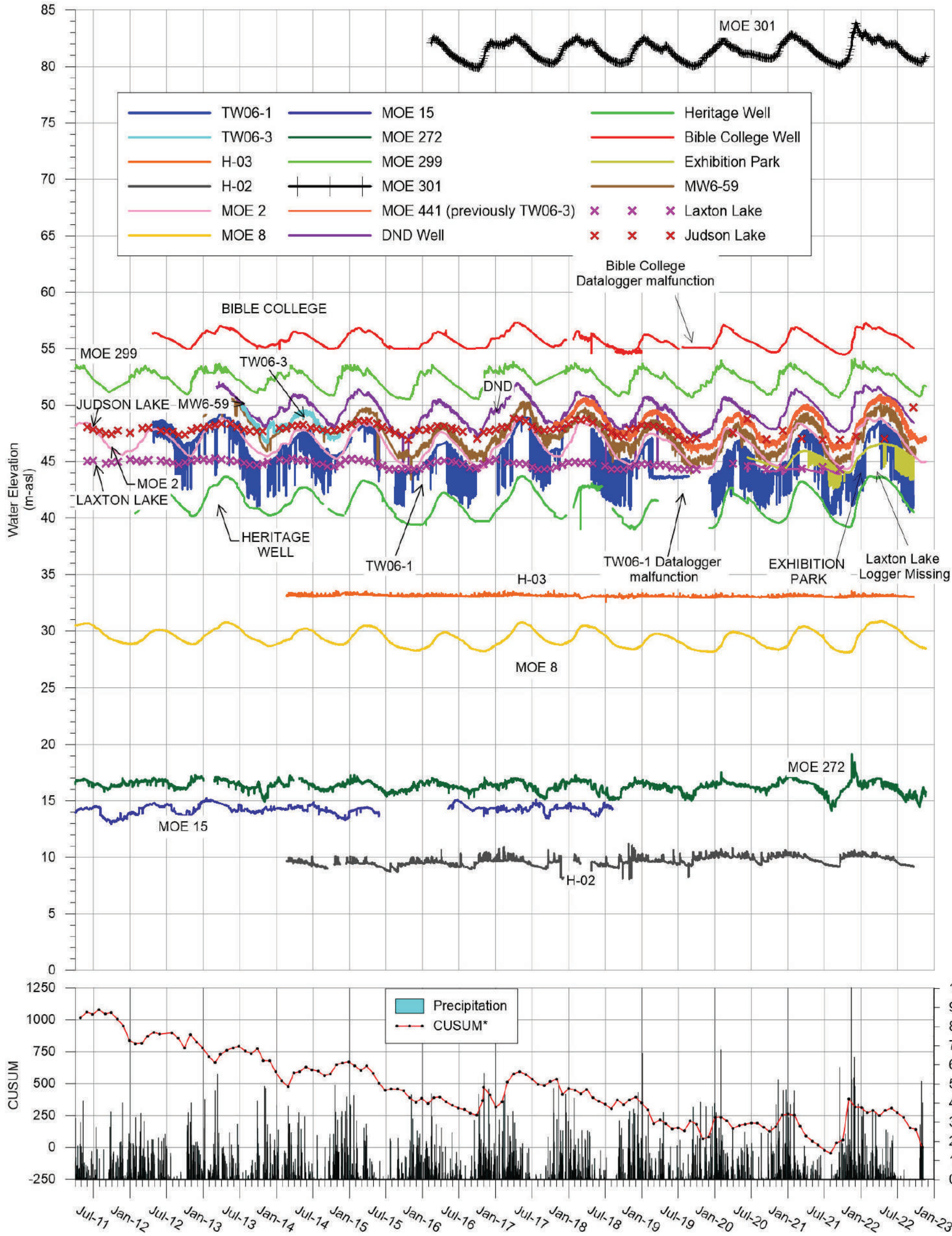


Manual readings denoted with "✕"

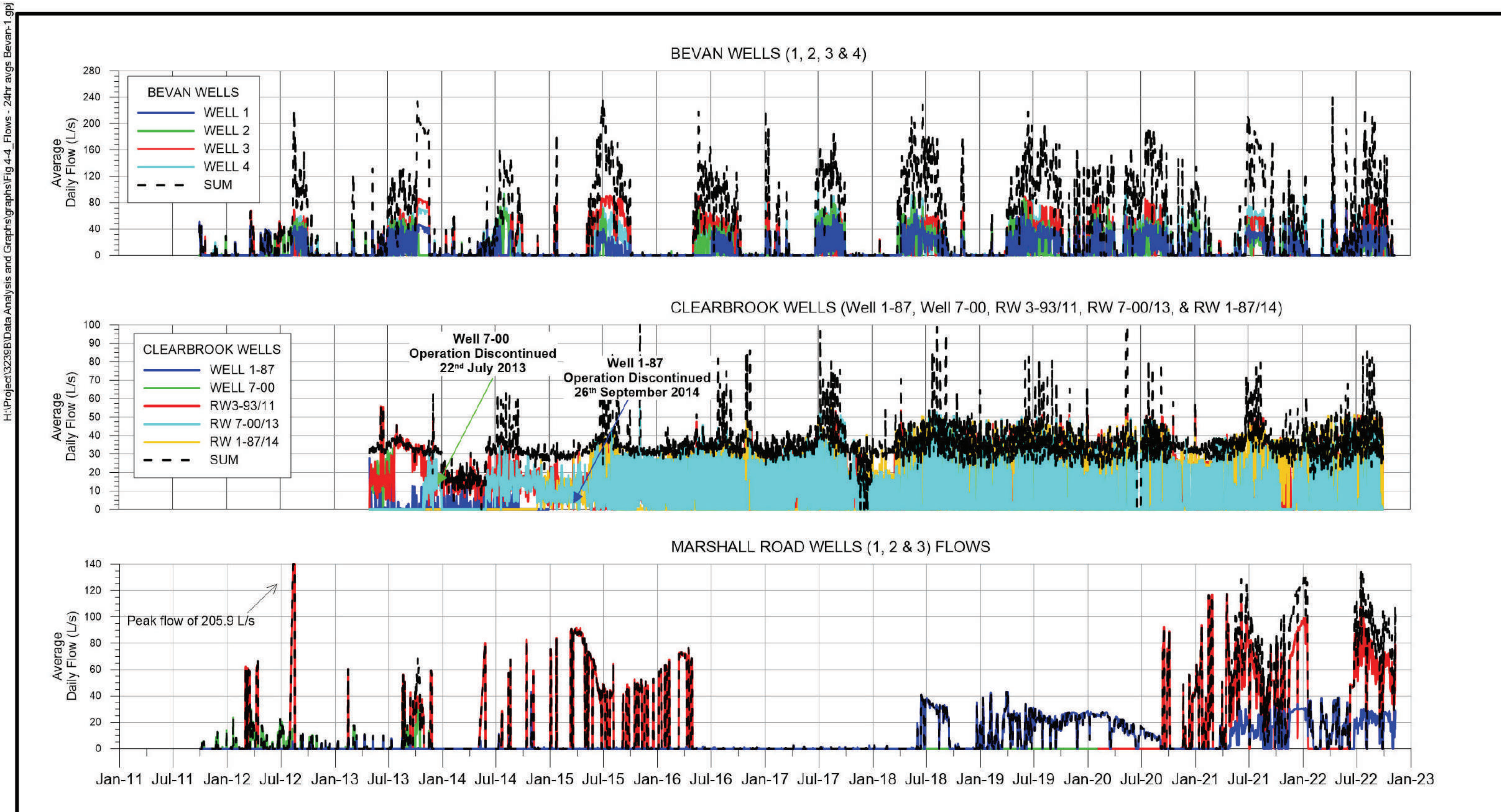
* CUSUM= Cumulative sum of deviation from mean monthly precipitation based on data collected between January 1945 and November 2022. All precipitation data from Environment Canada station at Abbotsford Airport.

CITY OF ABBOTSFORD
UPDATED HYDROGEOLOGICAL ASSESSMENT
BEVAN WELLS PROJECT

PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

HYDROGRAPHS FOR 2011 TO 2022 SURFACE AND GROUNDWATER LEVEL TRENDS

BY:	DATE:
RC	NOV 22
APPROVED:	FIG:
DJT	4-3



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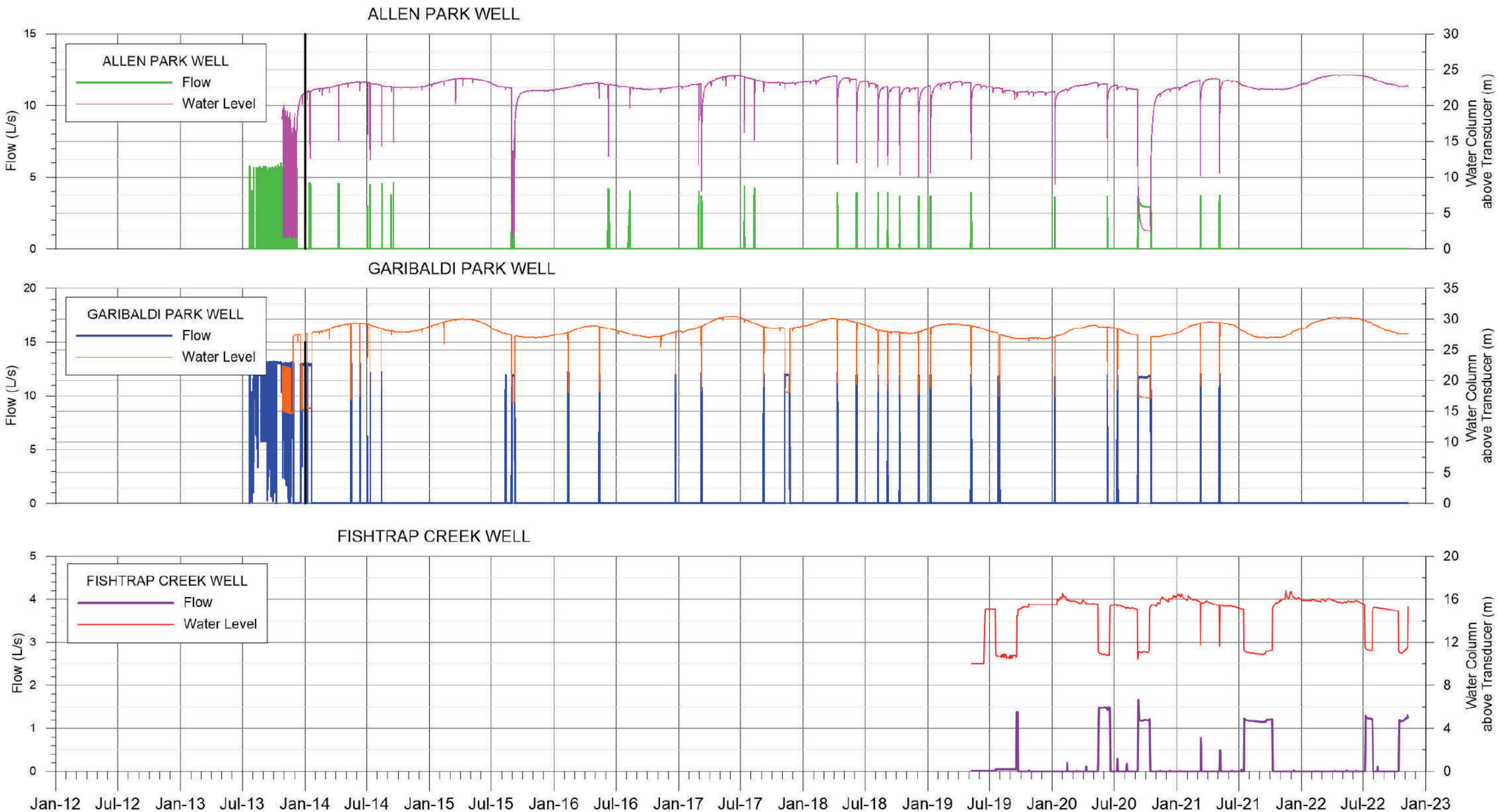
UPDATED HYDROGEOLOGICAL ASSESSMENT
BEVAN WELLS PROJECT

PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

PUMPING RATES FOR BEVAN, CLEARBROOK AND MARSHALL WELLS

BY:	DATE:
RC	NOV 22
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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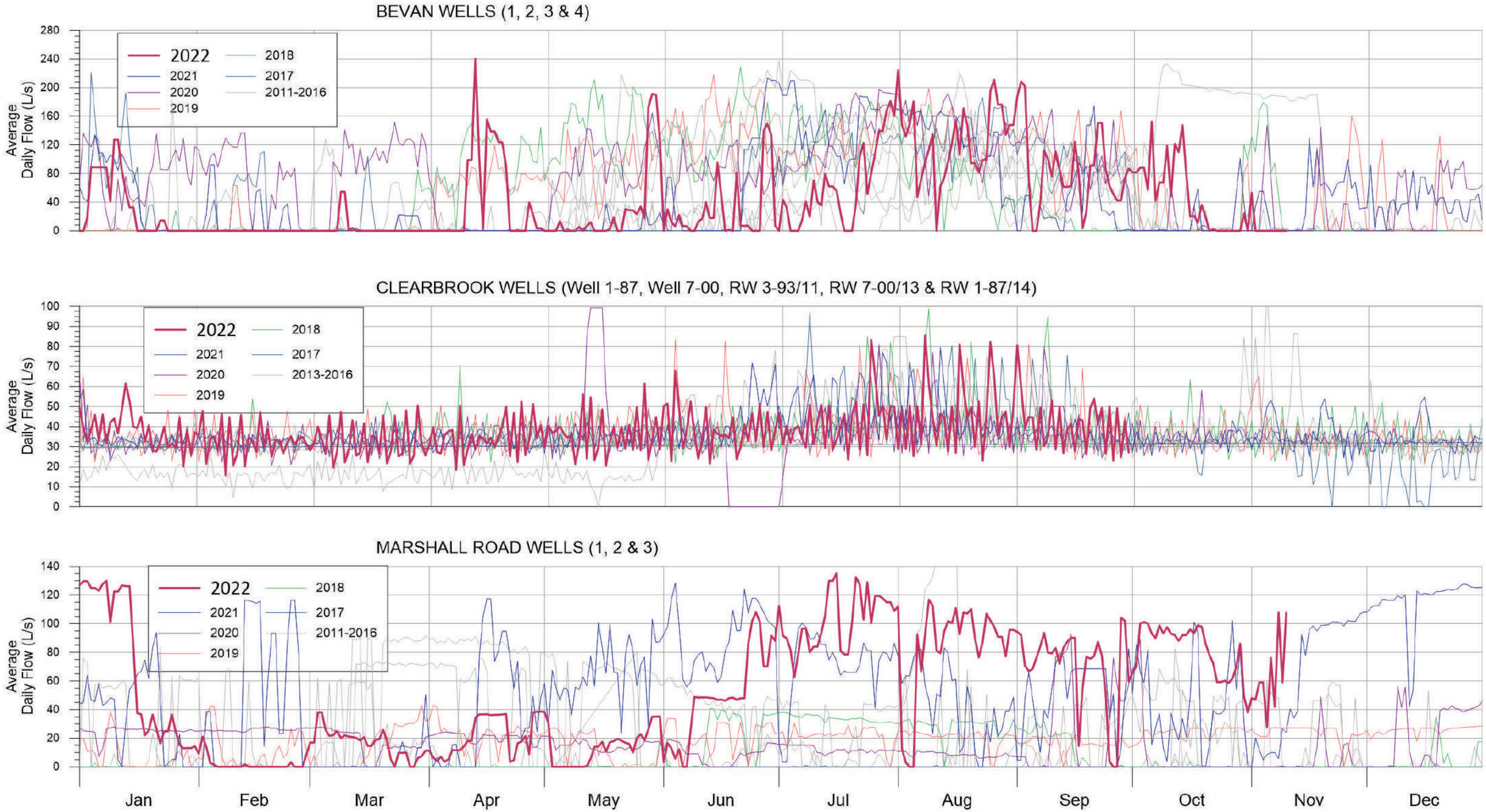
UPDATED HYDROGEOLOGICAL ASSESSMENT
BEVAN WELLS PROJECT

PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

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

BY:	DATE:
RC	NOV 22
APPROVED:	FIG:
DJT	4-5



CITY OF ABBOTSFORD
UPDATED HYDROGEOLOGICAL ASSESSMENT
BEVAN WELLS PROJECT

PITEAU ASSOCIATES
GEOTECHNICAL AND WATER MANAGEMENT CONSULTANTS

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

BY:	DATE:
RC	NOV 22
APPROVED: DJT	FIG: 4-6

4.2.4.2 Lake Level Results

Year-over-year water level trends for Laxton Lake and Judson Lake (Table 4-7) were consistent in 2021-2022. Laxton and Judson Lake water levels are illustrated in Figure 4-3.

4.3 Successes, Challenges and Suggested Changes

Well levels in Year 11 remained consistent with previous monitoring years. All data was successfully collected for the Year 11 monitoring report. There are no suggested changes for the Year 12 (2021-2022) groundwater monitoring program.

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

	Year 1		Year 2		Year 3		Year 4		Year 5		Year 6		Year 7		Year 8		Year 9		Year 10		Year 11	
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)**		**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**
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	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	0.24	0.01
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	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	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	0.00	0.00
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	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	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	0.17	0.80	N/A	0.28
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	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	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	0.07	0.07	N/A	N/A
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	0.09

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 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.

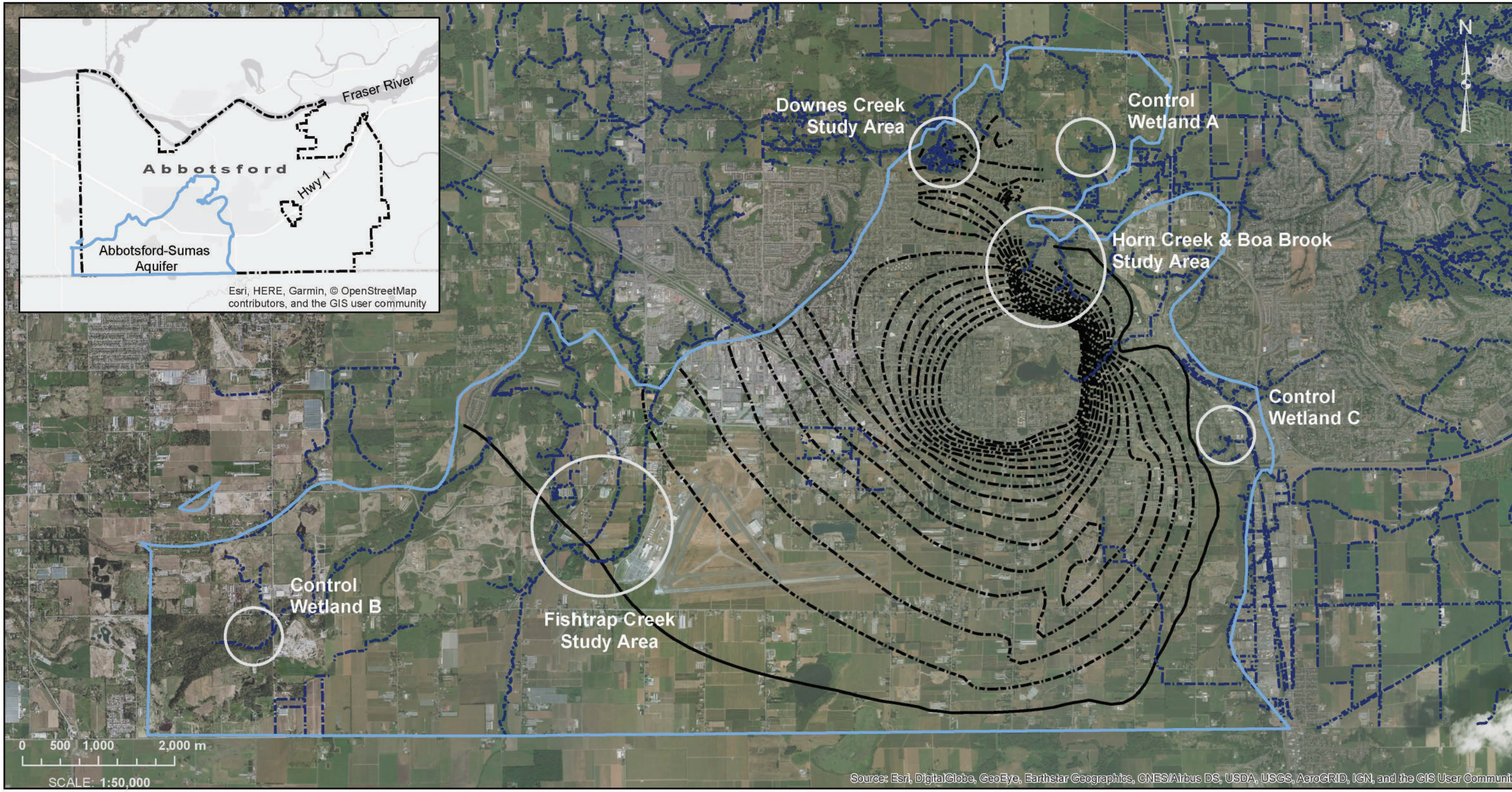
The shallow groundwater wells were installed according to the design and materials recommended in the Wetland Regulatory Assistance Program guidance document regarding installing monitoring wells and piezometers in wetlands (WRAP, 2000). Each groundwater well consists of a simple 1.25" PVC pipe with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

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)

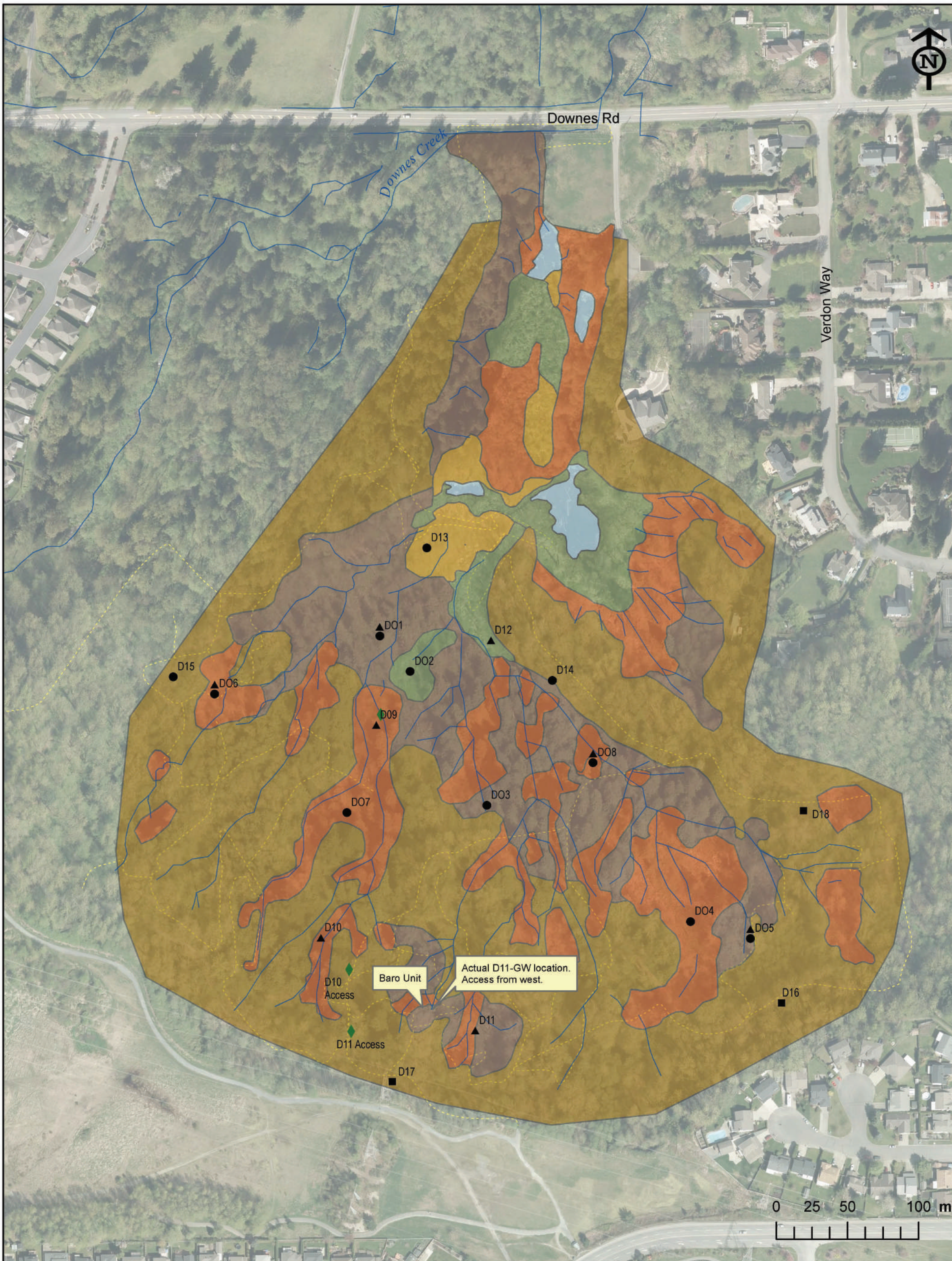
Created: April 2018
Projection: NAD 83 UTM Zone 10N
1:4,000

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

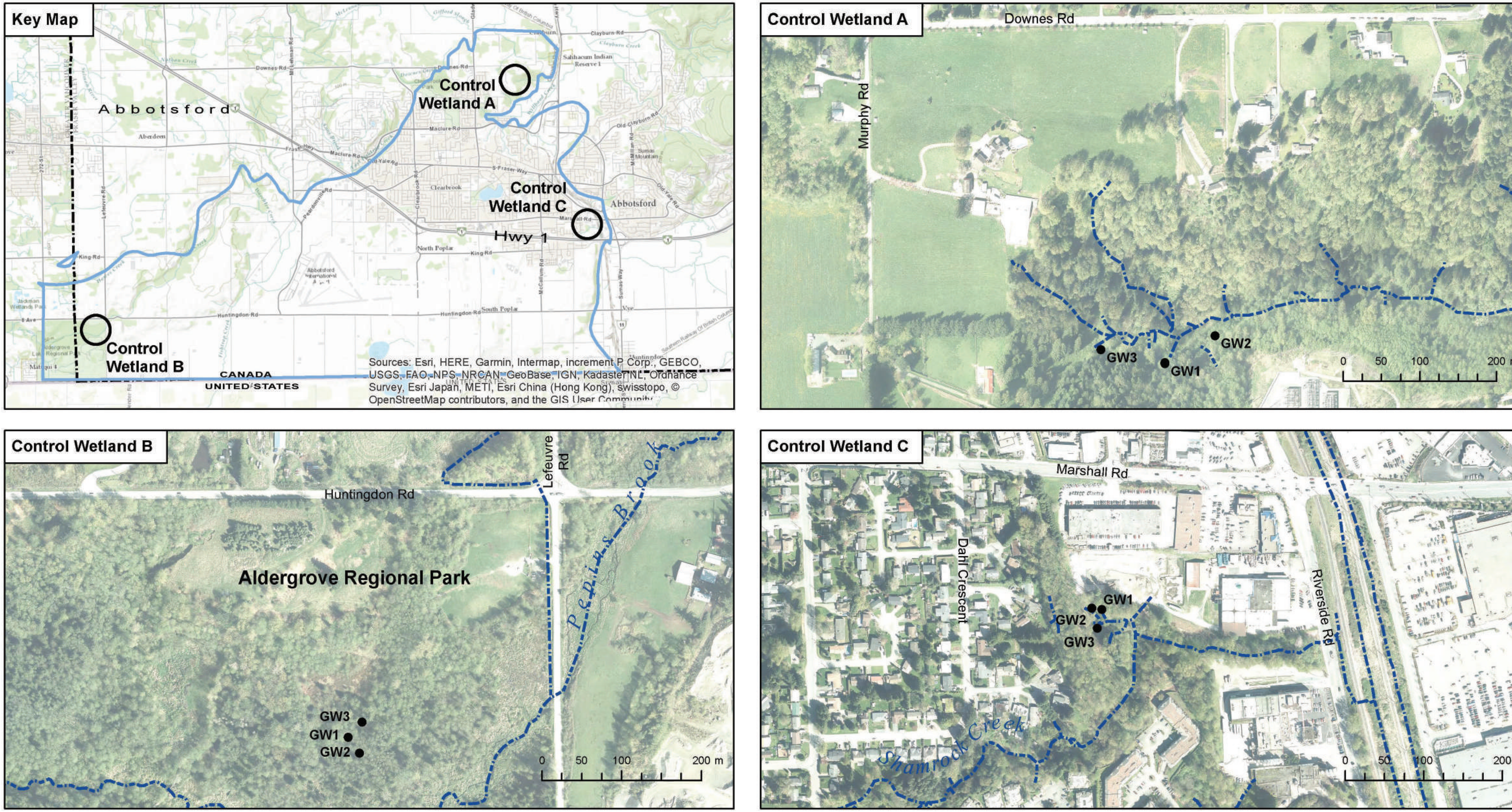
Prepared by: ENKON Environmental Ltd.

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

N

Prepared by: ENKON Environmental Ltd.

CITY OF ABBOTSFORD
FOR BEVAN WELLS PROJECT

Figure 5-5

Control Wetlands
Shallow Groundwater Well Locations

Date: April 2018

5.3 Results and Discussion

5.3.1 Monitoring Wells

Shallow groundwater data graphs for April 2021 through to April 2022 are attached in Appendix O. Within the Bevan Wells zone of influence and at the control sites, groundwater depths generally declined during the summer. However, the magnitude of change was variable (Figure 5-6). The 2021 summer groundwater levels were lower than in previous years at most sites with minimum levels occurring in August or early September. The lower summer groundwater levels in 2021 likely were due to the unusually hot and dry summer.

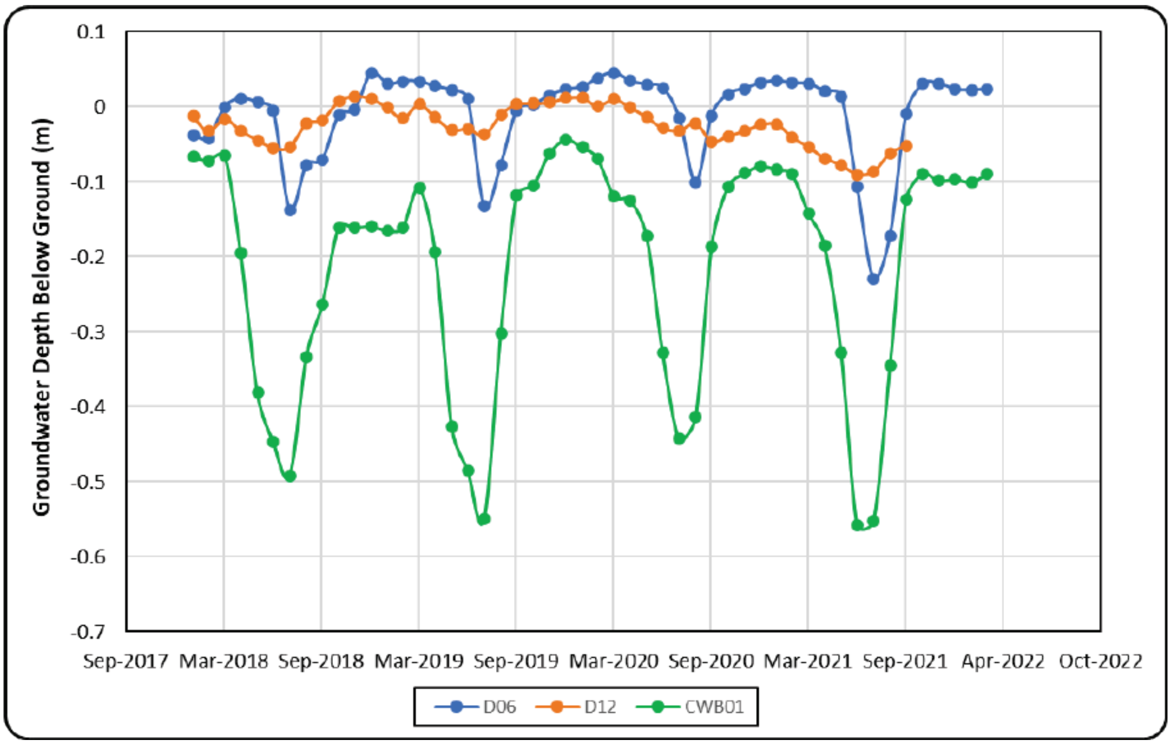


Figure 5-6 Temporal Variations in Groundwater Levels at Two Monitoring Wells in the Downes Creek Watershed and One Control Well

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 the F01 well, where water levels were above the top of the pipe briefly in November and early December. The other two Fishtrap Creek wells experienced data shifts after the October 2021 download that could not be explained by the field measurements, and the data are considered invalid. Of the remaining sites in the Bevan

Wells zone of influence, 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 2022 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 there has been no corresponding increase in water withdrawals.

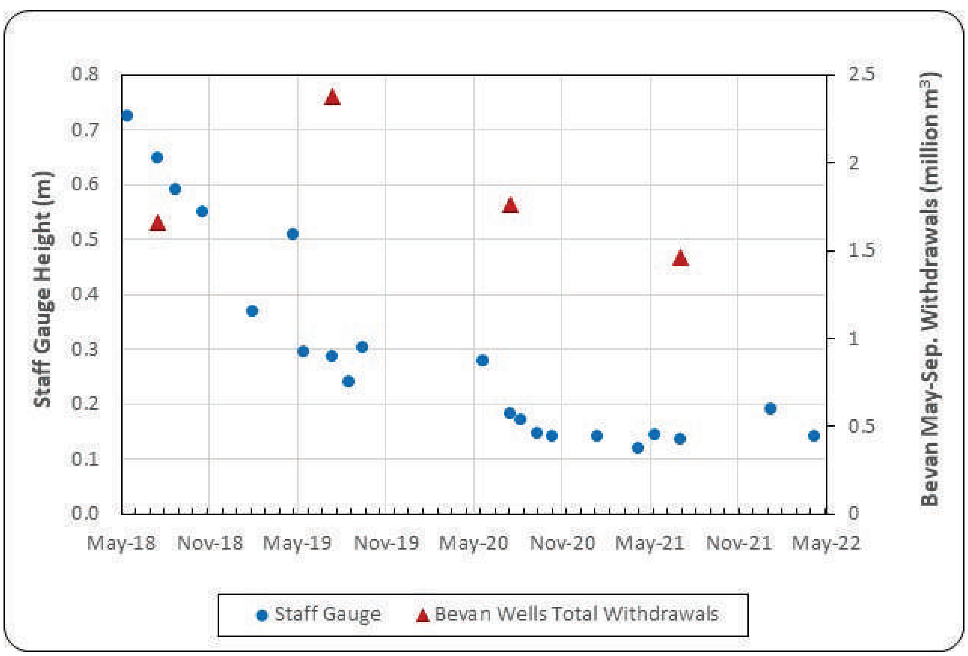


Figure 5-7Water Levels in the Downes Creek Open-Water Wetland, 2018-2022

No similar trends were observed in the flows in 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.

5.4 Successes, Challenges and Suggested Changes

The 2021 dataset is the fourth documentation of summer water table depths. Four 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 0.6 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.

Interpretation of the water level trend in the Downes Creek wetland was hampered by lack of samples from August through October 2021. This omission was due to the presence of an active wasp nest near the staff gauge. After a member of the field crew was stung, the crew abandoned monitoring at this site as long as the wasp nest was present.

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 (7) 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 fifth annual survey was completed in Fall of 2021.

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 in 2017 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 2021 annual monitoring, existing ground inspection plots were revisited, and only the vegetation species composition data was collected by ENKON's vegetation specialist and a field assistant.

The four initial 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. All seven (7) plots were assessed as part of the 2021 survey.

6.1.3 Results

6.1.3.1 Vegetation Changes

Vegetation cover within the TEM plots has remained similar over the past five years of monitoring, and none of the changes observed represent large shifts in the plant community. While some new species were observed within some of the plots (Appendix P), these species are not associated with a drier plant community. Some shrub vegetation showed fallen leaves or slight decay due to natural seasonal processes (e.g., temperature/light changes into Fall). No signs of drought stress or recent shrub or herb layer mortality due to drought stress were observed at any of the TEM plots. No changes in ecosystem boundaries were observed in traversing the Downes Creek, Horn and Boa, and Fishtrap 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 five years of data collection. Observed differences in vegetation cover were small in most cases (i.e., <10%). Larger shifts in 2021 cover by ecosystem indicator species as compared to 2020 are highlighted in Tables 6-1 (i.e., decreases) and 6-2 (i.e., increases).

Overall, decreases in cover were observed in key indicator species at 15 plots in 2021 (Table 6-1). Two 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, which can be 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.

Increased cover by some species was observed at 16 plots in 2021 (Table 6-2). At one of the sites, D15, the cover increases were attributed to increased decay at the time of survey. At one site, D08, a significant community shift appeared to be taking place, with vine maple (*Acer circinatum*) expanding greatly each year. This might represent a shift from low bench to high bench floodplain vegetation adjacent to the existing tributary to the east of the site.

Measurement error may have impacted cover estimates in 2021. 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 (i.e., D14 to D18). Leaf litter volume remained consistently deep and was comprised primarily of bigleaf maple. Plots D15 through D18 had varied cover of bigleaf maple (20% to 70%), which was reflected in depths of litter observed. No bigleaf maple (*Acer macrophyllum*) was noted at plot D14 during the 2021 survey, and the A layer was comprised of mostly Cascara (*Rhamnus purshiana*) and red alder (*Alnus rubra*). As noted during the baseline assessment, D06 contains stinging nettle (*Urtica dioica*), which the snails require for breeding. At D06, the cover of stinging nettle had increased in 2021 (16%) from 2020 (7%). The new plots D16, D17, and D18, were selected to contain stinging nettle, allowing additional tracking of nettle cover through time. The quantity of stinging nettle at plots D16, D17 and D18 varied compared to 2020 levels (i.e., D16 decreased from 12% to 8%, D17 increased from 6% to 7%, and D18 trace levels remained the same). Variations in cover between 2020 and 2021 may be due to plot location (e.g., D16 located farthest away from a mapped water source and in a sloped area, which may suggest drier conditions for vegetation growth compared to the other plots). The quantities of coarse woody debris at plots D14 and D15 remained similar to that observed previously. The 2021 monitoring showed no overall deterioration in the Oregon forestsnail habitat.

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
D01	Ws53	C	fringecup	*Tellima grandiflora*	-	0.1	2.5	2	-	
D02	Wm05	C	Common cattail	*Typha latifolia*	6	7	8	5	3.5	
D03	Ws53	B1	vine maple	*Acer circinatum*	11	11	19	12.5	9	
D03	Ws53	B	salmonberry	*Rubus spectabilis*	39	42	49	44	32	NE corner under Cascara
D03	Ws53	C	spiny wood fern	*Dryopteris expansa*	42	20	9	22	12	Many leaves down
D04	Ws52	C	common horsetail	*Equisetum arvense*	65	60	80	60	55	
D05	Ws53	A1	black cottonwood	*Populus balsamifera ssp. trichocarpa*	20	20	35	23	18	
D05	Ws53	C	common horsetail	*Equisetum arvense*	25	25	48	55	37.5	
D06	Ws52	B	salmonberry	*Rubus spectabilis*	27	45	23	40	38	
D07	Ws52	B	salmonberry	*Rubus spectabilis*	19	8	29	40	23.75	
D07	Ws52	C	spiny wood fern	*Dryopteris expansa*	22	14	5	5.5	4.5	
D07	Ws52	C	piggy-back plant	*Tolmiea menziesii*	2	1	5	16	9	
D08	Ws52	B1	red alder	*Alnus rubra*	-	10	5	10	6	Fallen but growing

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
D08	Ws52	B1	salmonberry	*Rubus spectabilis*	14	9	12	3	0.5	More in B2
D08	Ws52	B1	Western redcedar	*Thuja plicata*	5	15	6	4	tr	More cover not rooted; Nurse log
D08	Ws52	C	lady fern	*Athyrium filix-femina*	7	6	9	5	4.75	
D08	Ws52	C	spiny wood fern	*Dryopteris expansa*	11	5	11	7	6.5	
D15	7	A	red alder	*Alnus rubra*	12	20	10	11	5	
B01	Ws52	B	salmonberry	*Rubus spectabilis*	95	6	90	65	12	
B02	Ws51	C	lady fern	*Athyrium filix-femina*	5	8	4	12	6	
H01	Ws53	A	Western redcedar	*Thuja plicata*	60	40	20	24	22	
H01	Ws53	A2	paper birch	*Betula papyrifera*	1	10	1.5	8	-	Only in A3 and B1 layers
H01	Ws53	C	lady fern	*Athyrium filix-femina*	6	10	8	12	9	Some decay
H01	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	10	12	6	7	4	Decay
H02	Ws53	A	black cottonwood	*Populus balsamifera ssp. trichocarpa*	5	20	8	18	13	

Table 6-1 Decreases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	Species Name	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
H02	Ws53	A	paper birch	*Betula papyrifera*	7	9	2	4	3	
H02	Ws53	B2	salmonberry	*Rubus spectabilis*	45	35	25	35	3.5	
H02	Ws53	C	lady fern	*Athyrium filix-femina*	19	15	6	11	6.25	
FT01	8	B1	black twinberry	*Lonicera involucrata*	24	20	12	18	12	
FT01	8	C	lady fern	*Athyrium filix-femina*	-	5	0.5	3	1	*Solamum dulcamara*
FT01	8	C	spiny wood fern	*Dryopteris expansa*	27	15	40	14	3.5	
FT03	10	B	Sitka willow	*Salix sitchensis*	2	15	3	5	1	*Epilobium cilatum*
FT06	10	A	black cottonwood	*Populus balsamifera ssp. trichocarpa*	70	60	70	65	-	No data
FT06	10	B1	black twinberry	*Lonicera involucrata*	-	11	5	-	-	No data
FT06	10	B1	red-osier dogwood	*Cornus sericea*	42	40	53	65	-	No data
FT06	10	C	common horsetail	*Equisetum arvense*	0.5	2.5	5	1	-	No data

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
D01	Ws53	A	Western redcedar	*Thuja plicata*	18	13	21	20	20	
D01	Ws53	B2	salmonberry	*Rubus spectabilis*	7	2	13.5	7.5	15	
D01	Ws53	C	common horsetail	*Equisetum arvense*	33	7	18	16	38	
D01	Ws53	C	false lily-of-the-valley	*Maianthemum dilatatum*	0.5	0.1	4.5	0.5	2	
D01	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	8	10	10	14	18	Some decay; areas drier than usual
D02	Wm05	B	vine maple	*Acer circinatum*	13	11	18	5	18	
D02	Wm05	B	salmonberry	*Rubus spectabilis*	17	14	22	9	13.5	
D02	Wm05	C	lady fern	*Athyrium filix-femina*	8	8	16	12	15	
D02	Wm05	C	Western skunk cabbage	*Lysichiton americanus*	15	10	8	6	6	
D03	Ws53	C	lady fern	*Athyrium filix-femina*	0.5	4	8	3	5	1 is dead
D03	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	6	5	4	2	3	
D04	Ws52	C	lady fern	*Athyrium filix-femina*	3	3	20	tr	1	Many leaves down

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
D04	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	31	30	70	35	40	
D05	Ws53	B	salmonberry	*Rubus spectabilis*	27	20	24	14	20.25	
D05	Ws53	C	Western skunk cabbage	*Lysichiton americanus*	22	29	40	28	33.75	
D05	Ws53	C	lady fern	*Athyrium filix-femina*	10	7	17	7	10.75	
D06	Ws52	B	red elderberry	*Sambucus racemosa*	10	12	7	8	9.5	Trace in B2 layer
D06	Ws52	C	spiny wood fern	*Dryopteris expansa*	12	12	7	8	8	
D06	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	15	8	15	5	8	
D06	Ws52	C	piggy-back plant	*Tolmiea menziesii*	47	25	14	8	24	
D07	Ws52	C	lady fern	*Athyrium filix-femina*	1	2	11	2	3	
D07	Ws52	C	common horsetail	*Equisetum arvense*	5	18	10	23	35	
D07	Ws52	C	Western skunk cabbage	*Lysichiton americanus*	5	16	4	11	14	
D08	Ws52	B1	vine maple	*Acer circinatum*	11	12	32	33	36.25	
D13	Ws51	A	Pacific willow	*Salix lucida ssp. Lasiandra*	8	8	12	2	4	
D13	Ws51	A	red alder	*Alnus rubra*	42	40	17	7	15	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
D13	Ws51	C	lady fern	*Athyrium filix-femina*	14	4	13	6	7	
D13	Ws51	C	common horsetail	*Equisetum arvense*	12	3	8	4	7.5	
D14	7	A3	Cascara	*Rhamnus purshiana*	8	20	15	12	17	
D14	7	B	thimbleberry	*Rubus parviflorus*	20	25	18	17	22	
D14	7	B	salmonberry	*Rubus spectabilis*	33	25	18	8	18	
D14	7	C	sword fern	*Polystichum munitum*	35	25	30	21	45	
D15	7	A1	bigleaf maple	*Acer macrophyllum*	30	50	25	45	65	No leaves fallen
D15	7	B	salmonberry	*Rubus spectabilis*	68	70	30	34	48.33	Much less leaf coverage due to decay made inventory challenging
D15	7	B1	red elderberry	*Sambucus racemosa*	19	15	21	7	23	
D15	7	C	spiny wood fern	*Dryopteris expansa*	9	5	13	8	11	
B02	Ws51	A	Pacific willow	*Salix lucida ssp. Lasiandra*	15	9	4	3	4	

Table 6-2 Increases in Cover by Ecosystem Indicator Species between 2017 and 2021

Plot	Ecosystem Type	Layer	Common Name	*Species Name*	2017 (%)	2018 (%)	2019 (%)	2020 (%)	2021 (%)	2021 Notes
B02	Ws51	B	Hardhack	*Spiraea douglasii*	8	10	9	2.5	9.5	Browse observed
H01	Ws53	A	red alder	*Alnus rubra*	15	10	4	4	5	
H01	Ws53	B	Western redcedar	*Thuja plicata*	10	5	1	2.5	9	Slight decay. Mostly B1 layer, trace in B2 layer
H01	Ws53	B2	stink currant	*Ribes bracteosum*	0.5	10.5	0.5	tr	tr	
FT01	8	B1	Cascara	*Rhamnus purshiana*	-	25	20	21	25	
FT01	8	B1	red elderberry	*Sambucus racemosa*	40	35	70	33	55	All decayed, few leaves
FT04	5	A1	Douglas-fir	*Pseudotsuga menziesii*	9	8	14	12	22	
FT04	5	B	paper birch	*Betula papyrifera*	-	4	4	1	2	
FT07	10	B1	baldhip rose	*Rosa gymnocarpa*	0.5	1	15	5	5	

6.1.4 Successes, Challenges and Suggested Changes

After five years of data collection (2017-2021), neither plant mortality nor changes to ecosystem boundaries have been observed, and no major shift in species composition (i.e., >50%) 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 any 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 were to be monitored on an annual basis for the first five years after establishing a “baseline” in 2017 to identify typical vegetation and shallow groundwater conditions. The following constitutes data from fall 2021, the fourth year of monitoring following the 2017 baseline.

6.2.2 Methods

Ten hydric indicator plant plots have been established within the watersheds of interest: 8 plots in the Downes Creek watershed (Figure 5-4) 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 between September 13 and September 16, 2021, about a week earlier than the 2020 data collection. The 2021 field work occurred four 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 in 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. Thus, it is likely that sampling of all 2021 plots occurred before the plants were fully mature.

At each plot, line intercept transects 15 m long (10 m for Horn Creek plots H01 and H02) were marked with labelled 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 along the transect (distance from start) and longest petiole length recorded. Rules for determining whether plants petioles that intersect the transect and are included in the plot were developed and applied and are available upon request.

6.2.3 Results and Discussion

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

In 2021, average petiole length per plot ranged from 31.83 cm to 54.79 cm (Table 6-3), with an average of 45.14 cm for all plots, excluding D11 and H01-LA1 (no data available because plots could not be found). This value is lower than the 2019, 2018 and 2017 data, which had average petiole lengths of 47.62 cm, 48.11 cm and 48.36 cm respectively; however, the 2021 average petiole length was higher than the 2020 data (i.e., 40.00 cm). Average petiole lengths have varied throughout the five years at each site, but there have been few consistent year-to-year trends (Figures 6-1 and 6-2). The 2021 mean petiole length was lower than the 2017 measurements at 8 of the 9 sample sites with collected 2021 data, and in 2 cases the 2021 results were also lower than the 2020 data.

Table 6-3 Indicator Plant Plot Results 2017 to 2021

Plot #	Average of Petiole Length (cm)					Density (Plants per Metre)*					Total Petiole length per metre (cm)				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
B02-LA1	52.85	49.89	43.76	30.17	38.25	0.87	3.13	1.67	2.40	2.13	45.80	156.33	72.93	72.40	81.60
D01-LA1	63.47	60.95	58.62	51.00	53.07	2.27	2.87	2.27	2.33	3.00	143.87	174.73	129.53	119.00	159.20
D05-LA1	55.15	51.88	54.74	47.83	53.71	1.33	2.20	1.53	1.20	1.60	73.53	114.13	83.93	57.40	85.93
D06-LA1	54.29	50.90	51.35	41.41	43.37	0.93	2.07	1.73	1.13	2.87	50.67	105.20	78.73	46.93	124.33
D08-LA1	35.40	37.11	33.83	33.00	32.23	0.33	0.60	0.40	0.40	0.47	11.80	22.27	13.53	13.20	15.04
D09-LA1	46.58	49.35	51.50	34.00	46.20	0.80	1.53	2.00	1.93	2.00	37.27	75.67	103.00	65.73	92.4
D10-LA1	43.83	43.92	NA**	48.29	52.85	0.40	0.80	NA**	0.93	0.87	17.53	35.13	NA**	45.07	45.8
D11-LA1	38.80	41.55	44.33	34.91	NA***	0.33	0.67	0.60	0.73	NA***	12.93	27.70	26.60	25.60	NA***
D12-LA1	56.98	58.97	56.84	51.93	54.79	1.73	2.13	1.67	1.73	1.93	98.77	125.80	94.73	96.93	105.93
H01-LA1*	41.96	44.96	44.85	31.71	NA***	0.93	1.53	1.30	0.93	NA***	39.17	68.93	58.30	44.40	NA***
H01-LA2*	42.67	39.75	36.35	35.76	31.83	1.80	2.13	1.70	1.13	0.60	76.80	84.80	61.80	60.80	19.10

*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.

***Plot could not be found.

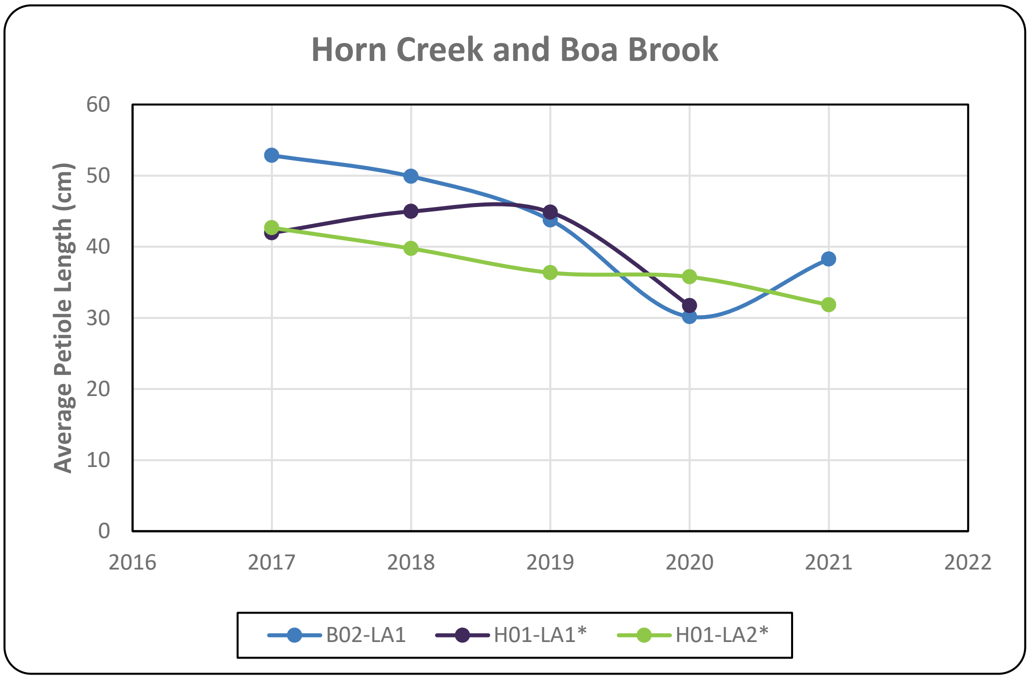


Figure 6-1 Comparison of the Average Petiole Length for the 2017 to 2021 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed

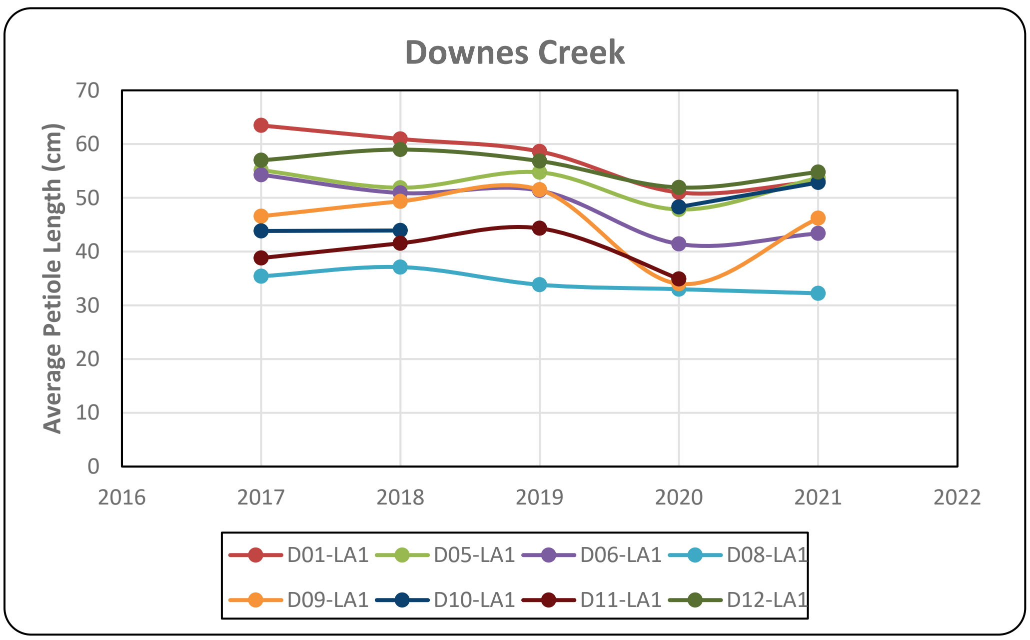


Figure 6-2 Comparison of the Average Petiole Length for the 2017 to 2021 Skunk Cabbage Line Intercepts in the Downes Creek Watershed

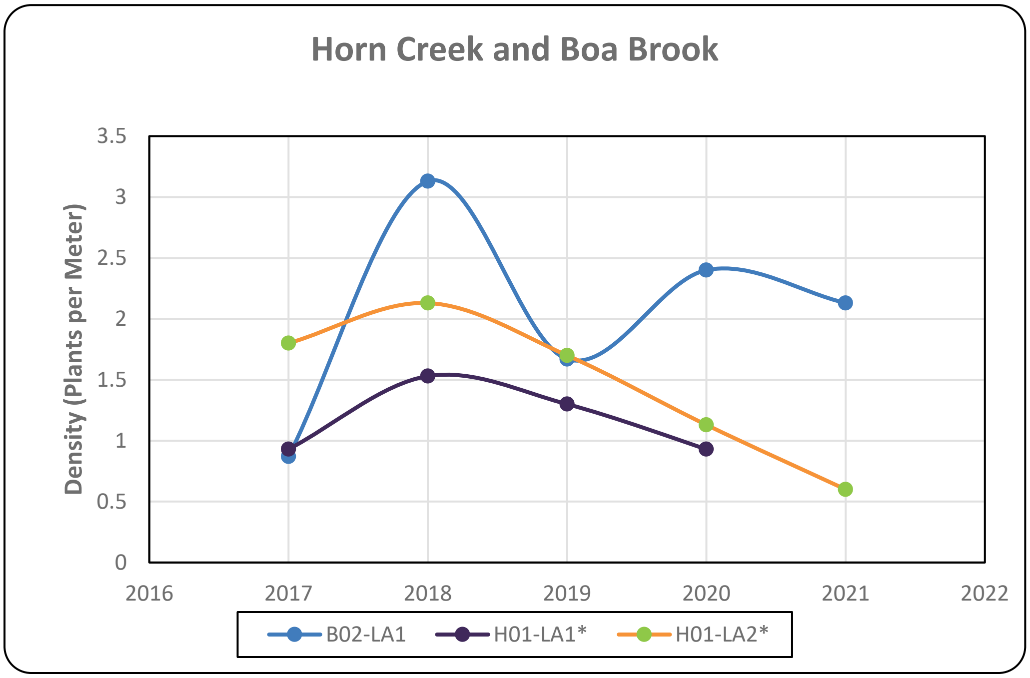


Figure 6-3 Comparison of the Density of Plants Encountered by the 2017 to 2021 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed

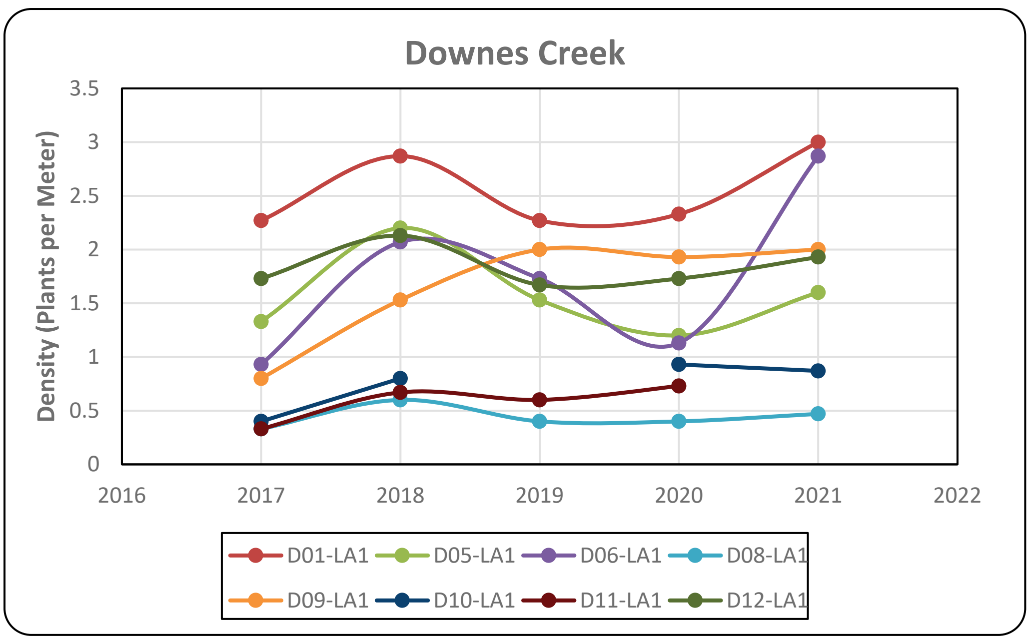


Figure 6-4 Comparison of the Density of Plants Encountered by the 2017 to 2021 Skunk Cabbage Line Intercepts in the Downes Creek Watershed

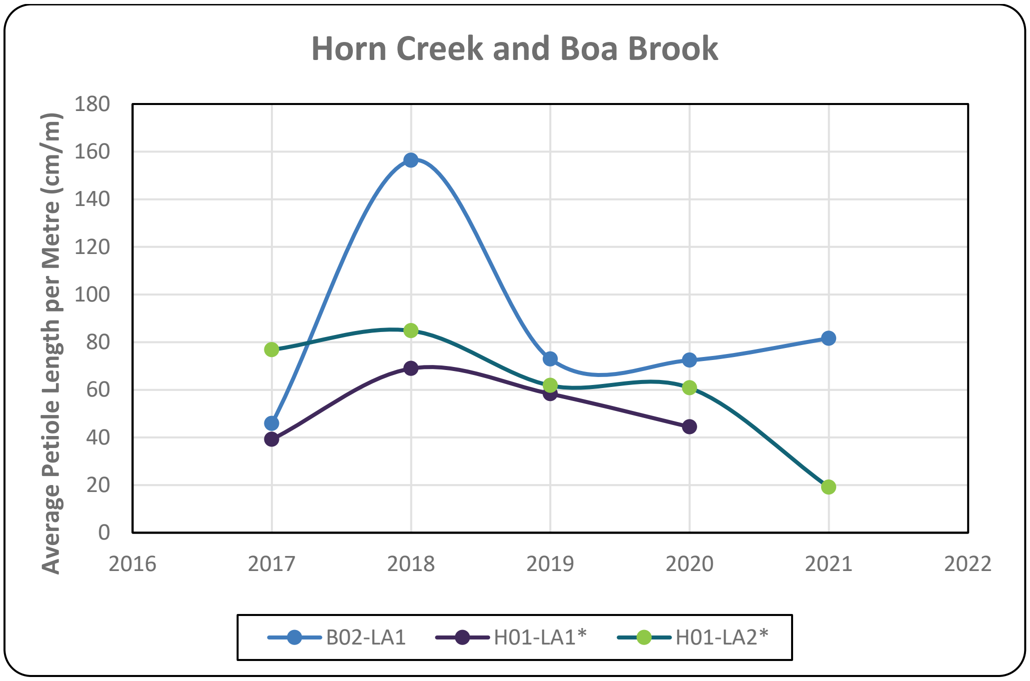


Figure 6-5 Comparison of the Average Petiole Length per Metre for the 2017 to 2021 Skunk Cabbage Line Intercepts in the Horn Creek/Boa Brook Watershed

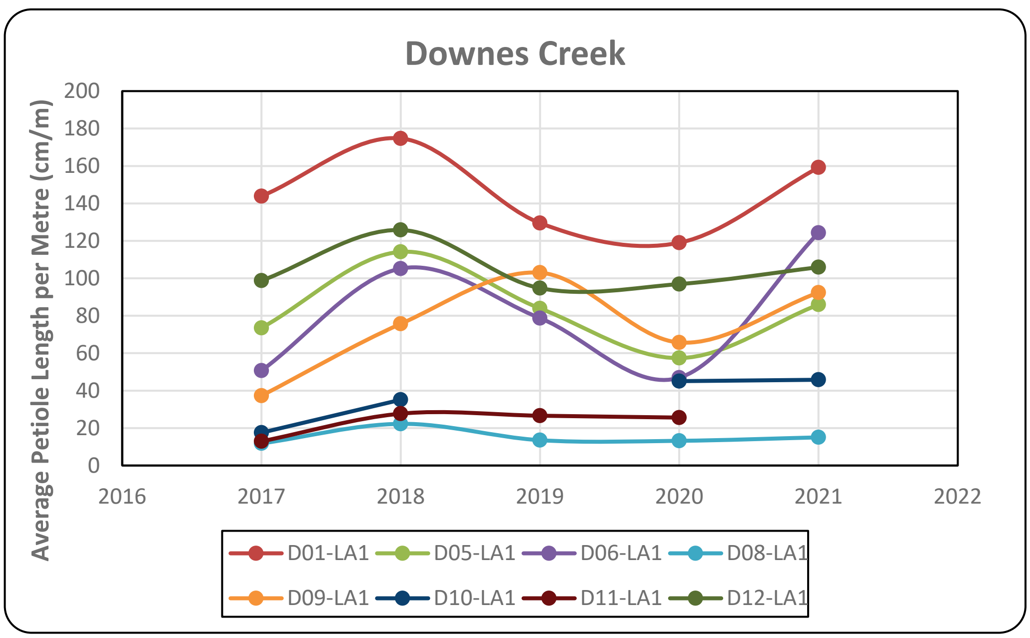


Figure 6-6 Comparison of the Average Petiole Length per Metre for the 2017 to 2021 Skunk Cabbage Line Intercepts in the Downes Creek Watershed

In 2021, the average plant density (as number of plants per metre) was higher than the 2017 density at 8 of the 10 sample sites with 2021 data (Figures 6-3 and 6-4). The 2021 density was lower than the 2020 value at 4 sites. Sites D01, DO5, DO6, DO8, DO9, and D12 had greater plant densities in 2021 than in 2020. No consistent pattern was apparent in density through time across the sites.

Petiole length per metre values decreased at 1 of the sites in 2021 compared with 2017; however, trends were not consistent across all sites (Figures 6-5 and 6-6). The 2021 average petiole length per metre was 81.04 cm compared to 58.86 cm in 2020, 72.31 cm in 2019, 90.06 cm in 2018, and 55.29 cm in 2017.

Statistical analyses were conducted to provide support for the observed changes in indicator plant parameters. The analyses included linear regressions on average petiole lengths in selected plots (B02-LA1, H01-LA2, D01-LA1, and D08-LA1) and Mann-Kendall non-parametric trend analyses on all indicator parameters. Unlike regression analysis, the Mann-Kendall test considers direction of the trend but makes no assumptions about linearity. This analysis was performed using the MAKESENS application for Excel (Salmi *et al*. 2002). The Mann-Kendall analyses included all plots for which there was no missing data. The analyses also included separate averages over the monitoring period for plots without missing data and for all plots.

The regression analyses showed a highly significant ($p = 0.0024$) decrease in average petiole length at H01-LA2 and a significant decrease ($p = 0.025$) at D01-LA1 (Table 6-4). The decreases noted in average petiole length at both plots may be due to their locations and amount of canopy cover present (i.e., skunk cabbage thrive in consistently wet, mucky areas with partial sun to light shade, as excessive heat from strong constant sunlight is not conducive to growth). Both plots, D01-LA1 and H01-LA2, are in open canopy areas that may experience greater levels of direct sunlight during the growing season. The decreases at B02-LA1 ($p = 0.069$) and D08-LA1 ($p = 0.072$) were not statistically significant based on a significance criterion of $p <0.05$. Both plots are in areas with greater canopy cover.

According to the Mann-Kendall tests the only significant ($p<0.05$) temporal trend was a decrease in average petiole length at H01-LA2 (Table 6-5). There were no significant upwards or downward trends in plant density or average petiole length per meter, nor were there any trends at the watershed level. Thus, the indicator plant measurements showed no adverse effects attributable to operation of the Bevan Wells. However, the power of the Mann-Kendall test is low for fewer than eight data points (Holbert 2019).

Table 6-4 Decreases in Skunk Cabbage Petiole Length over Time (2017 – 2022): Regression Results

B02-LA1

Source	df	SS	MS	F	Significance
Regression	1	239.317	239.317	7.726	0.069
Residual	3	92.926	30.975		
Total	4	332.242			

H01-LA2

Source	df	SS	MS	F	Significance
Regression	1	65.895	65.895	92.57	**0.0024**
Residual	3	2.136	0.712		
Total	4	68.030			

D01-LA1

Source	df	SS	MS	F	Significance
Regression	1	94.556	94.556	17.63	**0.025**
Residual	3	16.086	5.362		
Total	4	110.642			

D08-LA1

Source	df	SS	MS	F	Significance
Regression	1	10.920	10.920	7.478	0.072
Residual	3	4.381	1.460		
Total	4	15.301			

df – Degrees of Freedom SS – Sum of Squares MS – Mean Squared

Bold indicates statistical significance. Significance set at $p < 0.05$.

Table 6-5 Significance of Mann-Kendall Tests for Trends in Skunk Cabbage Indicator Parameters, 2017 - 2022

Average Petiole Length						
Time Series	**First Year**	**Last Year**	**n**	**Mann-Kendall S**	**Significance**	**Sen's Slope Estimate**
B02-LA1	2017	2021	5	-8	p<0.1	-4.21
D01-LA1	2017	2021	5	-8	p<0.1	-2.61
D05-LA1	2017	2021	5	-4		-0.438
D06-LA1	2017	2021	5	-6		-3.06
D08-LA1	2017	2021	5	-8	p<0.1	-0.800
D09-LA1	2017	2021	5	-2		-0.572
D12-LA1	2017	2021	5	-6		-1.21
H01-LA2	2017	2021	5	-10	**p<0.05**	-2.68
D-Average [a]	2017	2021	5	-8	p<0.1	-1.31
D-Average All [a]	2017	2021	5	-2		-0.376
Plant Density						
Time Series	**First Year**	**Last Year**	**n**	**Mann-Kendall S**	**Significance**	**Sen's Slope Estimate**
B02-LA1	2017	2021	5	2		0.273
D01-LA1	2017	2021	5	5		0.052
D05-LA1	2017	2021	5	0		-0.004
D06-LA1	2017	2021	5	4		0.333
D08-LA1	2017	2021	5	3		0.029
D09-LA1	2017	2021	5	7		0.250
D12-LA1	2017	2021	5	1		0.025
H01-LA2	2017	2021	5	-8	p<0.1	-0.465
D-Average [a]	2017	2021	5	4		0.129
D-Average All [a]	2017	2021	5	4		0.138
Total Petiole Length per Metre (cm)						
Time Series	**First Year**	**Last Year**	**n**	**Mann-Kendall S**	**Significance**	**Sen's Slope Estimate**
B02-LA1	2017	2021	5	2		6.60
D01-LA1	2017	2021	5	-2		-6.17
D05-LA1	2017	2021	5	0		-2.19
D08-LA1	2017	2021	5	2		0.611
D09-LA1	2017	2021	5	4		11.6
D12-LA1	2017	2021	5	0		0.588
H01-LA2	2017	2021	5	-8	p<0.1	-13.2
D-Average [a]	2017	2021	5	0		2.84
D-Average All [a]	2017	2021	5	4		4.31

a D-Average is average of all plots having 5 years of data. D-Average All is average of all plots. **Bold** indicates significance. Significance is set at p<0.05. Blank indicates p>0.1.

6.2.4 Successes, Challenges, and Suggested Changes

Due to the assessment timing change included in the OEMP, the 2018 to 2021 fieldwork was completed 4 to 5 weeks earlier than the 2017 baseline, with a goal of viewing plants largely prior to decay. Per the OEMP, all plots must be assessed after approximately 1065 growing degree days (assuming a threshold temperature of 10 degrees Celsius). For planning purposes, surveys should be completed after September 20 annually; however, all 2021 surveys were completed a few days prior to the threshold (September 13-16). As a result, all sites were inventoried prior to the growing degree day threshold. Even though the 2021 inventory was completed before the maturation threshold, decay was observed in all plots. The 2021 survey dates also met the October 1 completion deadline laid out in the OEMP (i.e., before petiole decomposition).

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 11 (May 2021 – April 2022) environmental monitoring of the Bevan Wells Groundwater Supply Development Project. Year 11 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 11. In 2021, the maximum daily withdrawal was 20.769 ML/day, and the total withdrawal was 1,7459 ML or 58% of the total allowable groundwater diversion (2,505 ML/year).

Flows measured in the creeks during 2021-22 were within range of previous measurements and did not exhibit any long-term declining trends. The seasonal low flows measured in Downes Creek remained above the 27.9 L/s threshold that represents a 10% reduction from the lowest flow measured in this creek in September 2008 (prior to commissioning of the Bevan Wells). Creek flows below this amount may trigger further assessment and/or mitigation if due to the operation of the Bevan Wells.

A challenge arose with the flow measurements at the new Fishtrap Creek SCADA station. Due to variability in low flow measurements, it has not been possible to develop a rating curve for the site. As a result, to mitigate potential low-flow periods, the Fishtrap mitigation well was operated from July to October 2021.

Flow monitoring at several sites experienced challenges related to unusually high water levels. Flooding associated with an atmospheric river in November 2021 resulted in dislodging the WT-01 staff gauge, logger, and PVC pipe. The D-04 Hobo logger also went missing. High water persisted to the extent that the F-04 staff gauge was fully submerged in January 2022, and the stream was too deep for manual flow measurements.

Low water also presented challenges. The staff gauge at B-01 was above the water line from July through October 2021. Waechter Creek was dry at the WT-01 monitoring station from July through September 2021, and in May 2021 the water level was too low for an accurate manual flow measurement.

Although the Bevan Wells have been used extensively in Years 3 through 11, 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, H-02 and the Willband Creek reference site (W-01). 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 11 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 2021 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. Since 2018, the drying trend indicated by precipitation data is consistent with lower seasonal groundwater peaks and troughs, which were similar to low levels observed in 2015 and 2016. There was no evidence of a progressive year-over-year decline in water levels in any of the observation wells.

Year 11 was the fourth 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. No unanticipated adverse effects were identified in Year 11 monitoring. The four years of mesohabitat and shallow groundwater is not sufficient to draw conclusions, but there were no changes that would suggest an immediate need for a mitigation well for Downes Creek (Condition #25).

Minimum shallow groundwater levels could not be measured at two plots in Fishtrap Creek or at the three plots in Control Wetland B due to a layer of gravel that limited the depths to which the sensors could be installed. 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.

There was an overall decrease in water level in the Downes Creek wetland from 2018 to 2022. The decrease did not correspond to withdrawals by the Bevan Wells. However, interpretation of the water level trend was hampered by lack of samples from August through October 2021. This omission was due to the presence of an active wasp nest near the staff gauge. After a member of the field crew was stung, the crew abandoned monitoring at this site as long as the wasp nest was present.

After five years of data collection, the vegetation monitoring showed neither major shift in species composition nor changes to ecosystem boundaries. Trend analyses of indicator plant (skunk cabbage) parameters showed decreases in average petiole length in two plots, one in the Horn Creek and one in the Downes Creek watershed but no trends at the watershed level. Thus, the monitoring program showed no changes that would suggest an immediate need for a mitigation well. However, the data are quite variable due to year-to-year differences in leaf drop and decay. 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.

Four years of conducting the expanded monitoring program required by the 2017 Amendment have resulted in some challenges that may require adjustments to the program. Specific issues are related the expanded flow and mesohabitat monitoring stations.

Several expanded flow monitoring stations have consistently been problematic. The manual stream flow data recorded at B-02, D-02, D-03 and D-04 have been too variable to establish a stage-discharge rating curve, and Waechter Creek at WT-01 has frequently been dry during the summer. ENKON recommends that a qualified professional hydrologist in consultation with a qualified professional fisheries biologist re-evaluate the expanded flow monitoring sites to determine whether:

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

For several years beavers have been active at F-02 and F-03, changing the site characteristics. 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.

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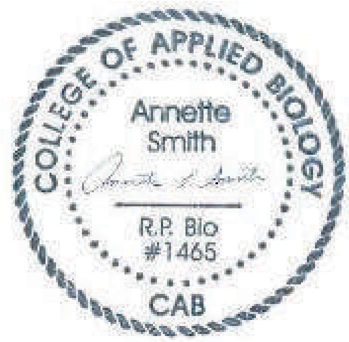

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