Morrison Creek Headwaters

Wetland and Tributary Mapping & Hydrological Study

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1 INTRODUCTION

Morrison Creek is a salmon-bearing stream in the Puntledge River Watershed in Courtenay, BC. This productive creek supports spawning populations of pink, chum, coho, and chinook salmon, cutthroat trout, and rainbow/steelhead. The headwaters of Morrison Creek have numerous springs and wetlands that provide clean, cool and consistent flows to Morrison Creek year-round which directly relates to the productivity of this salmon stream (Figure 2).

The Morrison Creek Streamkeepers, a volunteer group in Courtenay, BC, have identified the critical importance of protecting these headwaters in order to maintain the healthy salmon population in this watershed, and to provide habitat for a range of wildlife, including 8 Species-at-Risk (Table 1). The majority of the land in the headwaters is private managed forest land within the Village of Cumberland and the Comox Valley Regional District boundaries.

Table 1. Species-at-risk identified within the Morrison Creek Headwaters.

Common Name	Scientific Name	SARA	COSEWIC	BC List
Western brook lamprey, Morrison Creek population*	*Lampetra richardsoni* (Morrison Creek population)	Schedule 1-E	Endangered	Red
Cutthroat trout, *clarkii* subspecies	*Oncorhynchus clarkia clarkii*	n/a	n/a	Blue
Northern red-legged frog	*Rana aurora*	Schedule 1 - SC	Special Concern	Blue
Western painted turtle (Pacific coast population)*	*Chrysemys picta* (Pacific coast population)	Schedule 1 - E	Threatened	Red
Roosevelt elk	*Cervus canadensis roosevelti*	n/a	n/a	Blue
Northern pygmy owl (*swarthii* subspecies)	*Glaucidium gnoma swarthi*	n/a	n/a	Blue
Common nighthawk	*Chordeiles minor*	Schedule 1-T	Special Concern	Yellow
Great blue heron (*fannini subspecies*)	*Ardea herodias fannini*	Schedule 1 - SC	Special Concern	Blue
*Property includes designated critical habitat				

In order to facilitate protection of aquatic habitat within the Morrison Headwaters, the Morrison Creek Streamkeepers made the decision to accurately map the wetlands, stream tributaries and source springs in the area. Up-to-date, accurate mapping is key to ensuring these sensitive habitats are protected. The most recent mapping exercise in this area was completed in 2014 and was limited to aerial photo analysis and synthesizing existing geospatial data[1]. The most recent ground truthing exercise was completed in 2003[2]. Many of the wetlands are either undersized or missing altogether in existing mapping of environmentally sensitive areas used by local government and the springs have never been located or mapped.

[1] Comox Valley Conservation Strategy. (2014). *Comox Valley SEI (Version 3)*.
[2] Ellefson, J. (2003). *Morrison Creek Headwaters Sensitive Habitat Inventory & Mapping Report*. Accessed from <https://drive.google.com/file/d/1n05br0Qob50FXr-dBrkY7waupWTkArZkMNlHihoxK1eR07GuOiN1HLZ3fxjg/view>

The primary objectives of this project are twofold:

1. To accurately map the tributaries, wetlands and springs within the headwaters of Morrison Creek
2. To obtain hydrological data for the Headwaters, including the sources of water, the effect of precipitation, and seasonal variation on both surface flow and groundwater levels

2 BACKGROUND

2.1 STUDY AREA

The study area encompasses the entirety of the Morrison Creek headwaters (the Headwaters) – a 543 ha area bounded by Highway 19 to the east, Lake Trail Road to the north, and a large gravel scarp to the south and west (Figure 1). Water emerges from the lower face of the scarp via a series of seeps and springs, supplying cold water year-round to a vast complex of wetlands and tributaries. This in turn provides mainstem Morrison Creek with a steady flow of cold, nutrient-rich water throughout the year, while the storage and groundwater recharge functions of the wetlands buffer mainstem from extreme freshets.

The headwaters slopes gently northwards and tilts eastward, with the network of tributaries exiting the northeast corner through two existing conservation areas and the new Morrison Headwaters Nature Preserve near Lake Trail Road.

The complex, hummocky terrain is a remnant of glacial retreat, which left a series of small depressions, low gravel knobs and ridges. While the area appears as a flat lowland, the complex micro-topography has produced scores of pocket wetlands. Due to the high water table all the depressions are permanently filled with water. In addition, hundreds of small and large beaver dams form chains of terraced ponds linked by a mosaic of channels. The Headwaters is covered by over 100 ha of wetlands.

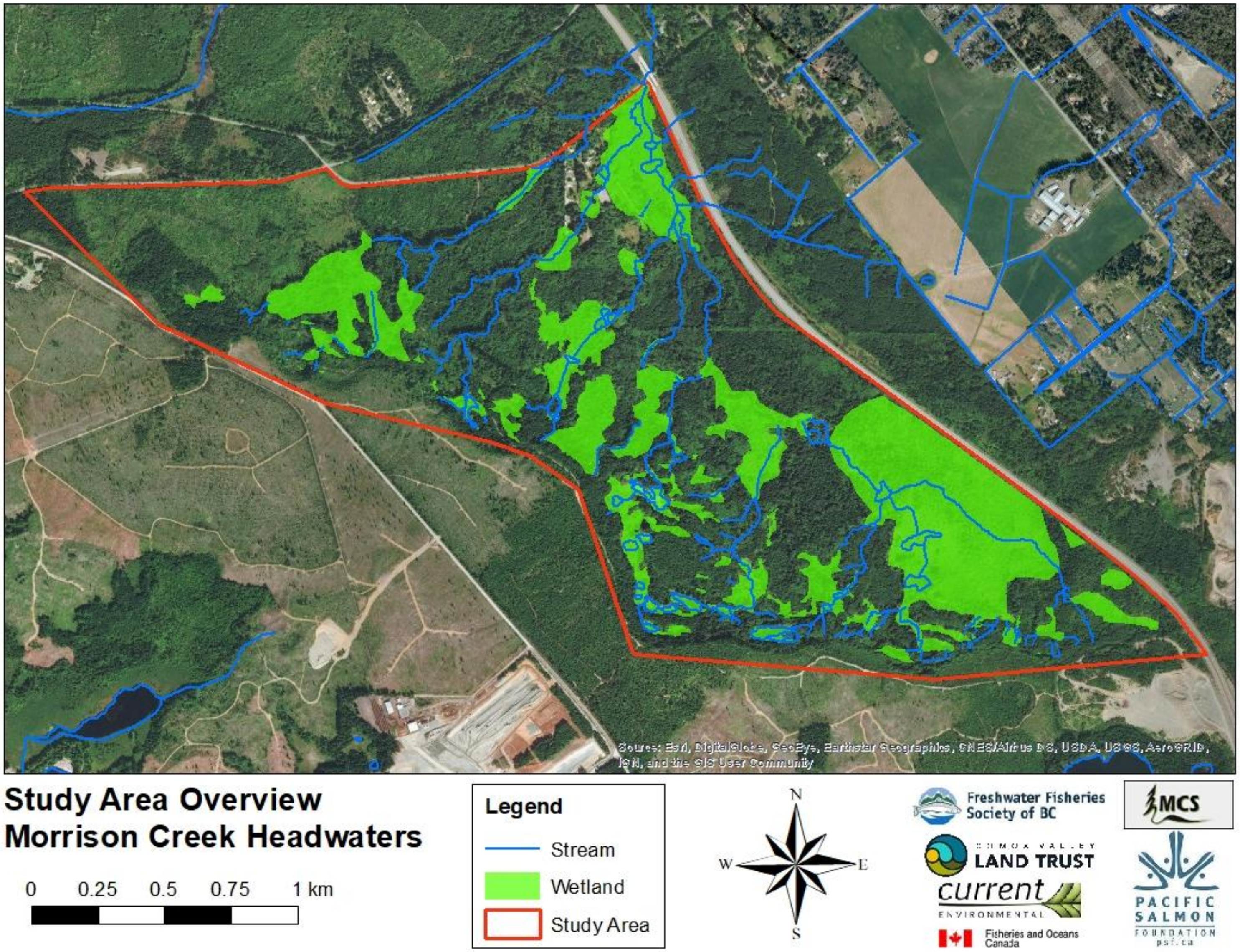

Figure 1. Study area overview, Morrison Creek headwaters.

2.2 OTHER STUDIES

Numerous other studies have been conducted within the Headwaters, including previous mapping exercises. These are summarized below:

- Comox Valley Project Watershed Society (March 2003). *Map - Upper Morrison Creek Water Features with Flow Study sites marked* (Jim Palmer)
- Ellefson, J (2003). *Morrison Creek Headwaters - Sensitive Habitat Inventory & Mapping Report*.
- Fisheries and Oceans Canada (2015). *Map – Geographic Extent of Critical Habitat for Morrison Creek Lamprey*.
- Fisheries and Oceans Canada (2015). *Map – Distribution of Morrison Creek Lamprey.*
- Lough, M. (1995). Study conducted for Ministry of Transportation and Highways prior to construction of Inland Island Highway. Addendum.
- Morgan, A. (2003). *Species lists from bird surveys of Cougar Run property, 1995 – 2003.*
- Morrison Creek Streamkeepers. (2015). *Map - Morrison Creek Sensitive Ecosystems and Conservation Areas.*
- CH2MHILL (Feb 2002). *Pidgeon Lake Regional Landfill Hydrogeological Investigation.*
- Water Survey of Canada (1999). *Principles of Discharge Measurement*
- Hamilton, S et al. (2019). *The Role of the Hydrographer in Rating Curve Development.*
- U.S. Dep't of Agriculture (1979). *Field Research Manual in Agricultural Hydrology.*
- Myer, Judy L. et al. (2007). *Where Rivers Are Born: The Scientific Imperative for Defending Small Streams and Wetlands.*
- Sirk, G. (2019). *Bird species on the Linton Property identified in surveys conducted in 2018-2019.*

3 METHODS

Background review was conducted for the mapping project from May – July of 2019. Field assessment was conducted between May 2019 – March 2020. For the hydrology project, a review was started in early 2019 of existing literature on the hydrogeology and hydrology of the area. A review was also undertaken of techniques for effective methods of level and flow monitoring in very small headwater streams. Some prototyping was done and a pilot monitoring station was established on one tributary to test various approaches. Methodologies for both projects are summarized below.

3.1 WETLAND AND TRIBUTARY MAPPING

A review of existing information and mapping was first conducted. Sources included:

1. Sensitive Ecosystem Inventory Mapping – shapefiles obtained from the CVRD
2. Sensitive Habitat Atlas

A series of georeferenced base maps was produced in ArcMap, using shapefiles of existing watercourse and wetland habitat obtained from the CVRD (Comox Valley Regional District). Areas of probable new wetland habitat were identified using photo-interpretation, and these areas were outlined using ArcMap and added to the basemaps.

Basemaps were then exported to tablets equipped with the Avenza Maps Pro application to record georeferenced field data. To improve accuracy and signal strength, operators carried Garmin GLO receivers linked to the tablets. Wetland edges were mapped, as well as unmapped tributaries, feeder channels, seeps, springs and other significant features. Wetland mapping employed a simple presence-absence technique and did not differentiate different wetland types. Wetland presence was determined using methodology outlined in *Wetlands of British Columbia: A Guide to Identification* (MacKenzie & Moran, 2004), primarily the presence of hydrophitic vegetation and hydric soils.

3.2 HYDROLOGICAL ANALYSIS

In early 2019 a review was conducted of existing literature on the hydrogeology and hydrology of the area. A review was also undertaken of techniques for effective level and discharge monitoring suitable for very small headwater streams. Some prototyping was done and a pilot monitoring station was established on one tributary to test various approaches. Monitoring stations were later established at eight other locations.

Hourly data was collected for water level, temperature and discharge in seven sub-basins within the Headwaters. In addition, groundwater level data was collected in two existing monitoring wells. This was tracked against hourly discharge data from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) gauging station in lower mainstem Morrison Creek, along with hourly rainfall records from a local weather station.

3.2.1 Groundwater Monitoring

Water level was continuously monitored using Solinst Leveloggers. Groundwater level and temperature was recorded in two existing drilled wells at approximately 4.5 m depth **(Photo 1)**. For stream monitoring, level/discharge, data loggers were placed in stilling wells installed upstream of suitable “control” points, constrictions in channel cross-section which cause marked changes in water level with fluctuating stream flow **(Photo 2)**.

Photo 1. Retrieving data logger from groundwater well

Photo 1: Levelogger is in stilling well (black pipe, lower centre), "control" point is at riffle/log, (behind top of stick). Upper mainstem site "Mainstem High"

3.2.2 Site Selection

Seven monitoring sites were selected in an effort to capture total discharge from each of the major sub-basins within the Headwaters having perennial flow **(Figure 2).** Candidate sites were based on the following criteria:

1. Capture as much of the sub-basin discharge as possible
2. Sufficient gradient to cause a defined, laminar flow over a broad range of stream stages.
3. Low turbulence
4. Low sediment deposition rate
5. Effective and stable control point downstream; having a constriction in stream cross-section which will cause a marked rise in water level with increasing flow, and one which is unlikely to erode or collect debris or sediment.
6. Within a few meters of a suitable flow-measuring site.
7. Banks able to contain freshets
8. Reasonable access

The sites chosen are provided in **Table 2 below.**

Table 2. Flow Monitoring Sites, Dates of Installation and First Measurement

Site	Date Logger Installed	First Measurement Taken
First Supply Creek	January 22, 2019	April 17, 2019
Nellie Creek	April 18, 2019	April 20, 2019
Trib 8	April 21, 2019	April 21, 2019
Sill Log Trib	May 2, 2019	May 2, 2019
ET	May 3, 2019	May 3, 2019
Mainstem High	May 3, 2019	May 3, 2019
Monkeyflower Trib	May 6, 2019	May 6, 2019

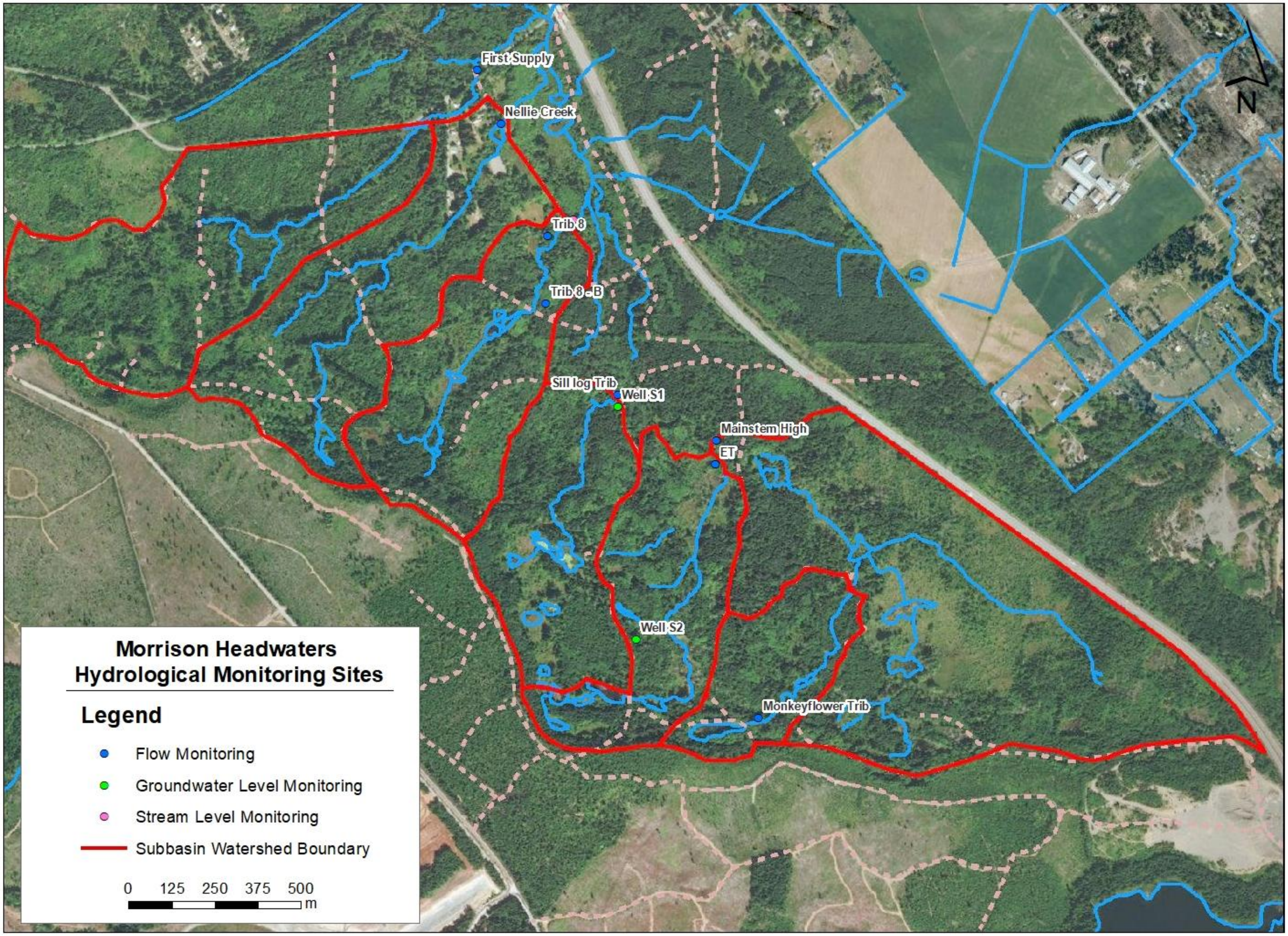

Figure 2. Sub-basins and monitoring sites

3.2.3 Stream Discharge Monitoring

Flow Measurements

Flow measurements were taken at each site multiple times . A total of 106 flow measurements were taken, covering as broad a range of conditions as possible, from lowest summer flow to extreme freshet. Discharge (Q) values were recorded against water level for the full range of flow conditions. A unique Stage Discharge Curve, or Rating Curve was produced for each site, allowing any water level value recorded by the Solinst Leveloggers to be converted to discharge.

Numerous methods and equipment types were tried. All sites feature difficult conditions for standard flow measurement methods. Channels are very small, mostly shallow gradient, sinuous tributaries with high complexity. While these make excellent fish habitat, these features confound efforts to measure stream flow. Most of the sites are quite remote; packing in tools, materials and monitoring equipment posed a significant challenge.

Two technologies were ultimately used, both producing very similar results:

1. Portable V-notch weirs - Used for earlier measurements at all but one site, which was too large for this technique **(Photo 3 and 6**). A portable weir plate was installed temporarily at each site for each flow measurement. Water level was allowed to reach a stable level, which was used for calculating Q (discharge). We used online calculators from San Diego State University for all weir calculations. http://ponce.sdsu.edu/onlineveenotch1.php and http://ponce.sdsu.edu/onlineveenotch2.php. The weir plate was then removed and the site left in its natural state until the next measurement
2. Ott MF Pro – A computerized instrument using electromagnetic sensor technology, used for later readings at all sites. **(Photo 4 and 5).**

In all cases, the Q value, in cubic meters/second was recorded for the water level at the time of flow measurement. This was used to construct the Stage-discharge, or Rating Curve to arrive at Q values for all other levels recorded by the leveloggers.

Solinst Leveloggers were installed 1 ½” ABS pipe stilling wells. In shallow tributaries they were installed below streambed level as shown in **Photo 7.**

Photo 3: Using 90° V-Notch weir (integrated tarp style) in Trib ET

Photo 4: Flow transect using Ott MF Pro at Monkeyflower Trib

Photo 5: Flow transect at Mainstem High using Ott MF Pro during moderately high flow conditions

Photo 6: Using 90° V-Notch weir on Trib 8 culvert

Photo 7: Typical stilling well/Levelogger setup, allowing use in very shallow water. Stick indicates typical streambed level. Note ½" lateral pipe wrapped in filter fabric to exclude sediment when lateral is buried. Short sump allows logger to be below streambed, but above sediment. Main pipe perforated with a series of 1/8" holes above streambed level.

Weather

The Cumberland Elementary weather station (part of the School-based Weather Station Network) was used to obtain hourly rainfall data due to its proximity to the site (http://www.victoriaweather.ca/dataavgs.php?field=raintotal&interval=60&id=191&notable=1). Hourly barometric pressure data was used to compensate raw values from the level loggers to provide actual water level.

Snow presented a problem. We found no reliable, local data for snowfall and no means of determining its contribution to stream flow.

4 RESULTS

As mentioned in Section 2.2, there have been various mapping efforts conducted in the Headwaters, both on the ground and using aerial interpretation. Because of the dynamic nature of wetland and tributary habitat in the Headwaters (due to beaver activity and other natural events), existing mapping products varied widely in their accuracy. Existing polygons were assessed, and those that appeared to still be relatively accurate were not mapped in detail in order to avoid re-duplicating efforts.

4.1 WETLAND AND TRIBUTARY MAPPING

4.1.1 Wetland Habitat

A total of 124.4 ha of wetland habitat was covered by the study. This total includes 110.8 ha of previously identified wetland habitat that was confirmed to be accurate, and 13.5 ha of newly identified wetland habitat.

Although wetland types were not differentiated during the study, there were a range of wetland types observed during the assessment. These included: treed swamps, open water ponds, and marshes. Photos of typical wetland types are provided below.

Photo 8. Skunk cabbage swamp, characterized by lower water levels and a treed overstory.

Photo 9. Open water pond. The majority of open water ponds in the Headwaters have been created by beavers.

Photo 10. Open water pocket with marsh habitat along the perimeter.

4.1.2 Tributary Habitat

The total length of new tributary habitat mapped during the project was approximately 4.8 km. Tributaries varied widely in discharge, substrate, and size. Numerous tributaries were identified with potential trout spawning habitat. This suggests that isolated populations of trout could be self sustaining within Morrison Headwaters. These projects did not formally study fish populations or habitat features, we found extensive areas of excellent and complex rearing habitat in most tributaries. Patches of suitable spawning gravel were observed in all tributaries. Coho juveniles were observed at all but one flow monitoring site (Monkeyflower), and some adult coho arrived at all monitoring sites except Monkeyflower. Trout were observed in several ponds and tributaries.

4.1.3 Springs and Seepage Slopes

A total of 13 discreet springs were identified, along with 28 seepage slope areas with a total length of 2.1 km. Although technically wetlands due to the presence of deep (>40 cm) humisol soil and hydrophitic vegetation, these areas were categorized separately due to their importance to the hydrology of the Headwaters.

These areas are unique due to their slope position and hydrology; rather than stagnant flow these areas are characterized by spring water moving on or just below surface through the site. In some locations discharge is more concentrated, forming discreet channels. This water drains down the escarpment, entering wetlands or tributaries near the toe of slope. The eastern two-thirds of the area drains directly into wetlands comprising upper mainstem Morrison Creek. Drainage from all other parts of the roughly 4000 meter escarpment length feed one of 6 sub-basins.

Photo 11. Seepage slope, characterized by a treed canopy and hydrophytic shrubs. Often bisected by seepage channels.

4.2 HYDROLOGICAL ANALYSIS

4.2.1 Principal Findings

We found all tributaries maintained good flow and temperature throughout the hottest, driest weather. Even the two smallest streams (1 to 1.5m width) contributed 5% or more to average mainstem flow[3]. **(Table 3).** The approximate area of each sub-basin was estimated using GIS[4]. Highest water temperatures were well within limits for salmonids **(Table 4).** Note that temperature values are extreme highs, only lasting a few hours and on a very few days. A more comprehensive view of summer water temperature is shown in **Figure 3, 4 and 5.**

No single tributary is responsible for sustaining base flow in Morison Creek; all tributaries make a significant contribution and all tributaries have good flow independent of rainfall. Similarly, we found that all the springs and seeps together were responsible for maintaining base flow, rather than one or two major springs. All of the tributaries of Morrison Headwaters are fed by multiple seeps and small springs. While this hydrological study did not attempt to identify the source or sources of the groundwater which feeds the seeps and springs, it is reasonable to conclude that all aquifers upslope to the south and west of the Headwaters are important for maintaining the flow regime within the tributaries and mainstem Morrison Creek. This in turn is essential for maintaining the unusually high fish productivity and diversity in Morrison Creek.

Table 3. % of Mainstem Flow Contributed by Tributaries.

	All Sites_% of Mainstem Flow During Discharge Measurements						
	1st Supply	Nellie	Trib 8	Sill Log	ET	Mainstem High Flow includes ET + Monkeyflower	Monkeyflower
Minimum	5.7	6.8	3.2	3.1	2.9	24.1	15.0
Average	9.2	15.7	5.7	7.3	13.0	47.5	14.8
Maximum	13.9	31.9	8.5	11.5	18.0	57.8	14.6
Stream width at flow transect (m)	1.5	2.0	1.3	1.3	1.1	3.8	1.0

[3] These values were calculated from the Q values obtained during on-site flow measurements, rather than those derived from the Rating Curves.

[4] Basin areas and boundaries are approximate due to very subtle topography and some inter-basin surface and sub-surface connections, which can vary with beaver activity, debris jams and other changes.

Table 4. Sub-basin areas and Max Temperatures

Morrison Sub-Basin Areas and Maximum Temperatures			
Tributary	**Area (m^2)**		**Maximum Water Temperature (°C) (Highs are very brief)**
First Supply	493,112		14.5
Nellie	425,086		15.0
Trib 8	332,441		18.5
Sill Log	301,503		17.5
ET	296,459		17.0
Mainstem High	841,192	Flow site also captures ET & Monkeyflower	16.5
Monkeyflower	170,116	Area captured by logger approximately 1/6 of basin	17.5

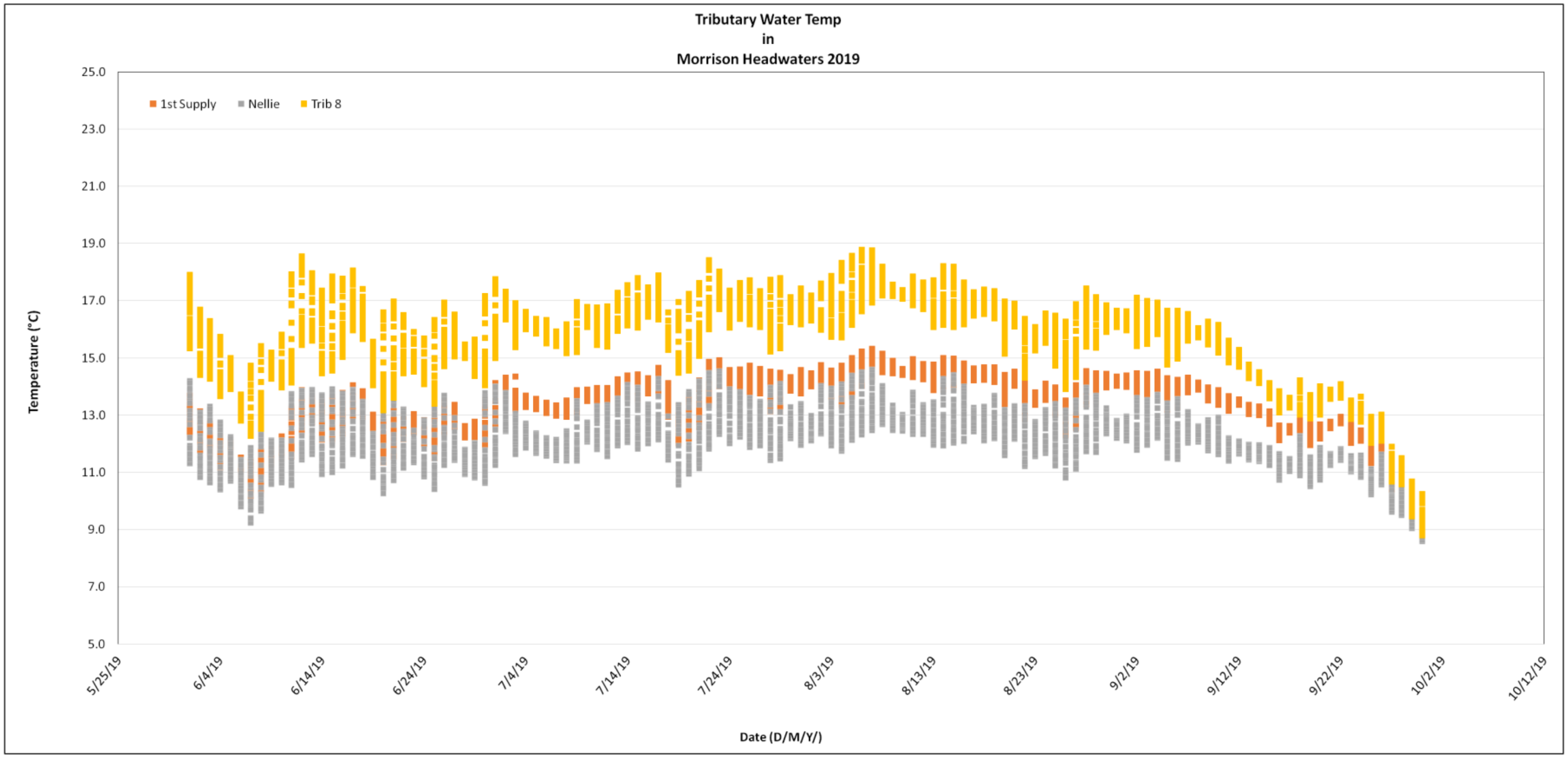

Figure 3. Tributary Summer Water Temperatures

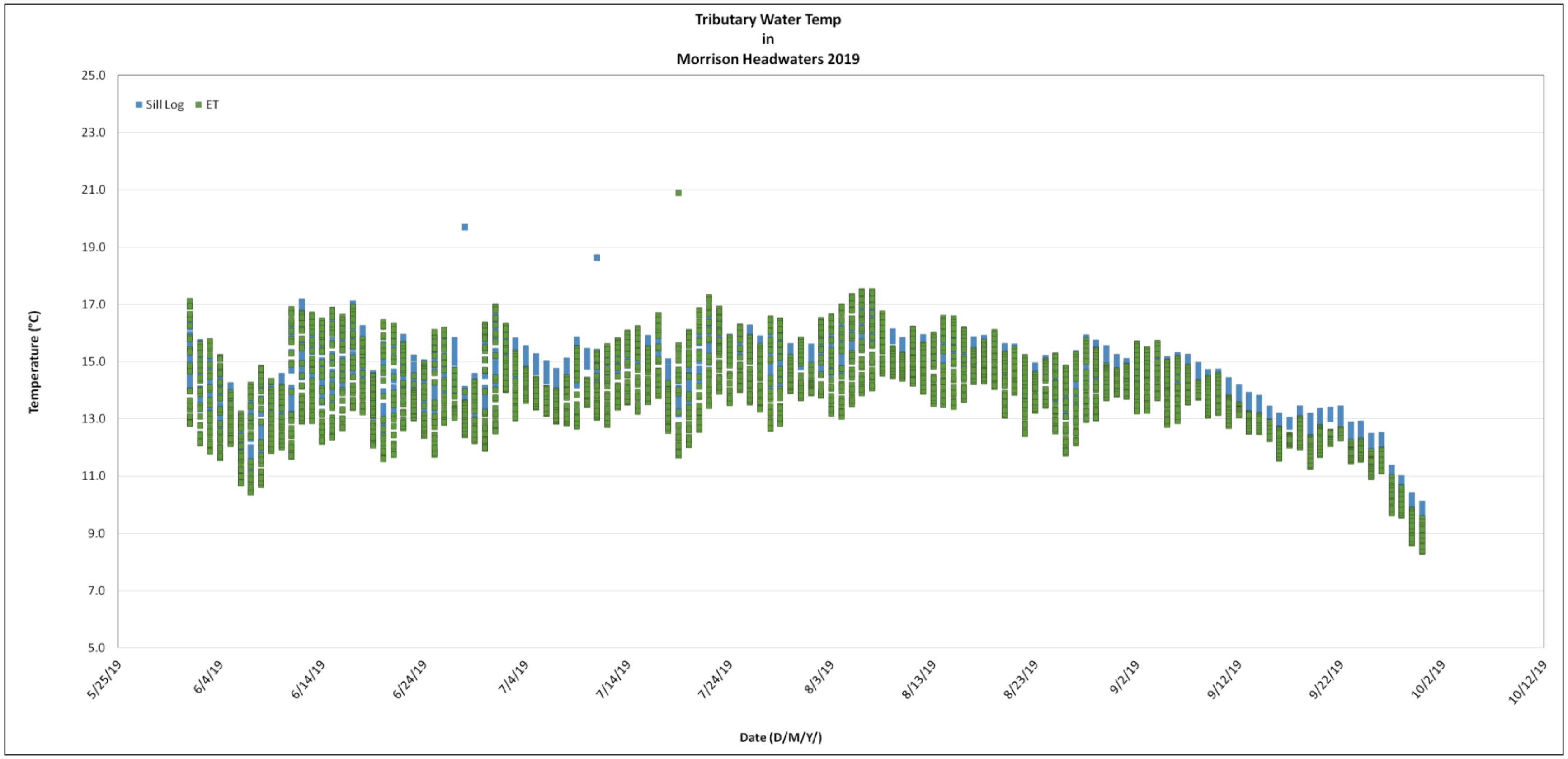

Figure 4. Tributary Summer Water Temperatures

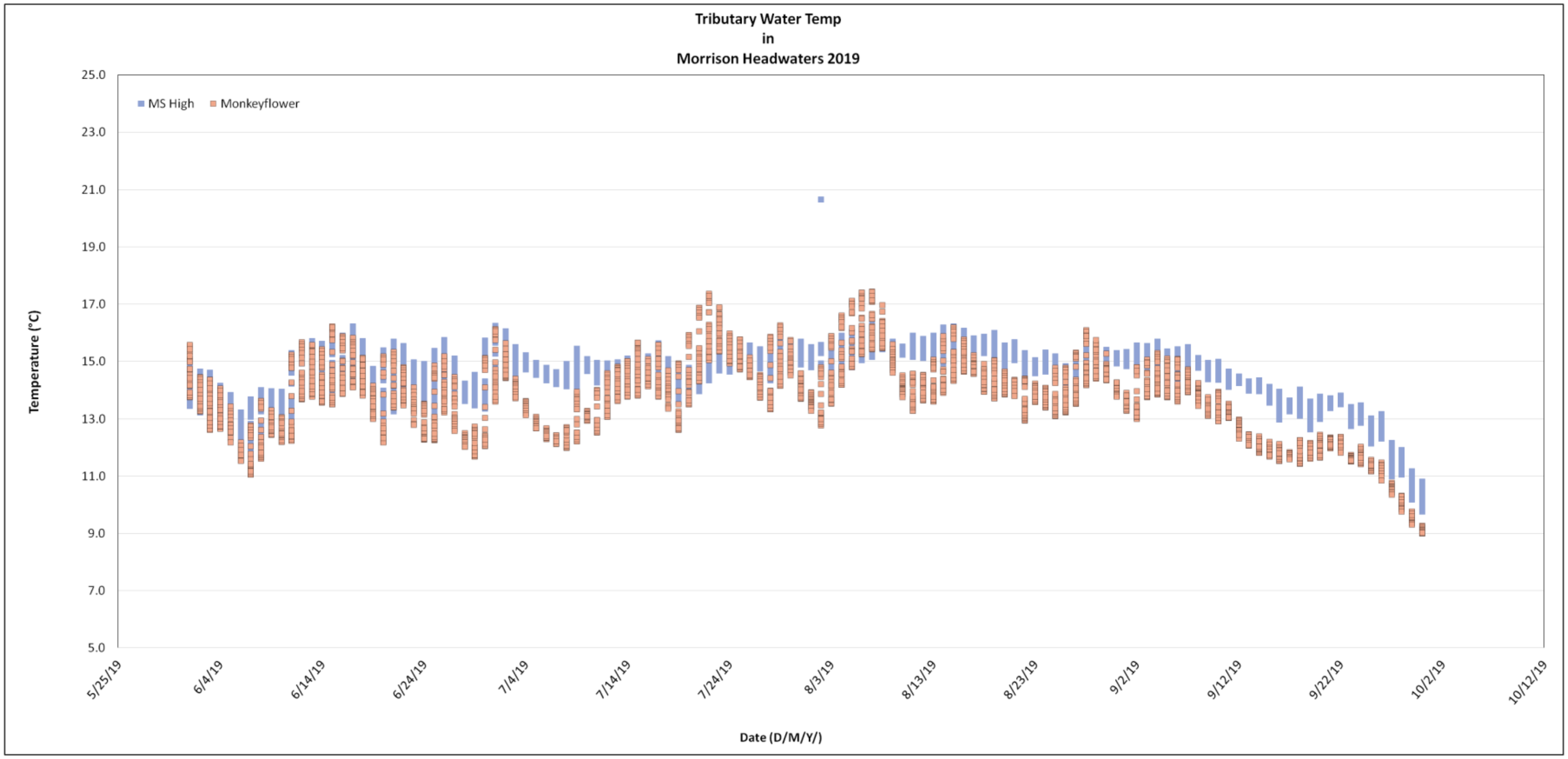

Figure 5. Tributary Summer Water Temperatures

4.2.2 Water Sources and Flow Variations

The Mapping and Hydrology projects were closely tied. We traced each tributary to its ultimate sources and mapped our findings. In many cases the source was a maze of smaller and smaller channels **(Photo 11)**, many as small as 0.2m, mostly ending in seepage areas near the base of the escarpment. This appears to be the source of Morrison Creeks excellent base flow regime.

Photo 12: Tracing one of hundreds of small feeder channels in Morrison Headwaters. These channels collect flow from seepage areas, directing it to wetlands or the beginnings of tributaries.

A graph showing data from all flow sites for the study period is shown below **(Figure 6).** An Excel workbook showing all data is attached.

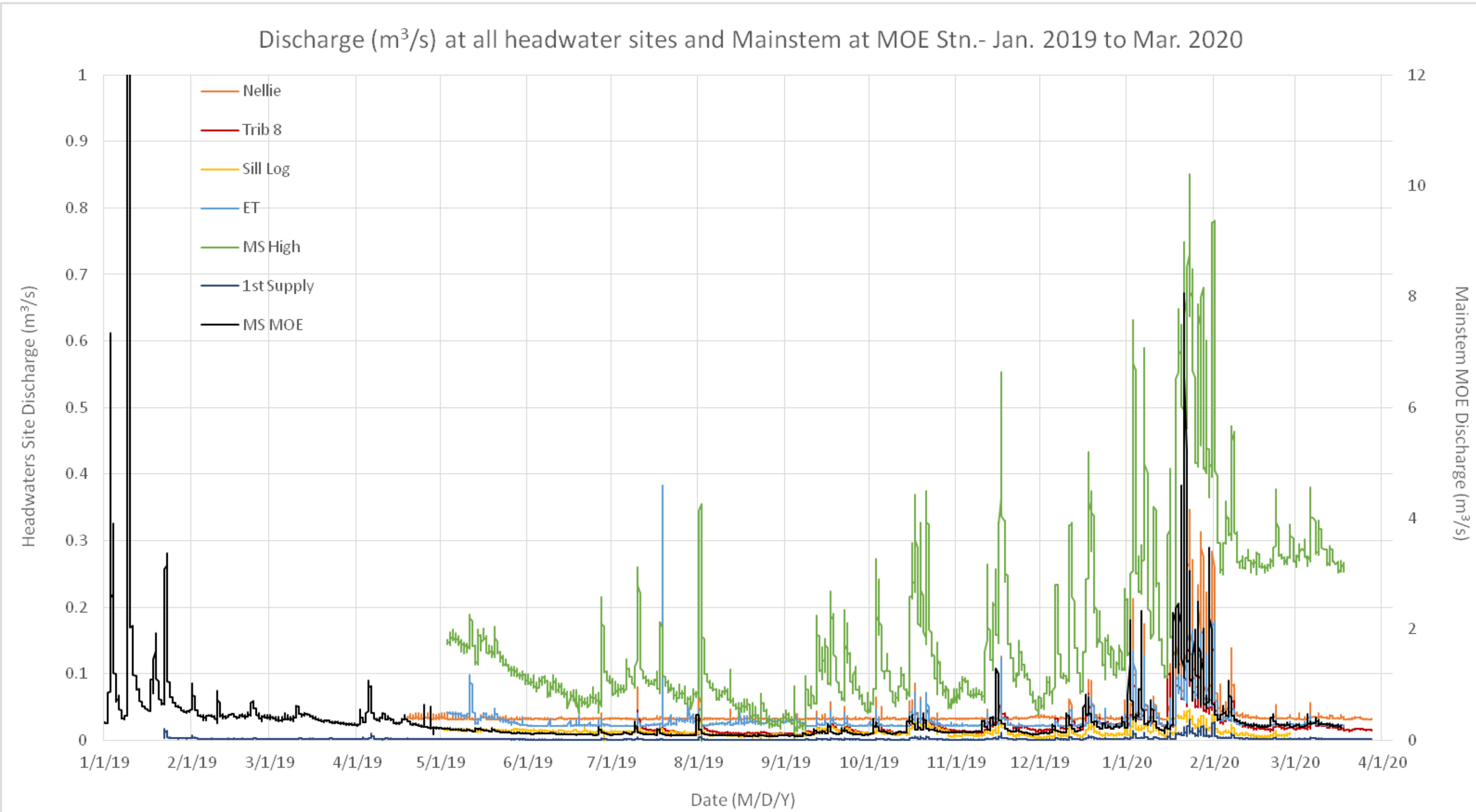

Figure 6, Stream Flow-All Sites. (Note: MS High [in green] includes Monkeyflower and ET discharge)

4.2.2.1 Rating Curves

A Stage/Discharge curve or Rating Curve is a mathematical relationship correlating water level, as captured by the data loggers, to stream discharge, based on actual measured discharge captured during site visits; it is unique for every site. Further analysis of the data by experts is needed in order to refine the relationship for these sites. Streamflow graphs presented here should be considered "drafts" since they are based on good field data, but analysis that still needs work. We will continue this work and present our findings at a later date

4.2.3 Problems Encountered

4.2.3.1 Monkeyflower Trib

Monkeyflower Trib, near the southwest corner of the Headwaters only had one marginal site for level/flow monitoring. The control point was prone to collecting debris, which alters the stage/discharge relationship. Discharge was remarkably stable, however. During the 10 good quality measurements over the study period, flow ranged from 0.006 to 0.013 cms. , substantial discharge considering the site is only about 100m from the escarpment. We also found a very good potential trout spawning area just downstream of the monitoring site. During mapping we also found a significant additional tributary feeding Monkeyflower and a site farther downstream which looks promising for future flow monitoring.

4.2.3.2 Flow Measurements and Access

Morrison Headwaters is a very large area without road access to monitoring sites, requiring hiking in to all but one site. Packing in the tools and materials for setting up the sites and for subsequent flow measurements was a significant challenge. We found measuring discharge in small tributaries difficult. Several methods were attempted including Swoffer 2100, Velocity-Head Rod, and Sontek Flow Tracker. None worked well at our sites. In the end we used 90° V-Notch weirs for all earlier measurements and an electromagnetic Ott MF Pro meter for all later measurements. Both worked well. We developed a good working relationship with FLNRORD, who provided a lot of technical support, training and long-term use of sophisticated equipment. We also relied heavily on data from their gauging station which tracks total flow in lower mainstem Morrison Creek, near the confluence with the Puntledge River
http://aqrt.nrs.gov.bc.ca/Data/DataSet/Chart/Location/08HB0018/DataSet/QR/Working/Interval/Monthly/Calendar/CALENDARYEAR/2020/04
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4.2.4 Recommendations for Future Work

4.2.4.1 Data Analysis

Immediate work should be done to refine the Rating Curves for all sites. This will provide a much better picture of actual tributary discharge over the full range of stream stage, both during the study period and during ongoing monitoring. FLNRORD staff may be able to help with this. Otherwise, further funding will be required. A considerable amount of data and correlations of data is presented in the attached Excel workbook.

4.2.4.2 Ongoing Monitoring

A lot of effort went to finding suitable monitoring sites, setting up the level logging stations and finding effective flow measuring methods. A considerable effort also went into setting up the data processing and compiling system. Relatively little effort is needed to continue this work. This would document and provide an early warning for any long-term changes in stream flow and give weight to efforts to protect source water for Morrison Creek.

4.2.4.3 Habitat Protection

This study provides documentary evidence of just how unusual this area is and it goes a long way to showing how this area functions and why Morrison Creek has such healthy fish populations. This evidence should be used to support conservation of the area. Protection of the aquifers to the south and west of the study area is also important for maintaining base flow in Morrison Creek. This is supported, at least in principle at the Provincial level by the Water Sustainability Act and at the Federal level under SARA by the Action Plan for the Morrison Creek Lamprey

4.2.4.4 Research

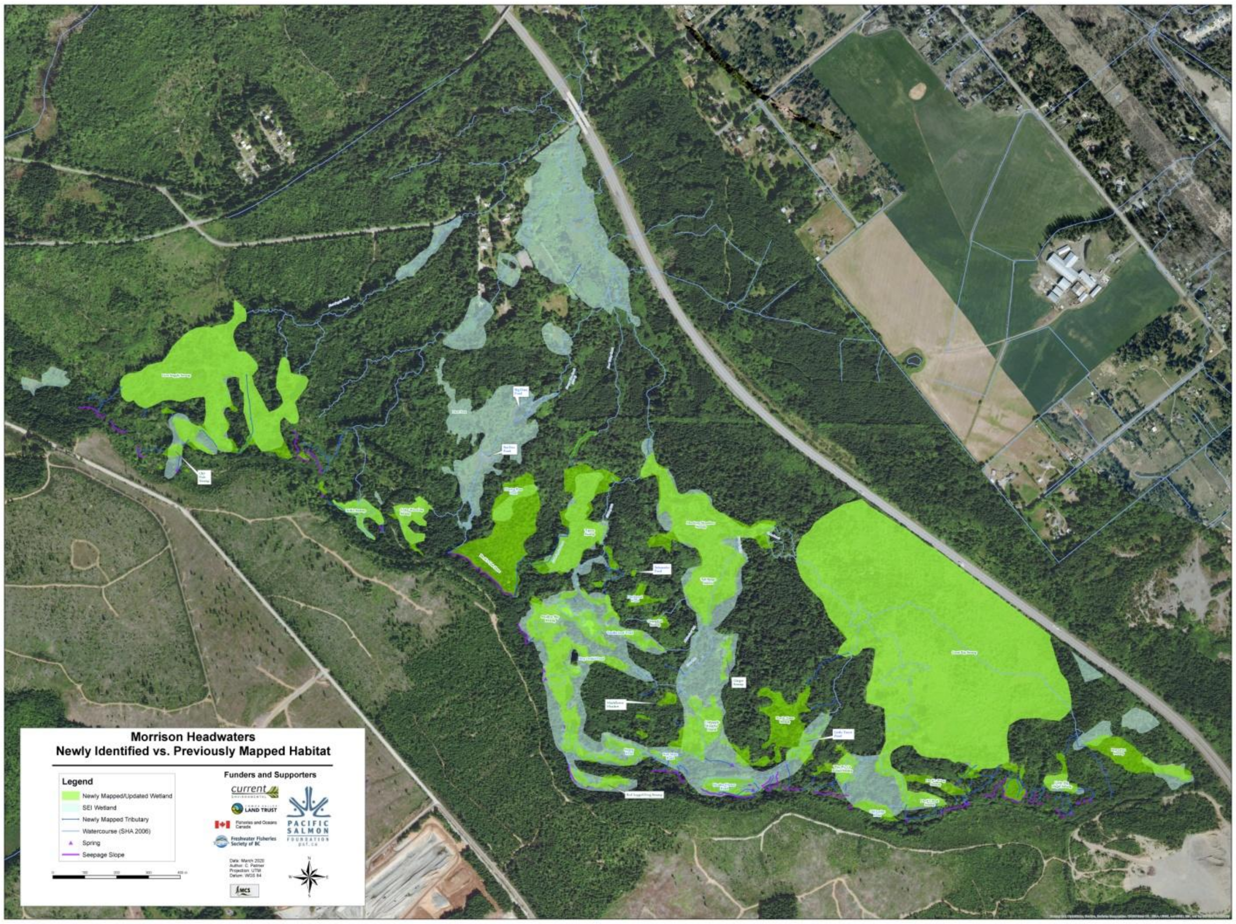
Both the Hydrology and Mapping studies reveal just how unusual the Morrison Creek Headwaters is. It would provide an excellent classroom for university level students and researchers in a number of disciplines, including biology, hydrology, hydrogeology, botany and geomorphology, to name a few. A good hydrogeological study was done by CH2MHILL[5], primarily for the area to the west. Additional work needs to be done for the area south of the Headwaters.

- [5] CH2MHILL (Feb 2002). *Pidgeon Lake Regional Landfill Hydrogeological Investigation*.

APPENDIX A – WETLAND AND WATER SOURCES MAPS

Newly identified tributaries, springs, seepage slopes and wetlands

APPENDIX B – COMBINED CURRENT AND PREVIOUS MAPPING



New and previously mapped areas