A Habitat, Water Quality, and Stream Invertebrate Assessment Report for Cottle Creek in Nanaimo, BC

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1.0 EXECUTIVE SUMMARY – Josh Campana

The purpose of this paper is to outline the project undertaken to assess the general health and conditions of Cottle Creek in Nanaimo, British Columbia for the fall of 2023. The objective of the project was to evaluate the stream habitat, hydrology, invertebrate count, riparian zones, and general water quality in order to compare to past projects undertaken at Cottle Creek as part of a long-term observational study on the area. Four sample sites were selected along the length of Cottle Creek within which all tests were conducted. These tests consisted of invertebrate sampling and identification via Hess Sampler, various hydrology and water quality-based tests, measures of riparian depth and species distribution, and stream habitat unit assessments.

These assessments were conducted by a team of four students over the course of 40 days, with sampling procedures taking place on October 24th, October 26th, October 31st, November 9th, November 20th, and November 23rd. The reasoning for the spread of these tests was to record data from both before and after the influence of the fall rains to determine the difference in water quality. This report also contains recommendations for the continuation of this project, with minor changes to the current layout of the testing system and testing sites. Overall, our data suggests that Cottle Creek meets the basic BC aquatic life guidelines, although it tends to be of fair health rather than good when considering all stream parameters.

2.0 INTRODUCTION – Geoffrey Dell

Our four-person student team, based out of Vancouver Island University and the Natural Resource Protection program, completed an environmental monitoring project on Cottle Creek in Nanaimo, British Columbia from October 24th, 2023, to November 23rd, 2023. The primary aim of this project was to continue collecting annual data on the condition of Cottle Creek, to establish long-term trends to assist in the management of the watershed.

2.1 Project Site Overview

Located in the north end of the city, the Cottle Creek watershed is composed of multiple stream branches that flow through a variety of city parks and is approximately 4.5 km^2 in area (Ware & Rundel, 2012). These branches include Upper Cottle Creek, which originates at headwaters off Rutherford Road and travels into the western side of Cottle Lake, and North Cottle Creek, which originates at Lost Lake and travels into the northern side of Cottle Lake (Ware & Rundel, 2012). Lower Cottle Creek is the final branch, which comes out of the eastern side of Cottle Lake and discharges into Departure Bay near the Brandon Islands (Google Maps, 2023). Throughout our assessment, it was found that Cottle Creek is relatively shallow and slow moving. Compared to other Nanaimo streams like the Millstone or Nanaimo Rivers, Cottle Creek is much narrower and arguably of less cultural significance.

The four survey sites used for analysis have been historically surveyed by Vancouver Island University students, in this same combination, since 2015 (Dennill et al., 2015). Although, some survey groups have occasionally opted for different sites like Kampman et al. in 2020. One site is found in Upper Cottle Creek, and the remaining three are all within Lower Cottle Creek. All sites are easily accessible, often being accessed from a nearby road (Table 1) and provide an accurate representation of the topography of the entirety of Cottle Creek. The length of the creek from site 1 to site 4 is 3.26 kilometres, including the length of Cottle Lake, according to Avenza maps.

Table 1. An overview of all four site locations for the 2023 Cottle Creek survey.

Site #1	
UTM Coordinates	10 U 427937 E, 5452177 N
Access Point	Arrowsmith Rd/Landalt Rd
Site #2	
UTM Coordinates	10 U 428891 E, 5452249 N
Access Point	Rock City Rd
Site #3	
UTM Coordinates	10 U 430233 E, 5451920 N
Access Point	Nottingham Dr
Site #4	
UTM Coordinates	10 U 430524 E, 5451403 N
Access Point	Stephenson Point Rd

2.2 Historical Overview and Land Use

The Cottle Creek watershed is situated amongst urban parks and heavy residential areas, with little for significant commercial or industrial activity. The largest park, Linley Valley Cottle Lake Park, encompasses all Cottle Lake and most of North Cottle Creek. However, the steam still flows through smaller recreational parks including Lost Lake Trail Park and Cottle Creek Park (City of Nanaimo, 2023). Aside from the suburb-style neighborhoods, the estuary for the system is right next to the Department of Fisheries and Oceans Pacific Biological Station.

Regarding the ecosystem, the tributaries lie within the Douglas-fir bio geoclimatic zone and contain a wide diversity of species associated with Garry oak (*Quercus garryana*) and arbutus tree (*Arbutus menziesii*) ecosystems (Ware & Rundel, 2012). With the majority being second-growth forests, the Cottle Creek watershed is also home to Douglas firs (*Pseudotsuga menziesii*), red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and pacific yew (*Taxus brevifolia*) (Hlywka et al., 2022). Additionally, understory vegetation like Salal (*Gaultheria shallon*), evergreen huckleberries (*Vaccinium ovatum*), salmonberry (*Rubus spectabilis*), and invasive Himalayan blackberry (*Rubus armeniacus*) can also be found in the area (Hlywka et al., 2022). A natural population of coastal cutthroat trout (*Oncorhynchus clarkii clarkii)* have historically been found throughout the stream network, though it is not a spawning stream for anadromous pacific salmon due to the unpassable culvert drop into Departure Bay (Ware & Rundel, 2012). It must be stated however, that according to the records on file with the BC Ministry of Environment, cutthroat trout have not been observed in Cottle Creek and reported on since 1994 (MoE, 2023). Though with that said, the pumpkinseed sunfish (*Lepomis gibbosus*) was documented to be in the stream as recently as 2017 (MoE, 2023).

2.3 Potential Environmental Concerns

The concerns associated with Cottle Creek are heavily linked to urbanization, and less so the works of industry or agriculture. Looking at recreational activity in the parks, there is potential for excessive bank erosion and habitat destruction with regular human presence. Along the south side of Cottle Lake, evidence of heavy foot traffic wearing away the landscape and collapsing banks was observed at regular intervals. With many dog owners taking advantage of the park amenities, concern for cultural eutrophication on a small scale due to fecal matter is valid (Hlywka et al., 2022). From what was gathered throughout the project, general littering is surprisingly infrequent with little for garbage in the stream or along the riparian zones.

However, being a residential area, the risk of pollutants entering the stream via run-off that originates from roads and driveways is high (Kampman, 2020). With that being said, there should be special concern of excessive sediment loading at any road crossings or culverts throughout the stream, like at site 1 (Hlywka et al., 2022). The use of any fertilizers on resident's property also may pose an issue, with general nutrient enrichment over time being a possibility (Hlywka et al., 2022). While agriculture operations in general are not a concern as stated, it should be noted that there is a small private farm up the right bank of the creek at site 1, so there is potential for excessive nitrogen and phosphorus inputs with a disruption of the red field ratio (P Morrison, pers. comm., Oct 5, 2023).

2.4 Project Objectives

Determining overall stream health while identifying factors that may be degrading Cottle Creek's strength and productivity were the primary focus of the project, to continue collecting long-term data for Vancouver Island University and the City of Nanaimo. The aim is to draw comparisons to previous stream surveys completed by Vancouver Island University students as far back as 2012 (Ware & Rundel, 2012), to establish trends to assist in guiding the management of Cottle Creek.

Several types of methodologies were utilized, to ensure that a comprehensive evaluation of the stream was completed. General habitat observations, hydrological evaluations, water quality analysis, and the identification of present invertebrates were used to accurately assess Cottle Creek's health. The condition of stream banks and the surrounding riparian areas were also observed to identify Cottle Creek’s level of susceptibility to erosion events that could drastically alter the system.

In order to be able to present the data for future use, all collected data has been professionally compiled, analyzed, and discussed in a context that considers realistic impact mitigation and monitoring efforts. At the end of this report, there are recommendations and suggestions for future studies or management ideas based upon the data collected.

3.0 MATERIALS AND METHODS

3.1 Sampling Stations – Josh Campana

3.3.1 Location Characteristics

All our survey sites along Cottle Creek displayed a healthy variety of flora and fauna with very little presence of litter or human activity near the creek. Survey Site 1 rested in a shallow valley leading into a culvert under Landalt road and was surrounded by numerous trees and a lush riparian area that was met with farmland and roadways on either side. Survey Site 2 was located in Linley Valley at the narrow end of Cottle Lake, just before the lake transitions back into Cottle Creek. This site is surrounded by trails and generally steep slopes, as well as numerous riparian grasses and small brush amidst larger cedar and fir trees.

Survey Site 3 was located near Cottle Creek Park, about 200 meters into a wetland riparian area that saw restoration efforts around 2007. This site had small riprap built up along the bank, and numerous small trees spanning the wetland area intermingled with skunk cabbage and other shrubbery. Finally, Survey Site 4 was located just above Departure Bay, and flowed through a culvert under Stephenson Point Road that ended with a significant drop-off into Departure Bay. The site was bordered on all sides by thick Himalayan blackberry bramble and English ivy, but this was contrasted by large cedar trees and other riparian vegetation.

3.3.2 Sampling Frequency

Site samples were taken in two separate sets of data, with sample collection taking place on October 24th, October 26th, October 31st, November 9th, November 20th, and November 23rd. One set of data collection was scheduled in October before the fall rains, and one set was scheduled in November after the rains to assess the difference in water quality. Water samples were taken for ALS laboratory testing twice, once in October and once in November, for sites 2 and 3. For all sites, following the same pattern of once in October and once in November, additional water samples were collected for water quality testing in lab on campus by VIU students (Table 2). These results were then compared to parameters listed in the British Columbia Approved Water Quality Guidelines.

Hydrology was also accessed by obtaining an average water velocity for each site, on two occasions, with the use of three velocity test replicates. Lastly, invertebrates were also sampled for each site, on two occasions, with the use of three replicates as well (Table 2).

Table 2. Kiera Brown - An overview of the frequency of sampling for each stream parameter.

Site Number	Coordinates	Parameters	Frequency of Sampling	Quantity of Samples Per Visit (Total # of Samples)
1	10 U 427937 E, 5452177 N	Hydrology	Twice	1 (2)
		Water Quality	Twice	1 (2)
		Invertebrates	Twice	3 (6)
2	10 U 428891 E, 5452249 N	Hydrology	Twice	1 (2)
		Water Quality	Twice	1 (2)
		ALS Samples	Twice	1 (2)
		Invertebrates	Twice	3 (6)
3	10 U 430233 E, 5451920 N	Hydrology	Twice	1 (2)
		Water Quality	Twice	1 (2)
		ALS Samples	Twice	1 (2)
		Invertebrates	Twice	3 (6)
4	10 U 430524 E, 5451403 N	Hydrology	Twice	1 (2)
		Water Quality	Twice	1 (2)
		Invertebrates	Twice	3 (6)

3.2 General Habitat and Hydrology – Geoffrey Dell

As stated, the four survey sites were selected based on the sites historically used in previous monitoring projects. However, to provide data that could allow for sites to be easily compared between one another, each site was defined as a 10-metre stretch of stream that was most representative of the area. Within each of these 10-metre stretches, the study area was separated even further into habitat units with defined boundaries. The habitat unit classifications used included glides, riffles, and pools. A glide is a part of the stream that has fast flowing, unbroken water (P Morrison, pers. comm., Oct 19, 2023). A riffle consists of fast flowing water that is typically shallow and is broken up by substrate (P Morrison, pers. comm., Oct 19, 2023). A pool is slow moving and deep water with a near 0% gradient (P Morrison, pers. comm., Oct 19, 2023). Additional classifications include cascades and falls; however, these were not relevant to the survey sites and so they were not utilized (O Hargrove, pers. comm., Sep 24, 2022).

Bankfull channel width (m) and depth (cm) measurements were taken once at each site. The bankfull channel width measurement was taken at the widest point of each 10-metre stretch, with the depth measurements being taken in the same location. A surveyor's tape measure was used to get the width, and a wooden pole was used to get the depths. Each bankfull depth was obtained using the average of three depths across the width of the stream, with the depths taken at set intervals being 1/4, 1/2, and 3/4 of the way across. Additionally, the gradient for each site was also measured using a Suunto model PM-5/360 PC clinometer.

Further measurements were then acquired for each habitat unit, starting with the length of the habitat unit (m). Much like with the bankfull measurements, the wetted width (m) and wetted depths (cm) were obtained at a location most representative of the habitat unit. The wetted depth was also determined by averaging three depths across the wetted width, at intervals equivalent to that of the bankfull depths. If a pool habitat unit was identified, the maximum depth of the pool (cm) was also assessed with the use of the wooden pole. Unlike the bankfull widths and depths, the wetted widths and depths for the habitat units were taken twice throughout the project to allow for a comparison between late October and late November water levels.

Habitat variables like the composition of the substrate, and the amount of instream and canopy cover were also judged by the surveying team. Over each site, the percentage of fines (<2 mm), gravel (2 – 64 mm), cobble (64 – 256 mm), boulders (>256 mm), and bedrock making up the substrate under the water was recorded. In the same way, the percent of the stream featuring factors that qualify as instream cover was also assessed, being items like large woody debris, undercut banks, and aquatic vegetation. Counts for the number of pieces of large woody debris in each site were also done. Lastly, by standing in the stream and determining how much of one's direct line of sight to the sky was obstructed by overhanging vegetation, the percent of canopy cover available for the site was also defined. The overall percentage of each of the substrate types, instream cover, and canopy cover across all four sites was later calculated (using the late October wetted measurements) to provide a stronger understanding of these factors for Cottle Creek in general.

The last hydrological factor calculated by the surveying team pertains to water discharge. In the field, water velocity was measured by dropping a ping-pong ball into a glide (or riffle if a glide was not available) and timing how long it took to travel over a defined 5-metre distance. This test was repeated three times to obtain an average velocity for every site, on two separate occasions with one visit in late October and another in late November. Then, using the wetted widths and depths corresponding to each month, an estimate as to the amount of water being discharged by the stream in those areas was determined.

3.3 Water Quality – Kiera Brown

Water quality was assessed for Cottle Creek through both in-field and laboratory analysis. The parameters measured included dissolved oxygen, temperature, pH, alkalinity, conductivity, turbidity, hardness, nitrates, and reactive phosphate. A total of 10 water samples were collected over the course of the survey period, with one sample being taken from each site on two occasions. For quality control, an additional field blank was taken once for each event, using distilled water into a pre-cleaned container. This field blank would serve as a control to observe any potential contamination found in the sampling process.

In addition to water being collected for in-class laboratory analysis, two samples from each sampling event were sent to ALS Testing Laboratory Company, which provided an analysis of the pH, conductivity, hardness, nitrates, and reactive phosphate. These measurements were then used to compare with the results found in-lab to provide confirmation that lab results were accurately measured. Additional parameters measured by ALS included other nutrients such as ammonia, and heavy metals such as copper, iron, and lead. These parameters allow for a deeper insight into stream health as they would otherwise be inaccessible for study.

Measurements of temperature and dissolved oxygen were taken in-field using a handheld metering device. Water samples for laboratory analysis were taken using pre-labelled plastic bottles with screw caps. Each sample was taken midstream facing towards the flow of water. Each bottle was rinsed three times using stream water, pouring the used water downstream to avoid contamination. After rinsing, the bottles were filled, capped, and placed in a cooler to maintain their temperature as much as possible during transportation. Once out of field, these samples would be transferred to a refrigerator to be preserved until laboratory analysis, with a maximum period of seven days between sampling and analysis.

Laboratory analysis was concluded over two sessions, measuring pH, alkalinity, conductivity, turbidity, hardness, nitrates, and reactive phosphate. Water samples were agitated prior to testing to mix any sediment that may have settled during transportation and storage. All glassware used in this process were rinsed with distilled water prior to use and all equipment was calibrated prior to testing.

PH and conductivity were measured using handheld metering devices. Conductivity was the first and most critical parameters to measure as it impacts testing regarding alkalinity and hardness. Alkalinity was measured by used an acid titration method with a color indicator to signify a change in pH. The amount of acid used to influence the pH of the water sample can then be used as a metric to calculate the amount of resistance to acidification in the water. Hardness was measured with a EDTA (ethylenediaminetetraacetic acid) titration with a metal ion indicator. The amount of EDTA solution added required to trigger the indicator can then be used to calculate the concentration of calcium carbonate in the sample.

Turbidity was assessed with a nephelometer, a machine that casts a light through a sample of water to detect the concentration of scattered light caused by the suspended particles in the sample. Similarly, nitrates and reactive phosphate were measured using spectrophotometers, which act similarly to a nephelometer but cast the light at a different angle. To measure these nutrients, additional solvents were also added to the water samples to separate and suspend the nutrients for the meter to read.

3.4 Riparian Zone – Josh Campana

When examining the riparian zones of our survey sites on Cottle Creek, our site assessments were mainly focused on the depth of riparian vegetation, the type of vegetation, and the land use of the area surrounding the riparian zone. The objective of these tests was to assess the general health and biological makeup of the riparian areas around Cottle Creek and determine whether the surrounding area influenced the general health of the stream system.

Several methods were employed to accurately measure the riparian area at each of the four selected research sites. Firstly, a measurement was taken using a measuring tape from the edge of the waterline in the creek back to the edge of the visible riparian vegetation. This measurement allowed us to determine the extent of the riparian habitat, which can tell us how much of a buffer the stream has from runoff pollutants and other harmful additives. The extent of the riparian vegetation can also tell us how wide the waterflow of the stream reaches, as the presence of riparian specific vegetation will give us a clear boundary.

Another method that was employed when measuring the riparian zone of Cottle Creek was the application of a land use assessment. This method involved a survey by foot around the borders of the creek to determine what the general makeup of the area appeared to be. These areas could be determined as agricultural, residential, park area, or any other general classification of land use. This information can give us a general idea of possible pollutant or nutrient sources located close to the stream area, as well as telling us what hazards we should be on guard for when working in the area.

Finally, we observed the type of vegetation found in the riparian areas along Cottle Creek at each of our four sample sites. The objective of this survey method was to get an idea of the diversity of vegetation, which could tell us whether we have a high density of pollution tolerant species, or a high density of invasive species. This would help us understand if the sample site were near a source of pollution, or possibly near an area that is more susceptible to invasive plants and animals. Overall, this method gives us an understanding of the sensitivity of the ecosystem around our sample sites.

3.5 Stream Invertebrates – Cole Herbert

Invertebrate samples were collected at sites 1, 2, 3, and 4. Each sample was compiled in triplet using a Hess sampler. The area sampled at each location is described as $0.9m^2 \times 3 = 0.27m^2$, and this was done on two separate occasions. The area where the Hess sampler entrapped was irritated by turning up sediment and organic matter and ensuring that organisms clinging to larger rocks contributed to the sample. A different crew member performed each sample in triplicate sets. Sampled organisms were supplemented with 70% ethanol to perform ethical dispatch and ensure preservation. Field samples were then sealed in jars for transport. Upon removal from the field, specimens were carefully analyzed under a compound microscope using a dichotomous key to identify each macroinvertebrate accurately and efficiently into taxonomic groups. Identification conclusions for organisms were discussed amongst students and experts to describe the data set accurately.

Invertebrates were then counted to perform calculations to quantify stream health. This was done by producing indexes of Pollution Tolerance, EPT (Ephemeroptera Trichoptera, Ephemeroptera), EPT to total Ratio, and Predominant Taxon Ratio. These calculations contributed to an overall site assessment rating scored on a scale of 1-4; a score of 1 would represent a stream of poor health, whereas a 4 would be given to streams of good health. The Shannon Wiener Diversity Index was utilized as another tool for comparison. The resulting values were then juxtaposed with other sites, previous collection sampling periods, and records. Invertebrate data was processed at Vancouver Island University and was supervised by Phillip Morrison.

4.0 RESULTS

The monitoring project produced an abundance of data that is invaluable for determining the current health of Cottle Creek, and the threats it faces going forward. The results of the general habitat and hydrology, water quality, riparian zone, and stream invertebrate monitoring is detailed in the following subsections.

4.1 General Habitat and Hydrology – Geoffrey Dell

4.1.1 General Habitat

From the survey areas it has been gathered that the width of Cottle Creek from bank-to-bank is relatively consistent, having a mean bankfull channel width of 7.1 metres. However, this average is skewed due to the width of the stream bed in site 2 being over three times that of any other site (Table 3). In contrast the average bankfull channel depth found in each site does fluctuate, but no single site is a drastic outlier. The mean bankfull channel depth for the entire creek is 69.9 centimetres, so at its fullest, Cottle Creek is still not a particularly deep stream. Site 4 has the capacity for the largest amount of water volume to pass through over a narrow area of all the sites, due to a width to depth ratio of 4.6:1 (Table 3).

Table 3. General habitat variables for the Cottle Creek stream bed.

Habitat Variable	Site 1	Site 2	Site 3	Site 4
Bankfull Channel Width (m)	4.7	14.8	4.4	4.4
Mean Bankfull Channel Depth (m)	0.39	0.83	0.57	0.96
Width **:** Depth Ratio	12.1 : 1	17.8 : 1	7.7 : 1	4.6 : 1
Gradient (%)	1	0	8	6

Regarding the habitat unit classifications, six were identified between the four survey sites, being two glides, three rifles, and one pool. The largest habitat unit was the single pool, taking up the entirety of site 2 and having an area of 134 square metres in late October and an area of 140 square metres in late November. At its deepest point, the pool was found to have a depth of 82 centimetres. The smallest unit was the riffle within site 3, only having an area of 7.8 metres for both assessments, however riffles were still the habitat unit with the second largest area overall when looking at all four sites together (Table 4, 5). The wetted depth was, expectedly, almost always deepest at the centre point of the stream with the average for riffles and glides overall being relatively close, being 16.8 and 28.7 centimetres in October (Table 4), and 27.1 and 34.3 centimetres in November (Table 5). However, site 1 was often significantly shallower than the other sites, regardless of the habitat unit or time of year.

The total area surveyed between all four sites in October was 223.04 square metres, though 60% of this area is composed of the site 2 pool, with 21% being made up of riffles and 19% being made up of glides (Table 4). For November, the total area was 244.63 square metres, with 58% being the pool, and 42% being an even split between riffles and glides (Table 5). The following tables serves as a comprehensive overview of the measurements associated with each individual habitat unit for both October and November. Each box represents a unit (ex/ S1-G1 means site 1, glide 1), with the length to the left, the habitat area to the right, the wetted depths along the top with the mean wetted depth below it, and the wetted width along the bottom. Additional statistics can be found compiled at the bottom of the page.

Table 4. The data set for October habitat unit measurements in Cottle Creek.

L = 4.9 m	12 cm	D = 26 cm	14 cm	$\bar{x}$ = 17.3 cm	W = 2.2 m	**S1-G1**	Area = 10.78 m^2
5.1	2	8	15	$\bar{x}$ = 8.33	2.6	**S1-R1**	Area = 13.26
10.0	34	65	54	$\bar{x}$ = 51	13.4	**S2-P1**	Area = 134.00
2.0	8	21	10	$\bar{x}$ = 13	3.9	**S3-R1**	Area = 7.80
8.0	34	53	33	$\bar{x}$ = 40	3.9	**S3-G1**	Area = 31.20
10.0	28	32	27	$\bar{x}$ = 29	2.6	**S4-R1**	Area = 26.00

Mean Pool L = 10.0 m
Mean Pool W = 13.4 m
Mean Pool D = 51.0 cm
Mean Pool Area = 134.00 m^2
Total Pool Area = 134.00 m^2
Total Site Area = 223.04 m^2

Mean Riffle L = 5.7 m
Mean Riffle W = 3.0 m
Mean Riffle D = 16.8 cm
Mean Riffle Area = 15.69 m^2
Total Riffle Area = 47.06 m^2
Percent Riffles = 21%

Mean Glide L = 6.5 m
Mean Glide W = 3.0 m
Mean Glide D = 28.7 cm
Mean Glide Area = 20.99 m^2
Total Glide Area = 41.98 m^2
Percent Glides = 19%

Table 5. The data set for November habitat unit measurements in Cottle Creek.

L = 4.9 m	11 cm	D = 23 cm $\bar{x}$ = 18 cm W = 3.6 m	20 cm	**S1-G1** Area = 17.64 m^2
5.1	10	30 $\bar{x}$ = 20.67 2.9	22	**S1-R1** Area = 14.79
10.0	41	79 $\bar{x}$ = 60 14.0	60	**S2-P1** Area = 140.00
2.0	22	28 $\bar{x}$ = 26.67 3.9	30	**S3-R1** Area = 7.80
8.0	48	53 $\bar{x}$ = 50.67 4.3	53	**S3-G1** Area = 34.40
10.0	42	42 $\bar{x}$ = 34 3.0	18	**S4-R1** Area = 30.00

Mean Pool L = 10.0 m
Mean Pool W = 14.0 m
Mean Pool D = 60.0 cm
Mean Pool Area = 140.00 m^2
Total Pool Area = 140.00 m^2
Total Site Area = 244.63 m^2

Mean Riffle L = 5.7 m
Mean Riffle W = 3.3 m
Mean Riffle D = 27.1 cm
Mean Riffle Area = 17.53 m^2
Total Riffle Area = 52.59 m^2
Percent Riffles = 21%

Mean Glide L = 6.5 m
Mean Glide W = 4.0 m
Mean Glide D = 34.3 cm
Mean Glide Area = 26.02 m^2
Total Glide Area = 52.04 m^2
Percent Glides = 21%

In addition to site and habitat measurements, the surveyors also determined the general composition of the substrate for each site. This was done for the October site analysis only, so the percentages were calculated using the wetted widths and depths from that time period. However, the substrate composition did not change drastically in a single month's time, and so this data is still an accurate representation of Cottle Creek. On a purely site by site basis, the dominant substrate class was inconsistent. Site 1 was dominated by gravel, site 2 and 3 by fines, and site 4 by cobble, though when assessing the entire survey area, nearly 70% was classified as fines (Table 6). This is largely skewed by site 2, which was almost entirely silt and had little for gravel present and no cobble, boulders, or bedrock (Table 6). Of note, bedrock was only present in site 4, where it took up 1/4 of the site (Table 6). A total substrate composition of 100% would be expected for all sites, however due to potential rounding errors the addition of all 5 substrate percentages results in 105%. To compensate, a percent error of 5% has been added to the table (Table 6).

Table 6. Substrate compositions for all sites based on percent of total area covered.

Substrate Class	Site 1	Site 2	Site 3	Site 4	All Sites
Fines (%)	15	90	50	2	69.8
Gravel (%)	70	10	20	3	17.4
Cobble (%)	13	0	20	65	12.5
Boulders (%)	2	0	10	5	2.4
Bedrock (%)	0	0	0	25	2.9
Percent Error (%)	N/A	N/A	N/A	N/A	± 5

Much like the substrate composition assessment, the amount of instream and canopy cover present in the stream to protect juvenile salmonids and other fish species of interest was reviewed. Examining all four sites, Cottle Creek was found to have instream cover throughout 22% of the stream (Table 7), which was predominantly large wood debris (LWD), willows, overhanging vines, and undercut banks. Site 4 had more instream cover than the other 3 sites combined, possibly correlated to having the deepest water when full as previously mentioned (Table 3), though with that said none of this cover was identified as LWD (Table 7). In fact, large woody debris that is suitable for fish habitat was hardly available throughout the Cottle Creek sites, with the only substantial amount being found in site 1 at 12 pieces (Table 7).

Table 7. Cover available for all sites based on total area covered.

Cover Variable	Site 1	Site 2	Site 3	Site 4	All Sites
Instream Cover (%)	20	20	10	52	22
Canopy Cover (%)	35	60	90	55	62
LWD (# per 10 m)	12	2	0	0	N/A

Comparatively, there was notably more canopy cover available for the stream across all the sites, with a total of 62% of the creek being covered by overhanging vegetation (Table 7). The amount of canopy cover per site varied between the range of 35% and 90%, with site 1 on the lowest end of the spectrum and site 3 on the highest end (Table 7).

4.1.2 Hydrology

When evaluating the velocity of the water, an attempt was made at each site to time the movement of a ping-pong ball across the surface of the water three times. This was done once in late October, and again in late November when water levels rose. Unfortunately for the October assessment of site 2, the water was essentially standing, and the velocity could not be measured. Therefore, the average velocity and discharge for the entire creek was calculated with the omission of site 2, as noted in the table below (Table 8). With October water levels, it was found that site 3 had the highest average velocity and discharge. When averaged out between all sites, the velocity was 0.58 m/s with a discharge of 0.43 m^3 of water per second.

Table 8. Average water velocity and discharge for all sites in the October survey (* does not include site #2).

Habitat Variable	Site 1	Site 2	Site 3	Site 4	All Sites
Average Water Velocity (m/s)	0.41	<0.05	0.70	0.64	0.58*
Average Water Discharge (m^3/s)	0.12	N/A	0.81	0.36	0.43*

When the velocity was measured again in November, the ratio between sites was relatively similar but speeds were faster. Given the results from the October survey, site 1 unexpectedly ended up having a faster flow rate than site 4. The higher water levels also allowed for a proper assessment of the water velocity in site 2, thought as evident in table 9, it is still very slow moving at 0.09 m/s. Additionally, site 3 had the largest water discharge recorded for the 2023 project at 1.41 m^3/s. For all sites, the average velocity and discharge were found to be 0.73 m/s and 0.77 m^3/s, respectively (Table 9).

Table 9. Average water velocity and discharge for all sites in the November survey.

Habitat Variable	Site 1	Site 2	Site 3	Site 4	All Sites
Average Water Velocity (m/s)	0.90	0.09	1.06	0.85	0.73
Average Water Discharge (m^3/s)	0.44	0.57	1.41	0.65	0.77

4.2 Water Quality – Kiera Brown

A total of 14 water samples were analysed through either laboratory analysis or through ALS. These samples included a sample from all four sites on two separate occasions, along with a field blank for each sampling event. As seen in table 10 and 11 below, results varied greatly between sampling events, through were comparable to the analysis done by ALS. Field blanks showed minimal sampling impact. BC regulations for aquatic life water quality are also listed, as found in the water protection and sustainability branch summary report of 2018 and 2021 (Water Protection & Sustainability Branch, 2018; Water Protection & Sustainability Branch, 2021).

Table 10. Water Quality Analysis of Cottle Creek Samples taken on 10/24/2023.

Parameter	Site 1	Site 2	Site 2 ALS	Site 3	Site 3 ALS	Site 4	Site 4 Field Blank	BC Guidelines
Temperature (°C)	-	9.8	-	10	-	-	-	< 12
Dissolved Oxygen (mg/L)	-	73.7	-	81.7	-	-	-	> 8.0
pH	6.9	7.2	7.3	7.2	7.3	7.2	7.8	6.5 - 9.0
Conductivity (µS/cm)	129	172	178	211	223	141	0	-
Turbidity (NTU)	3.61	5.51	-	7.74	-	2.68	0.85	-
Alkalinity (mg/L $CaCO^3$)	5.6	4	-	5.2	-	3.2	<0.4	< 10 - 20
Hardness (mg/L $CaCO^3$)	48.0	56.0	58.7	64.0	75.4	40.0	0.1	-
Nitrates (mg/L)	1.48	0.17	0.205	1.48	1.55	1.83	0.08	< 3.0
Reactive Phosphate (mg/L $PO4^{3-}$)	0.05	0.34	<0.0010	0.40	<0.0010	0.03	0.03	0.005 - 0.015

Site 1 had results that fell within the guidelines for aquatic life in BC. The temperature measured in November was 6.3 degrees Celsius, below the 12 degrees recommended listed for waters with cutthroat trout during the fall. High dissolved oxygen levels were also seen, far exceeding the above 8.0 mg/L minimum recommended despite the decrease between sampling events. pH varied little between events, maintaining the most acidic sample site but remaining within guidelines. Site 1's alkalinity, as well as its nitrate levels, met BC guidelines. Site 1's hardness varied the least between sampling events, being the highest rated in the second sample set by approximately 15 mg/L. All site phosphate levels were seen to exceed the guidelines found, though some of these results may be from detection limitations with in-lab equipment as ALS analysis shows levels far below the recommendations.

Site 2 met all BC guidelines during both sampling events, aside from the reactive phosphate as stated above. Site 2 was one of the two sites additionally analyzed by ALS. These results are like that of the laboratory analysis conducted by students, with variances in the levels of reactive phosphate detected. All other parameters showed a similarity in result by >86%.

Table 11. Water Quality Analysis of Cottle Creek Samples taken on 11/20/2023.

Parameter	Site 1	Site 2	Site 2 ALS	Site 2 Field Blank	Site 3	Site 3 ALS	Site 4	BC Guidelines
Temperature (°C)	6.3	-	-	-	-	-	6.8	< 12
Dissolved Oxygen (mg/L)	54	-	-	-	-	-	60	> 8.0
pH	6.8	7.0	7.0	7.3	7.0	7.3	7.1	6.5 - 9.0
Conductivity (μS/cm)	145	112	120	0	119	126	122	-
Turbidity (NTU)	1.27	1.67	-	0.78	1.11	-	1.21	-
Alkalinity (mg/L $CaCO^3$)	8.0	3.6	-	<0.4	4.4	-	12.0	< 10 - 20
Hardness (mg/L $CaCO^3$)	56.0	32.0	37.2	1.7	36.0	41.1	36.0	-
Nitrates (mg/L)	0.21	0.31	0.30	0.06	0.50	0.43	0.85	< 3.0
Reactive Phosphate (mg/L $PO4^{3-}$)	0.03	0.17	<0.0010	0.02	0.06	<0.0010	0.02	0.005 - 0.015

Site 3 showed the highest levels of temperature and dissolved oxygen during the first sampling event, reading 10 degrees and 81.7 mg/L, respectively. Site 3 additionally saw the highest turbidity and conductivity levels between all sites during the first sampling event. Due to the relative nature of these parameters this likely was a result of stirring up sediment during sampling. Despite the extremity of these parameters, all measurements taken, aside from reactive phosphate, met BC guidelines for aquatic life. Site 3 showed the greatest variance between phosphate levels detected, showing a reading of 0.40 mg/L in lab but showing <0.0010 through ALS analysis. ALS analysis of samples from site 3 showed a comparability of >84% when disregarding reactive phosphate.

Site 4 varied little from measurements from other sample sites across both sampling events. The most notable parameter was alkalinity during the November sampling event. With a rating of 12 mg/L, this falls withing the maximum range for aquatic life, exceeding levels recommended for sensitive habitats. During the October sampling event, site 4 showed the lowest alkalinity level of 3.2 mg/L. Site 4 also showed the highest levels of nitrates, exceeding by a difference of 0.28 mg/L in the October sample and 0.35 mg/L in the November samples. However, these samples still fell below the recommended maximum of 3.0 mg/L. All other parameters, aside from reactive phosphate, met BC guidelines (Water Protection & Sustainability Branch, 2018, 2021).

4.3 Riparian Zone – Josh Campana

Regarding site 1, along Landalt road and adjacent to farmland, the banks along Cottle Creek are still full of vegetation and appear diverse and healthy. A collection of ferns, red cedars, maples, and Oregon grapes were discovered in abundance on both sides of the survey site. It should be noted that a log jam slightly upstream of the survey site caused several smaller side channels to form, but these channels quickly rejoined with the mainstream before entering the culvert directly downstream of the survey site. Riparian vegetation was almost equal on either side of the creek, but both sides were limited due to the presence of farmland and road development (Table 12).

Table 12. Summary of riparian zone variables for site 1.

Riparian Zone Variables	**Site 1**
Land Use	
Left Bank	Public Use
Right Bank	Farm
Vegetation Type	
Left Bank	Fern, Red Cedar, Maple, Oregon Grape
Right Bank	Fern, Red Cedar, Maple, Oregon Grape
Vegetation Depth (m)	
Left Bank	3.7
Right Bank	3.5

For site 2, downstream of Cottle Lake in Linley Valley Park, both sides of the stream were made up of recreational park land. Due to this fact, riparian vegetation was found to be able to spread to greater distances than those recorded at site 1. A collection of willows, ferns, red cedars, maples, Douglas firs, alders, and various grasses were discovered at the site, with the grasses heavily dispersed along the right bank. Riparian vegetation along the left bank climbed steeply uphill and appeared to gradually disperse as it gained elevation (Table 13).

Table 13. Summary of riparian zone variables for site 2.

Riparian Zone Variables	**Site 2**
Land Use	
Left Bank	Recreational Park
Right Bank	Recreational Park
Vegetation Type	
Left Bank	Willows, Ferns, Red Cedar, Maple
Right Bank	Douglas fir, Alder, Grasses
Vegetation Depth (m)	
Left Bank	16.5
Right Bank	12.3

Located directly south of Cottle Creek Park, both sides of the survey site 3 were composed of extensive wetland areas. The right bank had a much deeper riparian area, but it eventually turned into the border of a residential housing complex. A collection of willows, red cedars, coniferous trees, and skunk cabbages were observed. Both sides of the survey site appeared to be flooded, with the right bank being considerably sparser when it came to trees. The right bank riparian area was almost three times as deep as the left bank riparian area (Table 14).

Table 14. Summary of riparian zone variables for site 3.

Riparian Zone Variables	**Site 3**
Land Use	
Left Bank	Residential Park
Right Bank	Road/Housing
Vegetation Type	
Left Bank	Willows, Red Cedar, Coniferous
Right Bank	Willows, Red Cedar, Coniferous, Skunk Cabbage
Vegetation Depth (m)	
Left Bank	8.5
Right Bank	24.5

Being located next to a recreational complex and directly above the ocean, the riparian area of site 4 was fairly limited on both banks. A collection of thick blackberries, maples, red cedar, and English ivy covered both banks. The left side bank quickly transitioned to a small, forested area that appeared to cut off riparian vegetation quite rapidly. It should be noted that this survey site had considerably faster flow than any other survey site and was mainly composed of bedrock (Table 15).

Table 15. Summary of riparian zone variables for site 4.

Riparian Zone Variables	Site 4
Land Use	
Left Bank	Forest
Right Bank	Recreational Complex
Vegetation Type	
Left Bank	Maple, Red Cedar, Blackberry, English Ivy
Right Bank	Maple, Red Cedar, Blackberry, English Ivy
Vegetation Depth (m)	
Left Bank	4.3
Right Bank	3.4

To summarize our riparian zone findings across all sites, the following table can be used as reference (Table 16). Note that the average depth of the riparian zone on the left and right sides of the stream are 12.3 metres and 10.6 metres, respectively.

Table 16. Comparison of land use and vegetation depth between all four sites.

Riparian Zone Variables	Site 1	Site 2	Site 3	Site 4
Land Use				
Left Bank	Residential	Recreational Park	Residential Park	Forest
Right Bank	Residential	Recreational Park	Road/Housing	Recreational Complex
Vegetation Depth (m)				
Left Bank	20	16.5	8.5	4.3
Right Bank	2	12.3	24.5	3.4

4.4 Stream Invertebrates – Cole Herbert

Throughout the stream assessment, 576 invertebrates were collected. 50 invertebrates were pollutant intolerant, 267 were somewhat tolerant, and 259 were tolerant to contaminants. Amphipods contributed the most to the survey, as 245 were accounted for. Site 1 contributed 160 invertebrates: site 2, 109, site 3, 122, and site 4, 185. The sites did not experience seasonal change; the results remained consistent between visits. Sites assessment rating for site 1 was 1.75. Site 2 returned a result of 1.25. Site 3 was described as the healthiest site with a score of 2.125, and site 4 was also marginally ranked as 2, with both visits producing identical scores. Ratings did not fluctuate by more than half a score between visits. Site 1 fluctuated downward from a rating of 2 to 1.5. In contrast, Sites 1 and 2 both trended upward into late autumn. Site 2 fluctuated by 0.5, going from 1 to 1.5. Site 3 fluctuated as well, going from 2 to 2.25. Site 4, however, remained consistent at 2 for both sampling periods.

When analyzing the data set by category of tolerance, results for site number 1 displayed 6 intolerants, 3 were counted for site 2, 13 were found in site 3, and the most significant amount found was site 4 with a lump sum of 28. Somewhat tolerant species were most abundant in the data set. Site 1 had 18. Site 2 had 78, with the majority belonging to the amphipod taxon. Where amphipods made up the entire set, the greatest number of category 2 invertebrates were collected in site 4 with 140. Site 4 made up 52% of the data set for inverts somewhat tolerant to pollutants. Concerning pollutant-susceptible species, the samples from site one had the most significant amount, with 136. In contrast, the site contained 28, site 3, 78, and finally, the least pollution in the tolerant category, site 4 with 17.

Results in totality signified that conditions were marginal, as the site-to-site assessment ratings showed. The stream boasts site assessment scores ranging from 1 to 2.25. The outlier (site 3), located at the discharge outlet of Cottle Lake (site 2), suggested poor health; it could be that these less-than-ideal conditions are naturally occurring due to hydrological factors. All four sites had invertebrates that were intolerant to pollutants, leading to the belief that high concentrations of contaminants were absent from the stream during the collection. However, this does not support the conclusion that pollutants are not present to a degree. Invertebrates that contributed to the data sampler the greatest were amphipods and midge fly larvae, both of which have a degree of tolerance towards pollutants and were present at sites every sampled site.

5.0 DISCUSSION

5.1 General Habitat and Hydrology – Geoffrey Dell

5.1.1 General Habitat and Salmonid Standards

Physical features of a stream, such as channel width and depths, habitat unit types, substrate composition, and available cover all drastically influence the movement and quality of the water. As was previously established, coastal cutthroat trout are present in the Cottle Creek watershed (Ware & Rundel, 2012). When talking about stream health, referring back to preferred standards for salmonids can provide a strong baseline for determining if the hydrological factors of a waterbody are optimal for an ecosystem, considering salmonids role as indicator species. Stream salmonid requirements set out by Johnston and Slaney (1996) were reviewed, for the purposes of comparing their standards to the hydrological data collected from Cottle Creek.

Evaluating the bankfull channel width and depth measurements taken, we will focus on the ratio between the two factors for each site. For good quality habitat, salmonid populations will have the most success when the width to depth ratio is <10:1 (Johnston and Slaney, 1996). Unfortunately, site 1 and 2 both exceed this ratio, with site 1 being too shallow and site 2 being excessively wide (Table 3). However, when looking at the sites further downstream, the ratios are 7.7:1 and 4.6:1 for sites 3 and 4, respectively. With this feature, while cutthroat trout can be resilient to less than ideal conditions, they may thrive better in the areas of the creek closer to Departure Bay. Gradient is also an important stream attribute to consider, as it will directly affect the velocity and composition of the substrate (O Hargrove, pers. comm., Sep 24, 2022). Salmonids tend to prefer gradients <5%, especially on spawning grounds (Johnston and Slaney, 1996), though they are able to bypass areas up to 30% when travelling (O Hargrove, pers. comm., Sep 24, 2022). Cottle Creek appears to be relatively level throughout, and our site assessments reflect this (Table 3), so in this regard the stream is suitable for fish species of interest.

With that being said, salmonids often require pools for cover and cooler temperatures, but with Cottle Creek these seem to be rare throughout the watershed, instead being concentrated to the entirety of Cottle Lake and immediately downstream from the lake. Johnston and Slaney (1996) state that >55% of the stream being pools with a frequency of three every 100 metres is optimal. Of our survey sites, the only pool identified was the entirety of site 2, which was essentially an extension of Cottle Lake. This has skewed the data in the sense that 60% of the survey wetted area was made up of pools in October, and 58% in November, however we do not believe this is an accurate representation of the entirety of Cottle Creek as pools were not identified anywhere else, even in areas outside of the survey sites, so the pool frequency requirement was not met. The cutthroat trout likely resort to Cottle Lake for pool habitat, but the lack of pools may prevent them from spreading out further throughout the system.

Another area of concern is the quality of the substrate across nearly all the survey sites. Trout prefer gravel for spawning, 10 to 75 mm in diameter (O Hargrove, pers. comm., Sep 24, 2022), with less than 10% of fines present in the substrate as fines can clog up gills or prevent adequate oxygenation of eggs (Johnston and Slaney, 1996). Site 1 shows the best in this category, having 70% gravel, though its composition of 15% fines is only considered fair (Table 6). Sites 2 and 3 have extremely poor substrate for cutthroat trout, due to the high concentration of fines in both, with site 2 being nearly unusable especially as it is overall unproductive. The 65% composition of cobble in site 3 is less detrimental to trout and may in fact be ideal if the cobble is predominantly smaller pieces (Table 6). Adult cutthroat trout have also proven to like being around boulders for cover (O Hargrove, pers. comm., Sep 24, 2022), but the amount recorded in Cottle Creek is insignificant. Cottle Creek needs more gravel and less fines to become increasingly productive for fish species.

The amount of instream cover present in the stream ranged from 10% to 52%, depending on the site, with an average of 22% for the entire creek (Table 7). This is quite positive, as according to Johnson and Slaney (1996), having more than 20% instream cover is good. Site 3 was the only area to not meet this standard, however, at only 10% instream cover this is still considered to be fair (Johnson and Slaney, 1996). However, the addition of more large woody debris (LWD) to contribute to some of the cover available is still advisable, as LWD in particular is desirable by fish but was lacking outside of site 1. The canopy cover present in Cottle Creek fluctuated more between sites than instream cover did, but an average of 62% was still obtained for the stream (Table 7). From what has been visually identified, this is also believed to be an appropriate representation of the stream. By this metric, canopy cover in Cottle Creek falls between 40% and 70%, so it can be classified as fair (Johnson and Slaney, 1996). An increase in canopy cover would be beneficial but should be far from the biggest priority regarding the management of Cottle Creek.

One considerable issue with Cottle Creek that needs to be addressed is the large culvert found at site 4, which is also the barrier for pacific salmon to enter the watershed from the ocean. Perhaps one of the most common fish passage problems with culverts is the formation of a drop-off at the downstream end, which is the case for Cottle Creek (Kerr Wood Leidal Associates et al., 1980). From what has been assessed, the drop is less so due to erosion and more so due to poor installation, as the culvert should be in a spot where the gradient of the creek is near 0% and the velocity is uniform, but it was likely installed in a spot where the creek originally had a substantial gradient (Kerr Wood Leidal Associates et al., 1980). Additionally, while there is a second culvert in place higher up to help regulate a wider range of flow, the lowest is supposed to be in place to ensure fish passage during periods of low discharge, which it is not doing (Kerr Wood Leidal Associates et al., 1980). To correct this issue, the pool on the downstream end of the culvert could potentially be back flooded, by placing weirs downstream composed of large quarry rocks or gabions (Kerr Wood Leidal Associates et al., 1980).

5.1.2 Hydrology

Monitoring the change in velocity of a stream over time is critical, as velocity directly influences the migration of salmonids as well as their spawning tendencies, egg development, and juvenile rearing (P Morrison, pers. comm., Oct 19, 2023). The structure of the stream channel and how it changes overtime is also heavily impacted by the speed and amount of water being discharged (P Morrison, pers. comm., Oct 19, 2023). Between the October and the November survey, there was an increase in water velocity across all the Cottle Creek sites. On average, the velocity increased by 0.15 m/s, though if site 2 is excluded due to being an outlier with essentially standing water, the velocity increased by 0.36 m/s. This increase also corresponded with an increase in wetted width, depths, and water discharge, with site 3 and 4 nearly doubling the volume of water being displaced (Table 8, 9). With data that originally originates from Environment and Climate Change Canada, in Nanaimo it has been recorded that in October 2023 there was 230.7 mm of rainfall, while in November 2023 there was only 133.1 mm (Weather Stats, 2023). The increase in the velocity of Cottle Creek despite the decrease in overall rainfall between each month is surprising, however it must also be noted that the second round of velocity testing was done in an active downpour which would directly affect the results we acquired. Another possible reason the velocity increased, at least for all the sites downstream of Cottle Creek, is that Cottle Lake collected more water and filled to a point where it began discharging more water into the stream. Regardless, dissolved oxygen (DO) levels tend to correlate to hydrological factors like velocity (Kampman et al., 2020), and the recorded DO levels for fall 2023 exceed that of the recommended guidelines. In this aspect, the data collected on water volume and speed is not of significant concern.

Cottle Creek survey groups over the past 3 years have generally neglected to go quite as in-depth with their assessments of habitat features, regarding items like substrate composition and instream cover, however there is more data available for establishing velocity trends. In 2021 and 2022 the reported velocities for all four sites were lower than what was measured in 2023, regardless of the time of year (Beaupré-Walsh et al., 2021; Hlywka et al., 2022). The only exception to this is site 2, which was still very slow moving for 2021 and 2022 but not quite to the same extent observed this year (Beaupré-Walsh et al., 2021; Hlywka et al., 2022). The fastest velocity on record between 2021, 2022, and 2023 is 1.46 m/s, which was obtained in November of 2021 (Beaupré-Walsh et al., 2021), though this does come close to the 1.06 m/s recorded within the same time frame this year (Table 9). There are no notable outliers in all three sets of data regarding velocity, so it would appear water displacement is staying stable.

5.2 Water Quality – Kiera Brown

The overall water quality of Cottle Creek shows that all parameters meet the recommended guidelines regarding water quality for aquatic life in BC. Although the recommended reactive phosphate levels found in the samples analyzed in lab exceeded the 0.005 - 0.015 mg/L maximum, the ALS analyses suggest that these levels are lower than what was detected in lab. (Water Protection & Sustainability Branch, 2018; Water Protection &

Sustainability Branch, 2021). Increases in nutrient level such as nitrates and phosphates are likely a result of the urban surroundings, with influence from nearby residential areas and the farm located on the border of site 1. This is further suggested by the gradual increase in nitrates found moving from upstream to downstream.

5.2.1 Redfield Ratio

When looking at the Redfield ratio of Cottle Creek, both sampling events showed the waters varying 52% - 383% from the ideal ratio of 16:1 nitrate to phosphate. As seen in figure 1 below, majority of reading were nitrogen limited. This is likely due to the exceeding measurements of phosphate found at most sites. When comparing to the previous survey conducted in 2022, the average ratio was very similar, with the only variance coming from site 4. Both the October and November sample saw increased nitrate levels in site 4, resulting in a ratio that is phosphorous limited. The only other phosphate-limited ratio we got was during the October sampling in site 1. The difference between sampling events in site 1 is a result of the increased flow due to the rainfall that occurred in-between events.

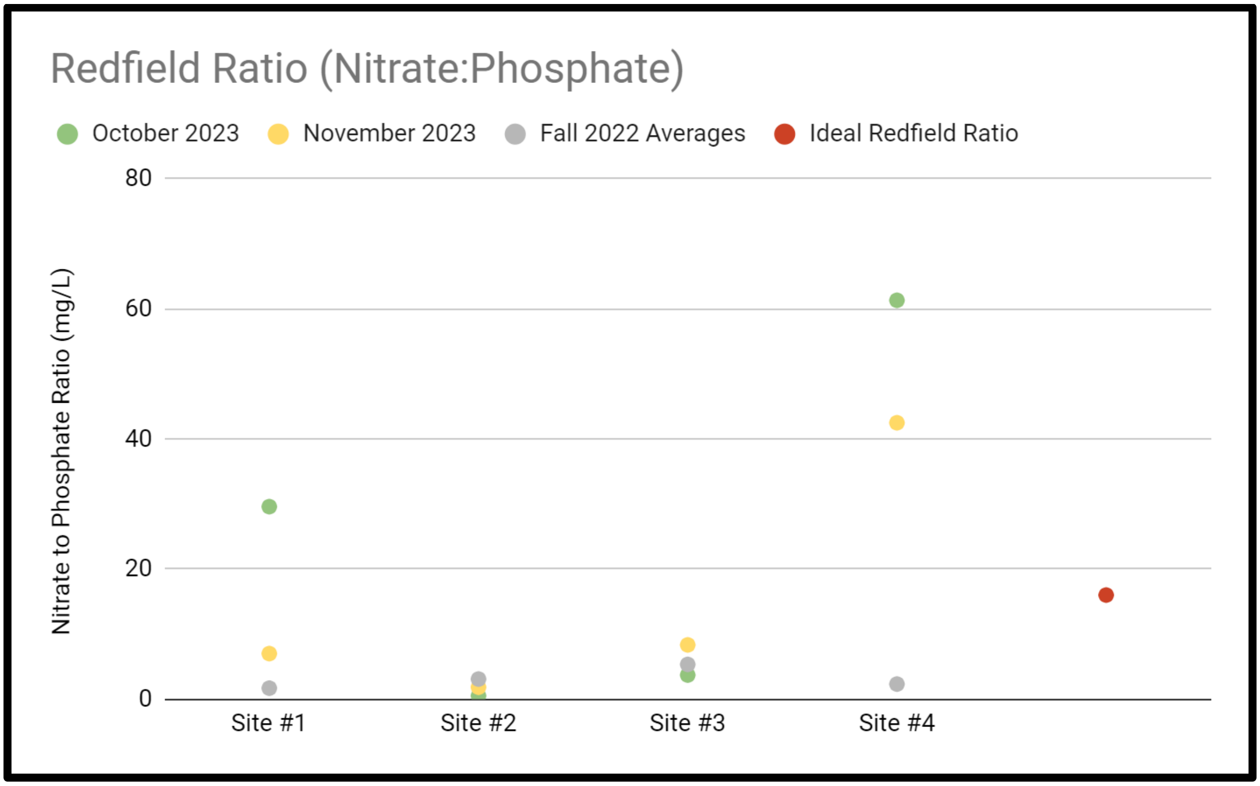

Figure 1. Redfield Ratio comparison between 2023 sites and 2022 average.

The variance in nutrient levels to the Redfield ratio suggests that the stream is not efficient in its use of nutrients and could indicate an imbalance in the abundance and diversity of organisms in the stream. This can result in algae blooms, depleted dissolved oxygen, and nutrient imbalances in the sediment resulting in invertebrate impacts. However, the shifts between samples suggest an acute variability that may not indicate such an excessive risk. The ALS readings also suggest that phosphorous levels are lower than what was measured. Additionally, the lack of excessive algae witnessed, and significant dissolved oxygen readings found at all sites suggest that the stream is not undergoing eutrophication (Hecky et al., 1993).

5.2.2 Previous Studies

When comparing to previous years, the most notable trend comes from the decrease in rainfall resulting in a spike in multiple parameters during the 2022 survey. As seen between the

October and November sampling events, increased rainfall and flow can greatly impact measurements and the overall interpretation regarding the health of the stream. As seen in figure 2 below, the alkalinity readings found in 2023 were more comparable to that of 2021. This is likely due to the comparable amount of rainfall between those years which additionally saw a decrease in suspended sediments within the stream (Beaupré-Walsh et al., 2021; Hlywka et al., 2022).

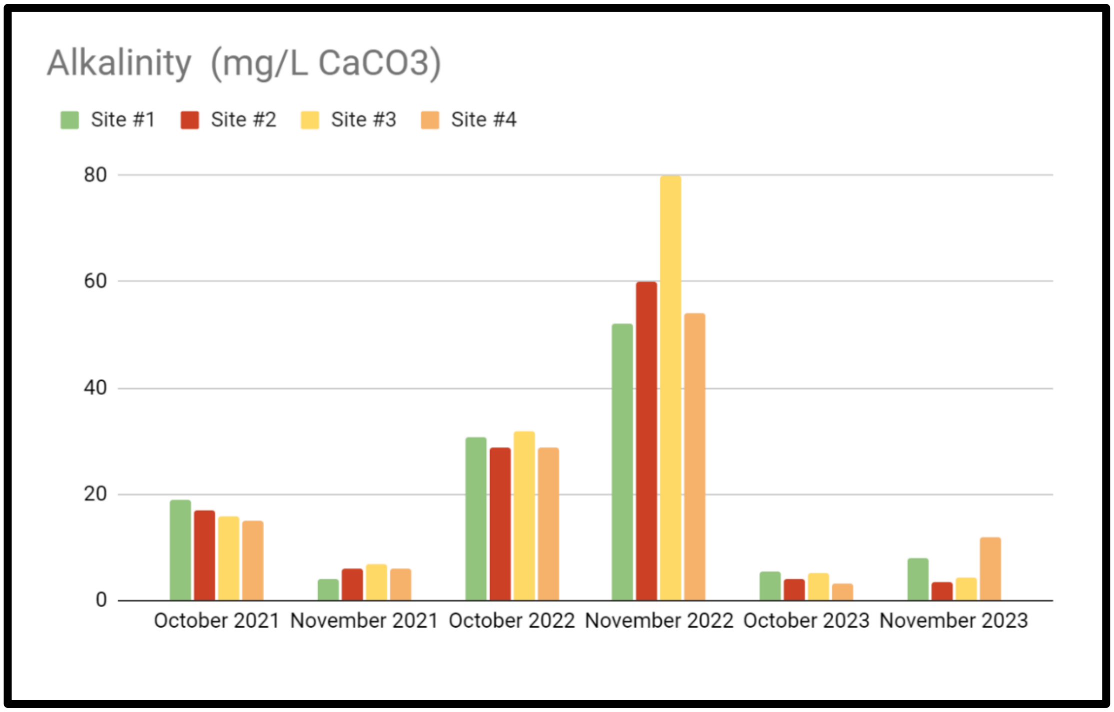

Figure 2. Alkalinity found at all sites between 2021-2023.

Rainfall affected multiple parameters, and this can be seen when looking at comparisons between the October and November sample as well as comparing 2023 to 2022. All parameters listed decrease with increased rainfall between October and November and were significantly lower when compared to 2022 averages. This is likely due to increased flow and dilution of the stream caused by the rainfall. This decreases sediments and nutrients present in the stream which in turn decreases conductivity and hardness. This may impact overall stream productivity due to reduced nutrients; however, the lowered measurements still fell within the BC Guidelines.

5.3 Riparian Zone – Josh Campana

The riparian zone data tells us that our riparian areas are relatively diverse and healthy across all four of our sample site locations. This selection of flora and fauna was found to be consistent with those species discovered in past reports, which suggests that this ecosystem has been stable for a considerable length of time along the stream boundary. We did notice some parks restoration work occurring along the access trail to site two near Cottle Creek while conducting our surveys, but they did not disturb the riparian area and the works did not appear to be increasing turbidity or introducing any chemicals that would have swayed our sample results for this area.

In terms of invasive species, the only vegetation we identified that was not native to the area was patches of English Ivy located at site 4 (Kampman et al, 2020). This species did not appear to be taking over the ecosystem, as the presence of thick blackberry brambles appeared to be limiting its spread around the immediate area. The land use on the edges of the riparian zone did not appear to have much of an effect on the depth of the riparian zone but may have had an effect of the types of vegetation found at each of the survey sites. Our results showed that the riparian areas found closer to residential areas or roads tended to show vegetation that grew quicker. These sites also tended to have smaller trees in general, as opposed to the sites located further from consistent human traffic. It should also be noted, however, that the sites with the greatest velocity and discharge were those located closer to roadways. This fact could be attributed to the presence of culverts in the stream.

It should also be noted that the thickness of the riparian areas did not appear to have any drastic effect on the invertebrate count or hydrology results at each of the testing sites, despite the varying depths of vegetation. The riparian zones did appear to retain sediments and stabilize the banks in sites 1 and 4, but site 2 and 3 each had their own challenges in this regard. Site two's width and low flow rate led to a buildup of sediment despite having well developed riparian zones, and site three's previous restoration efforts included riprap along the banks, which did not allow us to gauge how well the riparian area itself was retaining sediments. Another apparent effect of the riparian zones at our sample sites included a noticeably lack of litter in the stream area. This was a pleasant surprise, as most of our sample areas are located near residential or recreational areas that have a decently high rate of human traffic.

To summarize our findings on the riparian areas bordering our survey sites along Cottle Creek, we determined that the vegetation density and diversity suggested a healthy and developing ecosystem that did not show many signs of invasive species or accumulated pollutants. We also determined that the recorded depth of the riparian vegetation suggested that Cottle Creek had a substantial buffer against surface runoff from the farmland and residential areas along the stream edges at sample sites 1 and 4, as well as any roads or recreational areas found at the other sites.

5.4 Stream Invertebrates – Cole Herbert

Macroinvertebrates can reveal plenty of helpful information about a stream. They function as key indicators and essential contributors to the stream food web. These tiny and often forgotten aquatic organisms also support recreation fisheries and surrounding ecosystems. (Luell, 2020). They do this by converting nutrients from organic matter to a form that fish, and other organisms can consume. In addition, their variable sensitivity towards pollutants is a valuable analysis tool when conducting a stream health analysis.

All 3 categories of invertebrates were present at each site. Site 4, however, was the richest in pollution-intolerant species and had the strongest EPT ratio. 19 mayfly larvae and 9 stoneflies were captured here. In the context of stream health, this indicates that although site 4 is at the tail end of the system and is exposed to all contaminants in the system it is still able to sustain organisms of sensitivity to pollutants. An explanation for this may be that pollutants present further up the watershed were diluted to a point in which they do not affect the invertebrate community. It is also possible that habitat conditions are less appealing at sites 1 and 2. During high-flow events, invertebrates tend to drift downstream, which could explain the presence at site 4. This hypothesis is supported by the increase in invertebrates of all categories. Invertebrates that are somewhat tolerant were also present throughout the stream. This category was dominated by amphipods, the most of which were collected within site 4. There is no consistency through this category as populations increase from site 1 to 2 and then decrease from 2 to 3. The diversity seen in this category expressed limited; Dragonfly and alderfly contributed 1 and 8, respectively. The entire data set is dominated by category 2 somewhat tolerant species followed by pollution-tolerant organisms such as aquatic worms. The overview of the data would suggest that the system has been exposed to pollutants from surrounding developments and human activity.

Table 17. Invertebrate site assessment ratings for the 2023 survey.

Location	October	November	Average
Site 1	2	1.5	1.75
Site 2	1	1.5	1.25
Site 3	2	2.25	2.125
Site 4	2	2	2

Results in totality signified that conditions were marginal, as site-to-site assessment ratings in the table above depict. The stream boasts site assessment scores ranging from 1 to 2.25. The outlier (site 3), located at the discharge outlet of Cottle Lake (site 2), suggested poor health; it could be that these less-than-ideal conditions are naturally occurring due to hydrological factors. All four sites had invertebrates that were intolerant to pollutants, leading to the belief that high concentrations of contaminants were absent from the stream during the collection. However, this does not support the conclusion that contaminants are not present to a degree. Invertebrates that contributed to the data sampler the greatest were amphipods and midge fly larvae, both of which have a degree of tolerance towards pollutants and were present at sites every sampled site.

Table 18. Invertebrate site assessment rating averages for 2021, 2022, and 2023.

Location	2021	2022	2023
Site 1	1.5	3.5	1.75
Site 2*	-	3.375	1.25
Site 3	1.25	3.25	1.125
Site 4	1.25	3.25	2

If stream conditions were looked at objectively solely by utilizing invertebrate analysis, it would be concluded that stream health had a rapid decline. The results produced from site 2 showed a decrease rating of 2.125. This is a significant drop in condition from the study in 2022. (Beaupré-Walsh et al., 2021; Hlywka et al., 2022) Several factors could influence such a fluctuation. Water quality may have diminished over the years. In addition to this, an error was made at site 2. Samples of all types, including invertebrates, were taken too close to Cottle Lake. The reason there is such disparity in results at this specific site is likely a hydrological factor, as the composition of the stream is much different at the location sampled in 2023 versus 2022. (Beaupré-Walsh et al., 2021; Hlywka et al., 2022) It is possible that the results would be improved if samples were taken a mere 30-50 meters downstream. Results from 2021, however, resemble those from this analysis. (Beaupré-Walsh et al., 2021) The stream condition improved slightly at sites 1 and 2 while experiencing a minuscule decrease at site 3. Unfortunately, the location of site 2 was not consistent with the 2021 survey, so cross-examination could not be performed. It is also important to realize that invertebrate analysis is only a portion of the analysis and could be susceptible to environmental changes. (Beaupré-Walsh et al., 2021) The timing of samples may also skew the data as hatches of these organisms are difficult to predict. Looking at the results objectively, there was a decline in stream health from 2022 to 2023, which decreased by 7.125 between all four sites.

Table 19. Invertebrate site diversity index scores for the 2023 survey.

Location	Diversity Index Score
Site 1	1.41
Site 2	0.89
Site 3	1.35
Site 4	1.10

Diversity plays a vital role in the functionality of a stream system. A diverse system is best represented by site 1, as Shannon Wiener Calculations received a diversity index score of

1.41. Diversity amongst stream invertebrates is essential for maintaining the foundation of the stream even when conditions are altered. The figure above also displays the lack of diversity present within site 2. The hydrological composition of this site may be the primary factor producing a Diversity Index Score of 0.89. This data site was heavily made up of amphipods. Well, over half of the organisms in the data set at this specific sight were from that particular species. There is a defense of 0.63 between the lowest and highest scores, sights 1 and 2. Since scores increase further downstream, it is less likely to be an issue caused by contamination rather than the site's hydrology, as flow is relatively stagnant.

6.0 RECOMMENDATIONS FOR FUTURE STUDIES – Josh Campana

Future recommendations can be made for any other groups attempting to continue the Cottle Creek monitoring project. Firstly, it is highly recommended that studies of this stream system continue for the foreseeable future to ensure the collection of long-term data in order to give researchers a better understanding of how the creek changes over time when exposed to different variables. It is also recommended that most survey sites remain in the locations that were previously recorded by past study groups to ensure that the data collected from the stream system is as consistent as possible to previous reports.

New additions to field data collection could also be included as part of the Cottle Creek project. It would be recommended for future study groups to conduct a fecal coliform analysis, especially around the area of survey site 3. This is due to the fact that dog feces are expected to accumulate in urban park areas, and excessive runoff from these areas could spike nitrogen levels in the survey samples near this site. Other surveys of the stream system could include minnow trapping to determine the presence of fish species throughout the system to determine habitat requirements and possible restoration efforts that could take place in future years.

Continuing this point, an argument could be made to install a fish ladder at the end of survey site 4. The reasoning for this would be to allow salmonids to access the stream and Cottle Lake as possible spawning habitats. Currently the stream system ends in a culvert with a considerable drop-off, preventing any fish species from migrating upstream.

Finally, our team advises the relocation of site 2. This site sits at the narrow end of Cottle Lake and provides very little in terms of data for both current and past studies. The size and substrate composition are also very unique to that site, not being an appropriate representation of Cottle Creek as a whole. As was mentioned in the discussion, the strong contrast of site 2 to all the others tends to skew significant portions of the overall hydrological data for the project, for example the extrapolation that nearly 70% of the substrate in the creek is composed of fines (Table 6). It is recommended that the survey site be relocated further downstream from Cottle Lake, possibly all the way to the Linley Road access point. In 2020, Kampman et al. actually established a site there, though further studies of it were abandoned for the following years. Alternatively, and perhaps preferred, site 2 could also be moved to North Cottle Creek where it was originally located for the first three years of the project. It was not until 2015 when Dennill et al. moved the location to the eastern side of Cottle Lake, though from what has been gathered from previous reports, the hydrology in this area has changed dramatically and is not even remotely comparable to how it looked in 2015.

7.0 REFERENCES

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APPENDIX 1: Photos

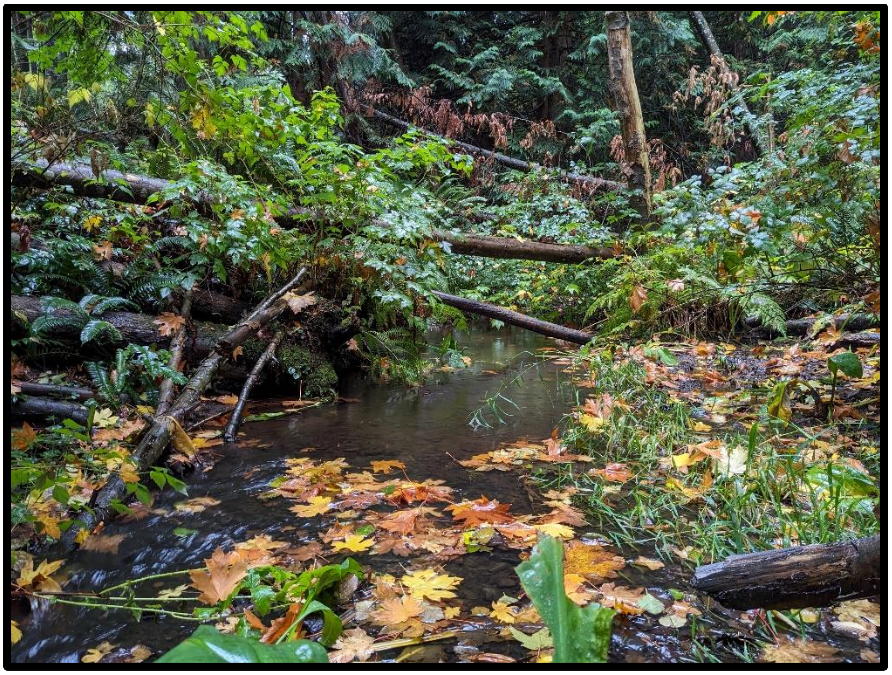


Figure 3. Site 1, looking upstream (Taken on October 10, 2023).

Figure 4. Site 1, looking downstream (Taken on October 10, 2023).

Figure 5. A wide-angle view of site 1, with Josh Campana and Cole Herbert measuring out the site (Taken on October 26, 2023).

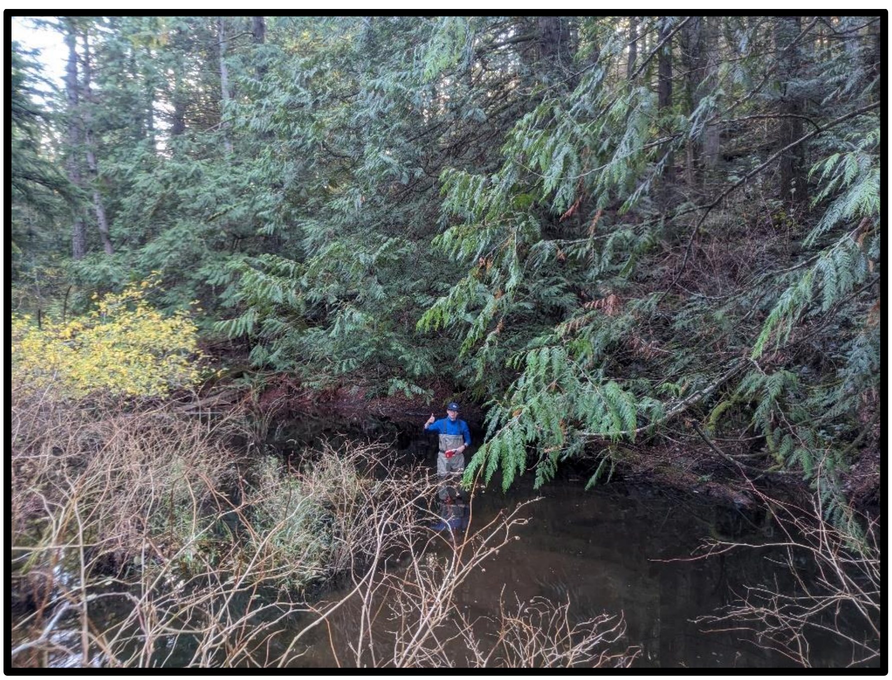


Figure 6. Site 2, with Cole Herbert preparing to measure out the wetted width (Taken on October 31, 2023).

Figure 7. Site 3, looking upstream (Taken on October 12, 2023).

Figure 8. Site 4, looking downstream. Note the two culverts in place to control varying levels of flow (Taken on October 10, 2023).

Figure 9. The downstream end of the culvert from site 4, with a drop-off that prevents pacific salmon from entering into Cottle Creek (Taken on October 11, 2023).

Figure 10. Cole Herbet using a Hess sampler to collect some invertebrates in site 3 (Taken on November 23, 2023).

Figure 11. Josh Campana using a Hess sampler to collect invertebrates in site 4 (Taken on November 9, 2023).

Figure 12. Josh Campana and Kiera Brown sorting through invertebrates in the field at site 1 (Taken on November 9, 2023).

APPENDIX 2: Maps

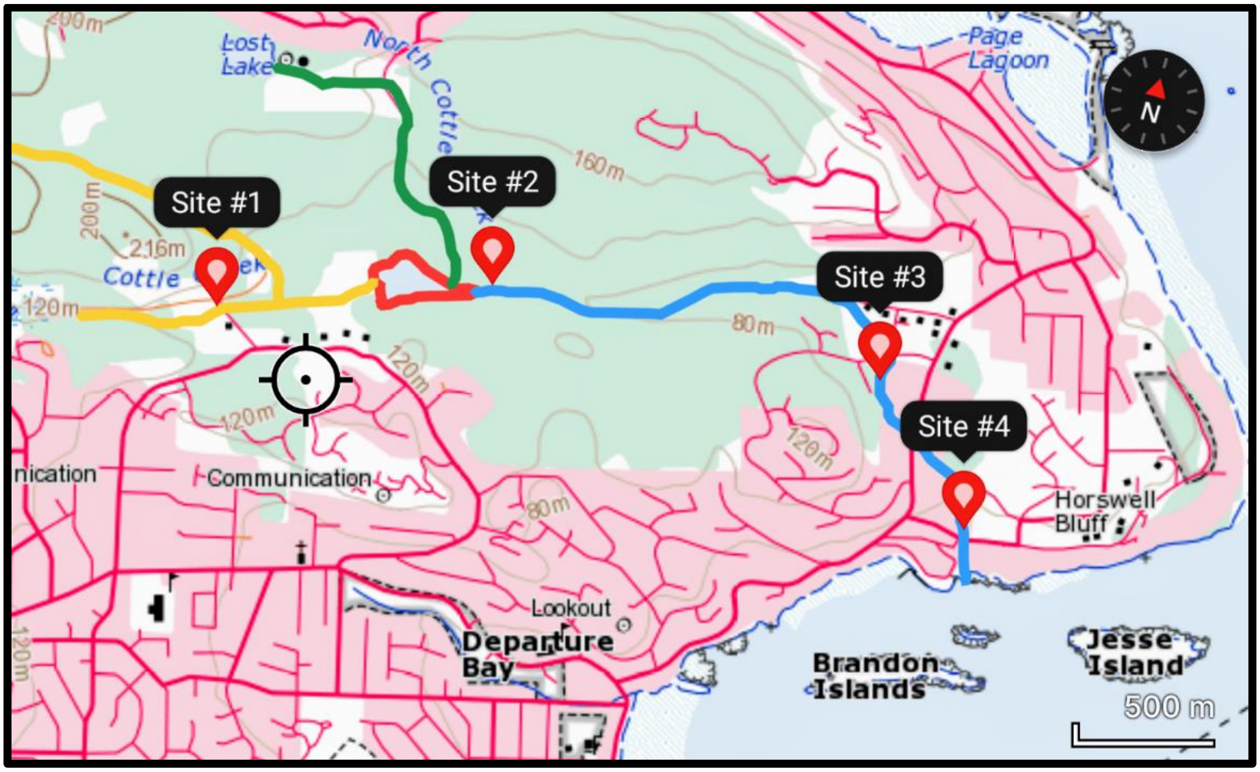


Figure 13. Geoffrey Dell - Avenza map of the Cottle Creek watershed in Nanaimo, BC. Yellow signifies Upper Cottle Creek, green signifies North Cottle Creek, red signifies Cottle Lake, and blue signifies Lower Cottle Creek.

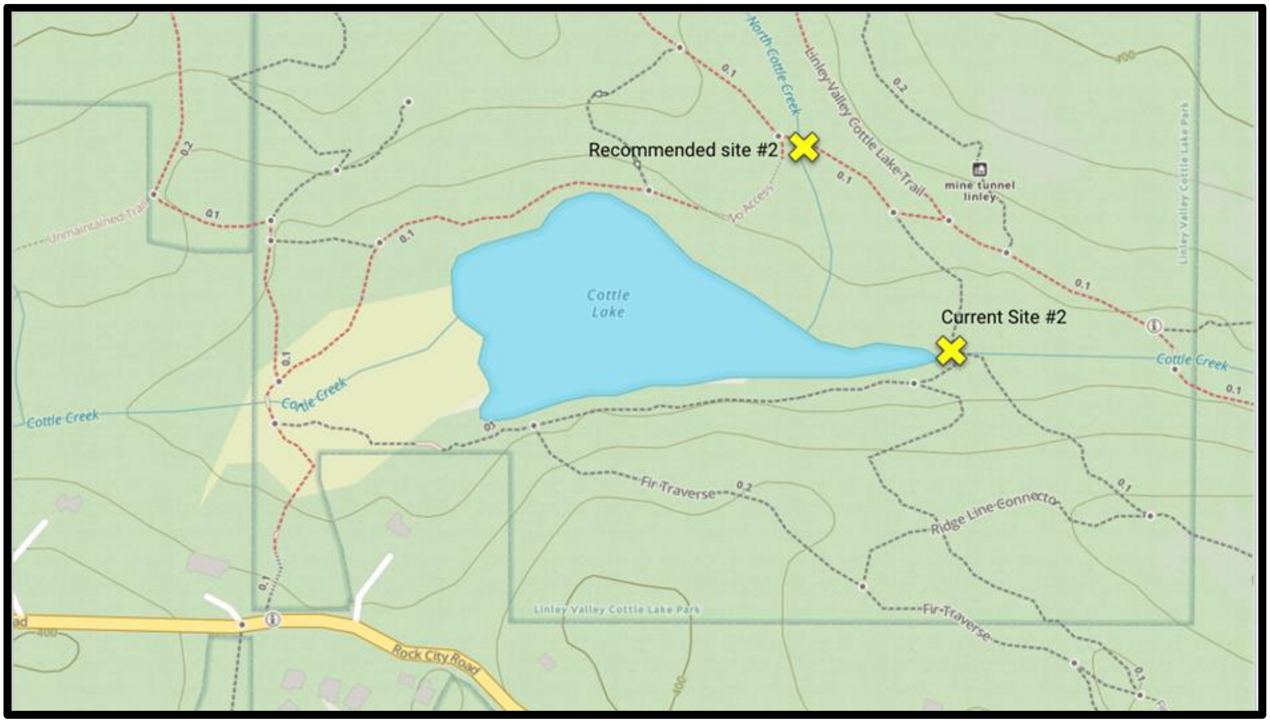


Figure 14. Cole Herbert - A map of Cottle Lake and the surrounding area, showing the location of site 2 for the 2023 survey and a recommended new location for future studies.

APPENDIX 3: Field Data Cards

RMOT 306 – Stream Survey **Page 1 of 2**

Site Card

Stream Name	Cottle Creek
Survey Dates	Oct 24th, 2023 to Dec 3rd, 2023
Field Crew	Dell, Brown, Campany, Herbert

Site No.	1
Site Length	10 m
Site UTM	10U 427937E 5452177N

Gradient (%)	1, [illegible] %
LWD	12

Bankfull Width (m)	4.7m
Bankfull Depth (cm) L(0.25, 0.5, 0.75)R	46/42/30

Water Velocity:	A)	B)
Distance (m)	5m	5m
Time (s) (3 Floats)	12.42, 12.23, 12.35	5.48, 5.82, 5.40
Glide Width (m)	2.25m	3.6m
Glide Depth (cm) Average	[illegible] cm 17.3	18 cm

Water Quality:	
DO (mg/l)	6.8
Temp (°C)	6.3
Cond. (µS/cm)	LAB
pH	LAB
Turbidity (NTU)	LAB

Riparian:	**Left**
Land Use	Public use
Vegetation Type	Fern, red cedar, maple, oregon grape
Vegetation Depth (m)	3.7m
Riparian:	**Right**
Land Use	Farm
Vegetation Type	Fern, red cedar, maple, oregon grape
Vegetation Depth (m)	3.5m

Figure 15. Geoffrey Dell - Site 1 field data card (1/2).

RMOT 306 – Stream Survey

Site Card

B)		A)
1	Habitat Unit No.	1
Glide	HU Type	Glide
4.9m	HU Length	4.9m
3.6m	HU Wetted Width (m)	2.2m
11/23/20	HU Wetted Depth (cm) L(0.25, 0.5, 0.75)R	12/26/14
N/A	Max. Pool Depth (cm)	N/A

Site Substrate	Composition (%)
Fines (<2 mm)	15%
Gravel (2-64 mm)	70%
Cobble (64-256 mm)	13%
Boulders (>256 mm)	2%
Bedrock (slab)	0%

B)		A)
~~2~~ 1	Habitat Unit No.	~~2~~ 1
Riffle	HU Type	~~[illegible]~~ Riffle
5.1m	HU Length	5.1m
2.9m	HU Wetted Width (m)	2.6m
10/30/22	HU Wetted Depth (cm) L(0.25, 0.5, 0.75)R	2/8/15
N/A	Max. Pool Depth (cm)	N/A

Instream Cover:	
Total %	20%
Composition	LWD, ISV, OV

Canopy Cover:	
Total %	35%

Additional Comments:

→Litter is Limited.

Figure 16. Geoffrey Dell - Site 1 field data card (2/2).

RMOT 306 – Stream Survey **Page 1 of 2**

Site Card

Stream Name	Cottle Creek
Survey Dates	Oct 24th, 2023 to Dec 3rd, 2023
Field Crew	Dell, Brown, Campany, Herbert

Site No.	2
Site Length	10m
Site UTM	10U 428891E 5452249 N

Gradient (%)	0 %
LWD	2

	A)	B)
Water Velocity:	<0.1 m/s	
Distance (m)	5 m	5m
Time (s) (3 Floats)	—	52.11, [illegible] 54.27s
Glide Width (m)	—	14m
Glide Depth (cm)	—	60cm

Bankfull Width (m)	14.8m
Bankfull Depth (cm) L(0.25, 0.5, 0.75)R	63/90/97

Water Quality:	
DO (mg/l)	8.36
Temp (°C)	9.8
Cond. (µS/cm)	LAB
pH	LAB
Turbidity (NTU)	LAB

Riparian:	**Left**
Land Use	Recreational Park
Vegetation Type	willows, ferns, red cedar, maple
Vegetation Depth (m)	16.5 m
Riparian:	**Right**
Land Use	Recreational Park
Vegetation Type	Douglas Fir, Alder, Grasses
Vegetation Depth (m)	12.3m

Interchangeable

Figure 17. Geoffrey Dell - Site 2 field data card (1/2).

RMOT 306 – Stream Survey **Page 2 of 2**

B) **Site Card** A)

1	Habitat Unit No.	1
	HU Type	Pool
10m	HU Length	10m
14m	HU Wetted Width (m)	13.4m
41/79/60	HU Wetted Depth (cm) (0.25, 0.5, 0.75) R	34/65/54
	Max. Pool Depth (cm)	82 cm

Site Substrate	Composition (%)
Fines (<2 mm)	90%
Gravel (2-64 mm)	10%
Cobble (64-256 mm)	0%
Boulders (>256 mm)	0%
Bedrock (slab)	0%

Instream Cover:	
Total %	20%
Composition	LWD, willows

Habitat Unit No.	—
HU Type	—
HU Length	—
HU Wetted Width (m)	—
HU Wetted Depth (cm) (0.25, 0.5, 0.75)	—
Max. Pool Depth (cm)	—

Canopy Cover:	
Total %	60%

Additional Comments:

- Made contact w/ City of Nanaimo staff. Given route to site to avoid their parks work (24/10/2023)
- Litter is limited.

Figure 18. Geoffrey Dell - Site 2 field data card (2/2).

RMOT 306 – Stream Survey **Page 1 of 2**

Site Card

Stream Name	Cottle Creek
Survey Dates	Oct 24th, 2023 to Dec 3rd, 2023
Field Crew	Dell, Brown, Camping, Herbert

Site No.	3
Site Length	10 m
Site UTM	10 U 430233E 5451920 N

Gradient (%)	8.0 %
LWD	0

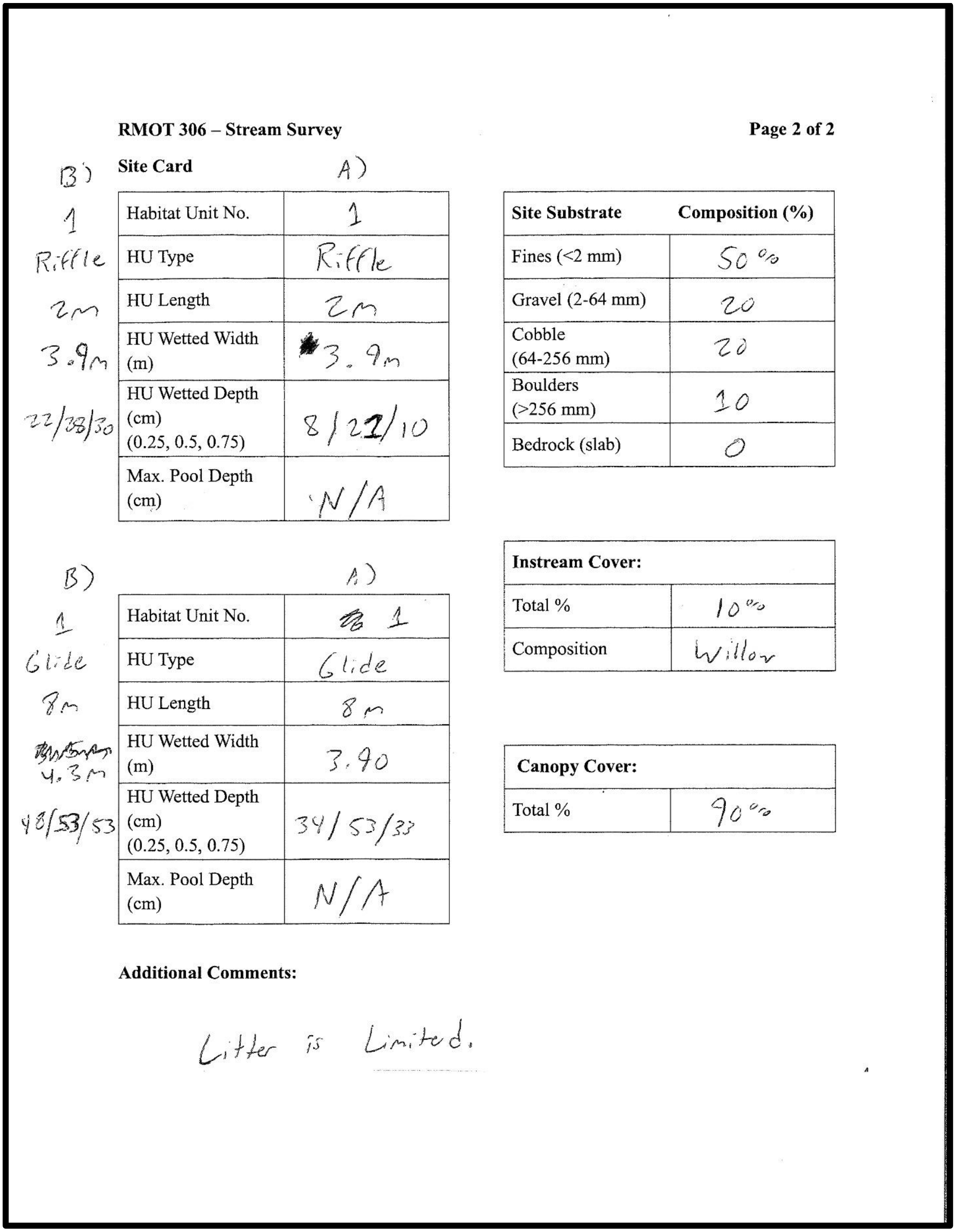
Bankfull Width (m)	4.4
Bankfull Depth (cm) (0.25, 0.5, 0.75)	40/60/70

Water Velocity:	A)	B)
Distance (m)	10 m	10m
Time (s) (3 Floats)	13.38, 24.6, 10.7	8.85, 10.67, 9.07
Glide Width (m)	3.90 m	3.5m
Glide Depth (cm) Average	40 cm	50.7cm

Water Quality:	
DO (mg/l)	
Temp (°C)	
Cond. (µS/cm)	LAB
pH	LAB
Turbidity (NTU)	LAB

Riparian:	**Left**
Land Use	Residential Park
Vegetation Type	willows, red cedar, conifers
Vegetation Depth (m)	8.5m
Riparian:	**Right**
Land Use	Road/Housing
Vegetation Type	willows, red cedar, conifers
Vegetation Depth (m)	24.5m

Figure 19. Geoffrey Dell - Site 3 field data card (1/2).



RMOT 306 – Stream Survey

Site Card

B)		A)
1	Habitat Unit No.	1
Riffle	HU Type	Riffle
2m	HU Length	2m
3.9m	HU Wetted Width (m)	3.9m
22/38/30	HU Wetted Depth (cm) (0.25, 0.5, 0.75)	8/22/10
	Max. Pool Depth (cm)	N/A

Site Substrate	Composition (%)
Fines (<2 mm)	50 %
Gravel (2-64 mm)	20
Cobble (64-256 mm)	20
Boulders (>256 mm)	10
Bedrock (slab)	0

B)		A)
1	Habitat Unit No.	1
Glide	HU Type	Glide
8m	HU Length	8m
4.3m	HU Wetted Width (m)	3.90
48/53/53	HU Wetted Depth (cm) (0.25, 0.5, 0.75)	34/53/33
	Max. Pool Depth (cm)	N/A

Instream Cover:	
Total %	10 %
Composition	Willow

Canopy Cover:	
Total %	90 %

Additional Comments:

Litter is Limited.

Figure 20. Geoffrey Dell - Site 3 field data card (2/2).

RMOT 306 – Stream Survey **Page 1 of 2**

Site Card

Stream Name	Cottle Creek
Survey Dates	Oct 24th, 2023 to Dec 3rd, 2023
Field Crew	Dell, Brown, Company, Herbert

Site No.	4
Site Length	10 m
Site UTM	10U 430524 E 5453403 N

Gradient (%)	6 %
LWD	0

Water Velocity:	A)	B)
Distance (m)	5 m	5 m
Time (s) (3 Floats)	7.04, 8.73, ~~MEAN~~ 7.82	5.98s, 5.12s, 6.01s
Glide Width (m)	2.60 m	3.0 m
Glide Depth (cm) Average	~~32 cm~~ 29 cm	34 cm

Bankfull Width (m)	4.4 m
Bankfull Depth ~~(cm)~~ (m) L(0.25, 0.5, 0.75)R	1.09/1.0/0.8

Water Quality:	
DO (mg/l)	7.5
Temp (°C)	6.8
Cond. (µS/cm)	LAB
pH	LAB
Turbidity (NTU)	LAB

Riparian:	**Left**
Land Use	Forest ~~Park~~
Vegetation Type	Maple, red cedar, blackberry, english Ivy
Vegetation Depth (m)	4.3 m
Riparian:	**Right**
Land Use	Recreational Complex
Vegetation Type	maple, red cedar, blackberry, english Ivy
Vegetation Depth (m)	3.4 m

Figure 21. Geoffrey Dell - Site 4 field data card (1/2).

RMOT 306 – Stream Survey Page 2 of 2

Site Card

B)		A)
1	Habitat Unit No.	1
Riffle	HU Type	Riffle
10m	HU Length	10m
3.0m	HU Wetted Width (m)	2.6m
42/42/18	HU Wetted Depth (cm) (0.25, 0.5, 0.75) R	23/32/27
N/A	Max. Pool Depth (cm)	N/A

Site Substrate	Composition (%)
Fines (<2 mm)	2%
Gravel (2-64 mm)	3%
Cobble (64-256 mm)	65%
Boulders (>256 mm)	5%
Bedrock (slab)	25%

Habitat Unit No.	—
HU Type	—
HU Length	—
HU Wetted Width (m)	—
HU Wetted Depth (cm) (0.25, 0.5, 0.75)	—
Max. Pool Depth (cm)	—

Instream Cover:	
Total %	52%
Composition	OHV, undercut rock

Canopy Cover:	
Total %	55%

Additional Comments:

• Litter is Limited.

Figure 22. Geoffrey Dell - Site 4 field data card (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/09/2023
Station Name: Site #1		Flow status: Riffle
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 1	EPT5 1
	Stonefly Nymph (EPT)	EPT3 1	EPT6 1
Pollution Intolerant	Dobsonfly (hellgrammite)		
	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 2	D1 2
Category 2	Alderfly Larva	8	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	7	1
	Watersnipe Larva		
Sub-Total		C2 15	D2 2
Category 3	Aquatic Worm (oligochaete)	1	1
	Blackfly Larva		
	Leech	32	1
	Midge Larva (chironomid)	4	1
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 37	D3 3
TOTAL		CT 54	DT 7

Figure 23. Kiera Brown - Invertebrate lab data card for site 1, on November 9, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 54

DENSITY: Invertebrate density per total area sampled:

54 ÷ From page 1 0.27 m^2 = 200 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C) S1 Leech

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 2 + 3 = S2 13

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 1 = S3 2

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 1 + 1) / 54 = S4 0.04

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 7

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

32 / 54 = S5 0.59

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 3

Average Rating
Average of R1, R2, R3, R4
2 - Marginal

Figure 24. Kiera Brown - Invertebrate lab data card for site 1, on November 9, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/23/2023
Station Name: Site #1		Flow status: Riffle
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 4	EPT5 1
	Stonefly Nymph (EPT)	EPT3	EPT6
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 4	D1 1
Category 2	Alderfly Larva		
	Aquatic Beetle	1	1
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva	2	1
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)		
	Watersnipe Larva		
Sub-Total		C2 3	D2 2
Category 3	Aquatic Worm (oligochaete)	16	2
	Blackfly Larva		
	Leech	1	1
	Midge Larva (chironomid)	82	1
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 99	D3 4
TOTAL		CT 106	DT 7

Figure 25. Kiera Brown - Invertebrate lab data card for site 1, on November 23, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 106

DENSITY: Invertebrate density per total area sampled:

106 ÷ 0.27 m^2 = 392.59 / m^2 (From page 1)

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): S1 Midge Larva

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 2 + 4 = S2 11

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 0 = S3 1

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 4 + 0) / 106 = S4 0.037

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 7

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

82 / 106 = S5 0.77

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 1
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

Average Rating
Average of R1, R2, R3, R4
1.5 - Poor/Marginal

Figure 26. Kiera Brown - Invertebrate lab data card for site 1, on November 23, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/09/2023
Station Name: Site #2		Flow status: Pool
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 1	EPT4 1
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3	EPT6
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 1	D1 1
Category 2	Alderfly Larva		
	Aquatic Beetle	1	1
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	61	1
	Watersnipe Larva		
Sub-Total		C2 62	D2 2
Category 3	Aquatic Worm (oligochaete)	2	1
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	5	1
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 7	D3 2
TOTAL		CT 70	DT 5

Figure 27. Kiera Brown - Invertebrate lab data card for site 2, on November 9, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 70

DENSITY: Invertebrate density per total area sampled:

70 ÷ 0.27 m^2 = 259.26 / m^2 (From page 1)

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): S1 Amphipod

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 2 + 2 = S2 9

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

1 + 0 + 0 = S3 1

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(1 + 0 + 0) / 70 = S4 0.014

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 5

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

61 / 70 = S5 0.87

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 1
EPT Index	R2 1
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 1

Average Rating
Average of R1, R2, R3, R4
1 - Poor

Figure 28. Kiera Brown - Invertebrate lab data card for site 2, on November 9, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/23/2023
Station Name: Site #2		Flow status: Pool
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1 2	EPT4 1
	Mayfly Nymph (EPT)	EPT2	EPT5
	Stonefly Nymph (EPT)	EPT3	EPT6
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 2	D1 1
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	16	1
	Watersnipe Larva		
Sub-Total		C2 16	D2 1
Category 3	Aquatic Worm (oligochaete)	20	2
	Blackfly Larva	1	1
	Leech		
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 21	D3 3
TOTAL		CT 39	DT 5

Figure 29. Kiera Brown - Invertebrate lab data card for site 2, on November 23, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 39

DENSITY: Invertebrate density per total area sampled:

39 ÷ From page 1 0.27 m^2 = 144.44 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): S1 Aquatic Worm

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 1 + 2 x 1 + 3 = S2 8

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

1 + 0 + 0 = S3 1

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(2 + 0 + 0) / 39 = S4 0.05

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 5

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

20 / 39 = S5 0.51

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 1
EPT Index	R2 1
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 3

Average Rating
Average of R1, R2, R3, R4
1.5 - Poor/Marginal

Figure 30. Kiera Brown - Invertebrate lab data card for site 2, on November 23, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/09/2023	
Station Name: Site #3		Flow status: Riffle	
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2	

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 1	EPT5 1
	Stonefly Nymph (EPT)	EPT3 1	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 2	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	7	1
	Watersnipe Larva		
Sub-Total		C2 7	D2 1
Category 3	Aquatic Worm (oligochaete)	40	2
	Blackfly Larva		
	Leech	4	1
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails	1	1
	True Bug Adult		
	Water Mite		
Sub-Total		C3 45	D3 4
TOTAL		CT 54	DT 7

Figure 31. Kiera Brown - Invertebrate lab data card for site 3, on November 9, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 54

DENSITY: Invertebrate density per total area sampled:

54 ÷ From page 1 0.27 m^2 = 200 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C)

S1 Aquatic Worm

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 1 + 7 = S2 15

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 1 = S3 2

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 1 + 1) / 54 = S4 0.04

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 7

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

40 / 54 = S5 0.74

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

Average Rating
Average of R1, R2, R3, R4
2 - Marginal

Figure 32. Kiera Brown - Invertebrate lab data card for site 3, on November 9, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/23/2023
Station Name: Site #3		Flow status: Riffle
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 11	EPT5 2
	Stonefly Nymph (EPT)	EPT3	EPT6
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 11	D1 2
Category 2	Alderfly Larva		
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	24	1
	Watersnipe Larva		
Sub-Total		C2 24	D2 1
Category 3	Aquatic Worm (oligochaete)	20	2
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	13	2
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 33	D3 4
TOTAL		CT 68	DT 7

Figure 33. Kiera Brown - Invertebrate lab data card for site 3, on November 23, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 68

DENSITY: Invertebrate density per total area sampled:

68 ÷ From page 1 0.27 m^2 = 255.56 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C)

S1 Amphipod

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 1 + 4 = S2 12

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 2 + 0 = S3 2

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 11 + 0) / 68 = S4 0.16

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 7

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

24 / 68 = S5 0.353

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 4

Average Rating
Average of R1, R2, R3, R4
2.25 - Marginal

Figure 34. Kiera Brown - Invertebrate lab data card for site 3, on November 23, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/09/2023
Station Name: Site #4		Flow status: Riffle
Sampler Used: Hess	Number of replicates 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 11	EPT5 1
	Stonefly Nymph (EPT)	EPT3 6	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 17	D1 2
Category 2	Alderfly Larva	3	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish	1	1
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva		
	Fishfly Larva		
	Amphipod (freshwater shrimp)	40	1
	Watersnipe Larva		
Sub-Total		C2 44	D2 3
Category 3	Aquatic Worm (oligochaete)		
	Blackfly Larva		
	Leech	10	1
	Midge Larva (chironomid)		
Pollution Tolerant	Planarian (flatworm)		
	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 10	D3 1
TOTAL		CT 71	DT 6

Figure 35. Kiera Brown - Invertebrate lab data card for site 4, on November 9, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 71

DENSITY: Invertebrate density per total area sampled:

71 ÷ From page 1 0.27 m^2 = 262.96 / m^2

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C) S1 Amphipod

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 2 + 2 x 3 + 1 = S2 13

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 1 + 1 = S3 2

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 11 + 6) / 71 = S4 0.24

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 6

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

40 / 71 = S5 0.56

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 2
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 3

Average Rating
Average of R1, R2, R3, R4
2 - Marginal

Figure 36. Kiera Brown - Invertebrate lab data card for site 4, on November 9, 2023 (2/2).

INVERTEBRATE SURVEY FIELD DATA SHEET (Page 1 of 2)

Stream Name: Cottle Creek		Date: 11/23/2023
Station Name: Site #4		Flow status: Riffle
Sampler Used: Hess	Number of replicates: 3	Total area sampled (Hess, Surber = 0.09 m^2) x no. replicates: 0.27 m^2

Column A Pollution Tolerance	Column B Common Name	Column C Number Counted	Column D Number of Taxa
Category 1	Caddisfly Larva (EPT)	EPT1	EPT4
	Mayfly Nymph (EPT)	EPT2 8	EPT5 2
	Stonefly Nymph (EPT)	EPT3 3	EPT6 1
	Dobsonfly (hellgrammite)		
Pollution Intolerant	Gilled Snail		
	Riffle Beetle		
	Water Penny		
Sub-Total		C1 11	D1 3
Category 2	Alderfly Larva	5	1
	Aquatic Beetle		
	Aquatic Sowbug		
	Clam, Mussel		
	Cranefly Larva		
	Crayfish		
Somewhat Pollution Tolerant	Damselfly Larva		
	Dragonfly Larva	1	1
	Fishfly Larva		
	Amphipod (freshwater shrimp)	90	1
	Watersnipe Larva		
Sub-Total		C2 96	D2 3
Category 3	Aquatic Worm (oligochaete)		
	Blackfly Larva		
	Leech		
	Midge Larva (chironomid)	7	2
	Planarian (flatworm)		
Pollution Tolerant	Pouch and Pond Snails		
	True Bug Adult		
	Water Mite		
Sub-Total		C3 7	D3 2
TOTAL		CT 114	DT 8

Figure 37. Kiera Brown - Invertebrate lab data card for site 4, on November 23, 2023 (1/2).

INVERTEBRATE SURVEY INTERPRETATION SHEET (Page 2 of 2)

SECTION 1 - ABUNDANCE AND DENSITY

ABUNDANCE: Total number of organisms from cell **CT**: CT 114

DENSITY: Invertebrate density per total area sampled:

114 ÷ 0.27 m^2 = 422.22 / m^2 (From page 1)

PREDOMINANT TAXON:
Invertebrate group with the highest number counted (in Col. C): S1 Amphipod

SECTION 2 - WATER QUALITY ASSESSMENTS

POLLUTION TOLERANCE INDEX: Sub-total number of taxa found in each tolerance category.

Good	Acceptable	Marginal	Poor
>22	22-17	16-11	<11

3 x D1 + 2 x D2 + D3

3 x 3 + 2 x 3 + 2 = S2 17

EPT INDEX: Total number of EPT taxa.

Good	Acceptable	Marginal	Poor
>8	5-8	2-4	0-1

EPT4 + EPT5 + EPT6

0 + 2 + 1 = S3 3

EPT TO TOTAL RATIO INDEX: Total number of EPT organisms divided by the total number of organisms.

Good	Acceptable	Marginal	Poor
0.75-1.0	0.50-0.74	0.25-0.49	<0.25

(EPT1 + EPT2 + EPT3) / CT

(0 + 8 + 3) / 114 = S4 0.096

SECTION 3 - DIVERSITY

TOTAL NUMBER OF TAXA: Total number of taxa from cell **DT**: 8

PREDOMINANT TAXON RATIO INDEX: Number of invertebrate in the **predominant taxon** (S1) divided by CT.

Good	Acceptable	Marginal	Poor
<0.40	0.40-0.59	0.60-0.79	0.80-1.0

Col. C for S1 / CT

90 / 114 = S5 0.79

SECTION 4 - OVERALL SITE ASSESSMENT RATING

SITE ASSESSMENT RATING: Assign a rating of 1-4 to each index (S2, S3, S4, S5), then calculate the average.

Assessment Rating	
Good	4
Acceptable	3
Marginal	2
Poor	1

Assessment	Rating
Pollution Tolerance Index	R1 3
EPT Index	R2 2
EPT To Total Ratio	R3 1
Predominant Taxon Ratio	R4 2

Average Rating
Average of R1, R2, R3, R4
2 - Marginal

Figure 38. Kiera Brown - Invertebrate lab data card for site 4, on November 23, 2023 (2/2).

APPENDIX 4: Data Calculation Worksheets

Habitat Data Calculations:

1

Mean Bankfull Channel Width

$$\frac{(4.7m + 14.8m + 4.4m + 4.4m)}{4} = \boxed{7.1m}$$

Mean Bankfull Depth:

$$1)\ \frac{(46+42+30)}{3} = +39.3$$

$$2)\ \frac{(63+90+97)}{3} = +83.3$$

$$\frac{275.6}{4} = \boxed{68.9cm}$$

$$3)\ \frac{(40+60+70)}{3} = +56.7$$

$$4)\ \frac{(109+100+80)}{3} = +96.3$$

$$= 275.6$$

Substrate Areas: HU length (m) × HU wetted width (m)

(site 3) Riffle 1 → $(2.0 \times 3.90) = 7.8\ m^2$

(site 3) Glide 2 → $(8.0 \times 3.90) = 31.2\ m^2$

(site 1) Glide 1 → $(4.9 \times 2.2) = 10.78\ m^2$

Site (1) ~~Glide~~ Riffle 1 → $(5.1 \times 2.6) =$ ~~[illegible]~~ $13.26\ m^2$

(site 2) Pool 1 → $(10 \times 13.4) = 134\ m^2$

(site 4) Riffle 1 → $(10 \times 2.6) = +\ 26\ m^2$

Total → ~~225.12 m²~~ $223.04\ m^2$

Figure 39. Geoffrey Dell - Mean bankfull channel width and depth calculations, and habitat unit area calculations for October.

2

Fines

- S1 G1 → $10.78\,m^2 \times 15\% = 1.62\,m^2$
- ~~S1 R2~~
- S1 R1 → $13.26\,m^2 \times 15\% = 13.41\,m^2$ → S1 $15.03\,m^2$
- S2 P1 → $134\,m^2 \times 90\% = 120.6\,m^2$
- S3 R1 → $7.8\,m^2 \times 50\% = 3.90\,m^2$
- S3 G2 → $31.2\,m^2 \times 50\% = 15.60\,m^2$ → S3 $19.50\,m^2$
- S4 R1 → $26\,m^2 \times 2\% = 0.52\,m^2$

Total Fines Across All 4 Sites:

$$\underbrace{15.03\,m^2}_{\text{Site 1}} + \underbrace{120.6\,m^2}_{\text{Site 2}} + \underbrace{19.50\,m^2}_{\text{Site 3}} + \underbrace{0.52\,m^2}_{\text{Site 4}} = \boxed{155.65\,m^2}$$

Percent Fines Across All 4 Sites:

$$100 \times (155.65\,m^2 / 223.04\,m^2) = \boxed{69.8\,\%}$$

Gravel

- S1 G1 → $10.78\,m^2 \times 70\% = 7.55\,m^2$
- S1 R1 → $13.26\,m^2 \times 70\% = 9.28\,m^2$ → $16.83\,m^2$
- S2 P1 → $134\,m^2 \times 10\% = 13.4\,m^2$
- S3 R1 → $7.8\,m^2 \times 20\% = 1.56\,m^2$
- S3 G2 → $31.2\,m^2 \times 20\% = 6.24\,m^2$ → $7.8\,m^2$
- S4 R1 → $26\,m^2 \times 3\% = 0.78\,m^2$

Total Gravel Across All 4 Sites:

$$\underbrace{16.83\,m^2}_{\text{Site 1}} + \underbrace{13.4\,m^2}_{\text{Site 2}} + \underbrace{7.8\,m^2}_{\text{Site 3}} + \underbrace{0.78\,m^2}_{\text{Site 4}} = \boxed{38.81\,m^2}$$

Percent Gravel Across all 4 Sites:

$$100 \times (38.81\,m^2 / 223.04\,m^2) = \boxed{17.4\,\%}$$

Figure 40. Geoffrey Dell - Substrate data calculations for fines and gravel.

Cobble

3

- S1 G1 → $10.78 m^2 \times 13\% = 1.40 m^2$
- S1 R1 → $13.26 m^2 \times 13\% = 1.72 m^2$ > $3.12 m^2$
- S2 P1 → $134 m^2 \times 0\% = 0.00 m^2$
- S3 R1 → $7.8 m^2 \times 20\% = 1.56 m^2$
- S3 G2 → $31.2 m^2 \times \cancel{65\%}\ 20\% = 6.24 m^2$ > $7.8 m^2$
- S4 R1 → $26 m^2 \times 65\% = 16.9 m^2$

Total ~~B~~ Cobble Across all 4 Sites:

$\underbrace{3.12 m^2}_{\text{Site 1}} + \underbrace{0.00 m^2}_{\text{Site 2}} + \underbrace{7.8 m^2}_{\text{Site 3}} + \underbrace{16.9 m^2}_{\text{Site 4}} = \boxed{27.82 m^2}$

Percent Cobble Across all 4 sites:

$100 \times (27.82 m^2 / 223.04 m^2) = 12.5\%$

Boulders

- S1 G1 → $10.78 m^2 \times 2\% = 0.22 m^2$
- S1 R1 → $13.26 m^2 \times 2\% = 0.27 m^2$ > 0.49
- S2 P1 → $134 m^2 \times 0\% = 0.00 m^2$
- S3 R1 → $7.8 m^2 \times 10\% = 0.78 m^2$
- S3 G2 → $31.2 m^2 \times 10\% = 3.12 m^2$ > 3.90
- S4 R1 → $26 m^2 \times 5\% = 1.3 m^2$

Total Boulders Across all 4 sites:

$\underbrace{0.49 m^2}_{\text{Site 1}} + \underbrace{0.00 m^2}_{\text{Site 2}} + \underbrace{3.90 m^2}_{\text{Site 3}} + \underbrace{1.3 m^2}_{\text{Site 4}} = \boxed{5.69 m^2}$

Percent Boulders Across all 4 sites:

$100 \times (5.69 m^2 / 233.04 m^2) = \boxed{2.4\%}$

Figure 41. Geoffrey Dell - Substrate data calculations for cobble and boulders.

4

Bedrock

- S1 G1 → $10.78 m^2 \times 0\% = 0 m^2$
- S1 R1 → $13.26 m^2 \times 0\% = 0 m^2$
- S2 P1 → $134 m^2 \times 0\% = 0 m^2$
- S3 R1 → $7.8 m^2 \times 0\% = 0 m^2$
- S3 G2 → $31.2 m^2 \times 0\% = 0 m^2$
- S4 R1 → $26 m^2 \times 25\% = 6.5 m^2$

Total Bedrock Across all 4 Sites = $\boxed{6.5 m^2}$

Percent Bedrock Across all 4 Sites:

$$100 \times (6.5 m^2 / 223.04 m^2) = \boxed{2.9\%}$$

Instream Cover Calculations

→ S1G1 → $10.78 m^2 \times 20\% = 2.16 m^2$ } $4.8 m^2$
→ S1R1 → $13.26 m^2 \times 20\% = 2.65 m^2$ }
→ S2P1 → $134 m^2 \times 20\% = 26.8 m^2$
→ S3R1 → $7.8 m^2 \times 10\% = 0.78 m^2$ } $3.9 m^2$
→ S3G2 → $31.2 m^2 \times 10\% = 3.12 m^2$ }
→ S4R1 → $26 m^2 \times 52\% = 13.52 m^2$

Total amount of instream cover:

$$\underbrace{4.8 m^2}_{\text{Site 1}} + \underbrace{26.8 m^2}_{\text{Site 2}} + \underbrace{3.9 m^2}_{\text{Site 3}} + \underbrace{13.52 m^2}_{\text{Site 4}} = \boxed{49.02 m^2}$$

Percent of instream cover across all 4 sites:

$$100 \times (49.02 m^2 / 223.04 m^2) = \cancel{21.9}\ \boxed{22\%}$$

Figure 42. Geoffrey Dell - Substrate data calculations for bedrock, and instream cover calculations.

5

Canopy Cover Calculations:

→ S1 G1 – $10.78m^2 \times 35\% = 3.72m^2$ } $8.41m^2$

→ S1 R1 – $13.26m^2 \times 35\% = 4.64m^2$

→ S2 P1 – $134m^2 \times 60\% = 80.40m^2$

→ S3 R1 – $7.8m^2 \times 90\% = 7.02m^2$ } $35.1m^2$

→ S3 G2 – $31.2m^2 \times 90\% = 28.08m^2$

→ S4 R1 – $26m^2 \times 55\% = 14.3m^2$

Total amount of canopy cover across all 4 sites:

$$8.41m^2 + 80.40m^2 + 35.1m^2 + 14.3m^2 = \boxed{138.21m^2}$$

~~Total~~ Percent of canopy cover across all 4 sites:

$$100 \times (138.21m^2 / 223.04m^2) = \boxed{62\%}$$

Water Velocity Calculations:

Site 1: Float 1 → $\frac{5m}{12.42s} = 0.4026 m/s$

Float 2 → $\frac{5m}{12.23s} = 0.4087 m/s$

Float 3 → $\frac{5m}{12.35s} = 0.4049 m/s$

Average velocity: $\frac{(0.4026 + 0.4087 + 0.4049)}{3} = 0.4054 m/s$

$= 40.54 cm/s$

Water Discharge: $(0.4054 m/s) \times 0.173m \times 2.25m \times 0.75$ (Depth; width)

$= 0.1184 m^3/sec$

$\approx \boxed{0.12 m^3/sec}$

Figure 43. Geoffrey Dell - Canopy cover calculations, and water discharge calculations for site 1 in October.

Water Velocity Calculations: 6

Site 3: Float 1 → $10m/13.38s = 0.7474\ m/s$

Float 2 → $10m/24.6s = 0.4065\ m/s$

Float 3 → $10m/10.7s = 0.9346\ m/s$

Average Velocity: $\frac{(0.7474 + 0.4065 + 0.9346)}{3} = 0.6962\ m/s$

Water Discharge: $(0.6962\ m/s) \times 0.40m \times 3.90m \times 0.75$

$= 0.81\ m^3/sec$

Site 4: Float 1 → $5m/7.04s = 0.7102\ m/s$

Float 2 → $5m/8.73s = 0.5727\ m/s$

Float 3 → $5m/7.82s = 0.6394\ m/s$

Average Velocity: $\frac{(0.7102 + 0.5722 + 0.6394)}{3} = 0.6406\ m/s$

Water Discharge: $(0.6406\ m/s) \times 0.29m \times 2.66m \times 0.75$

$= 0.36\ m^3/sec$

Figure 44. Geoffrey Dell - Water discharge calculations for sites 3 and 4 in October.

Data Calculations (Survey B) 7

Habitat Unit Areas:

S1G1 → ~~22.0~~ 4.9 × 3.6 m = 17.64 m^2

S1R1 → ~~8.0~~ 5.1 × 2.9m = 14.79 m^2

S2P1 → ~~42.9~~ 10 × 14m = 140 m^2

S3R1 → 2.0 × 3.9m = 7.80 m^2

S3G1 → 8.0 × 4.3m = 34.4 m^2

S4R1 → 10.0 × 3.0m = 30.0 m^2

Total = 244.63 m^2

Water Velocity (Survey B):

Site 1: Float 1 → $\frac{5m}{5.48}$ → 0.9124 m/s

2 → 5/5.82 → 0.8591 m/s

3 → 5/5.40 → 0.9259 m/s

$$\text{Average Velocity} = \frac{(0.9124 + 0.8591 + 0.9259)}{3}$$

= 0.8991 m/s

Water Discharge =

(0.8991) (3.6m) (0.18m) (0.75)

= 0.4370 m^3/sec

Figure 45. Geoffrey Dell - Habitat unit area and water discharge calculations for site 1 in November.

8

Site 2: Float 1 → 5 / 52.11 → 0.0960 m/s
2 → 5 / 61.01 → 0.0820 m/s
3 → 5 / 54.27 → 0.0921 m/s

Average velocity:

$$\frac{(0.0960 + 0.0820 + 0.0921)}{3}$$

$$\boxed{= 0.0900 \text{ m/s}}$$

Water Discharge:

$$(0.0900)(14\text{ m})(0.6\text{ m})(0.75)$$

$$\boxed{= 0.567 \text{ m}^3/\text{sec}}$$

Site 3: Float 1 – 10 / 8.85 = 1.130 m/s
2 – 10 / 10.67 = 0.9372 m/s
3 – 10 / 9.07 = 1.1025 m/s

Average velocity:

$$(1.130 + 0.9372 + 1.1025)/3 \rightarrow \boxed{1.0567 \text{ m/s}}$$

Water Discharge:

$$(1.0567)(3.5\text{ m})(0.507\text{ m})(0.75$$

$$\boxed{= 1.406 \text{ m}^3/\text{sec}}$$

Figure 46. Geoffrey Dell - Water discharge calculations for sites 2 and 3 in November.

Site 4: Float 1 → 5/5.98 → 0.8361 9

2 → 5/5.72 → 0.8741

3 → 5/6.01 → 0.8519

Average Velocity:

$$(0.8361 + 0.8741 + 0.8319)/3 = \boxed{0.8474 \text{ m/s}}$$

Water Discharge =

$$(0.8474)(3.0m)(0.34m)(0.75)$$

$$\boxed{= 0.6483 \text{ m}^3/\text{sec}}$$

Figure 47. Geoffrey Dell - Water discharge calculations for site 4 in November.

APPENDIX 5: Background Data Reports

Ministry of Environment

HABITAT WIZARD STREAMS REPORT

Dec. 10, 2023

WATERBODY INFORMATION	
Name:	COTTLE CREEK
Alias:	NORTH COTTLE CREEK
Alias (2):	
UTM Co-ordinate (Stream Mouth):	UTM: 10 430541, 5451311
Primary Mapsheet:	092G04
Primary Region:	Vancouver Island
Watershed Code:	920-401700
Waterbody Identifier:	00000PARK
Stream Length (m):	3.39
Stream Order:	1
Stream Magnitude:	1

SPECIES PRESENT

FISH SPECIES	LAST KNOWN OBSERVATION DATE
Cutthroat Trout	01-JAN-94
Pumpkinseed	10-MAY-17

STOCKING INFORMATION

DATE	SPECIES	RELEASED	STOCK	LIFE STAGE	HATCHERY

OBSTRUCTIONS

DESCRIPTION	HEIGHT	LENGTH	COMMENTS
Dam	0	0	(BARRIER TO ANADROMOUS FISH. REF# = 14-29)
Falls	0	0	(BARRIER TO ANADROMOUS FISH REF# = 14-29)

ONLINE WATER LEVELS

REFERENCE URL

This water body has online water level information available from Environment Canada and the Province of BC. Use the link(s) above to go directly to the station information on the BC River Levels website.

Figure 48. Habitat wizard stream report for Cottle Creek (1/2) (MoE, 2023).

WATER QUANTITY INFORMATION

The most current water survey information is available from the following Water Survey of Canada wel
http://scitech.pyr.ec.gc.ca/waterweb/selectProvin provides access to real-time water station in
http://www.wsc.ec.gc.ca/hydat/H2 provides access to archived water station information

STREAM SURVEY DATA

TRIBUTARY STREAMS

1:50,000 WATERSHED CODE	GAZETTED NAME	UTM	EASTING	NORTHING

REFERENCES

REFERENCE ID	REFERENCE TITLE
14-29	Nanaimo urban stream enhancement study.
14-31	not applicable

ADDITIONAL INFORMATION

Please see the Fisheries Information Data Queries (FIDQ) for additional and more detailed queries of fish and fish habitat information:

http://www.env.gov.bc.ca/fish/fidq/index

Please check the Ecological Reports Catalogue (EcoCat) for reference material and data that is available for online distribution:

http://www.env.gov.bc.ca/ecocat/

Figure 49. Habitat wizard stream report for Cottle Creek (2/2) (MoE, 2023).