Water Quality and Stream Invertebrate Population Analysis of Holland Creek, Ladysmith BC

Prepared by:
Riley Strang, Sam Skelcher and Jacob Cook

Prepared for:
Phillip Morrison

December 12, 2023

Executive Summary

Holland Creek running for an approximate 12km in the southern part of Ladysmith, British Columbia. This is a fish bearing stream holding Chum salmon (scientific name), coho salmon, rainbow trout, and cutthroat trout. This is the first time in 11 years that Holland Creek has been monitored by the BRNP 3rd year students. Two sampling events took place throughout the semester, first on November 1, and the second on November 28. Water quality analysis was conducted both in the field and in the lab. Lab sessions happened at the VIU laboratory as well some samples were sent away to be analysed by ALS Laboratories in Burnaby BC. The health of stream invertebrates and hydrology were both measured at all 4 of our sites (Figure 1). We found the stream to be in good health. The EPT populations we found to be "marginal" which, compared to the most recent study in 2012, is a drop. Overall, we saw good water quality, leaving us to believe that Holland Creek is a strong, healthy ecosystem

Acknowledgements

The students of RMOT 306 would like to take time to thank Phillip Morison for his help through this study and VIU faculty for lending us the equipment and laboratory to conduct the tests necessary. We would also like to thank ALS Laboratories for their help analysing water samples and getting them back to us in a timely manner.

Table of Contents

List of Figures and Tables

1.0 Introduction

1.1 Background & Historical significance

Holland creek is in Ladysmith BC and flows directly into the Pacific Ocean. Holland Creek originates on northern and eastern slopes of Coronation Mountain in the Vancouver Island range and flows north and east. The creek is approximately 12 km before entering Ladysmith Harbour. The creek is made up of a mainstream and one major tributary. Holland creek has not been analyzed since November 2012. No official data has come out of the creek in eleven years. In this time there has been a major construction project on the creek. In 2022 a new road and large set of apartment complexes were built along the edge of the riparian zone as well as a paved public access road with a culvert directly in the creek. Both from a pollution point of view as well as a wildlife perspective, these projects will have staggering changes on the stream. The creek flows directly out of Holland Lake, which is a level-controlled lake with a dam on each side, "the Company Dam" built in the early 1900's by the Willington coal company and the holland lake dam completed in 1980. These dams' control holland creek flow, this is important because the municipalities of Ladysmith and Saltair both pull water from Holland Lake.

1.2 Environmental concerns

The creek has not been surveyed in eleven years; this is the main concern. A significant lack of data on the creek invites a plethora of issues even in our regular climate. Over the last eleven years we have experienced floods and droughts, a severe heat dome, a significant atmospheric river, and a pandemic. While a pandemic may not seem like a direct environmental concern to a creek, Holland Creek is in an urban area and in a municipal park. Being an urban creek during the pandemic, Holland Creek would have seen an increase in anthropogenic activity over the pandemic as it was one of the few places people were allowed to go.

Holland Creek Park is located in the middle of Ladysmith BC, this means it is surrounded by urban influences. On both banks you can find houses, suburbs, apartments etc. it flows directly through a golf course, behind a Save-On-Foods, under the Trans-Canada highway and has multiple crossings throughout Ladysmith. One of these bridges was completed only in the last year. A large apartment complex was also built on the edge of the park and completed last year. When we initially surveyed the stream, we noticed significant sediment build up which could be attributed to the construction.

As part of ongoing salmon restoration measures, a coalition of both government and private companies have maintained and even established new salmon spawning habitat. The group is composed of the Pacific Salmon Foundation, Department of Fisheries and Oceans, D.R. Clough Consulting, and Copcan Holdings. These companies have added significant large woody debris and appear to maintain current habitat as well as created Holland Creek side Channel 1 which is a new channel created in the early 2000’s as an attempt to increase Coho Salmon (Oncorhynchus kisutch) recruitment.

2.0 Methods

2.1 Overview

Environmental monitoring was conducted at 4 sites along Holland creek, Ladysmith, British Columbia (Figure 1)

2.2 Sample Site Locations

Because the last study on Holland Creek was done 11 years ago, we strategically chose our sites to be able to monitor the effects of the new apartment complex. Two of our four sites have had large woody debris fastened into the banks to provide more salmon habitat.

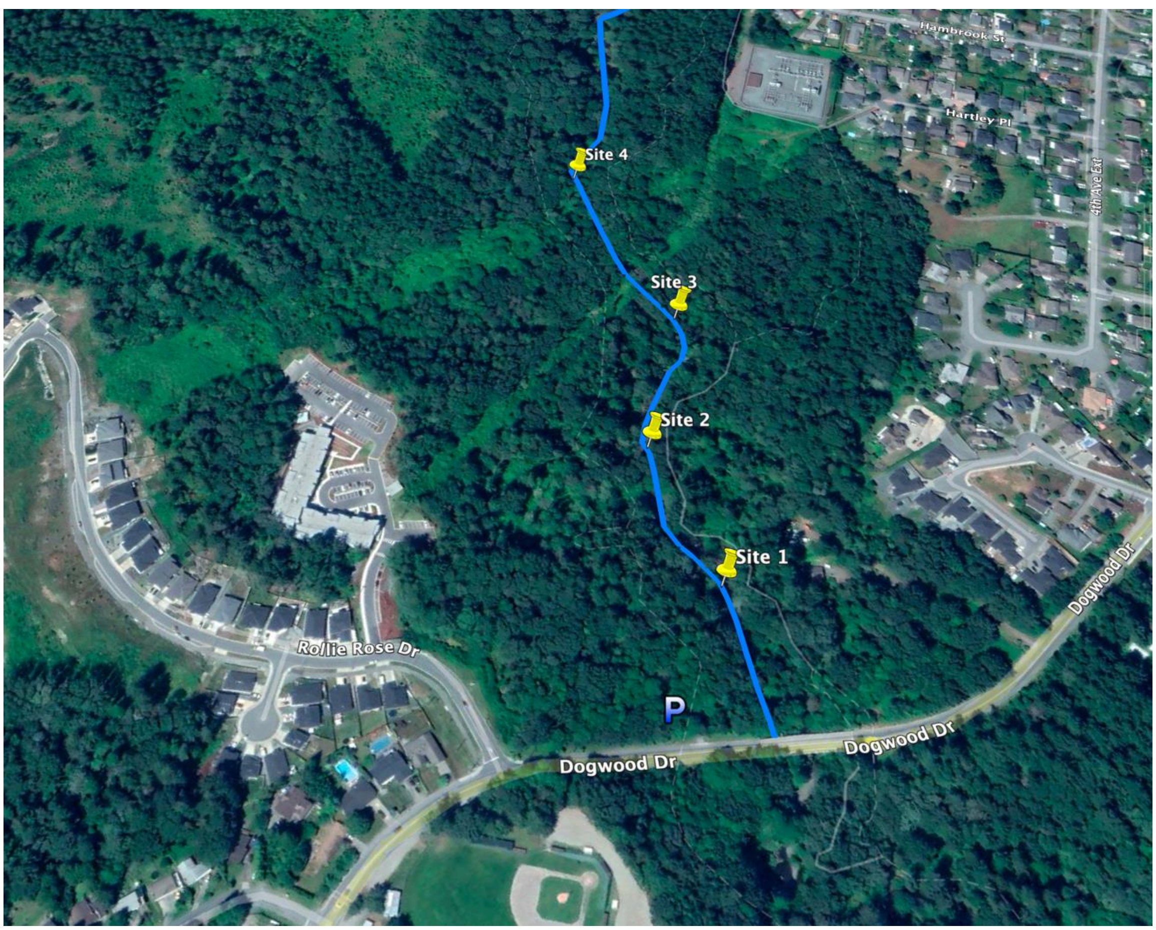

Figure 1: Map of Proposed Study Area and Selected Sampling Sites

Site 1

Site 1 is a glide that is located 100m up steam from the Holland Creek Trail Head on Dogwood Drive (10U 440741mE 5425619mN) (Figure 2). You can access this site from the trail beside site 2. This site has 15% canopy cover. The substrate at site 1 is made up of 50% cobble, 35% gravel and 15% sand.

Figure 2: Upstream view from the bottom of Site 1

Site 2

Site 2 is a pool located 100 meters upstream from site 1 (10U 440639mE 5425631mN) (Figure 3). Access to site 2 is directly from the holland creek trail. Site 2 is the primary way that our team accesses the creek. This site has a sediment make up of 40% boulder, 20% cobble, 20% gravel, 15% bedrock and 5% sand.

Figure 3: Upstream view from the bottom of site 2

Site 3

Site 3 is a riffle located 100 meters up steam from site 2 (10U 440551mE 5425666mN) (Figure 4). It is accessed by crossing the creek at site 2 and walking up a trail until site 3 is reached. Site 3 has a sediment make up of 30% boulder 50% cobble, 10% gravel and 10% sand. At this site there is a small pipe that leads to a culvert under the trail. This was put into place for salmon by the Pacific Salmon Foundation and Ladysmith Sportsman's Club

Figure 4: Upstream view from the bottom of Site 3

Site 4

Site 4 is a riffle 100 meters upstream from site 3 (10U 440481mE 5425726mN) (Figure 5). Site 4's sediment is made up of 30% boulder 50% cobble, 10% gravel and 10% sand. This site has 55% tree cover and which is made up of primarily big leaf maple. There is a trail that runs right beside site 4, a bench overlooking the site is on the side of the trail.

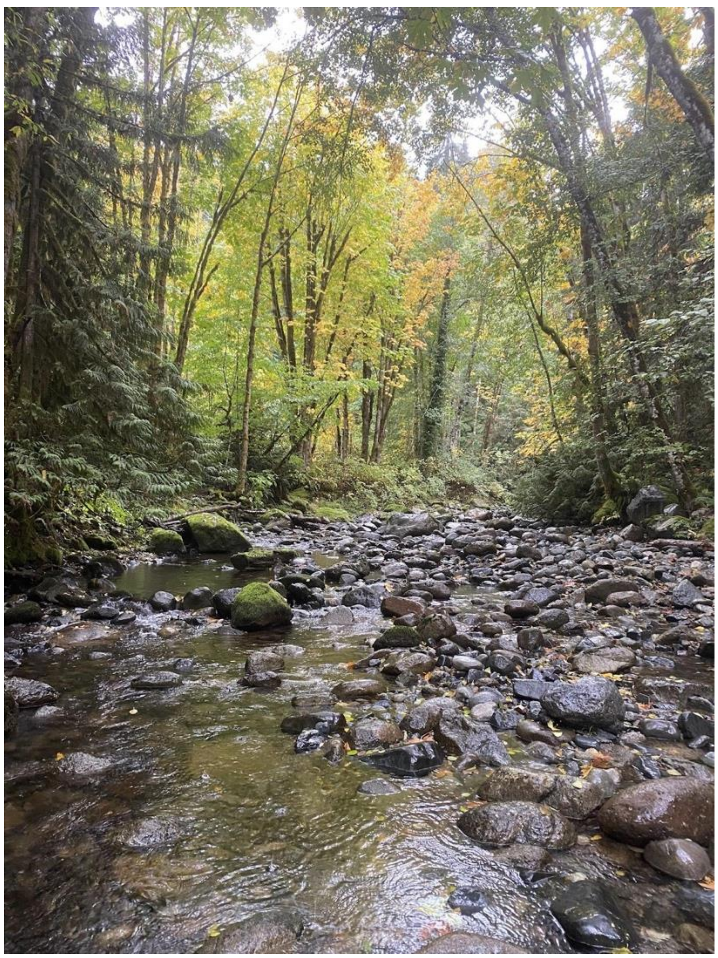

Figure 5: Upstream view from the bottom of Site 4

2.3 Hydrology

During the site visits of November 1 and November 28 we collected velocity, wetted width, bankfull width and mean depth at each of our 4 sites. When collecting velocity, we selected 10 meters at each site and timed how long it takes for a ping pong ball to float the 10m section of stream. Then averaging those times, we can get average velocity. This procedure was done at 25%, 50%, 75% of the wetted width to assure we got a true average. To assure continuity we marked, with flagging, the spots where we took bankfull and wetted width to assure the measurements were taken in the same location each time.

2.4 Water Quality

During field assessments, we measured water temperature, discharge, and dissolved oxygen. Electronic probes gauged temperature and dissolved oxygen, while discharge was determined using the float method. This method involves releasing a ping pong ball into a five-meter glide, timing how long it takes to reach the downstream end.

Water discharge is calculated by multiplying average velocity (m/sec) with average depth (m), wetted width (m), and a correction factor of 0.75 to consider friction near the stream's edges. Other parameters will be tested in either the VIU lab or the ALS lab

Water samples for laboratory analysis were collected during both events. A trip blank was obtained on each day of sampling. Additionally, two samples were gathered at sites one and three during each sampling event. One sample was dispatched to the ALS lab, and another was processed in the VIU lab, thereby generating duplicate data for these two sites on each sampling day. Sampling was conducted both midstream and from downstream to upstream. Prior to filling, sample bottles underwent a thorough rinsing process, repeated three times, with the exception of ALS bottles containing pre-installed preservatives. To prevent contamination by excess air, the sample bottles were intentionally overfilled. Subsequently, the samples were stored in a cooler until analysis.

2.5 Benthic Invertebrate Communities

Benthic macroinvertebrates were sampled at sites 1 and 3 on November 1st and November 28th. Each site had 1 sample taken during each event, for a total of 2 samples per site. A Hess sampler was used to collect the invertebrates and our methods followed the Stream Keepers guideline. A spray bottle was used after removing the sampler from the river to spray off any organisms that were left in the tube into the sample container to ensure all organisms were collected. After the collection tube was washed off, the contents of the sample container were poured into a bottle which was then filled with 70% ethanol for preservation of the organisms until they could be observed in a lab at VIU later. Sorting did not take place in the field.

Analysis in the lab involved sorting by taxonomy of the invertebrates. Once sorting was completed, we then used that information to calculate pollution tolerance, EPT index, EPT to total ratio, predominant taxon ratio, and the overall site assessment ratings.

3.0 Results and Discussion

3.1 General Field Conditions

Our first sampling event took place on November 1, 2023. The weather was rainy and windy. It took place between 12pm and 2pm. The second sampling event took place on November 28, 2023. It was a clear, sunny day, the sampling took place between 11am and 12:30pm.

3.2 Water Quality

3.2.1 Water Quality Analysis

Once we had all our data, we were able to amalgamate it and start assessing the state of the stream. We measured pH, conductivity, hardness, alkalinity, turbidity, nitrogen, phosphorus, dissolved oxygen, and the temperature of both the air and water. We tested once in late October and again in late November. We will call these events one and two. For each event we took field measurements as well as lab measurements which were taken. Event 1 was taken November 1st and Event 2 was taken November 28. All lab results were measured at VIU. In this section we will briefly discuss each element and compare it to trends from 2011. We also sent samples to ALS water testing in Vancouver BC which we will also discuss in this section.

Dissolved Oxygen

We measured dissolved oxygen in the stream. It's important for aquatic organisms. Fish need at least 6 PPM to survive and do well with over 8 PPM. Our stream has stable levels above 11 PPM, consistent since 2012. This is notable given nearby construction that can add sediment and limit oxygen. The high dissolved oxygen levels show the stream's resilience to human activities. This is significant for the health of fish and salmon eggs in particular.

Temperature

In our survey, we conducted monitoring of both air and water temperatures. Air temperature, susceptible to daily fluctuations based on ambient weather conditions, remains an essential dataset, offering insights into potential impacts on various aspects of water quality. However, our primary focus was on stream temperature, a more stable parameter directly influencing both stream and fish health. Given the preference of salmonids for lower oxygen levels and the positive correlation between lower temperatures and increased dissolved oxygen levels, stream temperature is a critical factor. Notably, our water temperature readings exhibited anomalies relative to seasonal and historical temperature trends. In contrast to the expected decline in water temperature during October, our observations indicate an almost twofold increase over the month of November. This deviates from the patterns observed in 2012, suggesting a departure from typical expectations.

pH

pH serves as a metric for water acidity, expressed on a 0 to 14 scale. Lower pH values denote increased acidity. In healthy streams, a neutral pH is typically around 7. Notably, a one-unit change on the pH scale within a month can signify a substantial alteration. In our stream, Event 1 exhibited markedly higher pH levels compared to Event 2. Despite this notable disparity, a discernible stabilizing trend is evident as we move back toward a neutral 7.

Conductivity

Water quality conductivity is the measure of the concentration of conductive ions in a water body. Our assessments reveal a consistent trend, registering at approximately 30, indicative of relatively low conductivity levels. A comparative analysis with the 2012 data exhibits a notable increase in average conductivity, signifying a positive and healthy trend.

Hardness

Hardness is the quantification of calcium accumulation in the water column. A substantial increase in calcium levels is observed between Event 1 and Event 2 in Holland Creek. Notably, over the past decade, there has been a significant upward trend in hardness. This observation bears potential implications, particularly concerning the fact that Holland Creek is an integral component of the Ladysmith drinking water system.

Alkalinity

The relationship between alkalinity and pH lies in how alkalinity can act as a buffer against changes in pH. Solutions with higher alkalinity are more resistant to fluctuations in pH when acids are introduced. This is because the alkaline components in the solution can react with the added acid, preventing a significant drop in pH. As shown in the table below we have a drop in alkalinity between events which would indicate the water becoming more acidic, which is confirmed by our drop in pH. This is adverse to the trend over the last 10 years where we see a significant change toward basic water.

Turbidity

Turbidity is the measure of suspended solids in the water column. This can affect many things such as conductivity and dissolved oxygen. Holland creek has stable turbidity though we do see a significant spike in turbidity between site 3 and 4. This change is probably due to the introduction of a side channel between these sites.

Phosphate and Nitrate

Nitrate (NO_3^-) and phosphate (PO_4^{3-}) are pivotal nutrients influencing the ecological dynamics of streams, with implications for plant and microbial growth. Elevated concentrations of these nutrients, frequently stemming from anthropogenic activities, can give rise to substantial environmental challenges. In our laboratory analyses, an initial observation of an unhealthy nutrient ratio approximating 3:1 indicates a pronounced nitrate limitation within the system. However, upon employing more precise measurements at an ALS facility, we discern a more favorable and ecologically sound ratio approaching the Redfield ratio of 16:1. This revelation underscores the significance of accurate nutrient assessments, revealing the nuanced nutrient dynamics within aquatic ecosystems and the potential for mitigating adverse environmental impacts through informed management strategies.

Comparisons

Comparing the trends observed in the 2012 study with our recent test in 2023, we note a combination of fluctuations and relative stability in key water quality parameters. Dissolved oxygen exhibits remarkable stability, with a fluctuation of less than 0.5 mg/l. While water temperature experienced a decline during the initial event, overall stability is evident. Over the past decade, there is a noteworthy 30% average increase in conductivity. The pH levels have shifted from the low 7 range to the low 8 range, indicating a trend toward a more basic water environment. Nitrate levels remained stable, but a substantial decline is observed in phosphate concentrations. Alkalinity is diminishing, thereby reducing the creek's capacity to resist pH fluctuations. Turbidity has witnessed a 50% reduction over the 10-year period, contributing to enhanced stream clarity. Lastly, hardness is on the rise, posing potential concerns for drinking water quality.

Characteristic (field)	**Event 1 (Avg)**	**Event 2 (Avg)**	**2012 event 1**	**2012 event 2**	**Trends**
Dissolved oxygen	11.6	11.5	11.7	11.2	Stable
Temperature (air)	10	4	10	5	Stable
Temperature (water)	2.25 C	5.8 C	6.6 C	4.9 C	Stable
Conductivity	27	28	22	18	Increasing
PH	8.05	7.9	6.9	7.16	Increasing
Nitrate	.115	.11	.12	.04	Stable
Phosphorous	.0325 mg/l	.0325 mg/l	.075	.14	Decreasing
Alkalinity	7.6	6.1	10	10.4	Decreasing
turbidity	.48	.51	2.5	.38	Decreasing
hardness	13.5	20.5	10	10	Increasing

Table 1: Trends between studies done in 2023 and 2012

3.3.2 ALS Data

Two sample sets were collected, and in-lab analyses were conducted alongside submissions to ALS Laboratories in Vancouver, BC. ALS data set 1(Appendix Table 12) presents an average of water quality measurements, facilitating a comparison with ALS data obtained in 2012. The equipment at ALS labs demonstrates superior capabilities in capturing values beyond the scope of our instruments, and it provides a higher degree of accuracy in measuring various properties. The ALS data generally aligns with our in-lab findings, with a few distinctions. Notably, the nitrogen-to-phosphate levels exhibit more pronounced regulation in the ALS dataset.

Examining the second data set (Appendix Table 13), our focus shifts to ammonia and metal concentrations in the water samples. The table highlights a consistent stability in these levels across the two sampling events. Comparative analysis against British Columbia water guidelines reveals that all recorded metal concentrations fall within permissible limits. Notably, certain parameters such as ammonia, lead, and vanadium hover close to the minimum detection limit, underscoring the precision and sensitivity of the analytical methods.

3.3 Benthic Invertebrate Communities

A total of 78 invertebrates were collected which consisted of 7 different species (Table . The predominant taxon for site 1 was mayfly, while at site 3 it was aquatic worms (oligochaete). There were significantly fewer macroinvertebrates collected compared to the previous study. The 2012 results showed a total of 330 total invertebrates from 3 samples (MacNeill S, Lattanzi B. 2012) which is significantly higher than our overall total at 78 invertebrates from 4 samples. A reduction in the number of invertebrates typically indicates a physical problem such as being below a dam, or construction taking place. The density per square meter of the invertebrates ranged from 111 to 411, which is much lower than the previous range of 533 to 727. Even with the reduction of invertebrates, the EPT to total ratio has improved to an average of “acceptable” which is higher than the previous “marginal” rating it received in 2012.

Overall site ratings for invertebrates at sites 1 and 3 were all between 2.5 - 2.75 which is categorized as “marginal”. We believe this is due to potential contamination or a localized event because there was a noticeable amount of sediment on top of the substrate during our initial site visit. Such an event would have affected the invertebrate community, and it appears they are now recovering since construction has been completed. The EPT populations were also determined to be “marginal” which is a drop from the previously reported level of “acceptable” in 2012.

Index Site 1	Nov 1'st 2023	Nov 28 2023
Pollution Tolerance	Marginal	Marginal
EPT Index	Marginal	Marginal
EPT to total ratio	Good	Acceptable
Predominant taxon ratio	Acceptable	Acceptable
Overall site assessment rating	Marginal	Marginal

Table 2: Site 1 Invertebrate Index

Index Site 3	Nov 1'st 2023	Nov 28 2023
Pollution Tolerance	Marginal	Acceptable
EPT Index	Marginal	Acceptable
EPT to total ratio	Acceptable	Marginal
Predominant taxon ratio	Acceptable	Acceptable
Overall site assessment rating	Marginal	Marginal

Table 3: Site 3 Invertebrate Index

The invertebrate community population in Holland Creek demonstrates a presence of both pollution tolerant, and pollution intolerant species. However, there were almost no species present from the somewhat-tolerant category. There is a clear reduction in abundance and density. The total pollution tolerance hasn't changed with it still being in the "marginal" category, and it is promising that the EPT to total ratio has improved.

Pollution tolerance	Species	Site 1	Site 3
Category 1	Mayfly Stonefly Gilled Snail Riffle beetle	5 4 1 0	3 16 0 1
Category 2	None observed	0	0
Category 3	Aquatic worm	0	17

Table 4 Species abundance by pollution tolerance categories November 1st

Pollution tolerance	Species	Site 1	Site 3
Category 1	Mayfly Stonefly Caddisfly	10 1 2	2 2 2
Category 2	Alderfly larva	0	1
Category 3	Aquatic worm Midge larva	4 1	6 0

Table 5 Species abundance by pollution tolerance categories November 28th

4.0 Conclusion and Recommendations

4.1 Recommendations

In this study we look at monitoring Holland Creek. We are emphasizing the importance of implementing an annual monitoring regimen. The creek's convenient locale, accessible to South Island students, further underscores the feasibility of this approach. As a crucial component of Ladysmith's drinking water system, prioritizing regular monitoring is imperative to ensure the quality and integrity of the water source. Additionally, we propose the establishment of new monitoring stations, extending beyond the initial focus area above the town proper. This expansion aims to capture valuable data from areas below the golf course, encompassing more urban-influenced reaches.

4.1.1 Annual Monitoring Implementation

The overarching concern of inconsistent monitoring necessitates the establishment of an annual monitoring protocol for the Creek. By adopting a yearly monitoring schedule, We aim to enhance the scope of data collection, providing a more accurate understanding of the creek's ecological dynamics. This approach ensures the timely detection of any emerging trends or issues.

4.1.2 Strategic Monitoring Station Placement

To optimize data collection, we recommend the strategic placement of additional monitoring stations. While the initial focus was on the area above the town proper, expanding the testing perimeter below the golf course and into more urban-influenced reaches is crucial. This expansion ensures an assessment of the creek's water quality, considering the potential influences from both natural and anthropogenic sources. The selected monitoring stations should be strategically located to capture variations in water quality throughout the creek's course.

4.1.3 Invertebrate Surveys for Ecological Health

An integral component of the proposed monitoring strategy involves conducting more comprehensive invertebrate surveys. Previous assessments have indicated a significant decline in invertebrate populations, warranting further investigation. By employing standardized invertebrate sampling methodologies, the survey aims to quantify and analyze the invertebrate population, not its variance. This data will contribute to assessing the ecological health of the Ladysmith Drinking Water System and identifying potential stressors affecting the invertebrate populations as these are key sentinel species.

4.1.4 Comparative Analysis with Previous Surveys

The study acknowledges the notable decrease in invertebrate populations compared to historical surveys. To elucidate the reasons behind this decline, a comparative analysis should be conducted. Factors such as land use changes, habitat alterations, and water quality parameters should be examined to identify potential causation. This analysis can guide targeted conservation and restoration efforts to mitigate any adverse impacts on the creek's ecosystem.

4.2 Conclusion

In conclusion, the proposed enhancements in monitoring frequency, station placement, and invertebrate surveys aim to provide a comprehensive understanding of the Ladysmith Drinking Water System Creek. These technical recommendations form a robust framework for sustaining the creek's ecological integrity and ensuring the continued delivery of high-quality water to the residents of Ladysmith while hopefully creating a healthy ecosystem for fish and fish habitat. With some increase in the levels of metals, and a reduced invertebrate population it is clear that construction and other human activity have influenced the creek, however, it appears to be a healthy and resilient ecosystem. We know that there are effects on the creek but a reliable baseline of data needs to be established to truly understand Holland Creek and its functions. With more frequent monitoring it would be easier to understand not only the effects of the changes, but more importantly what is causing them. Ladysmith has seen growth in its population in recent years and it doesn't appear to be slowing down which will likely cause an increase in water demand. Holland Creek is a beautiful and popular area for Ladysmith residents and many others, while also serving as the town's main water supply. It appears to be in good health with some minor concerns, and an increase in monitoring would help ensure it stays that way for a long time to come.

5.0 References

Atlas Science Environmental Robotics. 2022. Dissolved Oxygen In Water: PPM For Fish. <https://atlas-scientific.com/blog/dissolved-oxygen-in-water-ppm-for-fish/>. Accessed December 9, 2023.

MacNeill S, Lattanzi B. 2012. Holland Creek Environmental Monitoring Water Quality and Invertebrate Population Assessment. Prepared for John Morgan by RMOT 306. Nanaimo BC. 43 p.

Morrison P. 2023. RMOT 306 – C – Water Quality 2023. Nanaimo (BC): Vancouver Island University.

Taccogna, G. and K. Munro (eds). 1995. The Streamkeepers Handbook: a Practical Guide to Stream and Wetland Care. Salmonid Enhancement Program, Dept. Fisheries and Oceans, Vancouver, BC.

6.0 Appendix

Site #	**Event 1**	**Event 2**
Site 1	11.2	11.6
Site 2	11.9	11.2
Site 3	11.8	11.8

Site 4	11.8	11.5

Table 1: Dissolved oxygen results

Site #	**Event 1**	**Event 2**
Site 1	10	4
Site 2	10	4
Site 3	12	4
Site 4	9	4

Table 2: Water temperature results

Site #	**Event 1**	**Event 2**
Site 1	2	5.7
Site 2	2	6.9
Site 3	3	5.6
Site 4	2	5.5

Table 3: Air temperature results

Site #	**Event 1**	**Event 1 Lab**	**Event 2**	**Event 2 Lab**
Site 1	9.1	8.1	7.8	7.5
Site 2	8.8	8.1	7.9	7.7
Site 3	8.6	8.1	7.9	7.6
Site 4	8.4	8.1	7.9	7.7

Table 4: pH results

Site #	**Event 1**	**Event 1 Lab**	**Event 2**	**Event 2 Lab**
Site 1	30	37	36	30
Site 2	27	30	30	27
Site 3	25	30	28	27
Site 4	25	29	28	27

Table 5: Conductivity results

Site #	**Event 1 (lab)**	**Event 2 (lab)**
Site 1	13	20
Site 2	15	28
Site 3	14	16
Site 4	12	18

Table 6: Hardness results (Mg/Litre CaCO3)

Site #	**Event 1 (lab)**	**Event 2**
Site 1	9.5	6
Site 2	7.4	5.35
Site 3	7.8	6.25
Site 4	5.6	5.35

Table 7: Alkalinity results (# of drops)

Site #	Event 1Lab	Event 2 Lab
Site 1	.55	.59
Site 2	.39	.46
Site 3	.39	.31
Site 4	.65	.69

Table 8: Turbidity results (NTU)

Site #	Event 1 Lab	Event 2 Lab
Site 1	.02	.01
Site 2	.03	.02
Site 3	.03	.02
Site 4	.05	.08

Table 9: Phosphate results (mg/l)

Nitrate Table

Site #	Event 1 (Lab)	Event 2 (Lab)
Site 1	.12	.13
Site 2	.11	.11
Site 3	.11	.12
Site 4	.14	.8

Table 10: Nitrate results

Characteristic (field)	Event 1 (Avg)	Event 2 (Avg)	2012 event 1	2012 event 2	Trends
Dissolved oxygen	11.6	11.5	11.7	11.2	Stable
Temperature (air)	10	4	10	5	Stable

Temperature (water)	2.25 C	5.8 C	6.6 C	4.9 C	Stable
Conductivity	27	28	22	18	Increasing
PH	8.05	7.9	6.9	7.16	Increasing
Nitrate	.115	.11	.12	.04	Stable
Phosphorous	.0325 mg/l	.0325 mg/l	.075	.14	Decreasing
Alkalinity	7.6	6.1	10	10.4	Decreasing
turbidity	.48	.51	2.5	.38	Decreasing
hardness	13.5	20.5	10	10	Increasing

Table 11: Trends between studies done in 2023 and 2012

Characteristic	**ALS Event 1**	**ALS Event 2**	**2012 ALS 1**	**2012 ALS 2**
Conductivity	47.7	36.5	28.3	18.7
pH	7.0	6.89	7.02	6.4
Nitrate	.0660	.0530	.162	.0507
Phosphorus	.0080	.0061	.034	.0045
Hardness	14.4	11.4	11.55	7.15

Table 12: ALS Data 1

Characteristic	**Event 1**	Event 2

	Site 1	Site 3	Site 1	Site 3
Ammonia	.0068	<.0050	<.0050	<.0050
Aluminum	.124	.103	.0772	.0759
Antimony	<.00010	<.00010	<.00010	<.00010
Arsenic	.00014	.00012	.00011	<.00010
Barium	.00499	.00471	.00371	.00361
Beryllium	<.000020	<.000020	<.000020	<.000020
Bismuth	<.000050	<.000050	<.000050	<.000050
Boron	.036	.034	.030	.030
Cadmium	<.0000050	<.0000050	<.0000050	<.0000050
Calcium	4.25	3.75	3.80	3.12
Cesium	<.000010	<.000010	<.000010	<.000010
Chromium	<.00050	<.0050	<.0050	<.0050
Cobalt	<.00010	<.00010	<.00010	<.00010
Copper	.00120	.00124	.00082	.00067
Iron	.102	.061	.034	.027
Lead	.000072	.000060	<.000050	<.000050
Lithium	<.0010	<.0010	<.0010	<.0010
Magnesium	.767	.617	.640	.533
Potassium	.320	.282	.169	.140
Rubidium	.00059	.00066	.00033	.00036
Selenium	<.000050	<.00050	<.000050	<.00050
Silicon	3.43	3.23	3.40	3.19
Silver	<.000010	<.000010	<.000010	<.000010
Sodium	3.31	2.62	2.53	2.14

Strontium	.0321	.0251	.0239	.0195
Sulfur	.53	<.50	<.50	<.050
Tellurium	<.00020	<.00020	<.00020	<.00020
Thorium	<.00010	<.00010	<.00010	<.00010
Tin	<.00010	<.00010	<.00010	<.00010
Titanium	.00321	.00177	.00087	.00064
Tungsten	<.00010	<.00010	<.00010	<.00010
Uranium	.000039	.000037	.000034	.000034
Vanadium	.00067	.00050	<.00050	<.00050
Zinc	<.0030	<.0030	<.0030	<.0030
Zirconium	<.00020	<.00020	<.00020	<.00020

Table 13: ALS Data 2