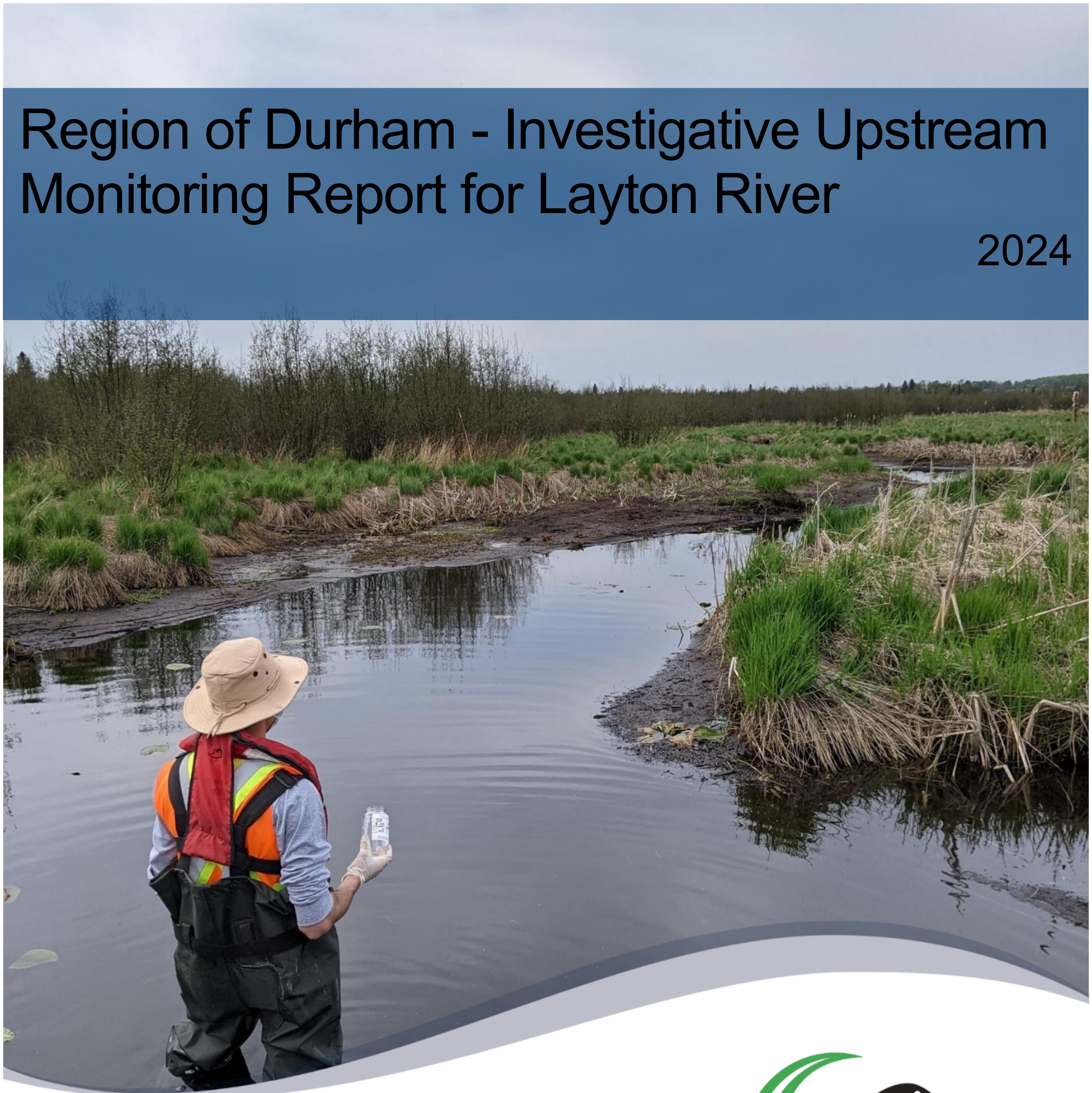
Region of Durham - Investigative Upstream Monitoring Report for Layton River

2024



KAWARTHA CONSERVATION

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About Kawartha Conservation

Who we are

We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?

Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support

We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance

In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*. The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan Monaghan.

KAWARTHA CONSERVATION

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Acknowledgements

We would like to acknowledge that many Indigenous Nations have longstanding relationships, both historic and modern, with the territories upon which we are located.

Today, this area is home to many Indigenous peoples from across Turtle Island. We acknowledge that our watershed forms a part of the treaty and traditional territory of the south-eastern Anishinaabeg.

It is on these ancestral and Treaty lands that we live and work. To honour this legacy, we commit to being stewards of the natural environment and undertake to have a relationship of respect with our Treaty partners.

The region of Kawartha Lakes was referred to as Gau-wautae-gummauh, a glistening body of water, in Anishinaabemowin. We are thankful to have an opportunity to work with Indigenous Peoples in the continued stewardship and care of this beautiful region.

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Executive Summary

From 2019 to 2022, Kawartha Conservation staff conducted water quality monitoring across 11 sites in Layton River watershed. Water quality, flow patterns, land use/land cover, and climate data were gathered and compiled into a comprehensive dataset for analysis.

Water quality analysis determined that there were three sites of concern (LR6, LR7, and LR8E) with marginal water quality indicating elevated levels of nutrients and reduced oxygenation. Results also indicated that there were no significant water quality concerns for pH, water clarity, and salts at the monitoring locations.

Water levels near the outflow of the river had variable ranges from 0.11 m during drought periods to 1.8 m during the spring melt. Overall, flow patterns are governed by the spring melt and rain events. Sites LR9, LR8E, and LR8W are near headwater sources and are governed by groundwater inputs, leading to consistent water levels.

Levels (mass) of nitrate were only found at LR8E, whereas phosphorus was found at LR6 and LR8E only. This further emphasizes the concern for site LR8E as it has elevated levels of nutrients and is situated near the headwaters of Layton River. Restoration/stewardship work at LR8E will support the regeneration of water quality downstream and should be a focus for future work with willing landowners.

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Abbreviations

%	Percentage
%CV	Coefficient of variation
µg/L	Micrograms per liter
µS/cm	Microsiemens per centimeter
ºC	Degree Celsius
CCME	Canadian Council of Ministers of the Environment
Cl	Chloride
Cond	Conductivity
CWQG	Canadian Water Quality Guideline
DO	Dissolved Oxygen
ERC	Ecological Reference Condition
et al.	et alibī (latin phrase) meaning and other authors
FNU	Formazin Nephelometric Unit
ha	Hectare
kg	Kilograms
km_2	Square kilometers
m_3/s	Cubic metre per second
mg/L	Milligrams per liter
n	Sample size
NH_3-N	Ammonia-Nitrogen
NO_2-N	Nitrite-Nitrogen
NO_3-N	Nitrate-Nitrogen
NTU	Nephelometric Turbidity Unit
p	p-value
PRC	Physical Reference Condition
PWQO	Provincial Water Quality Objectives
Temp	Temperature
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total suspended solids
Turb	Turbidity
yr	Year
ρ	Spearman's rho

1. Introduction

Lake Scugog is an artificial shallow lake situated in the Region of Durham, Central Ontario. Given its proximity to the Greater Toronto Area, the lake and its surrounding watershed have become popular destinations for tourism and recreational activities. It is estimated that Lake Scugog watershed generates more than $200 million in ecosystem services, including climate regulation, flood control, water purification, and recreational opportunities (Anielski Management Inc, 2019).

Kawartha Conservation developed the Lake Scugog Environmental Management Plan (LSEMP) to accomplish three primary objectives: 1) characterizing the Lake Scugog watershed, 2) identifying any water quality issues, and 3) proposing both short-term and long-term solutions that support the preservation and enhancement of ecosystem services. In the LSEMP report, the Nonquon River was second only to Cawkers creek as the largest contributor of phosphorus and nitrogen to Lake Scugog (Kawartha Conservation, 2010). As a result of the LSEMP report, a comprehensive investigation into Cawkers Creek was conducted between 2018 and 2021 to assess areas of concern characterized by 6the higher levels of exceedance of provincial and Canadian water quality thresholds (Kawartha Conservation, 2023a).

Following the investigation of Cawkers Creek, Kawartha Conservation turned its attention to Layton River, a part of the Nonquon River watershed, with the objective of pinpointing 'hot spots' that might exhibit elevated levels of nutrients or contaminants. By identifying these ‘hot spots’, remediation and restoration efforts can be focused upon with willing landowners and reduce the amount of contaminants flowing into Lake Scugog, contributing to enhancement of ecosystem and recreational services.

2. Methods

2.1. Study Area

Layton River holds the distinction of being the largest river within the Nonquon River watershed, ultimately flowing into the western basin of Lake Scugog (**Figure 1**). Stretching across approximately 21.8 kilometers, it courses from north near Manilla, to south toward Seagrave, converging with the Nonquon River just north of Scugog Line 12. The entire Layton River watershed encompasses an area of 52.3 km^2 with agricultural land accounting for roughly 63.2%, natural areas comprising 34.3%, and development covering 2.5% of the total land.

Layton River's outflow has been under continuous monitoring as part of the LSEMP program since 2004. Historical water quality data reveals that Layton River's outflow failed to meet the interim Provincial Water Quality Objective (PWQO) for total phosphorus in streams and rivers, set at 0.03 mg/L (MOEE, 1994) approximately 63.6% of the time. When total phosphorus levels are below the PWQO threshold of 0.03 mg/L, it is anticipated that excessive algae growth in rivers and streams should be mitigated.

2.2. Field and Laboratory Methods

A total of nine sites were selected for this study (**Figure 1**) capturing about 69% of the drainage area for Layton River watershed. Each site underwent monthly monitoring throughout the ice-free period, spanning from April to October between 2018 and 2021. It's noteworthy that no monitoring activities took place in 2020 due to the COVID-19 pandemic. During each monitoring session at these sites, both a surface water quality sample and an instant discharge measurement were collected.

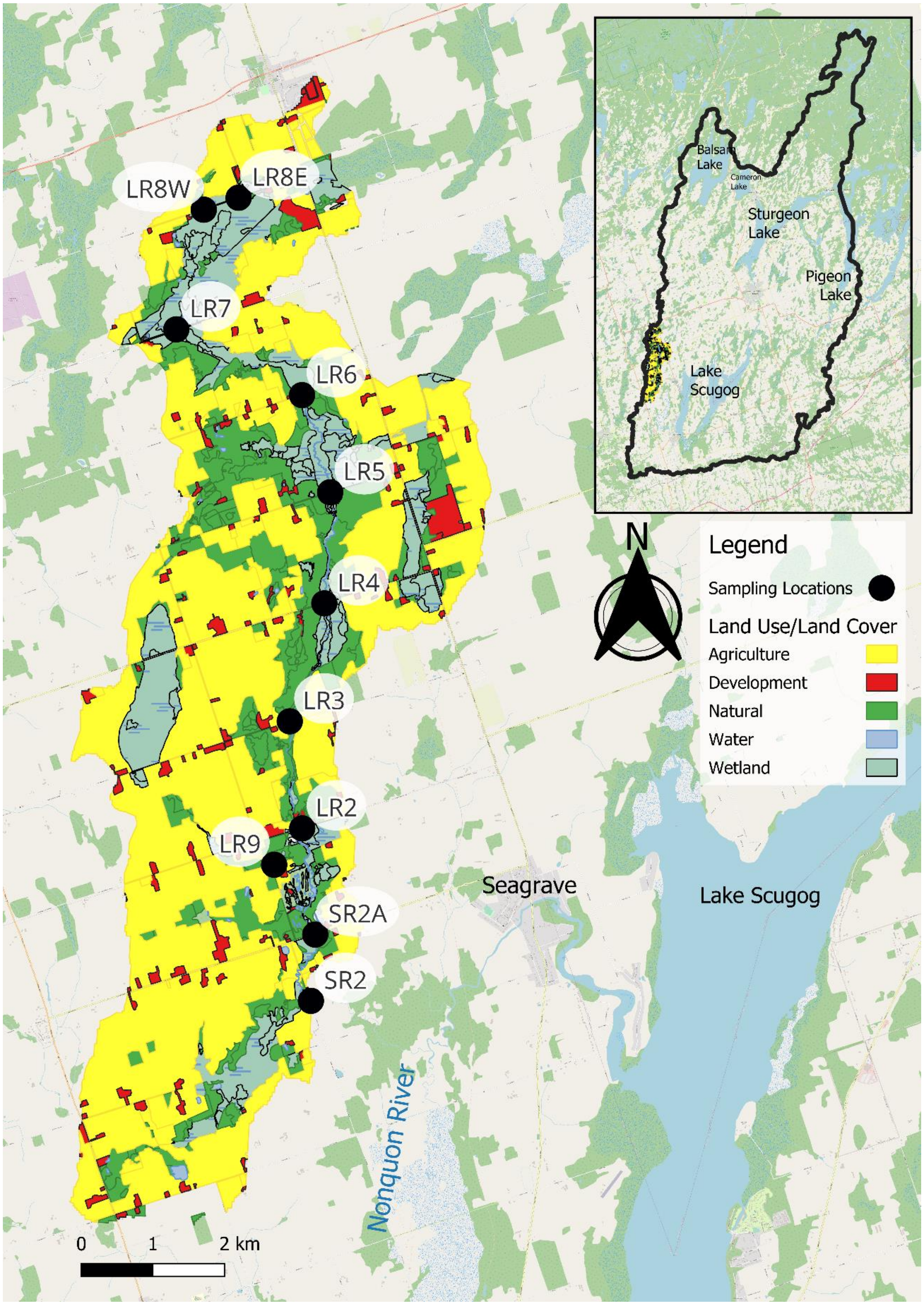


Figure 1. Sampling locations across the Layton River watershed along with land use/land cover, i.e., agriculture (yellow), natural (dark green), wetland (cyan), and developed (red).

Instant discharge measurements (in cubic meters per second, m^3/s) were determined by measuring the velocity and cross-sectional area of each site using a Flow-tracker and OTT MR Pro Flow Meter device. To maintain the integrity of the water sample and minimize the risk of contamination, the sample container underwent a thorough triple rinsing with water from the specific site before sampling. Surface water samples were obtained from a depth of 0.15 to 0.3 m below the water's surface.

Field parameters such as Water Temperature (Temp.), pH, Conductivity (Cond), Dissolved Oxygen (DO), and Turbidity (Turb) were all directly measured in the field using a water quality meter. Subsequently, these surface water samples were handled with care, stored at temperatures below 4°C during transport, and preserved to minimize potential alterations in water quality. They were then sent to Caduceon Environmental Laboratories for chemical analysis, including Chloride (Cl), Nitrite-N (NO_2-N), Nitrate-Nitrogen (NO_3-N), Ammonia-Nitrogen (NH_3-N), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), and Total Suspended Solids (TSS).

2.3. Data Analysis

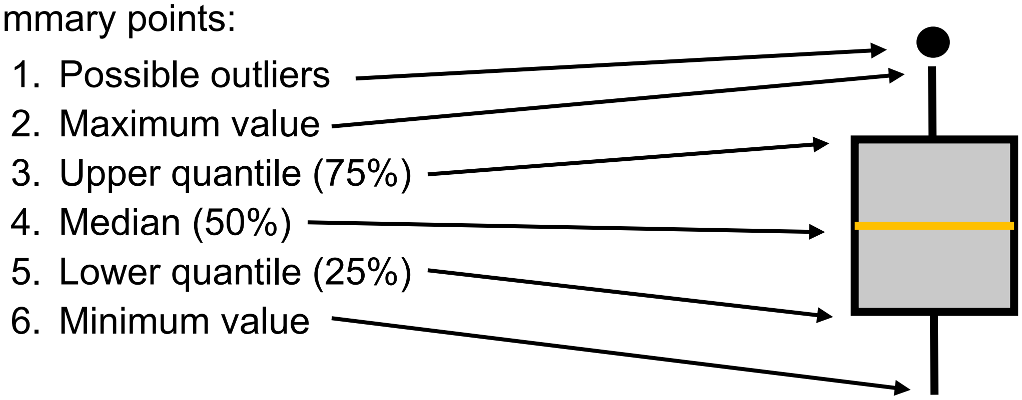
Additional data sources were integrated into this project, encompassing:

- Further water quality data sourced from the Lake Scugog Environmental Management Plan, specifically from site SR2 and SR2A, spanning the years 2019 to 2022.
- Supplementary flow and discharge data collected from the Layton River gauge station as part of the Lake Scugog Environmental Management Plan.
- Land use/ land cover (LU/LC) and catchment characteristics, procured through the Southern Ontario Land Resource Information System (SOLRIS) via the Ontario Watershed Information Tool (OWIT) (Government of Ontario, 2015).
- Climate data (precipitation) data was obtained through the Water Survey of Canada station at Mariposa Brook (Station ID: 02HG001).

All data analysis was conducted utilizing the statistical software R (R Core Team, 2021). The calculation of the Percent Coefficient of Variation (%CV) for pH adhered to the methodology outlined by Canchola et al., (2017). In instances where observations were absent, values were marked as NA, while those falling below detection limits were addressed using the R package NADA (Lopaka, 2020). Total Nitrogen values were derived through the sum of Nitrite-N, Nitrate-N, and Total Kjeldahl Nitrogen.

How to read boxplots (Box and Wiskers)

A boxplot is a graph that shows the spread of the data, along with six key summary points:



Quantile is a cut-off point when the data is ordered largest to smallest.

It is important to note that the majority of parameters deviated significantly from a normal distribution and did not conform to linearity assumptions. The relationships between these parameters were assessed through a spearman's correlation matrix and principal component analysis. Visual representations of individual datasets are presented in the form of boxplots.

Water quality results were compared to the following objectives and guidelines:

Parameter	**Value**
Dissolved Oxygen	6.0 mg/L (CCME, 1999) Temperature dependent (PWQO, MOEE, 1994)
pH	< 6.5 and > 8.5 (PWQO, MOEE, 1994)
Turbidity	8 FNU increase background (CCME, 2002)
Phosphorus	0.03 mg/L for rivers and stream (PWQO, MOEE, 1994)
Ammonia	0.019 mg/L as un-ionized ammonia (CCME, 2010) 0.02 mg/L as un-ionized ammonia (PWQO, MOEE, 1994)
Nitrate	3.0 mg/L as Nitrate-nitrogen (CCME, 2012)
Chloride	Long-term Exposure: 120 mg/L Short-term Exposure: 640 mg/L (CCEM, 2011)
Total Suspended Solids	25 mg/L increase form background (CCME, 2002)

The CCME Water Quality Index (WQI) (CCME, 2017) program was used to provide a convenient mean to summarize all water quality results. The WQI assesses the overall health of the site based on the number of parameters (such as those outlined above) that fail to meet guidelines, the frequency of the failure, and the total number of observations that fail to meet the guideline. The WQI digested the results and is able to assign the site to different categories based on the final score.

WQI Category	**WQI Score**	**Index Description (Taken from CCME, 2017)**
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment: conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

By combining the concentrations of water quality parameters obtained on the same day, considering the area of the upstream catchment, and incorporating discharge values, we can precisely calculate loadings using the following formula: Loading = (Concentration X Discharge) / Area. Annual loading values are derived from the summation of daily discharge values throughout the year and are expressed in kilograms per hectare per year (kg/ha/yr).

Total Nitrogen (TN) was calculated through the sum of nitrate, nitrite, and TKN. Prior to TN calculation, both nitrate-n and nitrite-n were converted to their nitrate and nitrite forms, respectively. The TN to TP (Total Phosphorus) ratios, as discussed in **Section 3.5**, were computed as TN / TP. Raw data can be found in **Appendix A** (Landuse)**, B** (Water Quality)**, B** (Hydrology), **C** (Principal Component Analysis).

3. Results and Discussion

A network of eleven monitoring sites was established for the continuous observation of Layton River from 2019 to 2022 (**Figure 1**). However, due to the COVID-19 Pandemic, monitoring of Layton River was temporarily halted during that period. Notably, sites SR2 to LR8 are situated along the main watercourse, while LR9 represents a sub-tributary of Layton River (**Figure 1**).

The LU/LC composition across the study sites exhibited a consistent pattern. Agriculture dominated the landscape, followed by natural areas, and lastly, urban, and developmental zones. In general, urban LU/LC areas accounted for less than 5% of the total land cover, with the exceptions being LR7 at 5.7% and LR8E at 10.9%. This trend has persisted since 2008, with agricultural land use remaining the dominant land cover type (refer to **Figure 2**).

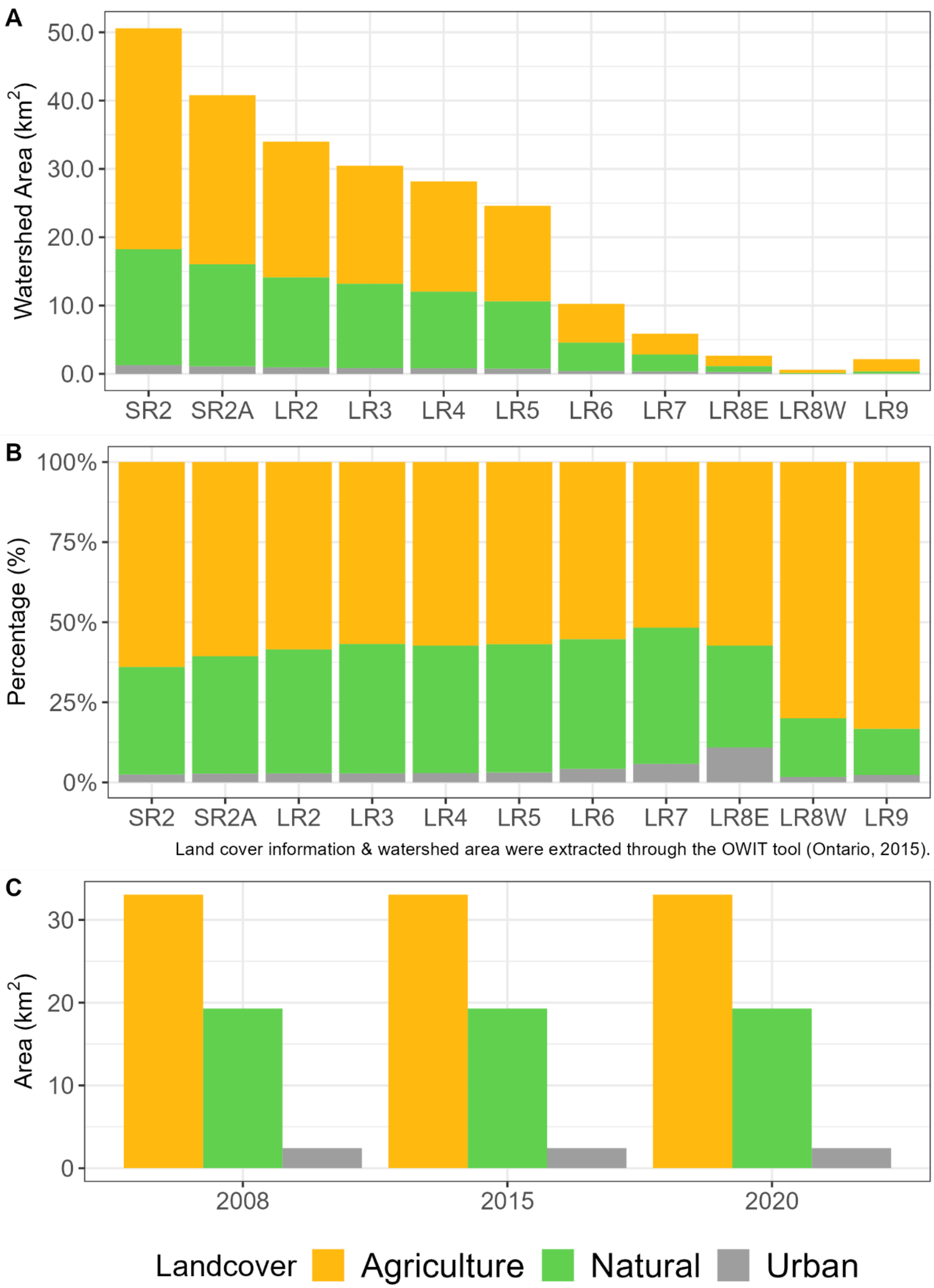


Figure 2. Land cover type by site catchment in km^2 (**A**) and percentage (**B**). Land cover type and area for the whole Layton River for each year: 2008, 2015, and 2020 (**C**).

Table 1 Number of observations, mean, median and coefficient of variation (CV%) of all physical and chemical parameters by site.

Site	Stats	°C Temp.	pH	µS/cm Cond.	NTU Turbidity	mg/L Dissolved Oxygen	mg/L Chloride	mg/L Nitrate-N	mg/L Ammonia-N	mg/L Total Kjeldahl Nitrogen	mg/L Total Phosphorus	mg/L Total Suspended Solids	mg/L Total Nitrogen
All	Count	158	149	158	141	154	115	115	112	115	115	114	115
	Mean	16.9	7.7	615.9	5.1	7.1	27	1.1	0.1	0.8	0	7.9	2.2
	Median	17	7.8	586	3	7.5	23.9	0.1	0.1	0.7	0	4	1.4
	CV%	22.2	63.8	23.5	204.8	40.2	46.5	177.8	73.5	56.4	75.1	354.5	93.5
LR2	Count	15	14	15	13	15	11	11	11	11	11	11	11
	Mean	16.4	7.9	597.5	3.5	8.5	26.6	0.4	0.1	0.8	0.1	3.9	1.7
	Median	16.3	8	565	2.6	8.5	23	0	0.1	0.6	0	2.1	1.6
	CV%	24.2	72.4	20.3	77.7	27.5	52.2	96.8	64.6	51	59.8	67.2	52.5
LR3	Count	14	13	14	12	14	10	10	10	10	10	10	10
	Mean	17.9	7.8	606.8	3.1	7.5	26.6	0.3	0.1	0.8	0	4.3	1.5
	Median	16.9	7.9	572	2.8	6.9	22.9	0	0	0.6	0	1.4	1.5
	CV%	33	58.2	32.8	55.4	38.1	52.1	122.4	63.3	53.5	58	79.6	32.8
LR4	Count	15	14	15	13	15	11	11	11	11	11	11	11
	Mean	17.7	7.7	609.6	5.7	6.6	26	0.4	0.1	0.8	0	4.1	1.4
	Median	18.3	7.8	576	1.6	6.6	20.6	0	0	0.7	0	1.7	1.2
	CV%	15.4	63.2	18.6	222.1	38.6	53.4	174.6	62.2	49.1	53.5	73.4	49.3
LR5	Count	22	21	22	20	22	12	12	12	12	12	12	12
	Mean	19	7.6	596.3	3.2	6.2	25.4	0.1	0.1	0.9	0.1	4.8	1.3
	Median	18.7	7.7	588	2	6.9	7	0	0	0.3	0	0.6	1
	CV%	31.6	61.6	33	99.7	53.8	57.8	116.9	89.8	63	79.9	82.2	43.5
LR6	Count	14	13	14	12	14	10	10	10	10	10	10	10
	Mean	18.7	7.4	604.1	2.3	3.6	22.1	0	0.1	1	0.1	10	1.1
	Median	18.6	7.5	575	1.1	2.6	19.6	0	0.1	0.7	0	3	1
	CV%	29.9	67.7	34	100.8	77.2	51.4	89.2	85	59.4	78.8	160	33.6

Table 1 Continued.

Site	Stats	°C Temp.	pH	µS/cm Cond.	NTU Turbidity	mg/L Dissolved Oxygen	mg/L Chloride	mg/L Nitrate-N	mg/L Ammonia-N	mg/L Total Kjeldahl Nitrogen	mg/L Total Phosphorus	mg/L Total Suspended Solids	mg/L Total Nitrogen
LR7	Count	21	20	21	19	21	11	11	11	11	11	11	11
	Mean	17.4	7.5	616	11.2	6.2	35.8	2	0.1	0.6	0	4.2	2.6
	Median	16.3	7.6	598	2	4.9	0	0	0	0	0	0	1.1
	CV%	37.4	69.5	39.6	194.5	75.4	63.4	99.8	72.4	55.8	65.9	79.4	89.5
LR8E	Count	13	12	13	11	13	11	11	11	11	11	11	11
	Mean	14.8	8.1	737.7	4.3	9.9	32	4.4	0	0.9	0	6.2	6.6
	Median	14.7	8.3	712	3	9.3	10.4	0	0	0.5	0	3	6.1
	CV%	37.3	61.3	43.8	60.4	38.6	77	86	81.9	112.8	51.6	74.2	44.1
LR8W	Count	15	14	15	13	15	11	11	11	11	11	11	11
	Mean	14.8	7.7	644.2	5.4	7.8	22.2	2.2	0.1	0.7	0.1	30.3	2.9
	Median	13.8	8.1	580	2.1	9.2	18.3	0	0	0.6	0	1.9	2.4
	CV%	20.4	144.7	29.6	142.6	36.8	62	105.6	80.5	67.3	132.7	248.2	90.4
LR9	Count	10	10	10	10	10	8	8	8	8	8	8	8
	Mean	15.3	7.9	606.4	3.1	7.9	24.6	1.3	0.1	0.8	0.1	3.4	2.6
	Median	13.6	8.1	605.5	1.6	7.1	15.4	0.1	0	0.3	0	1.1	2.2
	CV%	49.4	72.8	48.1	83.5	55.3	66.3	82.3	78.7	67.8	69.1	84.8	57.3
SR2	Count	14	12	13	12	9	14	14	13	14	14	13	14
	Mean	15.8	7.9	545.9	6.9	7.5	26.2	0.4	0.1	0.6	0.1	8.2	1.3
	Median	18.4	7.9	559.5	5.9	5.9	26.3	0.5	0.1	0.6	0.1	8	1.3
	CV%	39.5	52.5	31.2	58.9	55.7	20.6	84.1	45.6	22.8	40	49.4	16.4
SR2A	Count	5	6	6	6	6	6	6	4	6	6	6	6
	Mean	14.5	8	632.2	4.8	9	30.5	0.7	0	0.7	0	5.2	1.5
	Median	14.4	7.9	582.5	3.9	9.4	30.5	0.7	0.1	0.7	0	6	1.4
	CV%	47.9	34.1	34.5	74	36.7	15.7	31	22.2	11.1	44.9	40	12

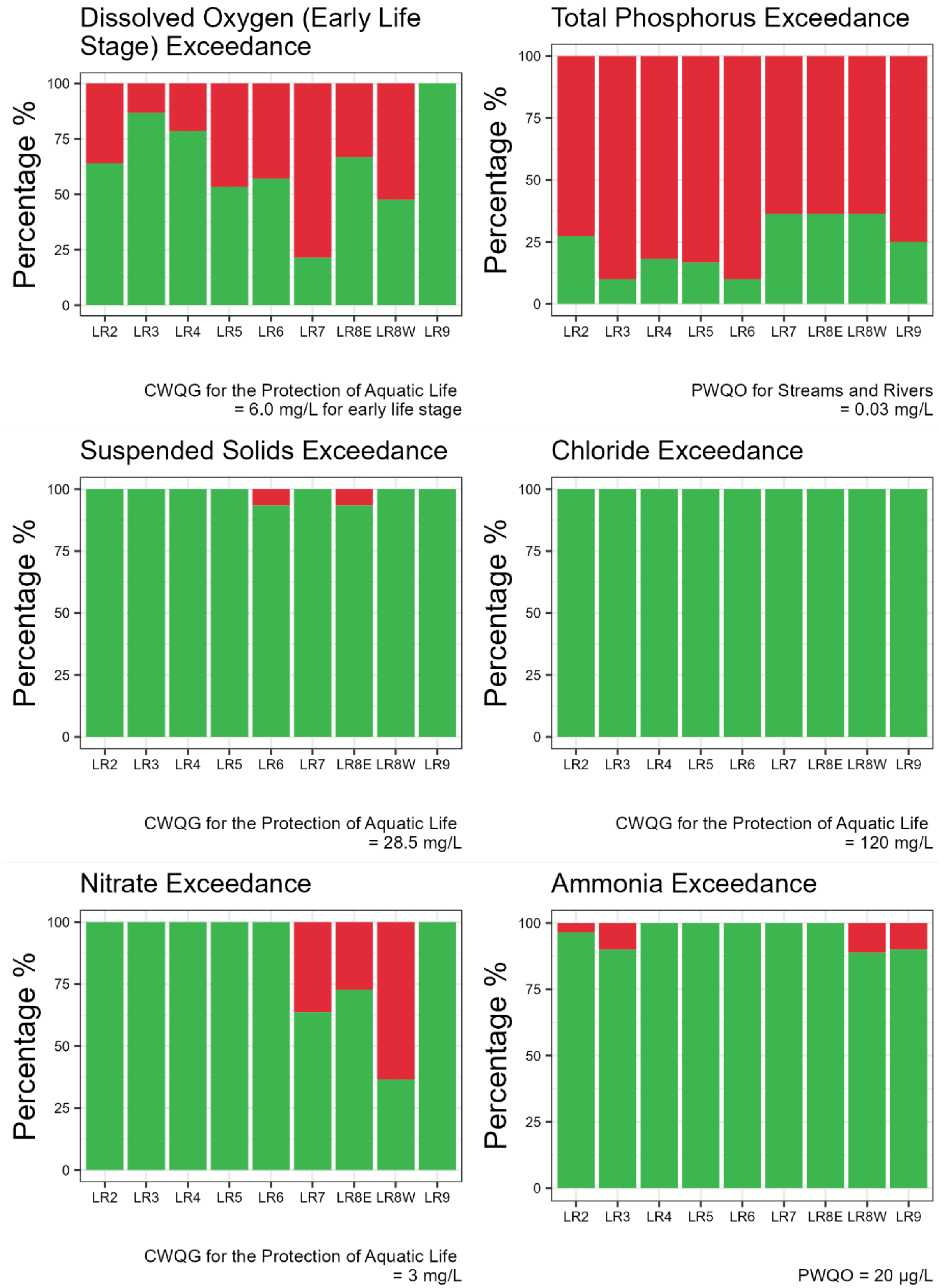


Figure 3. Exceedance percentage for dissolved oxygen, total phosphorus, total suspended solids, chloride, nitrate and ammonia per site. Red depicts exceeded percentage while green depicts acceptable percentages. Threshold values are given for each chart.

3.1. Dissolved Oxygen

Dissolved oxygen (DO) refers to the concentration of oxygen present in water. Oxygen is introduced into water through various natural processes, including the photosynthesis of aquatic plants, wave action, and the swift movement of water. It is a vital component for the survival of fish and other aquatic organisms. Different species exhibit varying oxygen requirements, with some being adapted to thrive in low-oxygen environments, while others necessitate higher oxygen levels. Furthermore, younger fish and fish eggs have higher demands for dissolved oxygen compared to other life stages.

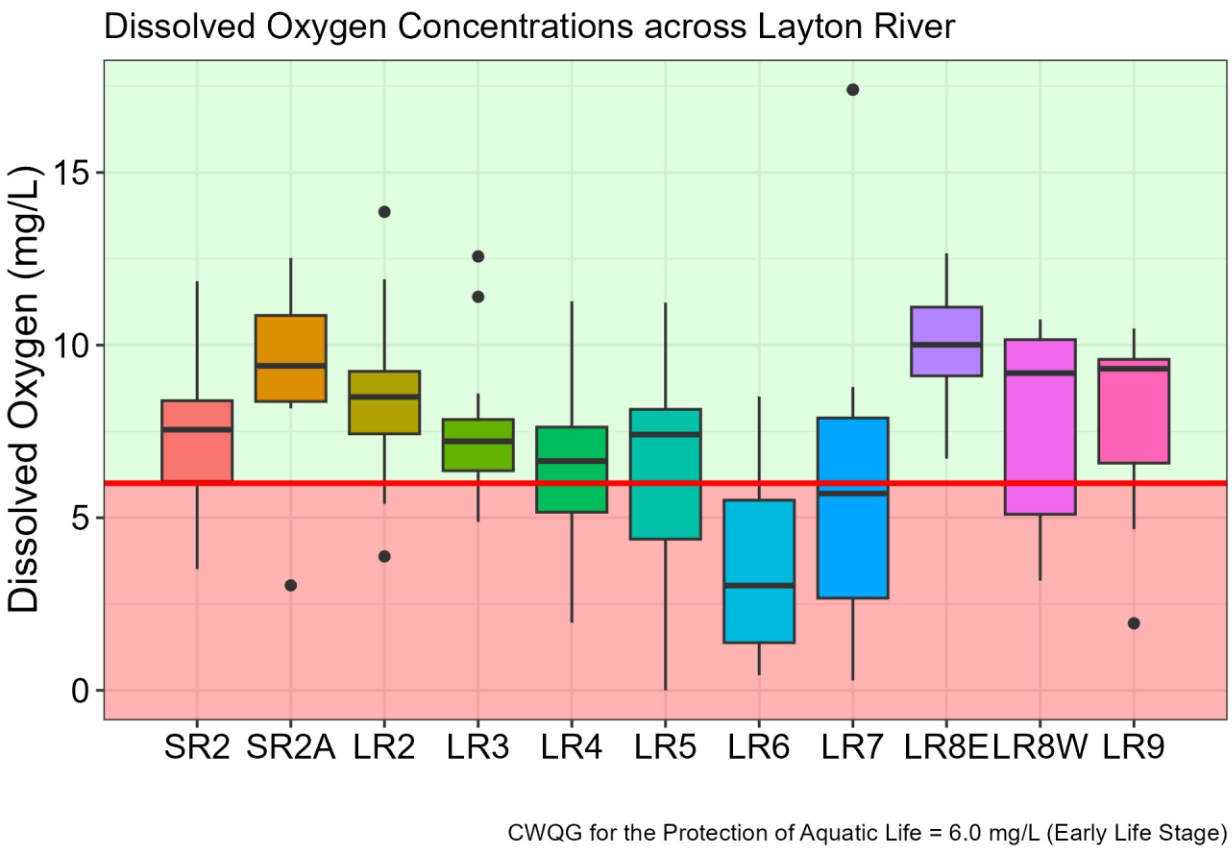


Figure 4. Range of dissolved oxygen levels across the eleven (11) sites on Layton River. The red line denotes the Canadian Water Quality Guideline for dissolved oxygen, where the area shaded in green depicts good levels of DO while the area below the line shaded in red denotes poor levels of DO.

In the case of a warm water system such as Layton River, we have established specific criteria to ensure the well-being of aquatic life. We have adopted a DO threshold of 6.0 mg/L, as recommended by the Canadian Council of Ministers of the Environment (CCME, 1999), to protect fish during their most sensitive life stage. Additionally, we consider temperature-dependent limits in accordance with the Provincial Water Quality Objective (MOEE, 1994).

Between 2019 and 2022, we conducted a total of 209 measurements of DO across Layton River. Among these observations, only 53, accounting for 34.4%, fell below the established threshold of 6.0 mg/L. This trend persisted when compared to the temperature-dependent thresholds set by the Provincial authorities.

When examining individual monitoring sites, notable rates of failure were observed at LR6 and LR7 (**Figure 3** and **4**), where more than 50% of the measurements (78.6% and 52.4%, respectively) were below the CWQG of 6.0 mg/L. Mean and median values of DO for LR6 and LR7 were calculated at 3.6 mg/L and 2.6 mg/L (LR6), and 6.2 mg/L and 4.9 mg/L (LR7) (**Table 1**).Following closely were LR4 (46.7%) and LR5 (42.9%) (**Figure 3** and **4**), where mean and median values were calculated at 6.6 mg/L and 6.6 mg/L (LR4) and 6.2 mg/L and 6.9 mg/L (LR5) (**Table 1**).

It is important to note that water temperature plays a significant role in DO levels. Colder waters tend to hold more oxygen, and this holds true for Layton River as demonstrated in **Figure 12**, where we observe a significant negative correlation between water temperatures and DO levels, i.e., the colder the temperature the higher the dissolved oxygen level. Among the monitoring sites in Layton River, LR8E, LR8W, and LR9 consistently exhibited excellent DO levels, median values are 9.3 mg/L, 9.2 mg/L, and 7.1 mg/L (**Table 1**). This is supported through their water temperature values where they maintained temperatures around 20°C during the months of July and August.

These sites are primarily groundwater-fed, as opposed to sites located further downstream, which may experience greater influence from surface water, such as surface runoff. Given the consistently favorable conditions at LR8E, LR8W, and LR9, these sites are of particular interest for hosting sensitive aquatic organisms and warrant further exploration.

3.2. pH

Water pH serves as a critical indicator of acidity or alkalinity within aquatic environments. It plays a pivotal role in regulating the availability of certain metals and influencing the suitability of aquatic ecosystems for various life forms.

In freshwater systems, water pH is predominantly influenced by the underlying geological composition. However, human activities, such as effluent discharge, smelting, and mining, can also alter pH levels, making the water either more acidic or more alkaline. The Provincial Water Quality Objective (PWQO) for pH, as established by the Ministry of Environment (MOEE, 1994), falls within the range of 6.5 to 8.5.

In the course of our program, we collected a total of 149 pH observations. Remarkably, only four observations fell outside the PWQO threshold of > 8.5 (**Figure 5**). All four of these values were notably more alkaline than 8.5. This alkalinity can be attributed to the geological characteristics of the region, specifically the presence of Phanerozoic bedrock, consisting of limestone and dolostone, which tends to produce alkaline soils and consequently results in more alkaline water readings.

The average pH value for Layton River was recorded at 7.7, with a median value of 7.8. pH values across the entire watercourse, encompassing all monitoring sites, exhibited a range from 7.1 to 10.3. Notably, the site with the highest alkalinity was LR8W, with an average pH of 8.09 and a median pH of 8.18 (**Table 1**). Elevated alkalinity can enhance water's resilience against rapid acidification. However, prolonged pH levels above 9 can have adverse effects on aquatic organisms and create environments conducive to the proliferation of certain unwanted species of algae, such as *Microcystis* and *Coccochloris*.

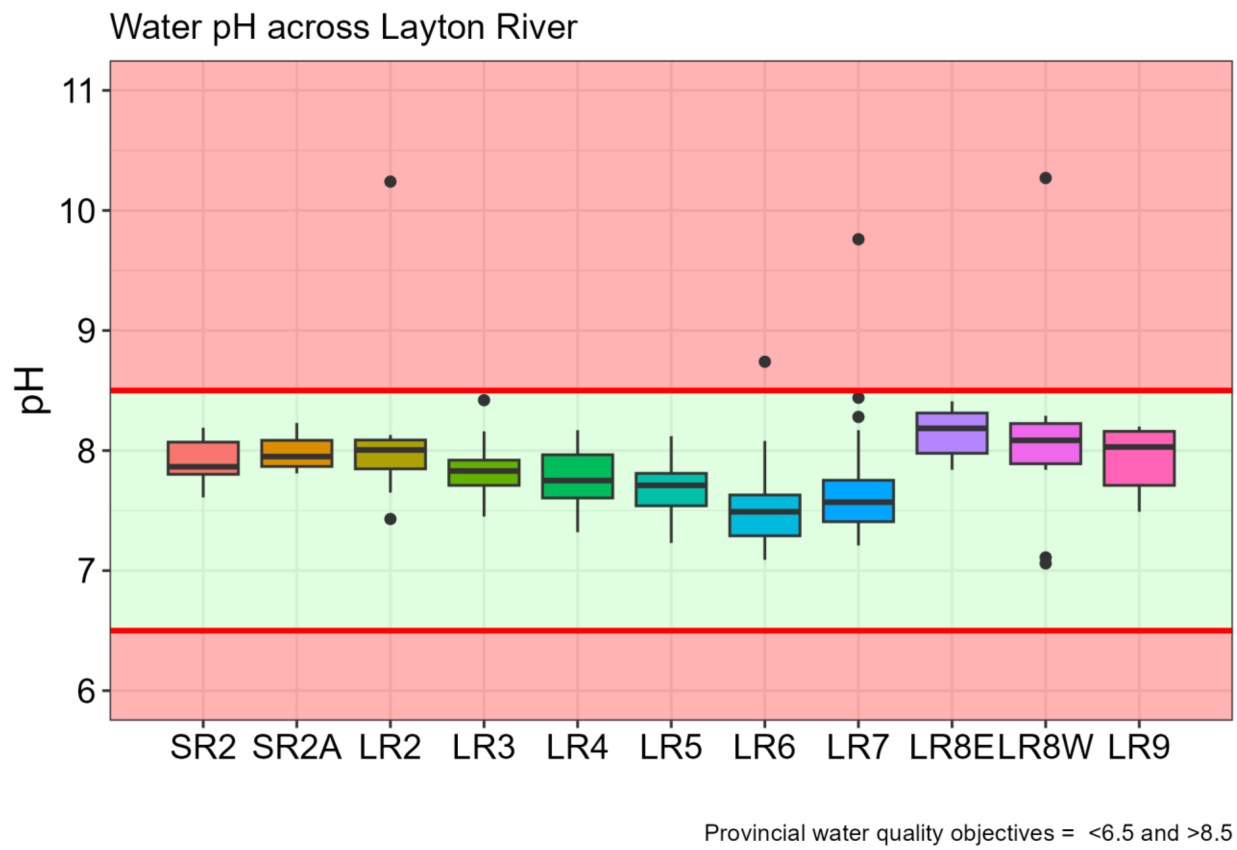


Figure 5. Range of pH levels across the eleven (11) sites on Layton River. The red lines denote the Provincial Water Quality Objectives thresholds for pH, where the area shaded in green depicts good levels of pH while the area below the line shaded in red denotes poor levels of pH.

Given that only 3% of pH readings exceeded the PWQO threshold, there is currently no immediate concern regarding water pH in Layton River. These results serve as a valuable baseline for future studies, which can monitor and compare water pH levels to determine if any concerning trends or deviations from the established standards are emerging within the Layton River ecosystem.

3.3. Turbidity

Turbidity is a measure of water clarity and can result from the presence of particles or substances, including dyes, within the water. A higher turbidity value indicates cloudier or murkier water. Typically, poor water quality is associated with elevated levels of turbidity. For instance, when an eroding riverbank gives way and introduces soil into the water, these soil particles can obstruct the passage of light, causing the water to appear turbid or murky. This can also be applied to point-source discharge from treatment/industrial facilities.

The Canadian Water Quality Guidelines for the Protection of Aquatic Life, as established by the Canadian Council of Ministers of the Environment (CCME, 2002), specify a maximum allowable increase of 8 nephelometric turbidity units (NTUs) from background levels. However, in the Kawartha Region, there hasn't been a defined "background" turbidity value established. Therefore, we adopted the median turbidity level of 2.25 Formazin Turbidity Units (FTUs), which was derived from data collected from 30 headwater streams in the Oak Ridge Moraine by Maude and DiMaio in 1996. Headwater streams are considered minimally impacted by human activities and typically have vegetated catchments. It is important to note that 1 NTU is considered equivalent to 1 FNU (Formazin Nephelometric Unit) and 1 FTU (Formazin Turbidity Unit). Applying this data to the CWQG results in a threshold value of 10.25 FNU.

At this established limit, only 8 observations (**Figure 6**), which represent 5.7% of all samples across all monitoring sites and events, exceeded the turbidity threshold. Notably, no single site consistently exhibited failure rates for turbidity, indicating that there are no significant concerns regarding its impact on aquatic life in the study area.

These findings suggest that the levels of turbidity in the water are generally within acceptable limits, and there are no immediate concerns related to its potential effects on aquatic ecosystems.

Although there no established benchmarks of turbidity within the Kawartha Region Conservation Authority's administration area, we recommend that such benchmarks are established. Methods should be similar to Maude and DeMaio (1996) by sampling least disturbed catchments. In addition, sampling should occur to capture a range of water and discharge levels.

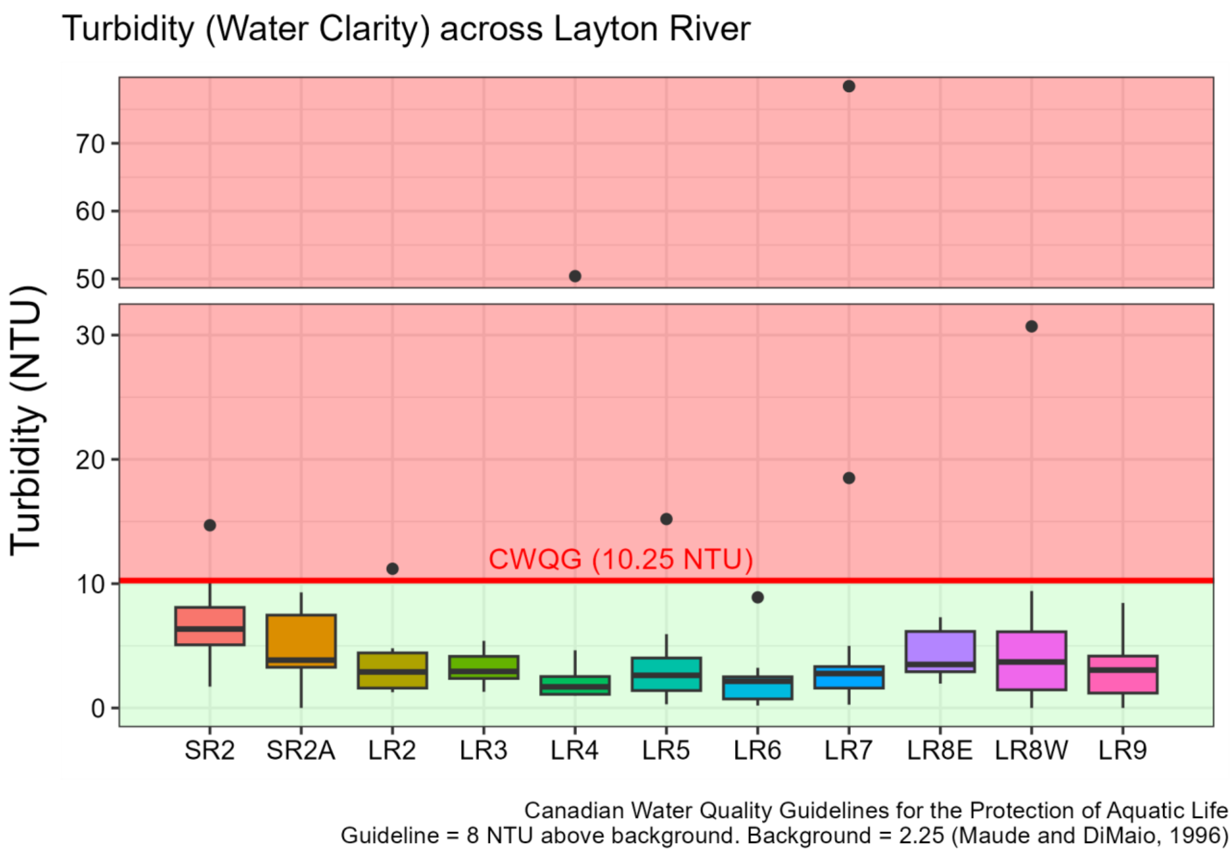


Figure 6. Range of turbidity levels across the eleven (11) sites on Layton River. The red line denotes the Canadian Water Quality Guideline for turbidity, where the background level was taken from Maude and DiMaio (1996). The area shaded in green depicts good levels of turbidity while the area above the line shaded in red denotes poor levels of turbidity.

3.4. Phosphorus (Total)

Phosphorus, a non-toxic and naturally occurring essential nutrient, plays a vital role in the growth of plants and animals. It is essential for DNA synthesis and bone formation. In freshwater ecosystems, phosphorus often serves as a limiting nutrient, controlling the extent of life that can thrive within the system. The balance of phosphorus can be adjusted to increase or decrease the abundance of life within an ecosystem. In aquatic systems, plants—whether rooted plants or algae—are the primary consumers of phosphorus. The growth of these plant groups not only contributes to the food supply for herbivores, including smaller fish, but also provides habitat for higher trophic-level organisms.

However, excessive phosphorus levels in a water system can lead to uncontrolled plant growth and algae blooms. These events can have adverse effects on human and environmental health, disrupt the aesthetics of the site, and diminish its recreational capacity. In our study of Layton River, we conducted over 100 samples across multiple monitoring years. Total phosphorus results indicate that the river is highly productive and can be classified as eutrophic, with approximately 58.3% of samples falling within the range of 0.035-0.1 mg/L (CCME, 2004). Being a highly productive system, the river can have a large carrying capacity with more aquatic organism than those that are nutrient poor.

The Ontario Provincial Water Quality Objective (PWQO) outlines an interim threshold of 0.03 mg/L for rivers and streams, designed to prevent excessive plant growth, roughly 77.4% of samples failed to meet the 0.03 mg/L threshold. (**Figure 7)**.

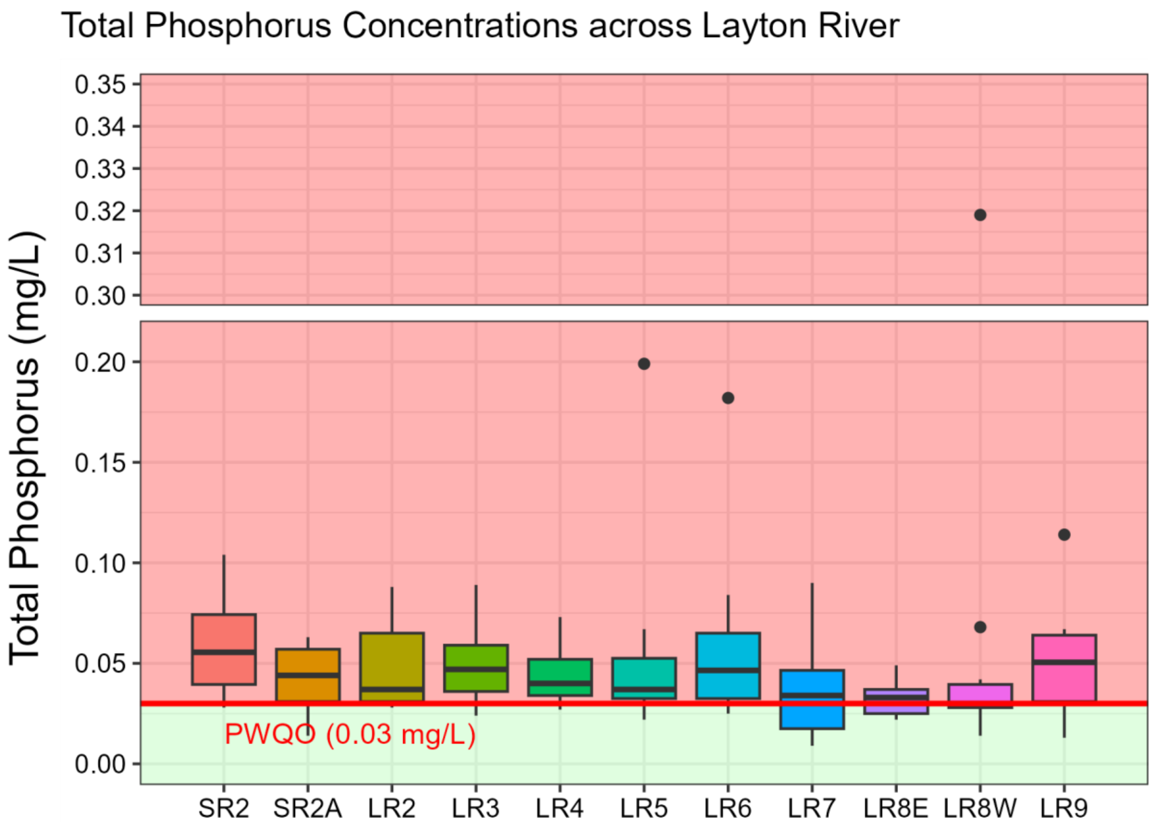


Figure 7. Range of total phosphorus levels across the eleven (11) sites across Layton River. The red line denotes the PWQO for total phosphorus (0.03 mg/L), where the area shaded in green depicts good levels of total phosphorus while the area above the line shaded in red denotes poor levels of total phosphorus.

Upon evaluating phosphorus levels at individual sites, we observed substantial exceedances, ranging from 63.6% to 90% of all samples. Most mean and median values at each site exceeded the PWQO (**Table 1; Figure 3** & **7**). Site LR3 and LR6 exhibited the highest exceedance rates, both at 90% (**Figure 3**). While it is common to expect higher phosphorus levels downstream, LR6, situated in the middle, deviated from this expectation. Therefore, it is crucial to focus on stewardship and restoration activities in the upstream area of LR6, engaging willing landowners in the process.

Our findings also revealed a correlation between higher phosphorus levels and warm periods, particularly during the summer (refer to **Figure 12**). The increased flow during the spring may dilute phosphorus levels in the river, whereas reduced water flow in the summer may lead to phosphorus concentration. Summer precipitation events, coupled with elevated human activities, may contribute to nutrient-rich runoff entering Layton River. Addressing phosphorus concerns from upstream of LR6 necessitates the establishment of both man-made and natural systems designed to capture and treat runoff effectively.

Based on the data, Layton River demonstrates a high level of productivity, with nutrient levels capable of sustaining a robust foundation of aquatic plants—a critical support system for all living organisms, including humans. Rooted plants and algae are the predominant phosphorus consumers in water, underscoring the importance of promoting the growth of native rooted plants to mitigate the risk of excessive algae growth, which can degrade water quality and pose health risks. A healthy foundation of rooted plants and algae can contribute to a healthy mass of fish higher up the trophic level.

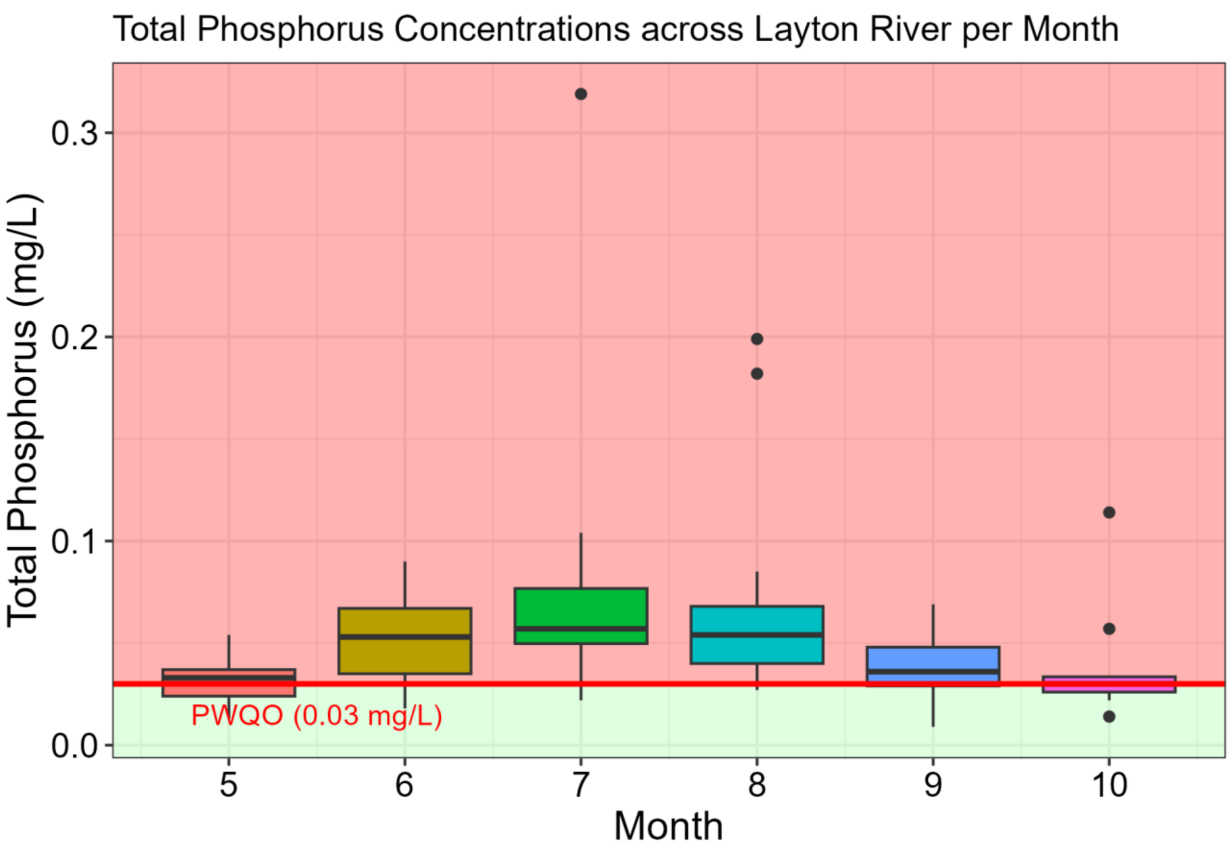


Figure 8. Range of total phosphorus levels (all sites) across months (5 = May, 6 = June, 7= July, 8 = August, 9 = September, and 10 = October). The red line denotes the Provincial Water Quality Objectives (PWQO) for total phosphorus (0.03 mg/L), where the area shaded in green depicts good levels of total phosphorus while the area above the line shaded in red denotes poor levels of total phosphorus.

3.5. Nitrogen

Similar to phosphorus, nitrogen is an essential nutrient vital for the growth of both aquatic plants and animals. Nitrogen can exist in various forms within water, depending on the biological and chemical conditions. Within the nitrogen group, we assessed the water for ammonia-nitrogen, Total Kjeldahl nitrogen (TKN), nitrite-nitrogen, and nitrate-nitrogen. The majority of the total nitrogen values (approximately 52%) were composed of TKN, followed by nitrate, and finally, nitrite as expected. The prevalence of TKN in TN indicates that the majority of nitrogen in Layton River is in the form of organic nitrogen.

While both phosphorus and nitrogen are essential nutrients for plants and animals, the ratios of total nitrogen to total phosphorus (TN:TP) can provide a basic understanding of which nutrient is limiting the system. Typically, TN:TP ratios below 20 suggest nitrogen limitation, while ratios exceeding 50 are indicative of phosphorus limitation (Guildford and Hecky, 2000). This information can assist managers in determining which nutrient source to manage for maintaining a healthy ecosystem.

In our calculations, the mean and median TN:TP ratios of 524 and 144, respectively, suggest that Layton River is phosphorus-limited. This implies that phosphorus is the primary nutrient limiting plant growth in this ecosystem, and controlling phosphorus inputs can help regulate plant growth effectively.

3.5.1. Ammonia (-Nitrogen)

Ammonia-nitrogen is particularly accessible for uptake by plants, including rooted plants, algae, and phytoplankton. Consequently, it acts as a catalyst for rapid algae blooms and uncontrolled growth of aquatic vegetation. At elevated levels, ammonia-nitrogen can have adverse effects on the blood chemistry, growth, and behavior of fish and other aquatic organisms.

Common sources of ammonia include agricultural runoff, stemming from fertilizers and livestock waste, as well as urban sources such as stormwater and treatment plants. Industrial discharges and natural processes, such as the decomposition of organic matter in soil and water, also contribute to ammonia levels. For ammonia, there exist both Provincial Water Quality Objectives and Canadian Water Quality Guidelines for the Protection of Aquatic Life. These limits and guideline values are based on the concentration of un-ionized ammonia, a parameter that can be calculated with water temperature and water pH.

In our study of Layton River, we collected and analyzed 83 water samples. Remarkably, only three of these samples exceeded the prescribed limits set by both the Provincial Water Quality Objectives and the Canadian Water Quality Guidelines. Each of these exceedances was isolated to specific sites (LR2, LR7, and LR8W) at one time. However, the extent of the exceedances was notably significant, with values as follows: PWQO = 0.02 mg/L (MOEE, 1994), LR2 = 0.12 mg/L, LR8W = 0.12 mg/L, LR7 = 0.08 µg/L. These sites also exceeded the Canadian Water Quality Guidelines (CCME, 2010).

It's important to highlight that these isolated exceedances were associated with individual events and do not raise significant concerns based on our monitoring data. The infrequency of such occurrences suggests that Layton River generally maintains ammonia levels within acceptable limits.

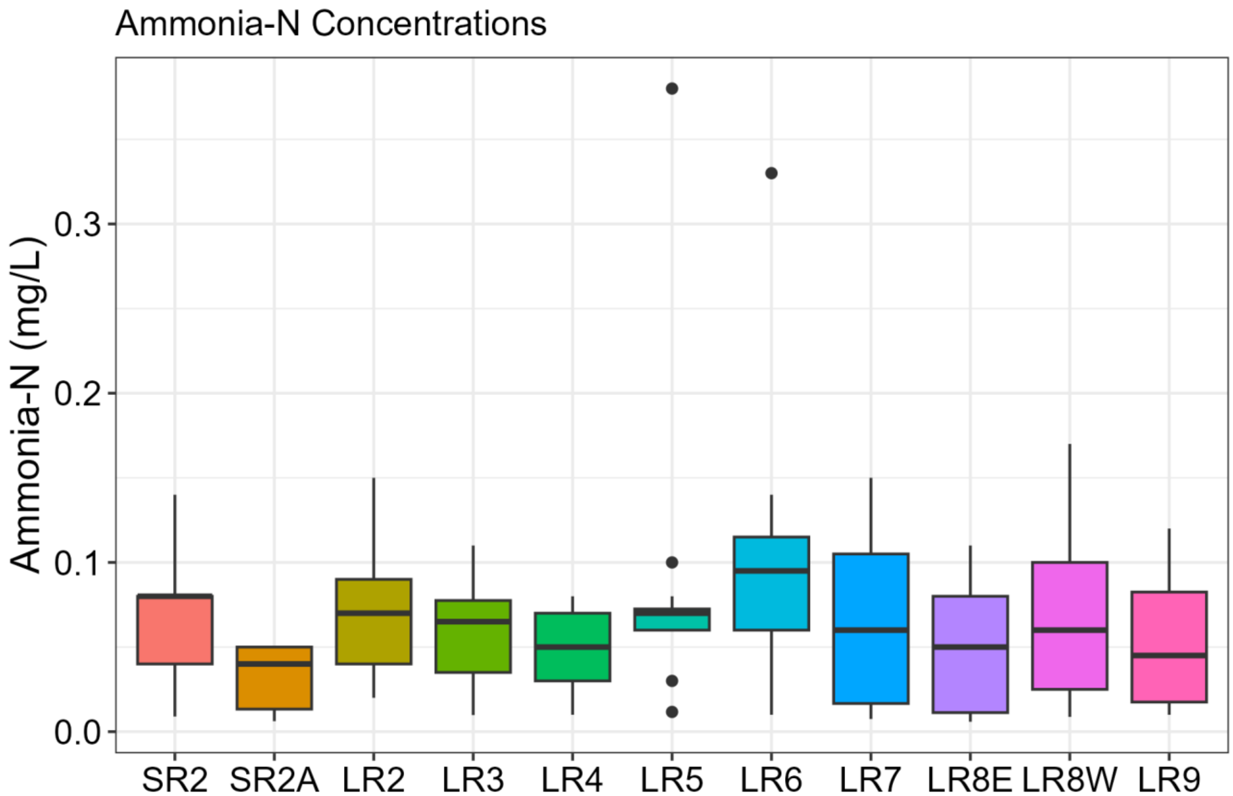


Figure 9. Range of ammonia-n levels across the eleven (11) sites across Layton River.

3.5.2. Nitrate (-Nitrogen)

During the decomposition of organic matter, bacteria, and fungi, particularly in the presence of oxygen, have the capability to convert organic nitrogen into inorganic nitrite then rapidly into inorganic nitrate. Natural systems tend to have levels below 1.0 mg/L (McNeely and Dwyer, 1979). Elevated levels of nitrate in water can have significant implications, including contributing to harmful algae blooms. These blooms, when massive in scale, can lead to oxygen depletion in the water as the algae die and decompose. Furthermore, heightened nitrate concentrations can interfere with the blood's capacity to transport oxygen, consequently affecting the behavior and growth of aquatic animals.

Much like ammonia, sources of nitrate include agricultural runoff, originating from fertilizers and livestock waste, as well as urban contributors such as stormwater and treatment plants. Industrial discharges can also release nitrate into aquatic systems. The Canadian Water Quality Guideline (CWQG) for nitrate-nitrogen is set at 3.0 mg/L as the acceptable threshold for long-term exposure, i.e., ≥7d exposures for fish and invertebrates, and ≥24h for aquatic plants and algae (CCME, 2012).

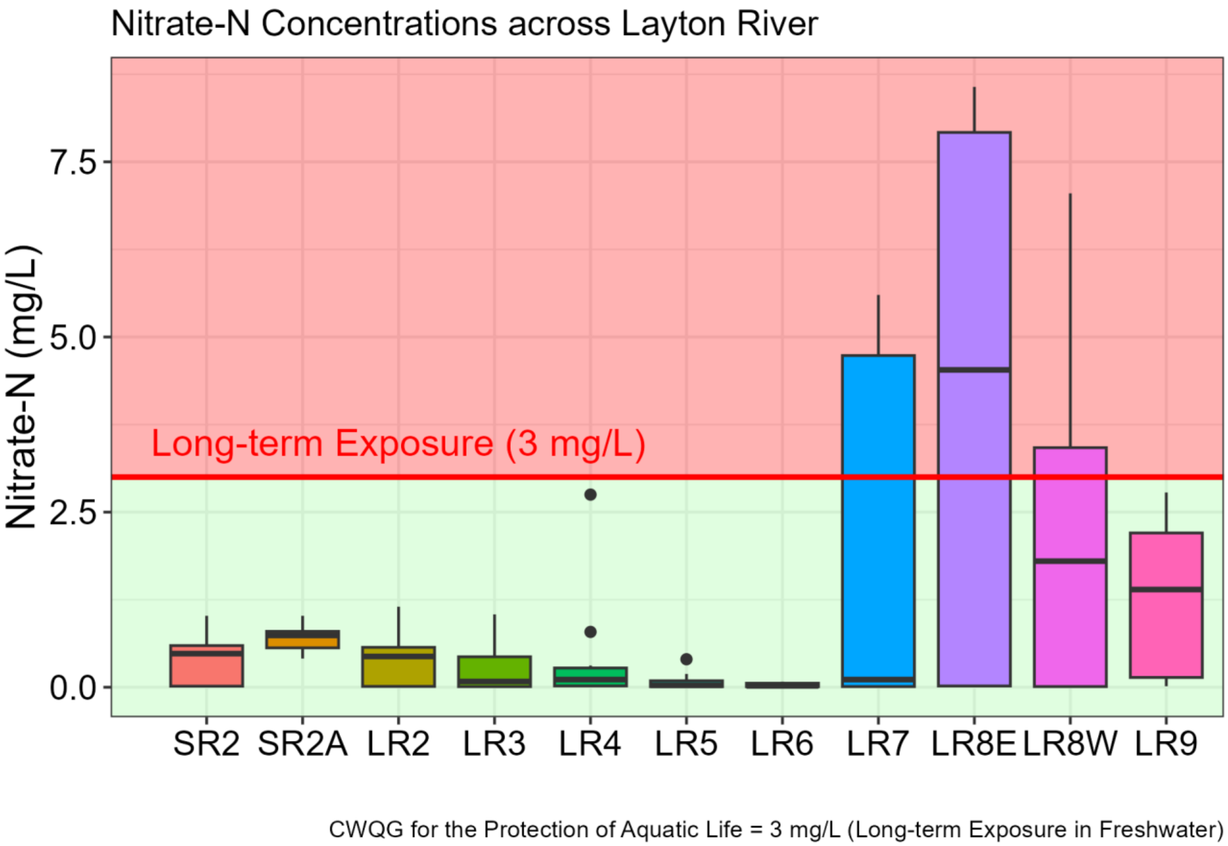


Figure 10. Range of nitrate-n levels across the eleven (11) sites across Layton River. The red line denotes the CWQG for the protection of aquatic life for nitrate-n (3.0 mg/L) for long-term exposure (CCME, 2012), where the area shaded in green depicts acceptable levels of nitrate-n while the area above the line shaded in red denotes poor levels of nitrate-n.

In our study of Layton River, we conducted analyses on a total of 84 water samples. At the CWQG threshold of 3.0 mg/L, 14 samples were found to have nitrate-nitrogen levels exceeding this guideline. These exceedances were predominantly observed in the upper reaches of Layton River, specifically at LR7, LR8E, and LR8W. Among these sites, LR8E is of particular concern, as more than half (63.6%) of all collected samples surpassed the CWQG. Additionally, LR8E's location at the headwaters of Layton River (**Figure 1**) suggests that its nitrate contributions may be affecting downstream sites such as contributing to exceedances at LR7. Continued input of nitrate can stimulate excessive algae growth and prolonged exposure to levels above the guideline can be toxic to warm-bodied animals such as cows and humans.

These findings emphasize the importance of addressing nitrate levels, particularly at LR8E, to mitigate potential impacts downstream on Layton River. Following work such as stewardship/restoration with monitoring should be implemented at LR8W, followed by LR7 to address this concern and to ensure that implemented work is working correctly.

3.5.3. Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) in water is the collection of various nitrogen-containing compounds, including organic nitrogen and ammonia. TKN is a crucial parameter in water quality assessment because it provides insights into the overall nitrogen content and bioavailability in aquatic ecosystems. In rural areas, common sources of TKN often originate from agricultural activities, such as the application of organic fertilizers, livestock waste runoff, and the decomposition of organic matter in soils (which leaches into the water or groundwater).

Since nitrogen is also an essential nutrient for the growth of plants, excessive TKN can contribute to uncontrollable algal growth, and potentially leading to issues like rapid eutrophication and impaired water quality. Monitoring and managing TKN levels in rural watersheds are essential for mitigating the adverse environmental impacts associated with nitrogen enrichment and ensuring the health of aquatic ecosystems.

Presently, no regulatory guidelines or objectives specifically targeting Total Kjeldahl Nitrogen (TKN) in water quality management have been established. However, natural TKN concentrations typically fall within the range of 0.1 mg/L to 0.5 mg/L (McNeely and Dwyer, 1979). Our analysis yielded both mean and median TKN values (**Table 1**) of 0.8 mg/L and 0.7 mg/L, respectively, indicating that Layton River exhibits elevated TKN levels in comparison to these natural reference ranges. For an in-depth examination of potential sources contributing to TKN in the watershed, please refer to section **3.5.1 Ammonia-N**, and section **3.5.2 Nitrate-N.**

3.6. Chloride

Chloride ions are typically abundant in salt minerals and seawater, which is primarily associated with oceans. In terrestrial environments, they are less common but can occasionally be found in ancient ocean bed deposits. Due to their relative scarcity in terrestrial settings, freshwater ecosystems have not naturally evolved to cope with high inputs of chloride. In modern times, chloride salts are commonly employed for de-icing roads and walkways. Chloride-containing materials are also utilized in municipal water and wastewater treatment processes. Upon release into the environment, chloride salts readily dissolve in water. This dissolution results in chloride ions becoming free and mobile within aquatic systems.

Out of the 95 samples analyzed for chloride content, none approached or reached the CWQG set for the protection of aquatic life, which stands at 120 mg/L (CCME, 2011). The highest recorded concentration was 63.5 mg/L, significantly lower than the CWQG threshold of 120 mg/L.

The observed chloride concentrations generally align with natural ranges for the Lower Great Lakes, falling within the 10-30 mg/L range (Evans and Frick, 2001), and across Canada, which typically averages around 8.3 mg/L (McNeely et al., 1979). Approximately 80% of all collected samples registered levels below the natural threshold of 30 mg/L. The lack of in municipal water and wastewater treatment plants across Layton River suggest that anthropogenic sources of chloride may originate from domestic uses along roads and walkways. In addition, dust suppressant applications during the summer months may also contribute to chloride levels in the water.

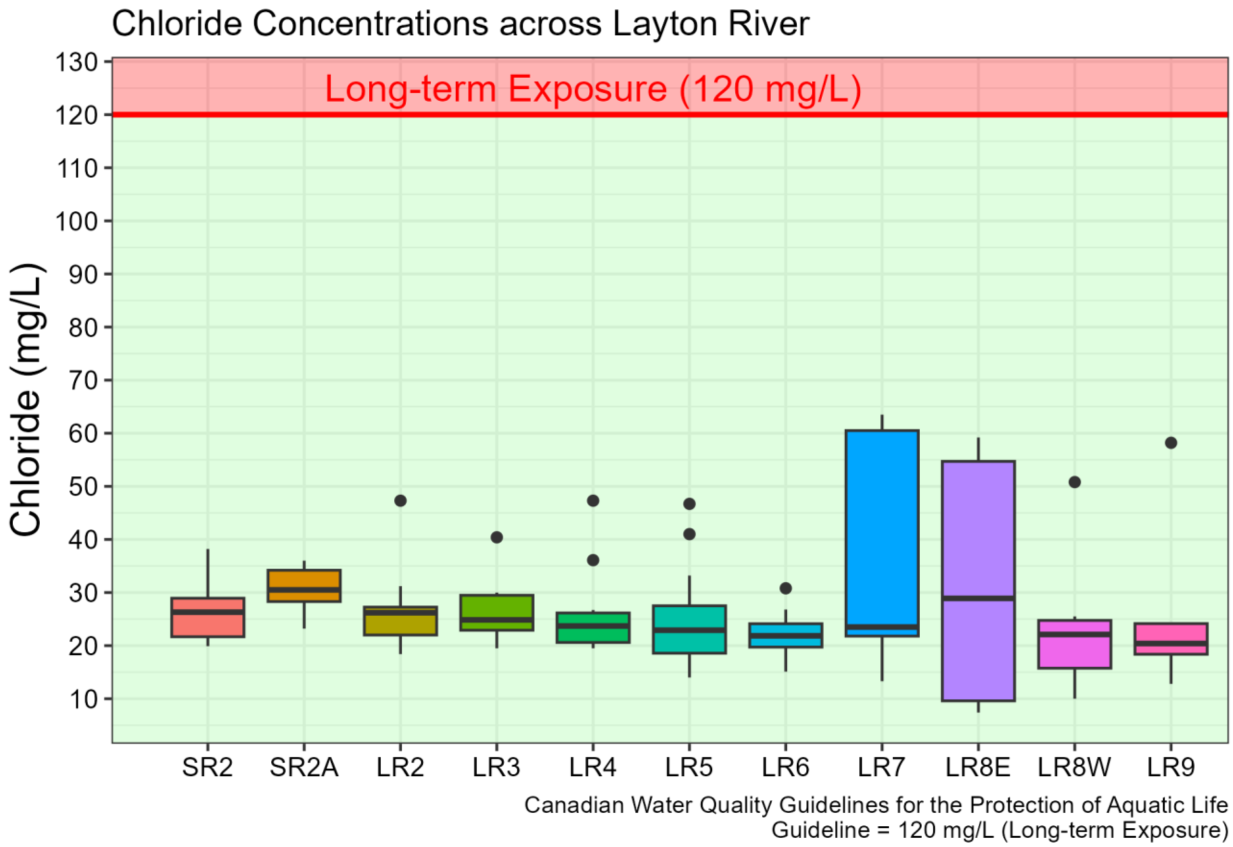


Figure 11. Range of chloride levels across the eleven (11) sites across Layton River. The red line denotes the Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life for chloride (120 mg/L) for long-term exposure, where the area shaded in green depicts acceptable levels of chloride while the area above the line shaded in red denotes poor levels of chloride.

In contrast to Layton River such as those in more urbanized watersheds like Williams Creek, chloride levels have been found to exceed the CCME guideline more than 75% of the time (Kawartha Conservation, 2023a), with chloride levels exceeding the 640 mg/L mark, surpassing the short-term guideline which can result in negative consequences to aquatic life within 24 to 96 hours (CCME, 2011).

The findings indicate that Layton River faces no significant concerns regarding current potential impacts due to chloride. However, prolong use of domestic salt can lead to increased Cl levels in Layton River, which can pose greater risk to ecosystem and human health. For example, certain freshwater mussels are one of the most sensitive to Cl (CCME, 2011) and the lost of populations can lead to poorer water quality (freshwater mussels are filter feeders). Although there have not been extensive mussel surveys across Layton River, Kawartha Conservation staff have found Flutedshel Mussel (*Lasmigona costata*) which adults can have steep mortality rate when Cl exceed 1000 mg/L (Burton et al., 2023). However, Burton et al. (2023) only assessed mortality in a laboratory study, whereas mortality may be greater at lower Cl level in the field (Hintz et al., 2022). Thus, continue work must address the usage of salt to prevent ecosystem degradation, even in areas with lower Cl levels.

3.7. Total Suspended Solids

Similar to turbidity (**Section 3.3**), total suspended solids (TSS) can influence water clarity. TSS is a measure of the number of particles present in water, with increased particle concentration leading to reduced water clarity. These particles can originate from various sources, including soil, algae, or woody debris. When suspended solids enter the water, they can adversely affect the gills of aquatic fish and macroinvertebrates, leading to discomfort, altered behavior, and, in some cases, mortality (Bash et al., 2001; Kjelland et al., 2015; Tuttle-Raycraft and Ackerman, 2019).

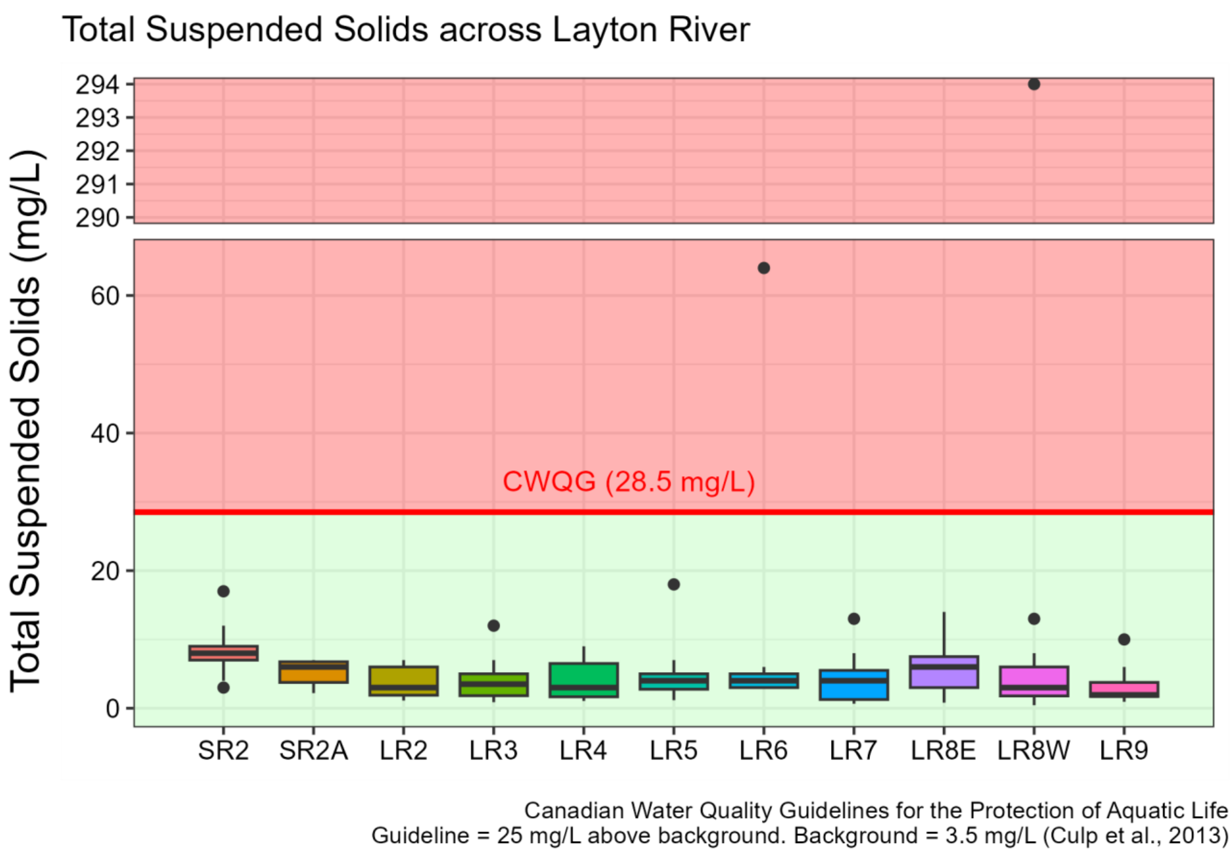


Figure 12. Range of total suspended solids levels across the eleven (11) sites on Layton River. The red line denotes the CWQG for total suspended solids, where the background level was taken from Culp et al. (2013). The area shaded in green depicts an acceptable level of total suspended solids while the area above the line shaded in red denotes poor levels of total suspended solids.

The CWQG for the Protection of Aquatic Life concerning Total Particulate Matter aims to establish a threshold that safeguards various aquatic biota, including fish and benthic invertebrates, across North America, from the impacts of suspended solids (CCME, 2002). According to this guideline, there should be no more than a 25 mg/L increase in TSS from the background level (CCME, 2002).

Similar to turbidity, there is no established background concentration of TSS in the Kawartha Region (**Section 3.3**). Consequently, we utilized the Ecological Reference Condition (ERC), derived from the work of Culp et al. (2013), which relates TSS concentrations to the relative abundance of EPT (sensitive benthic taxa). Combining this ERC with the data, we derived a threshold of 28.5 mg/L for Layton River. At this threshold, only two samples failed, representing a mere 1.75% of all samples collected within Layton River. These two values are considered extreme outliers when compared to the broader dataset (**Figure 11**). Our sampling program for Layton River only occurred during low water level periods (**Appendix B**). We would expect that that TSS levels would be higher than what is presented in this study; as we have found that TSS levels in agricultural dominated watersheds range from 6.14 to 9.20 mg/L during small precipitation events (Kawartha Conservation, 2023b). Levels of TSS would be greatly increased in larger precipitation events as erosion of soils would be greater.

When more soils and other particles enter the water, it impacts the gills of aquatic organism and macroinvertebrates, causing discomfort, change in behaviour, and higher risk of death (Bash et al., 2001; Kjelland et al., 2015; Tuttle-Raycraft and Ackerman, 2019). When these particles settle out of the water column, they can cover/smother critical spawning nest or incubating eggs (Bash et al., 2001). Thus, ongoing efforts can be focused on prevention of particles from entering the water through proper installation of erosion and sediment controls and appropriate riparian buffers.

While there are no significant concerns regarding water clarity (Low exceedances of TSS), it has become evident through this study and previous reports (Kawartha Conservation, 2023a, b) that there exists a knowledge gap concerning the background conditions of water clarity in Layton River and many other streams throughout the region. Future research endeavors should prioritize the assessment of background water clarity levels in minimally impacted watersheds, encompassing a range of weather and water level conditions.

3.8. Water Quality Index

Using the Water Quality Index (WQI) (CCME, 2017) for all sampling years, we provided a general statement of the site health. Of the 11 sites assessed, five (5) were found to have ‘Good’ status, two (2) had ‘Fair’ status, three (3) with ‘Marginal’ status, and one (1) was not calculated for (**Table 2**).

Table 2. Water Quality Index results for all sites across all sampling years.

Site	WQI Category	WQI Score
LR2	Fair	71
LR3	Good	90
LR4	Fair	79.1
LR5	n.a	n.a
LR6	Marginal	62.7
LR7	Marginal	55.4
LR8E	Good	86.9
LR8W	Marginal	50
LR9	Good	89.8
SR2	Good	80.6
SR2A	Good	90.1

3.9. Drivers of Water Quality

We utilized Principal Component Analysis (PCA) and a Spearman's correlation matrix to examine the relationships between water quality, climate, and land use in Layton River. However, the analysis only explained 33.9% of the variability in the dataset, implying the presence of unaccounted-for drivers in Layton River. Further details on the PCA can be found in **Appendix C**.

The correlation matrix (**Figure 13**) and the principal correlation analysis (**Figure 14**) revealed several key relationships:

- Generally, nutrients, discharge, and land cover emerged as the primary drivers of water quality in Layton River. Specifically:

  Top Five Contributors to Dimension 1 in **Figure 14:**

  - Latitude
  - Nitrate-N
  - Discharge
  - Precipitation within 48 hours
  - Percent Urban

  Top Five Contributors to Dimension 2 in **Figure 14**:

  - Total Phosphorus
  - Total Suspended Solids
  - Percent Agriculture
  - Percent Natural
  - Air Temperature

- Agriculture land use exhibited a significant negative correlation with urban and natural land use. This indicates that an increase in agriculture corresponds to a decrease in natural and urban land cover (**Figure 13**). This finding aligns with the dominant agricultural landscape in Layton River (**Figure 2**). The scarcity of natural cover was positively associated with nitrate-nitrogen levels (**Figure 13**).

- While some groundwater influence was observed (Kawartha Conservation, 2009), discharge was found to be correlated with precipitation events within 48 hours (**Figure 13** & **14 A**).

- Catchments characterized by higher natural land cover exhibited reduced levels of total suspended solids (**Figure 12**), while those with a higher proportion of agricultural land cover were correlated with elevated levels of total suspended solids (**Figure 14 A & B**).

- Notably, LR8E and LR8W exhibited distinct water quality characteristics compared to other sites due to their status as headwater sites (**Figure 14 B**). The differences between these two sites and the rest of the sites suggest terrestrial influences on the landscape that result in significant downstream variations in water quality. Sites LR9 and SR2 were also identified as unique with distinct water quality characteristics, with LR9 having its catchment and SR2 being the most downstream site, representing a cumulative measure of all water quality inputs.

- Total phosphorus exhibited a significant positive relationship with total suspended solids and clarity (turbidity), potentially indicating disturbance of sediment (sediment resuspension), increased algae growth, and contributions from the catchment (runoff).

- Both precipitation periods (Day of and within 48 hours) were significantly correlated with turbidity (**Figure 13**), implying that the accumulation of soils and bound nutrients could contribute to reduced clarity in Layton River, either through soil deposition or algae growth.

Correlations between turbidity and discharge, as well as discharge to precipitation (48hrs), supports the notion that runoff inputs can reduce clarity.

- The analysis suggests a potential relationship between phosphorus and ammonia & organic nitrogen (TKN), hinting at similar sources of phosphorus and nitrogen in Layton River (**Figure 13**).

- Nitrate was found to be negatively correlated with natural land cover and discharge, indicating that in this predominantly agricultural watershed, nitrogen inputs from agriculture may have infiltrated groundwater and is discharging into Layton River during periods of low discharge (baseflow).

- Elevated levels of Nitrate were also associated with LR8W and LR8E (**Figure 14 A & B**), supported by **Figure 9**, where both sites exceeded CCME Nitrate Guidelines.

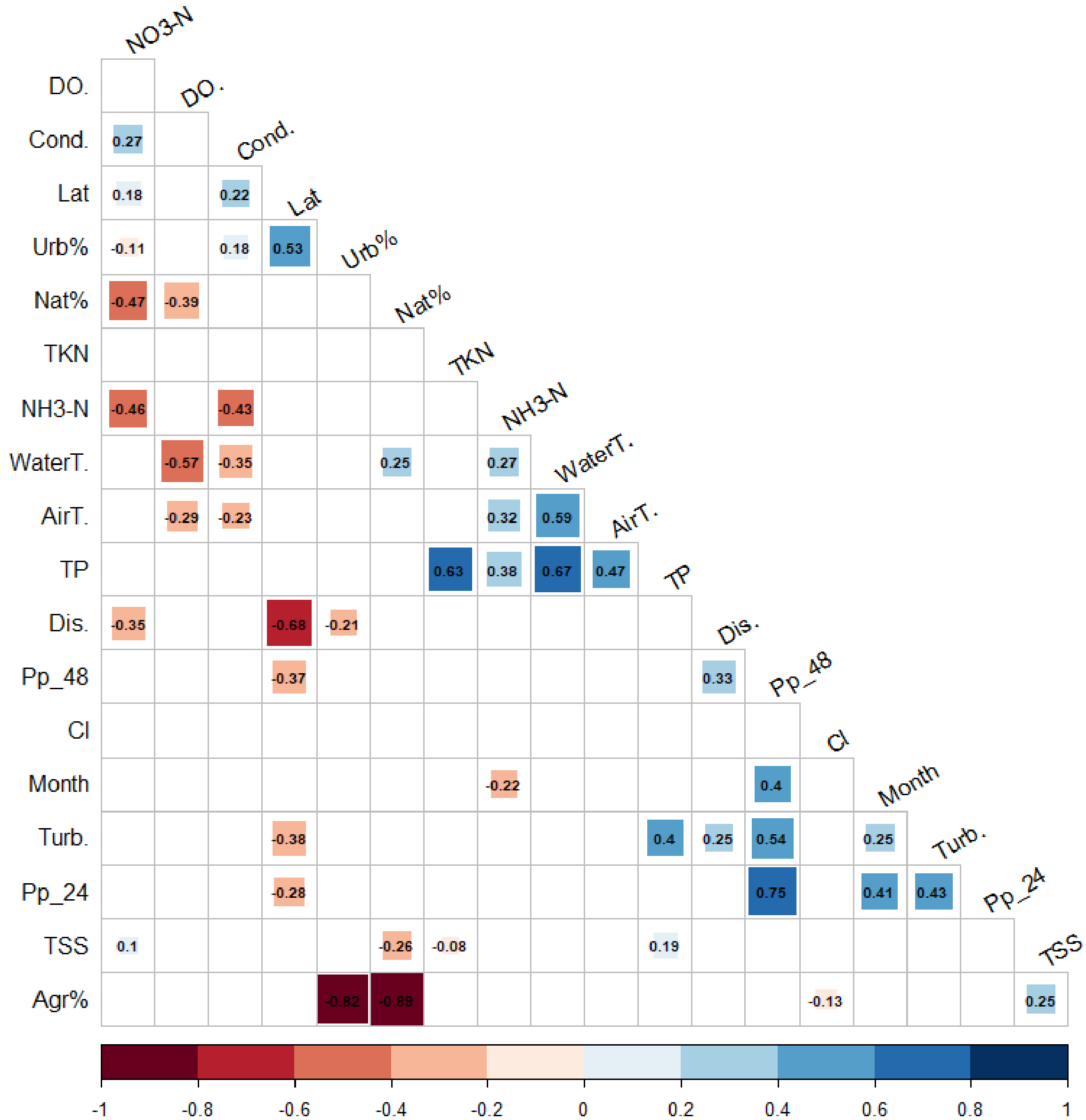


Figure 13. Sparman's correlation matrix between key physical, hydrological, hydrochemical, and landcover parameters. Only significant (p<0.001) correlations values are shown. Positive correlations are depicted with blue colouration while negative correlations are depicted with red colouration.

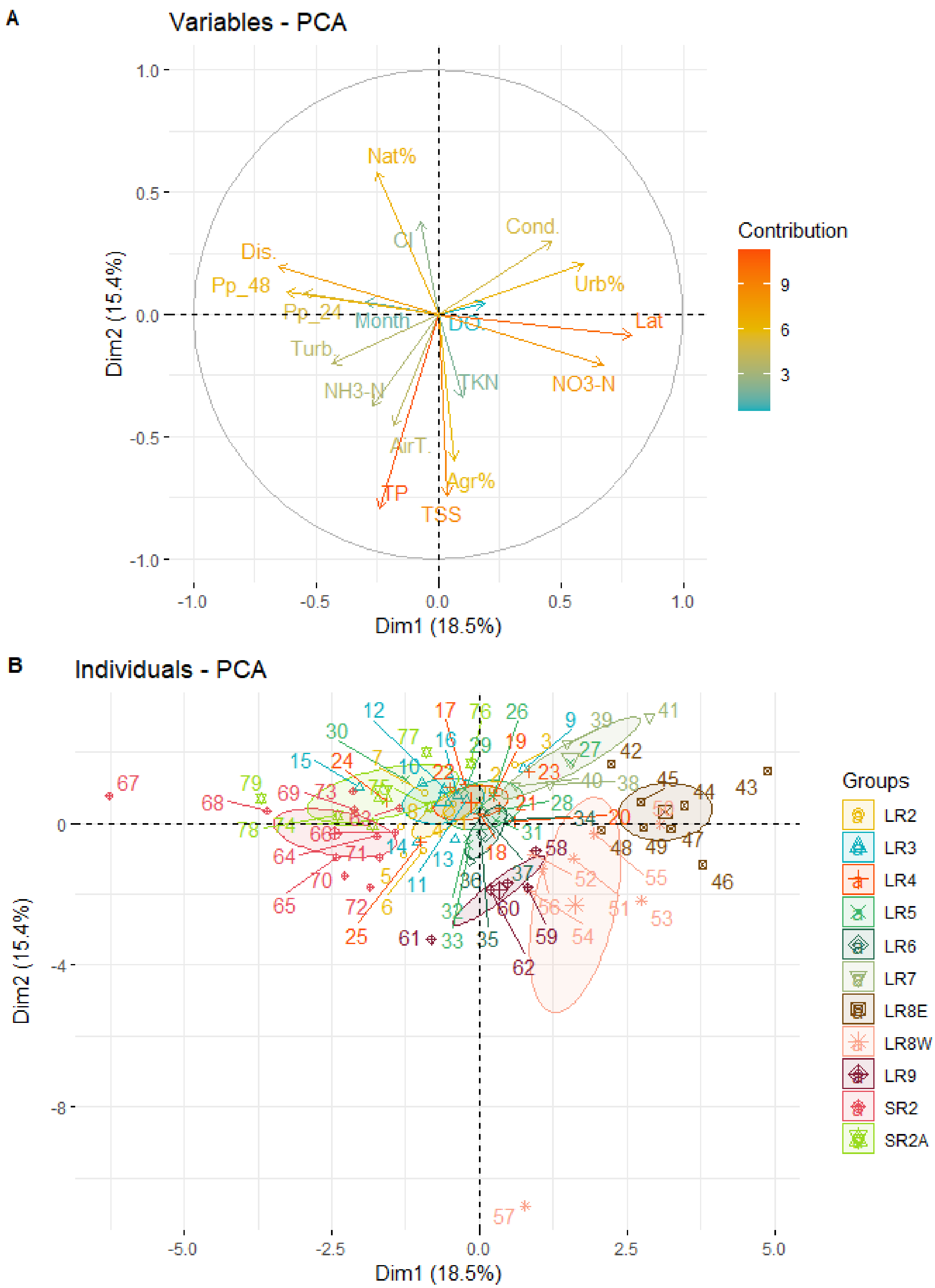


Figure 14. Principal Component Analysis (PCA) of key physical, hydrological, hydrochemical, and landcover parameters partitioned by their contributions (**A**) and by groups, i.e., sites (**B**).

3.10. Stream Flow

Stream levels and discharge (the volume of water per second) are closely interlinked, as higher water levels enable more water to flow through the river. These two variables, namely level and discharge, are primarily influenced by three key drivers:

- Spring Freshet and Snowmelt: This driver accounts for elevated water levels and discharge.
- Rain Events: Rainfall events can also impact both water level and discharge.
- Groundwater: this driver provides the baseline flow for the river and is predominate during periods of drought.

In the case of Layton River, the highest water levels and discharge consistently occur from late February through the end of March (refer to **Figure 15** and **16**), while the lowest levels are typically observed during the period from mid-August to mid-September. Even during the lowest water level periods, there remains a degree of water movement, which can be attributed to groundwater inputs as documented in the Kawartha Conservation Nonquon Report (2009).

Water levels in Layton River can exhibit substantial variability, ranging from over 1.8 meters during the spring freshet to as low as 0.11 m during drought periods (see **Figure 16**). This represents a notable difference of 1.69 m. On average, the month of April records the highest volume of water, with approximately 4.5 million m^3, while September typically has around 1.6 million m^3 of water. Detailed information on total and average volumes can be found in **Appendix B**.

The impact of rainfall becomes evident when examining **Figure 16.** During the months of January to March-April, the absence of precipitation does not significantly affect the higher water levels of Layton River. However, as we move beyond this period, water levels respond noticeably to rain events, rising in response to rainfall and receding during dry spells.

The years 2021 and 2022 exhibited different discharge trends when compared to the historical average. In 2021, the highest discharge levels occurred during November. Conversely, the same year witnessed the lowest discharge in April. In 2022, the highest discharge was observed during much of the freshet period (**Figure 15**).

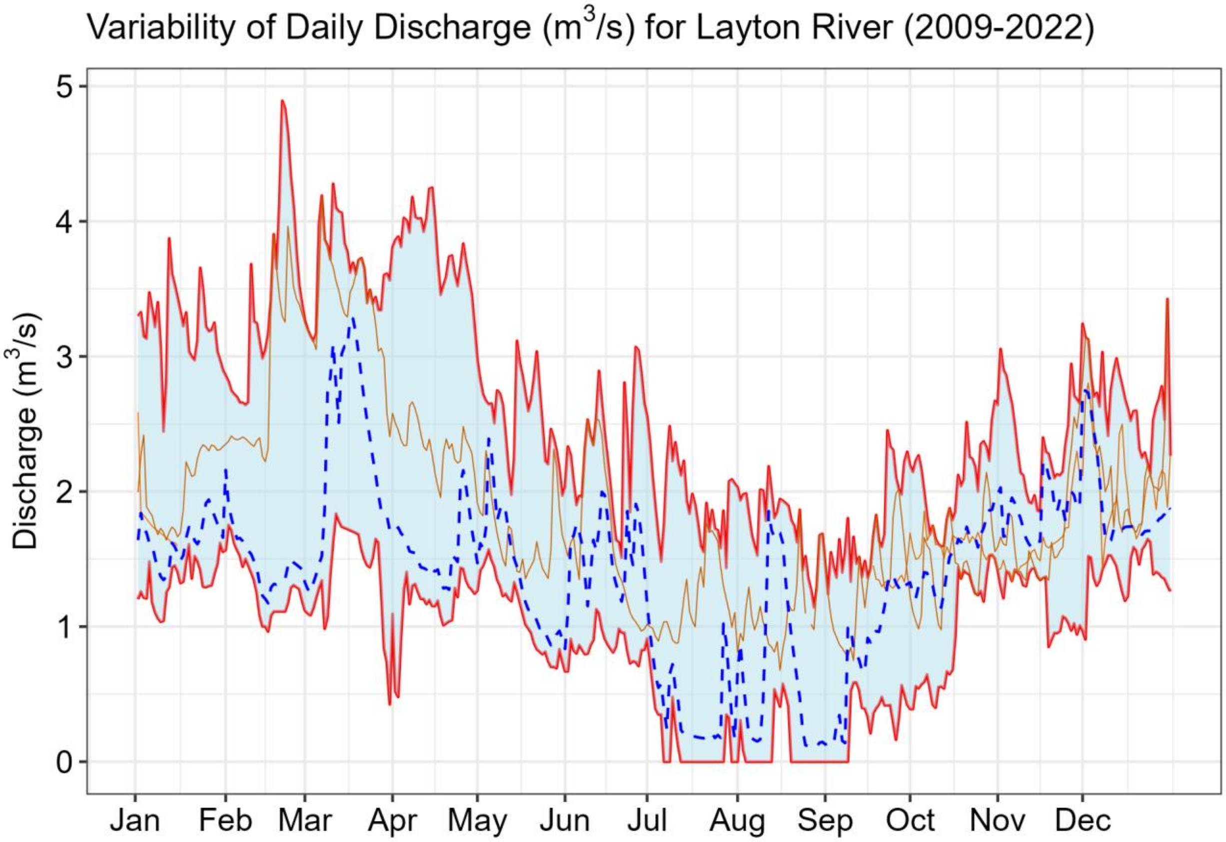


Figure 15. Illustration the variability (range) of daily discharge for Layton River spanning from 2009 to 2022. The red lines represent the maximum (top) and minimum (bottom) discharge values recorded during this period. The blue dashed line denotes the average discharge value. The orange to brown lines depict the discharge values for the sampling years (2019, 2021, 2022).

The Township of Brock and Scugog has predicted an increase in both total precipitation and the frequency of extreme precipitation days due to climate change (Delaney et al., 2020). Furthermore, there will be more occurrences of extreme heat days and extended periods of consecutive dry days. These predictions are expected to alter the flow patterns of Layton River. Anticipated changes include greater fluctuations in water levels in response to extreme precipitation events and prolonged dry spells, leading to pronounced rises and falls in water levels.

Continuous stream monitoring of Layton River, particularly at SR2A, is strongly recommended to consistently capture the full range of flow dynamics exhibited by Layton River. This becomes especially crucial when water levels are projected to experience extreme fluctuations.

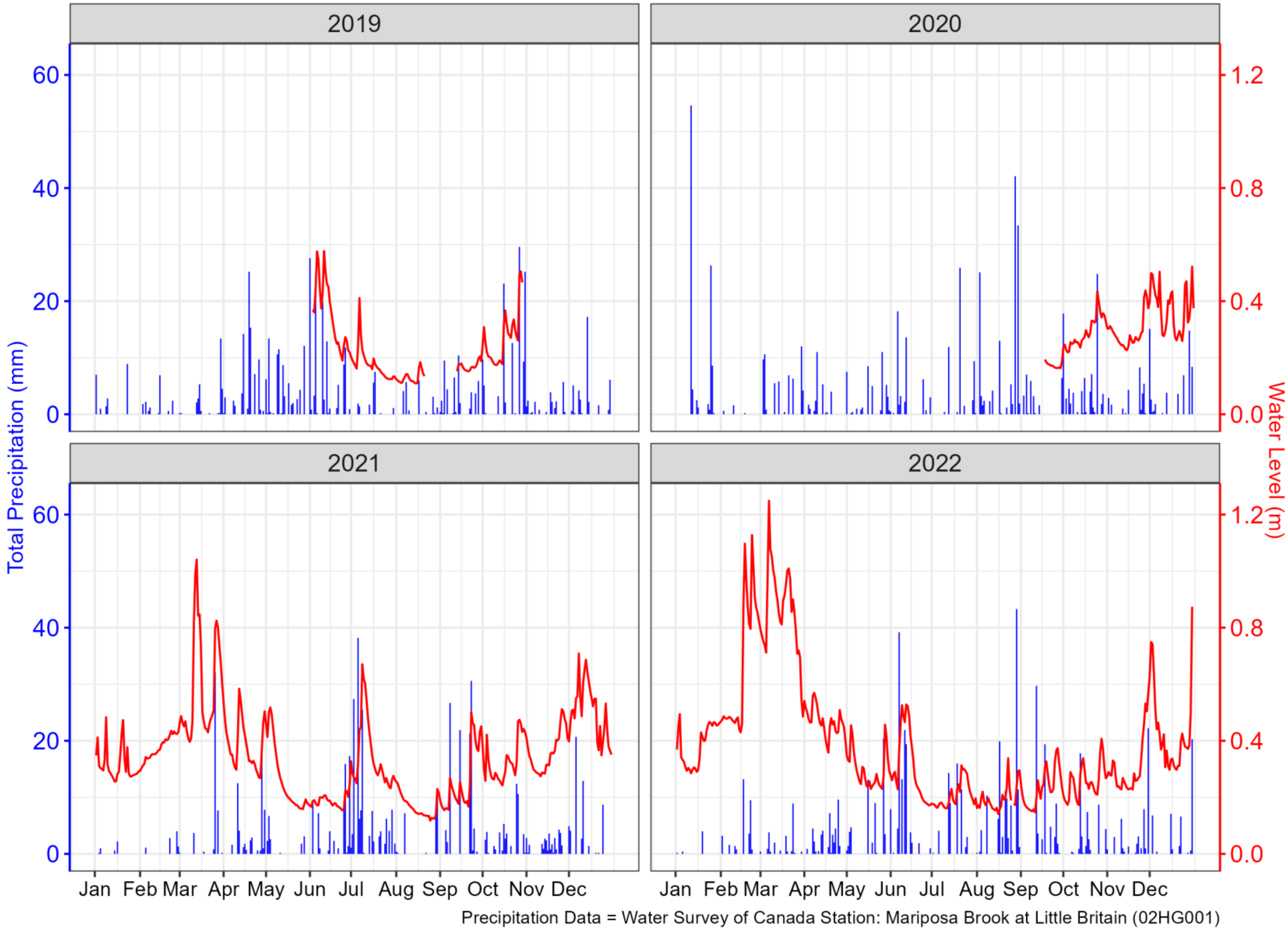


Figure 16. Total precipitation (Blue bars) and stream level (red lines) at SR2A (Saintfield Road) throughout the monitoring year of 2019 to 2022.

3.11. Loadings

By integrating the assessment of discharge, water quality concentrations, and the geographical area of Layton River, we have calculated the nutrient and sediment load within the river. It's important to note that our sampling efforts may not have captured high flow events, and consequently, the values presented in this report may underestimate the actual nutrient and sediment inputs. This is particularly significant because it is well-documented that nutrient inputs tend to be elevated during periods of high flow, i.e., spring melt and during rain events (Eimers *et al.,* 2007; Miles *et al*., 2013; Irvine *et al*., 2019).

To assess the extent of contamination and determine the treatment required to meet established limits and guidelines, we have employed the respective limits and recommended guideline values. Given that much of the water quality concerns revolve around Nitrate and phosphorus, it was anticipated that these two parameters would exhibit excessive loads.

Table 3. Excess nitrate and phosphorus load per site. Red values depict concerning sites.

Site	Nitrate	Phosphorus
LR2		0.09
LR3		0.09
LR4		0.066
LR5		0.028
LR6		**0.032**
LR7		0.0002
LR8E	**1.6**	**0.006**
LR8W		0.008
LR9		0.014

Upon evaluating contaminant loads at all monitored sites (**Table 2**), it becomes evident that phosphorus levels consistently exceeded established limits. Notably, one site, LR8E, displayed excessive nitrate loads, further exacerbating water quality concerns.

Remarkably, suspended solids and chloride did not exhibit excessive loads at any of the monitoring sites. This outcome aligns with our earlier findings, where phosphorus (**Section 3.4**) and nitrate (**Section 3.6**) exhibited some exceedances, while suspended solids (**Section 3.8**) and chloride (**Section 3.7**) remained within acceptable limits.

One particular concern highlighted in **Table 2** is the substantial excess of nitrate at site LR8E, amounting to approximately 1.5 kilograms per day per hectare of excess nitrate within the catchment. Given this significant excess of nitrogen and phosphorus, it is imperative that this catchment area receives focused attention for stewardship and remediation efforts, ideally in collaboration with willing landowners.

Additionally, it is worth noting that the area upstream of LR6 exhibits elevated phosphorus loadings. The loading of phosphorus increases substantially from 0.0002 kilograms per day per hectare at LR7 to 0.032 kilograms per day per hectare merely one concession road downstream. While other sites, LR2 and LR3, also registered higher phosphorus loads, these may be attributed to upstream sources, as all sites upstream displayed excess phosphorus.

This comprehensive assessment provides valuable insights into the distribution of contaminant loads across the monitoring sites and highlights critical areas for remediation and conservation efforts.

4. Conclusion

Throughout the course of the Durham Region – Investigative Upstream Monitoring initiative, we conducted comprehensive monitoring activities across nine sites from 2019 to 2022, focusing on water quality and instantaneous water quantity. To bolster our dataset, we drew upon supplementary data from two sites as part of the Lake Scugog Environmental Management Plan. This combined approach empowered us to achieve several critical objectives:

- Characterizing Water Quality Conditions: Our extensive monitoring efforts enabled us to paint a vivid picture of the water quality conditions prevalent in Layton River.
- Identifying Key Relationships and Drivers: Through rigorous analysis, we uncovered crucial relationships and drivers governing water quality dynamics within the river.
- Highlighting Sites of Concern: Our assessments revealed specific sites within the watershed that exhibited elevated inputs of contaminants, thus pinpointing areas warranting immediate attention.

Over the duration of our study, spanning from 2019 to 2022, we observed noteworthy water quality concerns in the realms of dissolved oxygen, total phosphorus, and nitrate. However, it is important to note that no significant water quality concerns emerged for total suspended solids, turbidity, chloride, and water pH.

In dissecting the hydrological aspects of Layton River, we recognized that water levels and discharge are principally influenced by three factors: the spring freshet occurring from February to April, precipitation events commencing from May onward, and groundwater inputs during periods of low precipitation.

Notably, nutrient conditions emerged as the predominant drivers of water quality in Layton River, closely intertwined with land use patterns. The two headwater sites stood out as distinct entities, bearing a relatively higher degree of development. This distinction was particularly pronounced at site LR8E, where nitrate levels surpassed the Canadian Water Quality Guideline for the Protection of Aquatic Life. Alarmingly, LR8E exhibited excess nitrate loads, with 63.6% of all samples surpassing the guideline, marking it as the sole site with this concerning distinction.

The assessment of phosphorus levels across Layton River revealed that they consistently exceeded the Provincial Water Quality Objective, with all sites demonstrating a significant proportion of exceedances, ranging from 72.7% to 90%. Of paramount concern was site LR6, where upstream contributions accounted for a staggering 90% of exceeded samples and phosphorus load, signifying a pressing need for phosphorus reduction measures throughout the watershed. Particular emphasis should be placed on the area between LR6 and LR7.

In light of the comprehensive data gathered and the insights gleaned from our assessment, we fervently recommend that priority stewardship activities be directed towards the restoration and conservation of sites LR6, LR7, LR8E and LR8W. Refer to **Figure 1** for a visual representation of these priority areas on the map.

To address monitoring gaps and to enhance our understanding of Layton River's water quality, we propose several recommendations. Firstly, it is crucial to establish baseline benchmarks for water clarity, encompassing measurements of both turbidity and total suspended solids (TSS). This initiative will provide valuable insights into the local context, enabling comprehensive comparisons with future data. It's worth noting that turbidity and TSS levels can exhibit considerable variation across distinct landscape types and weather event.

Furthermore, we advocate for an expanded monitoring approach, which includes assessments during periods of high-water levels and rainfall events. Such an approach is vital for a comprehensive evaluation of nutrient loads, as significant nutrient inputs often occur during these meteorological events. Given the anticipated impacts of climate change on regional precipitation and weather patterns, we anticipate a greater degree of unpredictability in Layton River's water levels. To effectively navigate these shifts, continuous monitoring at the existing site (SR2A) will be essential in capturing and comprehending these evolving dynamics.

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Region of Durham – Investigative Upstream Monitoring for Layton River

Appendix A: Landuse/Landcover

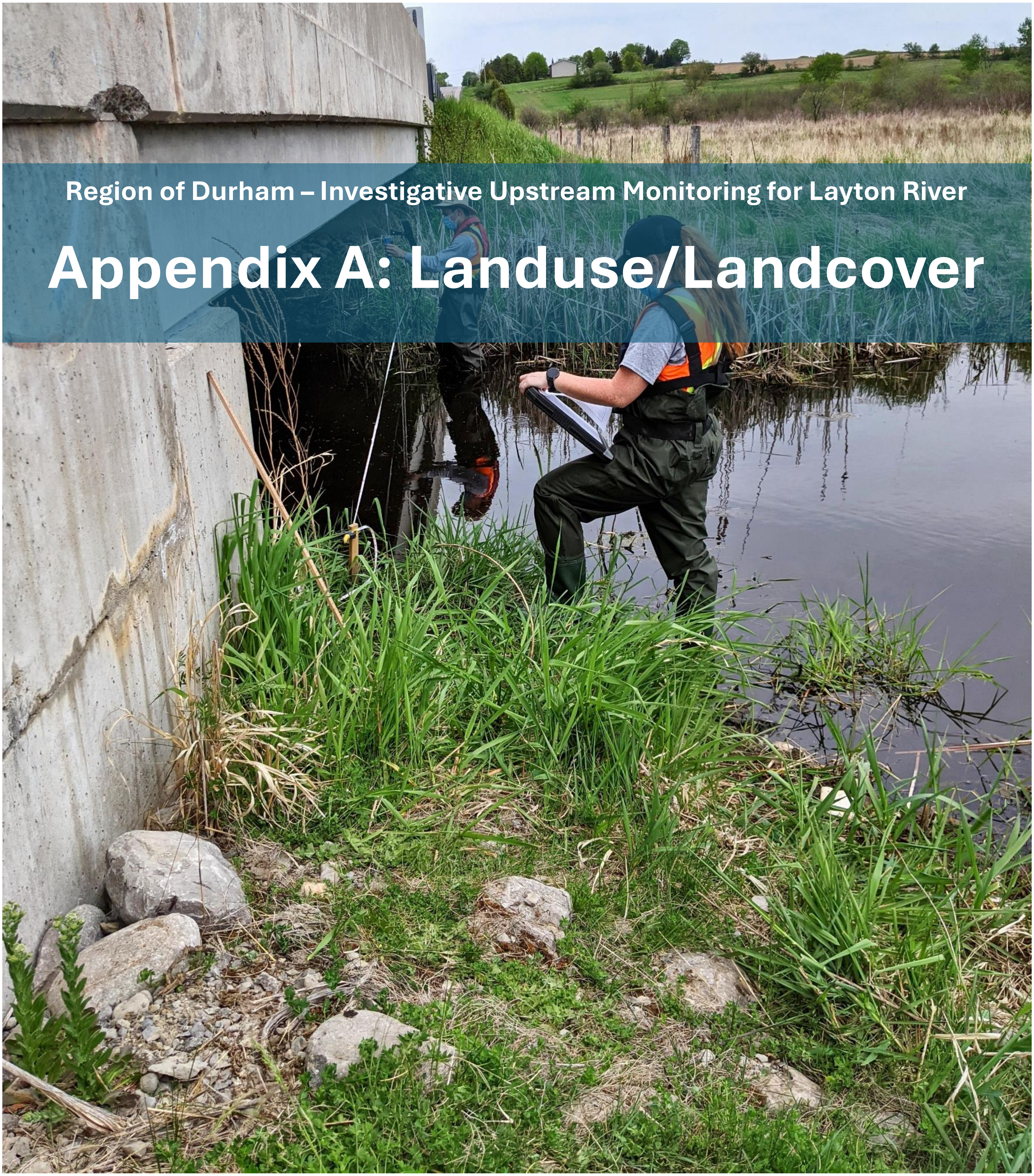

Table A.1. Site code, site coordinate and its watershed and land use/ land cover information. Data was collected through the Ontario Watershed Information Tool (Government of Ontario, 2015)

SID	LR2	LR3	LR4	LR5	LR6	LR7	LR8W	LR8E	Equiv_LR8E	LR9	SR2	SR2A
Latitude	44.2133	44.2268	44.2416	44.2555	44.2678	44.2765	44.2914	44.2928	44.2909	44.2088	44.1916	44.2000
Longitude	-78.9865	-78.9882	-78.9817	-78.9802	-78.9847	-79.0064	-79.0011	-78.9949	78.9979	-78.9915	-78.9857	-78.9847
Drainage Area (km^2)	34.048	30.506	28.211	24.653	10.27	5.896	0.599	n/a	2.668	2.158	50.638	40.843
Shape Factor	6.878	6.105	4.837	3.76	5.993	4.815	5.571	n/a	3.927	5.55	6.873	7.407
Length of Main Channel (km)	15.303	13.647	11.681	9.628	7.845	5.328	1.826	n/a	3.237	3.461	18.656	17.393
Maximum Channel Elevation (m)	318.94	318.94	318.94	318.94	318.94	318.94	307.84	n/a	318.94	313.4	318.94	318.94
Minimum Channel Elevation (m)	255.89	261.57	262.97	263.51	264.76	265.97	271.96	n/a	270.39	266.62	250.81	252.2
Slope of Main Channel (m/km)	4.12	4.2	4.79	5.76	6.91	9.94	19.65	n/a	15	13.51	3.65	3.84
Slope of Main Channel (%)	0.412	0.42	0.479	0.576	0.691	0.994	1.965	n/a	1.5	1.351	0.365	0.384
Area Lakes/Wetlands (km^2)	7.149	7.099	6.554	6.044	2.211	1.45	0.013	n/a	0.536	0.095	8.671	7.779
Area - Lakes (km^2)	0.148	0.121	0.039	0.021	0.002	0.002	0	n/a	0.002	0	0.203	0.156
Area - Wetlands (km^2)	7.001	6.979	6.515	6.024	2.209	1.448	0.013	n/a	0.535	0.095	8.469	7.623
Mean Elevation (m)	288.796	288.354	289.066	288.986	286.115	288.19	291.815	n/a	293.576	301.626	288.255	288.919
Maximum Elevation (m)	326.771	326.771	326.771	326.594	320.81	320.268	310.395	n/a	320.268	316.766	326.771	326.771
Mean Slope (%)	4.28	4.242	4.068	3.946	4.987	4.604	6.339	n/a	3.812	3.295	4.323	4.173
Annual Mean Temperature (°C)	6.6	6.6	6.6	6.6	6.6	6.6	6.6	n/a	6.6	6.8	6.8	6.8
Annual Precipitation (mm)	877	877	877	877	877	877	877	n/a	877	870	870	870
Other	0	0	0	0	0	0	0	n/a	0	0	0	0
Cloud/Shadow	0	0	0	0	0	0	0	n/a	0	0	0	0
Clear Open Water (km^2)	0.0972	0.0972	0.00022	0	0	0	0	n/a	0	0	0.13612	0.0972
Turbid Water (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Shoreline (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Mudflats (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Marsh (km^2)	0.6768	0.64148	0.57622	0.4437	0.1296	0.06728	0	n/a	0.0081	0	0.6768	0.6768
Swamp (km^2)	7.34558	7.26615	6.85778	6.33667	2.45677	1.5561	0.02813	n/a	0.5427	0.04725	8.694	7.85655
Fen (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Bog (km^2)	0.01597	0.01597	0.01597	0.01597	0.01597	0.01597	0	n/a	0.01597	0	0.01597	0.01597

Heath (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Sparse Treed (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Treed Upland (km^2)	0.18113	0.17888	0.16897	0.1494	0.06705	0.0315	0	n/a	0.0108	0.00473	0.22703	0.19485
Deciduous Treed (km^2)	0.92475	0.77153	0.6804	0.51907	0.13658	0.11993	0.02542	n/a	0.0108	0.072	1.55385	1.3581
Mixed Treed (km^2)	1.42695	1.05412	0.78435	0.62325	0.2115	0.0585	0.04005	n/a	0	0.12802	2.2689	1.82745
Coniferous Treed (km^2)	1.665	1.58265	1.43887	1.18912	0.71842	0.41197	0	n/a	0.11925	0	2.09362	1.92285
Plantations - Treed Cultivated (km^2)	0.15682	0.15682	0.15435	0.12577	0.0513	0.03375	0	n/a	0.0171	0	0.26077	0.18877
Hedge Rows (km^2)	0.67792	0.5787	0.5544	0.46418	0.3708	0.21645	0.01507	n/a	0.12352	0.05423	1.04602	0.81652
Disturbance (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Open Cliff and Talus (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Alvar (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Sand Barren and Dune (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Open Tallgrass Prairie (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Tallgrass Savannah (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Tallgrass Woodland (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Sand/Gravel/Mine (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Bedrock (km^2)	0	0	0	0	0	0	0	n/a	0	0	0	0
Community/Infrastructure (km^2)	0.95737	0.8595	0.8172	0.76185	0.43223	0.3384	0.01418	n/a	0.28958	0.0486	1.2816	1.10993
Agriculture and Rural Land Use (km^2)	19.87852	17.25862	16.11877	13.97992	5.65672	3.03255	0.4707	n/a	1.52775	1.80157	32.32373	24.7293

Region of Durham – Investigative Upstream Monitoring for Layton River

Appendix B: Water Quality

Table B.1. Raw physical and chemical data.

	D.D	D.D	YYYY-MM-DD	oC		uS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site	**Latitude**	**Longitude**	**Sample Date**	**Temperature**	**pH**	**Conductivity**	**Turbidity**	**Dissolved Oxygen**	**Chloride**	**Nitrate**	**Nitrite**	**Ammonia**	**Total Kjeldahl Nitrogen**	**Phosphorus**	**Total Suspended Solids**
SR2	44.1916	-78.9858	2019-03-27	-0.10	7.84	410.4	4.53	n/a	21.2	0.005	0.47	0.08	0.6	0.041	17
LR8W	44.2917	-79.0000	2019-05-22	13.7	7.84	445.7	0.74	9.30	22.9	0.005	0.08	0.06	0.60	0.030	3
LR6	44.2678	-78.9850	2019-05-22	13.1	8.08	445.0	0.80	8.11	22.1	0.005	0.13	0.09	0.70	0.034	5
LR4	44.2417	-78.9814	2019-05-22	12.7	7.99	465.7	1.58	10.87	24.5	0.005	0.29	0.07	0.60	0.040	6
LR5	44.2555	-78.98	2019-05-22	12.6	7.87	459.3	1.57	9.16	23.9	0.005	0.36	0.07	0.70	0.037	5
LR3	44.2268	-78.9880	2019-05-22	12.5	7.92	467.7	1.54	11.40	22.9	0.006	0.49	0.08	0.60	0.034	5
LR8E	44.2928	-78.9950	2019-05-22	11.0	7.84	642.0	1.96	12.18	55.5	0.006	3.55	0.09	0.40	0.022	6
LR2	44.2133	-78.9860	2019-05-22	9.3	8.07	561.0	1.58	11.91	18.4	0.007	3.77	0.06	0.60	0.029	3
LR7	44.2765	-79.006	2019-05-22	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2019-06-18	17	7.95	510.0	3.5	n/a	19.9	0.006	0.84	0.11	0.6	0.039	8
LR7	44.2765	-79.006	2019-07-09	22.8	9.76	463.9	n/a	2.79	13.3	0.006	0.05	0.10	0.70	0.054	<3
LR6	44.2678	-78.9850	2019-07-09	20.8	8.74	491.5	n/a	3.50	15.1	0.008	0.24	0.09	0.80	0.053	4
LR4	44.2417	-78.9814	2019-07-09	20.2	8.16	515.7	n/a	7.19	20.2	0.014	0.47	0.07	0.80	0.054	9
LR5	44.2555	-78.98	2019-07-09	20.9	8.09	514.3	n/a	6.43	18.5	0.011	0.49	0.10	0.80	0.05	3
LR3	44.2268	-78.9880	2019-07-09	18.2	8.42	515.5	n/a	7.67	19.5	0.014	0.90	0.08	0.80	0.061	7
LR2	44.2133	-78.9860	2019-07-09	18.6	10.24	495.4	n/a	8.40	19.6	0.013	0.93	0.15	0.80	0.066	7
LR8E	44.2928	-78.9950	2019-07-09	17.3	8.41	712.0	n/a	10.01	53.9	0.017	5.20	0.08	0.60	0.022	14
LR8W	44.2917	-79.0000	2019-07-09	22.7	10.27	480.6	n/a	3.18	18.3	0.007	<0.05	0.14	0.70	0.042	<3
LR9	44.2088	-78.9920	2019-07-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2019-07-17	21.1	7.83	560	7.42	n/a	22.2	0.015	0.63	0.09	0.7	0.095	12
LR7	44.2765	-79.006	2019-08-12	21.3	n/a	538.0	n/a	4.04	20.9	0.007	0.06	0.13	0.6	0.04	8
LR8W	44.2917	-79.0000	2019-08-12	16.4	n/a	550.0	n/a	3.66	25.5	0.013	0.15	0.17	0.6	0.068	3
LR4	44.2417	-78.9814	2019-08-12	20.7	n/a	641.0	n/a	9.38	47.3	0.024	1.03	0.08	0.6	0.048	7
LR2	44.2133	-78.9860	2019-08-12	18.4	n/a	550.7	n/a	13.86	26.2	0.011	1.18	0.08	0.4	0.064	6
LR3	44.2268	-78.9880	2019-08-12	16.9	n/a	565.4	n/a	12.57	29.4	0.015	1.74	0.11	0.5	0.069	4
LR5	44.2555	-78.98	2019-08-12	21.6	n/a	644.0	n/a	11.23	46.7	0.025	1.92	0.07	0.5	0.031	4
LR8E	44.2928	-78.9950	2019-08-12	11.7	n/a	737.0	n/a	12.66	59.2	0.019	5.82	0.05	0.3	0.046	7
LR6	44.2678	-78.9850	2019-08-12	22.0	n/a	583.0	n/a	8.51	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR9	44.2088	-78.9920	2019-08-12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2019-08-19	18.9	7.89	580	5.46	n/a	38.2	0.014	0.9	0.08	0.5	0.054	9
SR2	44.1916	-78.9858	2019-09-23	18.8	n/a	562.5	n/a	n/a	33.6	0.016	1.39	0.08	0.5	0.032	4
LR7	44.2765	-79.006	2019-10-01	14.9	7.26	441	0.27	1.97	23.2	0.008	0.33	0.09	0.7	0.034	<3
LR6	44.2678	-78.9850	2019-10-01	16.8	7.54	554	2.36	6.48	30.8	0.009	0.65	0.1	0.7	0.031	3
LR5	44.2555	-78.98	2019-10-01	15.7	7.63	588	1.76	8.25	41	0.01	0.79	0.06	0.6	0.022	4
LR4	44.2417	-78.9814	2019-10-01	14.3	7.68	609	1.9	7.57	25.6	0.007	0.8	0.08	0.7	0.033	3
LR2	44.2133	-78.9860	2019-10-01	12.1	7.87	633	1.27	9.08	31.2	0.009	0.84	0.09	0.6	0.028	6
LR3	44.2268	-78.9880	2019-10-01	13.7	7.95	577	4.3	8.6	30	0.007	1.77	0.07	0.4	0.024	<3
LR9	44.2088	-78.9920	2019-10-01	15.7	7.49	657	8.45	1.94	58.2	0.015	4.31	0.09	1.5	0.114	10

LR8W	44.2917	-79.0000	2019-10-01	17	7.11	555	1.46	3.45	25.2	0.006	<0.05	0.1	0.7	0.03	<3
LR8E	44.2928	-78.9950	2019-10-01	n/a	n/a	n/a	n/a	n/a	28.9	0.008	<0.05	0.08	0.6	0.03	<3
SR2	44.1916	-78.9858	2021-05-17	20.4	8.07	385.3	1.72	8.39	25.8	0.83	< 0.05	0.05	0.5	0.037	8
LR5	44.2555	-78.98	2021-05-19	21.8	7.81	528	2.3	7.41	21.9	0.19	0.08	0.08	0.7	0.037	5
LR4	44.2417	-78.9814	2021-05-19	18.3	8.17	549	1.27	11.27	26.7	0.79	0.08	0.05	0.6	0.05	< 3
LR2	44.2133	-78.9860	2021-05-19	15.1	8.13	550	1.38	9.59	26.5	1.15	0.11	0.05	0.6	0.037	< 3
LR3	44.2268	-78.9880	2021-05-19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-05-19	21.8	7.81	528	2.3	7.41	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR6	44.2678	-78.9850	2021-05-25	18.2	7.21	575	0.37	3.65	22	0.08	0.08	0.1	0.7	0.032	4
LR7	44.2765	-79.006	2021-05-25	17.2	7.61	598	0.95	8.38	26	0.75	0.08	0.06	0.5	0.017	< 3
LR8E	44.2928	-78.9950	2021-05-25	15.8	7.85	744	3.25	9.26	53	3.75	0.13	0.05	0.8	0.034	13
LR9	44.2088	-78.9920	2021-05-25	13.5	8.09	628	3.35	9.87	18.5	2.78	< 0.05	0.08	0.4	0.013	< 3
LR8W	44.2917	-79.0000	2021-05-25	12.8	8.05	636	1.46	10.68	10	7.05	< 0.05	0.03	0.6	0.037	13
LR7	44.2765	-79.006	2021-05-25	17.2	7.61	598	0.95	8.38	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2021-06-14	18.1	7.61	559	5.26	8.1	21.6	0.58	< 0.05	0.14	0.8	0.08	5
LR6	44.2678	-78.9850	2021-06-22	18.6	7.54	536	2.32	5.9	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-06-22	18.7	7.56	561	2.77	6.17	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-06-22	18.7	7.56	561	2.77	6.27	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-06-22	18.7	7.71	534	4.6	7.47	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-06-22	18.7	7.71	534	4.6	7.47	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR4	44.2417	-78.9814	2021-06-22	16.3	7.75	571	2.53	6.64	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR3	44.2268	-78.9880	2021-06-22	16.6	7.74	572	2.98	7.85	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR2	44.2133	-78.9860	2021-06-22	14.4	7.97	523	4.43	9.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR9	44.2088	-78.9920	2021-06-22	11.9	7.97	583	2.75	10.48	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8W	44.2917	-79.0000	2021-06-22	12.2	8.28	580	6.14	10.56	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8E	44.2928	-78.9950	2021-06-22	14.7	8.07	726	5.66	11.29	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR6	44.2678	-78.9850	2021-07-19	22.7	7.09	763.3	2.3	1.25	18.3	0.07	< 0.05	0.05	0.9	0.051	3
LR5	44.2555	-78.98	2021-07-19	23	7.39	529	3.06	4.38	18.6	0.09	< 0.05	0.07	0.9	0.06	< 3
LR7	44.2765	-79.006	2021-07-19	22.2	7.21	528	3.33	2.56	18.8	0.11	< 0.05	0.11	0.9	0.045	4
LR3	44.2268	-78.9880	2021-07-19	22	7.45	557	3.28	4.88	21.3	0.15	< 0.05	0.06	1	0.089	< 3
LR4	44.2417	-78.9814	2021-07-19	21.5	7.32	546	4.64	3.79	20.6	0.24	< 0.05	0.07	0.9	0.073	3
LR2	44.2133	-78.9860	2021-07-19	20.8	7.65	559	3.88	7.36	21	0.44	< 0.05	0.09	1	0.088	7
SR2	44.1916	-78.9858	2021-07-19	20.83	8.07	517	10.2	7.55	21.9	0.47	< 0.05	0.08	0.9	0.104	9
LR9	44.2088	-78.9920	2021-07-19	15.8	7.62	639	2.54	9.44	19.4	2.69	< 0.05	0.01	0.6	0.047	3
LR8E	44.2928	-78.9950	2021-07-19	17.5	7.85	733	7.2	10.5	56.2	4.53	< 0.05	0.11	1.1	0.049	8
LR8W	44.2917	-79.0000	2021-07-19	17.6	7.92	580	6.13	9.06	11.8	5.64	< 0.05	0.1	1.8	0.319	294
LR7	44.2765	-79.006	2021-07-19	22.2	7.21	528	3.33	2.56	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-07-19	23	7.39	529	3.06	4.38	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2021-08-16	18.8	8.1	509	10.1	6.05	26.8	0.79	< 0.05	0.08	0.5	0.077	9
LR5	44.2555	-78.98	2021-08-17	20.4	7.29	618	2.95	0.67	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR6	44.2678	-78.9850	2021-08-17	20.4	7.29	618	2.95	0.67	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR3	44.2268	-78.9880	2021-08-17	19.4	7.71	644	4.82	6.52	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-08-17	18.7	7.4	670	3.22	17.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a

LR7	44.2765	-79.006	2021-08-17	18.7	7.4	670	3.22	17.4	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR4	44.2417	-78.9814	2021-08-17	19.7	7.58	660	3.22	4.42	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-08-17	21.8	7.54	604	5.94	4.51	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR2	44.2133	-78.9860	2021-08-17	16.3	7.99	565	4.01	8.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8W	44.2917	-79.0000	2021-08-17	15.3	8.21	644	9.41	9.59	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR9	44.2088	-78.9920	2021-08-17	15	8.2	638	4.98	9.62	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8E	44.2928	-78.9950	2021-08-17	13.7	8.02	794	6.65	10.58	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-08-27	19.3	7.6	705	4.02	3.65	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-08-27	19.3	7.6	705	4.02	3.65	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR3	44.2268	-78.9880	2021-08-27	20.5	7.83	673	2.8	6.31	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR2	44.2133	-78.9860	2021-08-27	18.6	8.09	621	2.9	8.46	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR6	44.2678	-78.9850	2021-08-27	22.1	7.49	623	3.23	1.77	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR4	44.2417	-78.9814	2021-08-27	21.1	7.51	678	50.4	1.96	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-08-27	15.1	7.66	605	78.42	5.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-08-27	15.1	7.66	605	78.42	5.7	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR9	44.2088	-78.9920	2021-08-27	16.4	8.2	635	0.75	9.19	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8E	44.2928	-78.9950	2021-08-27	17.1	8.28	635	3.03	9.3	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8W	44.2917	-79.0000	2021-08-27	15.5	8.1	789	30.7	10.74	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-09-20	14.96	7.42	608	1.8	2.67	23.5	0.05	< 0.05	0.04	0.7	0.048	< 3
LR5	44.2555	-78.98	2021-09-20	16.61	7.73	588	0.9	8.66	17.3	0.1	< 0.05	0.06	0.8	0.049	3
LR4	44.2417	-78.9814	2021-09-20	14.79	7.75	612	1.1	7.68	23.7	0.31	< 0.05	0.03	0.9	0.04	4
LR2	44.2133	-78.9860	2021-09-20	12.77	8.08	591	2.6	8.82	23	0.54	< 0.05	0.07	0.7	0.035	3
LR9	44.2088	-78.9920	2021-09-20	11.36	8.1	640	0	9.49	12.8	2.04	< 0.05	0.01	0.3	0.016	< 3
LR8W	44.2917	-79.0000	2021-09-20	13.5	8.16	793	3.7	10.11	50.8	4.08	< 0.05	0.03	0.5	0.014	8
LR8E	44.2928	-78.9950	2021-09-20	14.26	8.3	636	2.8	9.11	7.4	8.24	< 0.05	0.01	0.3	0.028	3
LR6	44.2678	-78.9850	2021-09-20	15.08	7.48	566	1.1	2.45	19.6	< 0.05	< 0.05	0.12	1.1	0.069	3
LR3	44.2268	-78.9880	2021-09-20	13.93	7.86	606	1.7	7.83	22.9	< 0.05	< 0.05	0.05	0.9	0.044	3
LR7	44.2765	-79.006	2021-09-20	14.96	7.42	608	1.8	2.67	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-09-20	16.61	7.73	588	0.9	8.66	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2021-09-22	17.27	7.72	578	6.3	6.94	20.7	0.49	< 0.05	0.04	0.5	0.063	7
LR5	44.2555	-78.98	2021-10-12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8E	44.2928	-78.9950	2021-10-12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-10-12	17.04	7.58	623	1.4	0.29	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR6	44.2678	-78.9850	2021-10-12	16.64	7.63	590	0.5	2.57	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR4	44.2417	-78.9814	2021-10-12	15.81	7.75	626	2.4	5	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR5	44.2555	-78.98	2021-10-12	17.19	7.74	603	1.7	5.24	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR3	44.2268	-78.9880	2021-10-12	16.18	7.71	626	4.1	5.48	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR2	44.2133	-78.9860	2021-10-12	15.28	8.02	609	1.6	7.42	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2021-10-12	15.55	8.28	650	2.7	7.49	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR9	44.2088	-78.9920	2021-10-12	13.67	8.18	709	0	8.27	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR8W	44.2917	-79.0000	2021-10-12	13.81	7.06	786	3.7	9.19	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2	44.1916	-78.9858	2021-10-18	10.4	n/a	n/a	n/a	9.69	29.1	0.6	< 0.05	0.04	0.6	0.057	n/a
SR2	44.1916	-78.9858	2021-11-09	5.43	8.19	584	14.7	11.85	28.4	1.02	< 0.05	0.03	0.4	0.028	9

SR2A	44.2	-78.9847	2022-05-17	13.08	8.23	1064	3.8	12.52	28.6	1.02	< 0.05	0.05	0.7	0.029	< 3
LR4	44.2417	-78.9814	2022-05-24	18.47	7.89	966	1.7	5.62	20.6	0.11	< 0.05	0.03	0.8	0.027	7
LR2	44.2133	-78.9860	2022-05-24	15.32	8.1	1007	1.8	7.44	24.5	0.46	< 0.05	0.02	0.7	0.033	< 3
LR3	44.2268	-78.9880	2022-05-24	17.51	8.16	1001	1.3	7.5	23.9	0.52	< 0.05	0.03	0.7	0.036	12
LR8W	44.2917	-79.0000	2022-05-24	9.15	8.29	1210	0	7.68	19.6	2.24	< 0.05	< 0.01	0.5	0.022	4
LR7	44.2765	-79.006	2022-05-24	11.49	8.44	1137	2.1	7.89	61.1	4.67	< 0.05	< 0.01	0.4	0.015	4
LR8E	44.2928	-78.9950	2022-05-24	14.75	8.35	1378	2.4	8.28	8.8	7.6	< 0.05	< 0.01	0.5	0.022	< 3
LR6	44.2678	-78.9850	2022-05-24	n/a	n/a	n/a	n/a	n/a	20.1	< 0.05	< 0.05	0.01	0.7	0.025	5
LR5	44.2555	-78.98	2022-05-24	17.63	7.98	959	0.8	7.74	20.3	< 0.05	< 0.05	< 0.01	0.7	0.023	< 3
LR6	44.2678	-78.9850	2022-05-24	15.6	7.76	1010	0.2	4.33	24.8	< 0.05	< 0.05	< 0.01	0.8	0.042	3
LR9	44.2088	-78.9920	2022-05-24	20.24	7.89	467	4.3	6.02	24.1	0.99	< 0.05	0.07	0.9	0.054	< 3
LR5	44.2555	-78.98	2022-05-24	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LR7	44.2765	-79.006	2022-05-24	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
SR2A	44.2	-78.9847	2022-06-20	16.91	8.11	465	3.1	9.84	23.2	0.72	< 0.05	0.03	0.7	0.037	6
LR9	44.2088	-78.9920	2022-06-22	19.08	7.65	468	3.8	4.67	18	0.15	< 0.05	0.12	1.1	0.063	6
LR2	44.2133	-78.9860	2022-06-22	26.31	7.8	499	4.6	5.4	26.4	0.6	< 0.05	0.09	1	0.059	< 3
LR3	44.2268	-78.9880	2022-06-22	27.55	7.92	496	2.9	6.93	25.8	0.95	< 0.05	0.07	1	0.053	5
LR4	44.2417	44.2417	2022-06-22	15.27	8.16	568	1.1	7	19.5	2.75	< 0.05	0.03	0.7	0.035	< 3
LR8W	44.2917	-79.0000	2022-06-23	13.68	7.88	517	2.1	5.38	22.1	0.57	< 0.05	0.1	0.6	0.033	< 3
LR7	44.2765	-79.006	2022-06-23	15.52	8.03	665	5	8.79	60.4	5.6	< 0.05	0.02	0.4	0.018	7
LR8E	44.2928	-78.9950	2022-06-23	15.22	8.23	531	3.5	8.08	10.4	8.26	< 0.05	0.02	0.5	0.033	7
LR5	44.2555	-78.98	2022-06-23	20.94	7.54	446	3.5	1.93	14	< 0.05	< 0.05	0.06	1	0.067	< 3
LR6	44.2678	-78.9850	2022-06-23	20.37	7.22	506	2	0.8	21.7	< 0.05	< 0.05	0.14	1.1	0.084	6
LR7	44.2765	-79.006	2022-06-23	n/a	n/a	n/a	n/a	n/a	22.7	< 0.05	< 0.05	0.15	1.1	0.09	< 3
SR2A	44.2	-78.9847	2022-07-19	18.55	7.89	504	0	8.17	28.2	0.81	< 0.05	0.05	0.7	0.063	6
LR4	44.2417	44.2417	2022-08-16	18.86	7.77	576	1.1	5.32	21.3	0.11	< 0.05	0.01	1.07	0.065	< 3
LR9	44.2088	-78.9920	2022-08-16	n/a	n/a	n/a	n/a	n/a	21.4	0.11	< 0.05	0.02	1.12	0.067	< 3
LR5	44.2555	-78.98	2022-08-16	14.09	8.12	681	0.3	9.55	25.6	0.4	< 0.05	0.03	0.8	0.037	7
LR2	44.2133	-78.9860	2022-08-16	17.1	7.43	632	11.2	3.88	47.3	0.6	< 0.05	0.03	0.98	0.085	5
LR3	44.2268	-78.9880	2022-08-16	18.8	7.68	623	5.4	5.08	40.4	1.04	< 0.05	< 0.01	0.87	0.05	3
LR8W	44.2917	-79.0000	2022-08-16	13.6	8.07	536	4.5	4.82	13.2	2.76	< 0.05	< 0.01	0.23	0.027	< 3
LR7	44.2765	-79.006	2022-08-16	13.95	8.17	707	18.5	7.25	63.5	5.44	< 0.05	< 0.01	0.61	0.031	13
LR8E	44.2928	-78.9950	2022-08-16	15.01	8.39	569	7.3	6.71	7.4	8.57	< 0.05	< 0.01	0.48	0.036	4
LR5	44.2555	-78.98	2022-08-16	18.01	7.23	637	15.2	0	24.2	< 0.05	< 0.05	0.38	2.35	0.199	18
LR6	44.2678	-78.9850	2022-08-16	19.45	7.38	596	8.9	0.44	26.8	< 0.05	< 0.05	0.33	2	0.182	64
SR2	44.1916	-78.9858	2022-08-22	18.66	7.68	578	6.4	3.51	29.6	0.44	< 0.05	< 0.01	0.7	0.066	3
SR2A	44.2	-78.9847	2022-08-22	n/a	7.81	590	9.3	3.04	34.8	0.76	< 0.05	< 0.01	0.7	0.051	7
SR2A	44.2	-78.9847	2022-09-19	15.81	7.86	575	8.66	11.2	36	0.51	< 0.05	0.05	0.9	0.059	7
SR2	44.1916	-78.9858	2022-09-19	15.91	7.84	763	6.7	5.65	28.3	0.52	< 0.05	0.03	0.7	0.049	7
LR4	44.2417	44.2417	2022-09-20	17.15	7.5	560	1	5.44	36.1	0.11	< 0.05	0.03	1	0.029	< 3
LR2	44.2133	-78.9860	2022-09-20	16.26	7.84	567	4.8	8.65	28	0.14	< 0.05	0.03	0.9	0.029	< 3
LR3	44.2268	-78.9880	2022-09-20	16.61	7.59	572	2.6	6.75	29.5	0.18	< 0.05	0.03	0.9	0.036	< 3
LR8W	44.2917	-79.0000	2022-09-20	14.8	8.23	561	0.3	10.21	24.3	1.8	< 0.05	0.02	0.6	0.029	4

LR9	44.2088	-78.9920	2022-09-20	n/a	n/a	n/a	n/a	n/a	24.3	1.8	< 0.05	0.02	0.2	0.036	< 3
LR7	44.2765	-79.006	2022-09-20	18.18	7.41	571	1.4	3.56	60.6	4.8	< 0.05	0.01	0.4	0.009	4
LR8E	44.2928	-78.9950	2022-09-20	13.91	8.14	753	3.5	11.1	10.8	6.91	< 0.05	0.01	4	0.038	3
LR5	44.2555	-78.98	2022-09-20	17.44	7.58	597	0.3	7.81	33.2	< 0.05	< 0.05	0.07	0.9	0.033	4
SR2A	44.2	-78.9847	2022-10-17	8.14	8.01	595	3.9	8.96	32.4	0.41	0.07	< 0.01	0.7	0.014	3

Region of Durham – Investigative Upstream Monitoring for Layton River

Appendix C: Hydrology

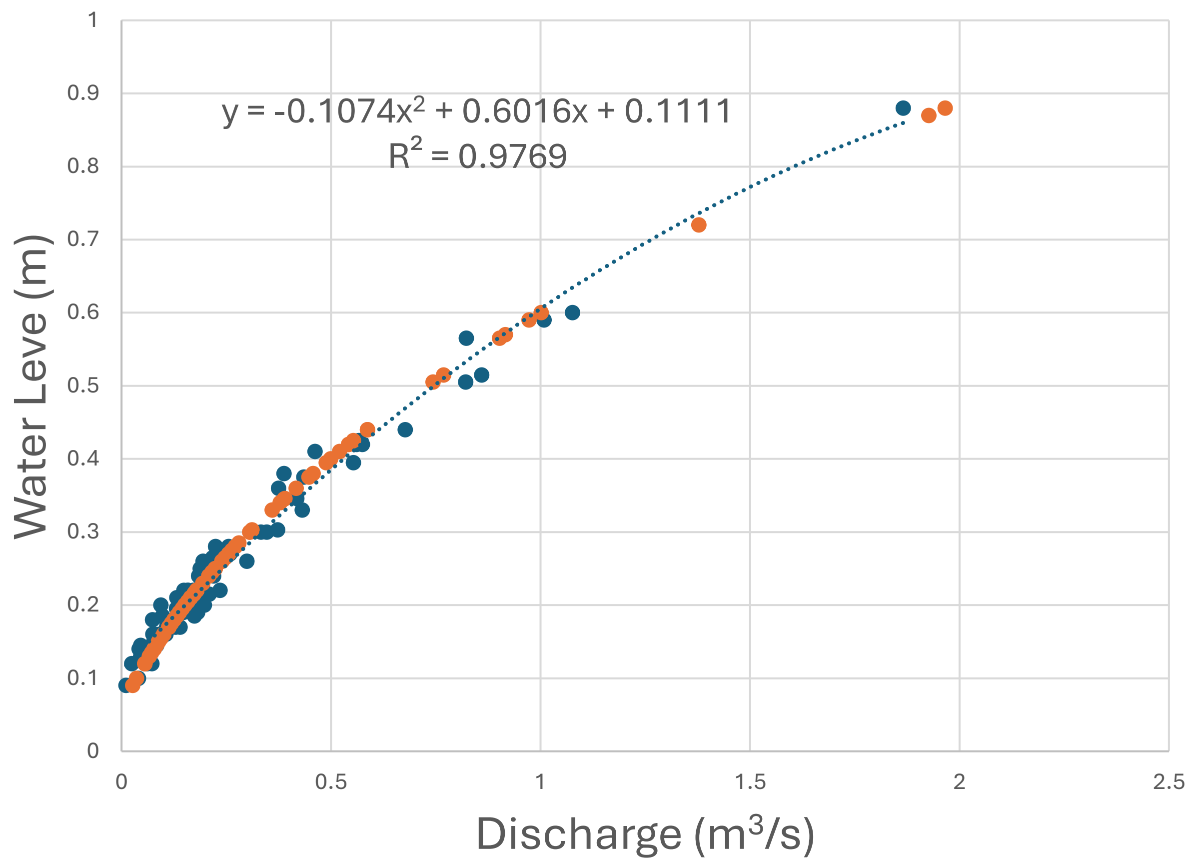

Figure C.1. Rating curve of Layton River at site SR2A from stage measurements (2009-2022).

Table C.1. Total discharge (m^3/s) at SR2A from 2009-2022 by January to December, and total per year.

	All Months	1	2	3	4	5	6	7	8	9	10	11	12
All	492,780,028	3,377,177	3,112,163	4,056,734	4,516,902	3,386,526	2,672,432	2,095,820	1,869,062	1,693,864	2,525,343	2,623,387	3,408,002
2009	7,535,147	-	-	-	-	-	-	-	-	-	-	2,224,678	5,310,469
2010	55,968,516	5,652,993	4,430,890	7,172,659	4,941,686	4,660,319	4,517,255	4,135,728	3,372,555	2,975,350	4,246,029	4,774,109	5,088,944
2011	54,530,595	5,361,125	5,688,939	8,665,618	6,896,583	6,035,535	3,814,160	2,928,958	3,772,296	3,038,077	2,906,073	-	5,423,231
2012	39,757,000	4,177,437	3,388,293	6,085,123	3,657,391	3,486,404	3,997,943	647,491	1,664,922	850,244	3,385,863	3,904,477	4,511,411
2013	47,251,164	4,989,335	4,836,780	6,192,102	7,464,696	3,195,388	4,547,840	2,607,329	2,267,153	3,002,959	4,382,057	3,635,165	130,361
2014	26,885,287	-	-	973,689	8,807,229	4,981,048	3,226,249	3,160,222	3,141,192	2,595,659	-	-	-
2016	19,593,072	-	-	-	236,650	3,422,639	2,369,604	1,647,476	1,723,421	1,190,953	2,978,675	1,642,406	4,381,247
2017	30,158,972	2,702,063	1,930,107	3,142,763	2,809,289	2,704,759	2,471,884	2,174,462	2,159,837	2,083,796	2,595,291	3,154,547	2,230,172
2018	53,903,574	7,713,644	7,712,784	5,467,249	8,217,430	3,810,879	-	1,863,320	2,458,305	1,509,500	3,924,676	5,664,057	5,561,730
2020	13,454,350	-	-	-	-	-	-	-	-	1,385,963	3,360,112	3,857,823	4,850,452
2019	2,235,642	2,235,642	-	-	-	-	-	-	-	-	-	-	-
2021	42,141,807	4,628,780	3,656,761	2,253,911	1,730,945	3,945,329	3,017,040	2,024,869	1,024,406	3,653,019	4,856,620	5,031,808	6,318,318
2022	59,691,055	5,432,748	6,914,879	9,063,735	6,093,978	4,495,366	4,294,347	3,190,478	2,720,331	3,415,623	3,897,519	4,342,408	5,829,643