Fish Passage Restoration and Habitat Enhancement

A project to address fish habitat fragmentation and degradation in the Annapolis River Watershed

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Nova Scotia Salmon Association
Adopt A Stream
Fisheries and Oceans Canada

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List of Acronyms

AAS	Adopt A Stream
ACAD	Aquatic Connectivity Analytical Database
CARP	Clean Annapolis River Project
cm	Centimetre
DFO	Fisheries and Oceans Canada
g	Grams
HSI	Habitat Suitability Index
HWY	Highway
kg	Kilogram
km	Kilometre
km^2	Kilometre squared
l	Litre
m	Meter
m^2	Meters squared
mg	Milligram
mm	Millimeter
NSE	Nova Scotia Environment
NSFHAP	Nova Scotia Fish Habitat Assessment Protocol
$\mu S/cm$	microSiemens

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Executive Summary

Habitat fragmentation caused by barriers within a watercourse (e.g. culverts) can impede the upstream and downstream movements of fish through a river system. Insufficient water depths, incorrect sizing, steep slopes, and large outflow drops are potential problems that can characterize a culvert as a barrier. When fish migration is restricted, populations can be negatively impacted. In 2007, the Clean Annapolis River Project (CARP) initiated the Broken Brooks program (renamed the Fish Passage Restoration and Habitat Enhancement Project in 2015) to assess aquatic habitat and fish connectivity within the Annapolis River watershed.

Building upon this work in 2023, the primary project objective was to assess fish habitat connectivity at private and public watercourse crossings for multiple target species. Since the inception of the Broken Brooks program in 2007, CARP has visited over 700 watercourse crossing sites. Of these, 415 were identified as culverts on fish-bearing streams and received detailed watercourse crossing assessments. During the 2023 field season, the focus was on crossings within the Annapolis River watershed previously assessed and restored by CARP. The aim was to evaluate the durability and effectiveness of remediation techniques, such as tailwater control structures, fish chutes, and baffles. From July to September, CARP visited 15 watercourse crossing sites where past remediation activities took place. The detailed information gathered in these assessments was entered into an online database that assessed the current barrier status of each culvert and offered recommended remediation options.

The second objective was to restore fish habitat connectivity within fragmented sub-watersheds. In 2023, six sites underwent restoration work, leading to five debris removals and one fish chute installation. These remediation activities are expected to benefit recreational anglers by enhancing access to target fish species in habitats where connectivity has been restored. Additionally, these improvements are anticipated to expand the area of aquatic habitat available for the spawning and rearing of salmonids and other native fish species. In total, these remediation activities have re-established access to 8.10 km of upstream habitat.

The project's third and final objective was to assess fish habitat quality, quantity, and usage in three priority sub-watersheds through data collection and analysis. The Fales River, Roxbury Brook, and Round Hill River each received five temperature data loggers to monitor thermal pollution. Fish sampling and electrofishing surveys were conducted to identify species composition and abundance in each river. Additionally, a stream bank erosion survey covered a 3 km stretch of the Fales River, identifying 26 sites where the river is experiencing severe erosion. Salmon redd surveys were also conducted along each watercourse, which resulted in the identification of 4 potential redds in the Fales River.

1.0 Introduction

Fragmentation of aquatic habitats is considered a serious concern and major restoration priority for many watershed groups across Nova Scotia. Infrastructure development and land use changes are often the cause of aquatic habitat fragmentation, and the importance of watercourse connectivity within a watershed is often overlooked during these changes (Woods, 2014). Watercourse crossings causing fragmentation affect ecologically significant processes by altering natural channel morphology and creating physical barriers which directly affect aquatic connectivity to both upstream and downstream habitat. The interruption of free travel of aquatic organisms, specifically anadromous fish species, can limit their access to suitable habitat required for spawning and rearing as well as limit their connectivity with neighbouring populations and ultimately limit the total production of the watershed (AAS, 2018).

Watercourse crossing structures are anthropogenic features often constructed to simplify human travel and include structures such as culverts, bridges, dams, and fords. Often installed improperly or not maintained, these structures can create physical barriers to fish passage. Although bridges are the preferred watercourse crossing structure allowing the most natural stream channel dynamics, culverts are the most commonly installed structure because they are cheap to build and quick to install; they are prefabricated and simply dropped into place and covered (Price *et al.*, 2010; AAS, 2018). If these culverts are not installed properly, are poorly designed or not maintained, they can block migration routes to suitable habitat that could otherwise be reached naturally by anadromous and freshwater species such as Atlantic salmon and brook trout. Culverts can impede fish migration through a wide variety of barrier types:

- Vertical/perching barrier at the inflow or outflow of the culvert
- Depth barrier resulting from an oversized culvert that is too wide
- Length barrier in long culverts that lack resting pools
- Turbulence barriers in baffled culverts
- Velocity barrier in undersized or high slope culverts
- Debris barrier
- Deterioration barrier as a result of lack of maintenance (Bouska and Paukert, 2009; AAS, 2018)

Loss of habitat in smaller brooks is equally as important as in larger river systems, as these provide significant spawning and rearing habitat for fish species. Land use changes surrounding a watercourse can lead to negative impacts such as erosion and sedimentation that damage aquatic ecosystems. Streams can become straightened and over-widened, which in turn can lead to greater erosion and sedimentation, thus reducing the thermal capacity of the watercourse, in-stream cover, and food availability from vegetation as well as appropriate flows for spawning (NSE, 2018). Remediation actions involve the installation of in-stream structures to help redirect the excess sand and silt while supporting natural stream processes, as well as the direct removal of the fine sediments from the stream bed to reveal the natural cobble and gravel substrate, thus enhancing the aquatic habitat for various species including, but not limited to Atlantic salmon and brook trout.

The Fish Passage Restoration and Habitat Enhancement Project (formerly "Broken Brooks") was conceptualized and initialized by the Clean Annapolis River Project (CARP) in 2007. Field work for the project has been ongoing since 2010 with the purpose of assessing and restoring aquatic habitat and connectivity within the Annapolis River watershed. As part of the Broken Brooks program, CARP has been assessing watercourse crossings within the watershed in an attempt to identify which ones pose barriers to fish and prioritize those which have been found to obstruct access to upstream habitats for remediation. In 2012, CARP adopted a sub-watershed assessment approach to allow for improved watershed management and planning. In 2015, the project name was changed to reflect the inclusion of in-stream habitat remediation and sub-watershed planning within the scope of the project. The focus of the 2023 season was on assessing culverts within the Annapolis River watershed and maintaining watercourse crossings that had received restoration efforts in previous years of the project. Additionally, in-stream data collection and monitoring were carried out in high-priority sub-watersheds to assess the quality and quantity of existing fish habitat.

2.0 Methodology

The 2023 field season built upon previous projects by CARP staff, in which efforts were focused on identifying, prioritizing, and restoring fish passage within the Annapolis River watershed. In addition, in-stream data collection and monitoring were completed in the Fales River, Roxbury Brook, and Round Hill River to guide decision-making on future restoration actions.

2.1 Watercourse Crossing Assessments

The protocol for assessing culverts for fish passage was adapted from the Nova Scotia Environment provincial guidelines (to determine non-barrier culverts), and from protocols developed by the British Columbia Ministry of Environment (Parker, 2000), Terra Nova National Park (Cote, 2009), U.S. Department of Agriculture, Forest Service, National Technology and Development Program (Clarkin, 2005), and the Department of Fisheries and Oceans Canada (DFO, 2007). The protocol was then modified to be more specific to the target species of brook trout and Atlantic salmon and the criteria for a passable culvert was updated (Taylor, 2011). In addition, The NSLC Adopt A Stream Aquatic Connectivity Program was developed in 2010 in collaboration with several partners, including the Clean Annapolis River Project, which provided the appropriate training and materials to perform culvert assessments. Assessments allow for culverts to be placed into one of three categories (non-barrier, partial barrier, or full barrier) with the intent to prioritize culverts for restoration activities to ensure aquatic connectivity.

During the 2023 season, culvert assessments were primarily focused on watercourse crossings within the Annapolis River watershed that had been assessed and restored in the past to evaluate the durability and effectiveness of commonly used remediation techniques. Refer to Appendices 6.1 and 6.2 for culvert data sheets and information on the data collected during a culvert assessment. For full details of the assessment procedure and a full list of equipment, refer to the NSLC Adopt-a-Stream Aquatic Connectivity Initiative: A Guide to Assessing Culverts for Fish Passage (AAS, 2018).

In previous years, culvert data was manually analyzed and each culvert was placed into one of three categories: non-barrier, partial barrier, or full barrier based on a criteria checklist. Once classified as a barrier type, remediation actions were determined, and restoration was prioritized based on the number of downstream barriers and the potential upstream habitat gain of each culvert. These two variables were subdivided into categories, each with a corresponding score. The culvert with the highest cumulative score was deemed to be the highest-priority culvert. After receiving a prioritization score, culverts were then classified into one of three categories: high, medium or low priority. These prioritization scores would be used to guide restoration work for future field seasons also taking into consideration feasibility, in-stream habitat quality above and below the culvert, and its location within the watershed. For further details and methods for prioritizing culverts used prior to the 2018 and 2019 seasons, refer to Fish Habitat Restoration and Enhancement: A project to address fish habitat fragmentation and degradation in the Annapolis River watershed (Stoffer, 2016).

In 2019, the Adopt A Stream Aquatic Connectivity Initiative, in partnership with the Clean Annapolis River Project, launched ACAD, the Aquatic Connectivity Analytical Database. This web-based tool was designed to manage assessment data and prioritize water crossings for remediation purposes and could be used by watershed groups across Nova Scotia. All of the assessment data gets entered into the database and each culvert, bridge, dam, ford, or other form of watercourse crossing is given a fish passage ranking along with potential remediation options. The culvert assessments collected during the 2023 season were entered and stored in the database, and their barrier status and remediation options were digitally calculated. Refer to Appendix 6.3 to view a map of potential watercourse crossings within the Annapolis River watershed and all culverts that have been assessed by CARP since 2010.

2.2 Fish Passage Restoration

Culverts selected for remediation were chosen based on their barrier status, upstream habitat gain, and complexity and cost of the restoration. Refer to Appendix 6.5 to view a map of all culverts within the Annapolis River watershed that have received restoration actions by CARP since 2010.

2.2.1 Debris Removals

Debris can often accumulate at stream crossings, resulting in blockages to fish passage through portions of a waterbody. Over time, leaf litter, fallen branches, garbage, and silt are transported into a stream directly from streambanks or by erosion. Debris can also be carried into streams indirectly during high flow events. Such debris can be transported downstream, where it may accumulate at restrictions in the channel such as at the inflow, outflow, or inside of a culvert. Once debris begins to accumulate, a snowball effect is created, where more and more debris will be caught upon existing debris, increasing the size of the blockage. Such blockages have the potential to build to where they can restrict flows through a watercourse crossing and impede fish migration through culverts. Grates, cages, and fences placed at the inflow of culverts to reduce blockages can often have the opposite of the desired effect and exacerbate the accumulation of debris, unless cleaned on a regular basis. Beaver dams can also be a significant source of debris, as beavers often barricade the interior or the inflow of culverts, or construct dams directly upstream or downstream of a watercourse crossing. Such dams can either entirely block movement through a culvert or can affect water levels by altering the water flow through a watercourse crossing.

Debris removals are therefore an important component of restoration work that is needed to maintain fish passage and adequate water flow through culverts. Debris removals were completed by CARP staff with various hand tools including saws, shovels, and brush clippers.

2.2.2 Tailwater Controls

One of the most common watercourse crossing issues that pose a threat to fish passage are outflow drops. Culvert outflow drops that are too high result in perched culverts that are not accessible to fish, thus closing off upstream habitat. The outflow drop of a culvert is calculated as the height difference between the outflow of the culvert and the tailwater control.

A tailwater control is located downstream of an outflow pool, and is the highest elevation point leading into the natural downstream channel. By increasing the height of an existing tailwater control, or establishing a new one, the depth of water in a culvert's outflow pool can be raised, thereby reducing, or even eliminating an outflow drop. The construction of tailwater controls alone as a remediation for outflow drops is not recommended for drops that exceed 30 cm, as they become less effective, and are more likely to pose another barrier to fish passage. For culverts whose outflow drops exceed 30 cm, tailwater controls are often used in combination with additional weirs constructed downstream, fish chutes, baffles, and/or low flow barriers.

In the 2023 field season, maintenance was carried out on one tailwater control structure. The structure was originally constructed by CARP staff and volunteers in 2015, based on a vortex rock weir design. The foundation of the rock weir consisted of large, flat footer stones, with smaller pebbles and gravel used to fill gaps between the larger stones, following calculations for rock sizing and utilizing materials available at the site. During the 2023 season, it was determined that the rock weir required maintenance. The maintenance work involved reinforcing the structure by replacing eroded rock material along the streambanks and edges of the weir to prevent further erosion and washout. For more in-depth information, calculations, and a comprehensive description of rock weir construction, please refer to Appendices 6.6 and 6.7.

2.2.3 *Fish Chutes*

Fish chutes are another feature, often used in addition to other culvert remediation actions, that are added to the outflow of a culvert to assist in reducing the effects of a large outflow drop. In 2016, a fish chute was installed in combination with a tailwater control structure to alleviate an outflow drop of over 50cm. Culvert measurements were used to calculate the required chute dimensions using a formula for determining baffle notch sizes. Unfortunately, upon a site visit in 2023, the chute had detached from its affixed baffles and was no longer attached to the culvert.

Using the same design as in 2016, a new chute was ordered from RKO Steel Ltd in Dartmouth, NS. The chute was made from 6.35 mm galvanized steel plate, and the length of the chute itself was increased from 540 mm to 750 mm. A wooden frame was constructed around the outflow of the culvert using pressure-treated 4x4 lumber. The fish chute was affixed to the wooden frame using galvanized lag bolts. Stainless steel corner braces were also attached to add additional reinforcement to the structure.

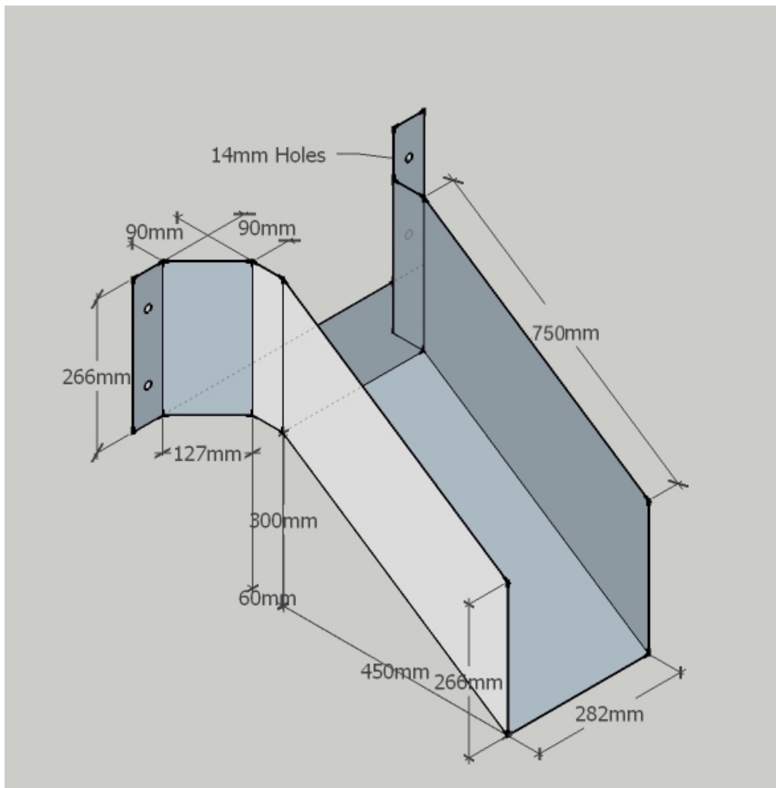

Figure 1. Fish chute design and dimensions.

2.3 <u>In-stream Data Collection and Monitoring</u>

CARP began developing restoration plans for sub-watersheds in 2012 to guide restoration and enhancement efforts. Targeted sub-watersheds included those that were previously identified and prioritized as suitable for salmonids (Wagner, 2013). Both the Fales River and Round Hill River systems were identified as priority sub-watersheds and have received some restoration and enhancement work in previous years by CARP. In 2021, the Roxbury Brook system was identified as having potential habitat for salmonids. Following the confirmation of Atlantic salmon presence in 2022, Roxbury Brook became a newly targeted sub-watershed for restoration and enhancement initiatives. During the 2023 season, in-stream data collection and monitoring took place in these three sub-watersheds to identify areas that could benefit from future restoration and enhancement activities.

2.3.1 Temperature Monitoring

In each of the three selected sub-watersheds, a total of five temperature data loggers were deployed. The deployment period for the loggers extended from June 18 to September 11, 2023, spanning the crucial summer season. The loggers were programmed to capture data at 30-minute intervals to collect information about annual temperature trends, identify areas in need of restoration to address thermal pollution, and identify important areas of thermal refuge to protect.

To ensure accurate temperature data collection, the loggers were deployed in pools, which inherently act as cool-water refuges for fish. Each logger was firmly affixed to a brick, which was further secured by tethering it to a nearby tree. This method was implemented not only to maintain the loggers in a stable position at the base of the pools but also to prevent any inadvertent displacement during the entirety of the monitoring phase, guaranteeing the accuracy of collected data.

Figure 2. (Left) HOBO pendant temperature logger. (Right) CARP staff, Brittni Scott, deploying a temperature logger.

2.3.2 Streambank Erosion Surveys

Over the course of several decades, the Fales River has experienced sediment accumulation from land-use impacts and bank erosion. The accumulation of fine sediments (particles smaller than 2 mm; Louhi et al., 2008) is widely acknowledged for its adverse effects on river ecosystems (Figure 3). Salmonid species prefer spawning in areas with coarse gravel and stone substrates, making them particularly susceptible to sediment accumulation (Hendry & Cragg-Hine, 2003; Klemensten et al., 2003). Therefore, during the 2023 field season, a survey was conducted along the Fales River to identify locations with severe erosion that might contribute to significant sediment inputs into the river.

The streambank erosion survey involved walking along the Fales River, documenting instances of severe erosion as they were encountered. At each site, measurements of bankfull width and wetted width, along with photographs and GPS coordinates, were recorded.

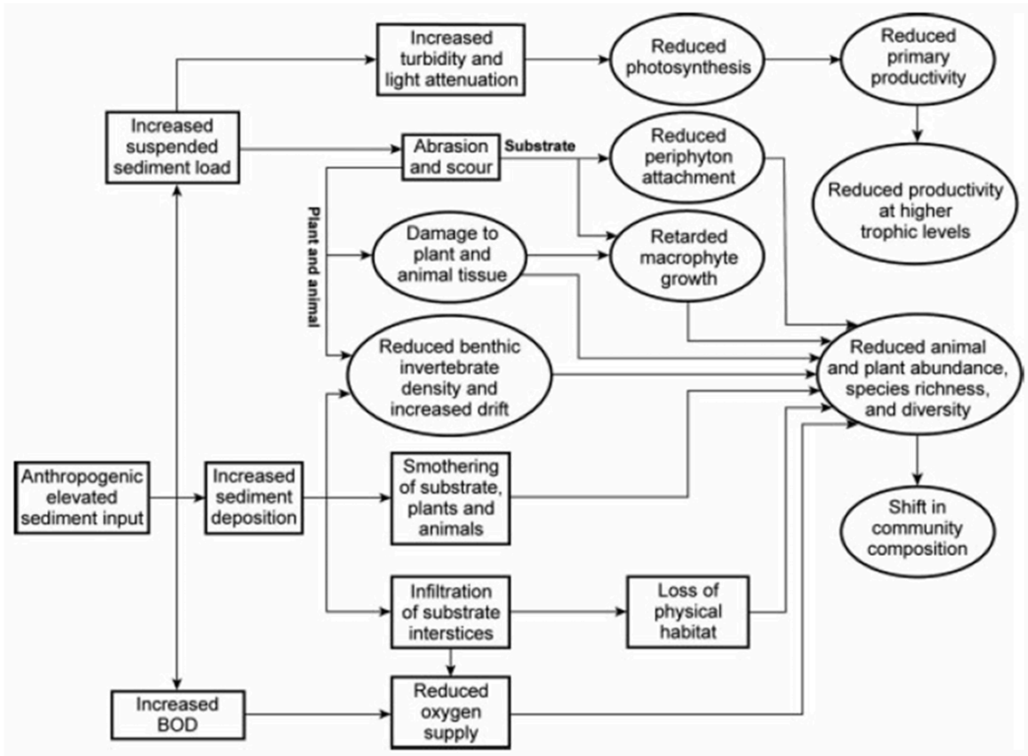

Figure 3. Negative impacts of anthropogenically enhanced sediment input (Kemp et al., 2011)

2.3.3 Fish Surveys and Sampling

Electrofishing is a scientific survey method used to sample fish populations and determine a variety of factors including species health, abundance, and density within an ecosystem. An electrical current is created between two submerged electrodes - a positive anode and a negative cathode. Galvanotaxis draws the fish towards the anode and once the fish is between the two electrodes, part of a closed circuit is formed and some of the current flows through the fish's body. The fish are then netted and placed in a temporary holding tank where they revive and can be assessed, measured, and sampled to collect various data.

In the 2023 field season, backpack electrofishing was carried out in the designated sub-watersheds. Each site represented an open reach with an average length of around 100 m. A single pass was executed at each site, documenting the captured fish species, and recording their fork length. The objective of these surveys was to compile a representative inventory of the fish species inhabiting each sub-watershed. Refer to Appendices 6.8 and 6.9 for an example of an electrofishing data sheet and information on the data that is collected during an electrofishing survey.

Additionally, redd surveys to identify potential Atlantic salmon spawning sites were conducted along the Fales River, Roxbury Brook and Round Hill River. The survey sites were chosen by considering areas where previous restoration efforts aimed at enhancing spawning habitats were implemented, as well as locations where juvenile Atlantic salmon had been observed in recent electrofishing surveys. A team of 3 staff members conducted the visual redd surveys, documenting the presence of redds by capturing photographs and recording GPS coordinates for each site encountered.

3.0 Results

Restoration efforts for the 2023 season resulted in considerable improvements to fish passage. Fifteen watercourse crossings within the Annapolis River watershed were assessed for fish passage. Six crossings received restoration work, which included: Five debris removals, one fish chute installation, and maintenance to one tailwater control structure. In total, 19.16 km of upstream habitat was made available through fish passage improvements.

Table 1. Summary of the 2023 fish passage restorations.

Restoration Site	Watercourse Name	Latitude	Longitude	Upstream Habitat Gain (km)	Restoration Work Completed
EAS009	East Moose River	44.6392	-65.5326	0.56	Debris removal & rock weir maintenance
ALL017	Grand Lake Flowage	44.6898	-65.5191	0.26	Debris removal
PET002	Petes Brook	44.8740	-65.1307	2.22	Debris removal
WAT004	Watton Brook	44.9702	-65.0261	1.50	Fish chute installation
TRO010	Troop Brook	44.7636	-65.5015	2.74	Debris removal
BLK004	Black River	44.9452	-65.0248	0.83	Debris removal

3.1 Watercourse Crossing Assessments

Throughout the 2023 field season, a total of 15 watercourse crossing sites were visited and assessed within the Annapolis River watershed. The primary focus was to complete assessments on watercourse crossings that had been assessed and restored in the past to evaluate the durability and effectiveness of commonly used remediation techniques. (Figure 4).

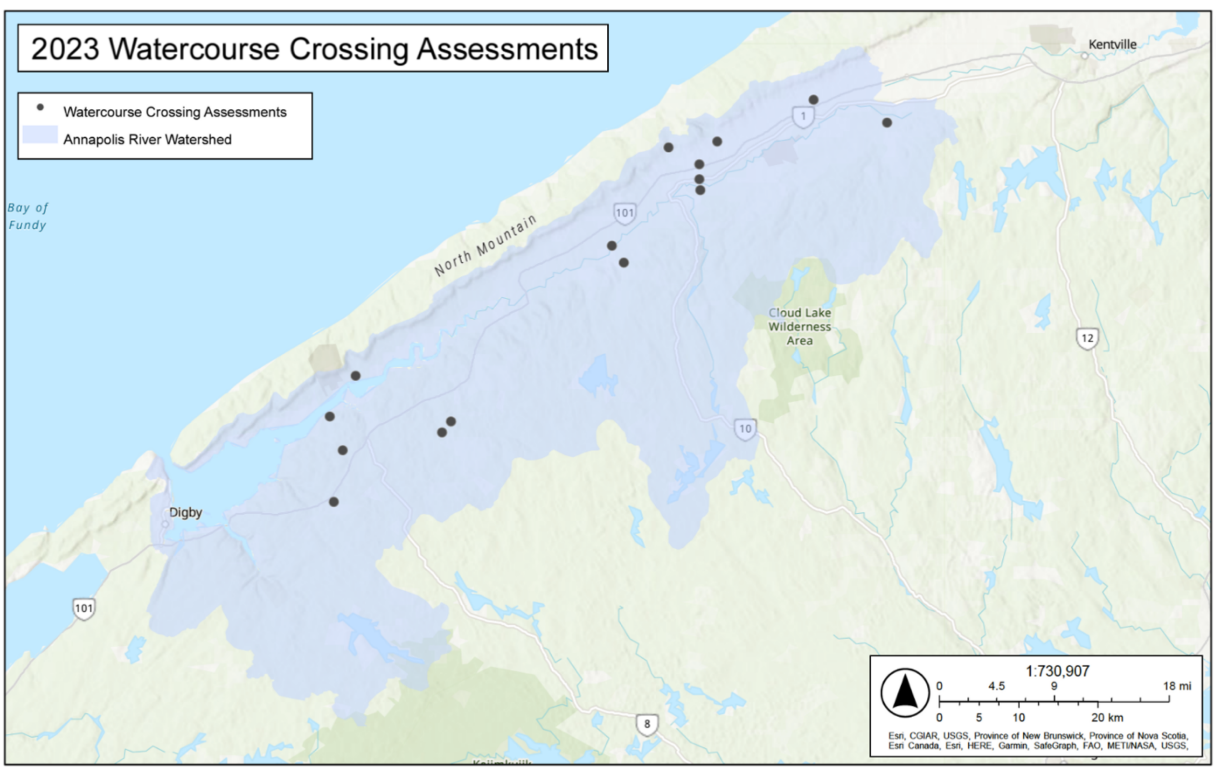

Figure 4. Map of 2023 watercourse crossing assessments.

Of the 15 watercourse crossings that were assessed, 3 were bridges, while 12 were a type of culvert. Table 2 shows the number of culverts that were found to have a visible outflow drop, water depth less than 15 cm anywhere in the culvert, no backwatering, a noticeable difference in the stream width above and below the culvert or a debris blockage present. Culverts that were initially found upon visual inspection to have any of these variables were theoretically posing an immediate form of barrier to fish passage and required a full, detailed assessment. However, the substantial rainfall experienced throughout the spring and summer of 2023 limited the number of full culvert assessments that could be conducted. The majority of the sites visited featured high-water levels and swift currents, creating unsafe conditions for performing a thorough assessment.

Of the 12 culverts assessed in 2023, more than half of the culverts (7 culverts, or 58.3%) had more than one contributing issue resulting in the restriction of fish passage. The watercourse crossings determined to be partial and full barriers to fish passage according to the AAS ACAD webpage were prioritized and received suggested remediation actions based upon complexity and cost efficiency. It's worth noting that 5 out of 6 sites with visible outflow drops had fish chutes affixed, and all sites were equipped with tailwater control structures, which were previously installed by CARP. Further details of all watercourse crossings assessed in 2023 can be found in Appendix 6.4.

Table 2. Rapid assessment results.

	Visible Outflow Drop	Water Depth Less than 15 cm Anywhere in the Culvert	Culvert is Backwatered Only Part of the Way or Not at All	Stream Width is Noticeably Different Above and Below the Culvert	Debris Blockage Present
Count	6	2	3	4	6
Percentage (%)	50	16.6	25.0	33.3	50

3.2 Fish Passage Restorations

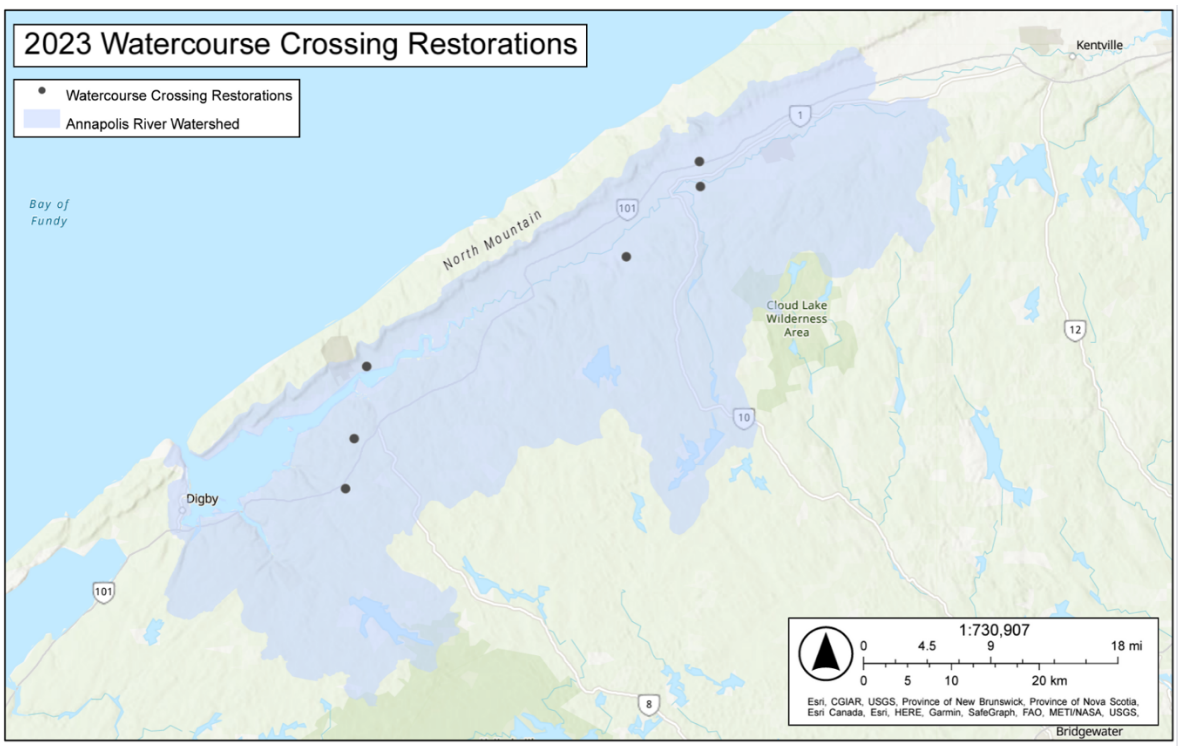

Figure 5. Map of 2023 watercourse crossing restorations.

3.2.1 EAS009

Location: Fraser Road
Stream Name: East Moose River
Remediation: Debris Removal and Tailwater Control Structure Maintenance
Upstream Habitat Gain: 0.56 km
Comments: EAS009 was a corrugated metal culvert positioned along the East Moose River. In 2015, a fish chute and tailwater control structure were installed at this location. Maintenance work on the tailwater control structure and a debris removal were conducted in the summer of 2023, restoring access to 0.56 km of upstream habitat.

Figure 6. EAS009 before (left) and after (right) the culvert inflow debris removal.

Figure 7. Before (left) and after (right) the tailwater control structure maintenance.

3.2.2 ALL017

Location: Clementsvale Road
Stream Name: Grand Lake Flowage
Remediation: Debris Removal
Upstream Habitat Gain: 0.26 km
Comments: ALL017 consisted of a pair of corrugated metal culverts. In 2015, a fish chute and tailwater control structure were installed at the site. When the site was revisited in 2023, obstructions from debris were observed both at the inflow and outflow of the culverts, resulting in flooding conditions upstream. A debris removal was undertaken to clear blockages from the culvert and accumulated debris downstream, restoring access to 0.26 km of upstream habitat.

Figure 8. ALL017 inflow (left) and outflow (right) blocked with debris.

Figure 9. ALL017 inflow (left) and outflow (right) after the debris removal.

3.2.3 PET002

Location: HWY 201
Stream Name: Petes Brook
Remediation: Debris Removal
Upstream Habitat Gain: 2.22 km
Comments: PET002 was a concrete culvert situated on Petes Brook. In 2018, CARP installed a fish chute and tailwater control structure at this location. Fortunately, those structures required no maintenance; however, there was an accumulation of sticks and woody debris observed at the culvert's inflow. A debris removal was conducted, restoring access to 2.22 km of upstream habitat.

Figure 10. PET002 before (left) and after (right) debris removal.

3.2.4 WAT004

Location: McColough Road
Stream Name: Watton Brook
Remediation: Fish Chute Installation
Outflow Drop: 56 cm
Upstream Habitat Gain: 1.50 km
Comments: WAT004, located on Watton Brook, consisted of a double wooden box culvert. In 2016, several enhancements were made to the site, including the installation of baffles, a low-flow barrier, a fish chute, and a tailwater control structure. However, during the 2023 site revisit, it was discovered that the fish chute had detached from the culvert and couldn't be located. A replacement chute was ordered and successfully installed in September 2023 to rectify the culvert's excessive outflow drop of more than 50 cm.

Figure 11. WAT004 before (left) and after (right) the fish chute installation.

Figure 12. CARP staff Levi Cliche and Shauna Forrestall installing the fish chute.

3.2.5 TRO010

Location: Post Road
Stream Name: Troop Brook
Remediation: Debris Removal
Upstream Habitat Gain: 2.74 km
Comments: TRO010 was a pair of corrugated metal culverts located on Troop Brook. Woody debris and other organic matter had accumulated at the inflow grates of both culverts. The debris was removed during the summer of 2023, re-establishing access to 2.74 km of upstream habitat.

Figure 13. TRO010 inflow before the debris removal.

Figure 14. TRO010 inflow after the debris removal.

3.2.6 BLK004

Location: HWY 201
Stream Name: Black River
Remediation: Debris Removal
Upstream Habitat Gain: 0.83 km
Comments: BLK004, located on the Black River, was a corrugated metal culvert. Downstream of the culvert, a significant accumulation of debris had formed, acting as a barrier to fish passage. The obstruction was successfully cleared, reopening access to 0.83 km of upstream habitat.

Figure 15. Downstream of BLK004 before (left) and after (right) debris removal.

3.3 In-Stream Data Collection and Monitoring

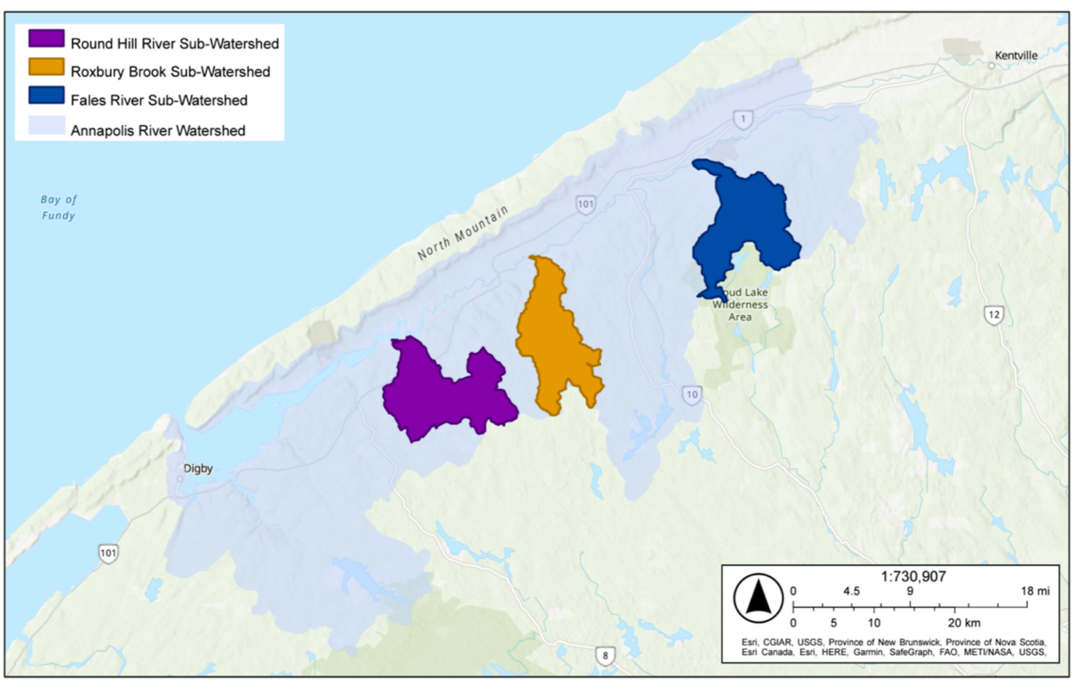

Figure 16. Map of target sub-watersheds.

Data collection within the Fales River, Roxbury Brook, and Round Hill River sub-watersheds encompassed several key activities, including temperature monitoring, streambank erosion surveys, electrofishing surveys, and Atlantic salmon redd surveys.

3.3.1 Temperature Monitoring

Each of the sub-watersheds received a series of five temperature data loggers. The data loggers were deployed from June 18 to September 11, 2023, to collect information about annual temperature trends, identify areas in need of restoration to address thermal pollution and to identify important areas of thermal refuge to protect.

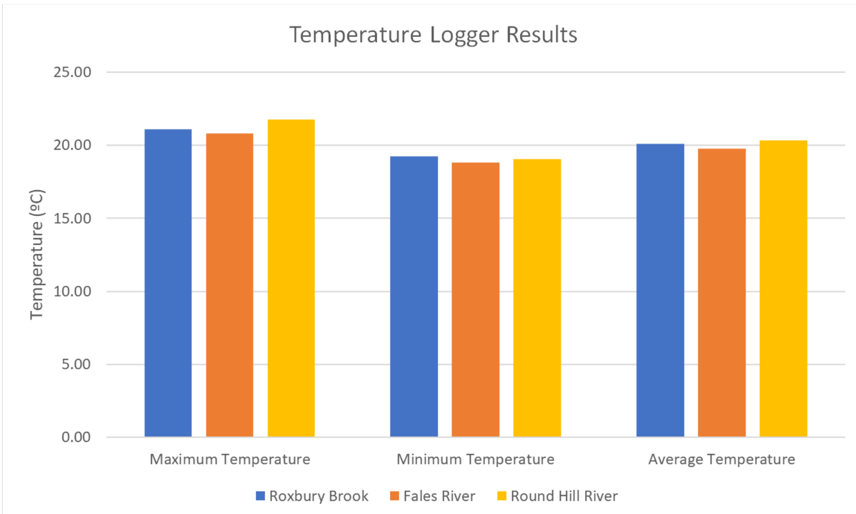

Figure 17. Comparison of maximum, minimum, and average temperature logger results for the three sub-watersheds.

The results showed very similar temperature trends among the three sub-watersheds. Notably, the Fales River consistently exhibited the coolest temperatures, whereas the Round Hill River consistently showed the warmest temperatures. In previous years, in-stream temperatures exceeding 27ºC were noted, whereas this year, the average maximum temperature for all three sub-watersheds was 21ºC. This year, unlike in previous years, witnessed a substantial amount of rainfall during the summer months. This heightened precipitation might have contributed to the observed cooler in-stream temperatures. Figure 18 provides a comparison of the temperature logger results for 2022 and 2023, and additional temperature monitoring results can be found in Appendix 6.12.

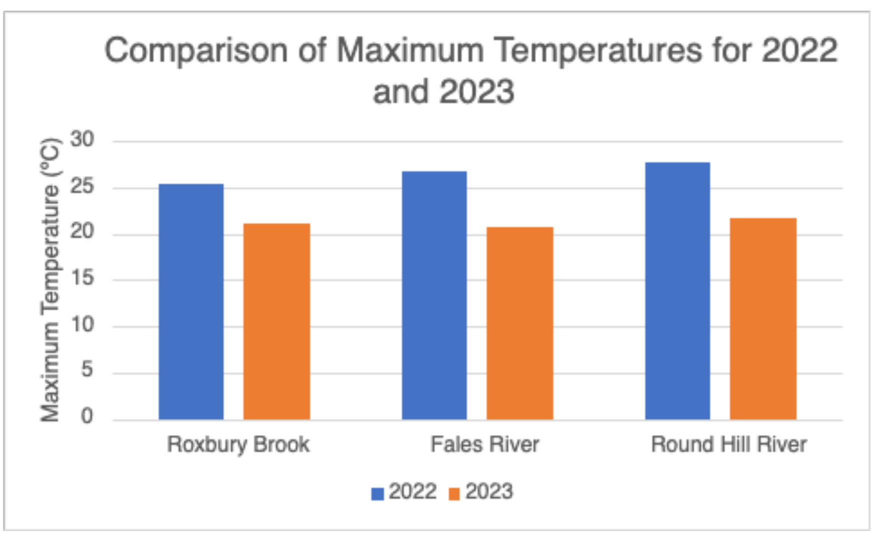

Figure 18. Comparison of maximum temperature results for 2022 and 2023.

3.3.2 Streambank Erosion Surveys

Streambank erosion surveys took place over a 3 km stretch of the Fales River on August 2 and 3, 2023. Within this stretch, 26 locations exhibiting significant erosion were pinpointed. In the context of this survey, an erosion site was defined as either having deep undercut banks or steep banks with exposed soil. Detailed erosion survey results can be found in Appendix 6.13.

Figure 19. Examples of erosion identified on the Fales River.

3.3.3 Fish Surveys and Sampling

Electrofishing surveys were carried out at two locations on the Fales River and one site on the Round Hill River, revealing the presence of four native fish species: white sucker, creek chub, three-spined stickleback, and American eel. Detailed electrofishing results, including pass and species information, can be found in Appendix 6.11.

Due to the substantial summer rainfall, elevated water levels posed significant challenges for safe entry into the rivers for electrofishing. Moreover, during periods of safe water levels, high velocity and poor visibility made netting extremely difficult. Given that electrofishing is restricted to the period between June 1 and September 30, limited efforts could be conducted under favorable conditions. To compensate for the shortfall in electrofishing efforts, fyke nets were deployed. Two fyke nets were set in the Round Hill River and Roxbury Brook on October 17, 2023. Deployed for approximately 20 hours, the nets were checked and retrieved on October 18. Unfortunately, the nets accumulated fallen autumn leaves, resulting in no fish being caught or observed.

Atlantic salmon redd surveys were carried out in late November along the Fales River, Roxbury Brook, and Round Hill River. A total of 1.2 km of stream was surveyed on the Fales River, leading to the identification of 4 salmon redds (Table 3). However, challenging survey conditions, including high water levels and poor visibility, were encountered on Roxbury Brook and Round Hill River, resulting in the absence of observed redds on these watercourses. Additional details from the redd surveys can be found in Appendix 6.11.

Table 3. Redd location on the Fales River.

Date	Transect #	Redd #	Latitude	Longitude
November 21, 2023	1	1	44.9620	-64.9318
November 21, 2023	2	2	44.9618	-64.9251
November 21, 2023	2	3	44.9612	-64.9240
November 21, 2023	3	4	44.9583	-64.9160

4.0 Recommendations

Recommendations are based on the 2023 field season as well as previous work through the Fish Passage Restoration and Habitat Enhancement Program.

A) Watercourse Crossing Assessments

I. Re-evaluate the barrier status of all watercourse crossing sites assessed in 2023 under low-flow conditions to enhance accuracy.

II. Assessments should be continued during future field seasons with a focus on priority sub-watersheds that lack detailed assessment data. These could include updating assessments that were completed prior to 2023 – different events may have occurred surrounding the crossing site leading to a change in the barrier status of previously assessed culverts during the past five or more years.

B) Fish Passage Restorations

I. Revisit all sites that have received restoration work in 2023 to ensure functionality of installed structures and to monitor accumulation of debris.

C) In-stream Data Collection and Monitoring

I. Continue in-stream data collection and monitoring in the Roxbury Brook to identify future in-stream restoration projects.

II. Continue planning restoration work on the Round Hill River and Fales River including additional installations of in-stream enhancement structures. The existing structures should be revisited for maintenance, and future actions should be identified for structures/enhancement further upstream.

III. Continue monitoring sediment inputs on the Fales River to identify additional sources of sedimentation.

IV. Future in-stream restoration projects should be identified, and sub-watershed management plans should be developed for other priority sub-watersheds within the Annapolis River watershed (Roxbury Brook, Black River, etc.).

5.0 References

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6.0 Appendices

6.1 Watercourse Crossing Data Sheet

NSLC adopt a stream

Aquatic Connectivity Program Crossing Assessment

SALMON

Site Information			
Crossing ID		Watershed Group Name	
Crossing Type	☐Culvert ☐Bridge* ☐Dam ☐Ford ☐Other	# of Culverts	
Field Crew		Date (dd/mm/yyyy)	
Stream Name		Time	
Road Name		Projection	☐ WGS 84 ☐ NAD 83
Ownership of Crossing	☐ Public Road ROW ☐ Rail Bed ROW ☐Private	Lat (deg, min, sec)	
Debris Blockage Present	☐Yes ☐No	Long (deg, min, sec)	
Description of Debris		Fish Habitat**	☐Yes ☐No

*If crossing is a bridge or other open bottomed structure, complete bridge section
**If crossing is identified as being on a fish bearing stream, then proceed with further data collection

Photo Files			
Upstream	File Name	**Downstream**	File Name
Toward Inflow		Toward Outflow	
Through Culvert		Through Culvert	
Looking Upstream		Looking Downstream	
Other		Other	

Bridge Dimensions			
Span (m)		Wetted Width Under Bridge (m)	
Rise (m)		Average Water Depth Under Bridge (m)	
Bridge Width (m)		Stream Width Ratio	

Rapid Assessment		
There is a visible outflow drop.		☐True ☐False
Water depth is less than 15cm in at least one location inside the culvert.		☐True ☐False
The culvert is not fully backwatered.		☐True ☐False
The stream width noticeably different above and below the culvert?		☐True ☐False

If the response to any of these questions is TRUE then continue with the full assessment.

Stream Characteristics					
Water Quality					
Air Temp (°C)		pH		DO (mg/L)	
Water Temp (°C)		Conductivity (µS/cm)		TDS (mg/L)	
Substrate Sizes (taken upstream of culvert in percent composition)					
Fines (<0.2cm)		Cobble (6.4-25.6cm)		Bedrock	
Gravel (0.2-6.4cm)		Boulder (>25.6cm)			

Channel Measurements (taken upstream)

	Pool	Riffle	Run	Average
Wetted Width (m)				
Bankfull Width (m)				
Stream Width Ratio				

Culvert Information						
Culvert Material	☐ Concrete ☐ Corrugated Metal Pipe (Spiral) ☐ Corrugated Metal Pipe (Annular) ☐ Corrugated Plastic ☐ Wood ☐ Other	Culvert Shape	☐ Circular ☐ Box ☐ Pipe Arch ☐ Open Arch ☐ Other	Entrance Type	☐ Projecting ☐ Headwall ☐ Mitered ☐ Wingwall ☐ Other	
		Is Culvert Deformed?	☐ Yes ☐ No	Deterioration	☐None ☐Moderate ☐Severe	Baffles: ☐ Present ☐ Absent
Culvert Bottom	☐ Closed ☐ Open If Open, Dominant Substrate:____			Variable Slope in Culvert	☐ Yes ☐ No	

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Culvert Dimensions					
Culvert Measurements (m)	WIDTH	HEIGHT	Corrugation (cm)	WIDTH	HEIGHT

Additional Information			
Inflow Habitat Type	☐ Pool ☐ Riffle ☐ Run ☐ Drop	Beaver Dam Present	☐ Yes ☐ No
Backwatered	☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%	Fish Observed	☐ Upstream ☐ Downstream
Embedment	☐ Embedded from Upstream ☐ No Embedment ☐ Embedded from Downstream ☐ Fully Embedded	X-Sectional Degree of Embedment	☐ 0% ☐ <20% ☐ >20%
Length of Culvert with Embedment	☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%		

Upstream of Culvert						
Elevations				**Measurements**		
	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)	Water Depth at Inflow (cm)		Velocity (m/s)
				Stagnation Depth at Inflow (cm)		
Crest of Riffle Upstream				Upstream Riffle to Inflow Invert (m)		
Inflow				Culvert Length (m)		
Upstream Channel Slope (%)						

Downstream of Culvert						
Elevations				**Measurements**		
	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)	Water Depth at Outflow (cm)		Velocity (m/s)
				Stagnation Depth at Outflow (cm)		
Outflow				Plunge Pool Bankfull Width (m)		
Plunge Pool Bottom				Outflow to Tailwater Control (m)		
Tailwater Control				Tailwater Control to 2nd Riffle Downstream (m)		
Crest of 2nd Riffle				Culvert Slope		
Pool Surface Elevation				Outflow Drop (cm)		
Downstream Channel Slope						

Tailwater Cross Section					
Widths	**Elevations**				**Measurements**
	Station	HI (m) (10 + change in tripod height)	FS (m) (survey rod reading)	Elevation (m) (HI - FS)	Water Depth (m)
Wetted Width (m)	1 (Left Bankfull)				
	2 (1/5 Bankfull Width)				
Bankfull Width (m)	3 (1/5 Bankfull Width)				
	4 (1/5 Bankfull Width)				
Bankfull Width / 5	5 (1/5 Bankfull Width)				
	6 (Right Bankfull)				

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<table>
<tr><th colspan="6">Baffle Information (Complete if culvert is baffled)</th></tr>
<tr><td>Baffle Height (cm)</td><td></td><td>Baffle Material</td><td colspan="3">☐ Concrete ☐ Metal ☐ Wood ☐ Other</td></tr>
<tr><td>Notch Depth (cm)</td><td></td><td>Baffle Type</td><td colspan="3">☐ Straight ☐ Diagonal
☐ Right Angled ☐ Other</td></tr>
<tr><td>Notch Width (cm)</td><td></td><td>Notch Chutes</td><td colspan="3">☐ Yes ☐ No</td></tr>
<tr><td>Number of Baffles</td><td></td><td>Notch Chute Material</td><td colspan="3">☐ Concrete ☐ Metal
☐ Wood ☐ Other</td></tr>
<tr><td>Distance Between Baffles (m)</td><td></td><td rowspan="2">Elevations</td><td rowspan="2">HI (m)
(10 + change in tripod height)</td><td rowspan="2">FS (m)
(survey rod reading)</td><td rowspan="2">Elevation (m)
(HI - FS)</td></tr>
<tr><td rowspan="3">Distance from Bottom Baffle to Outflow (m)</td><td rowspan="3"></td></tr>
<tr><td>Most D/S Baffle</td><td></td><td></td><td></td></tr>
<tr><td>Adjacent U/S Baffle</td><td></td><td></td><td></td></tr>
<tr><td>Drop Between Baffles (m)</td><td colspan="5"></td></tr>
</table>

Notes

Sketch

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6.2 Watercourse Crossing Assessment Parameters

Table 4. Variables assessed during watercourse crossing assessments.

Variable	Units	Description
Air Temperature	Celcius	The temperature of the air on the day of the survey
Average Water Depth Under Bridge	m	The water depth underneath the bridge taken in a location that is representative of the average depth
Backwatered	%	The surface of the outflow pool extending back into the culvert Is recorded as 25%, 50%, 75% or 100% backwatered
Baffle Height	cm	Height (highest point) of the baffle
Baffle Material		The material that the baffle is made of (wood, concrete, other)
Baffle Type		The shape of the baffles that are present (straight, diagonal, etc)
Bankfull Width	m	Horizontal distance between banks on opposite sides of the stream
Bridge Width		
Channel Measurements	m	Both wetted and bankfull measured taken at representative locations upstream of a structure. A measurement in metres of the width of the water course and bankfull width which best represents the true character of the watercourse
Conductivity	μS/cm	The ability of a solution (water) to carry an electrical current
Corrugation	m	The height and spacing between corrugations of a steel or plastic culvert
Crest of Riffle Upstream	M	An elevation measurement taken the first riffle of an identified location upstream
Crossing ID		An identification code unique to each crossing. This is a six-digit code; the first three digits are letters. These letters relate to the watercourse name or geographical location of the crossing. The last three digits are numbers, which relate to the crossings identification within the watercourse or geographical area.
Crossing Type		The type of crossing being assessed: culvert, bridge, dam, ford, other
Culvert Bottom Material		Material found in the bottom of the culvert (ie natural bottom, metal, etc)
Culvert Length	m	The length of the culvert being assessed
Culvert Material		The material that the culvert is made of (wood, steel, cement, stone)
Culvert Measurements	m	The width and height of the culvert measured at the outflow
Culvert Shape		The shape of the culvert being surveyed (box, round, etc)
Culvert Slope	%	The slope of the culvert calculated by: [(Elevation at Inflow - Elevation at Outflow)/Culvert Length] x 100
Culvert Width	m	The width of the culvert
Date		The date on which the culvert assessment was completed
Distance from Bottom Baffle to Outflow Invert	m	Distance measured in meters between the farthest downstream baffle and the culvert outflow
DO	mg/L	The amount of oxygen dissolved in the water
Downstream Baffle Elevation	m	Elevation measurement taken from the top of the baffle located farthest to the downstream end of the culvert
Downstream Channel Slope	%	The natural slope of the streambed calculated by :
(Elevation at Tailwater Control - Elevation at 2nd Riffle) x 100		

Drop Between Baffles	m	The difference in height between the upstream baffle elevation and the downstream baffle elevation
Elevation at Crest of 2nd Riffle	m	Elevation of the second riffle downstream of the outflow pool
Elevation at Inflow	m	An elevation measurement taken at the bottom of the inflow of a structure
Elevation at Outflow	m	An elevation measurement taken at the bottom of the outflow of a structure
Elevation Tailwater Control	m	An elevation measurement taken in the thalweg at the end of the outflow pool or at an identified location downstream of the structure
Depth of Embedment	cm	The depth to which the culvert is embedded within the substrate of the watercourse
Entrance Type		The design of the culvert inflow (projecting, wingwall, headwall)
Field Crew		The assessors collecting the data
Fish Habitat		The ability of the watercourse to support fish
Fish Observed		The observation of fish upstream and/or downstream of the culvert
Inflow Habitat Type	m	The stream characteristic immediately upstream of the culvert (pool, riffle, run, or drop)
Length of Culvert With Embedment	%	Proportion of the culvert that is embedded within the streambed, taken as a percentage either from upstream or downstream
Notch Depth	cm	The depth of the baffles notch, taken from the lowest portion of the baffle to the top
Notch Width	cm	The width of the lowest portion of the baffle
Outflow Drop	cm	The difference in height between the bottom of the outflow invert and the thalweg of the tailwater control. It is calculated by subtracting the tailwater elevation from the outflow elevation
Outflow Invert to Tailwater Control	m	Distance measured in metres from the culvert outflow to the 1st riffle located downstream
Ownership of Crossing		The person or entity responsible for the crossing
pH		The acidity of the water in the watercourse
Photos		The photos taken of the watercourse crossing site
Pool Bottom Elevation	m	An elevation measurement taken at the deepest part of the outflow pool
Pool Surface Elevation	m	An elevation measurement taken at the surface of the water in the outflow pool
Road Name		The name of the road that the crossing is located on
Rise	m	The height of the bridge across the road
Span	m	The width of the bridge from abutment to abutment
Station	m	The distance, starting from the left floodplain at the tailwater cross section, where elevation and water depth are measured. Stations between stream banks are determined based on Bankfull Width /5
Stream Name		The name of the watercourse where the structure is located
Stream Width Ratio		The value derived from dividing the average upstream channel width by the culvert width
Substrate Size		The proportion of each type of substrate found upstream of the culvert inflow
Tailwater Control to 2nd Riffle Downstream	m	Distance from the downstream tailwater control (1st riffle) to the 2nd riffle
Tailwater Cross Section		Based on the bankfull width, the cross section is divided into segments and measured for height and water depth

Time		The time that the culvert assessment began
TDS	mg/l	Total dissolved solids, the measurement of the combined content of all inorganic and organic substances in its suspended form
Upstream Baffle Elevation	m	Elevation measurement taken from the top of the baffle located farthest to the upstream end of the culvert
Upstream Channel Slope	%	The natural slope of the streambed calculated by : (Elevation at 1st Riffle - Elevation at Inflow) x 100
Upstream Riffle to Inflow Invert	m	Distance from the first upstream riffle to the culvert inflow
UTM Coordinates		GPS position of the watercourse crossing location, described with Northings and Eastings, using a NAD83 projection
Velocity Head	cm	A measurement of water velocity taken as the centimeter difference from the front to the back of a meter stick when placed in the stream
Water Temperature	Celcius	Downstream water temperature
Wetted Width	m	The width of the water taken at various stations
Wetted Width Under Bridge	m	The width of the water column under the bridge.

6.3 Annapolis River Watershed Watercourse Crossings

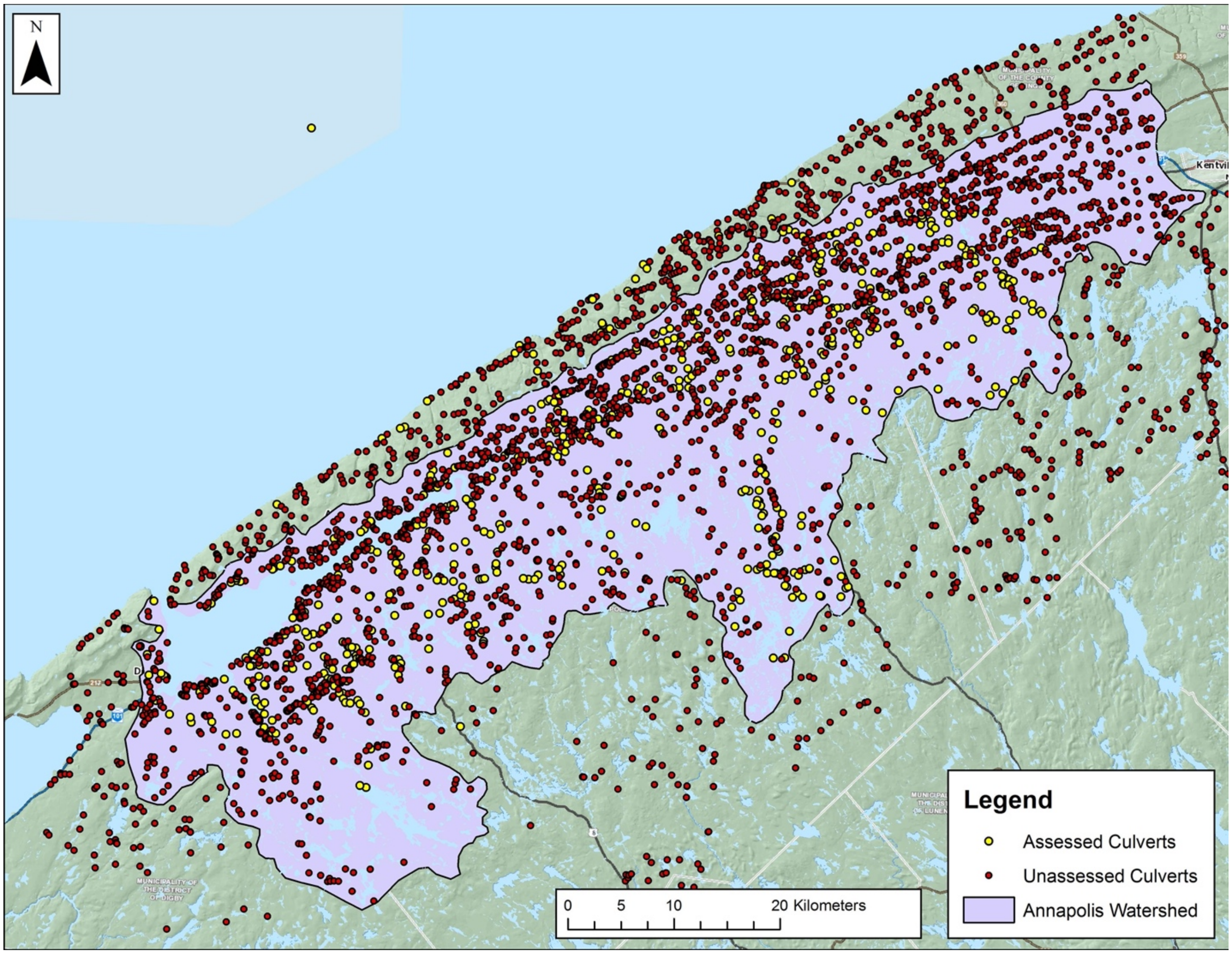


Figure 20. Map of all culvert assessments in the Annapolis River watershed from 2010 to 2023.

6.4 Details of Watercourse Crossings Assessed in 2023

Table 5. 2023 watercourse crossing detailed assessment results.

Culvert ID	Stream Name	Road Name	Latitude	Longitude	Crossing Type	Debris Blockage	Rapid Assessment			
							Is there a visible outflow drop?	Is the water depth less than 15 cm anywhere in the culvert?	Is the culvert backwatered only part of the way or not at all?	Is the stream width noticeably different above or below the culvert?
EAS009	East Moose River	Fraser Road	44.6392	-65.5326	Culvert	Yes	Yes	No	No	No
ALL017	Grand Lake Flowage	Clementsvale Road	44.6898	-65.5191	Culvert	Yes	Yes	No	No	Yes
RHR023	Eight Mile Brook	West Dalhousie Road	44.7082	-65.3829	Bridge	No	N/a	N/a	N/a	N/a
RHR036	East Branch Round Hill River	Spurr Road	44.7180	-65.3698	Culvert	No	No	No	No	No
BAL001	Balcom Brook	Highway 1	44.7236	-65.5376	Culvert	No	No	No	No	No
PET002	Petes Brook	Highway 201	44.8740	-65.1307	Culvert	Yes	Yes	No	No	No
WIS010	Wiswal Brook	Vault Road	44.9930	-65.0017	Bridge	No	N/a	N/a	N/a	N/a
WAT004	Watton Brook	McColough Road	44.9702	-65.0261	Culvert	No	Yes	No	Yes	No
HUT004	Hutchinson Brook	Hall Road	45.0118	-64.7670	Culvert	No	Yes	No	No	No
WAT002	Watton Brook	Harvest Moon Trail	44.9560	-65.0268	Culvert	No	No	No	No	No
OHB001	Oak Hollow Brook	Harvest Moon Trail	44.8907	-65.1474	Culvert	Yes	No	Yes	No	Yes
TRO010	Troop Brook	Post Road	44.7636	-65.5015	Culvert	Yes	No	Yes	Yes	Yes
BLK004	Black River	Highway 201	44.9452	-65.0248	Culvert	Yes	No	No	Yes	No
MOR008	Morton Brook	Highway 362	44.9867	-65.0688	Culvert	No	Yes	No	No	Yes
MCG009	McGee Brook	Brooklyn Street	45.0338	-64.8684	Bridge	No	N/a	N/a	N/a	N/a

6.5 Annapolis River Watershed Culvert Restorations

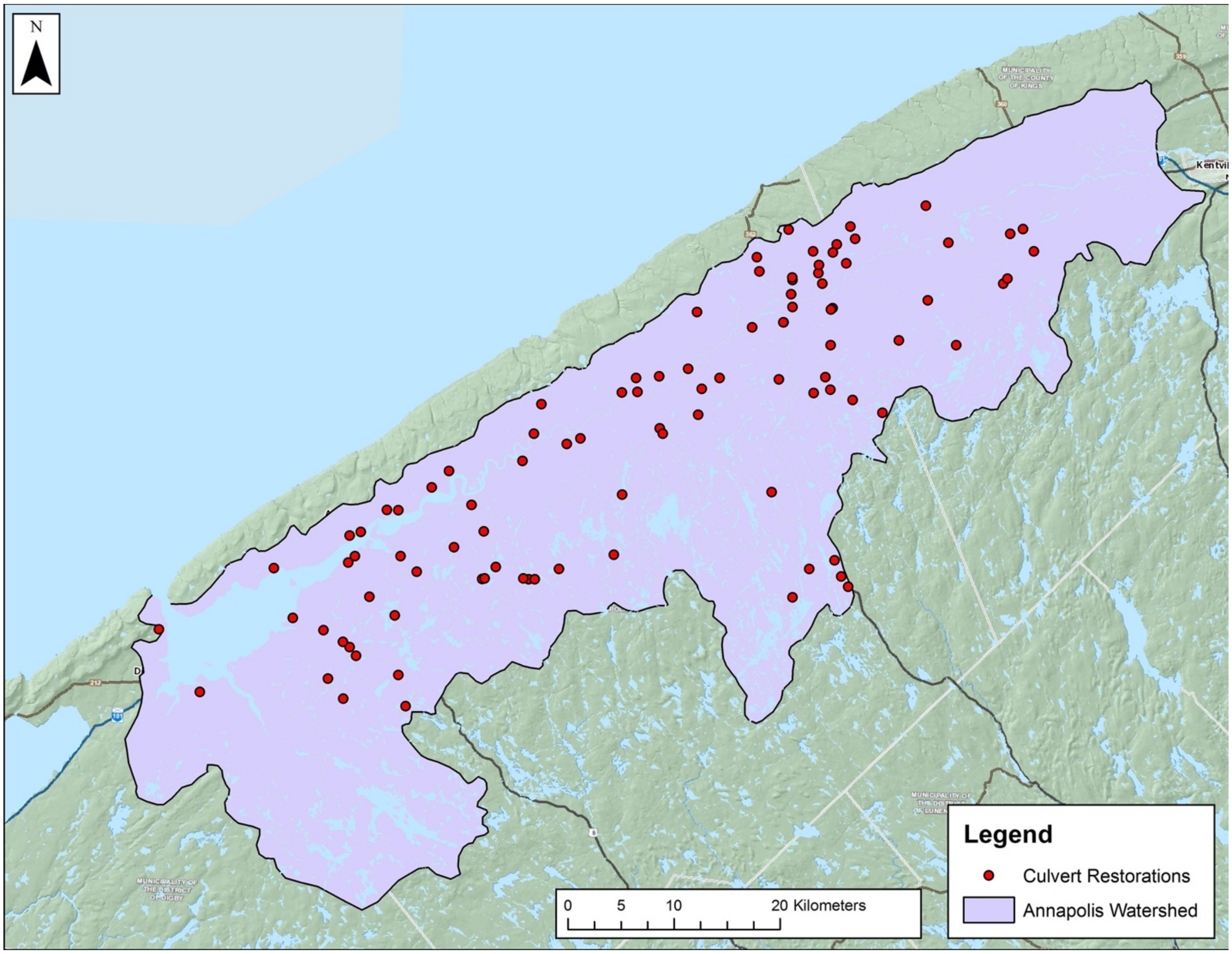


Figure 21. Map of all culvert restorations in the Annapolis River watershed from 2010 to 2022.

6.6 Rock Weir Design (Taylor, 2010)

The vortex rock weir is a U-shaped design, where the apex points upstream. The weir is designed to be either on 20° or 30 ° angles from the base of the weir. For our design, a 30° angle from the base of the weir was used (Figure 22). The location of the vortex rock weir is determined based on the ideal location of a tailwater control determined by the size of the outflow pool. The recommended length of an outflow pool is three times the culvert's diameter.

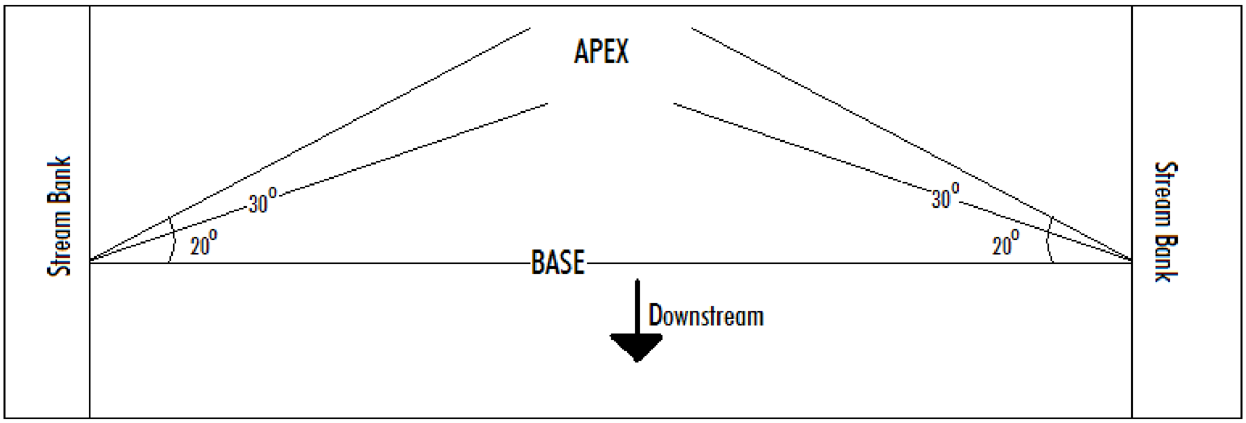


Figure 22. Vortex rock weir design (Taylor, 2010).

To determine the shape and materials needed for the construction of the weir, several formulae were used:

Volume (V) = Length (l) x Width (w) x Height (h)

Where the length (l) refers to the desired length of the rock weir to be constructed, the width (w) refers to the calculated width of the weir (using a height to base ratio of 1:3), and the height (h) refers to the desired height of the construction. The intent of the rock weir construction is to raise the level of water in the outflow pool, which is controlled by the weir's low flow notch (an area at the apex of the weir through which water can flow through during low flow conditions, serving as the weir's lowest point of elevation). The elevation of the low flow notch should ideally be 0.2D higher than the base of the culvert outflow (where D refers to the culvert's diameter) (DFO, 2015). The ends of the constructed weirs were tied into the banks about 15 cm beyond the full bankfull width of the streams.

Large, flat, footer stones make up the first layer of the rock weir. Weir stones, which are generally thicker than footer stones, are used to build the remainder of the weir. Smaller riprap is used as filler as well as bank stabilizer. Due to the prevalence of tailwater blow-outs since the 2016 restoration season, larger rocks are used whenever possible to reinforce the structure. Weirs are sealed with sediment from the stream bed, if available, to assist with blocking flow through the weir. Over time, the spaces in the weir will fill with various debris and leaf litter flowing through the stream.

The amount of water flow a weir can experience is affected by the size of the upstream catchment area, the channel slope, upstream land use, and rainfall. These factors must be taken into consideration when designing a rock weir structure that can withstand the elements. In order to determine the minimum rock diameter required to withstand high flow velocity conditions, it is necessary to calculate the incipient rock diameter as well as the amount of force the water would exert on the streambed as it flowed over it, known as the tractive force (Cummings *et al.*, 2004):

$$\tau \ (kg/m^2) = \text{Incipient Diameter (cm)}$$

Where τ represents tractive force, which is a measure of the amount of force that water will exert on a streambed as it flows over it. The equation used to calculate the tractive force is:

$$\tau = 1000 \times d \times s$$

Where d represents the depth of flow (in metres) and s represents the slope of the water surface. Measurements retrieved from the culvert assessments are used to determine the depth of flow (based on cross-sectional measurements) and downstream slope. However, during extreme dry conditions, measurements taken at the time of assessment may not be representative of usual conditions. To avoid issues with under-sizing, bankfull height measurements can be used in place of depth of flow where extremely low water levels were observed to have occurred.

6.7 Site Specific Rock Weir Calculations for EAS009 – East Moose River

Remediation:
Maintenance to rock weir initially installed in 2015.

Rock Volume:
Rocks located at the crossing site were used for weir maintenance.

Rock Size:
Based on the measurements recorded during the full culvert assessment survey, the downstream slope at EAS009 is 0.0707; the average water depth in the downstream is 0.11 m. Based on these measurements, the tractive force can be calculated:
T = 1000 X 0.11 m X 0.0707
An incipient diameter of 7.77 cm was calculated, using a safety factor of 2, giving a minimum rock size (diameter) of 15.55 cm.

6.8 Electrofishing Data Sheet

Electrofishing Field Sheet #:

Crew:

Site Information					
Site Name			Date (dd/mm/yyyy)		
Stream Name			Time		
Wetted Width (m)			UTM Easting (m)		
Reach Length (m)			UTM Nothing (m)		
Depth (m)	*D1 :*	*D2 :*		*D3 :*	*Average :*

Water Quality							
pH		DO (mg/L)		Conductivity (µS/cm)		Salinity (g/L)	
Water Temp (°C)		DO (% SAT)		Turbidity (NTU)		TDS (mg/L)	

Pass Information							
Pass Number	Time Start	Time End	Total Time	Pulse Width (ms)	Pulse Frequency (Hz)	Duty Cycle (%)	Volts

Species Information					
Pass Number	Species	Fork Length (cm)	Pass Number	Species	Fork Length (cm)

6.9 Electrofishing Survey Parameters

Table 6. Variables collected during electrofishing surveys.

Variable	Units	Description
Air Temperature	Celcius	The temperature of the air on the day of the assessment
Turbidity	NTU	Transparency of the water due to the presence of suspended particles
Salinity	g/L	The amount of dissolved salts in the water
Pass Number		Sample number
Time Start		Time recorded from the Electrofishing unit before the start of a pass
Time End		Time recorded from the Electrofishing unit at the end/completion of a pass
Total Time		Time End – Time Start using the numbers recorded from the Electrofishing unit (See 'Time Start' and 'Time End')
Pulse Width	ms	Duration of each individual pulse of electricity
Pulse Frequency	Hz	Number of pulses per second
Conductivity	µS/cm	The ability of a solution (water) to carry an electrical current
Duty Cycle	%	Frequency or pulse rate is
Date		The date on which the assessment was completed
Depth	cm	Depth measured at 3 locations that is representative of the survey site. Taken within the reach length.
Volts	V	Electrical pressure
DO	% SAT	The amount of oxygen dissolved in the water
DO	mg/L	The amount of oxygen dissolved in the water
Species		Identity of fish captured.
Fork Length	cm	Length of fish measured from the tip of the snout to the end of the middle caudal fin rays.
Field Crew		The assessors collecting the data
pH		The acidity of the water in the watercourse
Reach Length	m	Linear distance of area being surveyed
Site Name		The name of the site where the survey is taking place. Usually 'Test' or 'Control'
Stream Name		The name of the watercourse where the survey is taking place
TDS	mg/l	Total dissolved solids, the measurement of the combined content of all inorganic and organic substances in its suspended form
Time		The time that the assessment began
UTM Coordinates		GPS position of the HSI assessment location, described with Northings and Eastings, using a NAD83 projection
Water Temperature	Celcius	Downstream water temperature
Wetted Width	m	Width of the river that contains water at the time of the measurement

6.10 Redd Survey Data Sheet

Redd Survey Field Sheet #:

Crew:

Date	Site Name	Transect #	UTM Start		UTM End		Number of Redds Observed
			Easting	Northing	Easting	Northing	

Redd Locations

Date	Site Name	Transect #	Redd #	UTM	
				Easting	Northing

Notes

6.11 Fish Surveys and Sampling Results

Table 7. Electrofishing results for the Fales River Sub-watershed.

Site	Date	Reach Length (m)	Pass	Total Time of Pass	Pulse Frequency (Hz)	Volts (V)	Species Count Information							
							Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Total
Site 1 44.9587, -64.9145	July 26, 2023	65.00	1	460 seconds	80	250	0	0	2	0	0	4	0	6
Site 2 44.9591, -64.9122	July 26, 2023	75.00	1	830.9 seconds	80	250	0	0	6	1	1	3	0	11

Table 8. Fish survey results for the Round Hill River Sub-watershed.

Site	Date	Reach Length (m)	Pass	Total Time of Pass / Deployment	Pulse Frequency (Hz)	Volts (V)	Species Count Information							
							Atlantic Salmon	Brook Trout	Creek Chub	3-Spined Stickleback	White Sucker	American Eel	Brook Lamprey	Total
Site 1 Fyke Net 44.7722, -65.4038	October 17, 2023	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0
Site 2 Fyke Net 44.7659, -65.3993	October 17, 2023	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0
Site 2 Electrofishing 44.7659, -65.3993	September 15, 2023	50	1	2027.2 seconds	80	250	0	0	1	0	0	4	0	5

Table 9. Fish survey results for the Roxbury Brook Sub-watershed.

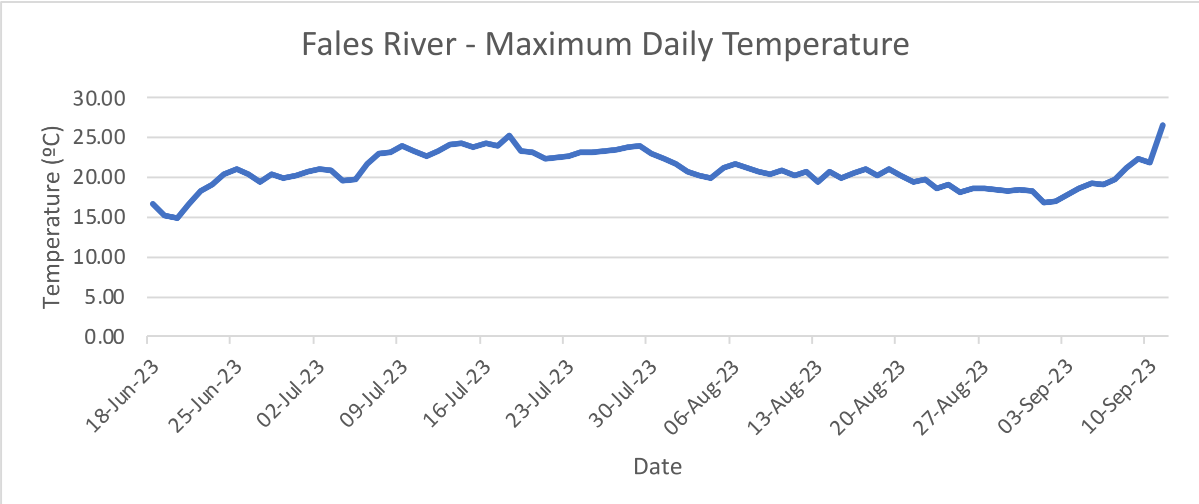
							Species Count Information							
Site	**Date**	**Reach Length (m)**	**Pass**	**Total Time of Pass / Deployment**	**Pulse Frequency (Hz)**	**Volts (V)**	**Atlantic Salmon**	**Brook Trout**	**Creek Chub**	**3-Spined Stickleback**	**White Sucker**	**American Eel**	**Brook Lamprey**	**Total**
Site 1 Fyke Net 44.8568, -65.1994	October 17, 2023	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0
Site 2 Fyke Net 44.8589, -65.2020	October 17, 2023	N/a	N/a	19.5 hours	N/a	N/a	0	0	0	0	0	0	0	0

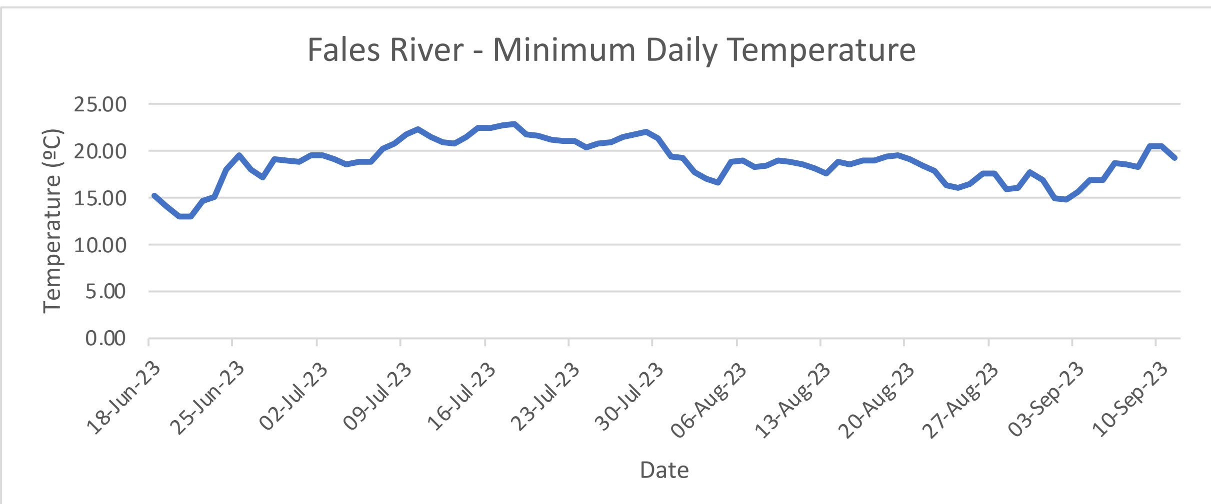
Table 10. Redd survey results.

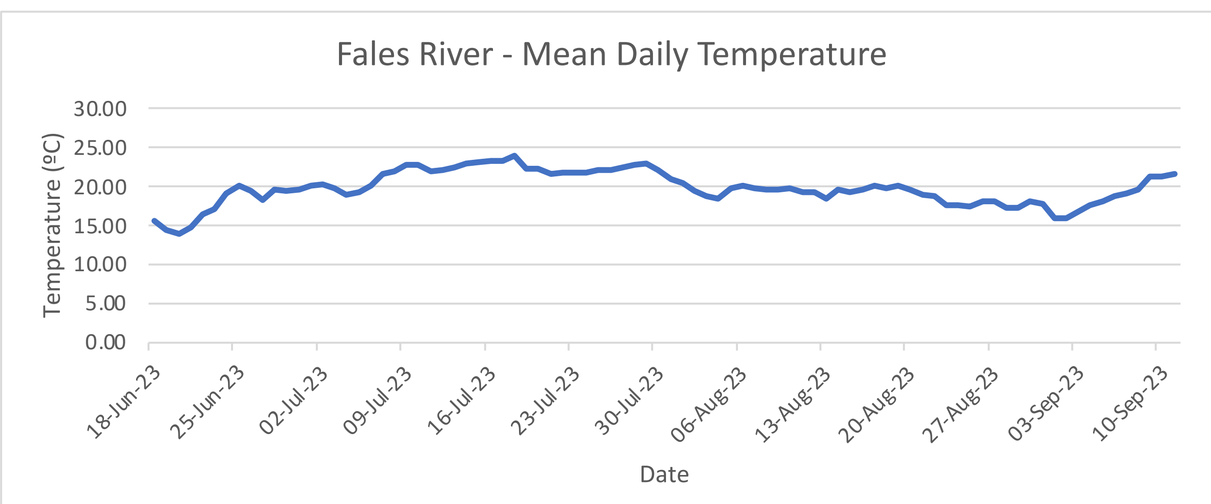
			Start		**End**		
Location	**Date**	**Transect #**	Latitude	Longitude	Latitude	Longitude	**# Redds Observed**
Fales River	November 21, 2023	1	44.9627	-64.9328	44.9610	-64.9312	1
Fales River	November 21, 2023	2	44.9611	-64.9300	44.9611	-64.9240	2
Fales River	November 21, 2023	3	44.9587	-64.9173	44.9583	-64.9153	1
Fales River	November 21, 2023	4	44.9590	-64.9122	44.9594	-64.9101	0
Roxbury Brook	November 21, 2023	1	44.8605	-65.2018	44.8573	-65.2000	0
Round Hill River	November 21, 2023	1	44.7661	-65.3991	44.7642	-65.3984	0

6.12 Temperature Data Logger Results

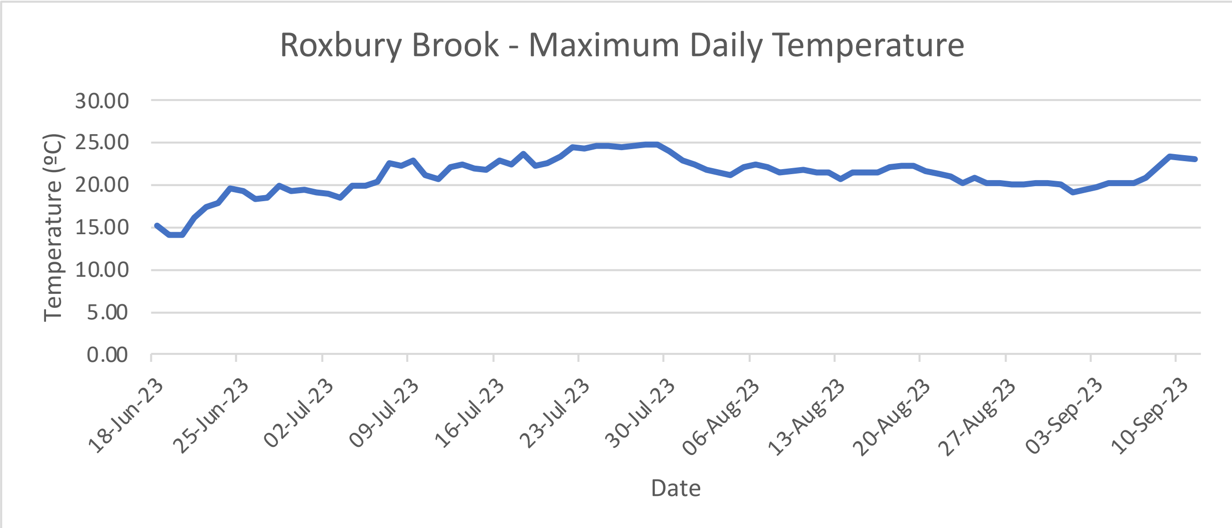
6.12.1 Fales River

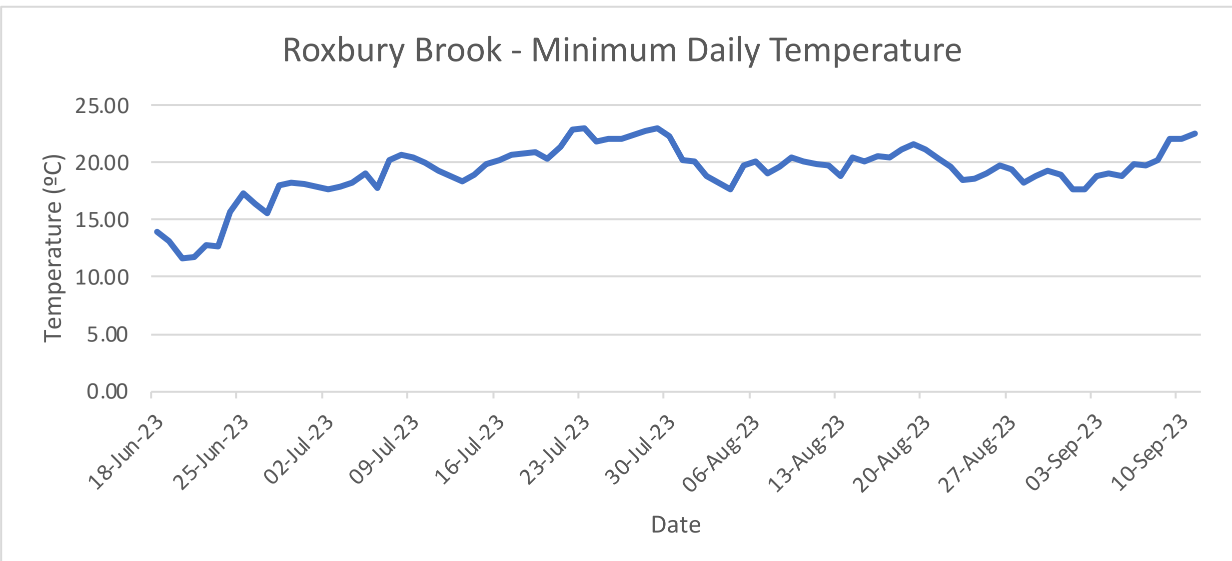


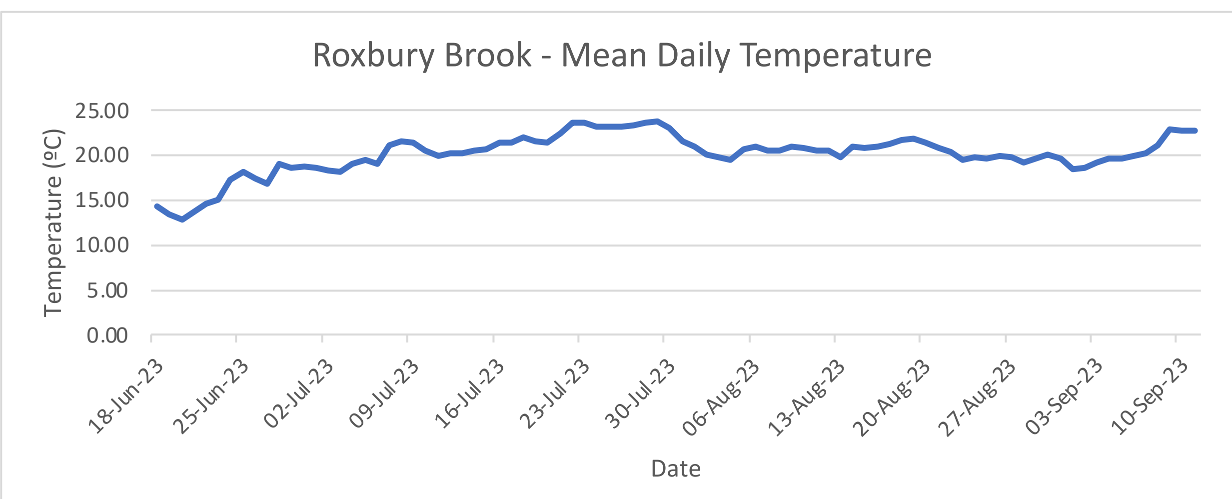




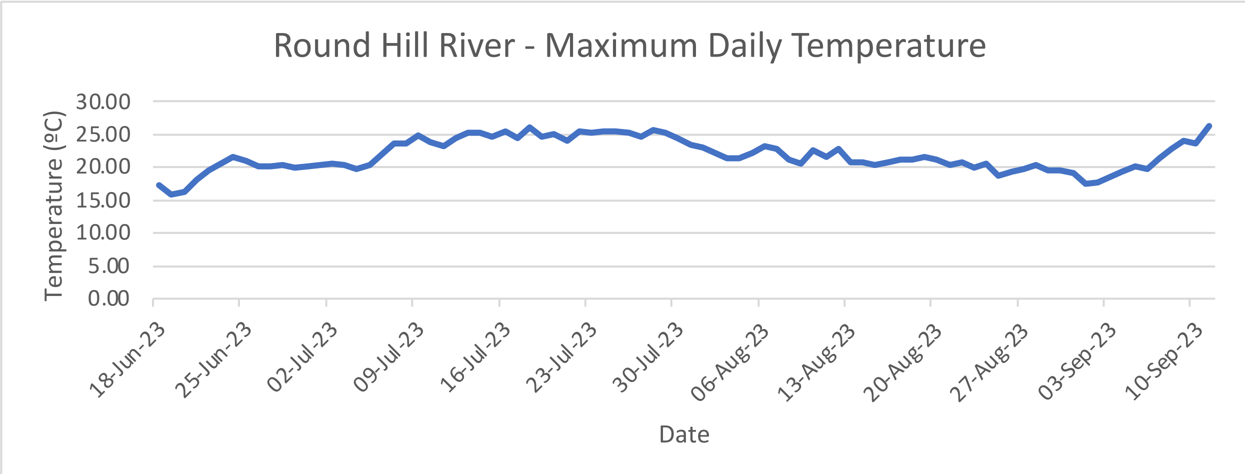
6.12.2 Roxbury Brook

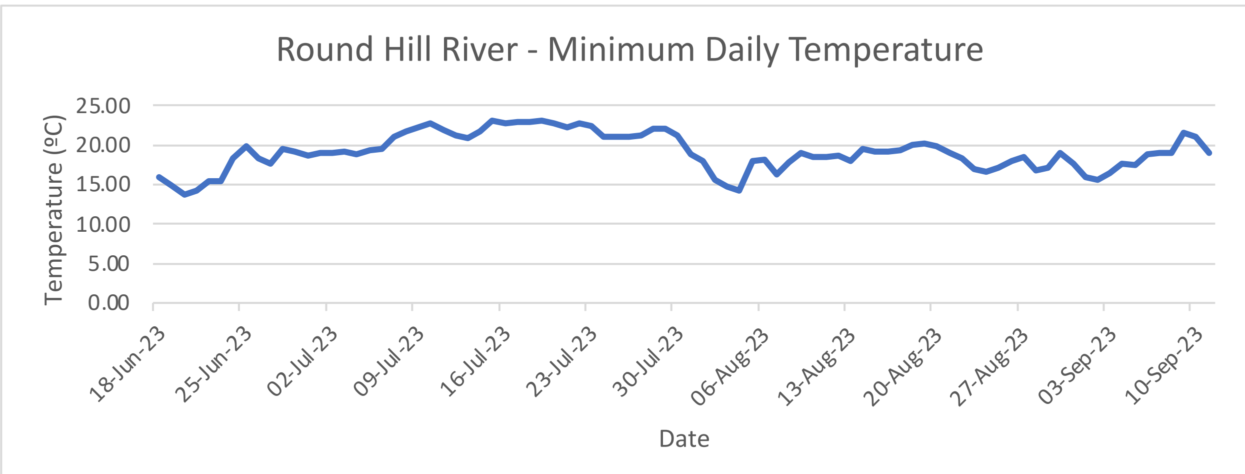


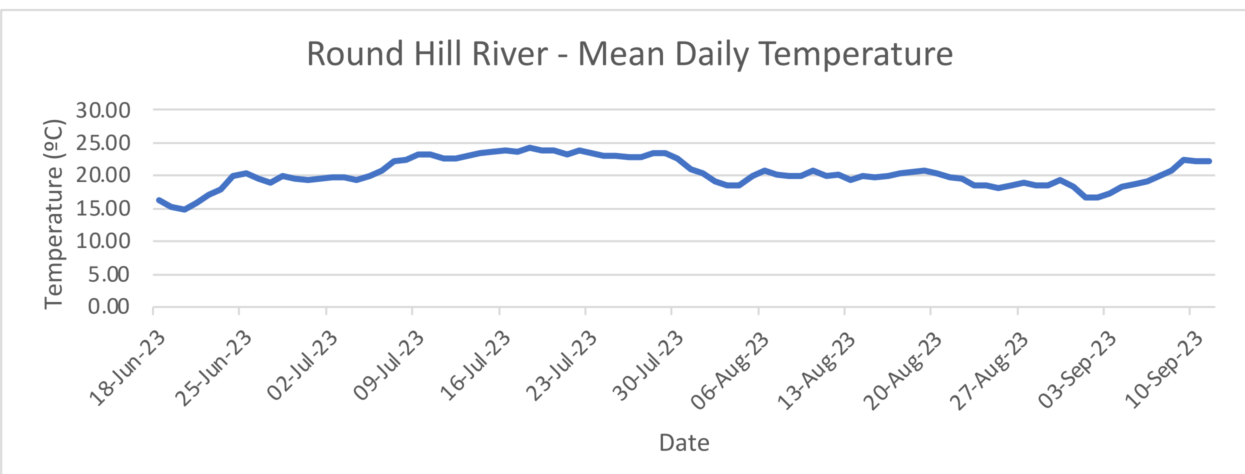




6.12.3 Round Hill River







6.13 Streambank Erosion Survey Results

Table 11. Streambank erosion survey results for the Fales River.

Site	Latitude	Longitude	Erosion Description
1	44.9620	-64.9317	Undercut bank and tree roots
2	44.9613	-64.9314	Steep bank with exposed soil
3	44.9611	-64.9313	Undercut tree roots with exposed soil
4	44.9608	-64.9314	Steep bank with exposed soil
5	44.9605	-64.9312	Undercut tree roots with exposed soil
6	44.9607	-64.9300	Steep bank with exposed soil
7	44.9613	-64.9296	Steep bank with exposed soil
8	44.9622	-64.9268	Undercut bank and tree roots
9	44.9625	-64.9264	Undercut bank and tree roots
10	44.9625	-64.9260	Undercut bank and tree roots
11	44.9621	-64.9253	Undercut bank and tree roots
12	44.9613	-64.9248	Steep bank with exposed soil and undercut tree roots
13	44.9613	-64.9216	Undercut bank and tree roots
14	44.9611	-64.9207	Steep bank with exposed soil and undercut tree roots
15	44.9590	-64.9211	Steep bank with exposed soil
16	44.9587	-64.9212	Steep bank with exposed soil
17	44.9587	-64.9145	Undercut bank and tree roots
18	44.9590	-64.9138	Steep bank with exposed soil
19	44.9590	-64.9120	Undercut bank and tree roots
20	44.9590	-64.9115	Undercut bank and tree roots
21	44.9595	-64.9105	Steep bank with exposed soil
22	44.9589	-64.9086	Steep bank with exposed soil
23	44.9588	-64.9073	Undercut bank and tree roots
24	44.9587	-64.9066	Steep bank with exposed soil
25	44.9588	-64.9057	Steep bank with exposed soil
26	44.9589	-64.9053	Steep bank with exposed soil and undercut tree roots