Fish Passage Restoration and Habitat Enhancement

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

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Atlantic Salmon Conservation Foundation
Loblaw Water Fund
Nova Scotia Salmon Association
NSLC Adopt A Stream
Nova Scotia Power

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List of Acronyms

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

The first objective of the project was to provide updated and detailed assessments for culverts within the watershed. Since 2010, a total of 674 sites have been visited and 388 of these crossings were identified as a culvert on a fish bearing stream within the greater watershed and have received detailed watercourse crossing assessments. During the 2019 field season, watercourse crossing assessments were primarily focused on crossings within the Annapolis River watershed that have not been assessed in the past, are in close proximity to the main stem of the Annapolis River or have a high potential for upstream habitat gain. From August to October, CARP visited 10 sites, 8 of which were culverts on fish-bearing streams requiring detailed assessments. The detailed information gathered in these assessments will be entered into an online database that will determine the barrier status of each culvert and will be given suggested remediation options.

The second objective was to implement restoration actions on culverts assessed and prioritized in previous years through the Fish Habitat and Broken Brooks program. In addition, culverts that had received previous restoration actions were revisited for maintenance. In 2019, three sites received restoration work, resulting in two debris removals and one tailwater control maintenance restoration. These remediation activities restored access to 8.1 km of upstream habitat and improved access to an additional 27.1 km.

The third and final objective of the project was to enhance in-stream habitat for Atlantic salmon, brook trout and other native aquatic species in two priority sub-watersheds within the greater watershed. Habitat enhancement work to improve habitat complexity and productivity for salmonids was initiated on the Fales River and the Round Hill River in the late 1990's where a number of instream restoration structures were installed. In 2019, a total of 1,481 m^2 of habitat was restored through the installation of instream structures on these two systems: 775 m^2 on the Fales River and 706 m^2 on the Round Hill River. An additional 150 m^2 of in-stream habitat on the Fales River was enhanced through SandWanding activities. The completion of these enhancement activities in addition to historic data and future data collection will be used towards the completion of a sub-watershed management plan for the Fales River and Round Hill River in future years.

1.0 Introduction

Fragmentation of aquatic habitats is considered a serious concern and major 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 (NSLC AAS, 2018).

Watercourse crossing structures are anthropogenic features often implemented 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 pre-fabricated and simply dropped into place and covered (Price *et al.*, 2010; NSLC 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; NSLC 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 2019 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 restoration work to improve in-stream habitat quality was carried out in high-priority sub-watersheds including the Fales River and the Round Hill River.

2.0 Methodology

The 2019 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 restoration actions were completed to address sedimentation in the Fales River and Round Hill River through the installation of in-stream structures and the removal of fine sediments from the streambed.

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 2019 season, culvert assessments were primarily focused on watercourse crossings within the Annapolis River watershed that had not been assessed in the past, are in close proximity to the main stem of the Annapolis River or have a high amount of potential upstream habitat gain. Refer to Appendices 6.1 and 6.2 for culvert data sheets and information on the data that is 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 (NSLC 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 off a criteria check list. Once classified as a barrier type, their remediation actions were determined and their restoration was prioritized based on the number of downstream barriers and the 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, based upon their scores. 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 as well as its location within the watershed. For further details and methods on 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 NSLC 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 is designed to manage assessment data and prioritize water crossings for remediation purposes and can be used by watershed groups across Nova Scotia. All of the assessment data is 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. Once ACAD is finalized, the culvert assessments collected during the 2019 season will be entered and stored in the database and their barrier status and remediation options will be digitally calculated. The feasibility of these actions will be reviewed and this information will then be used for future project work within the watershed. 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 from CARP databases and from prioritization lists for culverts that have been identified in previous years. Additional culverts were chosen for restoration activities based on previous remediation efforts and insights from the community; past remediation sites that have sustained damage to the point of impairment were chosen to be restored and given maintenance. Site visits were performed to determine the feasibility of restoration activities and the extent to which maintenance work was required. Refer to Appendix 6.5 to view 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, pick-axes, 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 at 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 exceeded 30 cm, tailwater controls are often used in combination with additional weirs constructed downstream, fish chutes, baffles, and/or low flow barriers.

The tailwater control structure that was maintained in the 2019 field season built upon a vortex rock weir design that was originally built by CARP staff and volunteers in 2017. Large, flat footer stones were used to construct the base of the rock weir structure while pebbles and gravel were used as fill to seal the gaps between the larger weir stones. Rock weirs are constructed using calculations for guidance in rock sizing, and by utilizing materials at each site. In 2019, it was determined that the overflow of the rock weir had blown out and required maintenance. The structure was reconstructed by rearranging and adding new materials to the existing rock weir to create less of a slope over the rock weir for fish passage. For further design information, calculations used, and a detailed description of the original rock weir construction, refer to Appendices 6.6 and 6.7.

2.3 In-stream Habitat Enhancement

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. Continued efforts to enhance in-stream habitat were undertaken in 2019.

In 1999, initial work was completed by CARP on the Fales River to improve habitat quality and complexity in the river, which had been altered by development in the surrounding area. Digger logs, deflectors, log cribs and low flow barriers were installed as part of this work with the goal of adding complexity and improving habitat quality in the long, flat stretch of river that contained little in-stream cover and severely eroding banks. In 2017, CARP staff began planning an extensive in-stream remediation project, involving the restoration of pre-existing digger logs, deflectors and log cribs, as well as the addition of new digger logs and deflectors, and SandWanding along various stretches of the river. Continued restoration and monitoring efforts by CARP in 2018 resulted in the discovery of two cohorts of Atlantic salmon, along with six other fish species supporting the value of restoring and enhancing this river's fish habitat. In 2019, continued sandwanding and the installation of an instream structure built upon past efforts to continue improvements to the quality of spawning grounds and pool habitat for the spawning and rearing of salmonids and other native fish species.

The Round Hill River received restoration efforts by CARP during the summer of 1997 and again in 1998 to enhance and restore the aquatic habitat in this important sub-watershed. A total of 32 digger log structures with deflectors were installed with the intention to narrow the channel and reposition the boulder substrate to create deeper pools within the river. Bank stabilization was also conducted to address the over-sedimentation within the stream as a result of land-use changes (Halliday, 1998). In 2019, some of these structures were revisited to determine structural integrity in a small section of the river and those of which were undersized or deteriorating were removed. In addition, one new in-stream structure was installed to build upon past efforts and to establish a newer and more current layout to suit the natural changes that have occurred to the Round Hill River over the past 20 years.

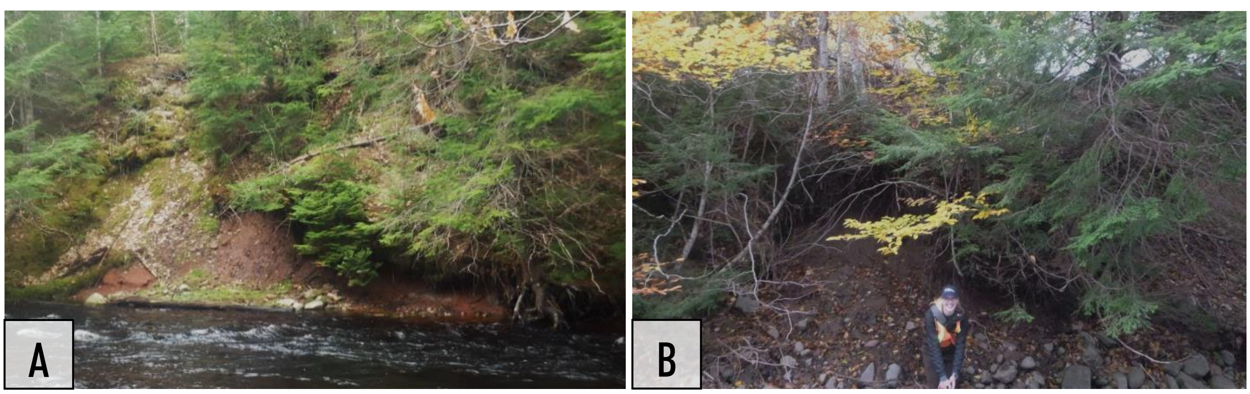

Figure 1. Eroding banks on the Fales River (A) and the Round Hill River (B).

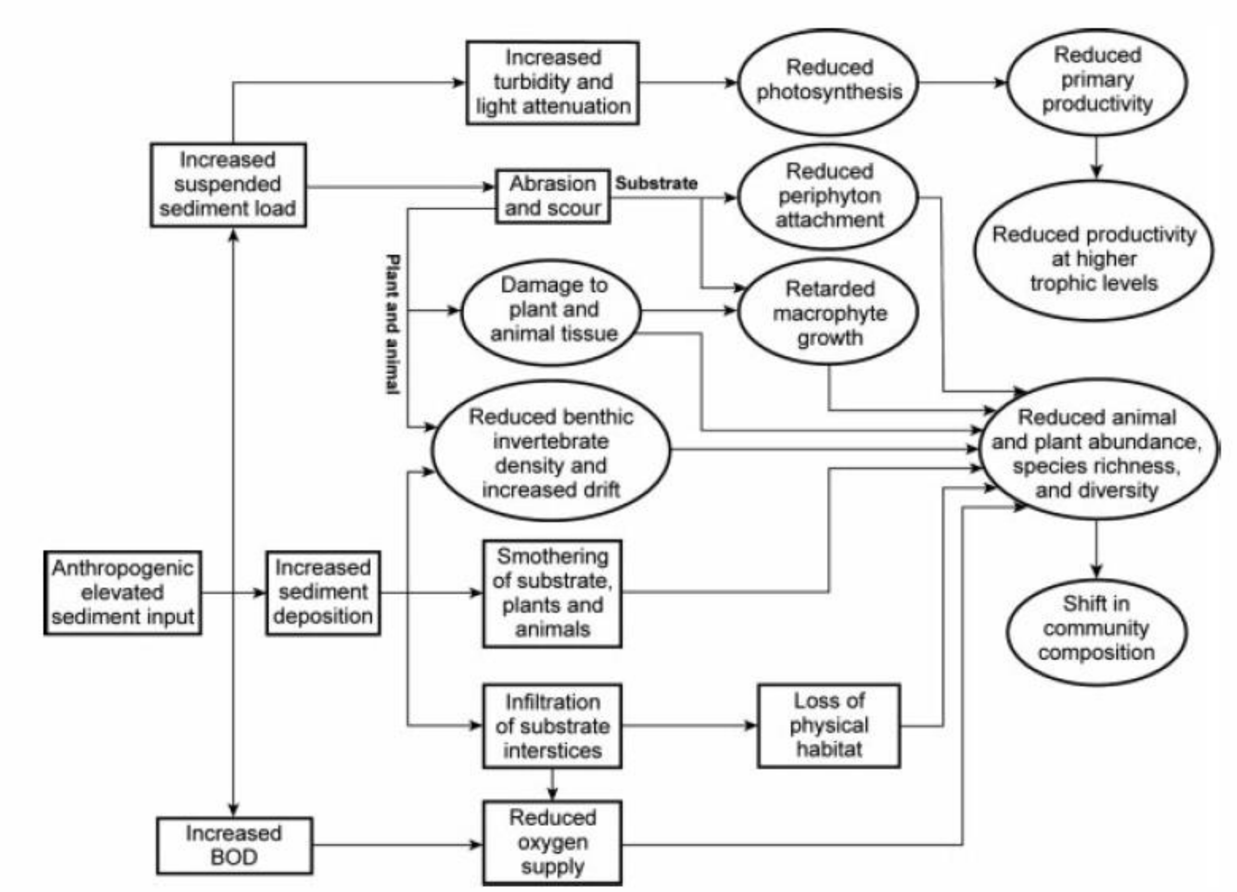

Figure 2. Negative impacts of anthropogenically enhanced sediment input (Kemp *et al.*, 2011).

Consultations with partners and experts were conducted to help identify additional activities for in-stream habitat enhancement work. It was identified that much of the available spawning habitat in the portion of the rivers accessible by salmonids was impacted with fine sediments, likely impairing successful spawning. Over several decades, the Fales River and the Round Hill River have filled in with fine sediments from land-use impacts and bank erosion (Figure 1). Fine sediment accumulation ($<$ 2 mm in size; Louhi *et al.*, 2008) has been widely recognized to pose detrimental effects to river ecosystems (Figure 2). Salmonid species prefer coarse gravel and stone bottoms for spawning and are particularly vulnerable to sediment accumulation (Hendry and Cragg-Hine, 2003; Klemensten *et al.*, 2003). As a result, the focus of 2019 was to assess the substrate conditions in two priority sub-watersheds within the Annapolis River watershed and to evaluate the success restoration efforts and enhanced habitat.

2.3.1 SandWanding

The SandWand system is a manually operated sediment removal tool that uses water jets and suction to remove surface and subsurface sediments. The two-part pumping system allows for the selective removal of fine sediments, which are simultaneously discharged through hoses to an off-stream site. The SandWand can be used to improve salmonid spawning and rearing areas by targeting key areas for sediment removal, such as the tail of a pool. Consequently, by bypassing riffled areas, SandWanding can be an effective tool for fine sediment removal while posing minimal threats to macroinvertebrate function (Sepulveda *et al.*, 2014).

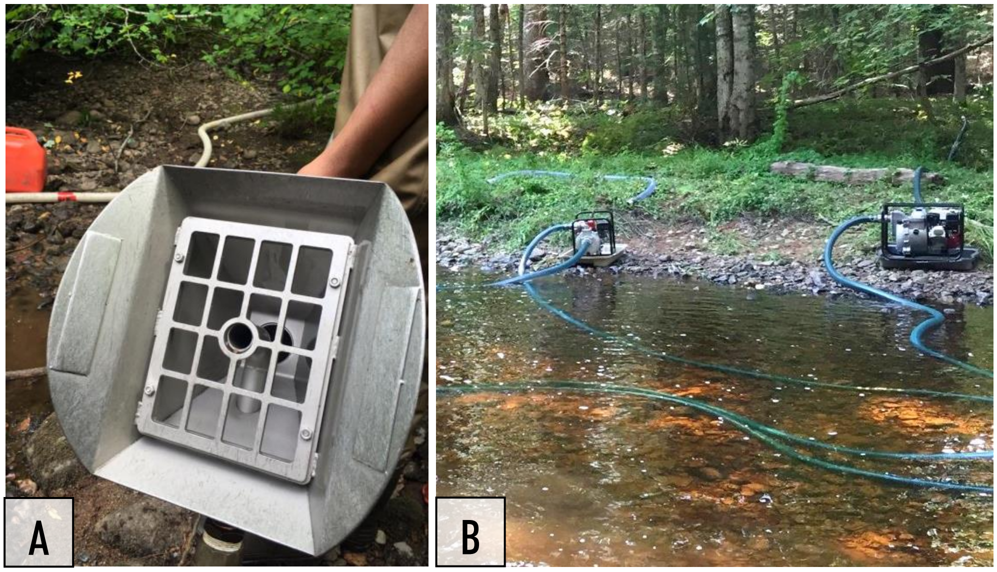

Figure 3. The SandWand head (A) and pump generators (B) used to remove fine sediment from the Fales River.

The SandWand head (Figure 3A) features a center hole which provides a water jet pointed at the riverbed. The water jet suspends the fine sediments, which are then vacuumed through the grate and into the trash hose. Sediments from the trash hose are deposited well away from bankfull levels to ensure that they are not carried directly back into the river with the first high flows. The nature of this operation allows for the realization of immediate results; however, longer impacts due to changes in embeddedness and sediment transport should also be monitored.

2.3.2 Digger Log Removal

Digger logs are an in-stream restoration structure installed in rivers that lack a meandering pattern with defined riffle-pool-run features. Digger logs were first installed in the Round Hill River in the late 1990's to improve pool/riffle formation and aquatic habitat within the system. In 2019, these structures were revisited and it was determined that the current layout of these structures was incorrect and the old log structures were now undersized and deteriorated. A new layout was established in consultation with experts and it was determined that Round Hill River would benefit from the removal of some of these structures to help the river return to its natural flow pattern. Digger logs were removed using a variety of hand tools including pry bars, log grabbers, and hand saws.

2.3.3 Deflectors

Deflectors are in-stream structures that are often used to help improve fish passage in wide, shallow streams by stabilizing the banks and consequently controlling erosion in addition to accentuating stream flow and keeping downstream of the structure free of sediment (NSE, 2018). The location of these structures were determined in consultation with partners and experts and were constructed and installed according to NSLC Adopt-A-Stream design protocols (Figure 4), adapted from the DFO publication titled '*Ecological Restoration of Degraded Aquatic Habitat: A Watershed Approach*' (DFO, 2006). All materials that were used for the construction of each deflector were sourced from their respective work sites and were installed using a variety of hand tools including saws, a pick axe, log grabbers, a gas powered drill, and an 8lb sledge hammer.

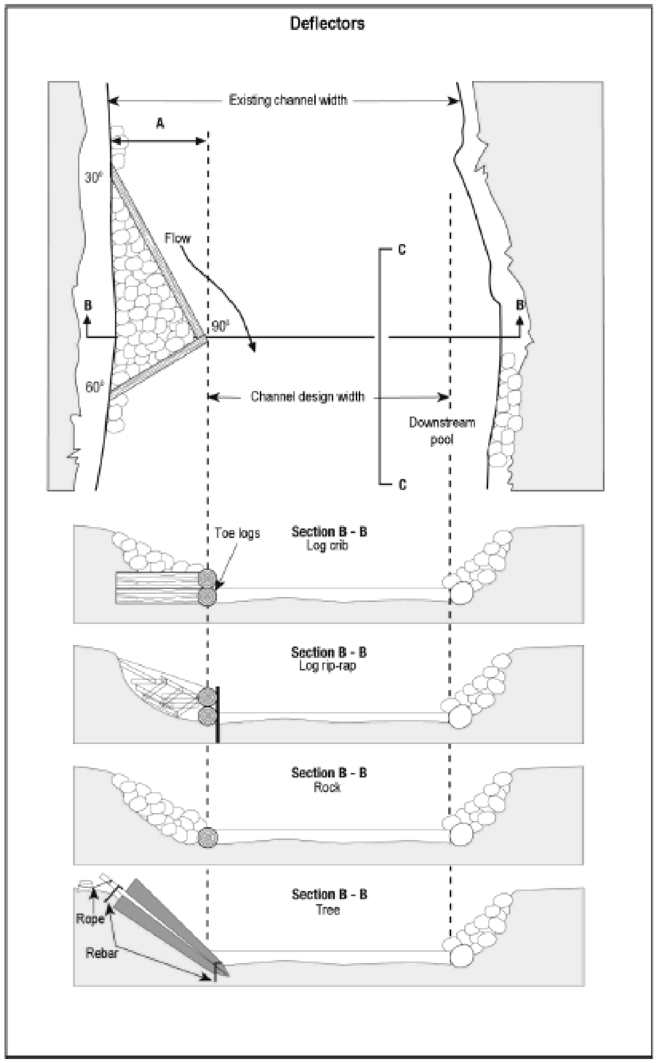

Figure 4. Conceptual drawing and guideline of several types of deflectors (NSE, 2018).

The Fales River received a single tree deflector in the 2019 field season that will act as a sediment trap for free flowing sediment in addition to helping to narrow the over-widened channel. A single spruce tree from the work site was cut with the brush still intact and on the tree. The deflector tree was installed on the left bank, slightly upstream of a natural right pool. It was placed on a 30° angle with the trunk end secured into the bank and the tree rebarred into place. Refer to Appendix 6.11 for a detailed sketch of the structure design.

A single log deflector was installed in the Round Hill River system in the 2019 field season to concentrate and redirect the stream flow. This deflector was installed on the left bank, slightly upstream of a natural right pool using hardwood logs from trees near the work site. The deflector was triangular in shape with a 30° angle on the bank at the upstream tip and a 60° angle on the bank at the downstream tip, making a 90° angle where the two logs meet. The logs were sloped up towards bankfull and secured in place using rebar. The deflector was filled using cobble and boulder from within the river up to bankfull height to help protect the bank from erosion. Refer to Appendix 6.11 for a detailed sketch of the structure design.

2.3.4 HSI Surveys

HSI is a tool that has been refined over many years as a method of evaluating the characteristics of a stream or river. Using habitat requirements and limiting factors for Nova Scotia's indicator species, these assessments help to determine whether the studied systems provide viable fish habitat. HSI surveys were completed in the 2019 field season along the Fales River and Round Hill River according to the updated (2018) Nova Scotia Fish Habitat Enhancement Protocol developed by AAS and Clean Nova Scotia (NSFHAP, 2018). Surveys were conducted as a pre-restoration and post-restoration activity focusing on the physical habitat and water quality and to examine and quantify the impacts of restoration efforts. Refer to Appendices 6.12 and 6.13 for an example HSI data sheet and information on the data that is collected during a culvert assessment.

The data that was collected was entered into the NSFHAP online data entry sheet, which evaluates the data based on habitat suitability models for brook trout and Atlantic salmon. The 15 features assessed in the field methods are largely based on an HSI for brook trout (Raleigh, 1982) and have been adapted to include Atlantic salmon and to suit conditions in Nova Scotia. The program calculates important criteria for each species in a range from 0-1, where poor quality is given a value of less than 0.4, moderate quality has a value between 0.4 and 0.8, and good quality has a value of greater than 0.8 (Table 1). The program colour codes these values, giving poor quality variables a red color, medium quality a yellow color, and good quality a green colour. The results from the surveys will aid in interpreting the impacts of restoration activities on the Fales River and Round Hill River and their effectiveness for enhancing in-stream fish habitat. Refer to *'The Nova Scotia Fish Habitat Suitability Assessment: A Fields Methods Manual'* (NSFHAP, 2018) for full details of the assessment procedure and for more detail on each of the habitat suitability variables that are assessed for Atlantic salmon and brook trout habitat.

Table 1. Habitat suitability index and quality rating values for brook trout and Atlantic salmon habitat (NSFHAP, 2018).

Suitability Value	Quality of Habitat	Result
0.00 – 0.39	Poor	Will support none or small numbers of Atlantic salmon or brook trout.
0.40 – 0.80	Moderate	Will support some Atlantic salmon or brook trout.
0.81 – 1.0	Good	Will support many Atlantic salmon or brook trout.
1.00	Optimal	Optimum habitat to support Atlantic salmon or brook trout.

Two sites were assessed on both the Fales River and Round Hill River, which corresponded to the restoration (test) site and a control site upstream. This was done to identify limiting factors for both Atlantic salmon and brook trout that naturally occur in the river system, and to quantify the impact of restoration activities. Surveys were conducted pre-restoration and post-restoration to provide updated and comparable information on the conditions of the river and the salmonid habitats within.

3.0 Results

Restoration efforts for the 2019 season resulted in considerable improvements to both fish passage and in-stream habitat. 10 culverts within the Annapolis River Watershed were assessed for fish passage. Three culverts received restoration work, which included: two debris removals, and one rock weir maintenance. In total, 8.1 km of upstream habitat was made available, and an additional 27.1 km of upstream habitat passage was improved. In-stream habitat enhancement work improved habitat productivity within a 43 m stretch of the Fales River restoring 150 m^2 with the use of SandWand equipment. Deflectors installed in both the Fales River and Round Hill River restored an approximate total of 1,481 m^2 of fish habitat in priority sub-watersheds. Finally, six old, undersized, and non-functioning digger logs were removed from the Round Hill River.

Table 2. Summary of the 2019 fish passage restorations.

Restoration Site	Watercourse Name	Easting	Northing	Upstream Habitat Gain (km)	Restoration Work Completed
LIB003	Little Brook	344071	4984005	2.3	Debris removal
OHB001	Oak Hollow Brook	330433	4973047	6.1	Debris removal
ROC011	Bear Brook	362994	498411	2.8	Rock weir maintenance

Table 3. Summary of the 2019 in-stream fish habitat enhancement work.

Restoration Site	Location	Easting	Northing	In-stream Habitat Restored (m^2)	Restoration Work Completed
Fales River	Greenwood, NS	347845	4980488	925	1 single tree deflector SandWanding
Round Hill River	Round Hill, NS	309830	4960345	706	1 single log deflector

3.1 Watercourse Crossing Assessments

Throughout the 2019 field season, a total of 10 watercourse crossing sites were visited and assessed within the Annapolis River watershed. The primary focus was to complete assessments on those watercourse crossings within the Annapolis River watershed that lacked detailed assessments and crossings along streams with high prioritization scores and maximum upstream gain (Figures 5 and 6).

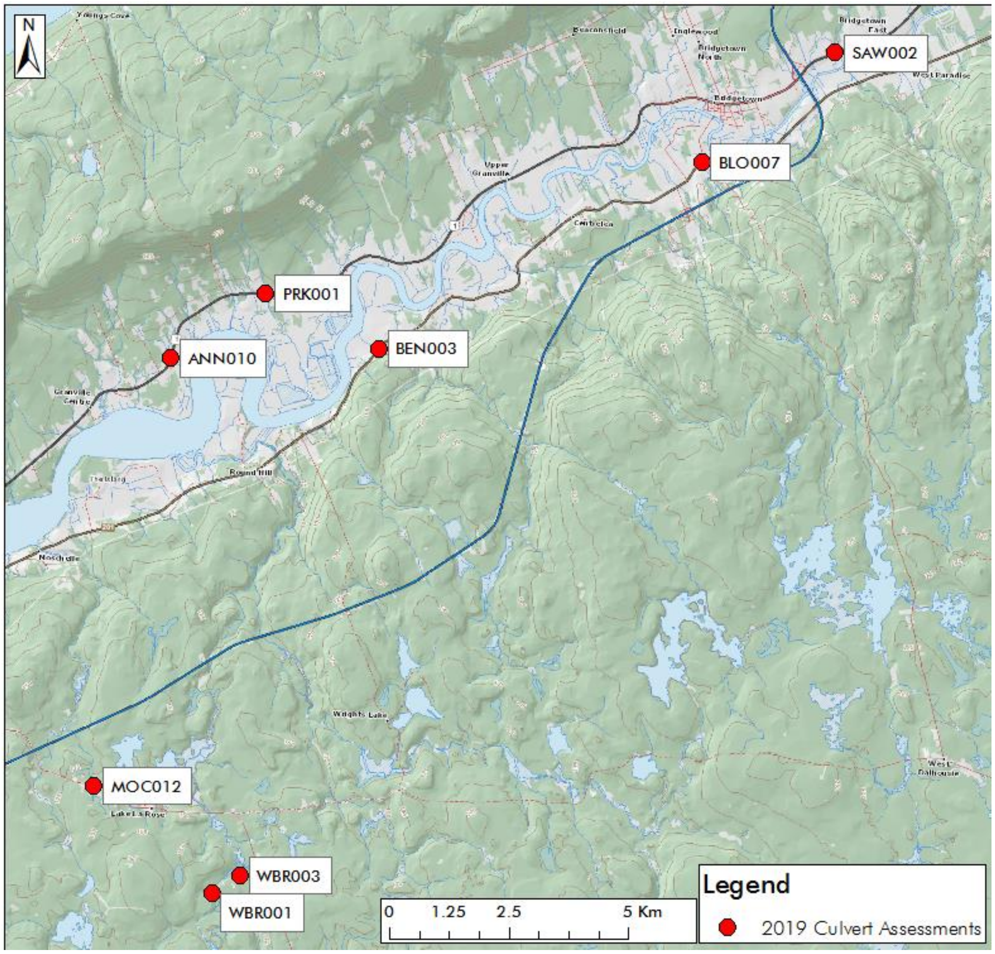

Figure 5. Map of 2019 culvert assessments in Annapolis County.

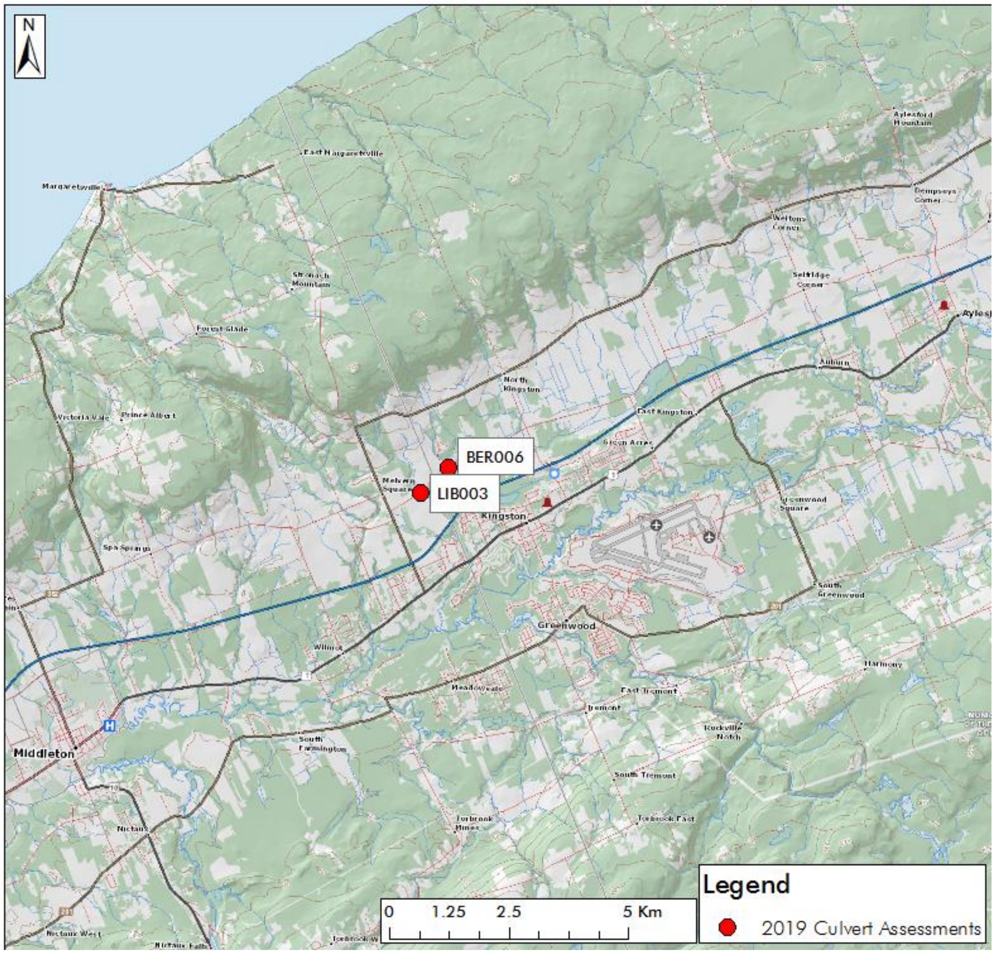

Figure 6. Map of 2019 culvert assessments in Kings County.

Of the 10 watercourse crossings that were assessed, two were found to be bridges, while eight were found to be a type of culvert. Table 4 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 debris blockage at the inflow of the culvert. Culverts that were initially found upon visual inspection to have any of these variables are theoretically posing an immediate form of barrier to fish passage and require a full, detailed assessment. Of the eight culverts assessed in 2019, more than half of the culverts assessed (5 culverts, or 62.5%) have 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 web-page, will be listed and prioritized and will receive suggested remediation actions. This information will then be used for restoration actions in the future. Further details of all watercourse crossings assessed in 2019 can be found in Appendix 6.4.

Table 4. Rapid assessment results for 2019 culverts that received full culvert assessments for fish passage.

	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	3	6	3	4	4
Percentage (%)	37.5	75.0	37.5	50.0	50.0

3.2 Fish Passage Restorations

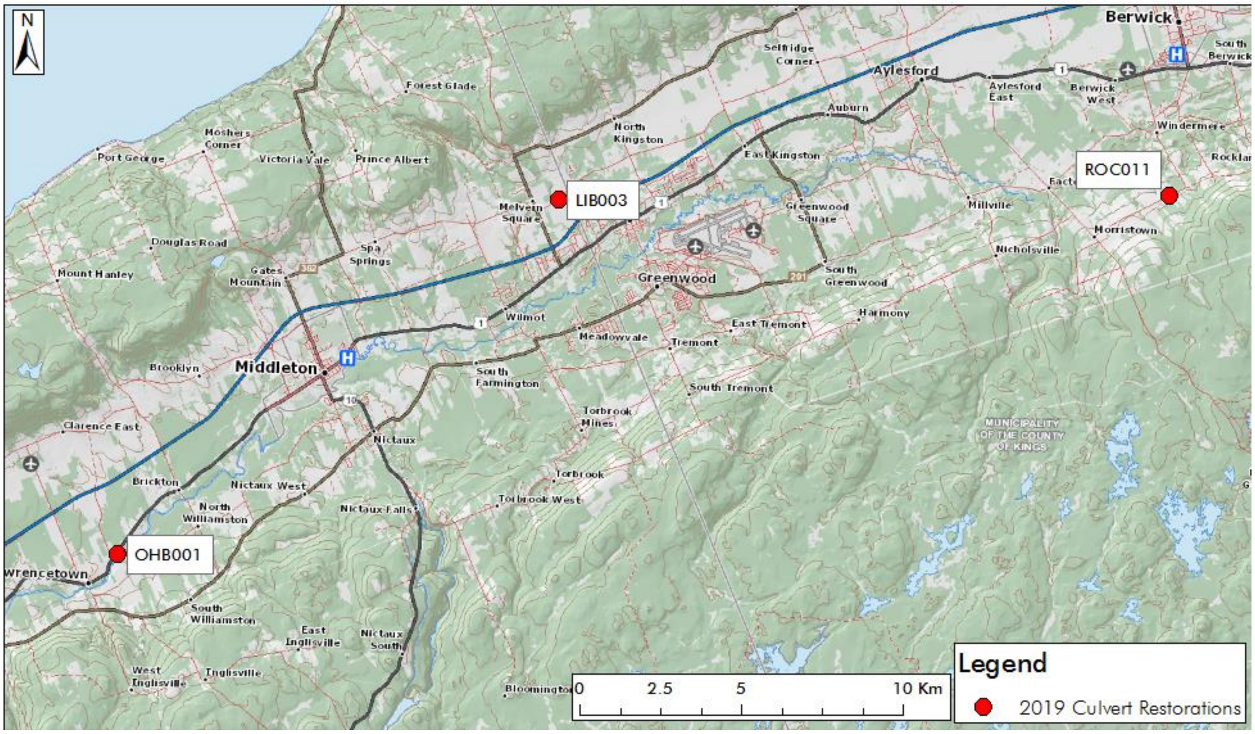

Figure 7. Map of 2019 culvert restorations.

3.2.1 LIB003

Location: Pleasant Street, Melvern Square, Kings County
Stream Name: Little Brook
Remediation: Debris removal
Outflow Drop: 0.1 cm
Slope: 0.48%
Upstream Habitat Gain: 2.3 km
Comments: Little Brook is one of the first tributaries connected to Walker Brook; a large and important tributary that connects directly to the Annapolis River. LIB003 was assessed for the first time in 2019 and is the first watercourse crossing on Little Brook with an upstream habitat gain of 2.3 km. Due to the severity of debris blocking the culvert's inflow, the culvert's minimal slope and outflow drop and its location within the Annapolis River watershed, this double, wooden culvert was a priority culvert for restoration efforts. The 1st Kingston Scouting Cubs volunteered alongside CARP staff to remove the large woody debris from the inflow of the culvert using shovels, rakes, loppers, and hand saws. The debris was disposed of off-site where it was not likely to fall back into the brook to allow the culvert to remain free for fish passage.

Figure 8. LIB003 debris removal before (A) and after (B).

Figure 9. Volunteers with the 1st Kingston Scouts Cubs helping to remove large woody debris from LIB003.

3.2.2 OHB001

Location: Annapolis County Rail Trail, Lawrencetown, Annapolis County
Stream Name: Oak Hollow Brook
Remediation: Debris removal maintenance
Outflow Drop: N/A
Slope: N/A
Upstream Habitat Gain: 6.1 km
Comments: OHB001 was first assessed in 2017 where the assessment could not be completed due to the degree of debris blockage at the inflow of the culvert. This double, stone and wood culvert received its first debris removal in 2017 by CARP staff. Upon revisiting this culvert during the 2019 season, after hurricane Dorian swept through Nova Scotia, it was apparent that the debris blockage had returned and a full culvert assessment still could not be completed. Large, heavy tree trunks and logs were stuck at the inflow of the culvert with large amounts of smaller sticks and leafy matter built up around the culvert inflow allowing almost no water to flow through either of the two culverts under the Annapolis County Rail Trail. The large upstream habitat gain of over 6 km above this watercourse crossing as well as its close proximity to the Annapolis River made this debris removal maintenance a priority for the 2019 field season. Volunteer students and teachers from the Lawrencetown Education Centre helped to remove the heavy debris blockage from OHB001 allowing for the water to move freely and allow for fish passage once again.

Figure 10. OHB001 debris removal before (A) and after (B).

Figure 11. Volunteer staff and students from the Lawrencetown Education Center helping to remove large woody debris from the inflow of the culvert that washed up as a result of hurricane Dorian.

3.2.3 ROC011

Location: Prospect Road, Windermere, Kings County
Stream Name: Bear Brook
Remediation: Rock weir maintenance
Outflow Drop: 48 cm – Restored (2017)
Slope: 1.58%
Upstream Habitat Gain: 2.825 km
Comments: ROC011 was first assessed in 2010 and received its first restoration efforts by CARP staff in 2017, where a fish chute was installed at the outflow of the culvert and a tailwater control structure was constructed. Upon revisiting this culvert in 2019, the rock weir's overflow appeared to have been blown out, causing more of a hindrance for fish swimming up from downstream and appeared to have trapped a few small fish in the outflow pool. During the 2019 field season, the overflow of the rock weir was disassembled and reconstructed by CARP staff. Large, flat rocks found on site were used for the maintenance restoration efforts to create a flat, easy-sloping overflow while the rock weir walls remained sturdy and continued to hold back water for the outflow pool.

Figure 12. ROC011 rock weir reconstructed to fix the structure's overflow to allow for fish passage once again.

3.3 In-Stream Habitat Enhancement

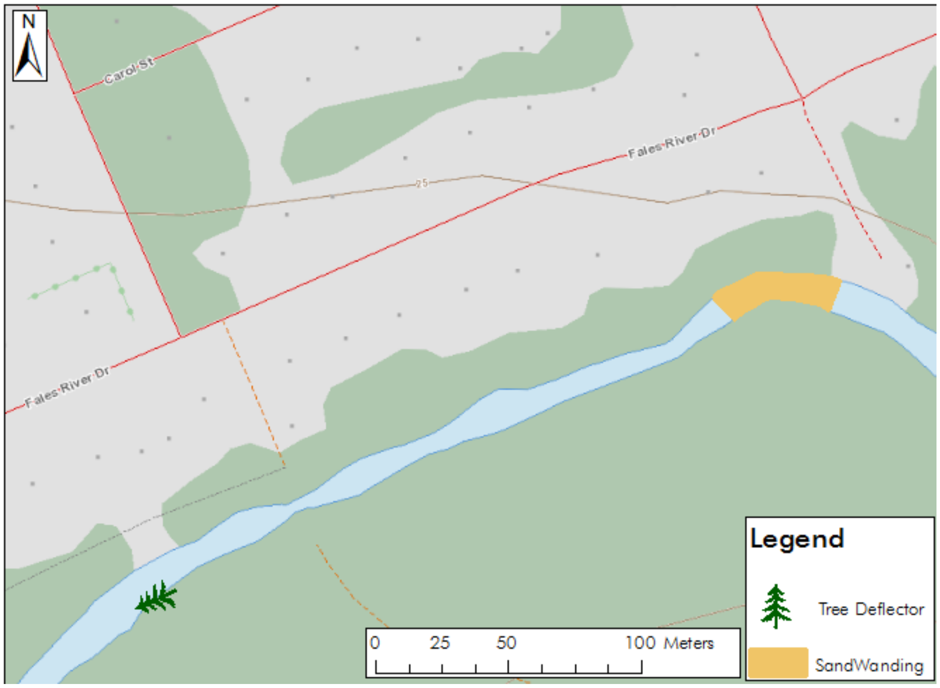

Figure 13. Site map of the 2019 completed restoration work on the Fales River.

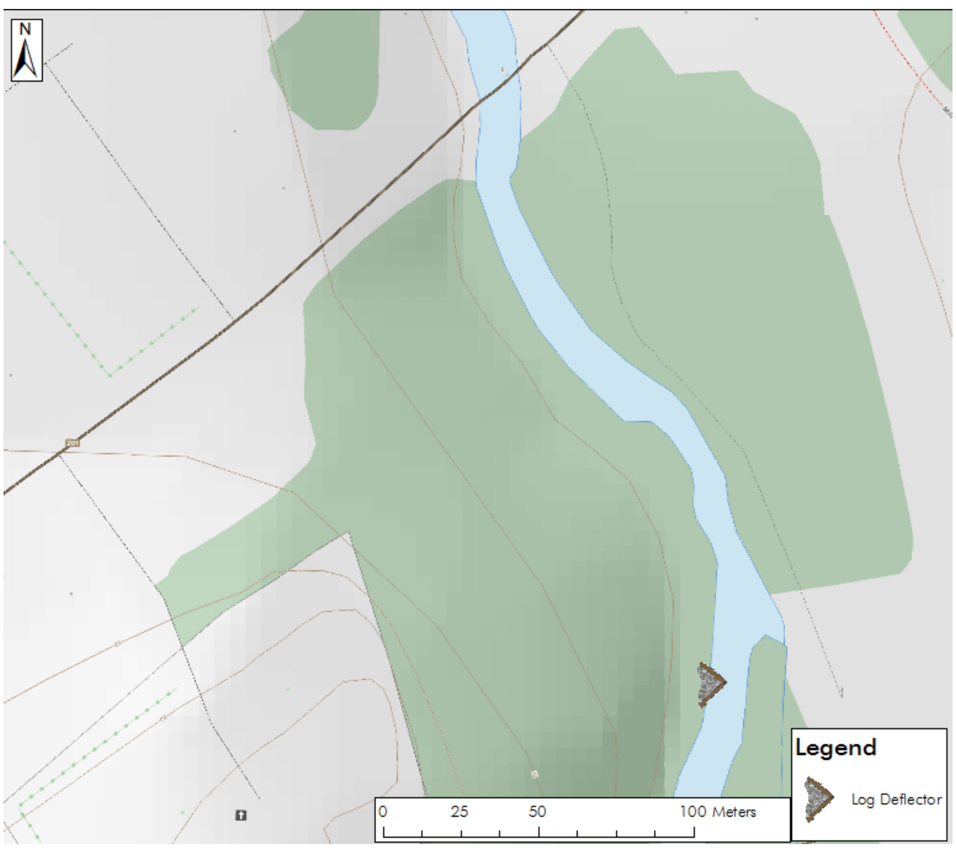

Figure 14. Site map of the 2019 completed restoration work on the Round Hill River.

2.3.1 SandWanding

Figure 15. Summer student Sebastian Conyers SandWanding in the Fales River.

SandWanding occurred during the 2019 season to enhance in-stream habitat within the Fales River, which has been prioritized for its good quality habitat for salmonids. The SandWanding was started at the head of a pool just below a natural riffle and run along a 43 m stretch. The fine sediment being removed from the river was deposited far from the river's edge to prevent the sediment from re-entering the river and a clean riverbed was noted when no fine sediments were moving through the SandWand hoses. SandWanding efforts resulted in approximately 150 m^2 of in-stream habitat enhancement. Refer to Appendix 6.9 for the location and distance measurements of the SandWanding sections conducted on the Fales River in 2019.

Immediate benefits of fine sediment removal were visually observed after the use of the SandWand. By targeting restoration activities to key areas of habitat, conditions in available spawning areas have been improved for the use of salmonid species. However, the results only show a snapshot of impacts to the physical habitat, and whether the treatment will have long term benefits is unknown. The changes to embeddedness and sediment transport as a result of the fine sediment removal via SandWanding may be altered or regressed from seasonal high flows. Therefore, the site will need to be reassessed in future years to document the long term impacts of restoration activities.

2.3.2 Digger Log Removal

Figure 16. CARP staff and volunteers removing a broken and undersized digger log from the Round Hill River.

A total of six undersized and degrading digger logs were removed from a section of the Round Hill River. Some of the logs installed in the late 1990's fell into the newly determined layout of the stream or were providing another beneficial purpose to the river and therefore were left in place. However, the digger logs removed during the 2019 field season had done little digging since their installation and many were completely or partially buried in the substrate. Refer to Appendix 6.10 for the locations of the digger logs removed from the Round Hill River in 2019.

2.3.3 Deflectors

Two, single deflectors were installed within priority sub-watersheds in the Annapolis River watershed to enhance salmonid spawning, rearing and migration habitats as well as address fine sediment within the streambed and the quality of salmonid habitat. These structures will aid in stabilizing stream banks and consequently controlling erosion in two rivers impacted by sedimentation as a result of land-use changes surrounding each respective watercourse.

Figure 17. Single, tree deflector installed by CARP staff on the Fales River.

In 2019, the Fales River received one in-stream restoration structure to enhance spawning, rearing and migration habitat. The single tree deflector will help to redirect the stream flow away from the eroding bank in addition to acting as a sediment trap for free flowing, fine sediments (Figure 17). This structure brought the stream bankfull width from an over-widened 14 m to the calculated design width of 11.36 m. The tree deflector installed in the Fales River restored a linear length of 68 m and an area of 775 m^2 of in-stream habitat. This in-stream structure will aid in stabilizing the stream bank consequently reducing erosion at the site.

Figure 18. West Kings District High School staff and students helping to fill the single log deflector with cobble and boulder on the Round Hill River.

The Round Hill River received a single, log deflector during the 2019 field season (Figure18). The deflector was installed to help concentrate flow as well as narrow and deepen the channel of an area of stream over-widened by approximately 2 m. The cobble and boulder rock from within the stream that was used to fill the frame of the deflector assisted in stabilizing the bank in addition to accentuating the natural pool downstream from the new structure. This single log deflector installed on the Round Hill River restored a linear length of approximately 65 m and an area of 706 m^2.

2.3.4 HSI Surveys

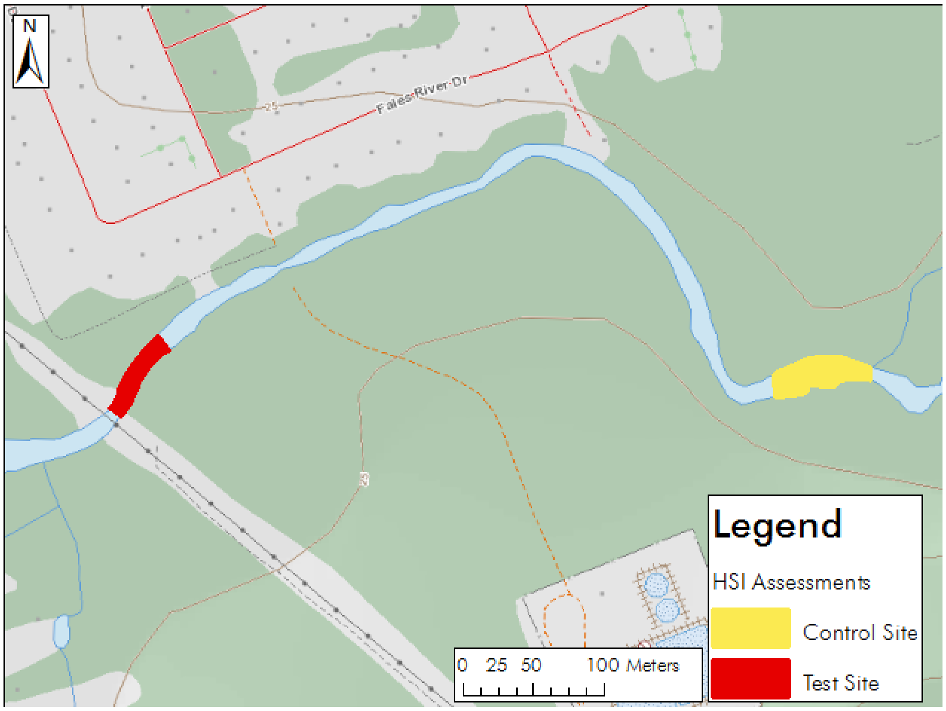

Figure 19. Site map of the HSI control and test site on the Fales River.

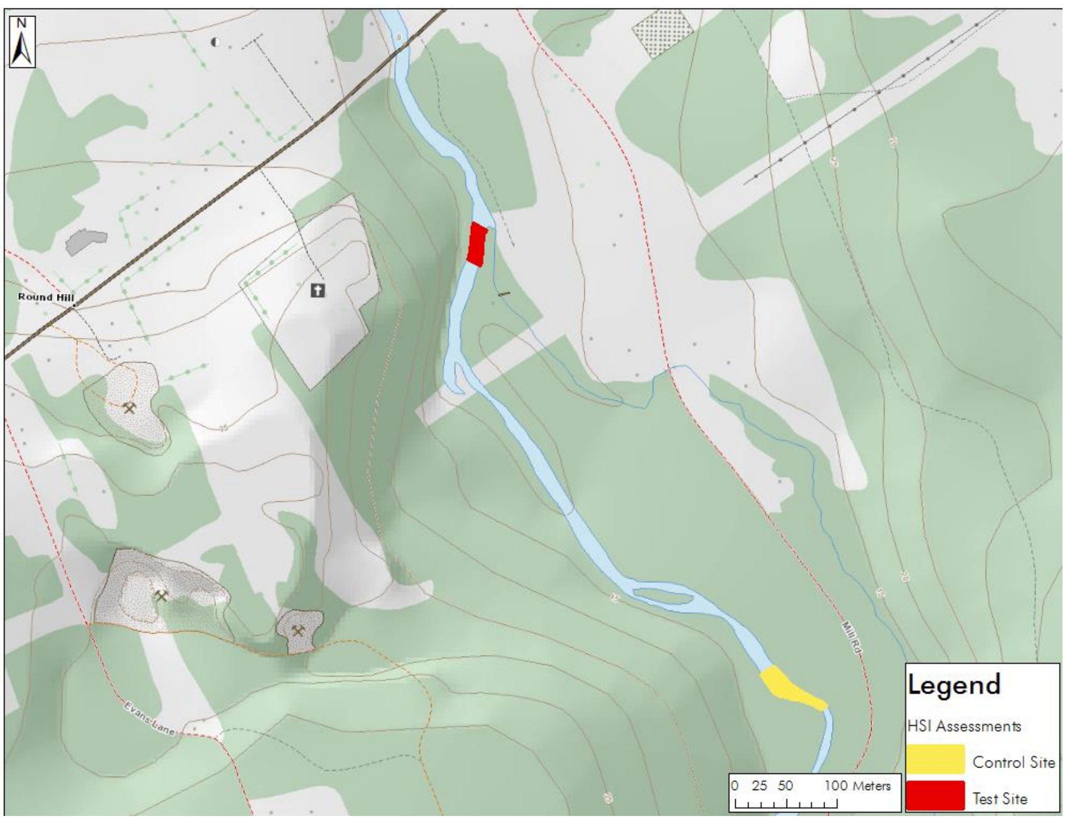

Figure 20. Site map of the HSI control and test site on the Round Hill River.

Figure 21. Volunteers and CARP staff completing HSI survey measurements on the Fales River (A) and the Round Hill River (B).

Through assessing representative variables and values of salmonid habitat features, Habitat Suitability Index (HSI) surveys were completed in the Fales River and Round Hill River to evaluate the quality of freshwater fish habitat pre-restoration and post-restoration. The test sites were located just downstream of where each deflector was planned to be installed, which also coincided with the starting location of SandWanding efforts on the Fales River. The control site on each river was located upstream of the test site at a location within the river that would remain unchanged and unaffected by the restoration activities. This was undertaken to identify comparable measures between the two sites and to quantitatively assess the impact of restoration actions.

The results on the Fales River remained relatively unchanged between the pre-restoration and post-restoration for both brook trout and Atlantic salmon criteria. The percentage of fines (substrate <0.2 cm) in spawning areas showed improvements for brook trout increasing from poor to moderate quality at the test site whereas the control site remained consistent. The average substrate size in brook trout spawning areas decreased at both the control site and the test site on the Fales River suggesting the restoration activities conducted in 2019 were not the reason behind this result (Table 5). The percentage of in-stream Atlantic salmon juvenile cover at the control site was the only category that showed any variation in the result suggesting possible impacts from sediment entering the Fales River upstream of the project location (Table 6).

Similar to the Fales River, the Round Hill River remained fairly unchanged in the results of the pre-restoration and post-restoration HSI assessments for both brook trout and Atlantic salmon criteria. The percentage of fines (substrate <0.2 cm) in spawning areas increased for both brook trout and Atlantic salmon, however this was evident at both the control site and the test site for each fish species and therefore these fines may be a result of another influence on the river system. Substrate for spawning and incubation, a unique target criterion for Atlantic salmon, improved from poor to good quality over the course of the field season, but this also may be a result of outside influences because of the similar increase in result scores between the control and test sites (Table 5 and Table 6).

Table 5. Habitat suitability criteria for brook trout at a control site and test site, before and after restoration activities.

			Percent In-stream Cover (Juvenile)	Percent In-stream Cover (Adult)	Dominant Substrate Type in Riffle-Run Areas	Average Size of Substrate in Spawning Areas	Percent Fines in Spawning Areas	Percent Fines in Riffle-Run Areas	Percent Substrate Size Class for Winter Escape
Fales River	Control Site	Pre-Restoration 2019/05/29	0.97	0.18	0.60	0.64	0.00	1.00	1.00
		Post-Restoration 2019/08/22	0.79	0.13	0.60	0.37	0.00	0.99	1.00
	Test Site	Pre-Restoration 2019/07/10	1.00	0.21	0.60	0.99	0.00	0.80	1.00
		Post-Restoration 2018/08/22	0.82	0.10	0.60	0.77	0.70	0.88	0.39
Round Hill River	Control Site	Pre-Restoration 2019/09/06	1.00	0.58	1.00	0.08	0.54	1.00	1.00
		Post-Restoration 2019/09/26	1.00	0.43	1.00	0.00	0.00	1.00	1.00
	Test Site	Pre-Restoration 2019/09/06	1.00	0.40	1.00	0.08	0.54	1.00	1.00
		Post-Restoration 2019/09/26	1.00	0.43	0.60	0.00	0.00	1.00	1.00

Table 6. Habitat suitability criteria for Atlantic salmon at a control site and test site, before and after restoration activities.

			Percent In-stream Cover (Juvenile)	Percent In-stream Cover (Adult)	Dominant Substrate Type in Riffle-Run Areas	Substrate for Spawning and Incubation	Percent Fines in Spawning Areas
Fales River	Control Site	Pre-Restoration 2019/05/29	0.97	0.18	0.60	1.00	0.00
		Post-Restoration 2019/08/22	0.79	0.13	0.60	0.86	0.00
	Test Site	Pre-Restoration 2019/07/10	1.00	0.21	0.60	0.99	0.00
		Post-Restoration 2018/08/22	0.82	0.10	0.60	N/A	N/A
Round Hill River	Control Site	Pre-Restoration 2019/09/06	1.00	0.58	1.00	0.04	0.08
		Post-Restoration 2019/09/26	1.00	0.43	1.00	0.96	0.00
	Test Site	Pre-Restoration 2019/09/06	1.00	0.40	1.00	0.04	0.08
		Post-Restoration 2019/09/26	1.00	0.43	0.60	0.96	0.00

*Scores with results listed as N/A, contain data that was not documented during the time of assessment and therefore their scores could not be computed.

4.0 Recommendations

Recommendations are based on the 2019 field season as well as previous work through the Fish Passage Restoration and Habitat Enhancement program.

A) Watercourse Crossing Assessments
   I. A full assessment should be completed on OHB001 in Lawrencetown, to collect all necessary data to assign an up-to-date barrier status for fish passage on this culvert. Now that the culvert is cleared of debris, the inside of the culvert is accessible to collect the data required to determine the outflow drop, culvert slope, and other measurements.
   II. Upon completion of the Aquatic Connectivity Analytical Database (ACAD), all assessment data completed by CARP should be entered onto the web-based tool. This will help to reclassify barrier status of all assessed culverts and suggest additional, feasible or newer remediation options for full-barrier culverts
   III. 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 2019 – 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 culverts that have received restoration work in 2019 to ensure functionality of installed structures and to monitor accumulation of debris.
   II. ROC011 should receive a second tailwater control structure to help raise water levels downstream of the currently existing rock weir that was maintained in 2019 to improve upon fish passage up to and through the culvert

C) In-stream habitat enhancement
   I. Continue restoration work on the Round Hill River including additional installations of in-stream enhancement structures. The 2019 deflector should be revisited, and future actions should be identified for structures further upstream.
   II. An Atlantic salmon and salmon habitat conservation plan for the Fales River sub-watershed to optimize habitat restoration efforts in future years of the Fish Habitat program should be developed. This document would be used help develop a strategy to optimally enhance the productivity of fish habitat within the Fales River and its tributaries.
   III. An Atlantic salmon and salmon habitat conservation plan for the Round Hill River sub-watershed to optimize habitat restoration efforts in future years of the Fish Habitat program should be developed. This document would be used help develop a strategy to optimally enhance the productivity of fish habitat within the Round Hill River and its tributaries.
   IV. Future in-stream restoration projects should be identified and salmon and habitat conservation plans should be developed for other priority sub-watersheds within the Annapolis River watershed (, South River, 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 Initiative: Culvert Assessment Data Sheet

SALMON ASSOCIATION

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

*If dam, ford, or other is selected then complete photo files, stream characteristics, and notes sections only; if bridge is selected complete bridge dimensions additionally.
**If culvert 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	
Is there a visable outflow drop?	☐ Yes ☐ No
Is the water depth less than 15cm anywhere in the culvert?	☐ Yes ☐ No
Is the culvert backwatered only part of the way or not at all?	☐ Yes ☐ No
Is the stream width noticably different above and below the culvert?	☐ Yes ☐ No
If the response to any of these questions is NO then continue with the full assessment.	

Stream Characteristics					
Water Quality					
Air Temp (°C)		pH		DO (mg/L)	
Water Temp (°C)		Conductivity (µS/cm)		TDO (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				

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Culvert Information						
Culvert Material	☐ Concrete ☐ Corrugated Metal Pipe (Spiral) ☐ Corrugated Metal Pipe (Annular) ☐ Corrugated Plastic ☐ Wood ☐ Other	Culvert Shape (check all that apply)	☐ Circular ☐ Box ☐ Pipe Arch ☐ Open Arch ☐ Multiple ☐ Other		Entrance Type	☐ Projecting ☐ Headwall ☐ Mitered ☐ Wingwall ☐ Other
		Deformation	☐ Yes ☐ No	Deterioration	☐ None ☐ Moderate ☐ Severe	Baffles ☐ Yes ☐ No
Culvert Bottom	☐ Unnatural ☐ Natural If Natural, Dominant Substrate:____________			Variable Slope		☐ Yes ☐ No

Culvert Dimensions					
Culvert Measurements	Width (m)	Height (m)	Corrugation	Width (cm)	Height (cm)

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 ☐ Embedded From Downstream	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
				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
				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 Downs		
Crest of 2nd Riffle				Culvert Slope		
Pool Surface Elevation				Outflow Drop (cm)		
Downstream Channel Slope						

Tailwater Cross Section					
	Elevations				Measurements
Widths (m)	Station	HI (m) (10 + change in tripod height)	FS (m) (Survey rod reading)	Elevation (m) (HI-FS)	Water Depth (m)
Wetted Width	1 (Left Bankfull)				
	2 (1/5 Bankfull Width)				
Bankfull Width	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>
<tr><th colspan="6">Notes</th></tr>
<tr><td colspan="6"></td></tr>
<tr><th colspan="6">Sketch</th></tr>
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6.2 Watercourse Crossing Assessment Parameters

Table 7. 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

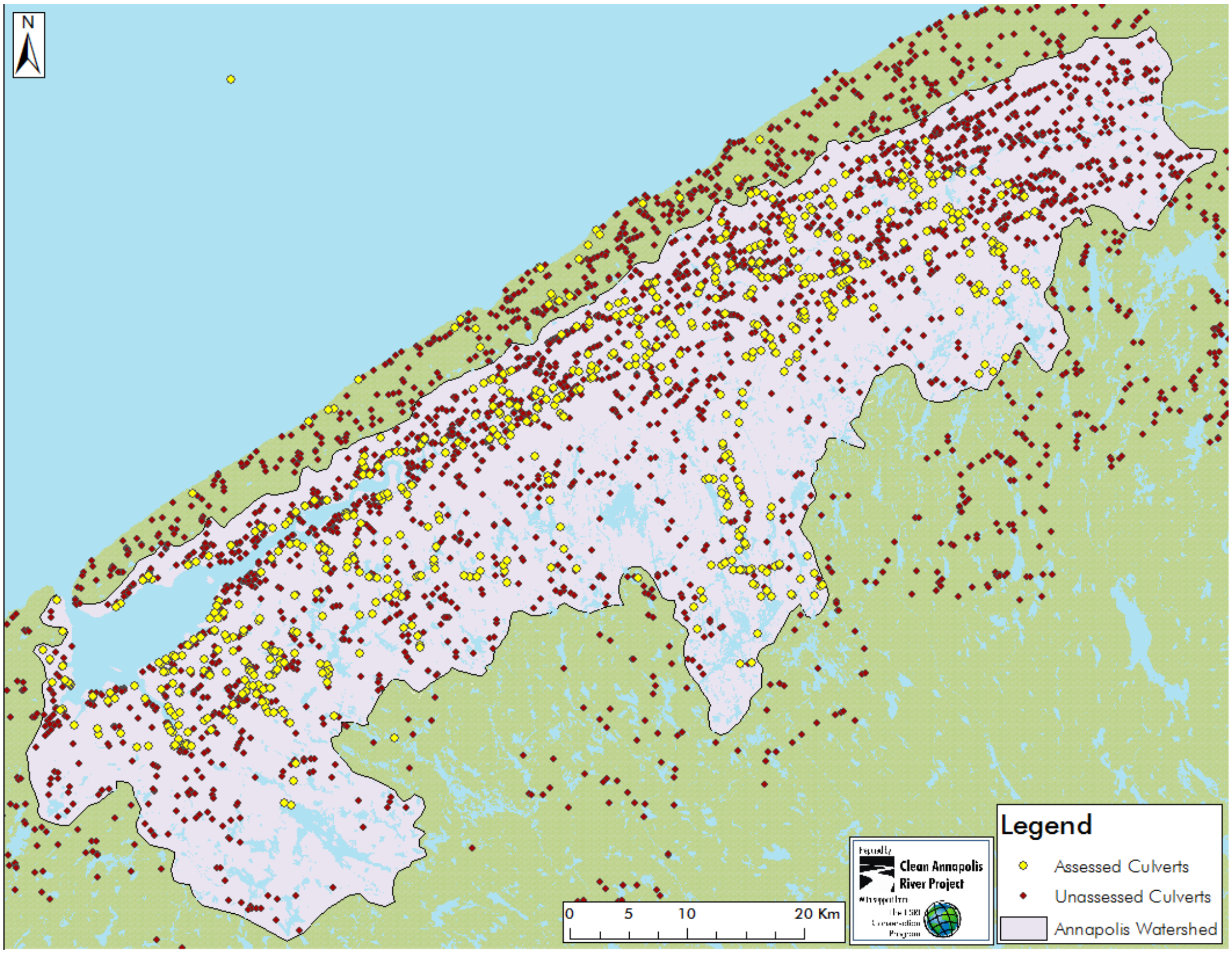


Figure 22. Map of all culvert assessments in the Annapolis River watershed from 2010 to 2019.

6.4 Details of Watercourse Crossing Assessed in 2019

Table 8. 2019 watercourse crossing detailed assessment results.

							Rapid Assessment					
Culvert ID	**Stream Name**	**Road Name**	**UTM Easting**	**UTM Northing**	**Crossing Type**	**Debris Blockage**	**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?**	**Slope (%)**	**Outflow drop (cm)**
ANN010	Annapolis River Tributary	Highway 1	317520	4962569	Culvert	No	No	Yes	No	No	0.20	-0.04
BEN003	Bent Brook	Highway 201	311897	4962777	Culvert	No	No	No	No	No	0.77	-0.37
BER006	Berry Brook	Brooklyn Street	344658	4984520	Culvert	No	No	Yes	No	Yes	0.89	-0.19
BLO007A	Annapolis River Tributary (near Bloody Creek)	Highway 201	318650	4966672	Culvert	No	Yes	Yes	No	Yes	0.31	0.43
BlO007B	Annapolis River Tributary (near Bloody Creek)	Highway 201	318650	4966672	Culvert	Yes	No	Yes	Yes	Yes	-1.01	0.40
LIB003A	Little Brook	Pleasant Street	344071	4984005	Culvert	Yes	No	Yes	Yes	Yes	0.48	-0.01
LIB003B	Little Brook	Pleasant Street	344071	4984005	Culvert	Yes	No	Yes	Yes	Yes	0.07	0.10
MOC012	Moschelle Brook	West Dalhousie Road	305910	4953608	Culvert	Yes	Yes	Yes	Yes	No	5.54	0.96
PRK001	Parker Brook	Highway 1	309512	4963931	Culvert	No	No	Yes	No	No	0.81	-0.02
SAW002	Saunders West Brook	Highway 1	321465	4968970	Bridge	No						

WBR001	West Branch Round Hill River	Old Quarry Road/Trail Off Perotte Road	308390	4951347	Bridge	No						
WBR003A	West Branch Round Hill River	Old Quarry Road/Trail Off Perotte Road	308992	4951724	Culvert	Yes	Yes	No	No	Yes	1.60	-0.03
WBR003B	West Branch Round Hill River	Old Quarry Road/Trail Off Perotte Road	308992	4951724	Culvert	Yes	No	Yes	No	No	0.85	-0.06

*Crossings with ID's listed with A or B, are double culverts at a single crossing site. Assessments are taken for each culvert individually to determine the degree of blockage each culvert presents

6.5 Annapolis River Watershed Culvert Restorations

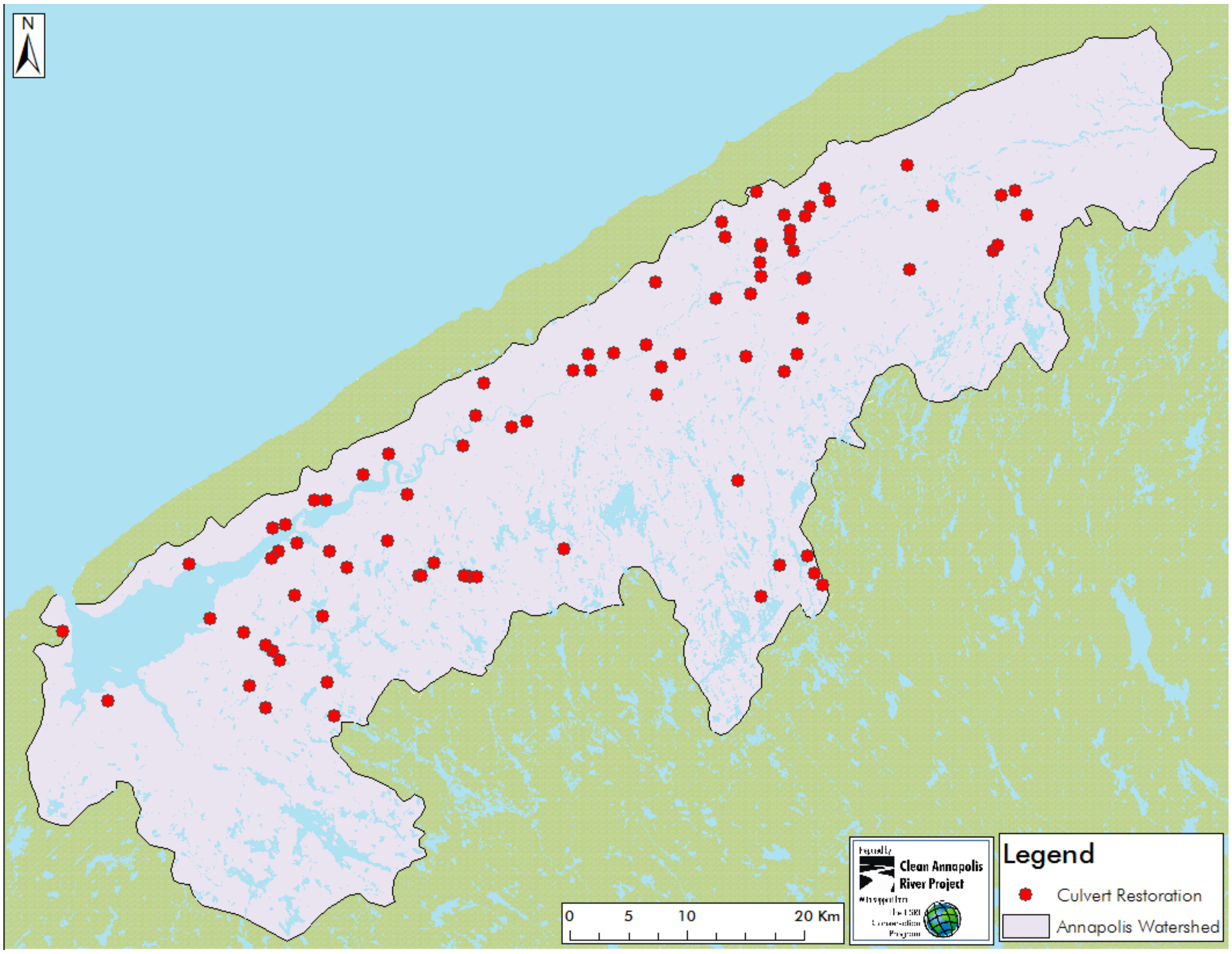


Figure 23. Map of all culvert restorations in the Annapolis River watershed from 2010 to 2019.

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 20º or 30 º angles from the base of the weir. For our design, a 30º angle from the base of the weir was used (Figure 24). 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.

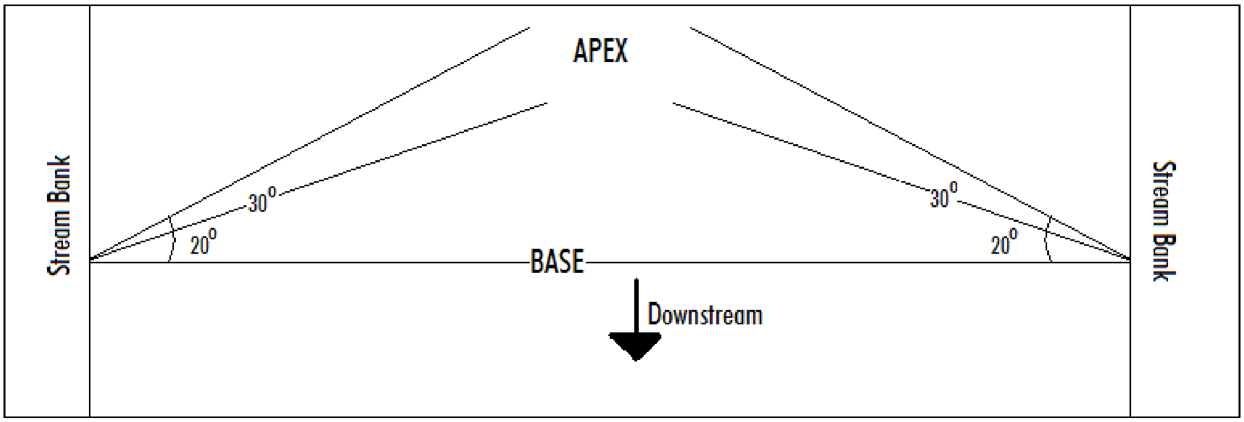


Figure 24. Vortex rock weir design (Taylor, 2010).

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

$$\text{Volume (V)} = \text{Length (l) x Width (w) x Height (h)}$$

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):

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

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

6.6.1 ROC011 – Bear Brook

*The following information and calculations are from the original rock weir installation that took place in 2017 by CARP staff.

Remediation:
One rock weir to raise tailwater pool level

Rock Volume:
Rocks located at the crossing site were used to construct the weir

Rock Size:
Based on the measurements recorded during the full culvert assessment survey in 2010, the downstream slope at ROC011 is 0.0407; the average water depth in the downstream is 0.065 m. Based on these measurements, the tractive force can be calculated:

T = 1000 X 0.065 m X 0.0407
T = 2.65 cm

An incipient diameter of 2.65 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 5.29 cm.

6.8 Fales River and Round Hill River Sub-Watersheds

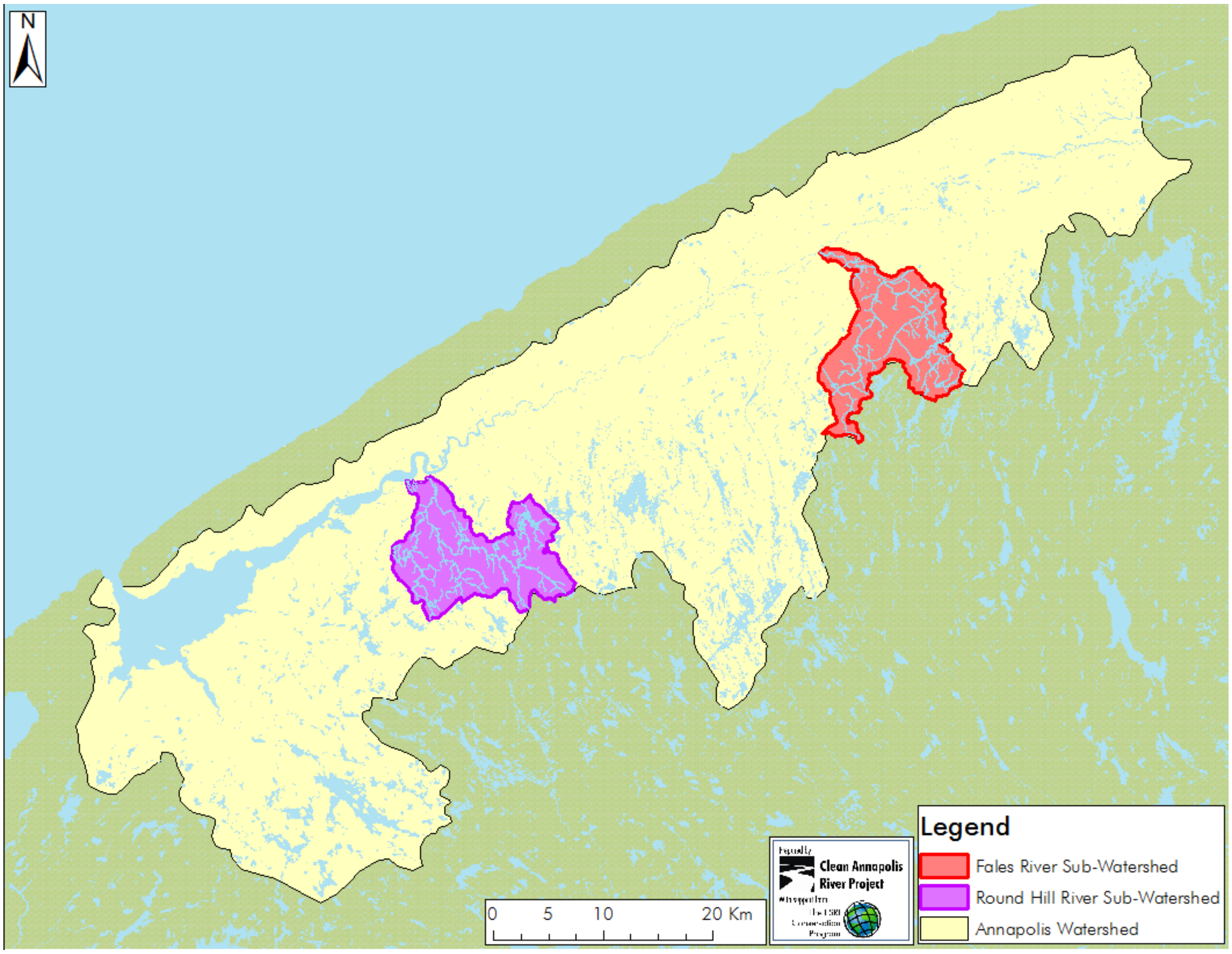


Figure 25. Location of the Fales River and Round Hill River sub-watersheds within the greater Annapolis River watershed.

6.9 SandWanding Distance Measurements

Table 9. Final SandWanding distances on the Fales River.

Start		End		Distance of SandWanding (m)
Easting	Northing	Easting	Northing	
348098	4980592	348057	4980587	43

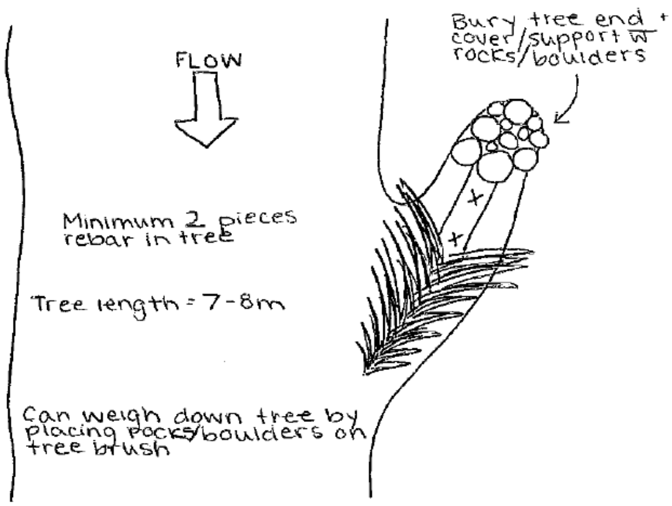
6.10 Digger Log Removal Locations

Table 10. Locations of the old, deteriorated digger logs removed from the Round Hill River in 2019.

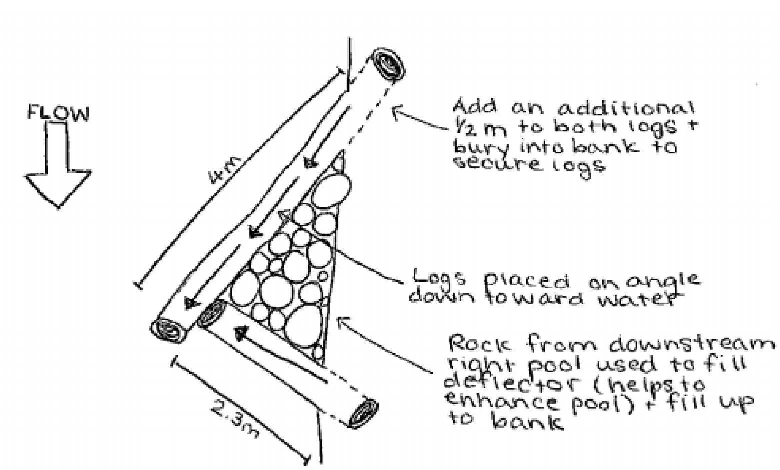
	Location	
	Easting	Northing
1	309821	4960372
2	309808	4960334
3	309828	4960228
4	309831	4960206
5	309877	4960149
6	309907	4960118

6.11 Design Sketch of In-Stream Restoration Structure

Structure: Single tree deflector
Site: Fales River, Greenwood, NS
Location: 347845, 4980488



Structure: Single log deflector
Site: Round Hill River, Round Hill, NS
Location: 309830, 4960345



6.12 Habitat Suitability Index (HSI) Data Sheet – NSFHAP

NSFHAP Field Sheet #:

River Name: ________________ Watershed Code: _____________ Date: ________________ Time: ________ Crew: ____________________

Site Boundary Coordinates: D/S ________________ ____________________ U/S _______________________ ____________________

Site Bankfull Width: ___________ Site Length: ___________ Transect Spacing: _____________ Stream Order: ___________

Air Temp: ____________Water Temp: __________ pH: _________ Conductivity: _________ TDS: _________ DO: _________

Channel Cross-sections										
	Floodplains		Height and Widths			Wetted Depths				
	Average Left Width	Average Right Width	Bankfull Width (m)	Bankfull Height (m)	Wetted Width (m)	1/4 of Width (cm)	2/4 of Width (cm)	3/4 of Width (cm)	Thalweg (cm)	Thalweg Location (m)
T1										
T2										
T3										

Substrate and Cover																					
				¼ Width					1/2 Width					¾ Width							
	GPS Coordinates		Habitat Type	Fines	Gravel	Cobble	Boulder	Bedrock	Fines	Gravel	Cobble	Boulder	Bedrock	Fines	Gravel	Cobble	Boulder	Bedrock	% Embedded	Instream Cover for Juveniles (# of fish)	Instream Cover for Adults (# of fish)
T1																					
T2																					
T3																					

Riverbanks and Riparian Area								
	% Trees	% Shrubs	% Grass	% Bare Soil	% Eroding	% Stable Ground	% Stream Shade	Ice Scar Height
Left Bank								
Right Bank								
Vegetation Index:					Avg:	Avg:		

Pool Measurements									
Transect #	Max Depth (cm)	Depth of Pool Tail (cm)	Est. Low Flow Max Depth (cm)	Average Length (m)	Average Width (m)	Final Pool Area (m^2)	% Pool Cover	Percentage of Pools	Pool Class Rating

Pictures	
#	Description

Avg. Substrate Size in Spawning Areas (*Brook trout*) (cm): ____________________
Avg. Substrate Size in Spawning Areas (*Atlantic salmon*) (cm): _________________
% Fines (*Brook trout Spawning*): _________________________
% Fines (*Salmon Spawning*): ____________________________
Point Bar Presence/Condition: ___________________________

Rock Grab: ☐ 3 Minute Kick: ☐
Net Type/Mesh Size: _____ /____
% EPT: ____ %Chironomids: __

Common Name				**Tally**
Midges				
Snails, Limpets				
Sow Bugs				
Aquatic Earthworm				
Beetles				
Mayflies				
Fishflies, Alderflies				
Stoneflies				
Caddisflies				

Notes and Section Sketch: Indicate right and left banks, tributaries and inflows, flow direction, and general river form description

6.13 Habitat Suitability Index (HSI) Assessment Parameters – NSFHAP

Table 11. Variables assessed during Habitat Suitability Index assessments.

Variable	Units	Description
Air Temperature	Celcius	The temperature of the air on the day of the assessment
Average Pool Length	m	Length of pool parallel to the flow
Average Pool Width	m	Width of pool perpendicular to flow
Bankfull Height	m	Height of elevation of the bankfull above the water surface
Bankfull Width	m	Horizontal distance between banks on opposite sides of the stream
Bedrock	%	Hard, solid rock often beneath surface materials such as soil and sediment
Boulder	%	Substrate measuring >25.6 cm
Channel		Area of the river within the bankfull, including potentially dry areas during low water and riverbanks, but not the floodplain
Cobble	%	Substrate measuring 6.4-25.6 cm
Conductivity	µS/cm	The ability of a solution (water) to carry an electrical current
Crest of Riffle		Area at the most downstream end of a pool or most upstream end of a riffle where a slow, deep section of river becomes a shallow and fast section. See also 'tail of pool'.
Date		The date on which the assessment was completed
Depth of Pool	cm	Depth of pool at the deepest section
Depth of Pool Tail	cm	Depth of water on the pool tail
Design Width	m	See also 'site bankfull width'
DO	mg/L	The amount of oxygen dissolved in the water
Embeddedness	%	Degree that boulder, cobble and gravel substrate is surrounded by finer sand and silt. Measured as percentage of fines underneath rocks.
Estimated Low Flow Max Depth	cm	How much of the pool will be covered in low flows
Final Pool Area	m^2	Total area of pool measured during the assessment
Floodplain	m	Relatively flat area of land adjacent to a river channel which gets submerged when water levels are high.
Field Crew		The assessors collecting the data
Fines	%	Sand or silt measuring <0.2 cm
Gravel	%	Substrate measuring 0.2-6.4 cm
Ice Scarring	m	Signs of damaging ice movement observed as scarring on riparian trees and shrubs
In-stream Cover (Adults)		Unembedded cover (substrate, aquatic vegetation, large woody debris, undercut banks, etc.) below the water surface that can shelter/hide a 10 cm long dowel (representing a juvenile fish)
In-stream Cover (Juveniles)		Unembedded cover (substrate, aquatic vegetation, large woody debris, undercut banks, etc.) below the water surface that can shelter/hide a 20 cm long dowel (representing an adult fish)
Meander Sequence (Full)		The meandering or sinuous pattern many rivers follow that feature steps, pools, riffles, and runs. A full meander sequence usually has two pool, riffle, and run areas in low gradient rivers and steps, pools and runs in higher gradient rivers.
Percentage of Pools	%	Calculated by determining the total area of each transect covered by pools

pH		The acidity of the water in the watercourse
Photos		The photos taken of the assessment site
Pool		Deep, slow section of river used by salmonids for cover and resting
Pool Class Rating		Pools can be classified as having an A, B or C rating based on depth and amount of cover
Pool Cover	%	Amount of pool bottom that is hidden by water colour, depth, or high surface velocities
Riffle		A shallow (<10 cm) and fast section of river that occurs between pools
Riparian Vegetation	%	Percentage of ground covered by trees, shrubs, grasses and sedges, and bare ground within 10 m of the banks edge
Riverbank Stability	%	Percentage of rooted vegetation and stable rocky substrate that protect riverbanks from erosion
Rock Grab Sampling		Cobble sized rock from a riffle is selected from the stream and the invertebrates/organisms on the bottom of the rock are counted and identified
Run		A moderately deep section, somewhat slower than a riffle, that occurs in varying locations in a river pattern
Site Bankfull Width	m	Proper stream width determined mathematically before entering the field. The formula is based on watershed area and annual precipitation. See also 'design width'
Site Length	m	6 channel width lengths or site bankfull width x 6
Spawning Areas (Brook Trout)		Spawning occurs in areas of groundwater upwelling which contains 2.5-6 cm gravel substrate
Spawning Areas (Atlantic Salmon)		Spawning occurs in areas of downwelling, such as the tail of pools or above a digger log which contains 2-9.5 cm g-cobble substrate
Step-Pool		Series of staircase-like pools, which usually occur in steeper channels
Stream Name		The name of the watercourse where the assessment is taking place
Stream Order		Measure of the relative size of a stream. The smallest streams in a watershed have the lowest numbers and the largest streams closest to the ocean have the highest numbers.
Stream Shade	%	Canopy cover created by riparian vegetation
Tail of pool		Area at the most downstream end of a pool or most upstream end of a riffle where a slow, deep section of river becomes a shallow and fast section. See also 'crest of riffle'.
TDS	mg/l	Total dissolved solids, the measurement of the combined content of all inorganic and organic substances in its suspended form
Thalweg	Depth: cm Location: m	Deepest section in a channel cross-section, and the area where the water will be found during low water events
Three-Minute Kick Sampling		Kick/disturbing the substrate for three minutes while a partner collects the invertebrates/organisms that are dislodged with a fine mesh net
Time		The time that the assessment began
Transect		Every two calculated bankfull widths
Transect Spacing	m	Site bankfull width x 2
UTM Coordinates		GPS position of the HSI assessment location, described with Northings and Eastings, using a NAD83 projection
Vegetation Index		Multiplication factors are used for each vegetation type and added together to obtain an index value
Water Temperature	Celcius	Downstream water temperature

Watershed Code		Obtained through the Nova Scotia environment and allows sites in the same watershed to be grouped together
Wetted Width	m	Width of the river that contains water at the time of the measurement

6.14 Habitat Suitability Index (HSI) Scores – NSFHAP

Table 12. Pre-restoration and post-restoration HSI scores for brook trout.

		Site Date	Percent Pools	Pool Class Rating	Percent In-stream Cover Juvenile	Percent In-stream Cover During Late Growing Season Adult	Dominant Substrate Type in Riffle-Run Areas	Average Percent Vegetation Along the Streambank	Average Percent Rooted Vegetation and Stable Rocky Ground Cover	Average Maximum Water Temperature	pH	Average Size of Substrate in Spawning Areas	Percent Fines in Spawning Areas	Percent Fines in Riffle-Run Areas	Percent Substrate Size Class for Winter Escape	Average Thalweg Depth During the Late Growing Season	Percent Stream Shade
Fales River	Pre-Restoration	Control 2019/05/29	0.50	0.60	0.97	0.18	0.60	0.51	0.77	1.00	1.00	0.64	0.00	1.00	1.00	0.10	1.00
		Test 2019/07/10	0.46	0.60	0.79	0.13	0.60	0.87	0.92	0.85	0.94	0.37	0.00	0.99	1.00	0.01	0.72
	Post-Restoration	Control 2019/08/22	0.72	0.60	1.00	0.21	0.60	0.65	0.99	0.47	0.88	0.99	0.00	0.80	1.00	0.14	0.72
		Test 2019/08/22	0.44	0.60	0.82	0.10	0.60	0.86	0.73	0.64	0.94	0.77	0.70	0.88	0.39	0.01	0.86
Round Hill River	Pre-Restoration	Control 2019/09/06	0.54	0.60	1.00	0.58	1.00	0.84	0.65	0.96	0.70	0.08	0.54	1.00	1.00	0.01	0.44
		Test 2019/09/06	0.36	0.60	1.00	0.43	1.00	0.95	0.95	0.93	0.48	0.00	0.00	1.00	1.00	0.18	0.65
	Post-Restoration	Control 2019/09/26	0.33	0.60	1.00	0.40	1.00	0.77	0.92	1.00	1.00	0.08	0.54	1.00	1.00	0.12	0.86
		Test 2019/09/26	0.37	0.60	1.00	0.43	0.60	0.95	0.95	1.00	0.70	0.00	0.00	1.00	1.00	0.25	1.00

Table 13. Pre-restoration and post-restoration HSI scores for Atlantic salmon.

		Site Date	Percent Pools	Pool Class Rating	Percent In-stream Cover (Juveniles)	Percent In-stream Cover (Adults)	Dominant Substrate Type in Riffle-Run Areas	Average Percent Vegetation Along the Streambank	Average Percent Rooted Vegetation and Stable Rocky Ground Cover	Summer Rearing Temperature During Growing Season	pH	Substrate for Spawning and Incubation	% Fines in Spawning Areas	Fry Water Depth	Parr Water Depth	Stream Order	Percent Stream Shade
Fales River	Pre-Restoration	Control 2019/05/29	0.46	0.60	0.97	0.18	0.60	0.51	0.77	0.52	1.00	1.00	0.00	1.00	1.00	0.90	1.00
		Test 2019/07/10	0.39	0.60	0.79	0.13	0.60	0.87	0.92	0.86	0.98	0.86	0.00	1.00	1.00	0.90	0.72
	Post-Restoration	Control 2019/08/22	0.87	0.60	1.00	0.21	0.60	0.65	0.99	0.44	0.94	0.99	0.00	1.00	0.98	0.90	0.72
		Test 2019/08/22	0.35	0.60	0.82	0.10	0.60	0.86	0.73	0.61	0.98	N/A	N/A	1.00	1.00	0.90	0.86
Round Hill River	Pre-Restoration	Control 2019/09/06	0.54	0.60	1.00	0.58	1.00	0.84	0.65	0.99	0.74	0.04	0.08	1.00	1.00	0.90	0.44
		Test 2019/09/06	0.22	0.60	1.00	0.43	1.00	0.95	0.95	0.95	0.39	0.96	0.00	1.00	1.00	0.90	0.65
	Post-Restoration	Control 2019/09/26	0.16	0.60	1.00	0.40	1.00	0.77	0.92	1.00	1.00	0.04	0.08	1.00	1.00	0.90	0.86
		Test 2019/09/26	0.23	0.60	1.00	0.43	0.60	0.95	0.95	0.99	0.74	0.96	0.00	1.00	1.00	0.90	1.00

*Scores with results listed as N/A, contain data that was not documented during the time of assessment and therefore their scores could not be computed.