Fish Passage Restoration and Habitat Enhancement

A project to address fish habitat restoration and enhancement in the Annapolis River watershed

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NSLC Adopt A Stream

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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
km	Kilometre
NSE	Nova Scotia Environment
NSFHAP	Nova Scotia Fish Habitat Assessment Protocol

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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 Habitat Restoration and 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 666 sites have been visited and 738 detailed watercourse crossing assessments have been completed within the greater watershed. During the 2018 field season, watercourse crossing assessments were primarily focused in the Fales River and Zeke Brook sub-watersheds. Additional culverts were surveyed in various areas within the watershed based on their upstream habitat gain and location from the main stem of the Annapolis River. From August to October, CARP visited 40 sites, 34 of which were culverts on fish-bearing streams requiring detailed assessments. The detailed information gathered in these assessments will be entered onto 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 Broken Brooks program. In addition, culverts that had received previous restoration actions were revisited for maintenance. In 2018, six sites received restoration work, resulting in four debris removals, two tailwater control restorations and two fish chute restorations. These remediation activities restored access to 18.42 km of upstream habitat and improved access to an additional 5.10 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. Work on the Fales River was initiated in the late 1990's to improve habitat complexity and productivity for salmonids. Various in-stream restoration structures were installed into this high priority stream. This year, CARP incorporated SandWanding into restoration activities to remove fine sediment from salmonid spawning habitat in the Fales River. In total, over 500 m^2 of in-stream habitat was enhanced through the removal of surface and sub-surface sediment.

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 ideal habitat that should 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 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 and thus reduces 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 removal of the fine sediments from the stream bed to reveal the natural cobble and gravel substrate, 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 2018 season was on assessing culverts within the Annapolis River watershed and restoring barrier culverts identified in previous years of this project. Additionally, in-stream restoration work that was started in 2017 on the Fales River was continued in the 2018 field season.

2.0 Methodology

The 2018 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 along the Fales River to directly remove fine sediment 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 2018 season, culvert assessments were primarily focused within the Fales River and Zeke Brook sub-watersheds. Additionally, culverts located outside of these sub-watersheds were chosen for assessments due to their location and close proximity to the main stem of the Annapolis River or their high amount of upstream habitat gain. Refer to Appendices 6.1 and 6.2 for culvert data sheets. 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 2018, refer to Fish Habitat Restoration and Enhancement: *A project to address fish habitat fragmentation and degradation in the Annapolis River Watershed* (Stoffer, 2016).

In 2018, the NSLC Adopt A Stream Aquatic Connectivity Initiative, in partner 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 2018 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 6.4 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 received 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 6.7 to view map of all culverts that have received restoration actions 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.

Tailwater controls built in 2018 employed a vortex rock weir design. Large, flat footer stones were used to construct the base of rock weir structures. Pebbles and gravel were used as fill to seal the gaps between the larger weir stones. Due to the prevalence of tailwater blow-outs on previously constructed weirs, all weirs constructed in 2018 minimized the use of rip-rap and emphasized the placement of larger stones for greater integrity. Rock weirs were constructed using calculations for guidance in rock sizing as well as utilizing materials at each site. For further design information, calculations used, and detailed descriptions of individual rock weir construction, refer to Appendices 6.5 and 6.6.

2.2.3 Fish Chutes

Fish chutes are another feature, often used in addition to other culvert remediation actions, are added to the outflow of a culvert to assist in reducing the effects of a large outflow drop. In 2018, one site was given a fish chute for installation as an additional remediation action to the overall restoration of the culvert. The chute was acquired in 2017, but could not be installed due to continuous rain events leading to abnormally high flows through the culvert. Culvert measurements were used to calculate required chute dimensions using a formula for determining baffle notch sizes with additional support and guidance from AAS. The galvanized, steel fish chute was affixed to the outflow baffles of a concrete culvert with prefabricated concrete baffles. Additional 4x4 cedar wood was placed atop the chute baffles for extra support and bolstering as well as for aesthetics.

Upon inspection of a restoration site completed the previous year, the fish chute along with its attached baffles, were missing from the wooden culvert it was affixed to. It is assumed that the high flows coming from upstream and through the culvert, along with the harsh winter weather and ice, had caused the fish chute and baffles to detach. The chute and baffles were retrieved from the bottom of the outflow pool and reinstalled to the culvert using longer, galvanized lag screws for better bolstering.

2.3 In-stream Habitat Restoration

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). The Fales River system, identified as a priority sub-watershed, has received some restoration work in the past. Continued efforts to enhance in-stream habitat were undertaken in 2018.

In 1999, initial work was completed by The Clean Annapolis River Project on the Fales River to improve habitat quality and complexity in the river that was altered after development began 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 to plan 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 conducted along various stretches of the river. SandWanding along a downstream stretch of the river was completed in 2017 and had restored approximately 1,625m^2 of in-stream habitat.

Figure 1. Eroding bank on the Fales River.

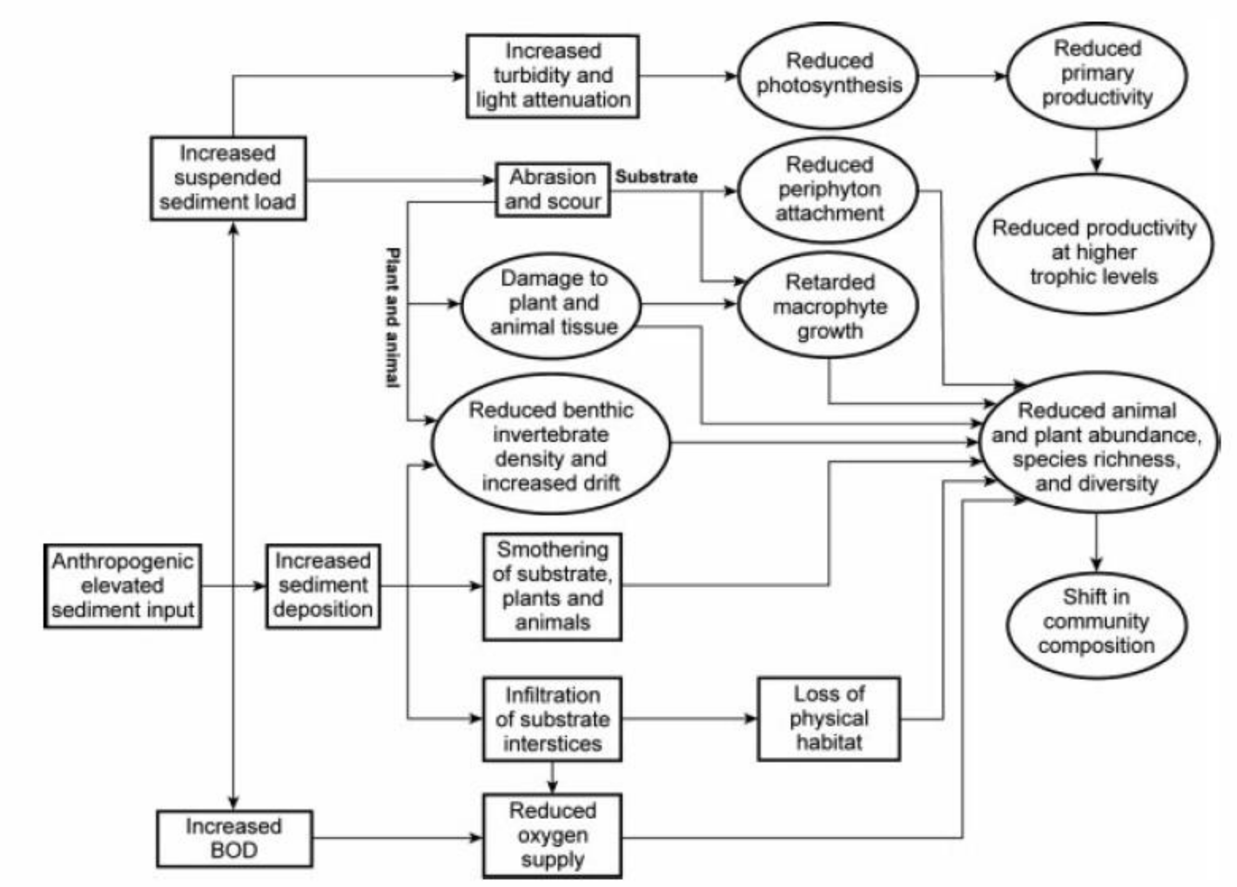

Figure 2. Negative impacts of anthropogenically enhanced sediment input (Kemp et al., 2011).

Substrate surveys, as part of habitat suitability assessments were conducted as a pre-restoration assessment. Consultations with partners and experts were also 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 river accessible by salmonids was impacted with fine sediments, likely impairing successful spawning. Over several decades, the river has filled in with fine sediments from land-use impacts and bank erosion (see figure 1 for an example). Fine sediment accumulation ($<$ 2 mm in size; Louhi *et al.*, 2008) has been widely recognized to pose detrimental effects to river ecosystems (see 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 2018 in-stream habitat enhancement was targeted at fine sediment removal.

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. Photographs of the SandWand head (A) and pump generators on river bank (B).

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 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 2017 field season along the Fales River according to the updated (2016) Nova Scotia Fish Habitat Enhancement Protocol developed by AAS and Clean Nova Scotia (NSFHAP, 2016). Refer to Appendix 6.8 for an example of a NSFHAP field sheet. Surveys were conducted as a pre-restoration activity focusing on the conditions of the substrate to demonstrate the success of SandWanding and determine its effectiveness for fine sediment removal.

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. 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 SandWanding activities on the Fales River and the technology's effectiveness for enhancing in-stream fish habitat.

3.0 Results

Restoration efforts for the 2018 season resulted in considerable improvements to both fish passage and fish habitat. 40 culverts within the Annapolis River Watershed, the majority within the Fales River and Zeke Brook sub-watersheds, were assessed for fish passage. Six sites received restoration work, which included: 4 debris removals, 2 fish chute installations, and 2 tailwater control installations. In total, 18.42 km of upstream habitat was made available, and an additional 5.10 km of upstream habitat passage was improved. Instream habitat enhancement work was also completed to improve habitat productivity within a 160 m stretch restoring 560 m^2 of the Fales River with the use of SandWand equipment.

Table 1. Summary of 2018 restorations.

Restoration Site	Watercourse Name	Easting	Northing	Upstream Habitat Gain (km)	Restoration Work Completed
BAT001	Bath Brook	315889	4966939	4.35	Debris removal
FRA001	Fraser Brook	306267	4961893	4.89	Debris removal
HRR004	Harris Brook	323413	4955556	2.31	Debris removal
MCG009	McGee Brook	352834	4988412	6.86	Debris removal
MOR008	Morton Brook	336906	4983558	1.96	Vortex rock weir, fish chute
PET002	Pete's Brook	331698	4971162	3.14	Vortex rock weir, fish chute

Restoration Site	Location	Easting	Northing	In-stream Habitat Restored (m^2)	Restoration Work Completed
Fales River	Greenwood	348214	4980428	560	SandWanding

3.1 Watercourse Crossing Assessments

Throughout the 2018 field season, a total of 40 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 Fales River and Zeke Brook sub-watersheds along with other crossings throughout the Annapolis River watershed that lacked detailed assessments, and crossings along streams with high prioritization scores and maximum upstream gain (Figures 4 and 5).

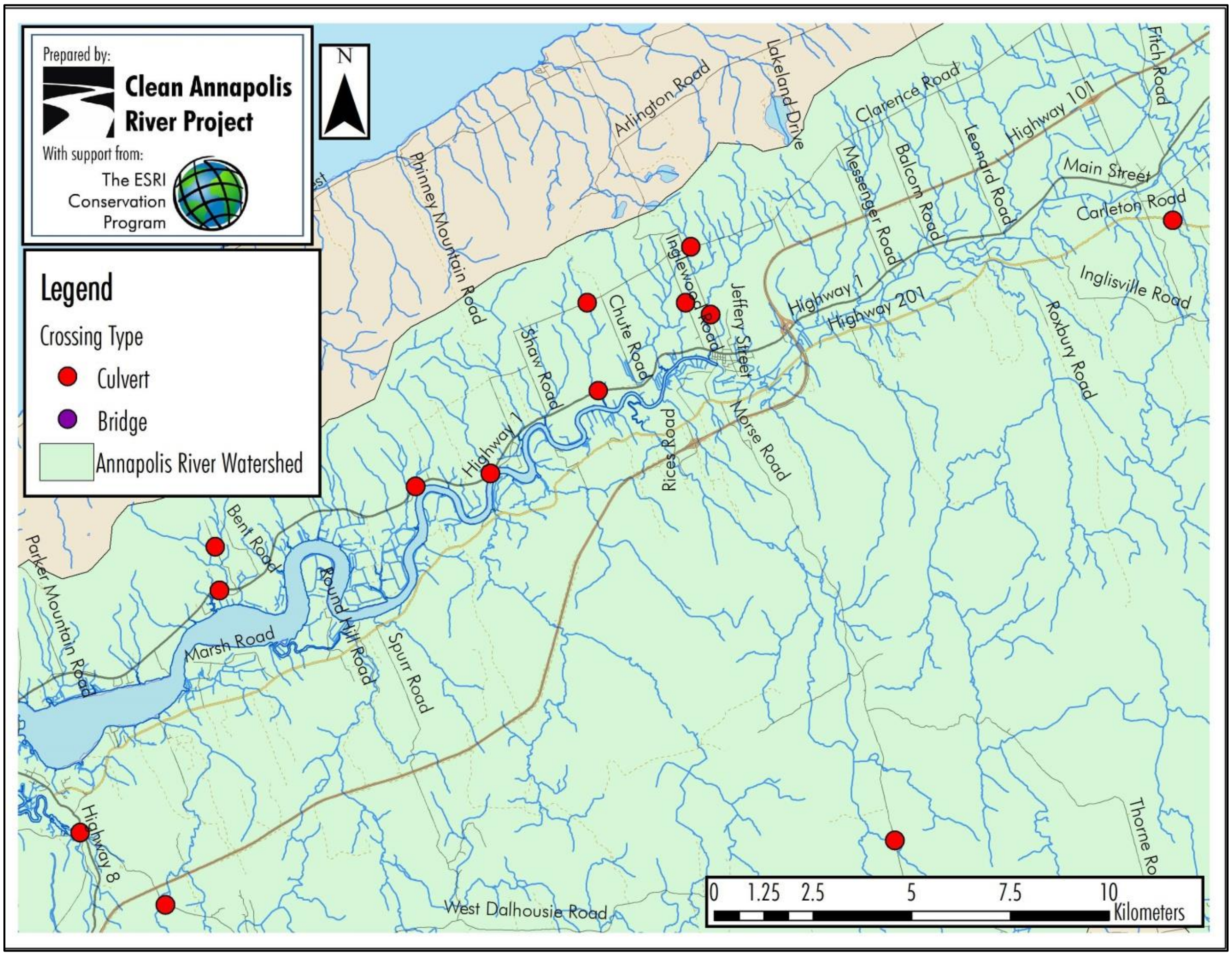

Figure 4. Map of 2018 culvert assessments from Annapolis Royal to Paradise.

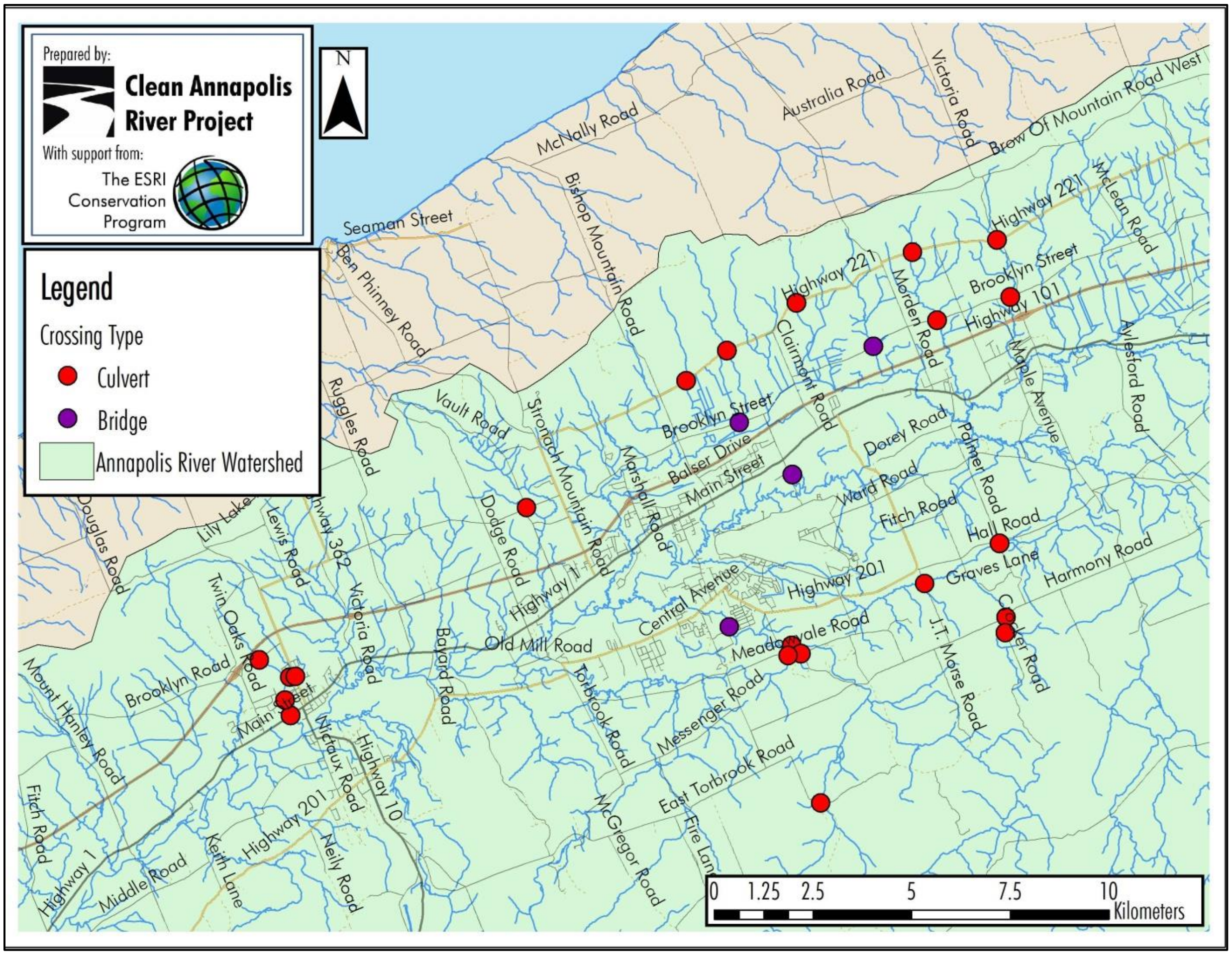

Figure 5. Map o 2018 culvert assessments from Middleton to Aylesford.

Of the 40 watercourse crossings that were assessed, six were found to be bridges, while 34 were found to be 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, and a noticeable difference in the stream width above and below the culvert. Culverts that were initially found upon visual inspection to have any of these variables are theoretically posing a form of barrier to fish passage and require a full, detailed assessment. Of the 34 culverts assessed in 2018, the majority of culverts (25 or 82%) have more than one contributing issue resulting in the restriction of fish passage and three culverts were found to have all five factors. 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 2018 can be found in Appendix 6.3.

Table 2. Rapid assessment results for 2018.

	Visible outflow drop	Water depth less than 15 cm	Culvert not completely backwatered	Stream width difference above and below	Debris blockage
Count	16	25	20	19	18
Percent (%)	47.0	73.5	58.8	55.9	52.9

3.2 Fish Passage Restorations

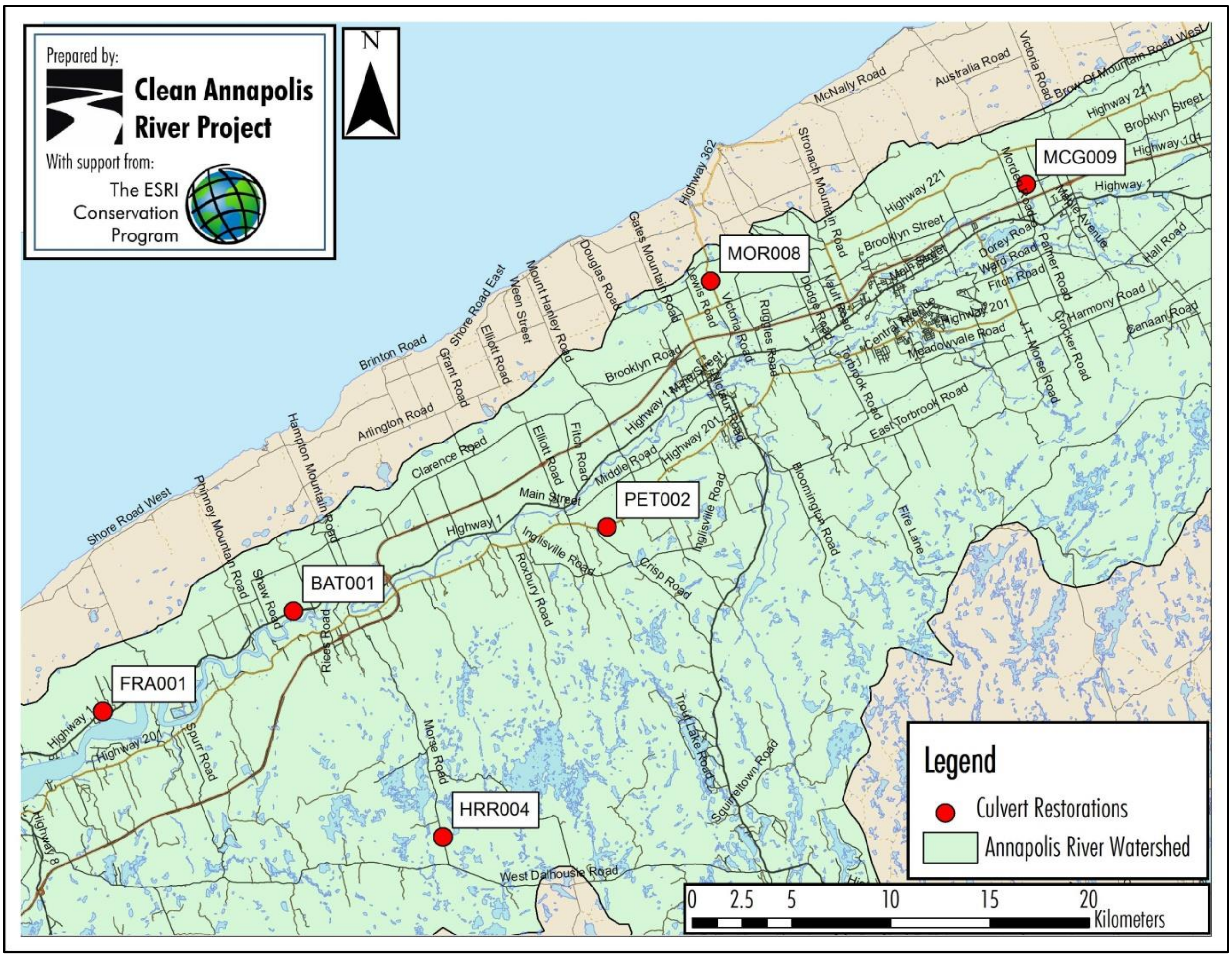

Figure 6. Map of 2018 culvert restoration locations.

3.2.1 BAT001

Location: HWY 1, Upper Granville, Annapolis County
Remediation: Debris removal
Outflow Drop: 19.0 cm
Slope: 0.62%
Upstream Habitat Gain: 4.38 km
Comments: BAT001 is the first crossing of Bath Brook, a tributary to the Annapolis River with a main stem that runs 4.34 km long. Due to its location and close proximity to the main stem of the Annapolis River, this concrete, box culvert received an immediate debris removal. During its assessment in 2018, it was suspected that an inactive beaver dam and erosion of the bank surrounding the culvert was the source of the blockage (Figure 7). Staff removed the woody debris of the blockage to open up the inflow. Large boulders could not be removed for a full debris removal and therefore additional debris removals will be necessary over the following years.

Figure 7. BAT001 before (A) and after (B) debris removal.

3.2.2 FRA001

Location: HWY 1, Granville Centre, Annapolis County
Remediation: Debris removal
Outflow Drop: 0.0 cm
Slope: 0.23%
Upstream Habitat Gain: 4.89 km
Comments: FRA001 is the first crossing of the 5.06 km long Fraser Brook. This double, wooden box culvert was blocked across the inflow with woody debris (Figure 8). Upstream of the culvert also contained small logs that were removed to prevent future blockages. Similar to BAT001, this culvert was a high priority debris removal because of its location and close proximity to the main stem of the Annapolis River as well as its large upstream habitat gain. Although not severe, the removal of this debris blockage will ensure all sizes of migrating fish species, including Atlantic salmon and brook trout, can pass freely.

Figure 8. FRA001 before (A) and after (B) debris removal.

3.2.3 HRR004

Location: Morse Road, West Dalhousie, Annapolis County
Remediation: Debris Removal
Outflow Drop: 26.0 cm
Slope: 0.81%
Upstream Habitat Gain: 6.25 km
Comments: HRR004 is the fourth upstream crossing of Harris Brook. This double, corrugated, metal pipe culvert had a significant debris blockage of rock and woody debris (Figure 9). Due to the significant upstream habitat gain of over 6 km, this culvert was a high priority for a debris removal. Although no fish were seen on site during the 2018 assessment and debris removal, a local property owner often fishes for an [unknown] trout species in the Harris Brook. Staff removed debris from the largely canopied culvert (Figure 9B) using a variety of equipment. 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 9. HRR004 before (A) and after (B)(C) debris removal

3.2.4 MCG009

Location: Brooklyn Street, Selfridge Corner (near Aylesford), Kings County
Remediation: Debris removal
Outflow Drop: 0.0 cm
Slope: -2.83%
Upstream Habitat Gain: 6.86 km
Comments: MCG009 is a large, concrete culvert that was newly installed in 2012. Found along the McGee Brook, with a main stem that runs approximately 6.86 km long, this natural bottom culvert is located downstream of a large pond. There was no debris blockage directly at the inflow, but fallen trees and debris upstream was impeding fish passage to the 6.86 km of habitat beyond the culvert (Figure 10). Staff and volunteers removed the blockages allowing for free flowing water to reach the culvert and therefore increasing connectivity to the rest of the brook (Figure 11).

Figure 10. MCG009 before (A)(B) and after (C) debris removal.

Figure 11. Volunteer students assisting in the debris removal at MCG009.

3.2.5 MOR008

Location: HWY 362, Spa Springs, Annapolis County
Remediation: Vortex rock weir, reinstallation of fish chute
Outflow Drop: 24.4 cm
Slope: 1.90%
Upstream Habitat Improvement: 1.96 km
Comments: MOR008 is a wooden, box culvert on Morton Brook. Having received restoration activities in 2017, the fish chute that had been installed along with its attached baffles had blown-out through the winter. Staff remediated the fish chute and affixed it to the culvert using longer, galvanized lag screws. A second vortex rock weir was also constructed during the 2018 field season downstream from the first weir (Figure 12). This weir will help to raise the water levels through the culvert and improve upon the fish passage established in previous years. The structure was reinforced with large boulders and upstream sediments were used to help seal the weir during the construction phase. The addition of the second rock weir decreased the outflow drop to 3 cm from the original 24.4 cm before any restoration work. Upon completion of the 2018 field season, the MOR008 site has 3 functioning culvert restoration structures to assist with fish passage (Figure 13).

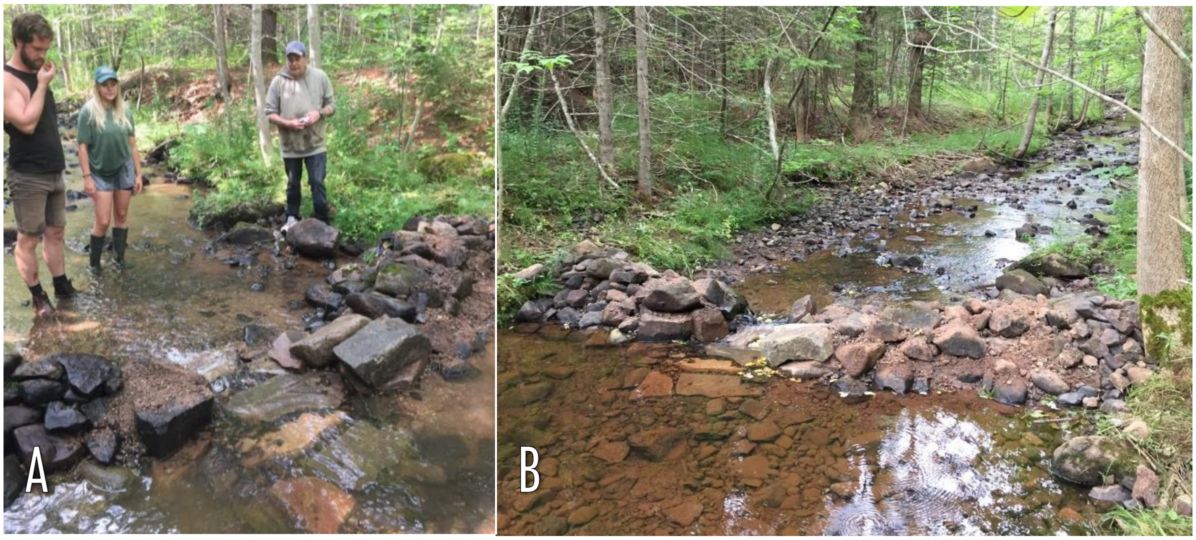

Figure 12. CARP staff constructing the MOR008 weir and the completed structure (B).

Figure 13. All current and working structures of the MOR008 site installed by CARP.

3.2.6 PET002

Location: HWY 201, South Williamston, Annapolis County
Remediation: Installation of fish chute, remediation of vortex rock weir
Outflow Drop: 23.2 cm
Slope: 3.33%
Upstream Habitat Improvement: 3.14 km
Comments: PET002 is a concrete, circular culvert with pre-fabricated concrete baffles located on Pete's Brook. The outflow pool houses many brook trout making this culvert a priority for remediation actions to assist these fish with migration. CARP staff installed two vortex rock weirs during the 2017 field season. Upon inspection in 2018, the first of the two weirs had completely blown out from the high flow events over the fall and winter seasons. A complete reconstruction of the rock weir was completed in the 2018 season using larger, heavier rock found on site (Figure 14A). The weir was also moved back approximately 1 m for better positioning to be bolstered to the bank and ensure no water was escaping around the weir. Large boulders were placed behind the walls of the weir for extra support. The fish chute that was acquired in 2017 was also installed (Figure 14B). It was affixed to the concrete using expanding bolts with additional 4x4 cedar posts installed on top of the concrete baffles for extra support. Upon completion of the 2018 field season, the MOR008 site has 3 functioning culvert restoration structures to assist with fish passage (Figure 15).

Figure 14. Reconstructed weir (A) and newly installed fish chute (B) at PET002.

Figure 15. All current and working structures at the PET002 site installed by CARP.

3.3 In-stream Habitat Restoration

3.3.1 SandWanding

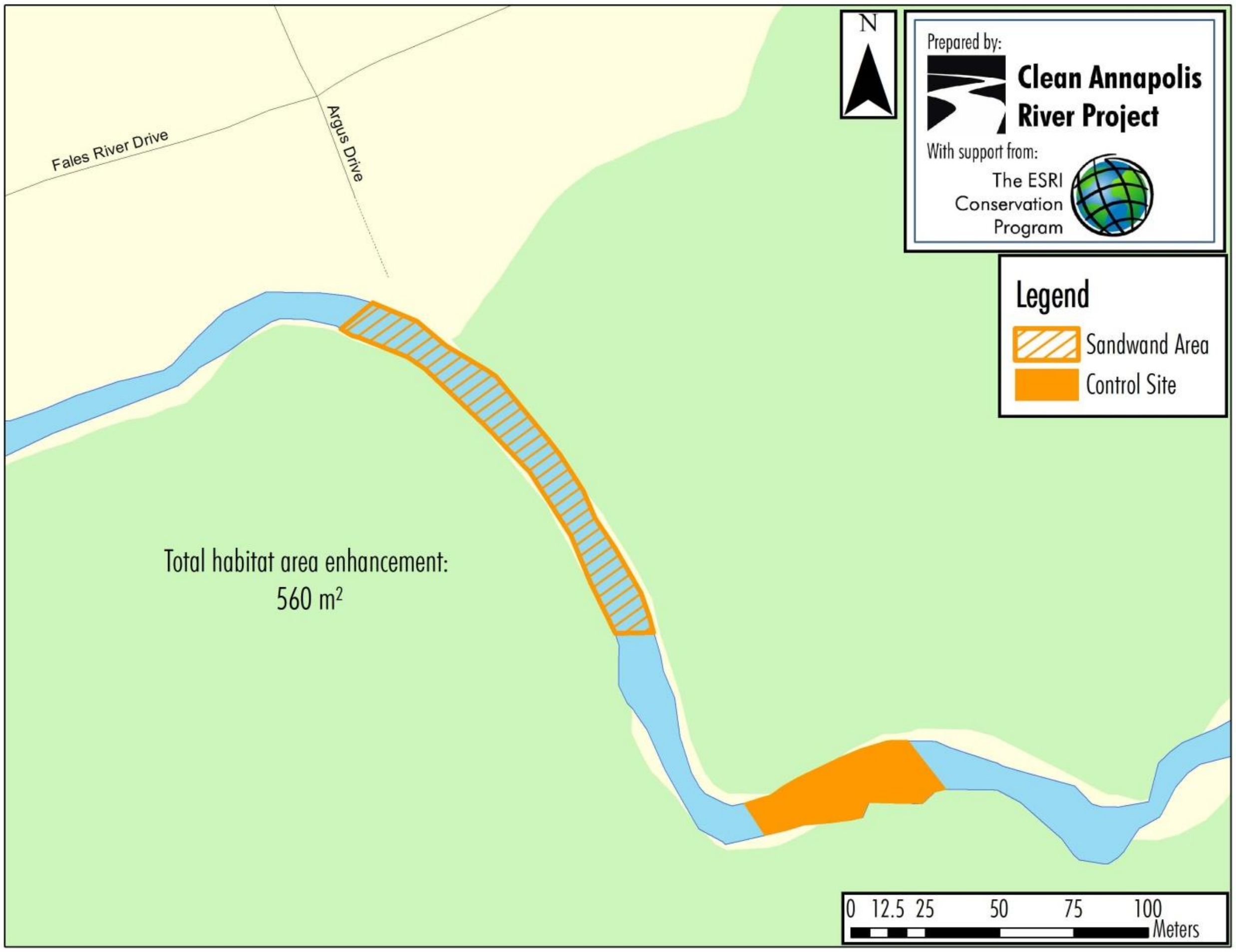

Figure 16. Site map of the SandWanding conducted on the Fales River.

Figure 17. SandWanding activities performed on the Fales River resulting in the removal of a large amount of fine sediments

Electrofishing conducted on the Fales River verified the presence of Atlantic salmon smolt and parr as well as brook trout, supporting the value of in-stream habitat restoration on this system. SandWanding occurred during the 2018 season to enhance in-stream habitat within the Fales River which has been prioritized for its good quality habitat for salmonids. The upstream end of the site chosen for restoration was located approximately 200 m upstream from the river access point on Argus Drive, Greenwood. The SandWanding was started at the head of a pool just below a digger log installed in the 1990's and run along a 160 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 (Figure 17B and 17D) and a clean riverbed was noted when no fine sediments were moving through the SandWand hoses (Figure 17B and 17C). SandWanding efforts resulted in approximately 560 m^2 of in-stream habitat enhancement.

Figure 18. The visual success of SandWanding and the removal of fine sediments.

Immediate benefits of fine sediment removal were visually observed after the use of the SandWand (Figure 18). Once removed, the fine sediments were deposited off site. It is likely that the observed changes in criteria can be attributed to the SandWand treatment because comparable changes did not occur in the control site. 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 and therefore, the site will need to be reassessed during the following field season to document the long term impacts of restoration activities.

Results presented below in Tables 3 and 4 have been chosen as representative of variables with the potential to be impacted by sediment removal. Post-restoration assessments at the Test and Control site on the Fales River could not be conducted during the 2018 field season as a result of inclement weather and unsafe water levels. These assessments are planned to be conducted in the early spring of 2019 to assess the effectiveness of the 2018 SandWanding activities. For a detailed table of all 15 pre-restoration habitat suitability criteria scores, refer to Appendix 6.9. Results for habitat suitability criteria are presented for both target species.

Table 3. Habitat suitability criteria for brook trout, before restoration activities.

Site Name	Date	Percent Instream Cover Juvenile	Percent Instream Cover During Late Growing Season Adult	Dominant Substrate Type in Riffle-Run Areas	Percent Fines in Riffle-Run Areas	Percent Substrate Size Class for Winter Escape	Avg Thalweg Depth During the Late Growing Season
Fales Pre-Control	10/11/2017	0.61	0.19	0.60	0.98	1.00	0.01
Fales Pre-Test (SandWand Site)	01/11/2017	0.30	0.23	1.00	1.00	1.00	0.04

Table 4. Habitat suitability criteria for Atlantic salmon, before restoration activities.

Site Name	Date	Percent Instream Cover Juvenile	Percent Instream Cover During Late Growing Season Adult	Dominant Substrate Type in Riffle-Run Areas	Summer Rearing Temperature
Fales Pre-Control	10/11/2017	0.61	0.19	0.60	0.00
Fales Pre-Test (SandWand Site)	01/11/2017	0.23	0.03	1.00	0.37

4.0 Recommendations

A) Watercourse Crossing Assessments

I. 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

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 2018 – 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 2018 to ensure functionality of installed structures and to monitor accumulation of debris.

II. All culverts that have received restoration work by CARP between the years 2010 and 2017 should also be revisited. Some restored culverts have not been checked for functionality or any accumulation of debris in over five years. In addition, methods of installation have since been updated and the structures built using older methods should also be updated.

III. All updated information on the construction of a vortex rock weir should be compiled into a document for easy accessibility and understanding. This document would include updated calculations, rock sizes, step-by-step procedures and directions on construction along with trouble shooting advice that could be used during in-field construction. A similar document could be made about the installation of fish chutes, baffles and low flow barriers.

C) In-stream habitat enhancement

I. HSI surveys should be completed on the Fales River at both SandWand (Test) and Control sites in the 2019 field season to document possible long-term effects of fine sediment removal on substrate and habitat within the Fales River.

II. Continue remediation work in the Fales River involving in-stream structures. Deflectors and digger logs should be revisited and bolstered with more rock if necessary, while future actions should be identified for structures further upstream and downstream.

III. Identify future in-stream restoration projects within other priority sub-watersheds (South River, Black River, Moose River, Round Hill River, etc.).

IV. Similar to the recommended document for the construction of rock weirs, all information about SandWanding should be compiled into a singular document. There is currently no document that describes the procedure of SandWanding including the setup, operation or calculations required. This could be beneficial to future in-stream restorations to ensure proper SandWanding is conducted without any negative repercussions on the habitat, proper and consistent calculations could be made on how much habitat was restored and this would also be useful as a trouble shooting guide in the field.

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6.0 Appendices

6.1 Culvert Assessment Data Sheet

NSLC adopt a stream

Aquatic Connectivity Initiative: Culvert Assessment Data Sheet

NOVA SCOTIA 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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Baffle Information (Complete if culvert is baffled)					
Baffle Height (cm)		Baffle Material	☐ Concrete ☐ Metal ☐ Wood ☐ Other		
Notch Depth (cm)		Baffle Type	☐ Straight ☐ Diagonal ☐ Right Angled ☐ Other		
Notch Width (cm)		Notch Chutes	☐ Yes ☐ No		
Number of Baffles		Notch Chute Material	☐ Concrete ☐ Metal ☐ Wood ☐ Other		
Distance Between Baffles (m)		Elevations	HI (m) (10 + change in tripod height)	FS (m) (Survey rod reading)	Elevation (m) (HI-FS)
Distance from Bottom Baffle to Outflow (m)		Most D/S Baffle			
		Adjacent U/S Baffle			
Drop Between Baffles (m)					

Notes

Sketch

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6.2 Description of Detailed Assessment Parameters

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 Details of Culverts Assessed in 2018

Culvert ID	Stream Name	Road Name	UTM Easting	UTM Northing	Crossing Type	Debris Blockage	Rapid Assessment				Slope (%)	Outflow Drop (cm)
							Is there a visible outflow drop?	Is the water depth less than 15cm anywhere in the culvert?	Is the culvert backwatered only part of the way or not at all?	Is the stream width noticeably different above and below the culvert?		
ALL007	Allain's Creek	Hwy 8/ Clementsvale Rd	302743	4955738	Culvert	No	Yes	Yes	No	No	3.38%	0.49
BAT001	Bath Brook	Hwy 1	315888	4966938	Culvert	Yes	No	Yes	Yes	No	0.62%	0.19
BAT004	Bath Brook	Clarence Rd	315604	4969181	Culvert	Yes	Yes	Yes	Yes	No	3.18%	0.34
BER007	Berry Brook	Marshall Rd	349166	4984499	Bridge	No	N/A	N/A	N/A	N/A	N/A	N/A
FAL002	Fales River	Trail off Rivercrest Lane	347567	4980635	Bridge	No	N/A	N/A	N/A	N/A	N/A	N/A
FAL005A	Fales River	Rocknotch Rd	349142	4980165	Bridge	No	N/A	N/A	N/A	N/A	N/A	N/A
FAL005B	Fales River	Rocknotch Rd	349142	4980165	Culvert	No	No	Yes	Yes	No	1.86%	N/A
FAL007	Fales River	Meadowvale Rd	349382	4979959	Culvert	No	Yes	Yes	No	No	3.97%	0.63
FAL011A	Fales River	E. Torbrook Rd	349893	4976156	Bridge	No	N/A	N/A	N/A	N/A	N/A	N/A
FAL011B	Fales River	E. Torbrook Rd	349893	4976156	Culvert	Yes	Yes	Yes	Yes	No	1.25%	0.34
FAS010A	Fash Brook	Clarence Rd	318238	4970596	Culvert	No	No	No	No	Yes	-0.18%	0.14
FAS010B	Fash Brook	Clarence Rd	318238	4970596	Culvert	No	No	No	No	Yes	-0.18%	0.19
FAS014	Fash Brook	Inglewood Rd	318111	4969176	Culvert	No	No	No	No	Yes	-0.28%	-0.29
FRA001A	Fraser Brook	Hwy 1	306273	4961884	Culvert	Yes	No	No	No	Yes	0.23%	-0.2
FRA001B	Fraser Brook	Hwy 2	306273	4961884	Culvert	Yes	No	No	No	Yes	0.05%	-0.15
GES001A	Gesner Brook	Hwy 1	311252	4964516	Culvert	No	Yes	Yes	No	No	1.18%	0.67
GES001B	Gesner Brook	Hwy 2	311252	4964516	Culvert	No	Yes	Yes	No	No	1.60%	0.56
GRA015B	Grave's Brook	Brooklyn St	354694	4989005	Culvert	Yes	Yes	Yes	No	Yes	0.00%	0.17
GRA015A	Grave's Brook	Brooklyn St	354694	4989005	Culvert		Yes	Yes	No	Yes	1.00%	0.35
GRA017	Grave's Brook	Hwy 221	354357	4990458	Culvert	No	No	Yes	No	Yes	0.98%	0.05
HOL001A	Hollow Brook	Fraser Rd	306172	4962988	Culvert	Yes	Yes	Yes	Yes	No	0.91%	0.16

HOL001B	Hollow Brook	Fraser Rd	306172	4962988	Culvert	No	Yes	Yes	Yes	No	2.75%	0.83
HRR004A	Harris Brook	Morse Rd	323414	4955540	Culvert	Yes	Yes	Yes	Yes	No	0.81%	0.26
HRR004B	Harris Brook	Morse Rd	323414	4955540	Culvert	Yes	Yes	Yes	Yes	No	0.57%	0.24
KED002	Keddy's Brook	Hwy 221	349269	4988853	Culvert	No	No	Yes	Yes	Yes	1.39%	0.08
LEW001A	Lewis Brook	Hwy 221	347498	4987650	Culvert	Yes	Yes	Yes	Yes	Yes	1.02%	0.8
LEW001B	Lewis Brook	Hwy 222	347498	4987650	Culvert	Yes	Yes	Yes	Yes	Yes	1.02%	0.79
LIL001	Lily Lake Brook	Hwy 1	336430	4978387	Culvert	No	No	No	No	Yes	0.00%	-0.1
LIL003	Lily Lake Brook	Marshall St	336290	4978769	Culvert	No	No	No	No	Yes	0.16%	-0.27
LIL004	Lily Lake Brook	School St	336415	4979355	Culvert	No	No	Yes	No	Yes	0.00%	0.1
LIL005A	Lily Lake Brook	Bentley Dr	335637	4979797	Culvert	No	Yes	No	No	Yes	-1.76%	0.05
LIL005B	Lily Lake Brook	Bentley Dr	335637	4979797	Culvert	Yes	Yes	No	No	Yes	-0.07%	0.01
LIL006	Lily Lake Brook	Commercial St	336550	4979373	Culvert	Yes	No	Yes	Yes	Yes	2.03%	-0.01
LNG001	Longley's Brook	Hwy 221	346470	4986875	Culvert	Yes	Yes	Yes	Yes	No	1.40%	0.97
MCG009	McGee Brook	Brooklyn St	352836	4988414	Culvert	No	No	No	No	Yes	-2.83%	-0.59
MCG016	McGee Brook	Hwy 221	352214	4990140	Culvert	No	Yes	Yes	Yes	No	1.06%	0.64
MEA001A	Fales River	Meadowvale Rd	349057	4979905	Culvert	Yes	No	Yes	Yes	Yes	0.98%	0.2
MEA001B	Fales River	Meadowvale Rd	349057	4979905	Culvert	Yes	No	Yes	Yes	Yes	3.01%	-0.02
MIL006	Mill Brook	Hwy 201	330470	4971261	Culvert	No	Yes	Yes	Yes	No	1.28%	0.57
MOC011 A	Mochelle Brook	West Dalhousie Dr	304897	4953905	Culvert	No	No	Yes	Yes	No	2.11%	-0.22
MOC011 B	Mochelle Brook	West Dalhousie Dr	304897	4953905	Culvert	Yes	No	Yes	Yes	No	1.06%	-0.24
RAY001A	Ray Brook	Hwy 1	313145	4964850	Culvert	Yes	Yes	Yes	Yes	Yes	1.45%	1.08
SHR003	Sherman Brook	Brooklyn St	313145	4964850	Bridge	No	N/A	N/A	N/A	N/A	N/A	N/A
SOL013A	Solomon Chute Brook	Hampton Mountain Rd	351221	4987751	Culvert	No	No	No	Yes	Yes	-5.22%	-0.03

SOL013B	Solomon Chute Brook	Hampton Mountain Rd	318735	4968881	Culvert	Yes	No	No	Yes	Yes	-6.22%	0.03
WAK004	Walker Brook	Brooklyn St	318735	4968881	Bridge	Yes	N/A	N/A	N/A	N/A	N/A	N/A
WIS013	Wiswal Brook	Spa Springs Rd	347825	4985820	Culvert	No	No	Yes	Yes	No	0.97%	0.26
ZEK011	Zeke Brook	Clairmont (South) Rd	342417	4983650	Culvert	No	No	No	No	Yes	-2.68%	-0.01
ZEK014A	Zeke Brook	Harmony Rd	352524	4981730	Culvert	Yes	Yes	Yes	Yes	Yes	1.26%	0.48
ZEK014B	Zeke Brook	Harmony Rd	354595	4980872	Culvert	Yes	Yes	Yes	Yes	Yes	1.26%	0.47
ZEK015	Zeke Brook	Crocker Rd	354595	4980872	Culvert	No	Yes	Yes	Yes	No	0.67%	0.09
ZEK016A	Zeke Brook	Palmer Rd	354579	4980483	Culvert	Yes	No	Yes	Yes	Yes	1.29%	0.2
ZEK016B	Zeke Brook	Palmer Rd	354425	4982754	Culvert	Yes	No	Yes	Yes	Yes	0.40%	0.26

6.4 Watercourse Crossing Assessments (2010-2018)

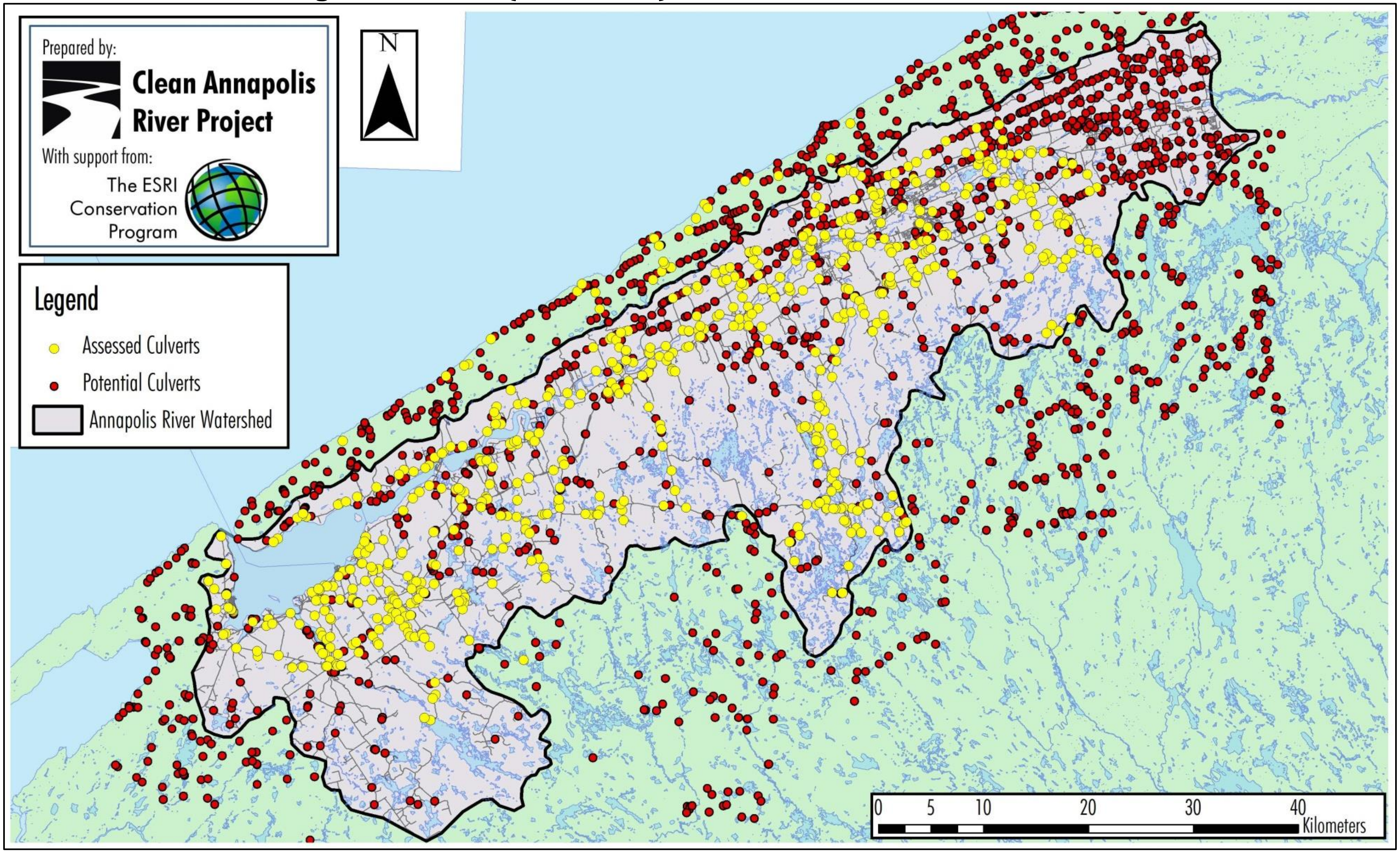

Figure 19. All watercourse crossings within the Annapolis River watershed.

6.5 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 19). 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.

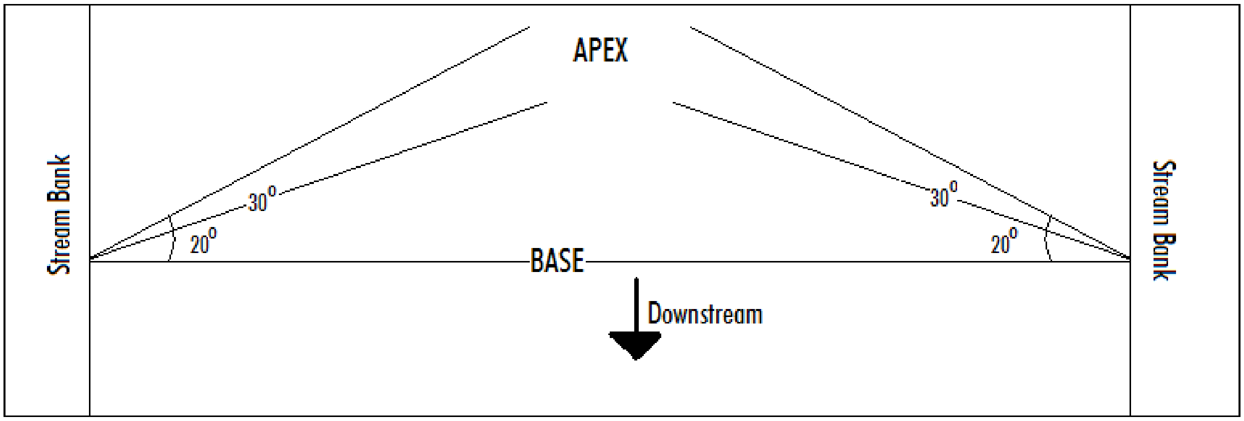

Figure 20. Vortex rock weir design (Taylor, 2010).

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):

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

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

6.6 Site Specific Rock Weir Calculations

6.6.1 Morton Brook: MOR008

Remediation:
A second rock weir to improve fish passage and raise the tailwater pool level higher.

Weir Rock Volume:
Lots of usable rocks are on site, no calculations required to order rocks. Some larger flat bed-stones needed for the base were hand-picked by CARP staff at Parker Mtn. Quarry and brought to the weir site the day of the weir construction.

Rock Size:
T = 1000 x d x s
T = 1000 x 0.0875m x 0.0121
T = 10.59

An incipient diameter of 10.59 cm was calculated. Using a safety factor of 2, gives a minimum rock size (diameter) of 21.18 cm.

6.6.2 Pete Brook: PET002

Remediation:
Reconstruction of the first rock weir downstream from the culvert.

Weir Rock Volume:
Lots of usable rocks are on site, no calculations required to order rocks. Some larger flat bed-stones needed for the base were hand-picked by CARP staff at Parker Mtn. Quarry and brought to the weir site the day of the weir construction.

Rock Size:
T = 1000 x d x s
T = 1000 x 0.193 m x 0.0339

T = 6.54 cm

Using the traditional calculation, an incipient diameter of 4.67 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 13.08 cm. However, due to the low flow conditions at the time which the measurements were taken, and the high flow risks, *d* was interpreted as bankfull height (0.265 m). Therefore,

T = 1000 x d x s
T = 1000 x 0.265 m x 0.0339
T = 8.98 cm
Using a safety factor of 2, gives a minimum rock size (diameter) of 17.96 cm.

6.7 Culvert Restorations (2010-2018)

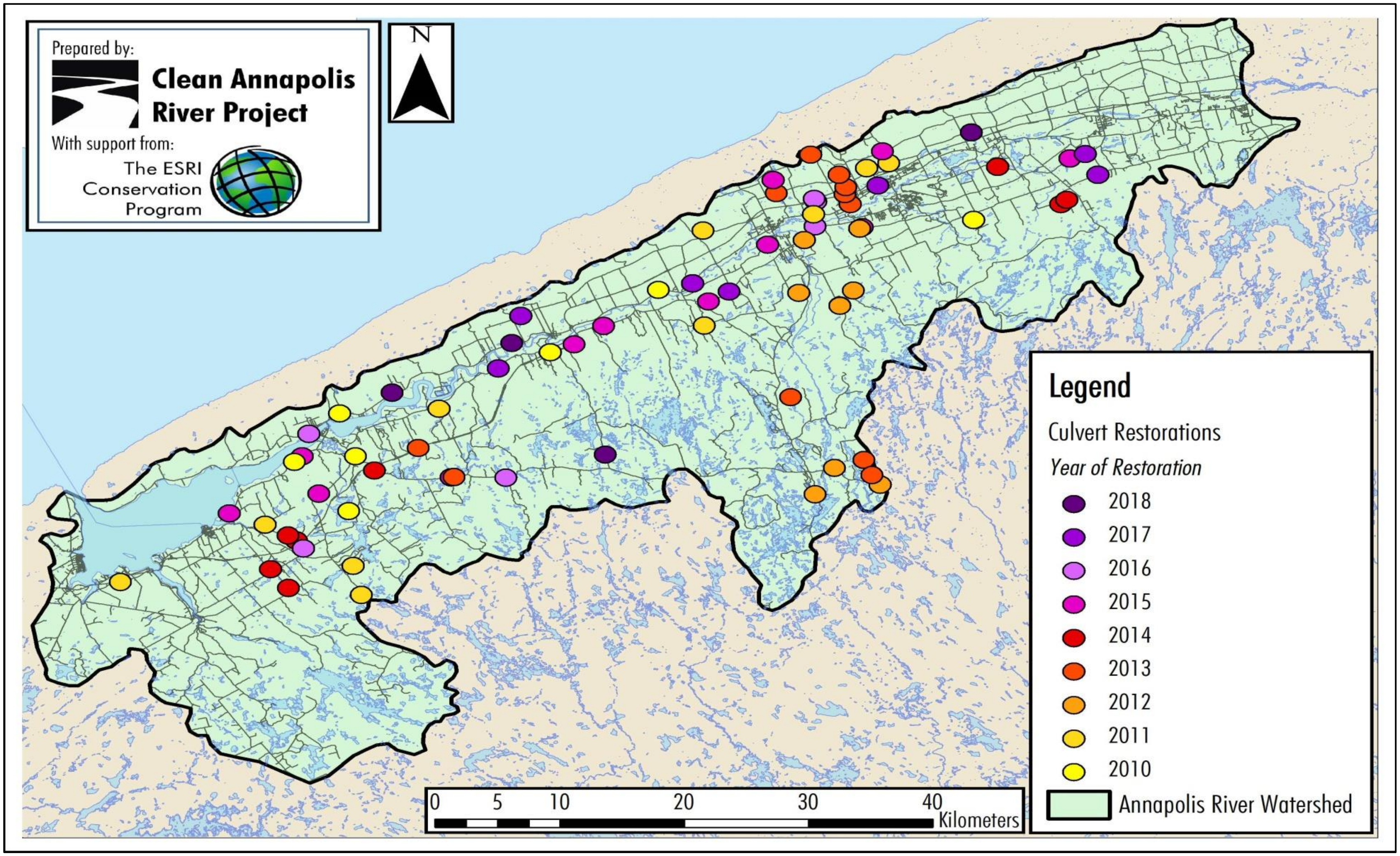

Figure 21. All culvert restorations completed by CARP within the Annapolis River watershed since 2010.

6.8 NSFHAP Field Data Sheet

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

6.9 Habitat Suitability Index Scores (NSFHAP)

6.9.1 Pre-restoration brook trout scores

Site Name	Date	Percent Pools	Pool Class Rating	Percent Instream Cover Juvenile	Percent Instream 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
Control	10/11/2017	0.67	1.00	0.61	0.19	0.60	0.71	1.00	0.89	0.87	N/A	N/A	0.98	1.00	0.01	1.00
Test	01/11/2017	0.34	0.30	0.23	0.03	1.00	0.55	0.95	0.96	0.66	N/A	N/A	1.00	1.00	0.04	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.

6.9.2 Pre-restoration Atlantic salmon scores

Site Name	Date	Percent Pools	Pool Class Rating	Percent Instream Cover (Juveniles)	Percent Instream 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
Control	10/11/2017	0.78	1.00	0.61	0.19	0.60	0.71	1.00	0.00	0.93	N/A	N/A	1.00	1.00	N/A	1.00
Test	01/11/2017	0.17	0.30	0.23	0.03	1.00	0.55	0.95	0.37	0.69	N/A	N/A	1.00	1.00	N/A	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.