Broken Brooks 2011:

Assessing and Restoring Aquatic Connectivity in the Annapolis River Watershed

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Clean Annapolis River Project

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Acknowledgements

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Executive Summary

Culverts are designed to re-route watercourses under roads and railbeds. However, changing the nature of a watercourse can have an adverse effect on aquatic species that live within it, such as fish. Improperly installed or malfunctioning culverts can become barriers to fish, thereby trapping them in segments of a watercourse. Culverts can negatively impact fish populations by restricting access to food, cool water refuges and spawning grounds.

In 2007, Clean Annapolis River Project (CARP) initiated the *Broken Brooks* project to evaluate watercourse crossings in terms of being passable to migrating fish. Sixty culverts were assessed and 55% were found to be partial or full barriers. The project was continued in 2010, with 777 preliminary assessments and 158 full assessments. Of the 777 preliminary assessments, 516 were culverts on fish bearing watercourses and 285 or 55% were deemed barriers.

In 2011, the assessment protocol was changed to improve data collection and classification. As most watercourse crossings on roads closest to the main stem of the Annapolis River were visited in 2010, those located further upstream were focused on in 2011. Sites located on main roads not visited in 2010 were also assessed. Each site was evaluated using the Fish Passage Index. Using the score generated, it was classified as passable, partial barrier, or full barrier. Full assessments were completed on partial and full barriers. If a culvert had a natural bottom or was backwatered, it was considered passable and a Fish Passage Score was not needed.

CARP staff visited 228 sites in the 2011 season. Of these, 144 were culverts on fish-bearing watercourses. Sixty-two, or 43%, were passable, while 82, or 57%, were found to be partial or full barriers. Two barrier bridges were also discovered.

In addition to assessments, remediations were also completed at eleven sites across the watershed. Nine debris removals were performed and two rock weirs were built to eliminate outflow drops and to backwater the culverts. Through these actions, approximately 26 km of upstream habitat was made available for migrating fish species. Including the downstream sections, over 58 km of habitat on the watercourses that were remediated was made accessible to fish.

Introduction

Clean Annapolis River Project (CARP) is a non-governmental organisation that works toward restoring and protecting the ecological heath of the Annapolis River watershed through science, leadership and community engagement. The Annapolis River watershed extends from Digby to Aylesford in the area between the highest elevation of the North and South Mountains. It is the third largest watershed in Nova Scotia and drains 2,000 km^2 of land, containing many watercourses and tributaries. The Annapolis Valley is highly populated and developed with many roads, railbeds and trails criss-crossing the watershed. In 2006, Andrea Coombs of Saint Mary's University identified 1,615 crossings where roads and watercourses intersect in the Annapolis watershed and on the shore of the Bay of Fundy. There are still many that are unidentified.

Culverts are commonly considered only as structures that allow water to flow under driveways and roads to reduce flooding. When viewed from an environmental standpoint, there is also concern whether a fish can swim though the culvert to access the variety of habitats within the watercourse ecosystem. For example, if a stream was 10 km in length and had eight culverts rerouting its water, it is possible that the stream could be broken into nine separate segments, if all culverts were barriers. This is an extreme example as most watercourses have both passable and barrier culverts.

There are many characteristics that can render a culvert impassible to fish. Slope, outflow drop, size, water depth, water velocity and debris blockages can all contribute to restricting access to watercourse habitat. Failure to meet multiple criteria contributes to the classification of a culvert as impassable. Proper installation and maintenance is necessary for culverts to function as fish passageways. Watercourse width, slope and depth, as well as future outflow scouring, should be considered to properly install a culvert and prevent a future obstruction. Watershed area and precipitation trends should also be considered to estimate water levels at times of high flow. All culverts should be installed according to provincial and federal guidelines and regulations, which are sympathetic to fish passage.

The target species in 2011 was a 10 cm brook trout, *Salvelinus fontinalis,* which is a native fish of Atlantic Canada. They swim for many kilometers to seek food, spawning grounds and cooler waters in the heat of the summer. Preferring cool, highly oxygenated watercourses with gravel beds, they often migrate in late summer/early fall to headwaters for spawning in the shallows of spring-fed waters. If these fish cannot swim through a culvert because the jump into the outflow is too high or the opposing water velocity is too great due to a steep slope, they will not reach valuable habitat upstream. Fish may parish if stream temperatures rise over 24°C and they are unable to migrate to cooler waters.

The *Broken Brooks* project was initiated by CARP in 2007 and continued in 2010 and 2011. CARP focused on road-watercourse crossings in the Annapolis River watershed.

Methodology

In 2006, 1,615 road-watercourse crossings were identified in the Annapolis River watershed and on the Bay of Fundy shore by Andrea Coombs from Saint Mary's University in Halifax, NS (Figure 1). In 2007, at the inception of the Broken Brooks project, 268 culverts were visited and 60 received full assessments. In the summer of 2010, 777 culverts received preliminary assessments and 158 received full assessments.

The assessment protocol in 2011 utilized those developed by the Mersey Tobeatic Research Institute (Barteaux, 2010), British Columbia Ministry of Environment (Parker, 2000), Terra Nova National Park (Cote, 2008) and the U.S. Department of Agriculture, Forest Service, National Technology and Development Program (Clarkin, 2005) to suit the needs of assessment in the Annapolis River watershed. There were three main steps:

1. Prioritizing Barriers within the Watershed
2. Field Assessments
3. Analysing Data

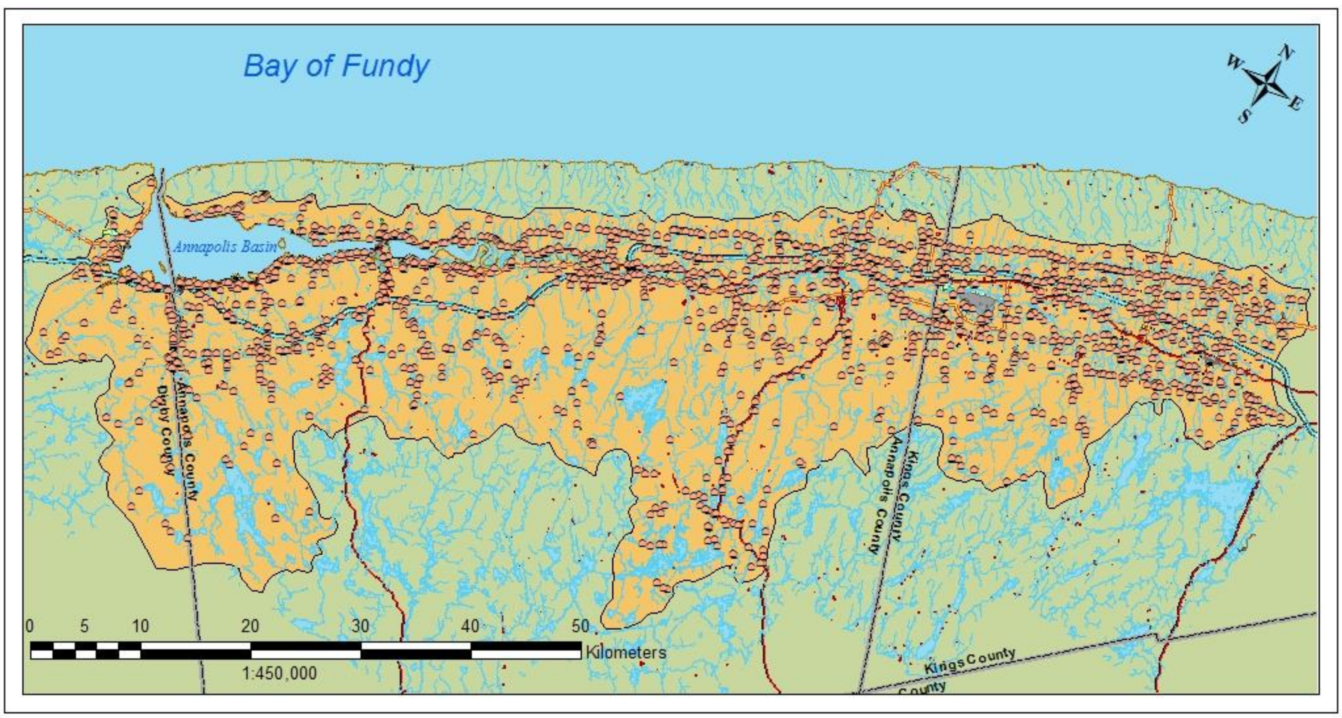


Figure 1. 1,615 potential road-watercourse crossings identified in the Annapolis River watershed and Bay of Fundy shore by Andrea Coombs in 2006.

Prioritizing Barriers within the Watershed

In 2010, field surveys focused on sites located along the main stem of the Annapolis River. In 2011, surveys were conducted further upstream in tributaries flowing into Annapolis River. Maps of the watercourse crossings identified in 2006, as well as those identified by CARP staff, were made in GIS and printed for the field crew. The coordinates were uploaded to a GPS unit for locating these sites in the field.

Field Assessments

1. Equipment

The equipment needed to carry out watercourse crossing surveys, including safety gear, is listed below in Table 1. Refer to Appendices for additional information on assessment procedures and protocols.

Table 1: Field Equipment List

Materials	Equipment	Safety
Clipboard	Surveying Automatic Level	Hip and/or Chest Waders
Data Sheets	Surveying Tripod	Rubber Boots
Pencil, Eraser, Sharpener	Surveying Level Rod	Rain Gear
Calculator	Surveying Rod Level	Flashlight
GPS or Topographic Maps	30m or 50m Measuring Tape	Long Rope
Camera	5 m Measuring Tape/Meter Stick	Field First-Aid Kit
White board or Chalk board	2 Stakes	Reflective Vests
Cell Phone	Mini Club Hammer	Orange Cones (to put around vehicle)
Extra batteries	Range Finder	Amber Light (to put on top of vehicle)
	Velocity Meter	PFD (if working in swift or deep water)
	Water Quality Sonde	Insect Repellant, Sun Screen, Sun Hat

2. Watercourse Crossing Information

Upon arrival at a site, the first half of the data sheet was completed (Appendix A). This included the names of the assessors, date, site information and physical characteristics such as shape and material of the structure. If it was backwatered, had a natural bottom or was sufficiently embedded, the structure was considered passable and no other information was gathered. For detailed information, see section 2.0 and 5.1-5.2 in *A Guide to surveying Culverts for Fish Passage* (Taylor, 2011)

3. Preliminary Fish Passage Score

If there was some question to a structure's ability to pass fish, the first page of the data sheet (Appendix A) was filled out to obtain a Fish Passage Score to determine if it was indeed a barrier and to what degree. For detailed information on culvert characteristics, see section 5.3-5.5 in *A Guide to surveying Culverts for Fish Passage* (Taylor, 2011).The criteria included embeddedness, outflow drop, stream width ratio, culvert slope and culvert length (Table 2). If the generated score was 0-14, the culvert was considered passable, 15-19 indicated a partial barrier and >20 was classified as a full barrier (Table 3).

Table 2. Fish Passage Index Criteria

Embedded	Index Value	Outflow Drop	Index Value	SWR	Index Value	Slope	Index Value	Length	Index Value
> 30 cm or > 20% of culvert diameter & continuous	0	<15cm	0	<1.0	0	<1%	0	<15m	0
< 30cm or 20% of culvert diameter but continuous or partial	5	15-30cm	5	1-1.3	3	1-3%	5	15-30m	3
No embedment or discontinuous	10	>30cm	10	>1.3	6	>3%	10	>30m	6

Table 3. Fish Passage Score

Cumulative Score	Result
0-14	Passable
15-19	Potential Barrier
≥20	Barrier

4. Full Assessments

If the Fish Passage Index produced a score of 15 or greater, indicating a barrier, a full assessment was completed on the back side of the data sheet (Appendix A). In addition to the values gathered for the preliminary assessment, specific measurements for inflow, outflow, tailwater control and watercourse characteristics were recorded. The water depths and velocity within the culvert inflow and the outflow, the high water mark, inflow drop, etc. were some of the measurements taken. Using surveying equipment, the upstream and downstream slope of the watercourse and a cross-section at the tailwater control were measured. Downstream widths and water quality data were also recorded. For detailed information on these measurements, see section 5.7-5.11 in *A Guide to surveying Culverts for Fish Passage* (Taylor, 2011).

Analyzing Data

Data collected was entered into an excel spreadsheet. At the close of the field season, maps were created in ArcGIS showing the structures and their ability to pass fish at each of the visited sites. Barrier culverts were also prioritized based on the degree of barrier and the restricted upstream habitat.

Results

The 2011 field season began in June and continued through until September. Two hundred twenty-eight potential water crossing sites were visited. The results are shown in Table 4. Similar to 2007 and 2010 results, more than half the culverts on fish-bearing watercourses were barriers to native fish species like brook trout. Research from 2011 showed that out of 144 culverts on fish-bearing watercourses, only 62 were passable, leaving 82 as partial or full barriers (Table 5). This accounts for 57% of culverts on fish-bearing watercourses as barriers to migration, while 43% were passable. In both 2007 and 2010, 55% of culverts visited were deemed barriers (Sullivan, 2008 and Taylor, 2010).

Bridges commonly exhibit natural bottoms, and therefore, most are passable. Two barrier bridges were discovered this past season. One was partially blocked by young trees and branches left in the watercourse; the other was damaged. Thirty-one of the water crossings visited were bridges and of these, two (6%) were barriers (Table 6).

Including bridges, 175 structures were located on identified fish-bearing watercourses. Including bridges, 84 (48%) of all 175 structures were deemed partial or full barriers to fish passage.

Table 4. Road-watercourse crossings in the Annapolis River watershed.

Type	Count	Percent
Passable Culverts	62	27%
Partial Barrier Culverts	14	6%
Barrier Culverts	68	30%
Bridge	29	13%
Barrier Bridge	2	1%
Not Fish Bearing	37	16%
Not Accessible	16	7%
TOTAL	228	100%

Table 5. Culvert assessment results for 2011

Culvert	Count	Percent
Passable	62	43%
Partial Barrier	14	10%
Full Barrier	68	47%
TOTAL	144	100%

Table 6. Bridge assessment results for 2011

Bridge	Count	Percent
Passable	29	94%
Partial Barrier	1	3%
Full Barrier	1	3%
TOTAL	31	100%

Based on the length of upstream habitat, the 144 barrier culverts were prioritized (Table 7). Low priority was given to culverts with <500 m upstream habitat, medium between 500-1000 m, and high priority culverts had >1000 m or 1 km of upstream habitat. The data shows that 50% of passable culverts were on watercourses with over 1 km of upstream habitat. More than half of partial barrier culverts were also located on watercourses with greater upstream habitat. Only 34% of full barrier culverts were located on high priority watercourses whereas 43% were on low priority watercourses of less than 500 m of upstream habitat.

Table 7. Priority rating for culverts assessed in 2011

Culvert	Count	Low	Medium	High
Passable	62	19%	23%	50%
Partial Barrier	14	21%	21%	57%
Full Barrier	68	43%	19%	34%

*May not add up to 100% as some culverts were found and assessed in field, but no watercourse could be located at that position on the topographic map in GIS. For these culverts, upstream habitat could not be measured and prioritized.

For most barrier culverts, more than one issue contributed to restricted fish passage (See Appendix D for criteria). Table 8 indicates the frequency an undesirable characteristic contributed to the barrier culvert. The top three issues with barrier culverts were improper size for the watercourse, outflow problems and slope. None of the barrier culverts were embedded.

Table 8. Barrier type percentage for partial and full barriers

Barrier	Count	Percentage
Improper size	44	31%
Outflow (drop, onto rocks, etc)	35	24%
Slope	32	22%
Debris	19	13%
Damaged	8	6%
Not Found	6	4%
Velocity	5	3%
Insufficient water depth	3	2%
Beaver Activity	1	<1%
Dam	1	<1%

In the preliminary assessment, each barrier was given a score based on its ability to meet criteria for embeddedness, outflow drop, stream-width ratio, culvert slope and culvert length. The higher the score, the greater the barrier. The 68 barriers assessed in 2011 are listed below in order of decreasing habitat and decreasing score. The recommendations for restoration are also included.

Table 9. Barrier Water Crossings found in 2011

Structure ID	Watercourse Name	Road Name	Northing	Easting	Problem	Recommended Fix	Score	U/S Habitat Gain
RHR013	Roundhill River	Hwy 101*	4956243	308358	Wrong size Outflow drop Slope	Tailwater control (baffles present) or re-install	32	>10
BAR001	Lake Mulgrave	Lake Mulgrave Rd	4933594	300078	Hydropower Dam	Install fish ladder	NA	70
LHL001	Grand Lake Stream	Rt. 8	4939351	308971	Needs Full Assessment	N/A	NA	8.9
WDE004 & 005	Wade Brook	Sissiboo Rd	4938746	290212	Wrong size Outflow drop Slope	Re-install and restructure downstream	37	8.5
ROA014	Roach Brook	Highway 101	4942586	284412	Debris	Debris Removal	NA	6.2
SMC016	Annapolis River Tribuatry	Marsh Road	4959354	305783	No culvert	Install culvert	NA	4.7
HAR008	Harris Brook	Clementvale Rd	4940974	292878	Velocity	Install baffles		4.6
NEB001	Neily's Brook	Brookyln St	4985309	346189	Debris	Debris Removal	NA	3.4
BLO025	Bloody Creek Brook	Morse Rd	4961385	322096	Wrong size Outflow drop	Re-install with baffles	36	2.8
WLH002	Walsh Brook	Lansdowne Rd	4940207	283527	Wrong size Outflow drop	Remove cement bottom in second half of culvert or re-install	26	2.8

DEE006	Deep Brook	Mary Jane Riley Rd	4945155	292624	Wrong size Outflow drop	Re-install or Tailwater control	24	2.8
BAI001	Baillie Lake Brook	Princedale Branch Rd	4941246	303790	Debris	Debris Removal	NA	2.65
KNI001	Kniffen Brook	Purdy/Chute Rd	4943206	290585	Wrong size Outflow drop Slope	Reinstall with baffles or create step-up pools	31	2.6
NEB004	Neilys Brook	Rt 221	4986463	345710	Outflow drop Negative slope	Re-install with baffles or step-up pools	20	2.3
ROA016	Roach Brook	Lansdowne Rd	4939787	285556	Wrong size	Re-install	NA	2
EBR008	Wrights Lake	Wright Lake Rd	312481	4955635	Completely submerged	Re-install	19	2
WES009	West Moose River	Clementsvale Rd	4943398	296264	Wrong size Outflow drop	Re-install	26	1.8
MCE015	McEwan Brook	Brooklyn St	4978404	331251	Outflow drop Slope	Tailwater control	NA	1.7
SOL009	Annapolis River Tributary	Centennial Dr	4967767	319427	Debris	Debris Removal	21	1.7
HRR005	Harris Brook	West Dalhousie Rd	4953891	324485	Wrong size Slope	Re-install with baffles	26	1.6
EAS006	East Moose River	Hwy 101*	4946751	299119	Wrong size Outflow drop Slope	Re-install with baffles	34	1.5
ACA002	Acacia Brook	Shelburne Rd	281920	4937225	Road Flooded	Install culvert	NA	1.47
WES001	West Moose River	Clementsport Rd	4946822	295132	Wrong size Outflow drop	Re-install or create step-up pools	26	1.4
MOC006	Annapolis River Tributary	Hwy 101 access rd	4954747	305406	Wrong size	Re-install	16	1.4
EBR011	East Branch Roundhill River	Woods Rd	4954999	316246	Wrong size Slope	Tailwater control	24	1.3
HAR004	Harris Brook	Middlesex Rd	4940062	293229	Wrong size Outflow drop Slope	Re-install or install step-up pools	34	1.2
BOG001	Bogart Brook	Chute Rd	4940530	290531	Wrong size Outflow drop Slope	Re-install with baffles and restructure downstream	39	1.13
HRR003	Harris Brook	West Dalhousie Rd	4954056	322348	Wrong size	Re-install	16	1.1
BLO 012-15	Bloody Creek Brook	Hwy 101*	318421	4965705	Outflow drop	Tailwater control		1.1
ACA001	Acacia Brook	South Old Post Road	4940487	281552	Wrong size Outflow drop Slope	Re-install and restructure downstream	36	1

GRD007	Grand Lake Stream	Grand Lake Rd	4945287	303365	Debris	Debris Removal	10	1
SOL010	Annapolis River Tributary	Hwy 1	319381	4967895	Culvert not installed or underground	Install culvert	NA	0.97
WES002	West Moose River	Clementsport Rd	4945932	296134	Wrong size Outflow drop Slope Damaged	Re-install	39	0.89
GRD011	N/A	Grand Lake Rd	4945012	303019	Wrong size Slope Debris	Re-install	26	0.76
EBR003	East Branch Roundhill River	West Dalhousie Rd	4953289	314891	Wrong size	Re-install	16	0.76
KNI002	Kniffen Brook	Purdy Rd	4943320	290515	Wrong size Outflow drop Slope	Tailwater control	26	0.73
EAS017	East Moose River	Clementsport Rd	4944737	298182	Wrong size Outflow drop Negative slope	Re-install	26	0.72
EAS009	East Moose River	Fraser Rd	4945996	299139	Outflow drop	Re-install with baffles	20	0.71
HLD002	Holdsworth Brook	Raquette Rd	4946132	279464	Outflow drop	Tailwater control and resize plunge pool	NA	0.7
DAN005	Annapolis Basin Tributary	Hwy 101*	4967633	321162	Wrong size	Re-install	15	0.7
GRD008	Grand Lake Stream	Grand Lake Rd	302907	494977	Culvert too short	Re-install	NA	0.69
EAS004	East Moose River	Trail off Fraser Rd	4946808	298532	Wrong size Outflow drop Negative slope	Re-install	31	0.62
BER003	Berry Brook	Brooklyn St	344293	4985811	Damaged	Re-install	NA	0.6
PET006	Petes Brook	Crisp Rd	4969949	332297	Wrong size Outflow drop Slope Rusted bottom	Re-install with baffles	31	0.59
HAR007	Harris Brook	Clementsvale Rd	4940833	292675	Wrong size Outflow drop Rock Debris	Re-install; remove rocks at inflow	21	0.58
GRD010	Grand Lake Stream	Forrest Drive	4944191	303126	Debris	Debris Removal	NA	0.56
NEB002	Neilys Brook	Bishop Mountain Rd	346173	4985612	Outflow drop	Tailwater control		0.53
HAR011	Harris Brook	Fed Rd	293430	4941972	Rip-rap at inflow	Debris Removal	NA	0.45

SPU003	Spurr Stream	Hwy 101 access rd	4958391	312679	Wrong size Outflow drop Slope	Re-install	26	0.42
PUR004	Purdy Brook	Hwy 101*	4945143	290026	Wrong size Outflow drop Slope	Re-install with baffles	42	0.4
LOO001	Bear River Stream	Peck's Hill	4938791	290970	Needs Full Assessment	N/A	NA	0.39
BUR005	Annapolis River Tributary	Mount Hanley Rd	332780	4974282	Stream running along road	Install culvert	NA	0.39
BUT006	Button Brook	Hwy 101*	4966500	320283	Wrong size Slope probable	Re-install with baffles	NA	0.37
HAR006	Harris Brook	Jefferson Rd	293399	4940321	Completely submerged	Re-install	>21	0.37
ROA019	Annapolis Basin Tributary	House 126 driveway	4942974	283130	Wrong size Slope	Re-install with baffles	NA	0.36
RHR010	Roundhill River	Mill Rd	4960221	310019	Debris	Debris Removal	26	0.36
HLD003	Holdsworth Brook	Route 217	4944188	279624	Wrong size Slope	Re-install	NA	0.3
SPU004	Spurr Stream	Hwy 101*	4957998	312829	Debris	Debris Removal	21	0.3
WES005	West Moose River	Clementsport Rd	4945158	296490	Wrong size Outflow drop Slope	Re-install	NA	0.29
WES016	West Moose River	Potter Rd.	298268	4943606	Completely submerged	Re-install	26	0.29
WES010	West Branch Moose River	Clementsvale Rd	4943153	295946	Wrong size Outflow drop Slope	Re-install or add Baffles and Tailwater control	34	0.28
BLO024	Bloody Creek Brook	Morse Rd	321985	4961814	Needs Full Assessment	N/A	NA	0.28
ROA015	Roach Brook Tributary	Hwy 101*	4942788	284984	Outflow Drop Slope Damaged	Re-install with baffles	31	0.27
BOY007	Boyce Brook	Hwy 101*	4945058	289342	Wrong size Outflow drop Slope	Re-install with baffles	42	0.25
ALL017	Grand Lake Flowage Stream	Clementsvale Rd	4951577	300384	Wrong size Outflow drop	Re-install	21	0.25
HEN001	Hennessy Brook	Fraser Rd	4948420	296051	Debris	Debris Removal	NA	0.23
SLK002	Spectacle Lakes	West Dalhousie Rd	4953086	329786	Needs Full Assessment	N/A	NA	0.18

ROA009	Roach Brook	Hwy 101 off ramp	4943803	286722	Wrong size Outflow drop Slope	Re-install with baffles	42	0.17
BOY008	Boyce Brook	Hwy 101*	4945044	289157	Wrong size Outflow drop Slope	Re-install with baffles	27	0.17
ROA017	Roach Brook	Mountain Gap Inn	283410	4943248	Outflow drop Damaged	Re-install		0.15
WES004	West Moose River	Quarry Rd	4945276	296557	Wrong size Outflow drop Slope	Re-install	39	0.14
BLO021	Bloody Creek Brook	Hwy 101*	4964956	317013	Active Beaver Dam at Outflow	N/A	NA	0.12
GRD004	Grand Lake Discharge	Rt 8	305098	4947679	No culvert	Install culvert	NA	0.12
DIG009	Digby Basin Catchment	St. Mary's St.	4943973	281257	Wrong size Outflow drop Slope	Re-install with baffles	31	0.11
GRD016	Grand Lake	Rt. 8	4946654	305977	Wrong size Outflow drop Slope	Re-install with baffles	34	0.1
BLO022	Bloody Creek Brook	Morse Rd	4963496	320929	Outflow drop	Tailwater control	15	0.1
WBR008	West Branch Roundhill River	trail off Rte 8	308562	4949637	Non-functioning	Re-install		0.07
WSL001	West Stoney Lake Stream	Rt. 8	303684	4950643	No culvert	Install culvert	NA	0.06
SAD003	Saunder's Brook	Access road adjacent to Hwy 101	4948556	300321	Wrong size Outflow drop	Re-install	21	0.04
EAS018	East Moose River	Clementvale Rd	299432	4945921	Inflow completely submerged	Investigate debris blockage or re-install	NA	0
NEG005	Negro Line Brook	Victory Rd	300461	4937163	Partly submerged Collapsed	Re-install	NA	0
BER005	Berry Brook	Boo Boo Lane	4984781	344421	Debris	Debris Removal	NA	

* NOTE: One of the main problems with the culverts on 101 is that they are very long and have steep slopes. These culverts should be large, baffled culverts, with the outflow meeting the watercourse gradient, eliminating outflow drops.

Restorations

Restorations for the 2011 season were completed in August and September under NSLC Adopt-A-Stream's NS Environment blanket approval for watercourse alteration. CARP remediated 11 watercourse crossings and restored more than 26 km of upstream habitat. In total, over 58 km of upstream and downstream habitat was opened up to fish migration on the individual watercourses. Remediations included nine debris removals and two rocks weir installations across the Annapolis River watershed (Figure 2). The chosen watercourse crossings, based on habitat quantity and quality, are listed below in Table 10.

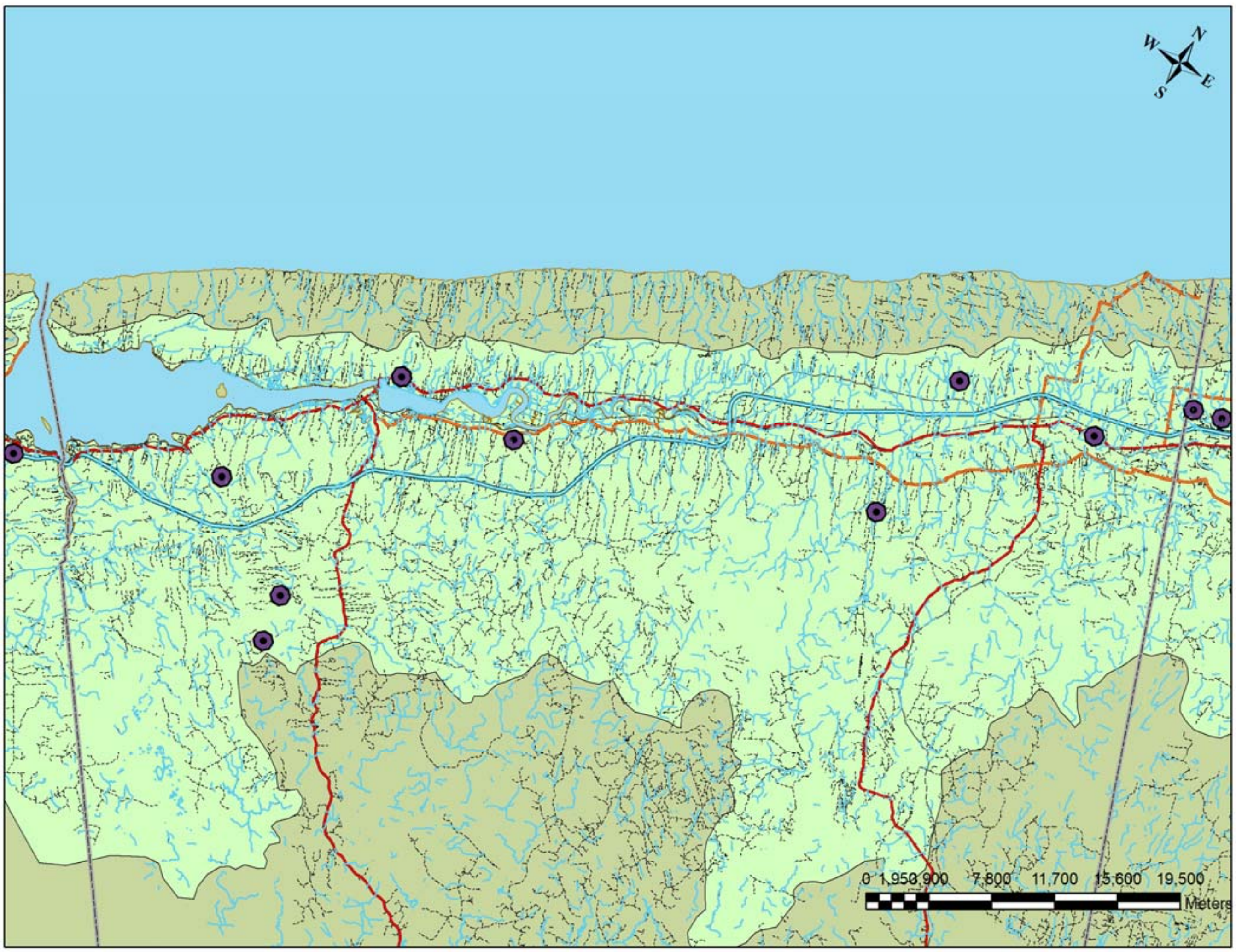


Figure 2. Restoration locations for 2011.

Table10. List of watercourse crossings remediated in 2011.

Site ID	Watercourse	Road	UTM Easting	UTM Northing	Restoration Type
BAI001	Bailey Lake Brook	Virginia Rd.	303790	4941246	Debris Removal
BER005	Berry Brook	Boo Boo Ln	344421	4984781	Debris Removal
GRD010	Grand Lake	Forest Dr	303126	4944191	Debris Removal
HEN001	Hennessey Brook	Fraser Rd	296051	4948420	Debris Removal
MCE015	McEwan Brook	Brooklyn Rd	331251	4978404	Rock Weir
MIL012	Millers Brook	Inglisville Rd	331371	4968722	Debris Removal
NEB001	Neilys Brook	Brooklyn Rd	346189	4985309	Debris Removal
RHR010	Roundhill River Stream	Mill Rd	310019	4960221	Debris Removal
ROA014	Roach Brook	HWY 101	284412	4942586	Debris Removal
TRO010	Troop Brook	Post Rd	302036	4959737	Rock Weir
WAT006	Watton Brook	Railbed	340135	4980070	Debris Removal

Debris Removals:

As a natural part of watercourse succession, branches and vegetative material are deposited in the watercourse from its banks or carried into it via high flow events. This debris can be carried downstream to larger water bodies or deposited on the banks when water levels drop. This debris is sometimes caught at a culvert's inflow because the sides of the culvert extend above the streambed. Often, a long branch is caught crosswise at the inflow, collecting more and more debris and creating a barrier to fish travelling both up and downstream. Grates and wire cages are sometimes placed at culvert inflows to reduce debris jams within a culvert. However, because the openings are usually quite small, they collect more material and if not cleaned regularly can become a greater problem.

BAI001 - Ballie's Lake

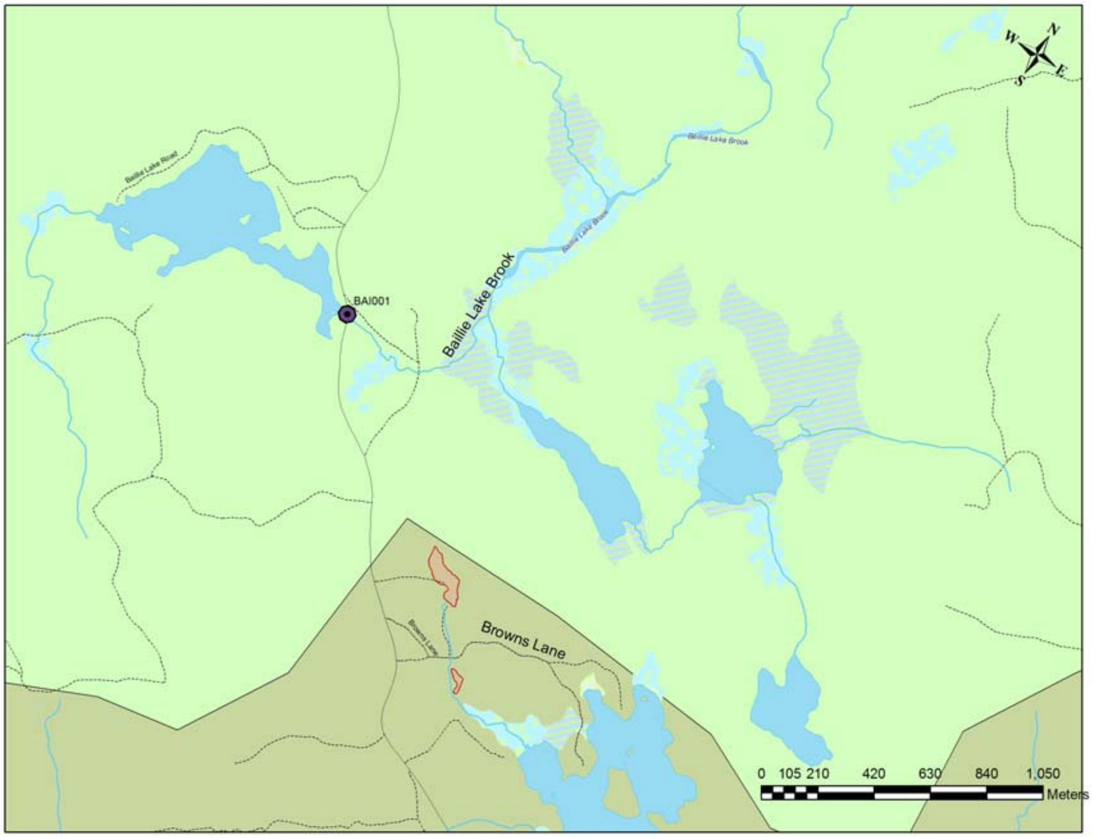


Figure 3. Map indicating location of Ballie Lake and the partial barrier culvert (BAI001).

BAI001 is a system of two steel culverts emptying Ballie Lake into Ballie Lake Brook. It is located on Virginia Road, near Milford (Figure 3). This is one of three road-watercourse crossings located on Ballie Lake Brook. One of these is located on a trail 400 m downstream and will need to be assessed as it was not previously identified in GIS. The other two restrict approximately 100 m and 800 m of upstream habitat. Ballie Lake Brook connects over 13 km of brook, wetland and lake habitat before emptying into Grand Lake. The lakes in this system include Springhill Mud Lake, Cranberry Lake and Little Annapolis Lake. The remediation of BAI001 restored access to 2.65 km of upstream habitat.

There is a debris cage located at the inflow of this culvert system that had collected a large quantity of material from the lake (Figure 4). Most of the debris was beaver sticks, root clumps, and decaying vegetation that was caught by the cage. The debris was approximately 3 ft high creating a partial dam with a high velocity drop making both a physical and velocity barrier. Figure 5 shows the water discharging from the outflow of the culvert before and after the remediation.

A  B 

Figure 4. Debris cage at Ballie Lake inflow before (A) and after (B) debris removal.

A  B 

Figure 5. Baillie Lake culvert outflow before (A) and after (B) debris removal from inflow.

The restriction the barrier presented on lake flow was evident by the water level drop observed when CARP staff returned the following day (Figure 6). Due to the debris cage, it is likely that material will continue to collect at the inflow of BAI001. It is recommended that the owners of the roadway remove the cage or check yearly for obstruction.

A B

Figure 6. CARP staff removing debris from inflow debris cage (A). Water level drop indicated on rock of Ballie Lake one day after debris removal (B).

BER005 – Berry Brook

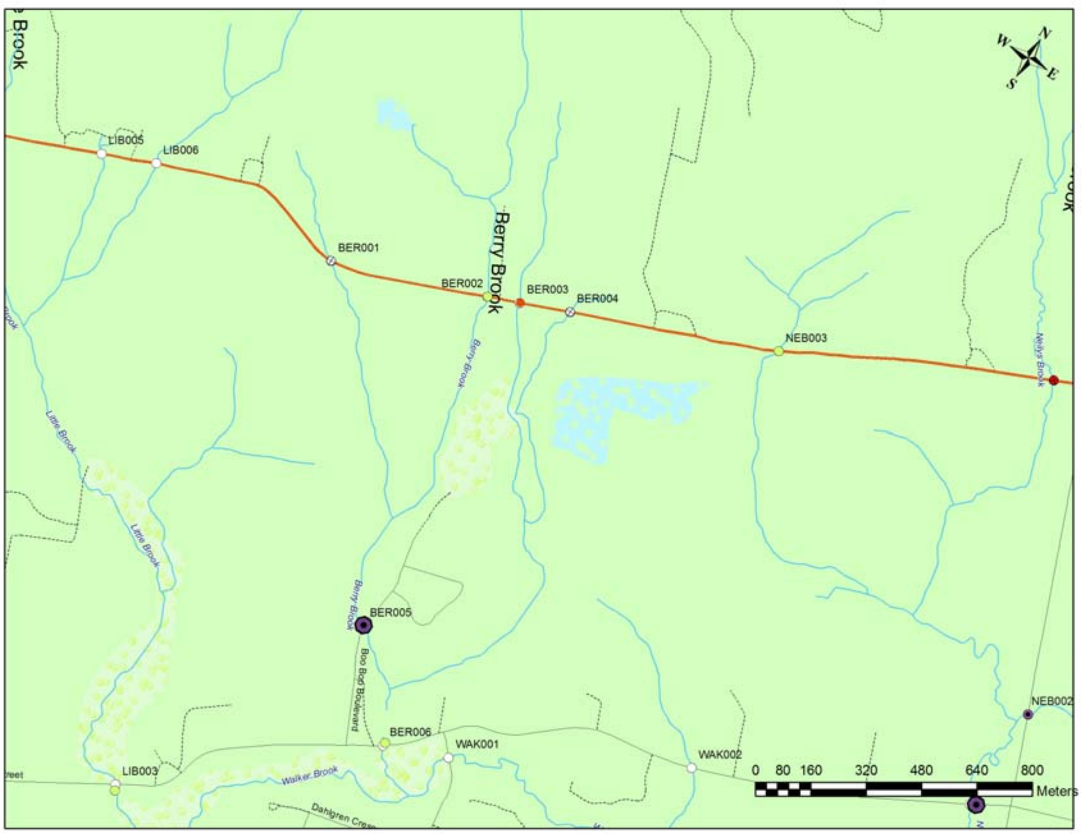


Figure 7. Map indicating location of Boo Boo Boulevard and the partial barrier culvert (BER005).

BER005 is one of six road-watercourse crossings on Berry Brook (Figure 7). Of these culverts, two are passable, two are not in fish habitat and one is a barrier. The road crossing directly downstream of BER005 is passable. Directly upstream, however, there is a private dam creating a large pond habitat. Berry Brook is approximately 7.7 km in length from its headwaters to where it meets Walker Brook. The debris removal at BER005 opened access to 4.26 km of habitat.

BER005 is located on a privately owned road and consists of two cement culverts and a steel culvert that form a double base with a cement culvert situated on top, perhaps to act as an overflow culvert. It appeared that trees had fallen into the brook at the inflow of the culverts, trapping other debris (Figure 8). The right bank was quite eroded which may have been the result of the rerouted water hitting the bank as it could not flow through the culverts. It is recommended that the owners assess the bank stability, as much of the lower support is lost.

A  B 

Figure 8. BER005 inflow before (A) and after (B) debris removal.

The debris was piled away from the brook in a location most likely to be safe from run off (Figure 9)

Figure 9. Debris pile from inflow after restoration of BER005.

GRD010 – Grand Lake Stream

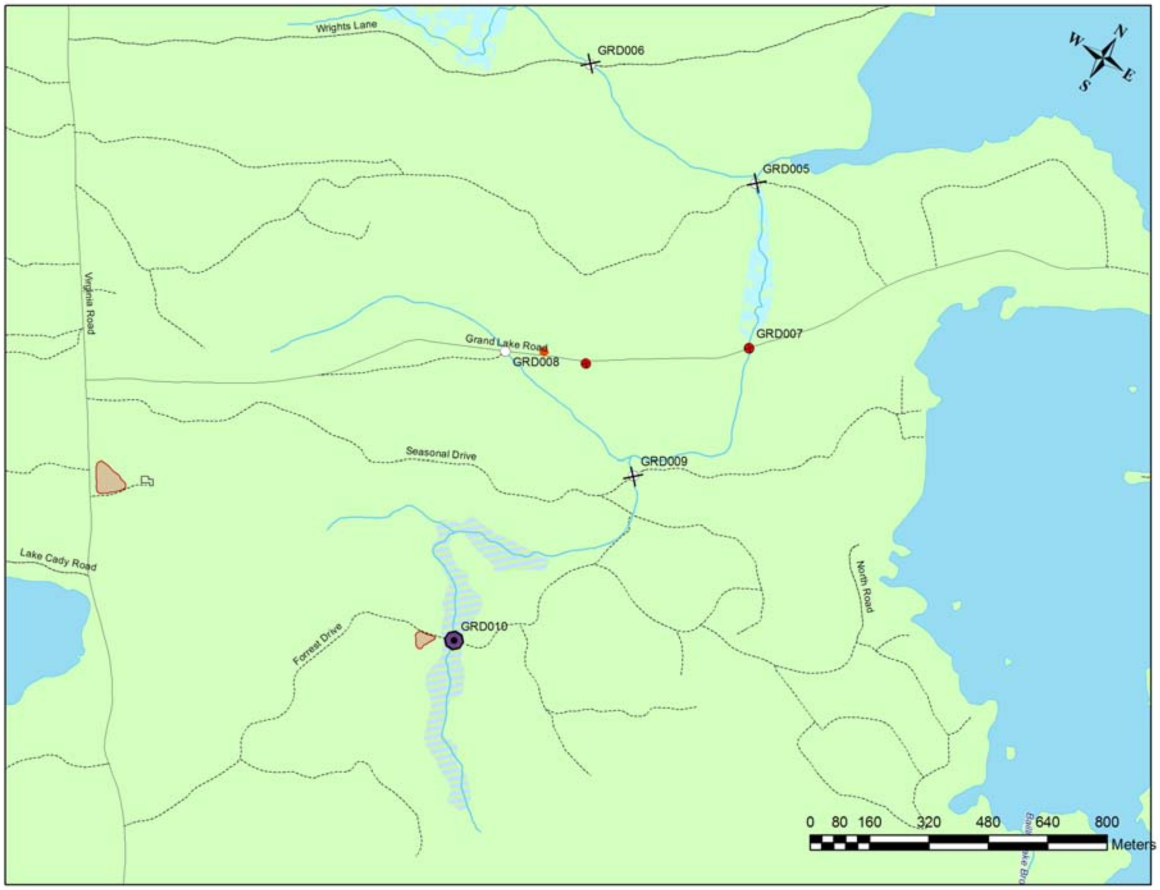


Figure 10. Map indicating location of Grand Lake and the partial barrier culvert (GRD010).

GRD010 is located on an unnamed watercourse that empties into Grand Lake. This branching brook contains seven road-watercourse crossings; three are not accessible, three are barriers and one is unidentified on GIS (Figure 10). The total length of the stream is 5.79 km and GRD010 restricted 560 m of upstream habitat including wetland.

A debris cage is located at the inflow of this culvert. It consists of a grill that can be lifted up and out of the side supports and cleaned. There was evidence of previous cleanings. Much of the material blocking fish passage was grasses and aquatic plants that had collected on the debris cage creating a mat-like barrier. CARP staff removed this material as well as material at the base of the cage that may have washed into the culvert when the grill was removed (Figures 11 and 12).

A B

Figure 11. GRD010 inflow before (A) and after (B) debris removal.

A B

Figure 12. A and B-CARP staff removing debris from inflow debris cage.

HEN001 - Hennessey Brook

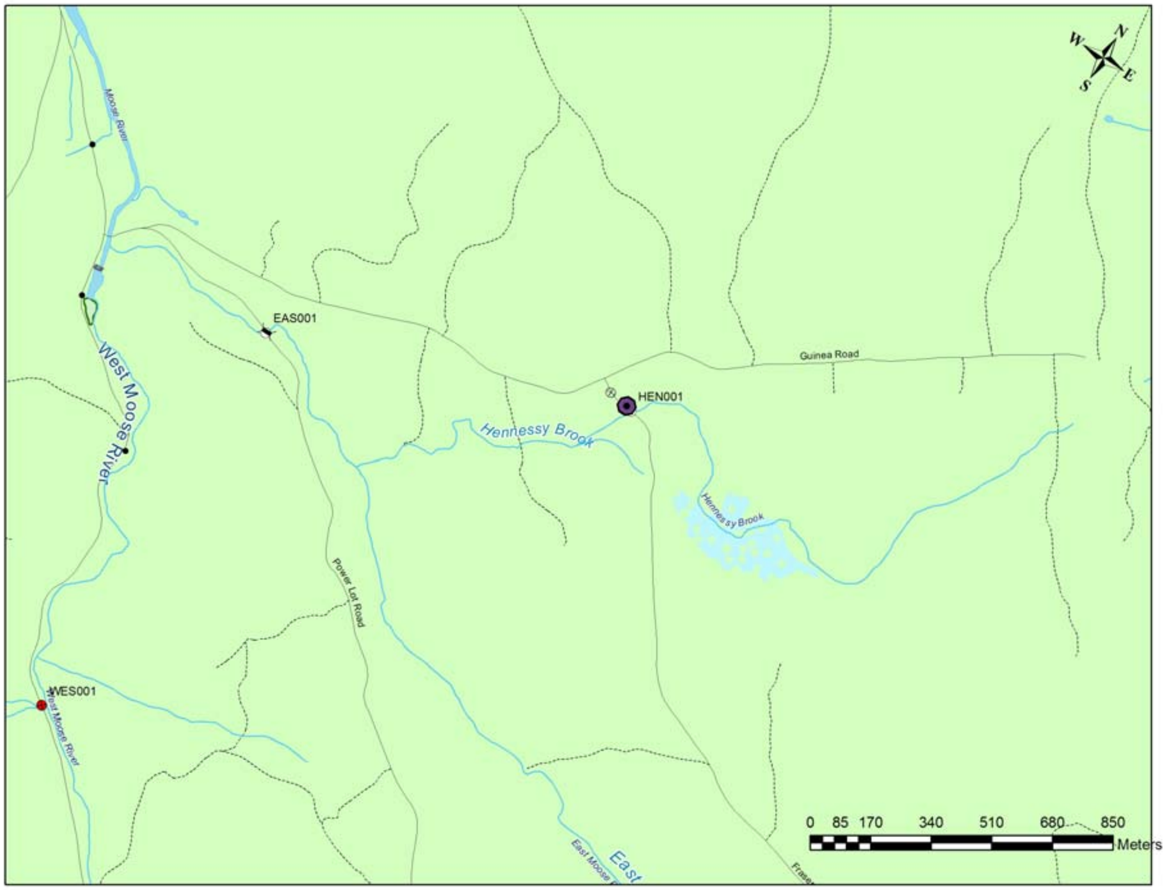


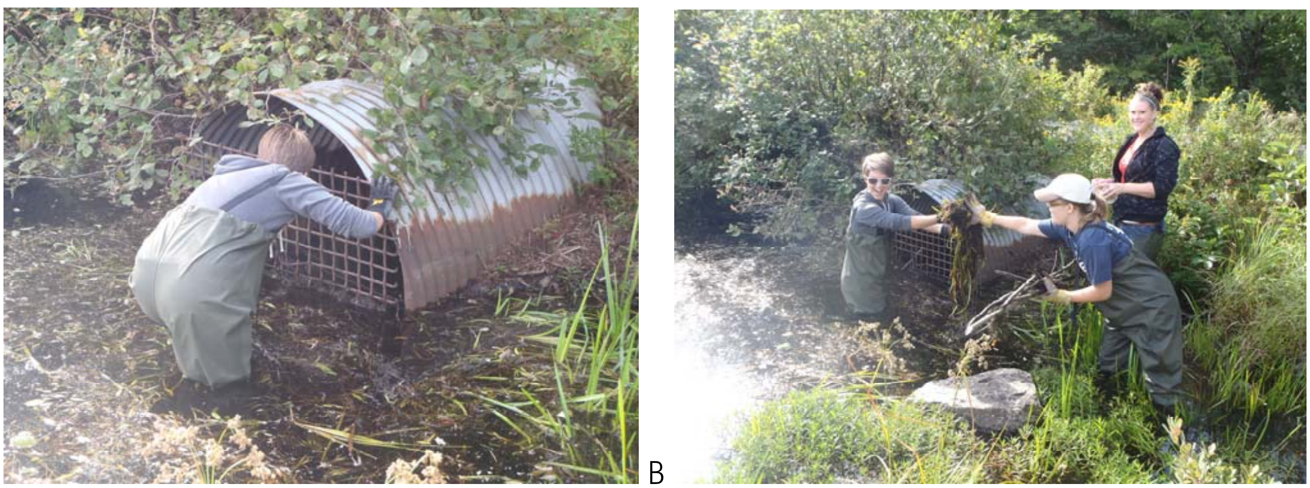
Figure 13. Map indicating location of Hennessey Brook and the partial barrier culvert (HEN001).

HEN001 is located on Fraser Road and Hennessey Brook, which is a tributary to the East Moose River (Figure 13). It has approximately 3 km of habitat, 1.8 km of which was not accessible to fish due to the barrier at HEN001. There are three road crossings on this brook; one (HEN001) is a partial barrier and the other two are located on trails which were not previously identified with GIS.

A debris cage is located at both the inflow and outflow of the steel, circular culvert. Large sticks and woody debris had collected at the base of the debris cage not allowing small vegetative material to pass (Figure 14). This blockage dammed a significant amount of the stream. After CARP staff removed this debris (Figure 15), there was a noticeable drop in the water level upstream of the culvert (Figure 16).

A B

Figure 14. HEN001 inflow before (A) and after (B) debris removal.



A B

Figure 15. A and B-CARP staff removing debris from inflow debris cage at HEN001.

A B

Figure 16. Water level drop upstream of HEN001 after a few hours noted by A- moss on rock. B- the brown colour of newly exposed vegetation

MIL012 – Millers Brook

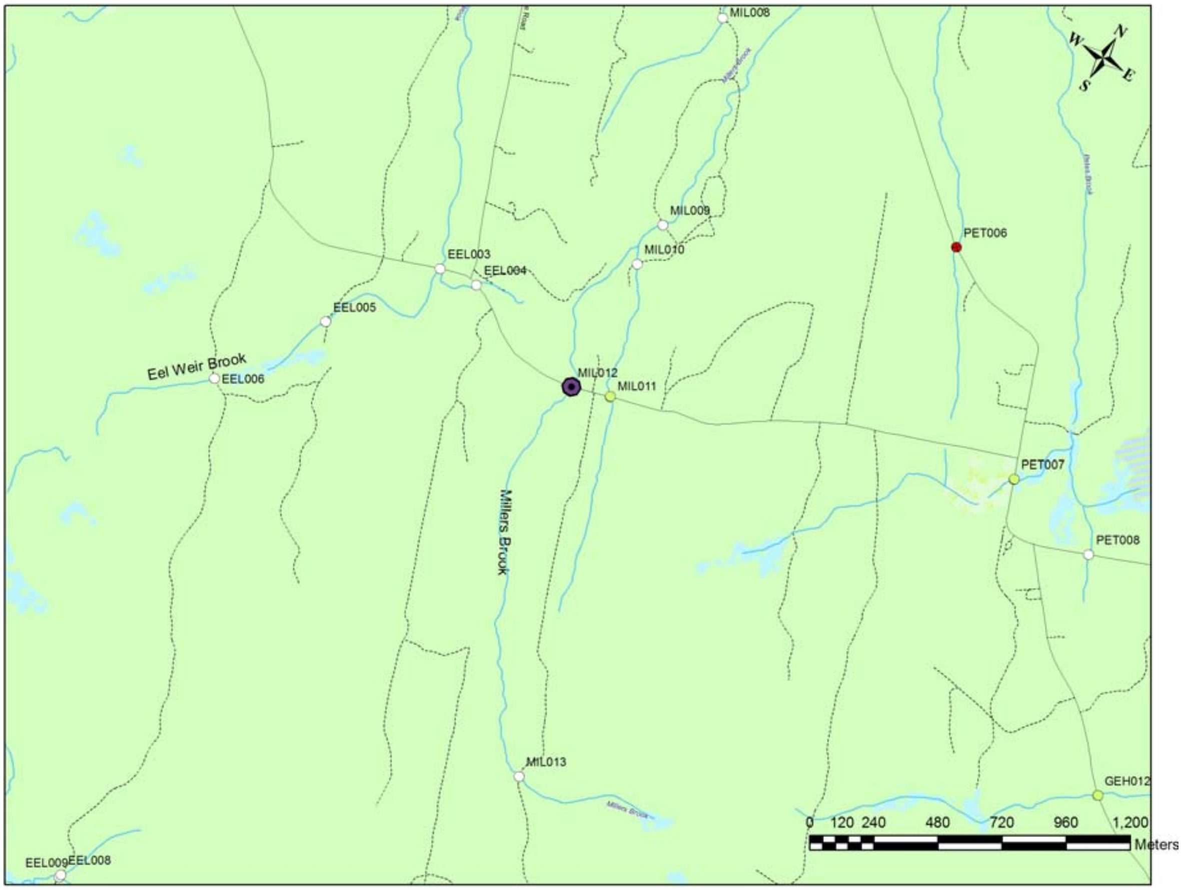


Figure 17. Map indicating location of Millers Brook and the partial barrier culvert (MIL012).

Millers Brook is a 10.3 km watercourse that flows directly into the Annapolis River near Lawrencetown from the South Mountain (Figure 17). There are twelve road crossings along the length of this brook; four are assessed as passable, five are located on trails and have not been visited, and two have not been previously marked on GIS. The only marked barrier is MIL012 which is a barrier bridge. Small trees and branches along the road and brook had recently been cut and left in the brook, creating an obstacle for migrating fish (Figures 18 and 19). CARP Staff removed the woody debris to allow a clear route for fish to swim.

A  B 

Figure 18. MIL012 outflow (brook level view) before (A) and after (B) debris removal

A  B 

Figure 19. MIL012 outflow (top view) before (A) and after (B) debris removal

NEB001 – Neilys Brook

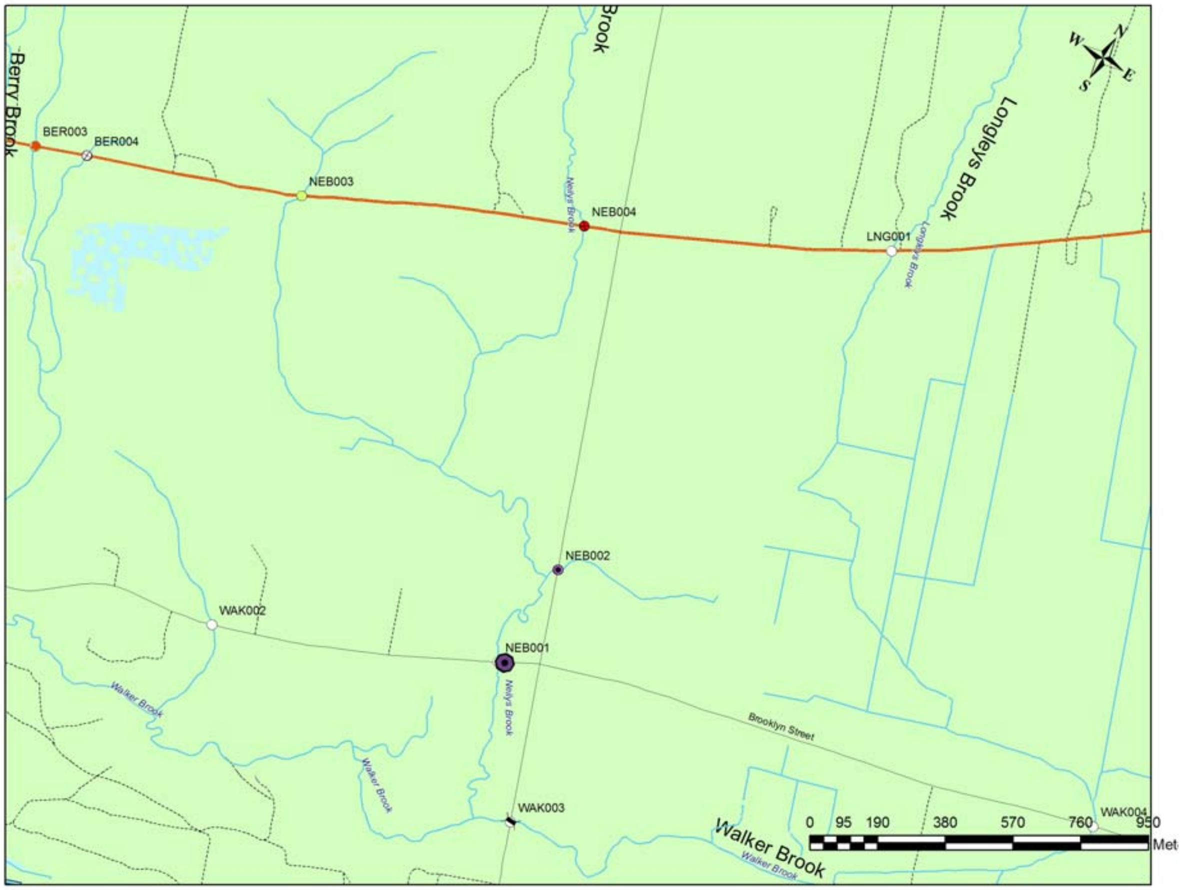


Figure 20. Map indicating location of Neilys Brook and the partial barrier culvert (NEB001).

NEB001 is located at the intersection of Neilys Brook and Brooklyn Street near Kingston (Figure 20). Neilys Brook is 7.4 km in length flowing from the North Mountain down to Walker Brook, which is a large watercourse that drains into the Annapolis River. There are seven road-watercourse crossings on Neilys Brook; one is passable, three are barriers, two are unmarked on GIS maps and one site near the headwaters still needs to be visited. By removing debris from NEB001, 3.4 km of upstream habitat (as well as access to the larger Walker Brook) was made available for migrating fish.

Two debris removals were accomplished at this site. The first was the removal of an abandoned beaver dam from branches overhanging the inflow of the main culvert. The material was removed from the tree to prevent it from continuing to fall into the inflow and blocking the culvert (Figure 21). The second removal was to restore flow through the main culvert. Material from the beaver dam that had floated downstream was caught at the culvert's entrance (Figure 22). CARP staff removed this debris to ensure continuous water flow through the culvert.


A B

Figure 21. NEB001 tree with remnants of an old beaver dam before (A) and after (B) debris removal.


A B

Figure 22. NEB001 inflow before (A) and after (B) debris removal.

RHR010 – Roundhill River

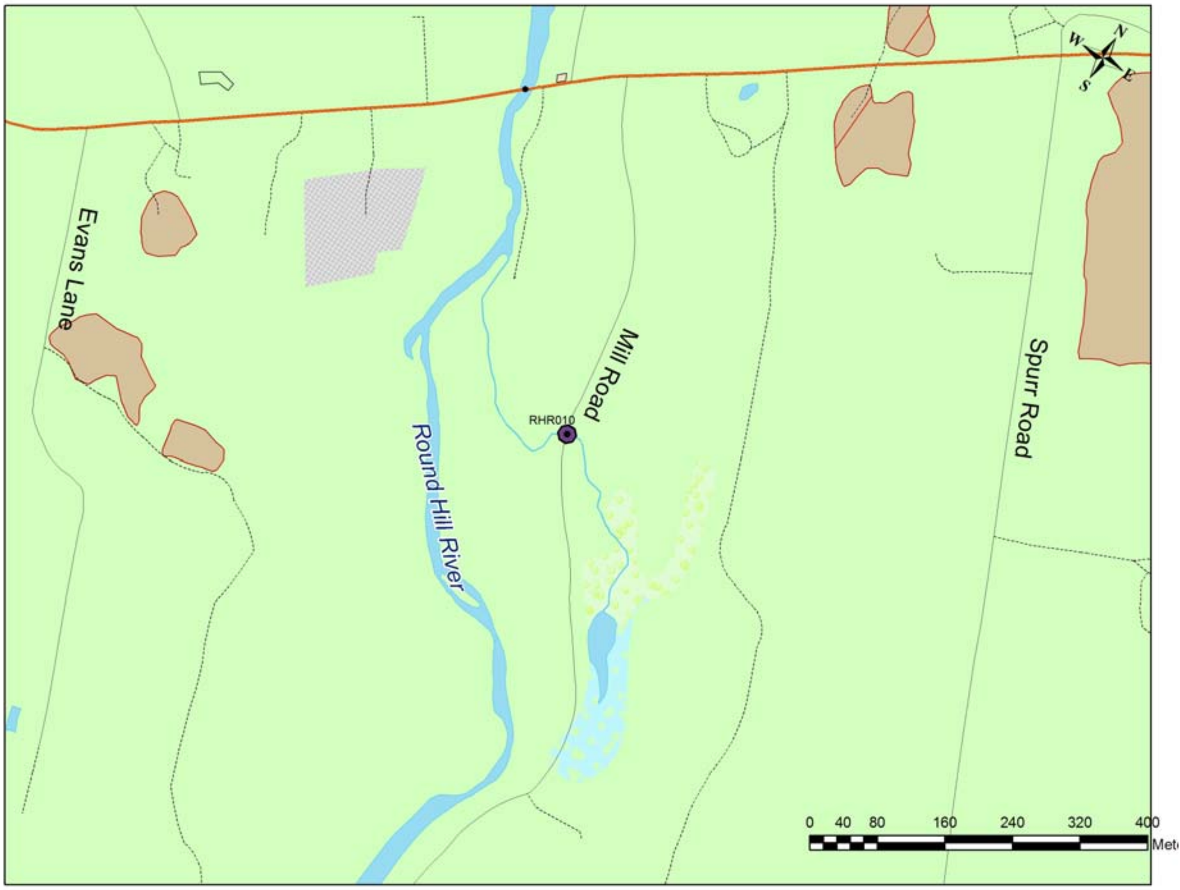


Figure 23. Map indicating location of Roundhill River and the partial barrier culvert (RHR010).

RHR010 is a steel culvert located on Mill Road where a tributary of the Roundhill River intersects Mill Road (Figure 23). This watercourse is about 660 m in length and the culvert restricted access to 360 m of upstream wetland, pond and watercourse habitat. This is the only culvert on this particular tributary. Small trees from the surrounding ditch were cut and left in the ditch, partially blocking access upstream of RHR010 (Figure 24). CARP staff cleared this debris as well as woody material caught on a low hanging branch downstream of the culvert.

A  B 

Figure 24. RHR010 upstream before (A) and after (B) debris removal.

ROA014 – Roach Brook

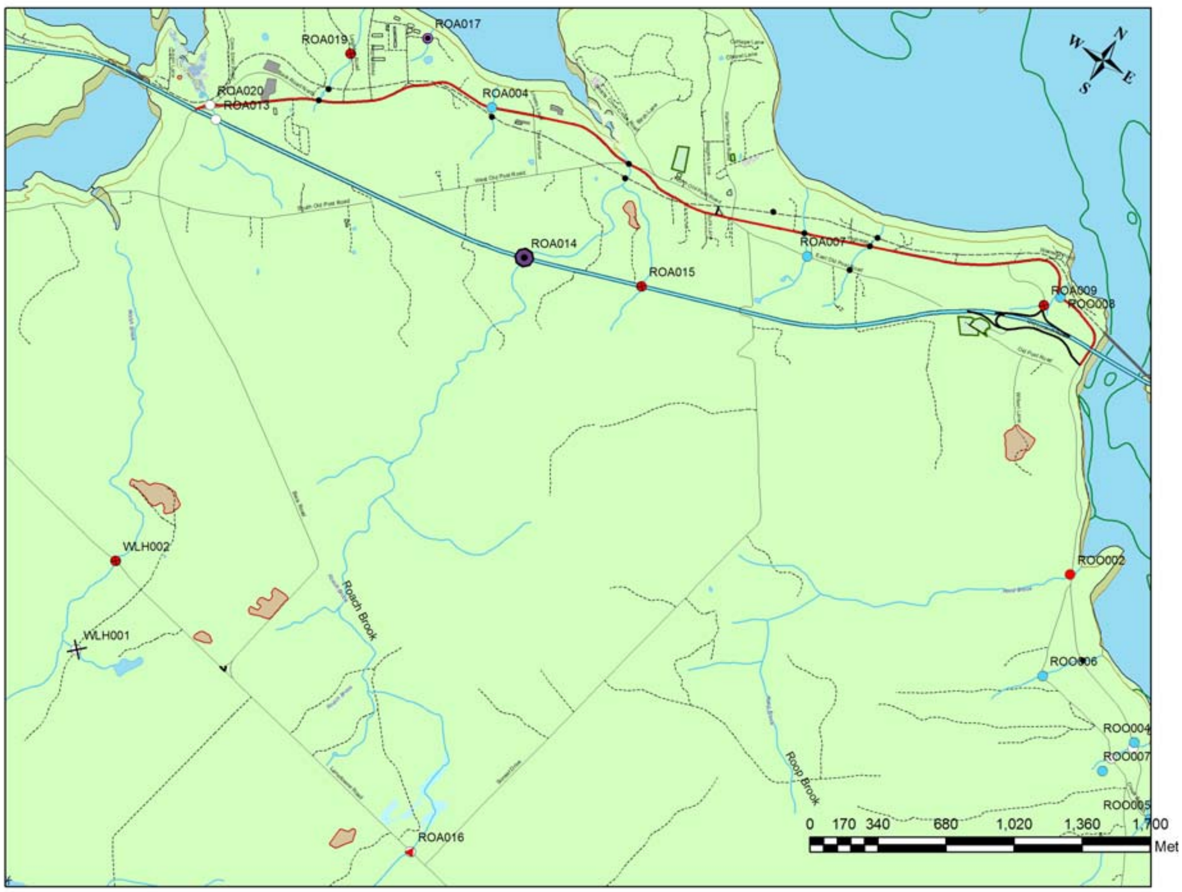


Figure 25. Map indicating location of Roach Brook and the partial barrier culvert (ROA014).

Roach Brook is a large watercourse that empties into the Annapolis Basin at Smiths Cove (Figure 25). ROA014 is a large, baffled culvert with a fish ladder at the outflow. It diverts Roach Brook under HWY 101.This brook has a total length of approximately 10 km, 6.2 km of which was restricted by the woody debris at the inflow of the culvert. The main problem was the remnants of an abandoned beaver dam that was falling into the brook from the left bank (Figure 26 and 27). There was also a large tree trunk across the culvert which was too large to be removed by hand by CARP staff. There are ten road crossings on this watercourse, five of which were unmarked on GIS maps and therefore not assessed. Out of the other five, two were passable and three were barriers. One of these barriers was ROA014, the other two are located in the upper portion of separate branches and limit approximately 2.2 km of upstream habitat.

A  B 

Figure 26. ROA014 upstream before (A) and after (B) debris removal.

Figure 27. ROA014 inflow viewed from inside culvert.

WAT006 – Watton Brook

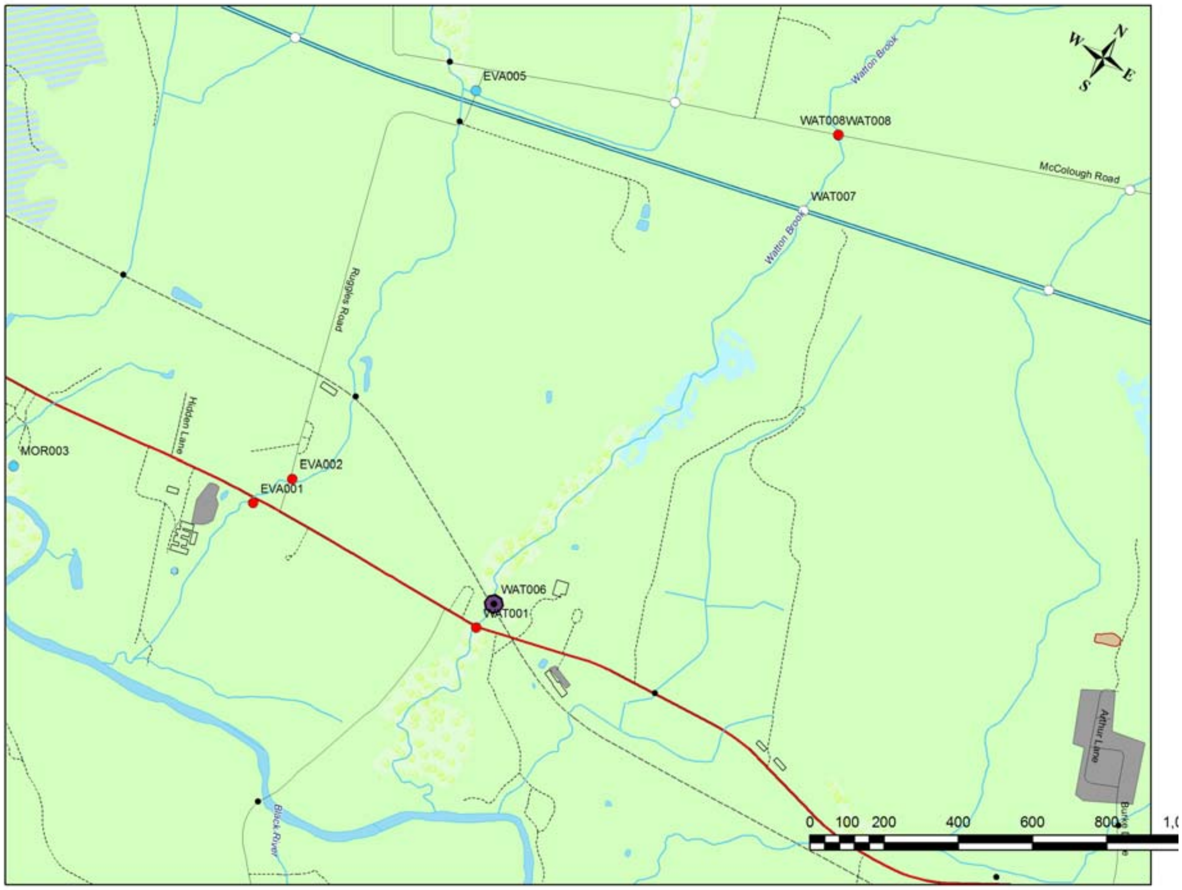


Figure 28. Map indicating location of Watton Brook and the partial barrier culvert (WAT006).

WAT006 is a culvert first assessed during the 2010 field season. It is a double-box, stone culvert located on the old rail bed in Wilmot (Figure 28). Watton Brook flows directly into the Annapolis River and is approximately 10.1 km in length. There are nine road-watercourse crossings on this brook, two were unmarked on GIS maps and therefore were not assessed, three have not yet been visited, and four were deemed barriers to fish passage.

The remediation at Watton Brook will require a multi-year initiative. A very large amount of material had accumulated at the inflow of this double culvert system (Figure 29). In part, it was caused by an abandoned beaver dam. However, there was evidence of illegal dumping into the brook (eg: horse stall doors). In addition, large logs and other woody debris had collected at the inflow, trapping smaller material. Due to the extent of built up sediment from prolonged blockage, staff only removed part of the barrier (Figure 30).

The site was re-visited approximately one month after the debris removal (Figure 31). Passage was possible through the right culvert, though the beaver dam material from the left bank had eroded into the brook, again blocking the left culvert inflow. It is recommended that the remainder of the beaver dam, as well as the material dumped on the bank above the culvert, be removed in 2012.

WAT001, which is located downstream of WAT006, was previously assessed in 2010. It should be re-visited to evaluate the possibility of remediation.

A  B 

Figure 29. WAT006 upstream before (A) and after (B) debris removal.

A  B 

Figure 30. WAT006 staff clearing the debris (A) and debris pile (B).


Figure 31. WAT006 one month after remediation efforts.

In-stream Structures:

Tailwater controls or rock weirs are in-stream structures that may be installed to restore fish migration through a barrier culvert. These structures are placed at the transition from the culvert outflow pool to the watercourse. A rock weir structure was selected for in-stream remediation as it was the most effective and affordable option for a non-profit organization such as CARP. A common problem concerning fish passage is that fish cannot jump into a culvert because the outflow drop is too high. Culverts with steep slopes can also be barriers even without an outflow drop. These issues may be remedied with the installation of a rock weir within or at the end of the plunge pool (tailwater control). A rock weir is carefully designed and placed to raise the water level in the plunge pool, thereby raising the water level in the culvert.

Rock Weir Design (Taylor, 2010)

The tailwater control is located downstream of the outflow pool. It is the highest elevation point leading into the natural downstream channel. The objective is to increase the height of the existing tailwater control or establish a new one. Increasing the height will thus increase the depth of the outflow pool reducing or eliminating the outflow drop. After extensive literature review, it was decided that a vortex rock weir design would be used as means of a tailwater control. This is a U-shaped design, where the apex points upstream. The weir is designed to be either on a 20° or 30 ° angles from the base of the weir. For our design, a 30° angle from the base of the weir was used (Figure 32).

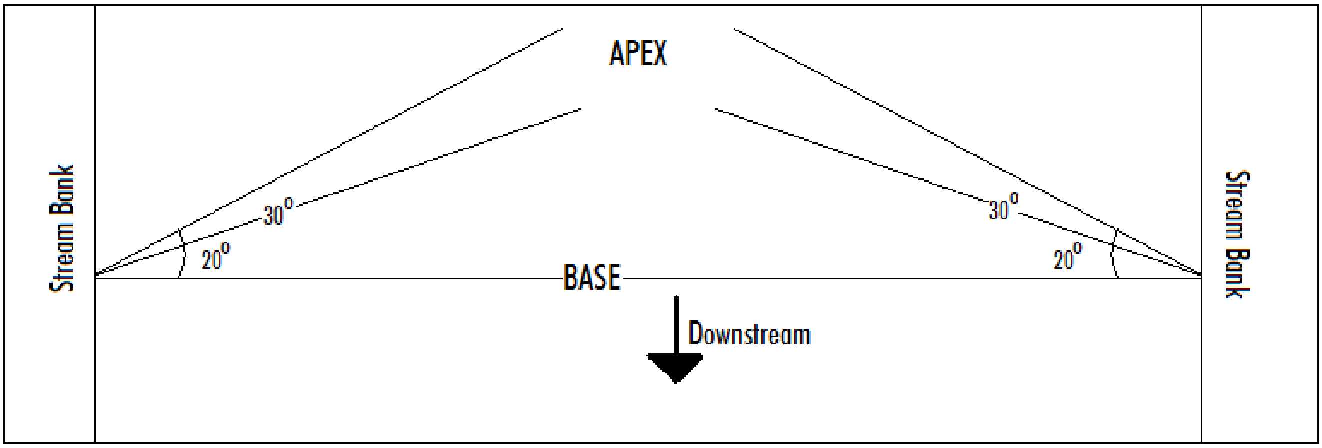


Figure 32: Vortex rock weir design

Footer stones, which are large, flat 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. Pebbles and cobbles are used as fill throughout the construction. It is recommended that the weir be tied into the sides of the bank at least 15 cm. When constructing the weir, a rock stabilization ratio of 1:1.5 was used (Taylor, 2010). For example: for every centimeter high you build the weir, the width of each side of the base is one and a half times that (1.5 cm). The apex of the structure is the lowest point of elevation, referred to as the low flow notch (an area along the weir where water can flow through during low flow conditions). The elevation of the low flow notch should be at or slightly higher than the elevation of the inflow end of the culvert if possible. The ends of the weir should be at or above bankfull height.

The recommended size of the outflow pool is a width twice the culvert's diameter, and for a double culvert, twice the combined diameter. The recommended length is three times the culvert's diameter, and for a double culvert, three times the combined diameter. The recommended depth of an outflow pool is 1.0 metre.

Rock Weir Installation (Taylor, 2010)

Procedure for installing a rock weir:

1. Using a measuring tape, the distance from the culvert outflow to the base of the rock weir was measured.

2. The position of the structure was marked at a 30° angle from the base of the weir to the apex, using a compass, stakes and string.

3. The outflow elevation at culvert edge and the ground elevation at the proposed apex were measured using surveying equipment.

4. The difference in elevation between the apex and the culvert outflow edge were determined.

5. The slope of the sides of the structure were made using a rise: run ratio of 1:1.5. This gives a height to base-width ratio of 1: 3. The width of the base was marked along the weir with flags.

6. The proposed base area was cleared for footer rocks.

7. The footer rocks were arranged within the staked area. Weir rocks were used to build the apex higher than the culvert outflow elevation and if possible, up to the inflow elevation. The automatic level was used to check the elevations of the apex, ensuring that it was not too high or too low.

8. As the weir rocks were laid in place, the weir was built higher as it approached the bank. Pebbles and cobbles filled the interstitial spaces between larger rocks.

9. The bank keys (bank portion of the weir) were tied into the bank at least 15 cm.

Rock weirs are designed to fill in gradually over time as the watercourse naturally deposits material in and around the structure.

TRO010 – Troop brook

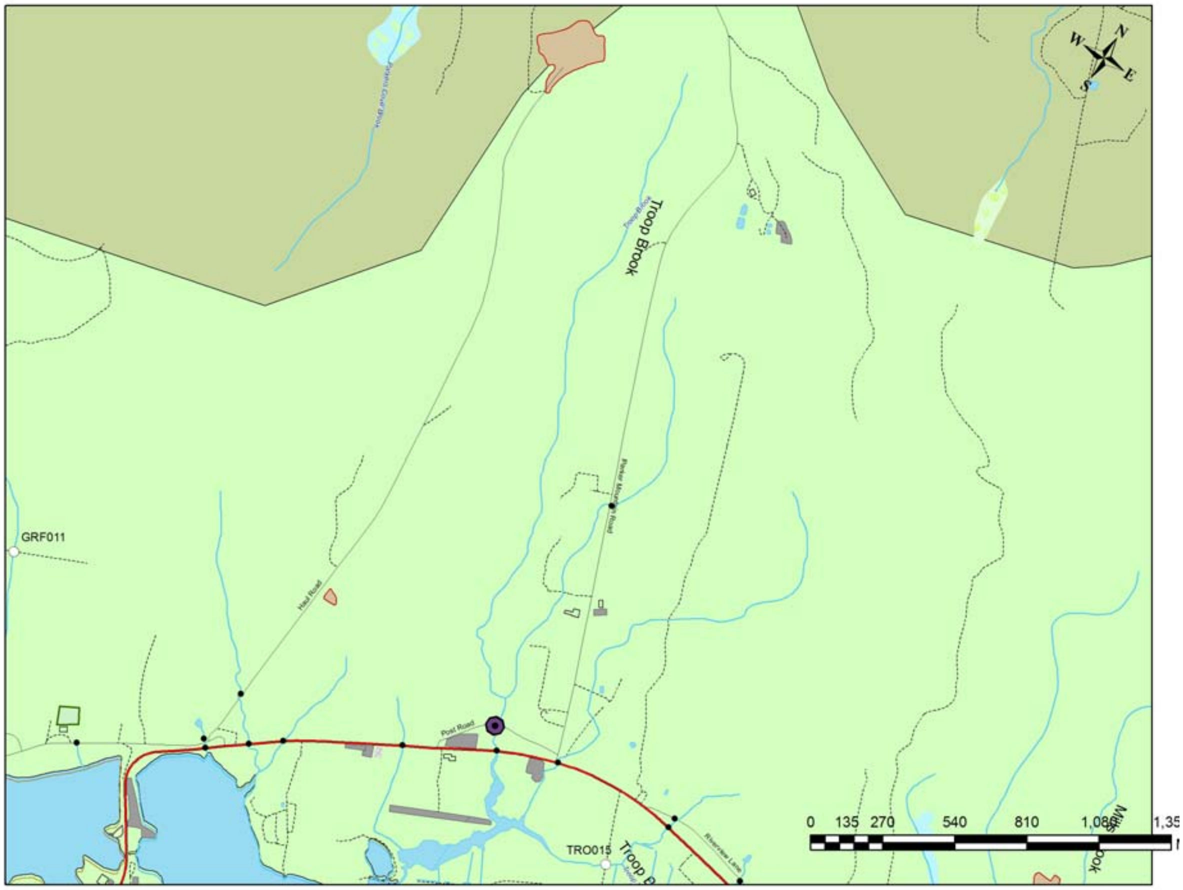


Figure 33. Map indicating location of Troop Brook and the full barrier culvert (TRO010).

Troop Brook is located in Granville Centre (Figure 33). Last season, a tailwater control weir was installed to reduce the outflow drop. It succeeded in bringing the pool surface to the culvert outflow and eliminating the drop. However, the slopes of the culverts are quite substantial at 1.6% and 1.9%, which is over the 1.0% guideline in the Fish Passage Index (Appendix D). To accommodate this slope, a second weir was installed further downstream creating a step-up pool type system, so the first weir could be raised slightly. The weir installed in 2010 (Weir A) also underwent maintenance to replace dislodged rock.

WEIR A

The tailwater control weir installed in 2010 was functioning well; however, some of its rock had been dislodged in the previous year. It also needed to be slightly higher to further backwater the culverts. CARP staff added rock to Weir A to help stabilize the structure and ensure continued function (Figures 34 and 35). During maintenance, the low flow notch was built slightly higher in hopes of backwatering the culvert at least half its length. The design of this tailwater control weir can be found in the 2010 report, *Broken Brooks: Repairing Past Wrongs* (Taylor, 2010).

A  B

Figure 34. Weir A before (A) and after (B) retrofit.

Figure 35. Weir A after extreme rain storm.

WEIR B

The second rock weir was to be installed downstream at a section with a natural accumulation of rock. The idea was to back the water to Weir A in order to raise its apex to further backwater the culverts.

Rock Volume and Sizing

To determine the amount of rock that would be required to build the rock weir, the following formula was used (Taylor, 2010):

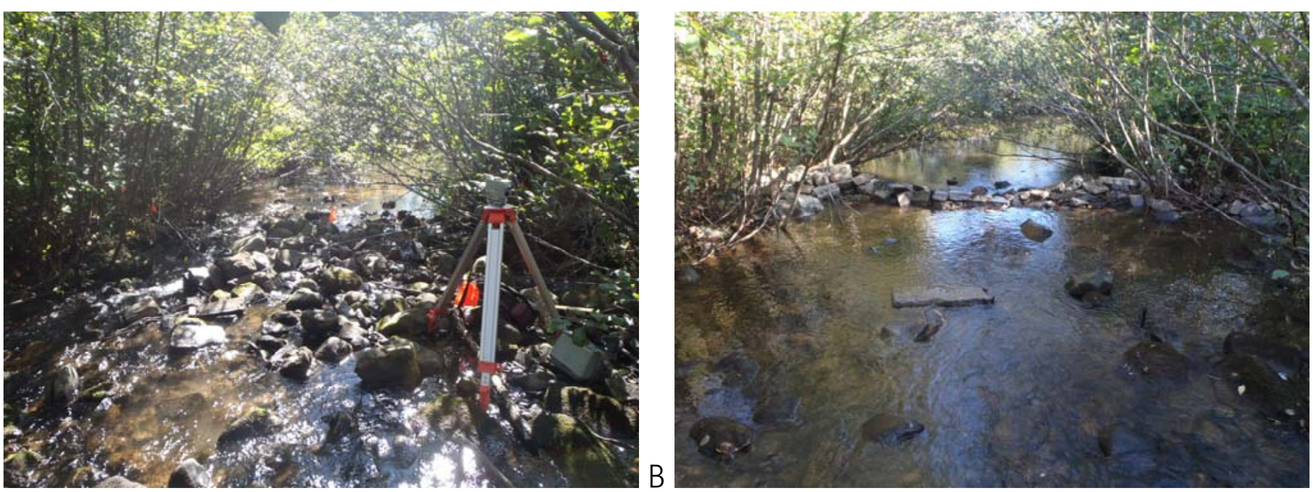
Volume (V)= Length (l) x 1/2Width (w) x Height (h)

Weir B was built to a height of 47 cm at the bank sloping to the low flow notch. With a height of 47 cm and a rock stabilization ratio of 1:1.5, the total width was 14 cm. Using an angle of 30°, the length was calculated to be 7.00 m, tying into each bank 0.71m, giving a total length of 8.42m. Inputting these values into the above formula gives resulting volume of 2.81 m^3.

$$V = 8.42 \text{ m} \times \tfrac{1}{2}(1.41 \text{ m}) \times 0.47 \text{ m}$$
$$V = 2.81 \text{ m}^3$$

Due to the fact that the incipient rock diameter was calculated for this brook last year, the already calculated value of 18 cm was used (Taylor, 2010).

The location of Weir B at TRO010 was mapped out and built in September (Figure 36).


A B
Figure 36. Weir B before (A) and after (B) rock weir installation.

MCE015 – McEwan Brook

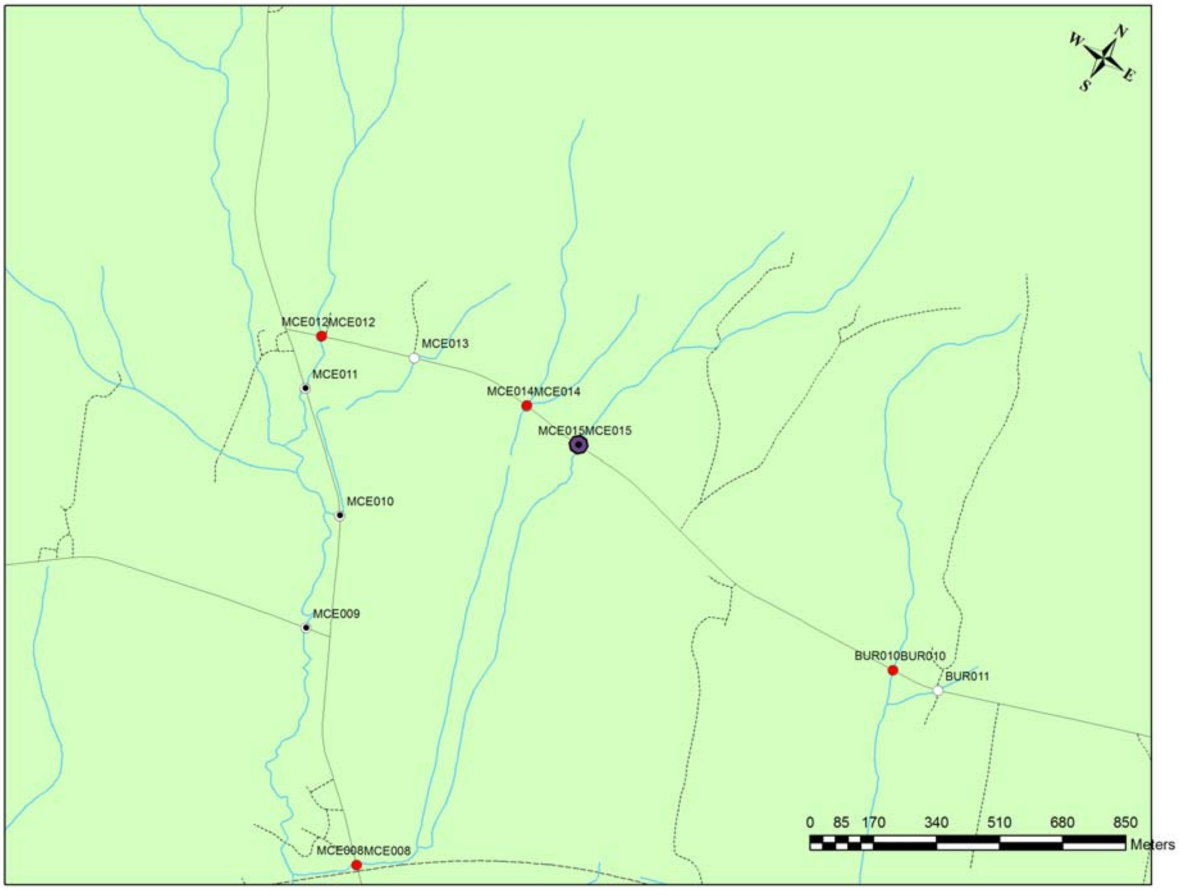


Figure 37. Map indicating location of McEwan Brook and the full barrier culvert (MCE015).

MCE015 is located on McEwan Brook in Brooklyn, NS (Figure 37). This branching brook is over 24 km in length with 1.7 km of fish habitat restricted due to an outflow drop and steep slope at MCE015. McEwan Brook has 21 road-watercourse crossing sites; 6 are passable, 5 are barriers, 2 were not assessed because of limited upstream habitat and 8 were on trails and not identified in GIS. MCE015 was chosen as a site for rock weir installation because it is easily accessible and contained quality brook habitat. The plunge pool at the outflow of the culvert was larger than necessary. Part of the restoration included shortening the pool length and filling in the sides of the pool to raise the water level in the culvert.

Rock Volume and Sizing

To determine the amount of rock that would be required to build the rock weir, the following formula was used (Taylor, 2010):

Volume (V)= Length (l) x 1/2Width (w) x Height (h)

The change (in height) between the culvert inflow and outflow was 15.4 cm. If the weir was built to the height of the inflow, it may be too high for the passage of young fish. Therefore, the goal was to backwater 50% of the 10 m culvert. The exposed height of the weir needed to be 32 cm from the pool bottom to achieve this. The required embeddedment (to reduce scour downstream of the structure) was calculated as 15 cm, giving a total height of 47 cm. With a height of 47 cm and a rock stabilization ratio of 1:1.5, the total width calculated was 141 cm. Using an angle of 30°, the length was calculated to be 5.94 m. Inputting these values into the above formula gives a volume of 2.00 m^3. Extra rock was ordered to fill in the edge of the plunge pool thereby reducing its size.

$$V = 5.94 \text{ m} \times \tfrac{1}{2}(1.41) \text{ m} \times 0.47 \text{ m}$$
$$V = 2.00 \text{ m}^3$$

In determining the minimum size of rock that would be required to construct a rock weir able to withstand the velocity of the water the incipient diameter of bed material was calculated (Cummings et al., 2004).

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

Where, *T* represents tractive force. The equation for tractive force is:
#

$$T = 1000 \times d \times s$$

Where, d is depth of flow in metres and s is the slope of water surface

Based on the measurements recorded during the full culvert assessment survey, the downstream slope at MCE015 is 0.0667; the average water depth in the downstream is 0.15 m. Based on these measurements, the tractive force can be calculated:

$$T = 1000 \times 0.15 \text{ m} \times 0.0667$$
$$T = 10.0 \text{ cm}$$

An incipient diameter of 10.0 cm was calculated, using a safety factor of 2, gives a minimum rock size (diameter) of 20.0 cm.

The location of the rock weir at MCE015 was mapped out and built in September (Figure 42). A survey level was used to measure the height of the low flow notch. Extra rock was used to fill in the edges of the plunge pool, however, less rock than expected was used due to time and transportation constraints.

A  B 

Figure 38. MCE015 before (A) and after (B) Tailwater control weir installation.

Approximately one month later, the rock weir appeared to be functioning (Figure 39). There was still a small outflow drop, possibly due to the plunge pool being too large, but the outflow drop was still significantly reduced (Figure 40). It is recommended that the site be revisited in 2012 as a follow-up.

Figure 39. MCE015 one month after installation.

A  B 

Figure 40. MCE015 Outflow before (A) and after (B) Tailwater control weir installation. NOTE: Photo A was taken in summer 2010 and photo B was taken October 2011, one month after weir installation.

Future Recommendations

1. Fish habitat surveys should be added the assessment procedures.
2. Watercourse crossings that are not in the original map layer should be added to maps before the field season. Check trails and private roadways.
3. Watercourses should be prioritized before assessment of a particular area and crossings dismissed if little upstream habitat is available.
4. Watercourses with the most potential for aquatic connectivity and quality habitat should the focus.
5. All crossings with potential habitat should be assessed, including those on public trails and private roads and trails (with property owner's permission).
6. Assessments of water crossings on Highway 101 should be completed.
7. Full assessments of culverts deemed barriers by preliminary assessment in 2010 should be completed.
8. Aerial photographs of the land surrounding possible remediation sites should be examined to prioritize restoration work.
9. BAI001 should have a follow-up to see if more debris has accumulated in the debris cage at the inflow of the Ballie Lake culvert.
10. The second stage of the debris removal at WAT006 should be completed.
11. Installing baffles in HAR008 is a potential remediation for 2012.
12. Creation of a database in Microsoft Access or a similar program would ease data entry. A data entry form that matches the assessment sheet would be the most beneficial and reduce errors.

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Appendices

Appendix A: Culvert Assessment Datasheet

Researchers: ______________________________

Site Information			
Culvert ID		Date (dd/mm/yyyy)	
Stream Name		Time	
Road Name		UTM Easting (m)	
Fish Habitat	☐ YES ☐ NO	UTM Northing (m)	
Photo Files	☐ U/S ☐ Inflow ☐ D/S ☐ Outflow ☐ Other	U/S Habitat Gain	
Ownership of Barrier	☐ Public Road ROW	☐ Rail Bed ROW	☐ Private

*If culvert is identified as being located on a fish bearing stream, then proceed with further data collection.

Culvert Information					
Culvert Shape	☐ Circular ☐ Box ☐ Pipe Arch ☐ Double ☐ Open Arch ☐ Other	Entrance Type	☐ Projecting ☐ Headwall ☐ Mitered ☐ Wingwall ☐ Other	Culvert Material	☐ Concrete ☐ CMP (spiral) ☐ CMP (annular) ☐ Corrugated Plastic ☐ Wood ☐ Other
Baffles	☐ Present ☐ Absent	Culvert Bottom Material	☐ Natural ☐ Unnatural ____________ ☐ Substrate ____________		
Notch Width (m)					
Notch Depth (m)					

Embedded		
(Check the box that applies and note depth of embedment or percent of embedment)	1) >30cm or > 20% culvert diameter & continuous	
	2) <30cm or <20% culvert diameter but continuous or partial	
	3) No embedment or discontinuous	

Outflow Drop	HI (m)	FS (-)	Elevation (m)	Outflow Drop (cm)	OD = Elevation at Outflow Invert – Elevation at Tailwater
2 Elevation at Outflow Invert					
4 Elevation at Tailwater (1st Riffle)					

Culvert Slope	HI (m)	FS (-)	Elevation (m)	Slope (%)	$\frac{\text{Elevation Inflow (m)} - \text{Elevation Outflow (m)}}{\text{Culvert Length (m)}}$
1 Elevation at Inflow Invert					
2 Elevation at Outflow Invert					
1 to 2 Culvert Length (m)					

Stream Width Ratio			
Upstream Bankfull Width (m)	1	2	3
Average Bankfull Width (m)	ACW = (1 + 2 + 3) / 3		
Culvert Width (m)			
Stream Width Ratio (SWR)	SWR = Channel Width / Culvert Width		

Fish Passage Score	
Embedded	
Outflow Drop	
SWR	
Culvert Slope	
Culvert Length	
TOTAL SCORE	

Fish Passage: ☐ Passable ☐ Partial Barrier ☐ Barrier

Suggested Remediation: RM / OBS / SS / EM / BW

Notes:

*If culvert is identified as a barrier or partial barrier to fish passage, then proceed with further data collection.

Outflow Measurements / Inflow Measurements

[2] Culvert Measurements (m)	WIDTH	HEIGHT	[1] Water Depth in Culvert (m)	
[2] Corrugation (m)	WIDTH	HEIGHT	[1] Water Velocity in Culvert (m/s)	
[2] Wetted Measurements (m)	WIDTH	DEPTH		
[2] High Water Mark (m)	WIDTH	DEPTH		
[2] Water Velocity in Culvert (m/s)				

	HI (m)	FS (-)	Elevation (m)		HI (m)	FS (-)	Elevation (m)
[2] Elevation at Outflow Invert				[1] Elevation at Inflow Invert			
[2 to 4] Distance from culvert to 1st riffle				[1 to 6] Distance from culvert to 1st Riffle			
[4] Outflow Elevation at 1st Riffle (Tailwater)				[6] Inflow Elevation at 1st Riffle			
[4 to 5] Distance from 1st Riffle to 2nd Riffle				Upstream Channel Slope (%)			
[5] Outflow Elevation at 2nd Riffle				NOTES:			
Downstream Channel Slope (%)							
Pool Surface Elevation							
[3] Pool Bottom Elevation							
[4] Elevation at Tailwater Control (1st Riffle)							
Pool Depth (m) [Elevation at Tailwater - Elevation at Pool Bottom]							

Additional Information			
Inflow Drop	☐ YES ☐ NO	Backwatered (%)	0 25 50 75 100
Beaver Activity	☐ YES ☐ NO	Fish Present (Type & #)	

Channel Measurements (Taken downstream of culvert)				
Wetted Width (m)	1	2	3	AVERAGE
Bankfull Width (m)	1	2	3	AVERAGE

Tailwater Cross Section (Recommended Points: Left bankfull, Left edge of water, Left toe of bank, Thalweg, Right toe of bank, Right edge of water, Right bankfull)

Station (m)	HI (m)	FS (-) (m)	Elevation (m) [HI – FS]	Water Depth (m)	Velocity (m/s)	Notes (Station description and Roughness Coefficient)

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

Notes & Sketch:

Appendix B: Supplemental Culvert Assessment Data Sheet

Site Information					
Culvert ID					
Culvert Information					
Culvert Shape	☐ Circular ☐ Box ☐ Pipe Arch ☐ Double ☐ Open Arch ☐ Other	Entrance Type	☐ Projecting ☐ Headwall ☐ Mitered ☐ Wingwall ☐ Other	Culvert Material	☐ Concrete ☐ CMP (spiral) ☐ CMP (annular) ☐ Corrugated Plastic ☐ Wood ☐ Other
Baffles	☐ Present ☐ Absent	Culvert Bottom Material	☐ Natural ☐ Unnatural ____________ ☐ Substrate ____________		
Notch Width (m)					
Notch Depth (m)					
Embedded					
(Check the box that applies and note depth of embedment or percent of embedment)	1) >30cm or > 20% culvert diameter & continuous				
	2) <30cm or <20% culvert diameter but continuous or partial				
	3) No embedment or discontinuous				

Outflow Drop

	HI (m)	FS (-)	Elevation (m)	Outflow Drop (cm)	OD = Elevation at Outflow Invert – Elevation at Tailwater
[2] Elevation at Outflow Invert					
[4] Elevation at Tailwater (1st Riffle)					

Culvert Slope

	HI (m)	FS (-)	Elevation (m)	Slope (%)	Elevation Inflow (m) – Elevation Outflow (m) Culvert Length (m)
[1] Elevation at Inflow Invert					
[2] Elevation at Outflow Invert					
[1 to 2] Culvert Length (m)					

Culvert Fish Passage Score	
Embedded	
Outflow Drop	
SWR	
Culvert Slope	
Culvert Length	
TOTAL SCORE	

Fish Passage: ☐ Passable ☐ Partial Barrier ☐ Barrier

Suggested Remediation: RM / OBS / SS / EM / BW

Notes:

Outflow Measurements

[2] Culvert Measurements (m)	WIDTH	HEIGHT
[2] Corrugation (m)	WIDTH	HEIGHT
[2] Wetted Measurements (m)	WIDTH	DEPTH
[2] High Water Mark (m)	WIDTH	DEPTH
[2] Water Velocity in Culvert (m/s)		

Inflow Measurements

[1] Water Depth in Culvert (m)	
[1] Water Velocity in Culvert (m/s)	

Additional Information			
Inflow Drop	☐ YES ☐ NO	Backwatered (%)	0 25 50 75 100
Beaver Activity	☐ YES ☐ NO	Fish Present (Type & #)	

Appendix C: Description of Full Assessment Parameters

No.	Variable	Units	Description
1.	Researchers		The assessors collecting the data
2.	Culvert ID		An identification code unique to each culvert. This is a six-digit code; the first three digits are letters. These letters relate to the watercourse name or geographical location of the culvert. The last three digits are numbers, which relate to the culverts identification within the watercourse or geographical area
3.	Stream Name		The name of the watercourse the structure is located on.
4.	Road Name		The name of the road that the culvert is located on
5.	Fish Habitat		The ability of the watercourse to support fish.
6.	Photos		The photos taken of the watercourse crossing site (U/S-upstream, Inflow, D/S-downstream, outflow, other)
7.	Ownership of Barrier		The person or organization responsible for the culvert
8.	Date		The date on which the culvert assessment was completed
9.	Time		The time that the culvert assessment began
10.	UTM Coordinates		The location of the culvert relative to NAD83 UTM Zone 20
11.	U/S Habitat gain		The distance of upstream habitat from the current site to the next barrier or un-assessed water crossing.
12.	Culvert Shape		The shape of the culvert being surveyed (box, round, egg)
13.	Entrance Type		The design of the culvert inflow (projecting, wingwall, headwall)
14.	Culvert Material		The material that the culvert is made of (wood, steel, cement, stone)
15.	Baffles	m	The presence of baffles within a culvert. Record the Notch width and height and the distance between placement.
16.	Culvert Bottom Material		Material found in the bottom of the culvert. Ex. Natural bottom
17.	Substrate in Culvert		Any substances in the culvert. Ex. Algae
18.	Embedded Depth	cm	The depth in which the culvert is placed in the ground
19.	Elevation at Outflow Invert	m	An elevation measurement taken at the bottom of the outflow of a structure
20.	Elevation at Tailwater (1st Riffles)	m	An elevation measurement taken in the thalweg at the end of the outflow pool or at an identified location downstream of the structure
21.	Outflow Drop	cm	The distance between the bottom of the culvert outflow and the thalweg of the tailwater control. It is calculated by subtracting the tailwater elevation from the outflow elevation and multiplying by 100.
22.	Elevation at Inflow Invert	m	An elevation measurement taken at the bottom of the inflow of a structure
23.	Culvert Length	m	The length of the culvert being assessed
24.	Culvert Slope	%	The slope of the culvert calculated by: ((Elevation at Inflow - Elevation at Outflow) /Culvert Length) x 100
25.	Upstream Bankful Width	m	The representative bankfull width at of a watercourse taken upstream of the structure.
26.	Culvert Width	m	The width of the culvert

27.	Stream Width Ratio		The value derived from dividing the average upstream channel width by the culvert width.
28.	Culvert Measurements	m	The width and height of the culvert measured at the outflow
29.	Corrugation	m	The height and spacing between corrugations of a steel or plastic culvert
30.	Wetted Width	m	The width of the water in the culvert
31.	High Water Mark	m	The depth and width of the high water mark, usually identified by a change in colour or rust
32.	Water Velocity in Culvert	m/s	The velocity of the water in the culvert
33.	Water Depth in Culvert	m	The water depth at the inflow
34.	Distance from Culvert to 1st Riffle	m	Distance measured in metres from the culvert to the 1st riffle (usually the Tailwater Control)
35.	Distance from 1st to 2nd Riffle	m	Distance measured in metres between two identifiable changes in elevation downstream
36.	Elevation at 2nd Riffle	m	A second change in elevation downstream of the outflow pool
37.	Downstream Channel Slope	%	The natural slope of the streambed calculated by : (Elevation at Tailwater Control - Elevation at 2nd Riffle) x 100
38.	Elevation at 1st Riffle	m	An elevation measurement taken the first riffle of an identified location upstream
39.	Upstream Channel Slope	%	The natural slope of the streambed calculated by : (Elevation at 1st Riffle - Elevation at Inflow) x 100
40.	Pool Surface Elevation	m	An elevation measurement taken at the surface of the water in the outflow pool
41.	Pool Bottom Elevation	m	An elevation measurement taken at the bottom water in the outflow pool approximately 30 cm from the outflow
42.	Pool Depth	m	The depth of the water in the outflow pool calculated by: Elevation of Tailwater Control – Pool Bottom Elevation
43.	Inflow Drop	m	A vertical drop into the structure from the natural streambed
44.	Beaver Activity		The presence of beaver activity at or near the structure or watercourse
45.	Backwatered	%	The surface of the outflow pool extending back into the culvert negating the problematic slopes. Is recorded as 25%, 50%, 75% or 100% backwatered.
46.	Fish Present		The observation of any fish observed. Include type, number and approximate size.
47.	Channel Measurements	m	Both wetted and bankfull measured taken at representative locations downstream of a structure. A measurement in metres of the width of the water column and full bank width which best represents the true character of the watercourse
48.	Tailwater Cross Section		Based on the bankfull width, the cross section is divided into segments, usually at intervals of 0.5m or 1.0m, depending of the width of the watercourse. This is marked by at a tape attached to two stakes of either side and perpendicular to the watercourse
49.	Station	m	The distance along the tape that the elevation, water depth and velocity are measured.
50.	Elevation (Cross Section)	m	An elevation which is taken at each width station

51.	Wetted Water Depth (Cross Section)	m	A measurement of the water depth at each width station
52.	Velocity (Cross Section)	m/s	A measurement of the velocity at each width station
53.	pH		The acidity of the water in the watercourse
54.	Water Temperature	Celcius	Downstream water temperature
55.	Conductivity	mS/cm	The ability of a solution (water) to carry an electrical current
56.	Turbidity	NTU	The cloudiness of the water, as a result of suspended solids
57.	DO	mg/L	The amount of dissolved oxygen in the water
58.	DO (SAT)	% (SAT)	The amount of dissolved oxygen saturation in the water
59.	Salinity	g/L	The dissolved salt content in a body of water
60.	Air Temperature	Celcius	The temperature of the air on the day of the survey

Appendix D: Fish Passage Index

Embedded	Value	Outflow Drop	Value	SWR	Value	Slope	Value	Length	Value
> 30 cm or > 20% of culvert diameter & continuous	0	<15cm	0	<1.0	0	<1%	0	<15m	0
< 30cm or 20% of culvert diameter but continuous or partial	5	15-30cm	5	1-1.3	3	1-3%	5	15-30m	3
No embedment or discontinuous	10	>30cm	10	>1.3	6	>3%	10	>30m	6

Cumulative Score	Result
0-14	Passable
15-19	Potential Barrier
>20	Barrier

Remediation Options

RM Removal of the structure and deactivation of the road if access is not required.

OBS Replacing the culvert with a bridge or other open bottom structure.

SS Replacing the structure with a streambed simulation design culvert or retrofit.

EM Adding substrate material to the culvert and/or possibly a series of downstream weirs to reduce overall velocity and turbulence and provide low velocity areas.

** NOTE: this option should be considered only on sites where there is no outflow drop, slope <1.0% and SWR <1.0

BW Backwatering the structure to reduce velocity and turbulence.

** NOTE: this option should be considered only on sites where outflow drop <30cm, slope <2.0% and SWR <1.2

Appendix E: Water Crossing Assessment Order of Operations

Water Crossing Assessment Order of Operations

1. Secure safe parking and don safety vests
2. Perform visual survey of the culvert and adjacent area
3. Fill water crossing information on datasheet

If the structure is deemed passable, fill out appropriate information on data sheet.

If there is some question of the structure's ability to pass fish, fill out the first page of the data sheet and generate a score using the Fish Passage Index. If the barrier is obvious, begin by completing the second page of the datasheet and then continue to the then continue first page.

4. Gather tools required from vehicle and return to the site.
5. Perform a preliminary assessment and calculate the Fish Passage Score or begin with second page of datasheet
6. Set-up surveyor's level while velocity and hydro lab readings are taken
7. Document culvert information and measurements recorded at outflow (shape, size, water depth, wetted depth, wetted width, high water mark (width and height), substrate depth (if any), outflow drop, and outflow pool depth
8. Measure the culvert length and water depth at inflow
9. Record elevations (Outflow culvert bottom, outflow pool surface, cross section, first and second riffle downstream)- include distances to riffles
10. Stake tape at bank full width (at tailwater control). Record elevations, depths and velocity of the cross-section.
11. Measure downstream wetted width and bank full width
12. Record elevations (Inflow culvert bottom and first riffle)- include distance to first riffle
13. Measure velocity at inflow
14. Measure three upstream bankfull widths for the Stream Width Ratio
15. Note recommendations for the culvert
16. Gather tools and return to vehicle

Appendix F: Equipment Checklist

*Check each box as the equipment is loaded into the vehicle.

MATERIALS

- ☐ Clip board
- ☐ Data Sheets (multiple, + copies on waterproof paper)
- ☐ Pencil, eraser, sharpener
- ☐ Calculator
- ☐ GPS
- ☐ Topographic Maps (1:10,000)
- ☐ Camera
- ☐ White Board with markers and eraser (for pictures)
- ☐ Extra batteries
- ☐ CARP Cell Phone
- ☐ SPOT

EQUIPMENT

- ☐ Automatic Level
- ☐ Tripod
- ☐ Level Rod
- ☐ Rod Bubble (orange)
- ☐ 30m Tape
- ☐ Measuring Tape (5m)
- ☐ Range Finder
- ☐ 2 Stakes
- ☐ Mini Sludge Hammer
- ☐ Velocity Metre
- ☐ HydroLab

SAFETY

- ☐ Hip and chest waders
- ☐ Rubber boots
- ☐ Rain Gear (enough for each crew member)
- ☐ Flashlight
- ☐ Long Rope (to repel down to culverts or to be used as a safety line)
- ☐ Field First-Aid Kit
- ☐ Reflective Vests
- ☐ PFD (if working in swift or deep water)

ADDITIONAL THINGS

- ☐ Check the battery levels in each electronic device
- ☐ Record the cell phone number on the sign-out sheet
- ☐ Stock the Broken Brooks folder with enough data sheets and supplemental sheets for the day

Appendix G: Leveling Procedures

CARP Automatic Level Survey Procedures for Culvert Assessments

Leveling Terminology

Bench Mark (BM): A permanent object that has a known elevation.

Temporary Benchmark (TBM): A moveable object that has a known elevation

Turning Point (TP): A fixed object used when determining the elevation of other points

Height of Instrument (HI): The elevation of the line of sight established by the instrument

Backsight (BS): The reading on the rod when held on a known or assumed elevation.

Foresight (FS):The reading on the rod when held at a location where the elevation is to be determined. Foresights are used to establish the elevation at another location.

Calculations

The level will be used to determine: the slope of the culvert, the slope of the stream and the horizontal cross-section of the stream. For our purposes we will calculate relative elevations, and will therefore not require a benchmark of known elevation. Instead we will give the instrument an arbitrary height of 10.000m.

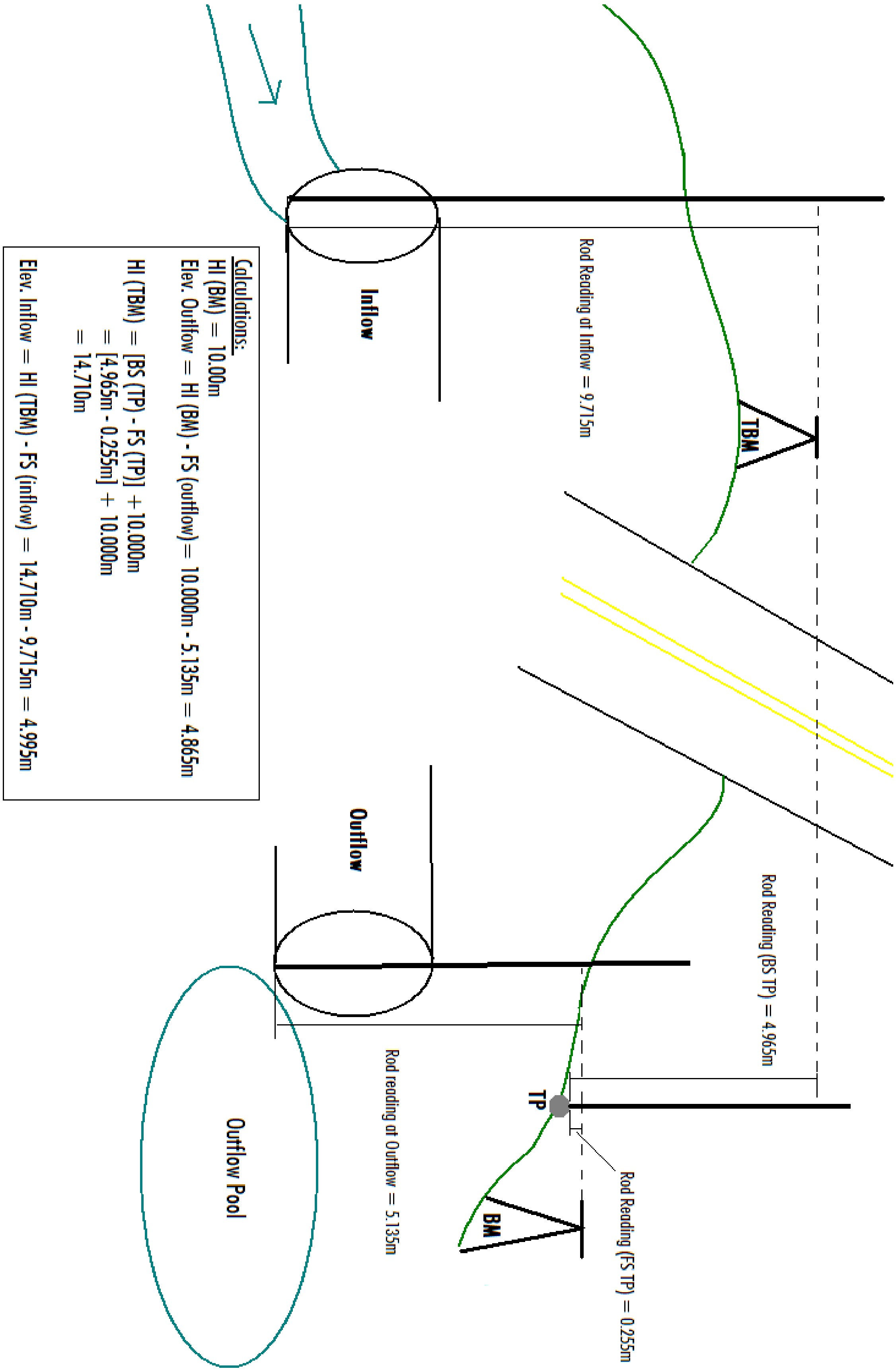
Elevation = HI (10.000m) – BS

Field Book Set-up

Example from diagram below:

Culvert ID	Coordinates		Date	Time	
	N	E			
Station	HI (BM)	FS	BS	HI (TBM)	Elevation
Cul. Outflow	10.000m	5.135	-	-	4.865m
TP	10.000m	0.255	4.965	14.710m	
Cul. Inflow	14.710m	9.715	-	-	4.995m

*In the field book on the adjacent page, draw the culvert and location of tri-pod and turning points for future reference.


Inflow
Rod Reading at Inflow = 9.715m
TBM
Rod Reading (BS TP) = 4.965m
Outflow
TP
Rod reading at Outflow = 5.135m
BM
Rod Reading (FS TP) = 0.255m
Outflow Pool
Calculations:
HI (BM) = 10.00m
Elev. Outflow = HI (BM) - FS (outflow) = 10.000m - 5.135m = 4.865m
HI (TBM) = [BS (TP) - FS (TP)] + 10.000m
= [4.965m - 0.255m] + 10.000m
= 14.710m
Elev. Inflow = HI (TBM) - FS (inflow) = 14.710m - 9.715m = 4.995m

Surveying Equipment

- Automatic Level
- Tri-pod
- Leveling Rod
- Hand Level
- Field Book, Pencils, Calculator
- Stakes and Hammer

Hint 1) Set-up the tri-pod in an area where you will be able to sight both the inflow and outflow edges of the culvert keeping in mind that you will also need to sight upstream and downstream elevations.

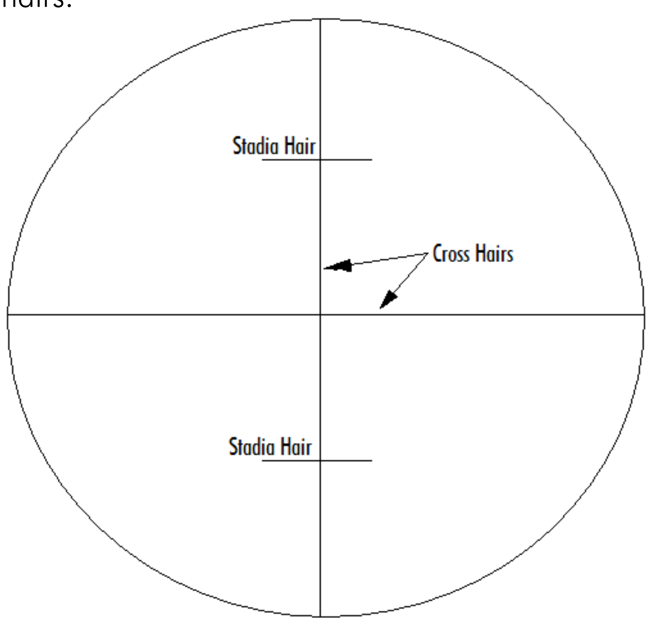
Tri-pod set-up location:

- The most idea location to set-up the tripod if possible is on the edge of the road
- If the edge of the road is not feasible, set-up the tri-pod on the downstream side in an area that will allow you to sight through the culvert.
- Another possible location, which will depend on the size of the culvert, is to set-up inside the culvert.

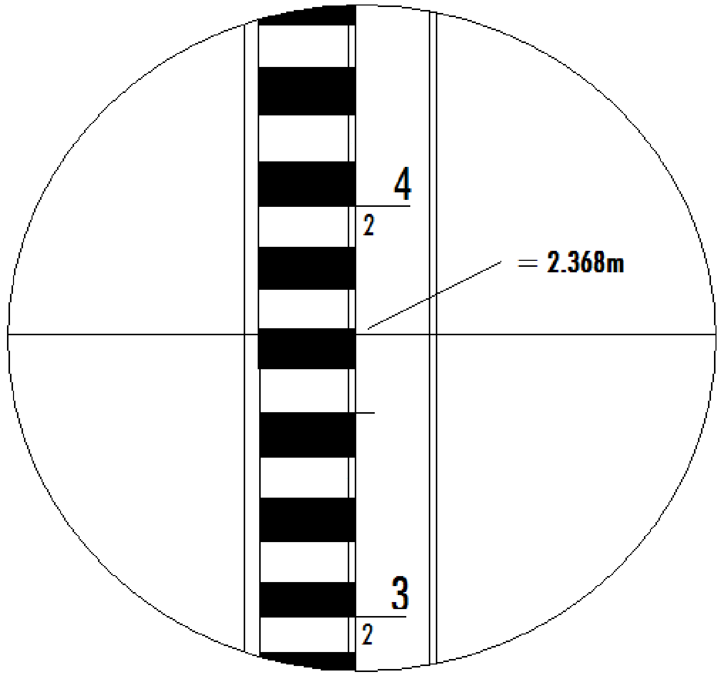
If it is not possible to sight both ends of the culvert with one set-up, you will need to establish multiple bench marks, and use turning points. (See diagram below)

The Level and Tri-pod

Arrangement of Cross Hairs: when you sight through the scope, you will see a vertical and a horizontal cross hair and two horizontal stadia hairs. Rod readings will be taken using the cross hairs.

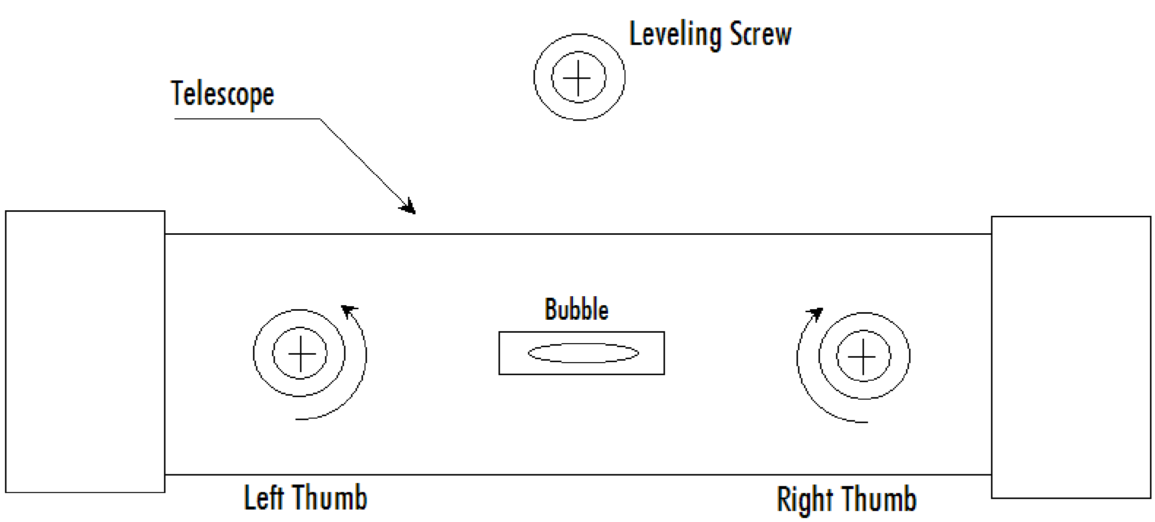


Rod Sighting: rod readings are taken to three decimal places (to the nearest millimeter).



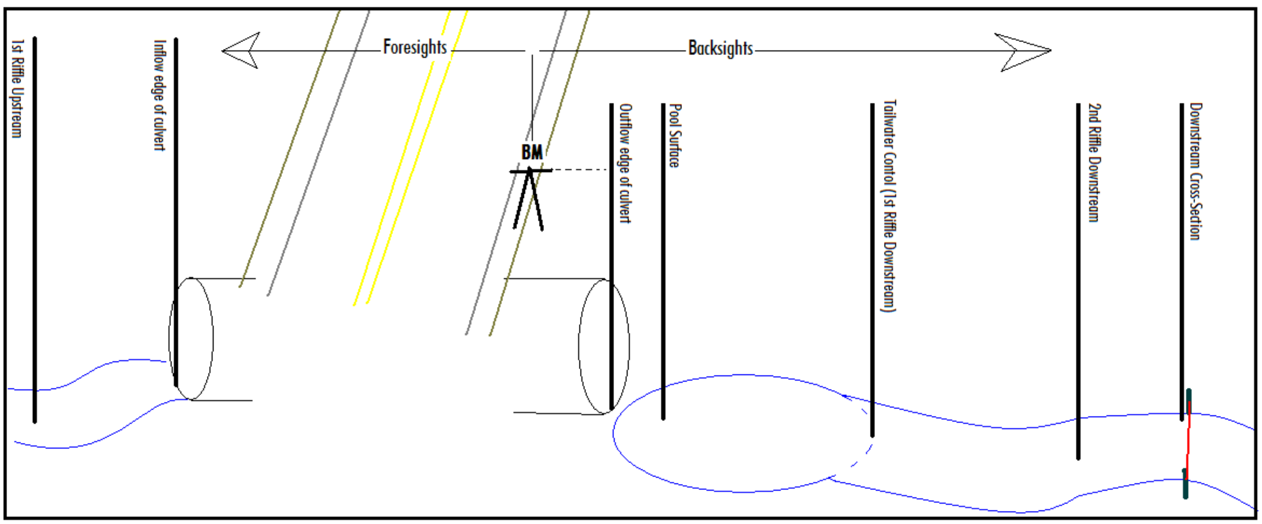
Setting up the Tri-pod:

1. Loosen the screws on each leg, elongate the legs to an appropriate height, and tighten the screws.
2. Establish the tripod; if on a hill have one leg pointing down hill and two pointing up.
3. Using the tri-pod base plate, firmly press each leg into the ground.
4. Mount the automatic level.
5. The thumb screws are ALWAYS turned in opposite directions by equal amounts simultaneously. The leveling bubble will always move in the direction of your left thumb.



Survey Procedures

Situation 1: Able to sight both inflow and outflow from the same bench mark.
Step 1) Set-up the tri-pod (preferably on the edge of the road). **Identify the lowest elevation point (usually the downstream cross-section) and the highest elevation point (usually the 1st Riffle upstream) and ensure both can be sighted from the same BM.
Step 2) Sight the outflow edge of the culvert. Record observations.
Step 3) Sight the outflow pool surface. Record Observations.
Step 4) Sight the tailwater control (1st Riffle). Record Observations.
Step 5) Sight the 2nd Riffle Downstream. Record observations.
Step 6) Sight the cross-section (minimum 5 observations). Record observations.
Step 7) Rotate the scope and sight the inflow edge of the culvert. Record Observations
Step 8) Sight 1st Riffle upstream. Record observations.

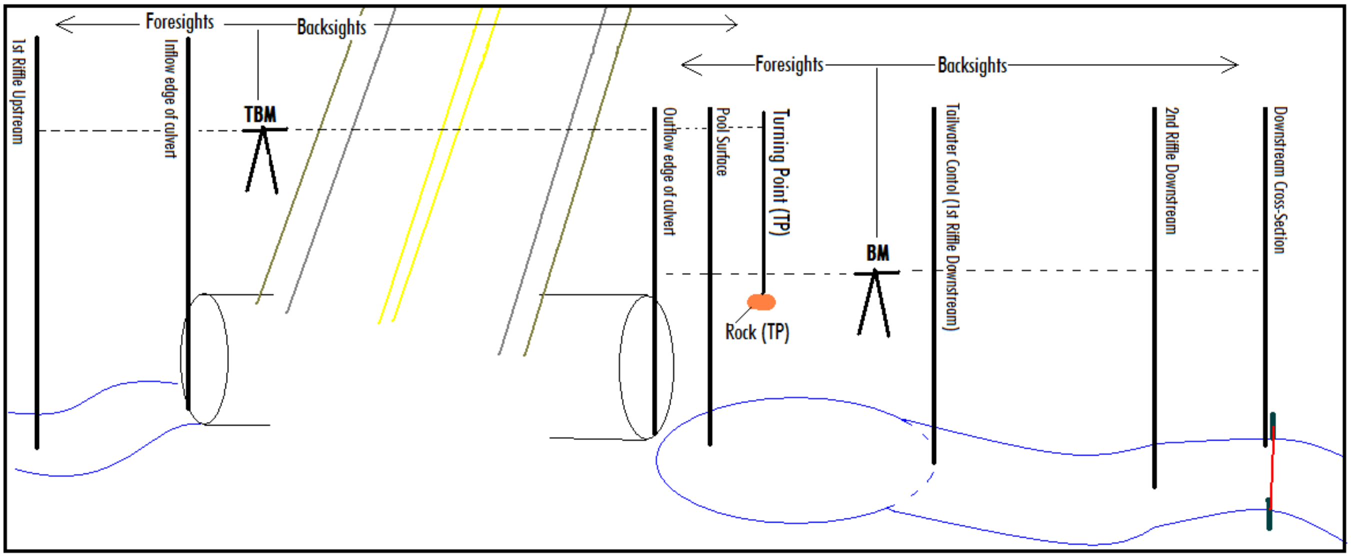


In this situation your field book should be set-up as follows:

Culvert ID	Coordinates		Date	Time	
	N	E			
Station	HI (BM)	FS	BS	HI (TBM)	Elevation
Cul. Outflow	10.000m	-		-	= HI - BS
Pool Surface	10.000m	-		-	
Tailwater (1st Riffle Downstream)	10.000m	-		-	
2nd Riffle Downstream	10.000m	-		-	
Cross-Section	10.000m	-		-	
0.00m	10.000m	-		-	
1.00m	10.000m	-		-	
1.50m	10.000m	-		-	
2.00m	10.000m	-		-	
3.00m	10.000m	-		-	
Cul. Inflow	10.000m		-	-	= HI - FS
1st Riffle (Upstream)	10.000m		-	-	

Situation 2: Require multiple bench marks in order to sight both upstream and downstream.

Step 1) Set-up the tri-pod
Step 2) Sight the outflow edge of the culvert. Record observations.
Step 3) Sight the outflow pool surface. Record Observations.
Step 4) Sight the tailwater control (1st Riffle). Record Observations.
Step 5) Sight the 2nd Riffle Downstream. Record observations.
Step 6) Sight the cross-section (minimum 5 observations). Record observations.
Step 7) Foresight a Turning Point (TP) [for example a rock in the ground]
Step 8) Re-establish the tri-pod in a location that you will be able to sight both the TP and the 1st Riffle Upstream.
Step 9) Backsight the TP [calculate the height your TBM: $HI_{(TBM)} = HI + (BS - FS)$]
Step 10) Sight the inflow edge of the culvert. Record observations.
Step 11) Sight the 1st Riffle Upstream. Record observations.



In this situation your field book should be set-up as follows:

Culvert ID	Coordinates		Date	Time	
	N	E			
Station	HI (BM)	FS	BS	HI (TBM)	Elevation
Culvert Outflow Edge	10.000m			-	
Pool Surface	10.000m			-	
Tailwater (1st Riffle Downstream)	10.000m			-	
2nd Riffle Downstream	10.000m			-	
Cross-Section	10.000m			-	
0.00m	10.000m			-	
1.00m	10.000m			-	
1.50m	10.000m			-	
2.00m	10.000m			-	
3.00m	10.000m			-	
TP (Turning Point)	10.000m			HI + (BS - FS) = XX	---
Culvert Inflow Edge	XX		-	-	= XX - FS
1st Riffle (Upstream)	XX		-	-	= XX - FS

Website with video links:
http://www.fs.fed.us/pnw/pep/index.html

(Some of the videos on this website give a step by step on how to perform a culvert assessment survey)

Appendix H: Safe work Practices

Broken Brooks Project	
Hazards Identified	Falling, working over water, slippery surfaces, unstable slopes, traffic, dust, noise, air quality in culvert, loss of balance (damaged culverts, beaver dams, loose sediment), face injury (branches), insects, poison ivy, animals (wild & domestic), falling rocks, electric fence, barbwire fence, farming equipment, sunburn, discharge of firearms during hunting season.
Hazard Specific Personal Protective Equipment	As required, life preservers, approved boots with aggressive & ankle support, hearing protection, orange safety vest, respiratory protection (mask), eye protection, insect repellant, sunscreen, long pants, waders.
Hazard Specific Training	Job-specific training

Safe Work Practices

- A #2 First Aid Kit is required
- No less then 2 persons must be present for culvert inspection and subsequent stream inspections
- Evaluate area before starting the culvert inspections to identify any possible hazards
- If birds nest are present in culvert, take necessary respiratory actions (where mask).
- Be aware of unstable slopes and weather conditions, like rain, which may increase the chance of slipping or falling
- Ensure a mobile phone will be present and powered on at all times
- Ensure that office is aware of culvert inspection locations before leaving to perform the fieldwork
- Take precautions around unstable terrain, like; river banks, damaged culverts and boulders
- Review the UV index before leaving the field and wear sunscreen at all times
- Wear hunter's orange during autumn hunting season
- When carrying gear make sure that one hand remains free to brace a fall, backpacks will be used when appropriate
- Park vehicle completely off the shoulder
- Set up a yellow flashing light on top of truck during all inspections for increased visibility
- Walk off the shoulder of the road in the direction of on coming traffic
- A reflective vest will be worn at all times when working near the road
- Stay hydrated and stay aware of extremes in temperature
- Always be alert of others and traffic that is near your area of work

Note, where necessary, refer to:

- CARP Health and Safety Policy
- CARP Remote Location Plan

Clean Annapolis River Project
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