A CULVERT SURVEY OF THE ST. MARY'S RIVER, GUYSBOROUGH COUNTY, NOVA SCOTIA, ASSESSING AND PRIORIZING CULVERTS AS OBSTRUCTIONS TO FISH PASSAGE.

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EXECUTIVE SUMMARY

Culverts are the primary method of stream crossing by roads in the Maritimes. Due to large road networks and drainage densities, there can exist a large number of culverts within a watershed. Improperly installed or ageing culverts can fragment the stream in which they are placed by obstructing fish movement. Movement by fish is critical to population sustainability, but culverts can interfere with upstream-downstream movement. This obstruction can come about by one or more of the mechanisms of (1) outfall drop, (2) water depth in culvert, or (3) water velocity in culvert. There is extensive roading in the St. Mary's River watershed in the form of highways and roads for forestry and agriculture. Culverts within the St. Mary's River watershed were assess in 2009 by the St. Mary's River Association to identify and priorize culverts for remediation to ensure fish access to upstream reaches. Culverts were assessed between June 29 and November 9, 2009 with efforts being concentrated on lower reaches of streams. Analysis focussed on perennial streams and evaluated culverts as likely obstructions due to depth, velocity or outfall barriers. Length of stream upstream of the culvert was an important factor in priorizing culverts.

Ninety nine culverts were assessed, with culverts being most commonly on small 1st order streams and bridges more common on 2nd and 3rd order streams. The West and North Branches were oversampled relative to drainage area, the Main Branch undersampled, and East Branch met the target of representation by drainage area. The predominant culvert type in this watershed is round Corrugated Metal Pipe (CMP) and secondly wooden box culvert. Of the 99 stream crossings, 62 could unambiguously be located on perennial streams ("fish habitat"). Of these 62, 40 did not meet criteria for water depth (>0.20 m), 35 had velocity in excess of 0.2 m/s, an 24 had an outfall drop >0.0 m. Use of simplistic, single value criteria are problematic however, and so further analysis included length of stream upstream of culvert made unavailable and consideration of the fish species of concern. From this analysis, eight culverts were identified as highest priority for restoration. Culverts under highways, as opposed to forestry roads, and use of wooden box culverts appear to be most problematic.

Prescriptions are provided for restoration of the eight highest priority culverts, and include use of baffles, pool development, and fishways. Costs are not quantified but are estimated on a subjective scale from Low to High. Recommendations are made regarding future culvert assessments and restoration monitoring requirements.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1.0 INTRODUCTION

Culverts are the primary method of stream crossings by roads in the Maritimes (Langill and Zamora, 2002). For example, in the period 1996-2000, notifications were filed with Nova Scotia Department of Environment (NSDoE) for 529 culverts (mean 105.8/year; SD = 39.3) with 60 of these (mean 12.0/year; SD = 4.9) being installed in Guysborough County (Langill and Zamora, 2002). When historical culverts are included, the number of these structures in a watershed can rise; Coombs (2006) identified as many as 1,615 culverts in the Annapolis River watershed. Given that culverts can be significant obstructions to upstream-downstream movement of fish, their prevalence can clearly be a potentially significant impact to the fish resources of a watershed.

Improperly installed or ageing culverts can fragment streams in which they are placed. Historically, the extent to which fish moved within a stream system on daily, weekly, or monthly time scales was not appreciated. In the past, culverts were viewed primarily as obstructive only during particular times of the year, for example during spawning migrations of salmonids. However, increasing evidence shows that fish move a great deal on much shorter time scales than previously thought. This movement is critical for access to spawning habitat, maintenance of populations in areas unsuitable for reproduction, access to prey, and avoidance of predators (Warren and Pardew, 1998). Indeed, dispersal barriers have recently been identified as a significant factor in fish population declines around the world (Poplar-Jeffers et al., 2009). There have been numerous studies evaluating percentages of installed culverts which are obstructive conducted in North America, most of these published in the "grey literature". With respect to Nova Scotia there are two published studies examining proportion of culverts obstructive to fish movement. Langill and Zamora (2002) conducted an audit of 50 culverts filed to be installed in Colchester, Cumberland, Halifax, and Hants Counties during 1999-2000. Six of the culverts were not installed (notification only but work not done) and 13 were on streams not considered fish habitat, leaving 31 culverts on fish-bearing streams assessed. Of these, 19 (61.2%) were considered "Non-fish passage" based on a culvert slope greater than 0.5%[1] and 13 (41.9%) were classified as non-fish passage due to perched outfall[2]. Hicks and Sullivan (2008) reported on culverts in the Annapolis River watershed. They assessed 60 culverts and found 22 (36.7%) were full barriers and 11 (18.3%) were partial barriers[3]. Other studies elsewhere have found culverts being obstructive infrequently (14.3% by Harper and Quigley, 2000), or in the majority of cases (69.2% by Poplar-Jeffers et al., 2009; 76.1% by Blank et al., 2005; 90.3% by Chestnut, 2002).

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[1] Note: A slope criterion of 0.5% may be conservative in assessing obstructions. Fish may be able to negotiate culverts >0.5% by using culvert walls and bottom and taking advantage of roughness elements.

[2] Note: Some of the culverts were obstructive in both slope >0.5% and perched outfall so the total obstructive is <u>not</u> the sum of the two categories.

[3] Hicks and Sullivan (2008) defined a full barrier as: outfall drops onto rocks, or pool depth at outfall <1.5 times outfall drop, or no water flows through culvert. A partial barrier was defined as: debris blocking culvert, or culvert depth too shallow for mature trout (<5 cm depth), or outfall drop even with adequate pool depth is barrier to juvenile trout.

Culverts are most commonly obstructive to fish passage from one or more of three mechanisms: (1) outfall barriers[4] (outfall drop too great for fish to leap into culvert, or outfall pool too shallow or non-existent, precluding leaping), (2) depth barrier (water depth in culvert insufficient to allow fish passage), or (3) velocity barrier (stream velocity in culvert exceeds swimming ability of fish). Each of these mechanisms depends upon the species and life stage of fish under consideration – the "design fish". Much of the work on culverts has been done on salmonids, particularly in western North America. General criteria have been derived for these three potential mechanisms of obstruction.

Outfall Drop: Historically a maximum drop of 0.31 m has been the criteria for outfall drop (Dane, 1978; Adams and Whyte, 1990), but this is a reflection of the design fish being adult salmonids which can jump well. In order to ensure passage of juvenile salmonids, and non-jumping species such as American eel, white sucker or cyprinids (minnows), the lower edge of the culvert needs to be submerged. Adams and Whyte (1990) maintain the length and width of the outfall pool should be twice the diameter of the culvert and depth at least 0.6 m. Gosse et al. (1998) suggest that the outlet pool should be dimensioned as Length=2 to 4X culvert diameter, Width=2 to 3X culvert diameter, Depth 0.5X culvert diameter and 1.0 m minimum depth (*see Recommendation #1*)

Water Depth in Culvert: Criteria for minimum water depth within the culvert barrel have been established as 0.20 m (Gosse et al., 1998) and 0.23 m (Dane, 1978; Adams and Whyte, 1990). This is also a reflection of passing adult salmonids, as juveniles will be able to traverse the culvert easily at much less depth, provided low velocity. Establishing a single criterion for water depth is problematic as discharge fluctuates, and frequently at low flow the channel upstream in riffles and shallow runs may be considerably less than 0.20 m. Depth should perhaps more appropriately be set as equal to or exceeding the depth of water in riffles upstream of the culvert (see *Recommendation #1*).

Water Velocity in Culvert: Water velocity criteria have been intensively researched as a great deal of work has been done on fish swimming performance which is directly related to this. Coarse guidelines (based on adult salmonids) were set as velocities not to exceed 0.9 m/s (for culverts >24.4 m length) and 1.2 m/s (culverts <24.4 m length) (Dane, 1978; Adams and Whyte, 1990). Belford and Gould (1989) estimated that a velocity of 0.6 m/s allowed passage of salmonids (including brook trout). Warren and Pardew (1998) found that fish passage was substantially reduced at water velocities >0.40 m/s for non-migratory, small stream (non-salmonid) fishes. Peake (2008) conducted a literature review of fish swimming speed relative to culvert design in Newfoundland and Labrador. His recommended maximum velocities for species of fish relevant here were:

American eel (juvenile)	0.20 m/s
Atlantic salmon (adults)	0.90 m/s
Atlantic salmon (parr)	0.30 m/s
Brook trout (adults)	0.50 m/s

[4] These outfall barriers are also known as perched culverts.

Brook trout (juveniles)	0.30 m/s
White sucker (adults)	0.60 m/s
White sucker (juveniles)	0.45 m/s
Three spine stickleback (adults & juveniles)	0.20 m/s

There is very little to no information on swimming performance of cyprinids (minnows), and Peake (2008) suggests that for those species for which data are lacking a maximum velocity of 0.30 m/s is recommended by extrapolating from other known species.

There are two ameliorating factors which may make any criterion used for maximum velocity conservative. First, small fish tend to swim near the culvert walls and bottom where velocity is substantially reduced due to boundary effects of the culvert wall. Thus, surface velocity may not be a reliable measure on which to base a criterion. Secondly, at least for Corrugated Metal Pipe (CMP) culverts and open-bottom culverts there are roughness elements (culvert corrugations or natural streambed, respectively) which reduces the water velocity. Thus, the fish may be able to pass culverts that initially appear to have water velocity in excess of criteria – a suggestion supported by Blank et al. (2005) when comparing actual tests of fish passage through culverts with passage classification by FishXing, a standard computer software for evaluating fish passage through culverts. Those authors found FishXing to be conservative and there to be considerable fish passage occurring despite the program assessing the culvert as a barrier.

A fourth criterion for culvert installation is the slope of the culvert, with a culvert, generally, not to exceed a slope of 0.5% (Dane, 1978; Adams and Whyte, 1990; NSDoE, 1997; Langill and Zamora, 2002). I have not included slope criterion in this research as this was not measured with sufficient accuracy to discriminate greater than or less than 0.5%.

The purpose of this research on culverts as barriers in the St. Mary's River was to identify and priorize culverts for remediation to ensure access to upstream reaches. Impassable barriers offer potential high yield restoration opportunities as a relatively small amount of effort may "open up" large amounts of currently unused habitat. The target species (design fish) were originally adult (spawner) Atlantic salmon and brook trout, but the analysis also assesses the culverts from the perspective of other fish species in the community.

2.0 STUDY AREA

The St. Mary's River drains an area of approximately 1,350 km^2 and is composed of four "branches" or major channels (Figure 1): the West Branch (56 km long; drainage area 470 km^2), East Branch (27 km long; drainage area 389 km^2), North Branch (27 km long; drainage area 82 km^2) and Main Branch (19 km long; draining entire watershed) (Hart-Buckland Nicks, 1995). These branches merge at two points. The East and North branches combine at 45^{o}18'23"N, 62^{o}03'49"W near Aspen, and the East and West branches at 45^{o}15'20"N, 62^{o}03'48"W, a short distance downstream of Glenelg Lake. Downstream of this latter confluence the river is known as the Main Branch and subsequently flows into the Atlantic Ocean via Northwest Arm at approximately 45°08'00"N, 61°59'01"W.

Dominant land use of the West Branch has been forestry (Rutherford, 2007), with agriculture comprising a small amount of land on this branch. Highway 348 runs along the north side of the river to Lower Caledonia, at which point it crosses the river and parallels the West Branch to Trafalgar. There is an extensive road network throughout the West Branch drainage of old and contemporary forestry roads. Dominant land use of the East Branch has been agriculture with lesser forestry activity. There is extensive roading throughout the East and North branches with Highways 347 and 7, respectively, paralleling these branches, and secondary and forest roads branching off of these main highways. Estimated road density[5] in the St. Mary's River watershed is 0.94 km/km^2.

3.0 METHODS

Field assessments of culverts were conducted between June 29 and November 9, 2009 to evaluate culverts for fish passage. A minimum of 100 culverts was targeted to assess and, ideally, culverts assessed would be distributed in approximate proportion to drainage area by each branch. Culverts were not randomly selected, but rather the survey was designed to concentrate initially on those areas in lower stream reaches near the confluences of streams and the St. Mary's River mainstem as impassable obstructions in these lower reaches would have the greatest effect. Culverts were visited and assessed using a standardized data sheet (Appendix 1) which was compiled and modified from other survey methodologies (e.g., Langill and Zamora, 2002; Hicks and Sullivan, 2008). In addition to general information collected, specific variables measured were: Road type (highway versus gravel), GPS location, culvert diameter, length, slope (measured with Abney Level or visually estimated), culvert shape and material, fill slope depth, culvert wetted width, high water mark, water depth, water velocity through culvert (floating chip method), culvert outfall drop, outfall pool dimensions, stream bankfull and wetted width. See Appendix 1 for complete list of information collected. On August 4 and 13, 2010, nine sites were re-visited to resolve ambiguities in the data.

Following the field assessment, culverts were assigned individual culvert identification numbers (1-99) for ease of identification. Culvert locations were subsequently mapped. Summary statistics were generated from all culverts assessed. Analysis focussed on the three mechanisms of obstruction: water depth, water velocity and outfall drop. A filter approach was taken in which culverts on non-ephemeral (perennial) streams were deemed to either meet conservative criteria (water depth >0.20 m, water velocity <0.20 m/s, outfall drop = 0.0 m) and not analyzed further, or to not meet these criteria and be subject to more detailed analyses. This more detailed analysis factored in length of stream potentially obstructed upstream of the culvert and fish species targeted for passage. Culvert water depth, water velocity, and outfall drop were each plotted against extent of stream above the culvert, and the culverts for each of these mechanisms

[5] Road density provided from Geographic Information System (GIS) data by Andrea Doucette of NewPage Port Hawkesbury and does not include the class of "cart track". Estimated distances of roads, by class, are: Collector 140 km; Loose surface 873 km; Major local 145 km; Minor local 61 km; and Trunk 45 km.

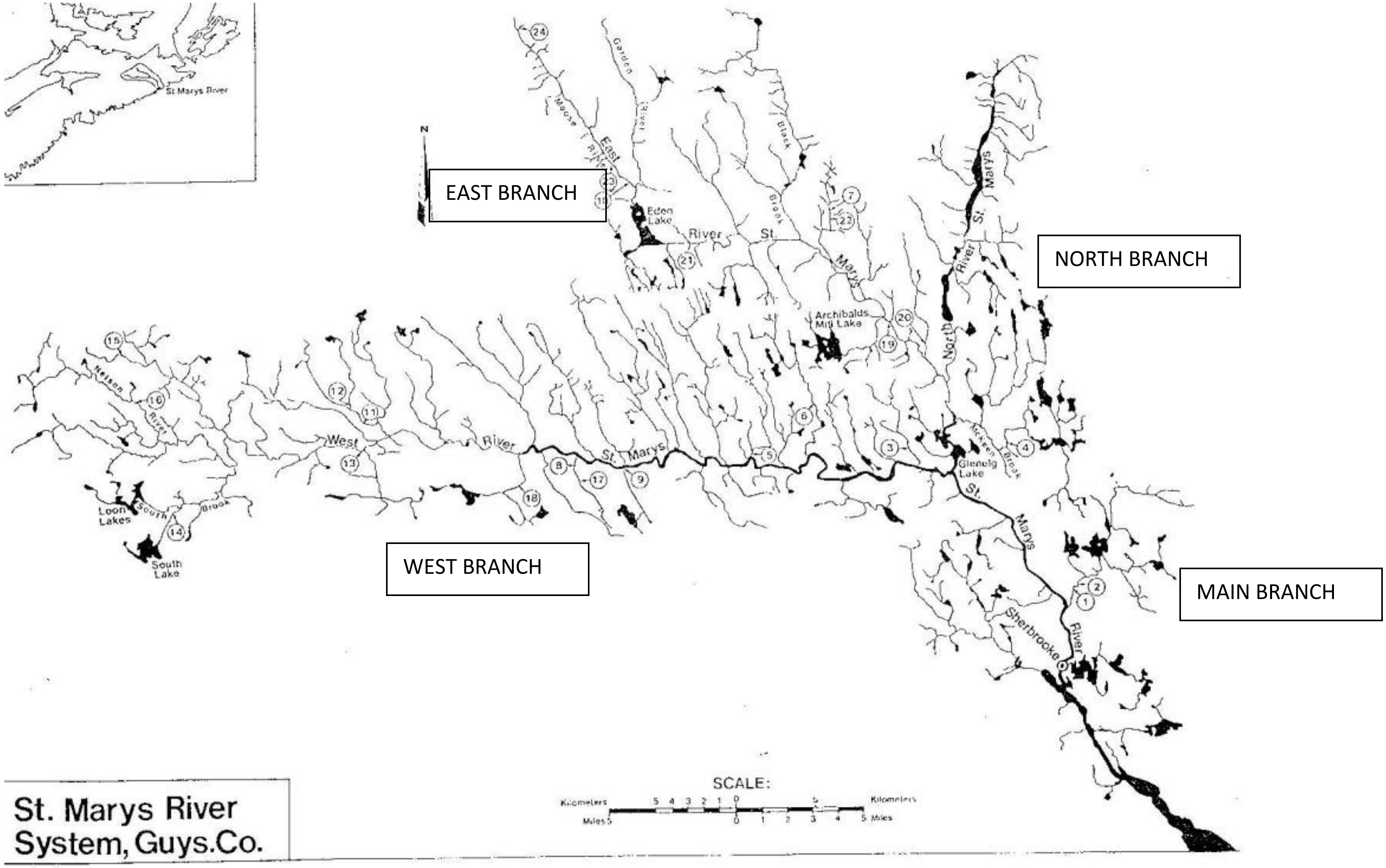


Figure 1: St. Mary's River watershed illustrating four "branches" of river. Circled numbers are electrofishing sites and not relevant to the report presented here.

then divided, subjectively, into those of primary concern and secondary concern. Streams of length <1.0 km upstream of the culvert were deemed not significant for the effort required for restoration. Based on the rankings of these culverts as being of primary or secondary concern, the eight most significant culverts were identified and priorized, and prescriptions for restoration of access through the culvert developed.

4.0 RESULTS & DISCUSSION

Between June 25 and November 9, 2009, a total of 99 culverts were assessed in the St. Mary's River watershed; this is one less than the targeted 100 culverts as culverts on larger, and hence more significant fish-bearing streams, are relatively rare in the watershed with bridges being a common structure for roads across 2^{nd} and 3^{rd} order streams. Culverts are very common on the small, 1^{st} order tributaries but less so on larger streams. The distribution of sampled culverts was 45.4% on the West Branch, 31.3% on the East Branch, 11.1% on the North Branch and 12.1% on the Main Branch (see Figure 2 for locations of assessed culverts). Areal distribution of drainage in the watershed is approximately 35% West Branch, 29% East Branch, 6% North Branch, and 30% Main Branch. From this it is apparent that the West and North Branches were oversampled relative to drainage area, the Main Branch undersampled, and the East Branch met the target of sampling according to areal representation in the drainage.

Culverts under highways (paved roads) constituted 32.3% of those assessments and under gravel (secondary) roads 67.6%. Summary statistics of culvert dimensions (length, diameter, shape and material) are provided in Table 1 and Figure 3 for all sites visited. The predominant culvert type is round Corrugated Metal Pipe (CMP), comprising 62.7% of surveyed culverts, followed distantly by wooden box culverts (14.9%). The remaining culvert types each contributed <10% of those surveyed.

Table 1: Summary statistics of culverts surveyed in St. Mary's River watershed.

	Culvert diameter (mm)	Culvert length (m)
Mean	1,056.5	12.7
Median	1,000.0	11.4
Standard deviation	511.9	4.75
Range	80 - 2,630	4.6 - 25.1
Number of culverts	98	89

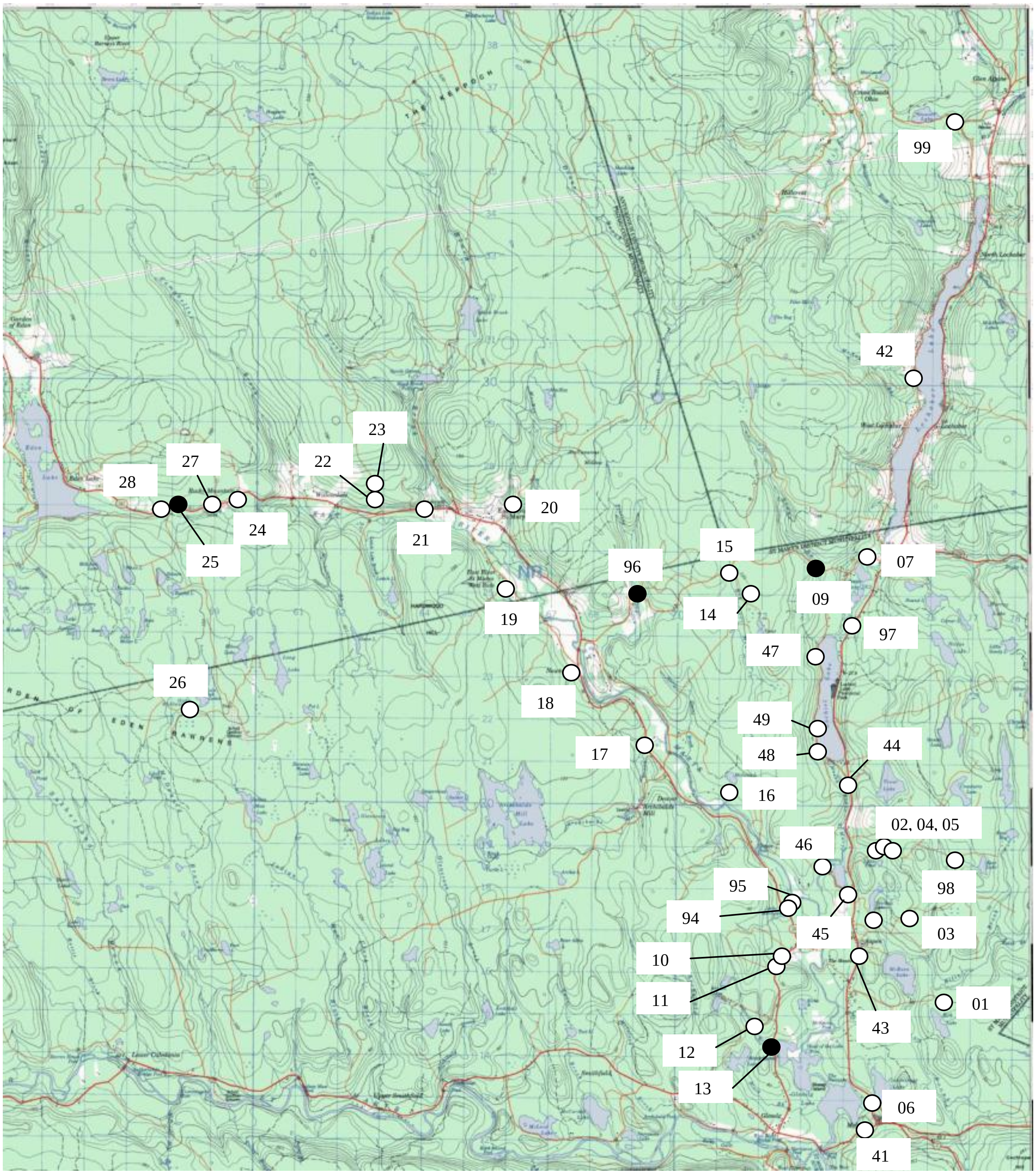


Figure 2: Approximate locations of culverts assessed in the East and North branches of the St. Mary's River. Numbers indicate culvert identification number. Filled circles are identified priority culverts. See also Appendix 2 for GPS and narrative description of location of culverts.

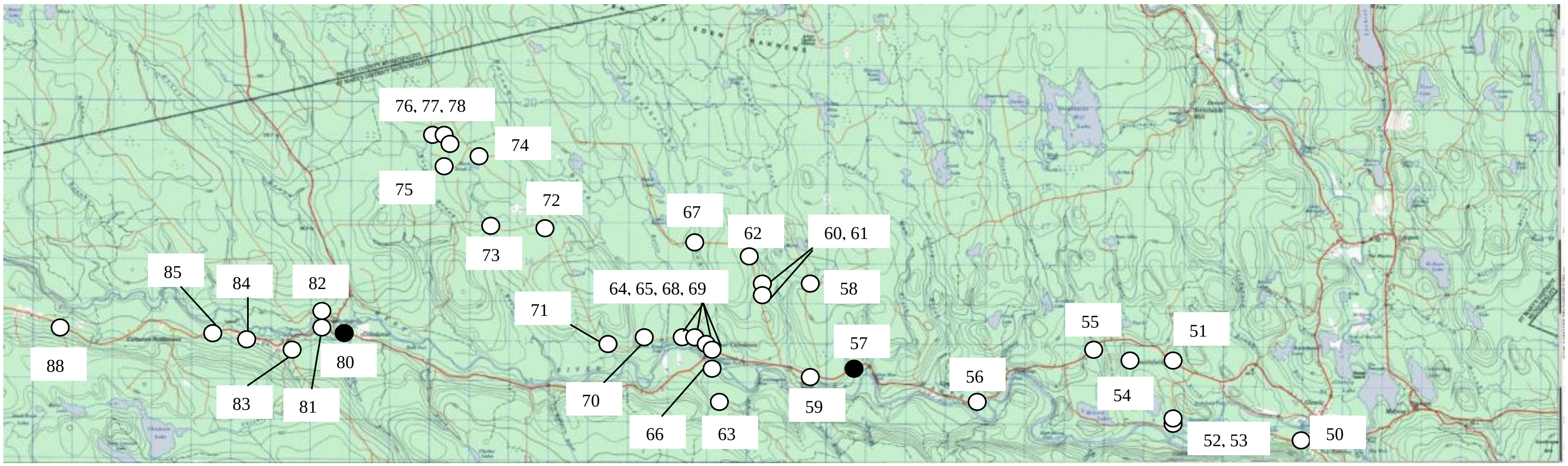


Figure 2 (cont'd): Approximate locations of culverts assessed in the West Branches of the St. Mary's River. Numbers indicate culvert identification number. Filled circles are identified priority culverts.

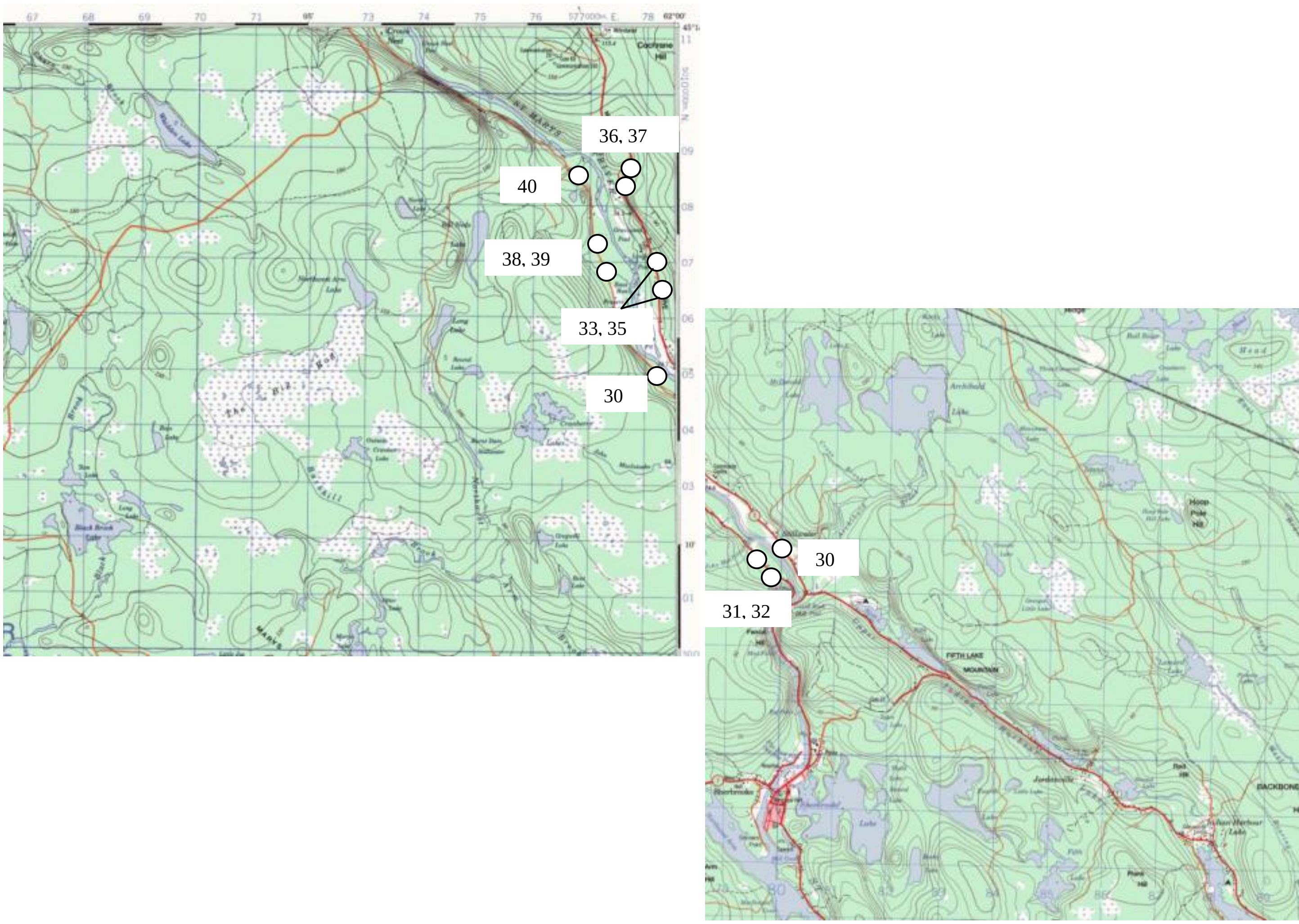


Figure 2 (cont'd): Approximate locations of culverts assessed in the Main Branch of the St. Mary's River. Numbers indicate culvert identification number.

Of the total culverts surveyed water depth was <0.05 m in 34% of the culverts, <0.10 m in 50% of the culverts, and <0.20 m in 68% (Figure 4). However, many of these were small culverts and small streams with naturally little water depth, and so this must be interpreted cautiously. Water velocities (measured in 78 culverts) were <0.2 m/s in 32% of culverts, <0.5 m/s in 62.8% and <0.9 m/s in 82% of those surveyed (Figure 4). Outfall drops in 96 culverts where this was measured was 0 m in 54%, <0.10 m in 69.8% of culverts and <0.20 m in 77.0% (Figure 4). There were extremes of velocity and outfall drop, in excess of 1.0 m/s and 1.0 m, respectively.

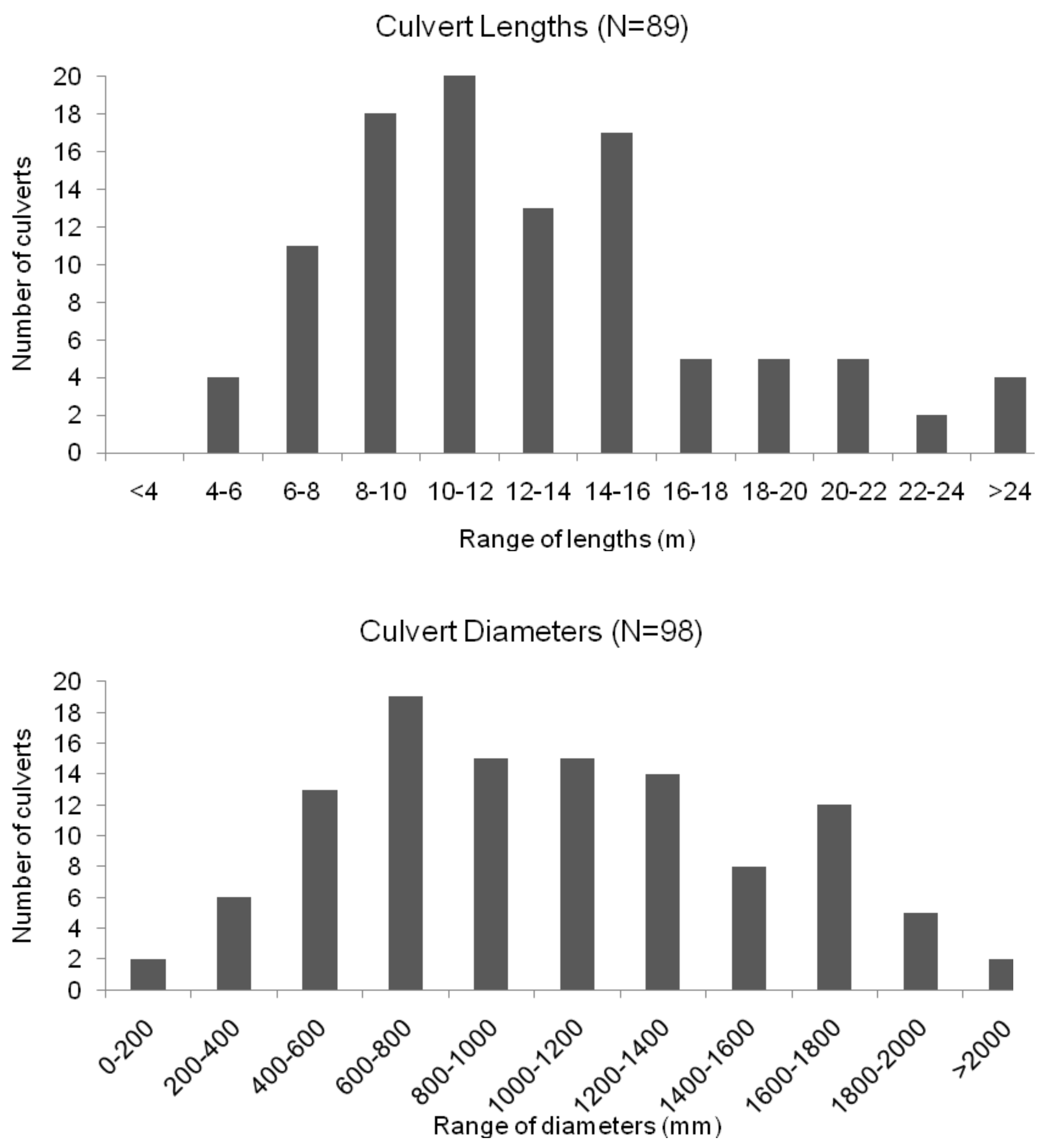


Figure 3: Frequency distribution of culvert lengths and diameters surveyed in the St. Mary's River watershed.

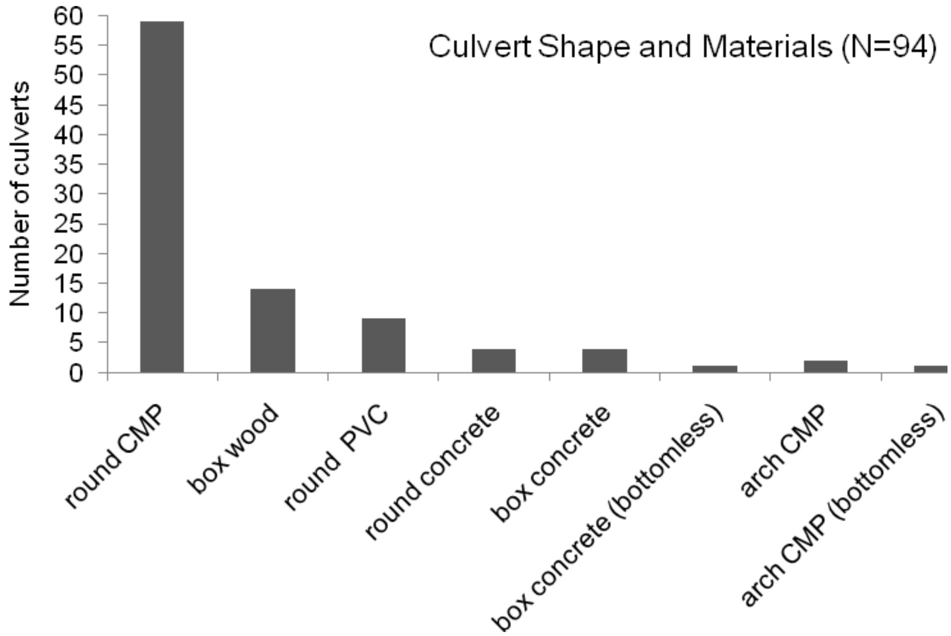


Figure 3 (cont'd): Frequency distribution of culvert shape and materials surveyed in the St. Mary's River watershed. CMP = Corrugated Metal Pipe.

Of the 99 culverts surveyed, 10 could not be unambiguously identified and mapped subsequent to the field visits, due to: (1) Locations provided in field notes ambiguous (N=3), (2) No road or brook on map at GPS coordinates provided (N=2), or (3) Road not on map so location of crossing approximate only; guessing this is correct stream (N=5). Of the remaining 89 culverts, 27 were on streams not shown on maps[6] suggesting the streams are ephemeral or insignificant. This left 62 culverts on perennial streams of which 40 were on 1st order streams, 16 on 2nd order streams, 3 on 3rd order streams, and 3 on lake or pond outflows. Culvert locations are shown in Figure 2.

Of the 62 culverts on perennial streams, 33% had water depth >0.20 m, 28.6% had velocities <0.20 cm/s and 60% had no outfall drop (i.e., 0.0 m) (Table 2). Those culverts in which these criteria were not met are illustrated in Figure 5.

[6] Maps used for locating culverts were 1:50,000 scale National Topographic Series using data from 1979 and from 1988 to 1997. Older maps were used in addition to more current maps to assess whether small tributaries were included on earlier maps and omitted on later versions.

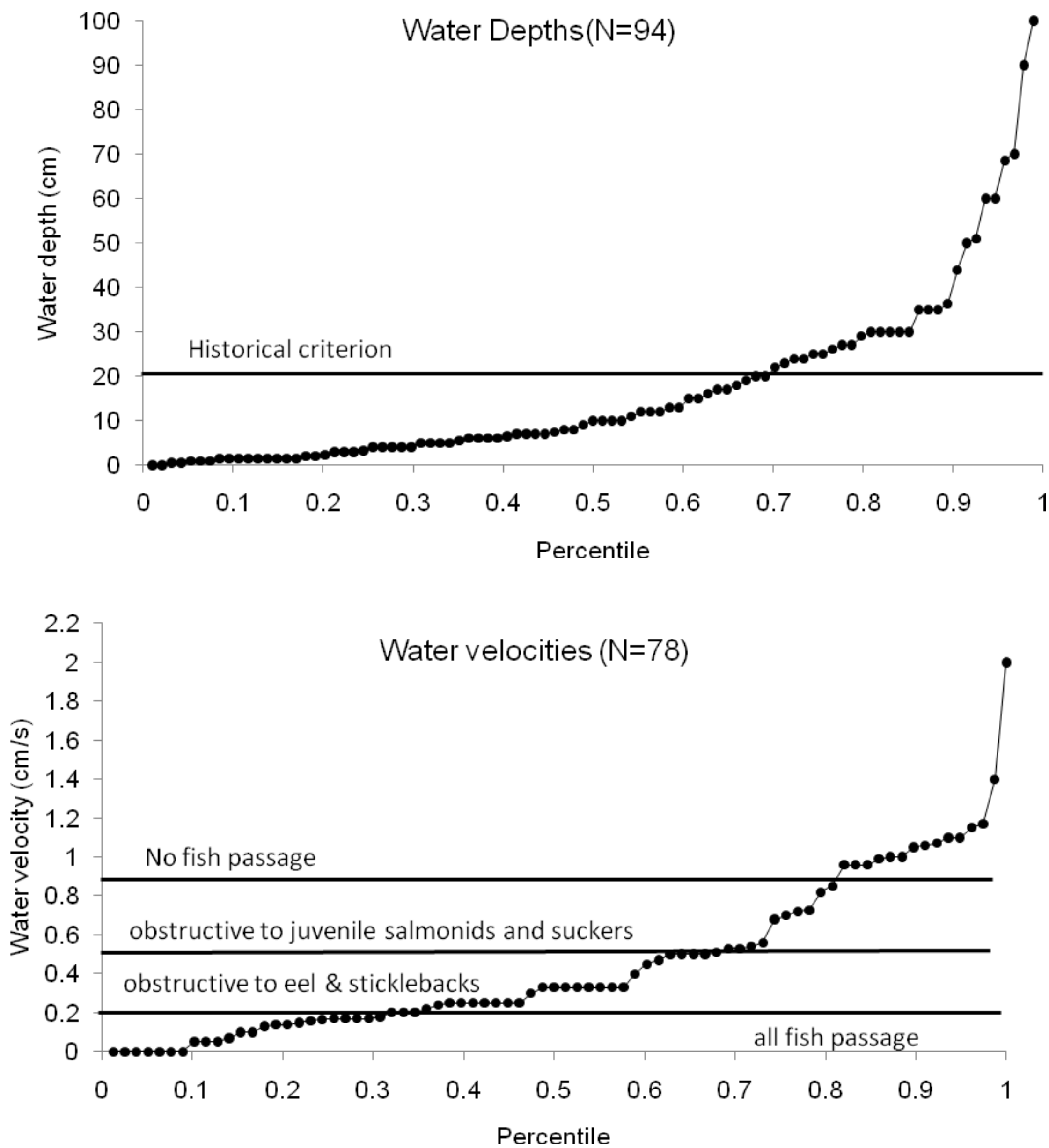


Figure 4: Frequency distribution of culvert water depths and velocities surveyed in the St. Mary's River watershed. Water velocities obstructive to various fish are interpreted from Peake (2008).

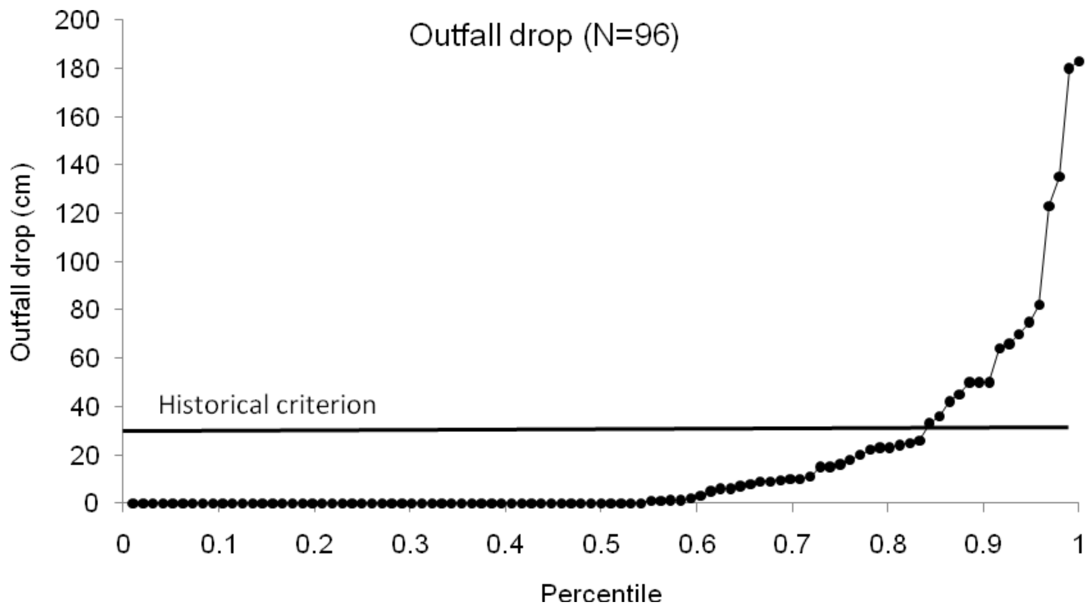
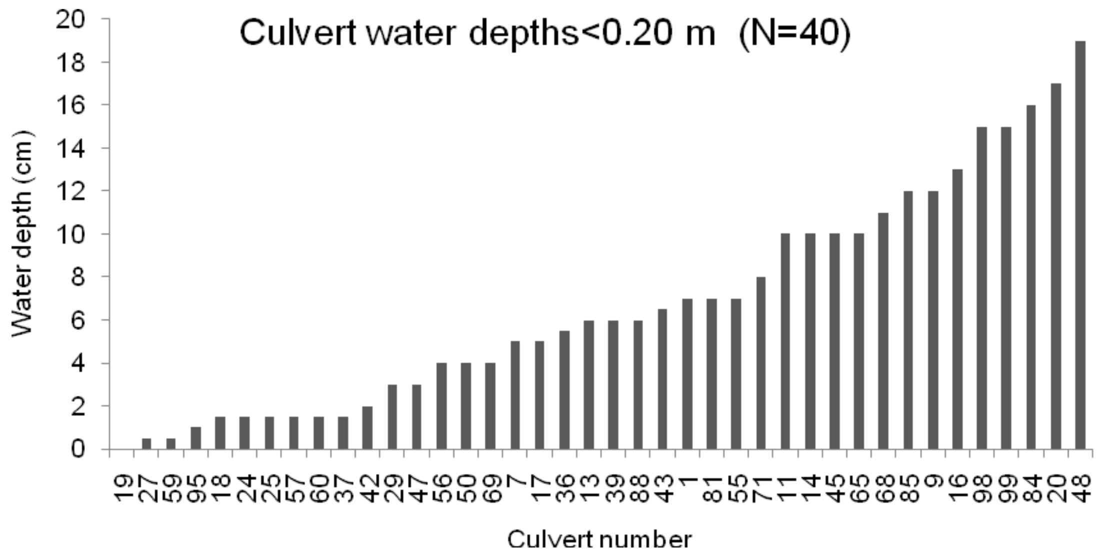


Figure 4 (cont'd): Frequency distribution of outfall drops surveyed in the St. Mary's River watershed.

Table 2: Summary statistics of criteria compliance on 62 culverts unambiguously located on perennial streams. Number of culverts in brackets.

	Criterion met	Criterion not met	Total measurements	Culverts which met criteria
Water depth	>20 cm/s (20)	<20 cm (40)	60	6, 12, 15, 26, 28, 52, 53, 58, 61, 63, 64, 66, 67, 73, 80, 89, 90, 94, 96, 97
Water velocity	<20 cm/s (14)	>20 cm/s (35)	49	1, 7, 16, 19, 47, 48, 53, 61, 64, 65, 81, 94, 95, 97
Outfall height	0 m (37)	>0 m (24)	61	1,6, 11, 12, 13, 14, 15, 16, 18, 20, 26, 28, 39, 42, 43, 44, 45, 48, 52, 53, 58, 59, 61, 63, 64, 65, 66, 67, 68, 73, 85, 88, 90, 94, 95, 97, 98



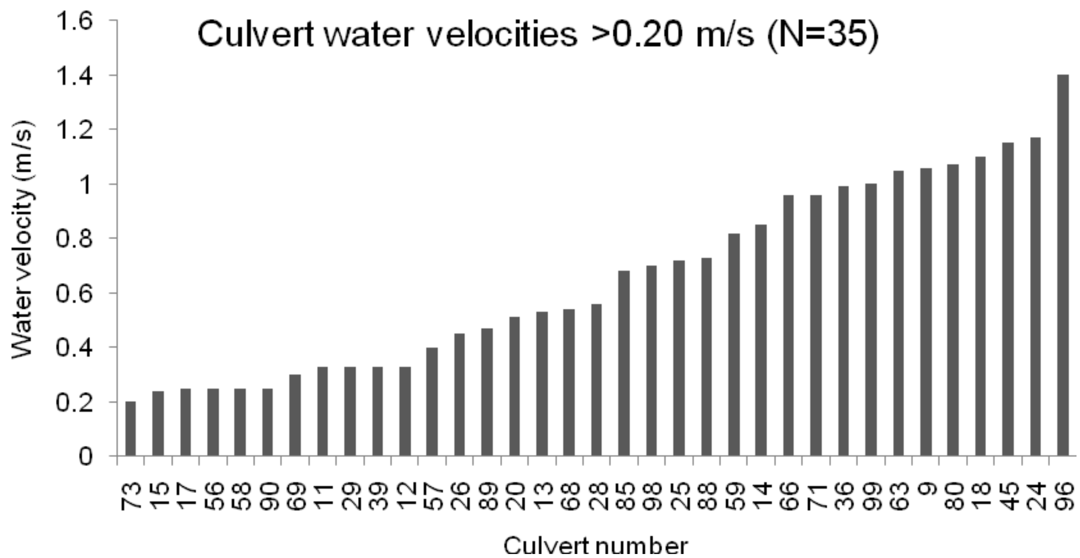


Figure 5: Frequency distribution of culvert water depths and velocities surveyed in the St. Mary’s River watershed which did not meet criteria.

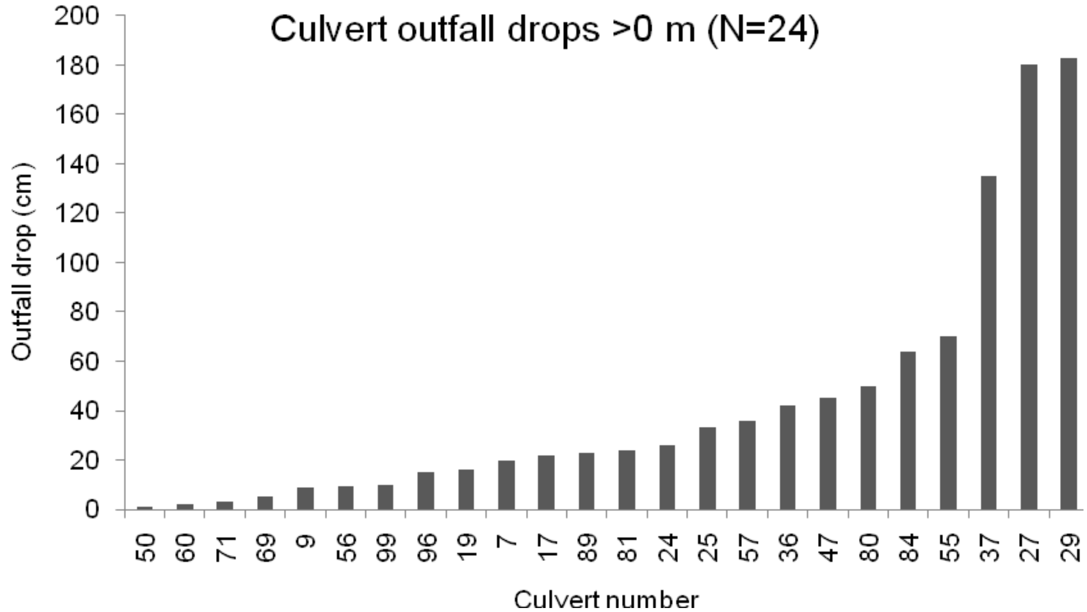


Figure 5 (cont'd): Frequency distribution of outfall drops surveyed in the St. Mary's River watershed which did not meet criterion.

These criteria should be treated as guidelines only, as expecting water depth of 0.20 m in a culvert on a 1st order stream with an average depth of 0.10 m is not realistic. Similarly, trying to use a single criterion for water velocity and outfall drop depend upon the species of concern for passage; the requirements to pass American eel is much different from that required for Atlantic salmon. Therefore this analysis attempted to factor in "importance" of culverts as potential barriers in terms of area lost upstream of the culvert, and those species likely affected due to culvert conditions. Culverts were priorized as being of either primary or secondary concern (see Figures 6-8 for definition of primary and secondary concern for each category of water depth, velocity, and outfall drop).

Based on Figures 6-8, six culverts are identified as of primary concern in more than one category, three as primary concern in only one category, six as primary concern in one category and secondary in another, and nine as secondary concern in more than one category (Table 3). Of the six highest priority culverts, they may be ranked in order of amount of upstream habitat to which access could be restored as: culvert numbers 80, 96, 9, 55, 24 and 37. Together these account for approximately 27.5 km of habitat not presently accessible. The first four culverts should likely be the highest priority as each contains >3.0 km of upstream habitat, while the latter two have only 1.5 and 1.8 km of upstream habitat. Secondary priority culverts should include, ranked in order of decreasing area upstream, 68, 13, 57, 19[7], 25, 7, 24, 37. Together these account for approximately 22.0 km of habitat upstream. The eight highest priority culverts in the St. Mary's River watershed are provided in Table 4, and these represent approximately

[7] Note: this culvert (#19) deemed not significant based on photographs from field survey. Small, ephemeral stream of very low fish habitat value.

42.0 km of stream length inaccessible (assuming each culvert obstructive). These eight are distributed as four on each of the West Branch and East Branch and 62.5% being highway culverts. Of note is that only 32.3% of the 99 culverts assessed were highway culverts, yet 60% of the problem culverts are associated with highway crossings. Similarly, wooden box culverts represent only 14.9% of the 99 culverts assessed but are 4 of the 8 problem culverts.

Detailed prescriptions to restore access for each of these nine culverts are provided below.

Table 3: Culverts identified as of primary or secondary concern by number of categories (categories are water depth, water velocity, outfall drop). Values are culvert identification number.

Primary concern in >1 category	Primary concern in 1 category, secondary concern in second	Primary concern in only 1 category	Secondary concern in >1 category
9	7	39	12
24	13	63	16
37	19	66	17
55	25		20
80	57		28
96	68		56
			85
			89
			90

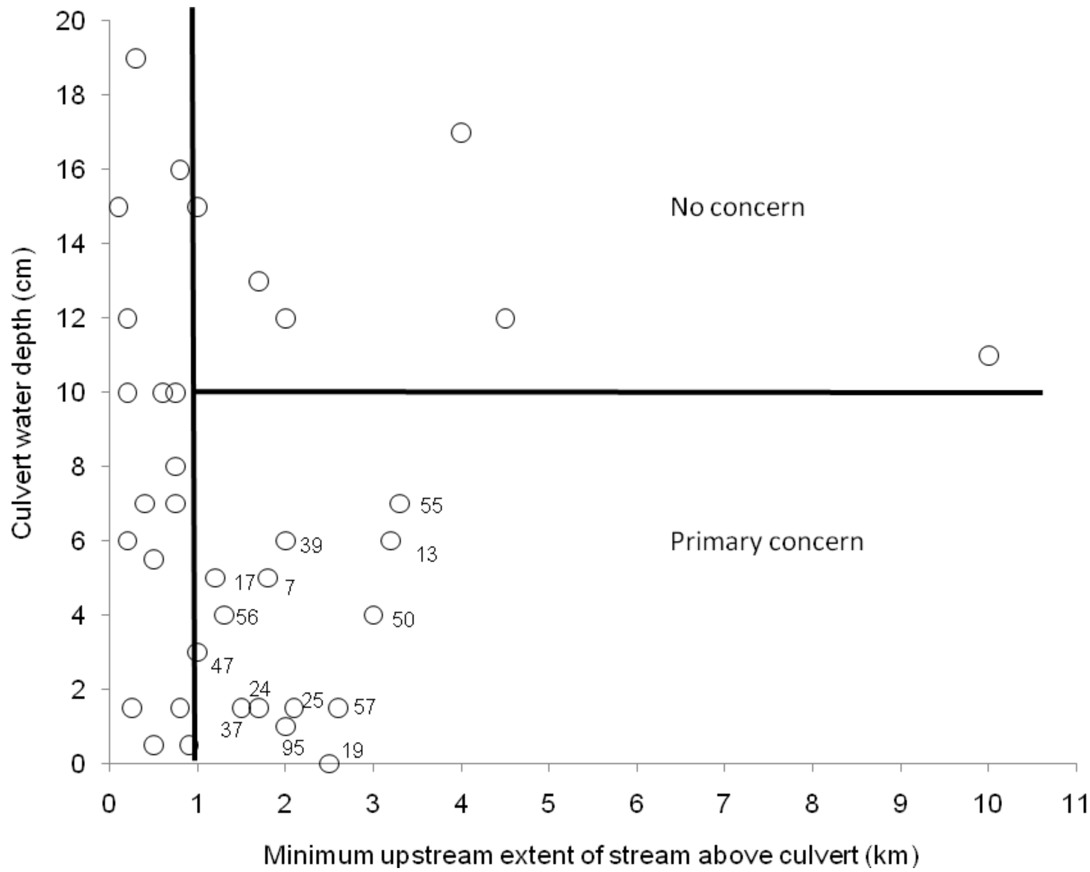


Figure 6: Plot of culvert water depth against length of upstream habitat potentially obstructed by culvert. Obstruction of upstream lengths of <1.0 km are considered not significant from a restoration perspective. Water depths in excess of 10 cm are considered to not pose an obstruction to most fish passage (i.e., "no concern"). Water depths of <10 cm, and upstream length >1.0 km are identified as problematic and individual culverts meeting these limits are presented by their identification number.

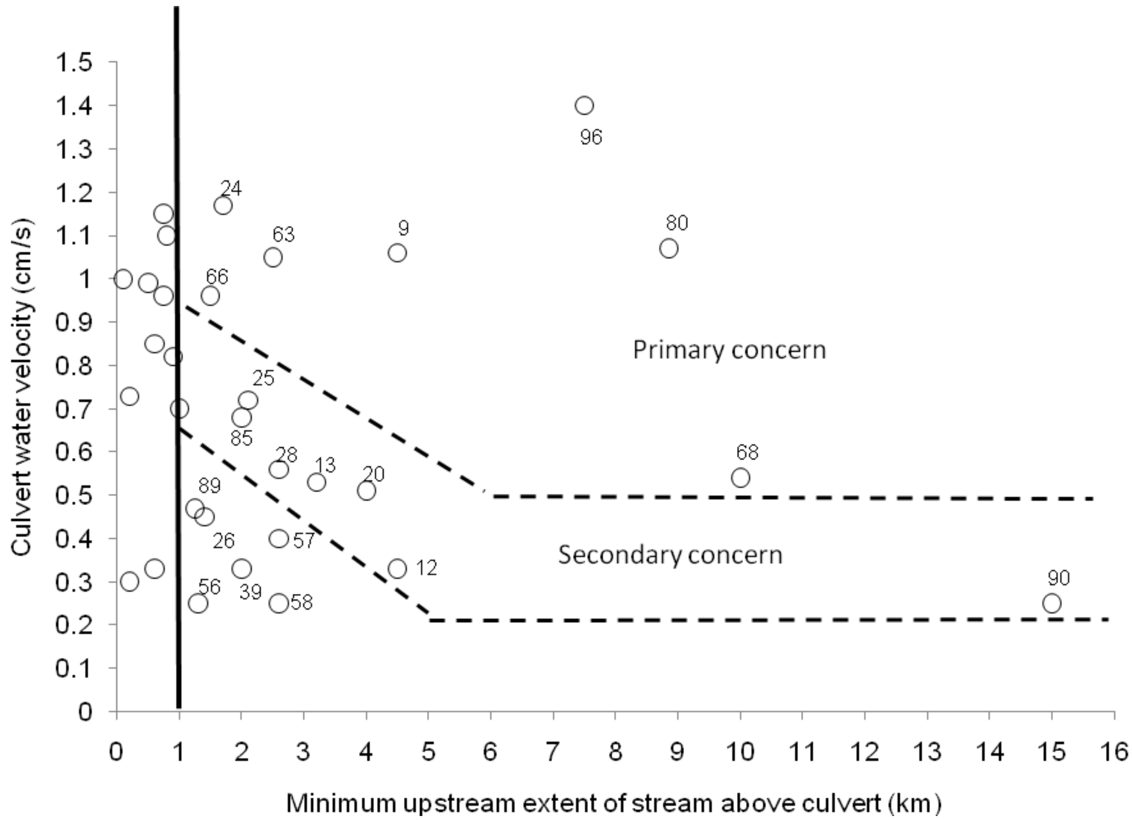


Figure 7: Plot of culvert water velocity against length of upstream habitat potentially obstructed by culvert. Obstruction of upstream lengths of <1.0 km are considered not significant from a restoration perspective. Velocities >20 cm/s begin to be obstructive to fish species and the degree of obstruction depends upon the ability of the fish species to swim. All culverts with water velocity >20 cm/s and upstream length >1.0 km are identified and individual culverts meeting these limits are presented by their identification number. Primary concern are those culverts likely to exceed swimming abilities of salmonids (adults and juveniles) and also obstructing longer lengths of stream. Secondary concern are those culverts likely to be obstructive to American eel or sticklebacks, of obstructive to salmonids but with relatively little stream length upstream of the culvert.

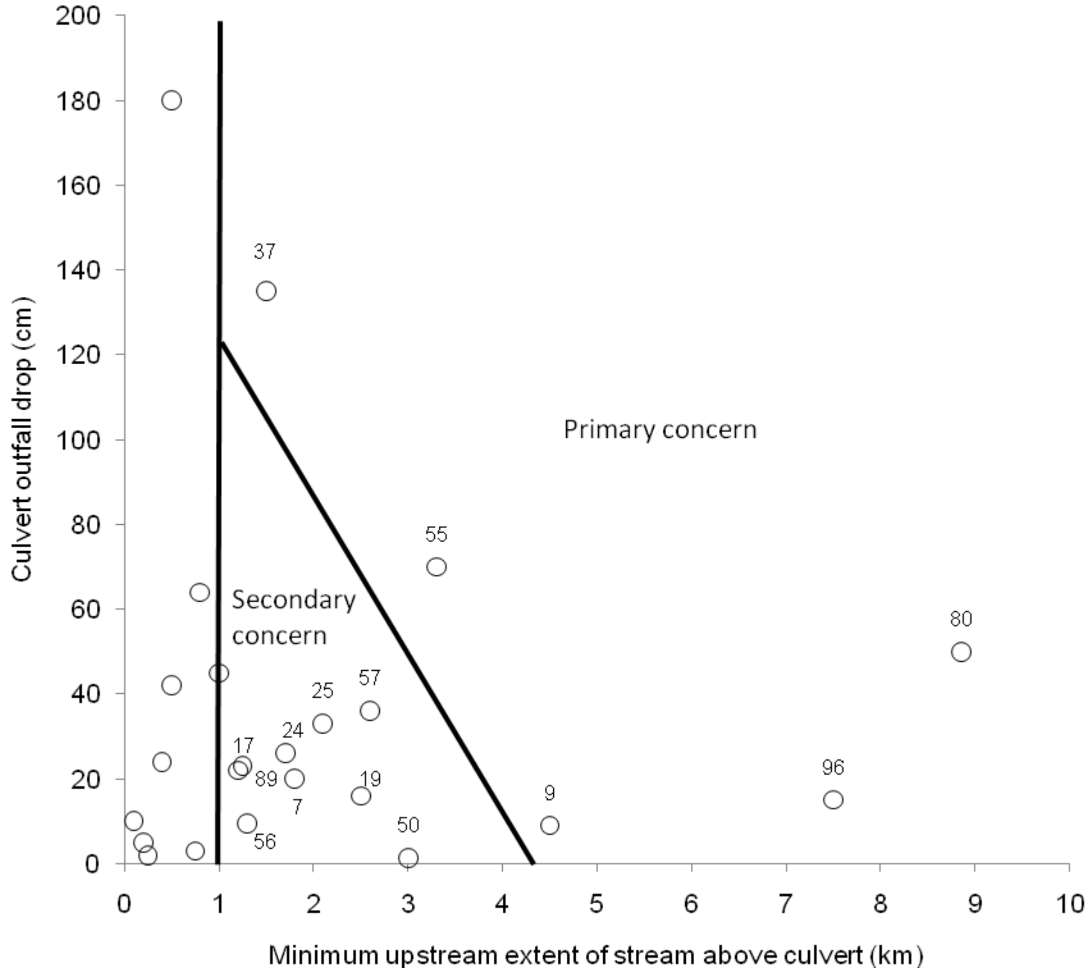


Figure 8: Plot of culvert outfall drop against length of upstream habitat potentially obstructed by culvert. Obstruction of upstream lengths of <1.0 km are considered not significant from a restoration perspective. All culverts with outfall drop >0.0 m and upstream length >1.0 km are identified and individual culverts meeting these limits are presented by their identification number. Primary concern are those culverts with either a large outfall drop or obstructing a long distance of stream. Secondary concern are those culverts obstructive of relatively little stream length upstream of the culvert.

Table 4: Summary table of highest eight priority culverts in St. Mary's River watershed

Culvert number	Stream name	Km habitat lost	Road type	Culvert type	Problem(s)	Solution(s)	Cost (Low, Medium, High)
80	McQuarries Brook	8.85+	Highway	Wooden box	Velocity; outfall drop	Baffles; fishway	Low
96	Fraser's Brook	7.5+	Secondary	CMP	Velocity; outfall drop	Baffles; pool development	High
9	Bogg's Brook	4.5+	Secondary	CMP	Velocity; depth; possibly outfall drop	Baffles; pool development	Medium-High
55	Unnamed tributary to MacLeod Lake	3.3+	Highway	Wooden box	Water depth; outfall drop	Baffles; fishway	Low
68	Hattie Brook	10.0+	Secondary	Arch CMP	Velocity	Baffles	Medium
13	Bryden Brook (Old Church Road)	3.2	Highway	CMP	Water depth; velocity	Baffles	Medium-High
57	Tributary upstream of Indian Man Pool	2.6	Highway	Wooden box	Water depth; outfall drop	Baffles; pool development or fishway	Medium-High
25	Tributary at Rocky Mountain	2.1	Highway	Wooden box	Water depth; velocity; outfall drop	Baffles; pool development or fishway	Medium-High

5.0 RESTORATION PRESCRIPTIONS

The following prescriptions are for the eight culverts identified as priorities in Table 4 and are provided in order of priority from greatest to least. See also Figure 2 for locations of culverts.

Culvert # 80 – McQuarries Brook (Highway 348 crossing)

This is a single wooden box culvert (15 m long X 2.3m width) suffering from excessive velocity and large outfall drop (Plate 1)

The prescription is:

1. Installation of wooden baffles. The baffles would not be the Offset Baffle design as the objective here is to not only reduce water velocity but also increase water depth. Thus, a weir approach similar to a fishway would be appropriate. Each weir should have a notch in the top to allow water to spill through. This work should be relatively easily completed by unskilled labourers using treated 2X6s (which would raise the water to a depth of 14 cm) notched to a depth of 5.0 cm. Bedload from upstream is not a significant problem here as the local gradient is low and so it is primarily fines being moved as bedload rather than gravel/cobble. Specific design of these baffles (number baffles in culvert; distance between them) should be determined in consultation with engineers or restoration experts with experience. The baffles can be installed by pre-drilling the wood and using large lag bolts to hold them in place.

2. The outfall drop of this culvert is problematic as development of an outlet pool to backwater the culvert would be extensive, requiring raising the water level by 0.5 m, and the culvert is effectively at the confluence of McQuarries Brook and the West Branch, St. Mary's River, leaving very little space in which to develop the pool. Further, the existing pool is very large and deep. I recommend that rather than pool development, a small fishway be constructed from the outfall pool into the culvert. The fishway design could be a continuation of the notched weir baffles and also made of treated lumber. Success of this structure to allow fish passage should be monitored (*Recommendation #2*).

The design fish for this restoration are salmonids, primarily adults, and the restoration concept is resting pools of $\geq$9.0 cm depth, and access between pools via the notch in the weir. This approach of wooden baffles and fishway, constructed and installed by hand, will be less expensive than extensive pool development.

Plate 1: Outfall of McQuarries Brook (Culvert #80).

Culvert # 96 – Fraser's Brook (College Grant Road crossing)

This crossing is paired CMP culverts (each 12.5 m long X 1.7 m width) with sluices attached at the downstream end to act as fishways (most likely not effective) and an insufficient attempt to create an outlet pool by using a notched plastic weir downstream of the culvert (Plate 2). This crossing suffers from excessive velocity and large outfall drop. In addition, the little flow present in the brook at low flows is split between the two large culverts resulting in shallow water depth in each culvert.

The prescription is:

1. Consult with Nova Scotia Department of Transportation and Infrastructure Renewal, Nova Scotia Department of Environment, and Department of Fisheries and Oceans about the possibility of installing an artificial, low berm to direct all flow into one of the two culverts during low flows. At higher flows the water would spill over the berm into the second culvert. The intent is to concentrate flow in a single culvert at low flow to ensure sufficient depth, and require restoration work on only a single culvert. The second culvert is then only for moderate and high flows.

2. Remove existing ineffective plastic weir and metal sluices.

3. In the culvert to which flow is directed, install baffles to reduce velocity. If all flow can be placed in one culvert at low flow there should be sufficient water depth and so the Offset Baffle design would be appropriate. If flow cannot be placed in single culvert, than full-span weir baffles in each culvert are recommended. Specific design of these baffles (number baffles in culvert; height of baffles, distance between them) should be determined in consultation with engineers or restoration experts with experience. These baffles will need to be fabricated of metal and bolted or welded in place, which is more complex than simple wooden baffles.

4. Raise outfall pool by constructing two downstream control weirs of rock. A single weir would result in a large drop and so there should be two, each of lesser drops. Pools should be designed to meet criteria of Gosse et al. (1998), which are more conservative than Adams and Whyte (1990).

The design fish for this restoration is adults and juvenile salmonids; the resulting flow through the culvert, unless extensively backwatered, is expected to remain too great a velocity for weak swimmers (non-salmonids). The restoration concept is to concentrate flow in a single culvert (to provide sufficient depth), reduce velocity (by baffles) and eliminate outfall drop (via pool development). The cost for this restoration will be relatively high due to specialized skills and equipment required for baffle fabrication and installation, and requirement of heavy machinery and supply of rock to construct weirs.

Plate 2: Outflow culvert on Fraser's brook (Culvert #96) at low flow; showing spillway intended for fish passage.

Plate 2 (cont'd): Culvert on Fraser's Brook (Culvert #96) at high flow; Note green plastic weir submerged in flow.

Culvert # 9 - Bogg's Brook (College Grant Road crossing)

This crossing is a large CMP culvert (15.9 m long X 1.8 m width) that has weakened over time and is "bent" or "kinked" approximately 4 m from inflow end. This crossing suffers from excessive velocity, insufficient water depth and a small outfall drop (Plate 3).

The prescription is:

1. Placement of baffles (notched weir) to decrease velocity and also increase water depth. As with Fraser's Brook (culvert #96) these baffles will need to be of metal and bolted or welded in place, which is more complex than simple wooden baffles. Specific design of these baffles (number baffles in culvert; height of baffles, distance between them) should be determined in consultation with engineers or restoration experts with experience.

2. The outfall drop is quite small (9 cm) and there is a well developed outfall pool already present. Construction a single small rock weir at the outlet pool discharge to raise the water by 12 cm is recommended to ensure entry of fish into the culvert barrel.

The design fish for this restoration are adults and juvenile salmonids. The resulting velocity through the culvert, unless extensively backwatered, is expected to remain too great for weak swimmers (non-salmonids). The restoration concept is to decrease velocity, increase water depth, and eliminate outfall drop. This restoration should be done in conjunction with Fraser's Brook (culvert #96) as both are on the College Grant road and approximately 5.5 km apart. For efficiency they should be done together as machinery and equipment are brought in to work on one.

The cost for this restoration may be relatively high due to specialized skills and equipment required for baffle fabrication and installation, and heavy machinery required to construct rock weir.

Plate 3: Inflow (left) and outflow (right) of culvert at Boggs Brook (Culvert #9).

Culvert # 55 – unnamed tributary to McLeod Lake (Highway 348 crossing)

This crossing is paired wooden box culverts (each approx 2 m wide; length not measured). This crossing suffers from insufficient water depth and large outfall drop. In addition, the inflow end of the culvert is collapsing (Plate 4). Further, the little flow there is in the brook is split between the two large culverts resulting in shallow water depth in each culvert.

The prescription is:

1. Removal of debris from upstream end.

2. Assess and determine how culvert may be repaired. Consult with Nova Scotia Department of Transportation and Infrastructure Renewal about options for repair.

3. Installation of wooden baffles, similar to McQuarries Brook (culvert #80) prescription. Each weir should have a notch in the top to allow water to spill through. This work should be relatively easily completed by unskilled labourers using treated 2X6s (which would raise the water to a depth of 14 cm) notched to a depth of 5.0 cm. Moving bedload from upstream may be problematic. These baffles will require more frequent monitoring and repair than those of McQuarries Brook. Specific design of these baffles (number baffles in culvert; distance between them) should be determined in consultation with engineers or restoration experts with experience. The baffles can be installed by pre-drilling the wood and using large lag bolts to hold them in place.

4. The outfall drop of this culvert is problematic as development of an outlet pool to backwater the culvert would be extensive, requiring raising the water level by 0.7 m. I recommend that rather than pool development, a small fishway be constructed from the outfall pool into the culvert, similar to McQuarries Brook. The fishway design could be a continuation of the notched weir baffles and also made of treated lumber. Success of this structure to allow fish passage should be monitored (*Recommendation #2*).

The design fish for this restoration are salmonids, primarily adults, and the restoration concept is resting pools of $\geq$9.0 cm depth and access between pools via the notch in the weir. The cost for this restoration is expected to approximate that of McQuarries Brook. It is recommended that this stream crossing be restored before McQuarries Brook as it is smaller and can be a useful pilot project to work out problems before moving on to the larger, and more distant, McQuarries Brook.

Plate 4: Inflow (upper) and outflow (lower) of culvert on tributary to McLeod Lake (Culvert #55).

Culvert # 68 - Hattie Brook (Barren Brook Road crossing)

This crossing is paired pipe arch culverts (each (10.7 m long X 1.0 m width). This crossing suffers from excessive velocity (Plate 5).

The prescription is:

1. Installation of baffles would be problematic in these culverts due to small culvert diameter and difficulty working in confined space. The outfall drop is very small. Outlet pool development of this crossing would backwater the culvert, thereby reducing water velocity and eliminating outfall drop. A single rock control weir to raise the water level should be constructed to backwater the culvert.

The design fish for this restoration are American eel, white sucker, and cyprinids. There is a large amount of habitat upstream of this location, and backwatering the culvert should allow passage for the weak swimmers in addition to the strong swimming salmonids. The cost for this restoration should be at a low-medium level due to requirement for rock and heavy machinery, but the required weir is small size and could be rapidly and easily constructed.

Plate 5: Inlet of paired arch pipe culverts (upper) and outflow of one of these culverts (lower) on Hattie Brook (Culvert #68).

Culvert # 13 – Bryden Brook, Glenelg (Church Road crossing)

This crossing is paired CMP culverts (each 4.75 m long X 1.5 m width). This crossing suffers from insufficient water depth and excessive velocity (Plate 6).

The prescription is:

1. Placement of baffles (notched weir) to decrease velocity and also increase water depth. As with Fraser's Brook (culvert #96) these baffles will need to be of metal and bolted or welded in place, which is more complex than simple wooden baffles. Each weir should have a notch in the top to allow water to spill through. These should be quite low-head weirs as there is evidence of a great deal of substrate movement in this stream and the objective is to minimize extent to which substrate is trapped in the culvert. Specific design of these baffles (number baffles in culvert; height of baffle, distance between them) should be determined in consultation with engineers or restoration experts with experience. Baffles will have to be robust to withstand impacts of moving bedload. Substrate accumulation will have to be monitored and removed on a regular (multi-year) basis (see *Recommendation #3*).

The design fish for this restoration are salmonids, primarily adults, and the restoration concept is resting pools of $\geq$9.0 cm depth and access between pools via the notch in the weir. The cost for this restoration may be relatively high due to specialized skills and equipment required for baffle fabrication and installation, and need to build very strong due to the dynamic nature of the streambed.

Plate 6: Inflow (upper) and outflow (lower) of Bryden Brook (Glenelg) to paired culverts (Culvert #13).

Culvert # 57 – Tributary upstream of Indian Man Pool (Highway 348 crossing)

This crossing is a single wooden box culvert (22.3 m long X 1.2 m width). This crossing suffers from insufficient water depth and large outfall drop (Plate 7).

The prescription is:

1. Installation of wooden baffles, similar to McQuarries Brook (culvert #80) prescription. Each weir should have a notch in the top to allow water to spill through. This work should be relatively easily completed by unskilled labourers using treated 2X6s (which would raise the water to a depth of 14 cm) notched to a depth of 5.0 cm. Specific design of these baffles (number baffles in culvert; distance between them) should be determined in consultation with engineers or restoration experts with experience. The baffles can be installed by pre-drilling the wood and using large lag bolts to hold them in place.

2. Raise outfall pool by 40 cm by constructing two downstream control weirs of rock. Need to use weir to raise the existing pool by 40 cm, then have that feed into a second pool a short distance downstream. A single weir would result in a large drop and so there should be two, each of lesser drops. Pools should be designed to meet criteria of Gosse et al (1998). Access by heavy machinery may be problematic in this area and result in considerable impact.

3. If the outlet pool is deemed not feasible, a small fishway be constructed from the outfall pool into the culvert, similar to McQuarries Brook. The fishway design could be a continuation of the notched weir baffles and also made of treated lumber.

The design fish for this restoration are salmonids, primarily adults, and the restoration concept is resting pools of $\geq$9.0 cm depth and access between pools via the notch in the weir. The outfall drop must be overcome to allow access upstream. The cost for this restoration will depend upon the option chosen. The wooden baffles will be inexpensive; the fishway relatively inexpensive, and pool development expensive due to need for heavy machinery and rock. Overall cost is classified as medium-high.

Plate 7: Inflow (upper) and outflow (lower) of unnamed tributary to Indian Man pool (Culvert #57).

Culvert # 25 - Tributary at Rocky Mountain (Highway 347 crossing)

This crossing is a single wooden box culverts (16.6 m long X 1.1 m width). This crossing suffers from insufficient water depth, excessive velocity and large outfall drop (Plate 8)

The prescription is:

1. Installation of wooden baffles, similar to McQuarries Brook (culvert #80) prescription. Each weir should have a notch in the top to allow water to spill through. This work should be relatively easily completed by unskilled labourers using treated 2X6s (which would raise the water to a depth of 14 cm) notched to a depth of 5.0 cm. Specific design of these baffles (number baffles in culvert; distance between them) should be determined in consultation with engineers or restoration experts with experience. The baffles can be installed by pre-drilling the wood and using large lag bolts to hold them in place.

2. Raise outfall pool by 40 cm by constructing two downstream control weirs of rock. Need to use weir to raise the existing pool by 40 cm, then have that feed into a second pool a short distance downstream. A single weir would result in a large drop and so there should be two, each of lesser drops. Pools should be designed to meet criteria of Gosse et al (1998).

3. If the outlet pool is deemed not feasible, the second option is a small fishway be constructed from the outfall pool into the culvert, similar to McQuarries Brook. The fishway design could be a continuation of the notched weir baffles and also made of treated lumber.

The design fish for this restoration are salmonids, primarily adults, and the restoration concept is resting pools of $\geq$9.0 cm depth and access between pools via the notch in the weir. The cost for this restoration will depend upon the option chosen. The wooden baffles will be inexpensive; the fishway relatively inexpensive, and pool development expensive due to need for heavy machinery and rock. Overall cost is classified as medium-high.

Plate 8: Inflow of unnamed tributary at Rocky Mountain (Culvert #25).

6.0 RECOMMENDATIONS

Based on this work the following recommendations, in addition to the specific prescriptions, are provided.

Recommendation #1: Due to a single depth criteria not being applicable on all streams (i.e., requiring a 0.2 m depth in culvert of a first or second order stream may be inappropriate), depth requirements should reflect the typical or average depth of fast water (i.e., in riffles) upstream of the culvert. Mean and maximum riffles depths for a minimum of three riffles upstream of the culvert during low or baseflow should be established as the minimum in-culvert required water depth.

Recommendation #2: Efficacy of fishways to provide passage on MacQuarries Brook, and the unnamed tributary to McLeod lake, should be monitored. This can be done by visual observation or marking fish downstream and recovering upstream. This would be a small research project.

Recommendation #3: Regular monitoring of installed baffles, and replacement of damaged ones, is required to ensure their proper functioning in the future. This monitoring also include removal of accumulating debris at culvert inflow and among baffles.

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APPENDIX 1

Data sheet used for 2009 culvert survey of St. Mary's River watershed

GENERAL INFORMATION

Date	
Recorders Name	
Branch	
Stream Name	
Written description of location	
Site Number	
Road Name	
Road Type	
GPS Location	

CULVERT CHARACTERISTICS

Culvert Diameter (mm)	
Culvert Length (m)	
Culvert Slope (%); include method of estimation	
Culvert Shape	
Culvert Material	
Fill Slope Depth (m)	
Culvert Wetted Width (cm)	
High Water Mark (cm)	
Culvert Water Depth (cm)	
Culvert Water Velocity (m/s)	
Culvert Outfall Drop (cm)	
Culvert Maintenance	Hi /Lo /Mod / No
Other comments	

APPENDIX 1 (cont'd)

Data sheet used for 2009 culvert survey of St. Mary's River watershed (Cont'd)

STREAM CHARACTERISTICS

Pool Dimensions (width, length, maximum depth) (m)		
Is pool undercutting culvert?	YES NO	
Stream stage	low/med/high	
Measure	**Measurement Below Culvert**	**Measurement Above Culvert**
Bankfull Width (m)		
Wetted Width (m)		
Water Depth (cm)		
Beaver Activity/Type		

BARRIER EVALUATION

Barrier	Full	Partial	None
Barrier Type			

SITE PHOTOS

Outlet view from downstream photo #		Inlet view from upstream photo #	
Downstream view from culvert photo #		Upstream view from culvert photo #	

APPENDIX 2

Detailed locations of culverts assessed in St. Mary's River culvert survey

Culvert Identification Number	Date	System Name	Road Name	Road Type	GPS Location	
1	07-Jul-09	McKeen's Brook	McKeen's Road	Secondary	45 17' 09.6"	62 01' 07.6"
2	25-Jun-09	McKeen's Brook	Graham's Road	Secondary	45 19' 07.8"	62 02' 13.7"
3	25-Jun-09	McKeen's Brook	Unnamed	Secondary	45 18' 23.4"	62 02' 15.5"
4	25-Jun-09	McKeen's Brook	Graham's Road	Secondary	45 19' 07.9"	62 02' 24.0"
5	25-Jun-09	McKeen's Brook	Graham's Road	Secondary	45 19' 13.8"	62 02' 37.3"
6	01-Sep-09	Cumminger Lake	Highway 7, Aspen	Highway	45 15' 58.7"	62 02' 49.0"
7	04-Sep-09	Boggs Lake	West Side Lochiel Lake	Secondary	45 22' 56.5"	62 02' 57.9"
8	25-Jun-09	McKeen's Brook	Unnamed	Secondary	45 18' 17.6"	62 03' 12.8"
9	04-Sep-09	Bogg's Brook	College Grant Road	Secondary	45 22' 51.8"	62 03' 52.1"
10	01-Sep-09	East Branch	Glenelg Church Road	Secondary	45 17' 55.7"	62 04' 19.8"
11	01-Sep-09	East Branch	Glenelg Church Road	Secondary	45 17' 47.0"	62 04' 31.9"
12	01-Sep-09	Bryden Brook	Glenelg Church Road	Secondary	45 16' 40.6"	62 04' 41.2"
13	20-Jul-09	Bryden Brook	Old Church Road	Secondary	45 16' 56.7"	62 05' 04.7"
14	06-Oct-09	Big Meadow Brook	Big Meadow Brook Road.	Secondary	45 22' 23.3"	62 05' 07.7"
15	04-Sep-09	Big Meadow Brook	College Grant Road	Secondary	45 22' 46.0"	62 05' 23.9"
16	14-Jul-09	MacInnis Lake	logging road off Cornects Road.	Secondary	45 19' 57.3"	62 05' 30.1"
17	25-Aug-09	Archibald's Mill Brook	Highway 347	Highway	45 20' 37.8"	62 06' 57.5"
18	25-Aug-09	East Branch	Highway 347	Highway	45 21' 35.4"	62 08' 11.0"
19	14-Jul-09	East Branch	Jimmy Greene Road	Secondary	45 22' 27.3"	62 09' 46.0"
20	06-Jul-09	McKay Brook	Unknown	Secondary	45 23'37.4"	62 09'26.9"
21	25-Aug-09	East Branch	Highway 347	Highway	45 23' 32.4"	62 11' 47.7"
22	21-Jul-09	East Branch	Unknown	Secondary	45 23' 45.8"	62 11' 56.1"
23	21-Jul-09	East Branch	Unknown	Secondary	43 23' 47.4"	62 11' 57.0"

Culvert Identification Number	Date	System Name	Road Name	Road Type	GPS Location	
24	25-Aug-09	East Branch	Highway 347	Highway	45 23' 44.9"	62 14' 23.9"
25	25-Aug-09	East Branch	Highway 347	Highway	45 23' 37.8"	62 14' 59.5"
26	06-Oct-09	MacDonald Brook	516 (Atv/Ski-doo trail)	Tertiary	45 21' 03.4"	62 15' 15.9"
27	25-Aug-09	East Branch	Highway 347	Highway	45 23' 38.6"	62 15' 37.4"
28	25-Aug-09	East Branch	Highway 347	Highway	45 23' 35.6"	62 15'49.8"
29	01-Sep-09	Main Branch	Highway 7, Stillwater	Highway	45 09' 50.7"	61 58' 46.7"
30	01-Sep-09	Main Branch	Highway 7, Stillwater	Highway	45 11' 01.3"	61 58' 54.9"
31	23-Sep-09	Main Branch	Waternish Road	Secondary	45 10' 44.7"	61 59' 03.6"
32	23-Sep-09	Main Branch	Waternish Road	Secondary	45 10' 51.9"	61 59' 13.5"
33	01-Sep-09	Main Branch	Highway 7, Stillwater	Highway	45 12' 11.8"	62 00' 12.9"
34	23-Sep-09	Main Branch	Waternish Road	Secondary	45 11' 33.9"	62 00' 16.1"
35	01-Sep-09	Main Branch	Highway 7, Stillwater	Highway	45 12' 43.1"	62 00' 17.2"
36	01-Sep-09	Main Branch	Highway 7, Cochrane Hill	Highway	45 13' 42.3"	62 00' 35.5"
37	01-Sep-09	Main Branch	Highway 7, Cochrane Hill	Highway	45 13' 38.1"	62 00' 38.4"`
38	23-Sep-09	Main Branch	Waternish Road	Secondary	45 12' 35.0"	62 00' 55.4"
39	23-Sep-09	Main Branch	Waternish Road	Secondary	45 12' 38.6"	62 00' 56.2"
40	23-Sep-09	Main Branch	Waternish Road	Secondary	45 13' 52.6"	62 01' 49.3"
41	01-Sep-09	Glenelg Lake	Highway 348, Melrose	Highway	45 15' 39.5"	62 02' 52.4"
42	06-Oct-09	Lochaber Lake	West Side Lochaber	Secondary	45 25 02.5"	62 01' 59.8"
43	01-Sep-09	East Branch	Highway 7, Aspen	Highway	45 17' 58.0"	62 03' 07.6"
44	04-Sep-09	North Branch	Highway 7	Highway	45 19' 46.6"	62 03' 13.5"
45	01-Sep-09	Wallace Lake	Wallace Lake Road	Secondary	45 18' 41.4"	62 03' 18.6"
46	01-Sep-09	North Branch	Wallace Lake Road	Secondary	45 18' 58.6"	62 03' 46.2"
47	04-Sep-09	Lochiel Lake	West Side of Lochiel Lake	Secondary	45 21' 49.4"	62 03' 49.7"
48	04-Sep-09	Lochiel Lake	West Side of Lochiel Lake	Secondary	45 20' 30.8"	62 03' 50.9"
49	04-Sep-09	Lochiel Lake	West Side of Lochiel Lake	Secondary	45 20' 50.5"	62 03' 51.2"
50	01-Sep-09	West Branch	Lead Mine Road	Secondary	45 15' 17.4"	62 05' 07.3"
51	26-Aug-09	McIntosh Brook	Highway 348	Highway	45 16' 22.5"	62 07' 29.5"
52	31-Aug-09	Tait Brook	Lake Road	Secondary	45 15' 29.6"	62 07' 31.5"

Culvert Identification Number	Date	System Name	Road Name	Road Type	GPS Location	
53	07-Jul-09	Tait Brook	Lake Road	Secondary	45 15' 29.1	62 07' 32.4"
54	26-Aug-09	Tait Brook	Highway 348	Highway	45 16' 22.5"	62 08' 23.4"
55	26-Aug-09	Mcleod Lake	Highway 348	Highway	45 16' 29.9"	62 09' 01.3"
56	26-Aug-09	West Branch	Highway 348	Highway	45 15' 48.6"	62 11' 16.7"
57	26-Aug-09	West Branch	Highway 348	Highway	45 16' 14.6"	62 13' 39.5"
58	31-Aug-09	MacDonald Brook	MacDonald Brook Road	Secondary	45 17' 25.4"	62 14' 29.1"
59	26-Aug-09	MacDonald Brook	Highway 348	Highway	45 16' 13.0"	62 14' 34.1"
60	10-Aug-09	MacDonald Brook	Sutherland's Brook Road	Secondary	45 17' 05.4"	62 15' 20.1"
61	10-Aug-09	MacDonald Brook	Sutherland's Brook Road	Secondary	45 17' 14.2"	62 15' 22.3"
62	10-Aug-09	MacDonald Brook	Sutherland's Brook Road	Secondary	45 17' 49.6"	62 15' 36.7"
63	31-Aug-09	MacDonald Mill Brook	MacDonald Brook Road	Secondary	45 15' 47.8"	62 16' 08.8"
64	30-Jun-09	Hattie Brook	Highway 348	Highway	45 16' 30.3"	62 16' 21.6"
65	27-Jul-09	West Branch	Barren Brook Road	Secondary	45 16' 40.8"	62 16' 35.4"
66	31-Aug-09	West Branch	MacDonald Brook Road	Secondary	45 16' 12.9"	62 16' 40.6"
67	10-Aug-09	Sutherland's Brook	Sutherland's Brook Road	Secondary	45 17' 59.0"	62 16' 43.3"
68	07-Jul-09	Hattie Brook	Barren Brook Road	Secondary	45 16' 45.4"	62 16' 46.1"
69	27-Jul-09	Hattie Brook	Barren Brook Road	Secondary	45 16' 45.3"	62 16' 46.4"
70	27-Jul-09	Barren Brook	Barren Brook Road	Secondary	45 16' 39.4"	62 17' 24.7"
71	27-Jul-09	West Branch	Barren Brook Road	Secondary	45 16' 38.9"	62 18' 23.1"
72	27-Jul-09	Barren Brook	Barren Brook Road	Secondary	45 18' 34.8"	62 19' 40.5"
73	27-Jul-09	Black Brook	Hattie Road	Secondary	45 18' 13.3"	62 20' 37.0"
74	27-Jul-09	Black Brook	Barren Brook Road	Secondary	45 19' 15.95"	62 20' 58.14"
75	27-Jul-09	Ross Brook	Barren Brook Road # 9	Secondary	45 19' 1.41"	62 21' 21.19"
76	27-Jul-09	Ross Brook	Barren Brook Road # 11	Secondary	45 19' 37.8"	62 21' 23.4"
77	27-Jul-09	Ross Brook	Barren Brook Road # 11	Secondary	45 19' 36.2"	62 21' 35.5"
78	27-Jul-09	Ross Brook	Barren Brook Road # 11	Secondary	45 19' 32.0"	62 21' 44.1"
79	27-Jul-09	Ross Brook	Barren Brook Road # 11	Secondary	45 19' 29.9"	62 21' 55.9"
80	02-Sep-09	MacQuarries Brook	Highway 348	Highway	45 16' 46.1"	62 23' 23.6"
81	02-Sep-09	West Branch	Highway 348	Highway	45 16' 44.0"	62 23' 32.4"

Culvert Identification Number	Date	System Name	Road Name	Road Type	GPS Location	
82	19-Aug-09	West Branch	Calgar Road	Secondary	45 17' 02.1"	62 23'53.0"
83	30-Jun-09	West Branch	Cameron Settlement Road	Secondary	45 16' 43.7"	62 24' 18.7"
84	02-Sep-09	West Branch	Cameron Settlement Road	Secondary	45 16' 43.9"	62 25' 20.3"
85	02-Sep-09	West Branch	Cameron Settlement Road	Secondary	45 16' 42.3"	62 26' 14.6"
86	19-Aug-09	Unknown	Calgar Road	Secondary	45 19' 41.6"	62 26' 58.9"
87	19-Aug-09	Cross Brook	Calgar Road	Secondary	45 20' 19.4"	62 27' 21.5"
88	02-Sep-09	West Branch	Cameron Settlement Road	Secondary	45 16' 47.5"	62 28' 40.8"
89	30-Jun-09	West Branch	Cameron Settlement Road	Secondary	45 17' 10.8"	62 30' 36.8"
90	02-Sep-09	Castley Brook	Highway 374	Highway	45 19' 06.4"	62 39' 30.6"
91	02-Sep-09	Castley Brook	Highway 374	Highway	45 18' 46.9"	62 39' 35.7"
92	31-Aug-09	Unknown	MacDonald Brook Road	Secondary		
93	02-Sep-09	Unknown	Cameron Settlement Road	Secondary		
94	26-Oct-09	outflow from Jordy Mitchell Lake	Unnamed	Secondary	45 18' 27.7"	62 04' 23.4"
95	26-Oct-09	outflow from Jordy Mitchell Lake	Highway 347	Highway	45 18' 26.5"	62 04' 25.4"
96	26-Oct-09	Fraser's Brook	College Grant Road	Secondary		
97	01-Nov-09	Unnamed (outflow from Hattie Lake)	Highway 7	Highway	44 22' 05.0"	62 03' 11.6"
98	01-Nov-09	McKeen's Brook	Kent Lake Road	Secondary	45 19' 0.1"	62 01' 35.2"
99	01-Nov-09	Stewart Lake	Unnamed	Secondary	45 28' 29.7"	62 01' 12.7"