Stream Crossing Inventories in
The Swan and Notikewin River
Watersheds of Northwestern Alberta

Alberta Conservation Association

Funded by Alberta Anglers, Hunters, and Other Conservationists

John P. Tchir
Paul J. Hvenegaard

Alberta Conservation Association
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Abstract

Aquatic habitat fragmentation, degradation and encroachment are important results of access infrastructure on lotic habitats and can limit the distribution, abundance and subsequent viability of fish stocks. During 2002, the effects of road crossings on fish habitat quality and connectivity in two Northern Alberta watersheds (Notikewin River watershed (NRW), Swan River watershed (SRW)) were examined. Stream crossings were identified through spatial analysis. Culvert crossings were quantitatively assessed for habitat fragmentation and qualitatively for sediment contributions. Culvert crossings (61% NRW, 74% SRW) failed to provide connectivity of potential fish habitat. Fragmentation was highest in the SRW with approximately 20% of the stream network fragmented as compared to 9.5% in the NRW. Culverts were inadequately sized to respective stream channels causing habitat loss due to encroachment in both watersheds. A large proportion of culverts surveyed (NRW 17%, SRW 18%) contributed moderate levels of silt to respective watercourses. The frequency of culverts rated as contributing high amounts of sediment was highest in the SRW (19%) compared to the NRW (3%). In the SRW, proportionately more bridges were rated as having high levels of silt deposition (NRW 8%, SRW 36%). Habitat fragmentation and silt deposition caused by culvert crossings found in these watersheds suggest stream-crossing practices and monitoring need to be significantly improved to conserve Arctic grayling (*Thymallus arcticus*) and other lotic sport fish species in Northern Alberta.

Keywords: culvert, crossings, fragmentation, fish habitat, encroachment

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1.0 Introduction

Connectivity of fish habitats is critical in conserving the distribution and abundance of lotic sport-fishes. Disruption of connective habitats has detrimental effects on fish communities and population viability. It is important to identify barriers to fish passage and sedimentation sources and develop remediation plans to reconnect these habitats with expediency. Migration of spawning fishes and subsequent maintenance of fish communities requires habitat connectivity (Morita and Yokota 2002).

Arctic grayling (*Thymallus arcticus*) are an important sport-fish and an indicator species of ecological integrity. Increased access to and across flowing waters are limiting production and in some areas recovery of this important species. These fish require unobstructed connectivity to critical habitats for spawning, rearing, and over-wintering. In the Notikewin and Swan River Watersheds Arctic grayling are an important sport-fish. However, high fragmentation rates resulting from degraded or poorly constructed crossings have a high likelihood of further reducing fish production and population stability.

The stream crossing assessment study in the Northwest region of Alberta was developed to identify all road stream crossings, quantify fragmentation caused by culvert crossings and qualitatively describe crossing site sediment deposition.

2.0 Study Area

The study was conducted in the Notikewin and Swan River Watersheds (Figure 1). The Notikewin River Watershed (NRW) located Northwest of Peace River drains an area 9,799 km^2, has 1,665 km of permanent roads and 544 road / stream intersections. The Swan River Watershed (SRW) is located South of Lesser Slave Lake and drains an area 3,117 km^2, has 3,931 km of permanent roads and 759 road / stream intersections.

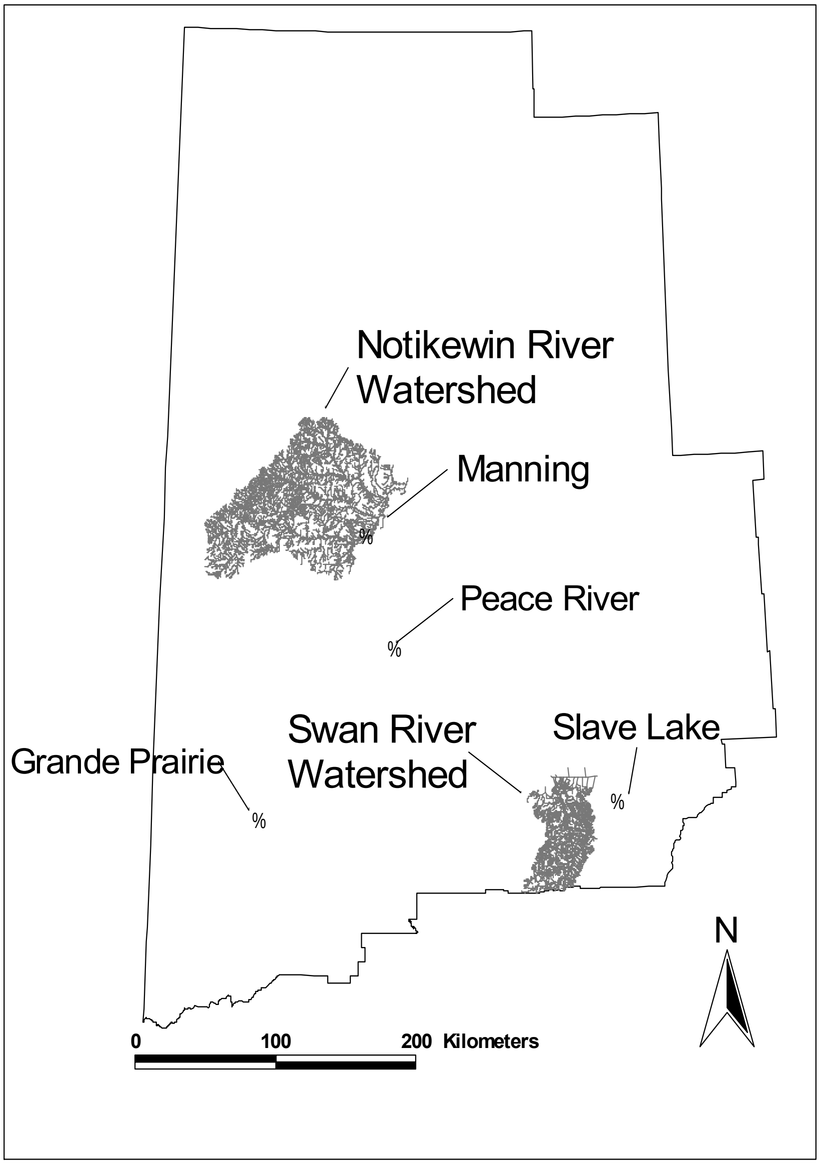


Figure 1. Stream crossing inventory study area, Northwestern Alberta 2002.

3.0 Methods

3.1 Site identification

Crossing sites were derived from road / hydrographic arc intersections. Crossing sites (point data) were spatially joined with the hydrographic line network to determine stream order of crossing sites. Site coordinates were further attributed with unique site numbers used to generate a waypoint list for field assessments. Current GIS data were not accurate or current enough to identify all roads and subsequent crossings in subject watersheds. Additional sites found during fieldwork were surveyed and added to the sample. Attempts were made to survey all crossings identified by GIS in the NRW; although, some sites in the Southwest portion were unreachable due to road conditions. Of the 759 crossings identified in the SRW, 406 were located on first order streams. Fish occurrence in first order streams was extremely low (unpublished fish inventory data) in the SRW; therefore, these crossings were removed from the sample.

3.2 Primary assessment

3.2.1 Identification of crossing type

Crossings were identified as: culvert, bridge, ford, or removed. Culverts and bridges were categorized by type and shape (e.g., Culvert – CMP, or Bridge – Bailey). If a culvert crossing was present and a defined stream channel existed the site was assessed for fish passage and sedimentation. Cross-ditch drains and crossings on intermittent streams were not evaluated.

3.2.2 Culvert properties (fish passage)

Culvert diameter was measured on round culverts; on elliptical, oval or box culverts, the widest distance across the opening was measured. Measurements were recorded in centimetres within ± 1 cm. Inadequately sized culverts encroach on fish habitat, constrict stream flow, increase velocities and may cause sedimentation and excessive scouring at the outlet (Parker 2000). Potential velocity barriers were identified for secondary assessment when culvert diameter was found to be less than half the stream bank-full width. Culvert length was measured in meters and was used to further assess potential velocity barriers. Culvert outfall drop was measured (i.e., distance from the bottom of the culvert outlet to stream water surface) in centimetres. Outfalls of five cm or more in height were considered complete passage barriers to native species.

Although, certain life stages of fish species may not have the ability to maneuver through culverts that are not set at or below substrate level (e.g., slimy sculpin (*Cottus cognatus*)).

3.2.3 Stream properties

Plunge pool depth at outfall (i.e., depth of the pool directly below the culvert outfall) was measured in centimeters. Plunge pool depth may limit fish passage at outfalls (Parker 2000). Although this variable was measured it was not used in analyses. Rooted width (bank-full width) was measured in meters at locations a minimum of 25 m upstream of the crossing to avoid influence of the culvert on channel morphology. This measure was used to calculate encroachment ratios and habitat loss due to encroachment as per Harper and Quigley (2000).

3.2.4 Sediment source assessments

The evaluation of stream crossings as sediment sources was qualitative and observational in nature. Sediment deposition caused directly by the crossing site was ranked for severity. Ranking was based on qualitative degree of sedimentation. Sites were assigned a rank of low moderate or high as sedimentation sources based on the following: evidence of siltation at or downstream of the source caused by rights-of-way instability, adequacy of vegetative cover, sediment control structure absence or failure, or disturbance. Stream crossing survey technicians standardized rankings through repetitive assessment of previously completed sites.

Bridge crossings have low probabilities of obstructing fish passage; therefore bridges were assessed for sediment deposition only. Methods of qualitative assessment were identical to those of culvert crossings with the addition of bridge deck spacing as part of the criteria.

3.2.5 Comments and photographic records

Comments were recorded regarding barrier type determination, and to provide additional description of observations pertaining to sedimentation or fish passage. Photographs were taken at each sight to document crossings and sediment contributing Rights of Way. Digital photos were taken of inlet, outlet, the two rights of way causing the most sediment deposition and additional photos were taken when necessary to provide complete record of the crossing.

3.3 Secondary assessments

Stream crossings having a culvert diameter less than half the rooted width of the stream and not considered a fish passage barrier by the results of the primary assessment were measured for culvert and stream parameters to be used in modeling of stream flow through the culvert to determine fish passage potential.

3.3.1 Culvert properties

Culvert water depths were recorded approximately 15 cm inside the culvert to ensure measurements were not biased by an in-fall or outfall at the culvert edge. Rust-line heights at the inlet and outlet measured at the same position that water depths were recorded to index high water marks at crossings. Corrugation dimensions were measured to determine the roughness coefficient for individual crossings. Culvert gradient was measured with a clinometer at the inlet and outlet of the crossing; slope was then averaged and recorded.

3.3.2 Stream properties

Wetted depths were measured at left, centre and right equidistant locations in the stream and reported as averages at three transects located at 50, 100, and 150 m upstream of the crossing. Average rooted depth was determined from three measurements of distance from the substrate to a line stretched level at the base of the most adjacent deeply rooted macrophyte. Measurements were taken at left, center and right equidistant locations in the stream at a single transect to determine approximate depth under high flow conditions.

Rooted, wetted widths and stream velocity were measured at the same transects as depths following methods outlined by Bain and Stevenson (editors, 1999). Stream velocity was taken at the same transect as wetted and rooted width and depth to determine discharge at average and high flows. Flow condition was visually assessed and ranked as low, moderate or high. Aquatic habitat was qualitatively assessed for fish species and life stage suitability (spawning, rearing or over-wintering).

3.4 Data analyses

Spatial analyses and queries were completed using Arc View 3.2; further data analyses were done in Microsoft Excel, and SPPS 9.0. Fall spawning sport-fish species have not been found in either the NRW or SRW. Subsequent further review of crossings void of water were removed from the sample and crossings with perceived low water conditions were not considered barriers.

4.0 Results

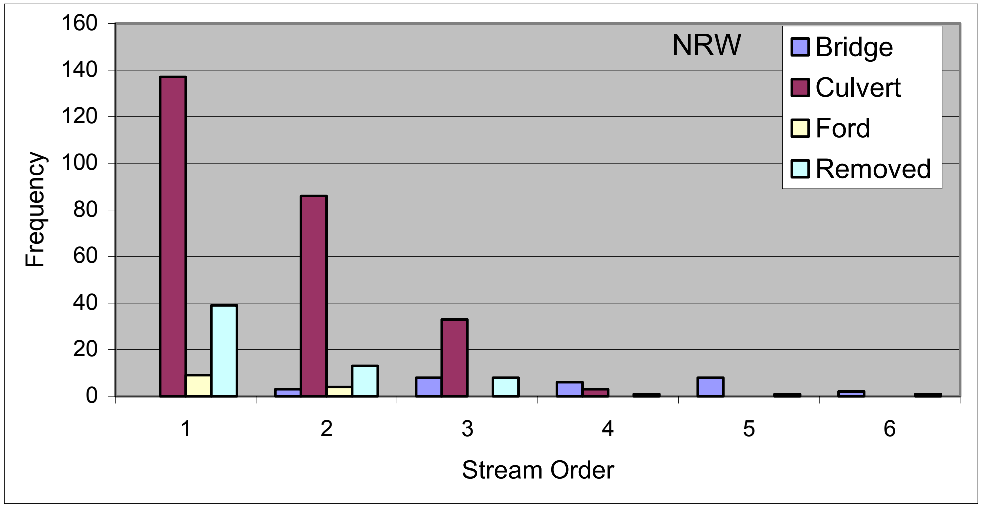
Stream crossing assessments were conducted from June through August of 2002. Crossings were identified using GIS, as road / hydrographic intersections (544 NRW, 759 SRW), additional crossings were identified (21 NRW, 4 SRW) and assessed during field inspections. Several crossings (61 in NRW and 44 in SRW) were not assessed as a result of access limitations. Crossings assessed with dry or indiscernible stream channels were not included in the analyses. In the SRW crossings on first order streams (406) were not examined as a result of low overall probabilities of fish occurrence. Of the sites assessed (413 NRW, 352 SRW), 362 and 260 in the NRW and SRW respectively were included for analyses and categorized by type (Table 1).

Table 1. Stream crossings assessed in the Notikewin and Swan River watersheds excluding dry stream channels, 2002.

Type	NRW	SRW
Bridge	27	50
Culvert	260	189
Ford	13	4
Removed	63	17

Crossing types were grouped by stream classification (Strahler 1964) (Figure 2). Bridges were observed on third order streams and larger; this structure was used exclusively to cross sixth order streams in both watersheds. Culvert frequency was negatively related to stream order (i.e., as stream order increased culvert frequency decreased). Fords were observed entirely on first and second order streams in the NRW, where as, fords in the SRW were found on second, fourth and fifth order streams. In general, fords were used by all-terrain vehicles and developed as a result of recreational or industrial use of deactivated roads. Removed crossings were found on all stream orders in the NRW and were most prevalent on first order streams. In the

SRW removed crossings occurred most frequently on second order streams, however, frequencies were more evenly distributed across stream orders excluding sixth order streams. Removed crossings were found mainly on deactivated or winter access types of roads.



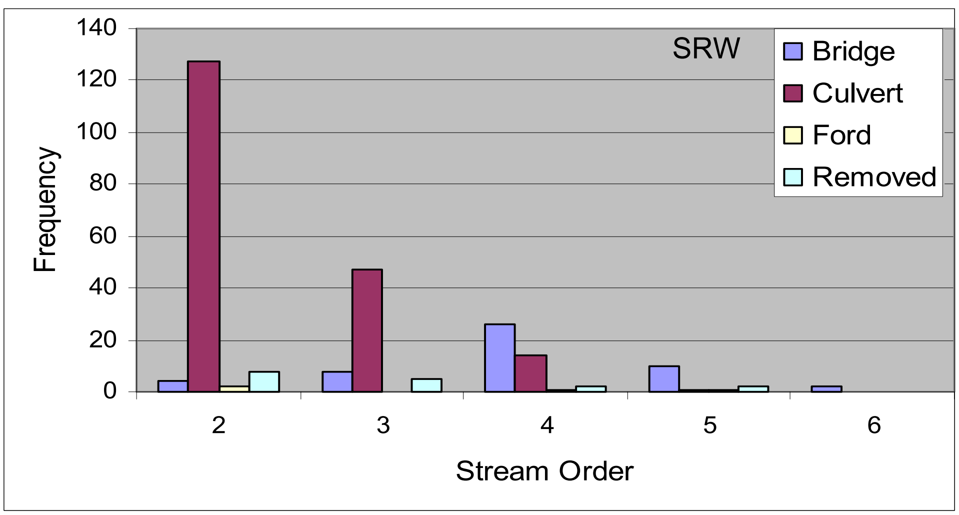
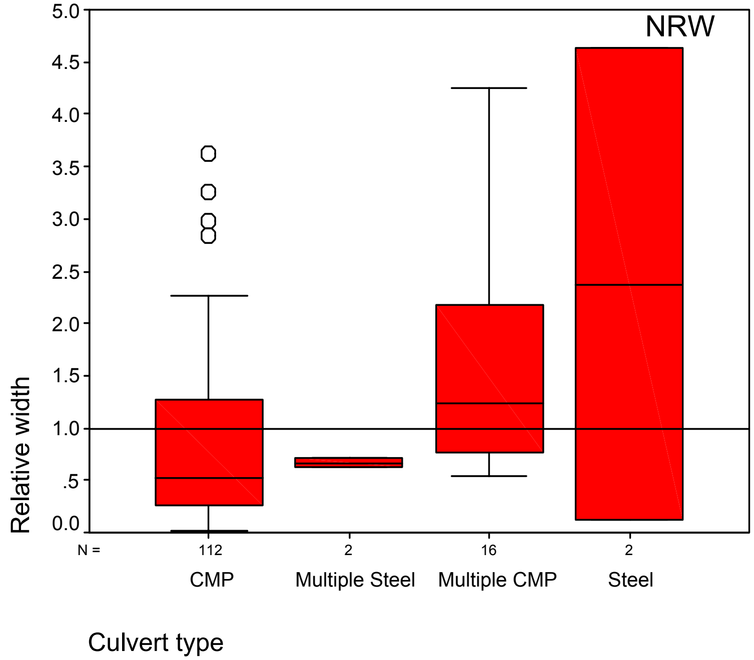


Figure 2. Crossing Type by stream order in the Notikewin and Swan River watersheds 2002.

Culvert crossing sites were categorized by type. Multiple culverts were found where old culverts failed or single culvert crossings could not accommodate variable flow conditions. Single and multiple steel pipe culverts (i.e., non-corrugated metal pipes) were rare, and appeared to be historic (i.e., >15 years old) crossing sites. Numbers of single and multiple corrugated metal pipes (CMPs) decreased as stream order increased; this relationship was most prevalent with single CMP crossings. Evidence of beaver activity was found at 35 and 16% of culvert crossings analyzed in the NRW and SRW respectively.

4.1 Habitat Loss due to encroachment

Culvert diameters were generally inadequate relative to channel widths, resulting in stream habitat loss caused by channel encroachment (Figures 3 and 4). There was a significant difference between single CMP diameter and bank-full width in both watersheds (NRW t 5.237, p 0.000, df 111; SRW t 4.355, p 0.000, df 104). The majority of CMPs in both watersheds caused encroachment (NRW 69.9%, SRW 83.7%). Crossing sites comprised of multiple CMPs also caused encroachment (NRW 43.8%, SRW 65.6%). There was a significant difference between the cumulative span of multiple CMPs and bank-full width in the SRW (t 3.679, p0.000, df 68). However, there was no significant difference between cumulative span of multiple CMPs and bank-full width in the NRW (p>0.05).



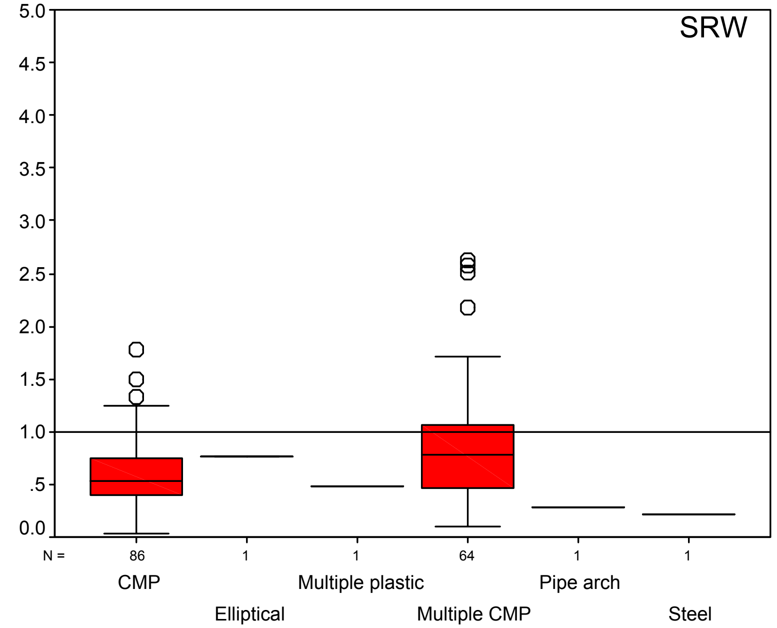


Figure 3. Box plots of relative width by culvert crossing type in the Notikewin and Swan River watersheds, 2002. The reference line at 1.0 relative width is the point at which the bankfull width equals culvert diameter. Values below 1.0 caused habitat loss due to encroachment.

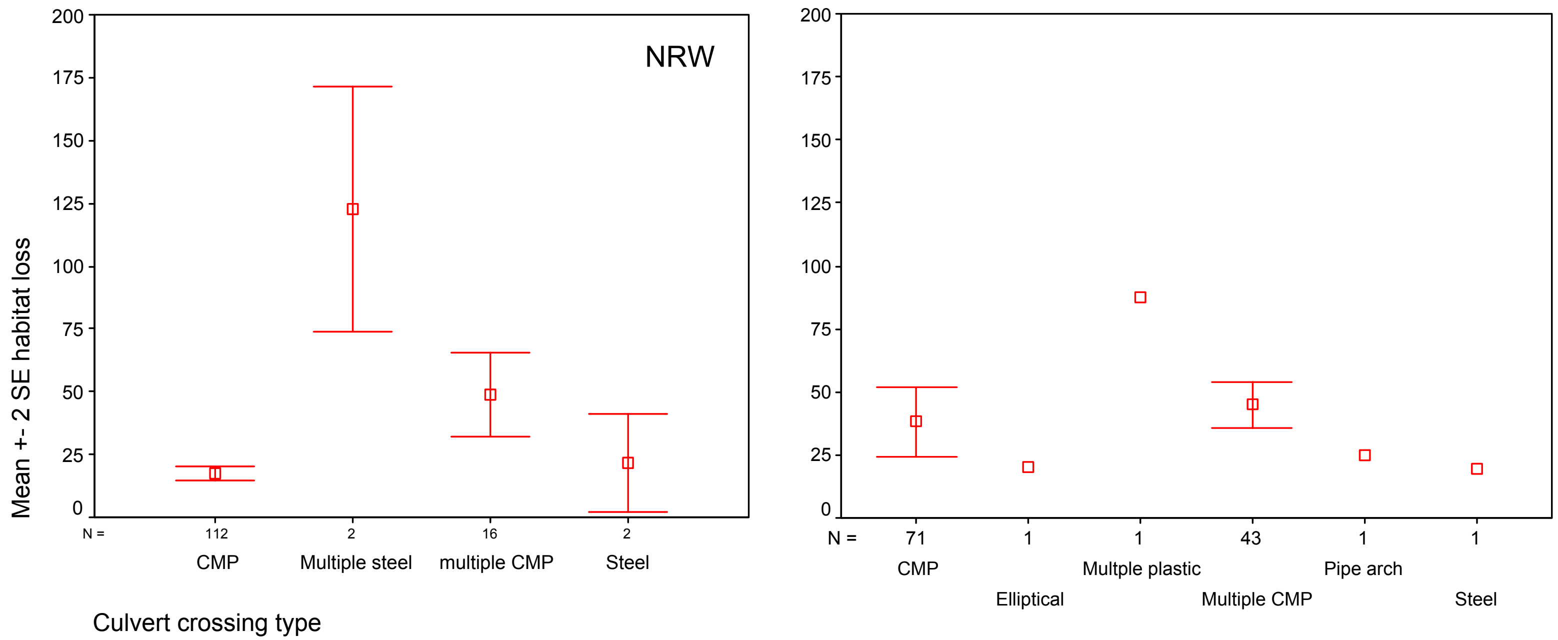


Figure 4. Average habitat loss due to encroachment (m^2) by culvert crossing type in the Notikewin and Swan River watersheds.

4.2 Habitat fragmentation

Culvert crossings failed (NRW 61%, SRW 74%) to provide connectivity of potential fish habitat at road crossings in both watersheds with the highest percentage of failures in the SRW. Culverts with low water levels were not considered barriers to fish species in either watershed. Outfall and debris related barriers were the most prevalent causes of fragmentation (Table 2). Most debris barriers were attributed to beaver activity. However, inadequate culvert sizing and placement also caused debris blockages. Barriers caused by damaged inlets or outlets of culverts were uncommon in both watersheds.

Table 2. Frequency of culvert failures in the Notikewin and Swan River Watersheds, 2002.

Type	NRW	SRW
Damaged pipe	4	4
Debris / beaver activity	47	20
*Other	10	7
Outfall	87	109
Velocity	11	1
Total	157	141

*Barriers caused by combinations of crossing conditions included: screens at culvert inlets, hanging inlets, submerged culverts and agricultural modifications.

Overall the SRW was impacted the greatest, with roughly 20% of the watershed fragmented by road stream crossings as compared to 9.5% in the NRW. Outfalls were the most numerous barrier type and subsequently caused the highest amount of fragmentation. However, location of the crossing site in the watershed is the most important variable when considering fragmentation (i.e., barriers located furthest downstream caused more fragmentation than those located in upper portions of the stream network). Barriers caused by debris accounted for nearly as much habitat fragmentation as outfalls with a difference of 51.75 km in the NRW. The spatial distributions and extents of fragmentation of culvert crossings obstructing connectivity in both watersheds are presented in Figures 5 and 6.

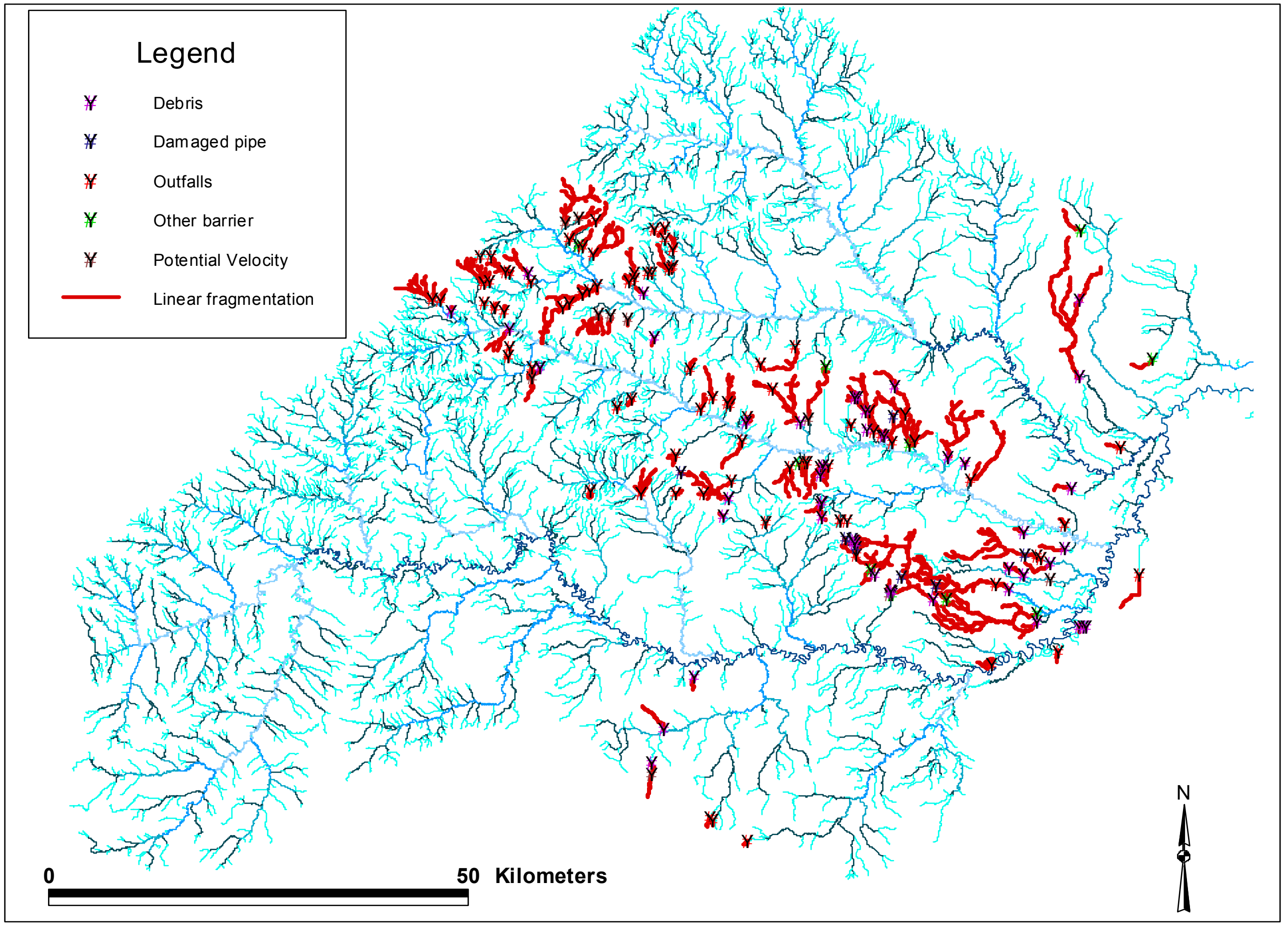


Figure 5. Spatial distribution and extent of potential fragmentation in the Notikewin River watershed, 2002.

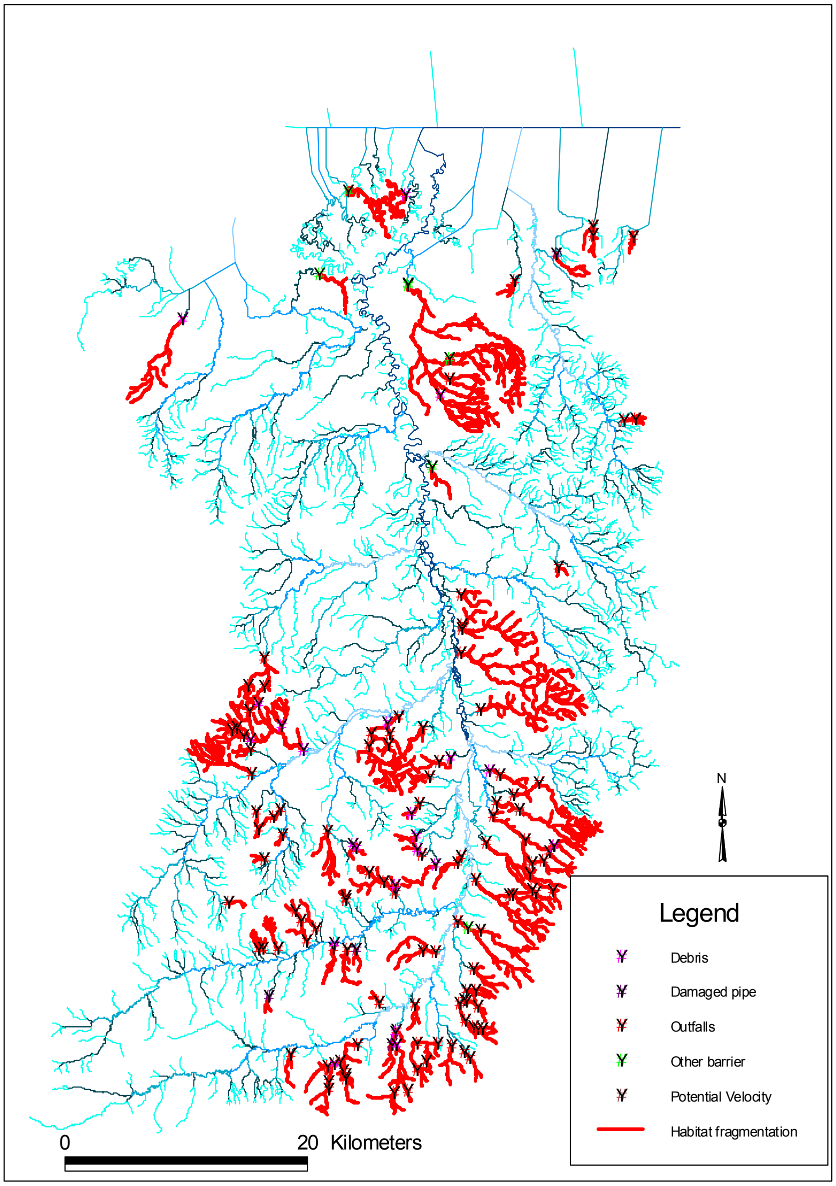


Figure 6. Spatial distribution and extent of potential fragmentation in the Swan River watershed, 2002.

4.3 Silt deposition

Qualitative visual assessments of silt deposition from crossing structures revealed large numbers of culverts surveyed (NRW 17%, SRW 18%) contributed moderate levels of silt to watercourses. The frequency of culverts rated as contributing high amounts of sediment was highest in the SRW (19%) compared to the NRW (3%). In the SRW, proportionately more bridges were rated as having high levels of silt deposition (NRW 8%, SRW 36%). Frequencies of crossing types rated as contributing moderate to high levels of silt are presented in Tables 3 and 4.

Table 3. Number of crossings rated as contributing moderate and high levels of silt to streams in the Notikewin River watershed, 2002.

	Bridge		Culvert		Ford		Removed	
Stream Order	Moderate	High	Moderate	High	Moderate	High	Moderate	High
1	0	0	29	6	3	0	6	1
2	0	0	11	1	0	1	0	0
3	3	1	8	2	0	0	2	1
4	1	0	0	0	0	0	1	0
5	3	1	0	0	0	0	0	0
Unknown	0	0	7	1	0	0	0	0
Total	7	2	55	10	3	1	9	2

Table 4. Number of crossings rated as contributing moderate levels of silt to streams in the Swan River watershed.

	Bridge		Culvert		Removed	
Stream Order	Moderate	High	Moderate	High	Moderate	High
2	0	1	22	23	2	0
3	3	2	12	12	0	0
4	7	12	3	4	0	0
5	4	5	0	1	0	0
6	1	0	0	0	0	0
Total	15	20	37	40	2	1

5.0 Discussion

The study showed that a substantial amount of potential fish habitat was fragmented in Northwestern Alberta as a result of road crossings. The majority of culvert crossings analyzed caused fragmentation and loss of potential fish habitat. The density of road crossings in the SRW was much higher than in the NRW. Subsequently, the degree of fragmentation and habitat loss due to encroachment was also much higher in the SRW. The association between access development and fish habitat loss was clear. Arctic grayling and other socially and ecologically important stream fish populations are vulnerable to fragmentation and reduced viability. Most riverine fish populations function as metapopulations; loss of habitat is the most important cause of extinction of these species. Fragmentation not only results in a reduction of amount of available habitat, it also causes a reduction in distribution of those habitats. The spatial structure and connectivity of critical habitats are important to conserve in order to maintain source and sub-populations (Morita and Yokota 2002).

Culvert crossings were significantly undersized relative to their respective stream bank-full width. The inadequacy of culvert sizing was more pronounced in the SRW compared to the NRW. Subsequently, the average habitat loss by crossing type was higher in the SRW. Culvert encroachment on the natural stream channel typically results in increased velocities through the culvert and increased likelihood of plugging with debris resulting in a passage barrier. Inadequately sized culverts have a larger ecological foot print than crossings that accommodate their respective stream channel bank-full widths. An increased risk of further habitat loss upstream of a CMP occurs when it is undersized (Harper and Quigley 2000).

Sediment control problems were proportionally highest in the SRW. Most sediment control problems were attributed to a lack of revegetation of the stream bank Rights-of-Ways, slope instability, and downstream scouring on CMP crossings. Bridge crossings, having large gaps in bridge decking unvegetated and unstable Rights of Ways, poor riprap and in-stream abutments contributed high amounts of silt to their respective watercourses. Although, bridges were not analyzed for encroachment in this particular study Harper and Quigley (2000) found shorter bridges had a larger ecological footprint as a result of adjacency of abutments to the stream channel, requiring extensive riprap for scour protection and resulting in increased habitat losses due to encroachment. Bridges having longer spans were found to require less riprap and minimized disturbance of the stream banks, thereby, reducing the overall footprint (Harper and Quigley 2000). Deactivated or removed crossings in both watersheds surveyed were often unvegetated with no sediment control structures present.

6.0 Recommendations

Using proportional habitat loss as a surrogate measure of stream-crossing practices, results indicated agencies responsible for the protection of fish habitat and proponents responsible for stream crossings, need to significantly improve existing stream crossing practices to conserve lotic fish communities in Northern Alberta. Stream fishing opportunities have degraded and it appears as though over-fishing may not be entirely culpable. The further adjustment of sport-fishing regulations with respect to flowing waters in Northern Alberta may not positively affect these specific populations. It is necessary to look at all of the major causes of the decline of these fisheries. An in depth retrospective study on abundance and distribution of stream fishes in relation to fragmentation and disturbance may be necessary to determine how much of the decline may be attributed to poor stream crossing practices. The disregard for fish habitat with respect to stream crossings will continue to increase fragmentation and the risk of isolation and extirpation of lotic fish populations in all watersheds affected by access development.

Continued use of CMPs on fish bearing streams may result in an unacceptable risk of habitat fragmentation and the further decline of Alberta's fisheries resource. The findings of this study support the position recommended by Harper and Quigley (2000) (i.e., to disallow use of CMPs on fish bearing streams). Best management principals with respect to installation of stream crossings have been well established (e.g., Adams and Whyte 1990; Adams et al 1986; Ashton and Carlson 1984; Baker and Votapka 1990; Bates et al 1999). However, access developers, have failed to apply these principals to practices, and regulatory agencies have not succeeded at monitoring current practices at the watershed scale.

A review of current provincial codes of practice and the monitoring system in place with respect to stream crossings is recommended. Amendments should be made where necessary so that fish passage is a requirement of all stream crossings on potential fish bearing streams. Monitoring of stream crossings with respect to habitat connectivity and erosion causing sedimentation should be improved so that it is effective.

A watershed restoration committee should be formed to address the loss of connectivity in the watersheds inventoried to date and continue looking at the watershed level effects of stream crossings on fish habitat. The committee should include partners from resource-based industries, regulatory agencies and academia. Standardized protocols for installation and field monitoring of streams crossings should be developed to make stream habitat connectivity (i.e., fish passage) and retention central objectives.

Repeat sampling of watersheds within a reasonable time by an impartial agency should be performed to evaluate progress and determine future issues.

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