Watercourse Crossings in Agro-Manitoba: Assessment of Operational Statement Applicability and Development of a Management Approach

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A thesis submitted for partial fulfillment of requirement for the Degree

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FACULTY OF GRADUATE STUDIES

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Watercourse Crossing in Agro-Manitoba: Assessment of Operational Statement Applicability and Development of a Management Approach

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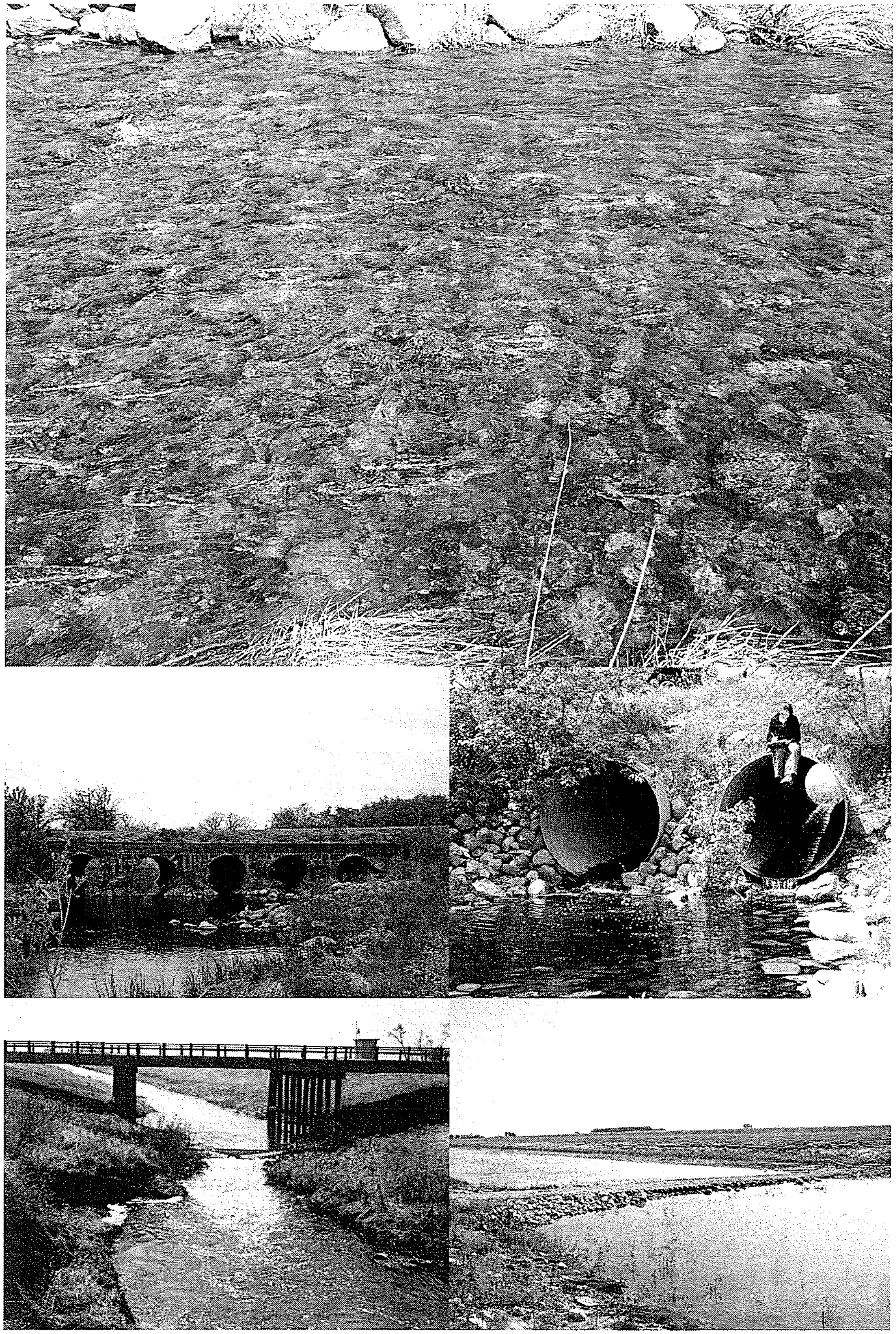
A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirement of the degree

MASTER OF NATURAL RESOURCE MANAGEMENT



Frontispiece: Pictures of fish and road crossings within Manitoba

Source: Department of Fisheries and Oceans (2007a).

ABSTRACT

The purpose of this research was to assess the applicability of an operational statement (OS) and develop a management approach that the Department of Fisheries and Oceans Canada (DFO) could use to incorporate economic, ecological, and social elements to achieve good governance as it applied to watercourse crossing projects in agro-Manitoba that reflected stakeholder needs and mandates.

A small watercourse-crossing inventory was conducted in the Morris River sub-watershed to obtain data that was combined with existing provincial data on fish species composition and abundance, and federal habitat classification data, to develop a comprehensive integrated GIS-based map.

Interviews were conducted with representatives from federal, provincial, and municipal governments who have a direct role in, responsibility for, or knowledge related to watercourse crossings, including a private consultant with local area knowledge.

A thorough literature review identified the many elements involved with watercourse crossing projects and their management to provide an understanding of the underlying complex issues. Climate change data was also examined to identify additional impacts that could also affect the development and implementation of an operational statement for Class E habitats.

This research determined that an operational statement for watercourse crossing projects could and should be applied to low risk Class E habitats within parts of the LaSalle, Morris and Plumb River sub-watersheds and extended to parts of the Seine, Rat, and Roseau River sub-watersheds as well, to accommodate the growing numbers of watercourse crossing projects that are anticipated over the next few years. The development and use of this OS and integrated GIS - based watershed map constitute the management approach that DFO should follow.

The proposed management approach enables DFO to comply with its mandate while being sensitive to the provincial and municipal governments' needs and recognizing the importance of the economic and social needs of agricultural community. The approach has support from those interviewed, as it will enable DFO Fish Habitat Biologists to focus on protecting high quality fish habitat and alleviate pressure on DFO's referral system. On a provincial and municipal level, the approach could increase regulatory compliance and reduce overall costs. It could also aid in strategic budgetary and logistical planning when maintaining and replacing ageing watercourse crossing infrastructure by identifying sensitive watercourse habitat and potential sites where an operational statement could apply. Recommendations are provided.

ACKNOWLEDGEMENTS

This research could not have been completed without the support of many individuals and organizations. I would like to thank the Department of Fisheries and Oceans for their financial and administrative support. I would like to thank my advisory committee: Mr. Thomas Henley (Professor and Associate Head, Natural Resources Institute), Dr. Joe O'Connor (Director of Fisheries Branch, Manitoba Water Stewardship), Mr. Ron Richardson (Director of Operations and Maintenance, Engineering and Operations Division, Water Control and Structures Branch, Manitoba Infrastructure and Transportation), Dr. Ken Stewart (University of Manitoba Senior Scholar); and Mr. Keith Kristofferson (Acting Manitoba District Manager, Department of Fisheries and Oceans Canada), I am indebted to each of these individuals for their advice, encouragement and guidance provided throughout the preparation and completion of this research.

I would also like to thank Mr. Dave Milani for providing me with the drain classification shapefiles; Mr. Chris Katopodis (Regional Engineer for the Department of Fisheries and Oceans); Mr.Dave Walty for providing locally acquired knowledge on crossing inventories; and Mr.Todd Schwartz, (Fish Habitat Biologist, Department of Fisheries and Oceans) for providing information regarding indicator species. I would like to especially thank Ms. Ashley Presenger (Fish Habitat Biologist, Department of Fisheries and Oceans) and Mr. Keith Kristofferson (Acting Manitoba District Manager, Department of Fisheries and Oceans Canada) for their help in conducting the field work for the crossing inventory. Assistance from ArcView specialists Mrs. Allyson Demski (GIS Teaching Assistant, Department of Geography and Environment, University of Manitoba) and Mr. Ronald Hemple was greatly appreciated.

Finally, I would like to thank members of the Department of Fisheries and Oceans, Manitoba Infrastructure and Transportation, Manitoba Water Stewardship, the Rural Municipality of Morris, the Rural Municipality of MacDonald and Panterra Management Ltd for taking the time out of their busy schedules to participate in the research and provide invaluable information.

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Acronyms

ADI – Agricultural Drainage Inventory

BMP – Best Management Practices

CEAA – Canadian Environmental Assessment Act

CD – Conservation District

DFO – Department of Fisheries & Oceans Canada

EC – Environment Canada

EPMP – Environmental Process Modernization Plan

FHMP – Fish Habitat Management Program

HFOM – Habitat Fisheries & Oceans Management

HADD – Harmful Alteration, Damage, or Destruction

IMS – Interactive mapping system

LOA – Letter of Advice

MB - Manitoba

MIAT – Manitoba Intergovernmental Affairs and Trade

MIT – Manitoba Infrastructure and Transportation

MOU – Memorandum of Understanding

MLI – Manitoba Land Initiative

MTGS – Manitoba Transportation and Government Services

MWS – Manitoba Water Stewardship Department

OS – Operational Statement

PoE – Pathway of Effects

PTH – Provincial Trunk Highway

RM – Rural Municipality

RMF – Risk Management Framework

RRBC – Red River Basin Commission

SARA – Species at Risk Act

Glossary

Adaptive Management – is a structured, iterative process of optimal decision making in the face of recognized biological uncertainty that is accepting of mandates to proceed on the basis of the 'best available scientific knowledge' (Wikipedia 2008; Lee and Lawrence 1986). The intent is to reduce uncertainty over time via system monitoring and through modification of management activities. "In this way, decision making simultaneously maximizes one or more resource objectives and, either passively or actively, accrues credible information needed to modify and improve future management. AM is often characterized as "learning by doing." (Wikipedia 2008).

Aquatic invertebrate – "any heterotrophic, eukaryotic, multicellular organism which lives in water, or a water-living life history stage of such an organism" (Stewart 2008).

Class Approach – groups together projects doing the same activity within similar environments that have similar risks and known effects on fish habitat into a single class and applies the same management strategy to all projects within that class

Connectivity – (of watercourses) as it applies to access and migration of fish species, the ability of fish to access all areas or reaches of a watercourse.

Crossing – a location where a road, highway, railway, or pipeline intersects a watercourse.

Dispersal – the process of spreading of individuals of a species or population, increasing the area it occupies, including the re-colonization of isolated areas possessing different fish species composition such as overland flooding to isolated headwater stocks if blocked downstream or in oxbow lakes.

Direct Fish Habitat – direct fish habitat includes watercourses where fish of any species can complete one or more of their life processes of spawning, rearing, feeding, overwintering, or migration. Direct habitat is provided by perennial and intermittent watercourses. Perennial watercourses either flow continuously throughout the year or permanently retain water with limited flow because they have large drainage areas or because they experience discharge from wetlands or groundwater. Drains with perennial flow provide habitat for a variety of fish species throughout the year and are the most valuable.

Due Diligence - taking all necessary and reasonable measures to prevent environmental harm arising from a human activity and reporting at once any accidents or damages to competent authorities for investigation, remediation and if necessary prosecution.

Ecological Integrity - where native components including abiotic components, biodiversity and ecosystem processes remain intact (Parks Canada 2006).

Fish Habitat - "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes" section 34(1) of the *Fisheries Act* (1985).

Indicator species - (as used in this research) Species of fish that are harvested for commercial, recreational or subsistence fisheries.

Indirect Fish Habitat – indirect fish habitat includes watercourses where flows are of insufficient duration for fish to complete one or more of their life processes (spawning, rearing, feeding, overwintering, or migration). These areas, while typically ephemeral, do provide water and nutrients to downstream areas. Works occurring in these areas can impact habitat downstream through the transport and deposit of sediment and other deleterious substances. Ephemeral watercourses typically have flows that are short-lived, or transitory, with meltwater runoff flows lasting for less than 21 days. For the rest of the year ephemeral drains are predominantly dry and typically flow for only a few hours to a few days after heavy rainfall events.

Maintenance – (as used in this research) maintenance work that is directly associated with the watercourse crossing such as filling scour holes under bridges, and placing riprap around culverts, etc. As is applies to this document the term maintenance does not apply to bank stabilization, dredging or vegetation removal works for any area other than within, or immediately adjacent to the crossing.

Operational Statement – is a document pertaining to a specific class of projects that can be used if all the conditions and mitigation measures outlined are met in lieu of submitting a formal project proposal for review by DFO. The document provides an outline of conditions that need to be present and measures that must be implemented to avoid a harmful alteration, disruption, or destruction of fish habitat, which ensures compliancy with subsection 35(1) of the *Fisheries Act.* It is recommended, but not mandatory, that if an operational statement is used a notification form should be sent to DFO for their records.

Precautionary Principle – a distinctive approach to managing threats of serious or irreversible harm [to the public or environment] where there is scientific uncertainty" (Environment Canada 2001). Even if cause and effect relationships are not established scientifically, an examination of the full range of alternatives including no action is necessary. An open, informed, and democratic process that includes potentially affected parties will identify and determine which precautionary measures should be taken, with the burden of proof of harm falling on the developer, not the public. "The precautionary approach recognizes that the absence of full scientific certainty shall not be used as a reason to postpone decisions where there is a risk of serious or irreversible harm. Even though scientific information may be inconclusive, decisions have to be made to meet society's expectations that risks be addressed and living standards maintained" (Environment Canada 2001).

Project – a one-time works, undertaking or job that has a clearly defined start and end date, "a scope of work to be performed, a budget, and a specified level of performance to be achieved" (Lewis 2000).

Sustainable Development - "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987).

Watercourse – a non-chlorinated body of water that forms a network within a watershed; a ditch, drain, creek, stream, dugout, pond, pool, river, lake or wetland that is natural or manmade and is or can be connected to other ditches, drains, creeks, streams, pools, dugouts, ponds, rivers, lakes and/or wetlands that are natural or manmade.

Note: Definitions are given as they apply to this document

1.0 INTRODUCTION

1.1 Legislative Mandate

Fisheries and Oceans Canada (DFO), Habitat Fisheries and Oceans Management (HFOM) has the legislated responsibility to protect fish and fish habitat under the habitat protection provisions of the federal *Fisheries Act*. The 1986 Policy for the Management of Fish Habitat was developed to outline an approach to protect fish and fish habitat in an effective and consistent manner, with a focus on no net habitat loss. Within this context, there is a need to develop a more systematic and pragmatic approach to water course crossings and habitat compliance strategies in Manitoba (MB) in order to streamline and speed up the project referral review process, making it more transparent and cost-effective.

To assess a project properly, DFO Fish Habitat Biologists require both specific and comprehensive information such as fish presence and abundance, habitat type and utilization, geomorphology, and hydrology in addition to the proposed work plans. Usually, the more information biologists have, the more accurately they can assess the current and possible long term effects a project could have on fish and fish habitat. To address this need for additional information, DFO Fish Habitat Biologists have recently conducted an inventory of the many streams and agricultural channels within agro-Manitoba (Figure 1). This inventory has identified numerous watercourses that various indicator fish species are using, as well as, the quality and quantity of the habitats present. These species (Appendix A) provide the social and economic link to downstream commercial, recreational, and subsistence fisheries where populations are under considerable pressure from ongoing human harvesting and/or developmental activities.

Source: Department of Fisheries & Oceans (2007a)

Figure 1: A map delineating Agro-Manitoba (yellow), the Morris River watershed and its sub watersheds (red), and the crossing inventory focus area within (diagonal bars).

From a management point of view, it is useful to know which watercourses indicator species are using and to relate this information to fisheries abundance data in downstream receiving waters such as lakes and rivers. The greater the number, diversity and value of fish species that are using a particular watercourse, the greater the requirement is to ensure that existing habitat quality and quantity are maintained or enhanced in that watercourse. This is extremely important and the underlying concept in DFO's proposed Habitat Classification System, which identifies five habitat classes from A-E, based on indicator species presence, habitat complexity, and flows. Combining the proposed Habitat Classification System with information on fish species abundance and diversity in a drainage network, along with information on the existing watercourse infrastructure present, allows Fish Habitat Biologists to more accurately assess the likelihood and extent of any impacts to that system that could result from any number of proposed developmental activities.

The careful management of agricultural drains is essential to ensuring the long-term sustainability of associated commercial, recreational and subsistence fisheries in lakes and larger rivers. This is the reason why projects within or near watercourses must be submitted for DFO review. Linking fish populations from a lake or river to their up-stream habitats based on stream order and habitat classification helps provide the social justification for more costly crossing infrastructure that may be required on the basis of fish use and habitat value. This information can also be used to help develop an effective class approach to low-risk stream crossing projects.

A class approach groups together projects doing the same activity within similar environments that have similar risks and known effects on fish habitat. One management application of a class approach is to develop project guidelines in the form of operational statements. An operational statement provides an outline of conditions that need to be present and measures that must be implemented to avoid a harmful alteration, disruption, or destruction of fish habitat (HADD) which ensures compliancy with subsection 35(1) of the *Fisheries Act.*

Approximately 15 Operational Statements have been created nationally with regional and district variations to accommodate geographical and hydrological variability for numerous low-risk situations to enable work to be done without formal DFO review. The Operational Statements are generic and are not prescriptive but do provide a list of mitigation measures for the proponent to follow to provide protection to fish and fish habitat. The statements were created to streamline the referral review process in an effort to make it more efficient, cost effective, transparent, and timely. Developments of class approaches and operational statements (OS) for other types of low-risk projects in Manitoba have been successful. Their presence continues to save time and money for all stakeholders involved. There are fewer projects for DFO to review, and in these cases, the proponents do not have to spend time and money on preparing a proposal for submission to DFO or waiting for DFO to authorize the works.

Development of a single class approach for all watercourse crossings is not appropriate given the great diversity of watercourses in agro-Manitoba, the proposed Habitat Classification System, and associated risk matrix. It may, however, be considered for the proposed Class D and/or Class E habitats as there is less risk from negative impacts resulting from development activities. To date, there has not been any attempt to develop a class approach for any watercourse crossings in Manitoba, given the level of associated risk, and the need to integrate diverse datasets.

The development of a class approach for watercourse crossings on Class D and /or E Habitats will require sensitivity to social, economic, political, and ecological factors. It will also require the integration of federal fish habitat data, provincial fish species and abundance data, fish habitat classification, crossing infrastructure, types and location inventories, fish passage velocity requirements and a risk management approach.

1.2 Problem and History

Conflicting demands between the fishing and agricultural industries arises primarily from the conflicting demands between agricultural producers' needs for adequate and cost effective drainage and watercourse crossings (usually small culverts) on one hand and the requirements for fish passage and connectivity between fish habitats on the other.

Farming activities are the economic backbone of the many agricultural communities that comprise agro-Manitoba. A large portion of this agricultural area is dependent on man-made drainage channels to prevent water from ponding on fields, which could affect seed germination, crop growth, and crop maturation due to the area's relatively flat topography. The needs of subsistence, sport, and commercial fisheries are dependent on high quality fish habitat in watersheds, which largely lie on agricultural land.

Before agricultural drains were constructed, natural streams and tributaries provided the high quality habitat resources and connectivity that fish depend on for food, shelter, and reproduction. However, increasing densities of human settlement and land use has decreased the amount and quality of fish habitat in agro-Manitoba. Channel creation and re-alignment within natural meandering watercourses has reduced the quality, quantity, diversity, and connectivity of aquatic habitats within them. Additionally, these alterations produce increased water velocities during spring runoff due to changes in hydraulic conveyance. As a result of these alterations, and subsequent reductions in the duration of peak flow, have negatively impacted spring spawning cycles for many valuable fish species. Therefore it is critical to ensure that all watercourse crossings be properly designed, installed and maintained to maximize the biological productive capacity of fish habitat within such drainage systems to preserve and enhance downstream fish populations both now and in the future.

In Manitoba, stream crossings are numerous and variable with respect to crossing type. In addition to the main highways, there is a grid-like network of roads, usually divided at every mile, which provides field access and service to the agricultural community. A crossing is required wherever a road traverses a constructed or natural stream channel. All watercourse crossing projects in Manitoba must be assessed by DFO prior to any work being done in or around a watercourse. Wait times for assessment and approval by DFO can be very lengthy. In Manitoba, DFO has 10 habitat biologists to review all projects proposals submitted. There has been an average of 632 projects submitted yearly to DFO over the past four years (2004-2007) (DFO 2007e). Access to accurate information quickly is a major problem. In addition, a comprehensive watercourse crossing inventory for Manitoba does not exist, and the proposed Habitat Classification System is in its infancy requiring Ottawa's approval and a few more years to improve its accuracy.

The construction and maintenance of drains and crossings normally falls under the jurisdiction of the provincial government and rural municipalities (RMs) within the province. The exceptions to this would be in the delegation of this responsibility to the newly emerging conservation districts (CDs) within the province. A main priority for the RM is the maintenance of road, crossing, and drainage infrastructure to benefit their constituents, who are primarily farmers. At the provincial level, there appears to be an administrative duality when it comes to water management and resource protection (standards, programming, and mandates). For example, within the Department of Manitoba Water Stewardship (MWS) one section the Fisheries section, has a mandate for conservation of fish and fish stocks, while another section has a mandate for developing and implementing drainage activities in a cost effective manner. This situation has been further complicated by the divestiture of the drain maintenance and construction activities and associated crossing infrastructure from MWS to another provincial administrative department, Manitoba Infrastructure and Transportation (MIT).

While DFO's mandate is to preserve fish habitat, MWS, MIT, RMs and four CDs have confirmed mandates to ensure adequate and timely drainage, in addition to the maintenance of water, road and railway infrastructure. While bridges are the least damaging to fish habitat and are preferred by DFO, they are generally more expensive to purchase and install in comparison to culverts. This often results in the installation of numerous steel corrugated circular culverts. The culverts are often either too narrow (diameters of 300 – 400 mm) and/or too long (30 – 40 m) which in peak flow periods produce velocities that are often far too high for fish passage and are therefore especially detrimental to fish species such as pike, sucker and walleye that travel upstream to spawn in spring.

In addition, bridges do not usually artificially constrain the channel, thereby keeping the velocities at the normal non-flood velocity at bank-full width. However, the budgets of the federal and provincial levels of government are usually provided on a yearly basis and the RM budgets potentially depend on local political demands. Given this short-term view of things, it is much easier (administratively speaking) and cheaper up front to install culverts rather than bridges.

1.3 Opportunity Statement

There was a requirement to determine if watercourse crossings could be assessed in a timelier and more cost effective manner, while ensuring that legislative requirements were met to protect fish and fish habitat within an ecologically sustainable development context.

This research proposed the way to merge the ecological and economic issues was to identify habitats of key importance through data integration and the development of a management approach (Integrated Watershed Map) to watercourse crossings on Class D and or E habitats through the assessment of the potential applicability of an operational statement. The development of integrative drainage maps when used in conjunction with an OS and Best Management Practices (BMPs) for watercourse crossings would save all parties time and money, which could be used to focus efforts on protecting higher valued fish habitat that are of key importance to sustaining fisheries resources in Manitoba. In doing so, ecological integrity and economic efficiency with respect to fish passage through stream crossings in agro-Manitoba would be realized.

A Risk Management Framework (RMF) was used to assist in the integration and assimilation of all relevant and pertinent data. The *Species at Risk Act* (SARA) was also considered in developing management strategies.

The questions addressed by this research were:

1. What were the requirements of fish passage and the current economic implications associated with watercourse crossing projects in agro-Manitoba?
2. What was the potential applicability of an integrated management approach to preserve and enhance ecological sustainability while still providing adequate agricultural drainage practices?

3. Could a comprehensive inventory map be developed and used strategically to facilitate the implementation of ecological sustainability in agricultural drainage practices? Would it be useful in aiding the development of an Operational Statement that could be used to streamline the water crossing reviews while still maintaining ecological integrity?

1.4 Purpose

The purpose of this research was to assess the applicability of an operational statement (OS) and develop a management approach that the Department of Fisheries and Oceans Canada (DFO) could use to incorporate economic, ecological, and social elements to achieve good governance as it applied to watercourse crossing projects in agro-Manitoba that reflected stakeholder needs and mandates.

1.5 Objectives

Objectives of this research were:

1. to identify businesses, resources and agencies that were concerned with or affected by the watershed management of the research area;

2. to determine the potential applicability of a class approach for watercourse crossings in agro-Manitoba based on proposed habitat classification and risk management models;

3. to develop and test an integrated watershed map as a decision making tool in watercourse crossing projects based on fish species composition and abundance, fish habitat and road crossing inventories and downstream dependent fish populations of concern;

4. to assess best practices available for watercourse crossing projects;

5. to develop concepts that could be used to develop an operational statement; and

6. to describe implications or next steps.

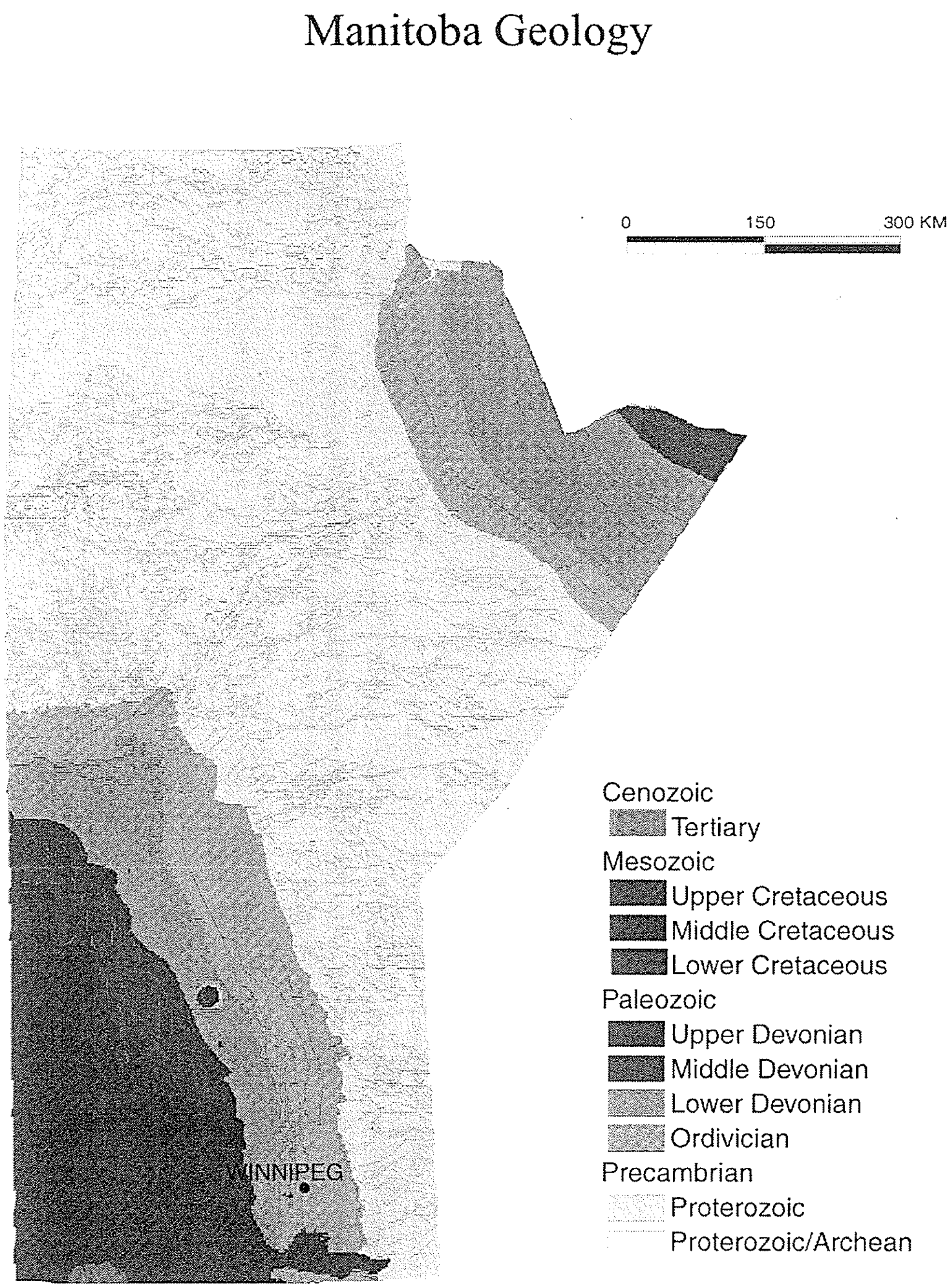
2.0 Background

2.1 Ecological and Technical Overview

2.1.1 Diversity of Habitats in Manitoba

Throughout the large number of watersheds present across the province of Manitoba, there are a wide range of different geologies, soil types, precipitation, temperatures, vegetation and water qualities which combine to create the diverse aquatic habitats observed in Manitoba (Figures 2, 3, 4, 5) (Falk Environmental 2000; Stewart and Watkinson 2002). The prairie region, extending north from the Manitoba-US border up to the Swan River area, west to the Saskatchewan border and east to the extent of cleared forest for agriculture, effectively encompasses agro-Manitoba. This area is of particular interest when dealing with watercourse crossings due to the grid like pattern of roads that exist.

The waters of the prairie region tend to be warmer and more turbid than those of the Hudson Bay coastal plain and the Canadian Shield (Stewart and Watkinson 2002). Streams in the prairie region tend to have low to moderate water velocities and meandering courses because of the low gradient. In comparison to the north and east regions, there are fewer lakes which typically have fine sediment substrates, contoured basins, and are relatively shallow. Lakes and streams of the Manitoba Escarpment (Turtle, Riding, Duck, and Porcupine Mountains) are the exception and are typically spring fed, cool, and clear. The north basin watersheds of lakes Winnipeg, Manitoba Winnipegosis are also exceptions (Stewart and Watkinson 2002).



Source: Viljoen, D.W., Chackowsky, L., Lenton, P., & Broome, H.J., 1998: Geology, Magnetic, and Gravity Maps of Manitoba: A digital perspective.1:1,000,000. Geological Survey of Canada and Manitoba Energy and Mines, GSC OF D3695, MEM OF99-12

Figure 2: A map of the geology of Manitoba

Obtained from: DFO Provincial Overview Training Module: Course Manual. Prepared by Mel Falk, Falk Environmental Inc. Consultant

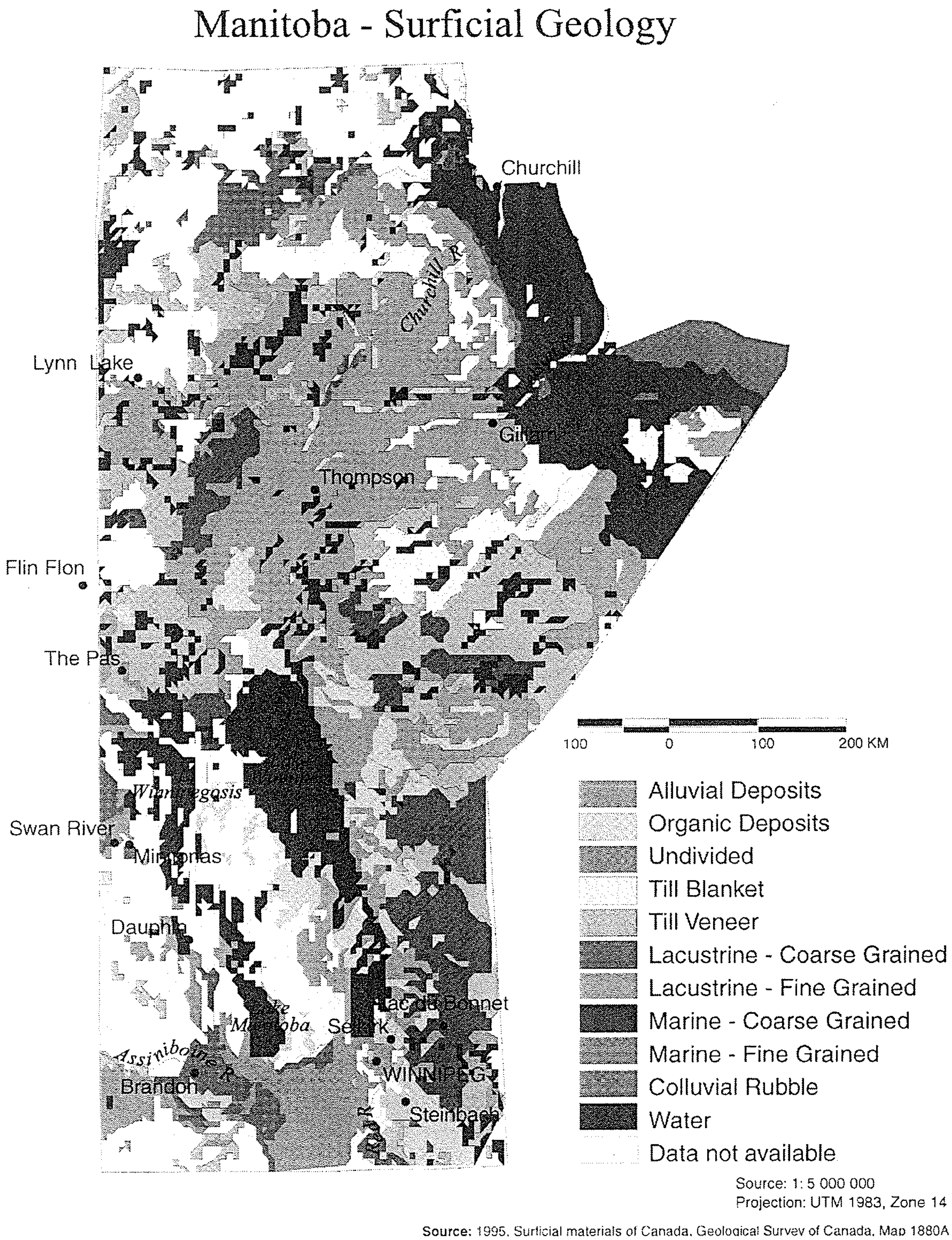


Figure 3: A map of the surface geology of Manitoba.

Obtained from: DFO Provincial Overview Training Module: Course Manual. Prepared by Mel Falk, Falk Environmental Inc. Consultant

Manitoba - Land Classification
(derived from AVHRR data)

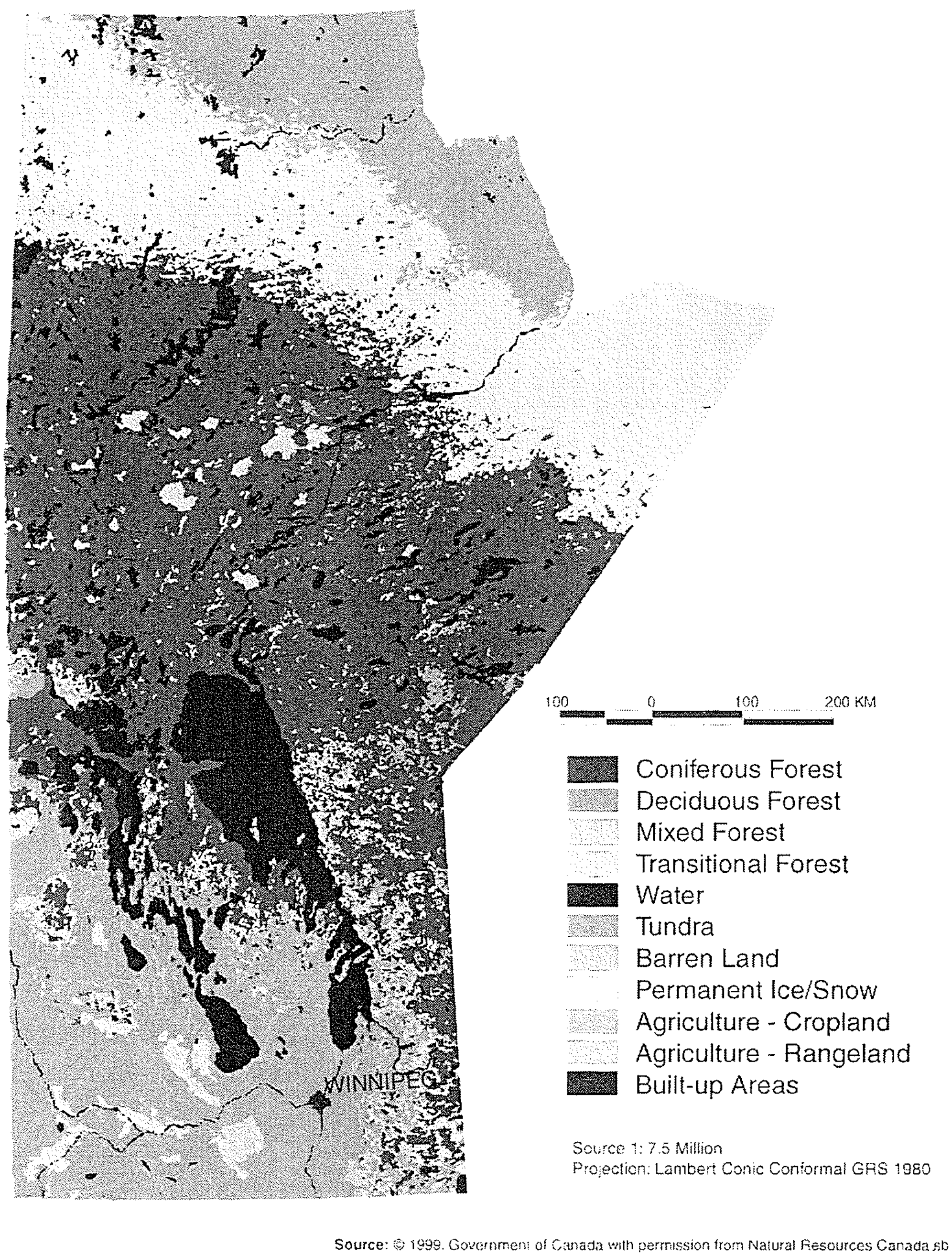


Figure 4 A land classification map of Manitoba.

Obtained from: DFO Provincial Overview Training Module: Course Manual. Prepared by Mel Falk, Falk Environmental Inc. Consultant

Manitoba - Watersheds

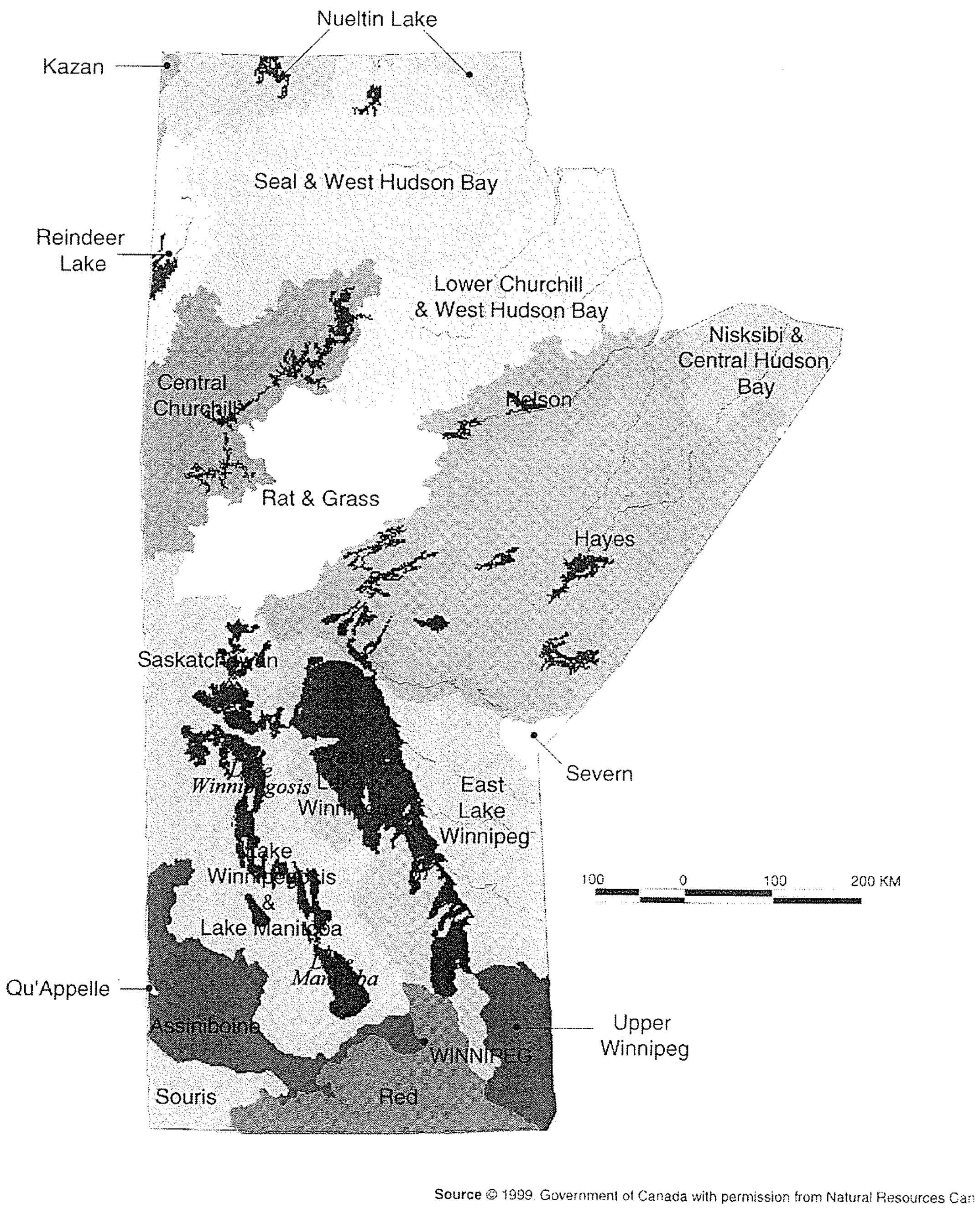


Figure 5: A map showing the major watersheds of Manitoba.

Obtained from: DFO Provincial Overview Training Module: Course Manual. Prepared by Mel Falk, Falk Environmental Inc. Consultant

It is important to note that local aquatic habitats can vary significantly over the course of the stream. This often provides the habitat diversity required for the many different species of fish within a single stream. Local habitats are typically defined and characterized by available cover, velocity/depth regime, sediment deposition, channel flow, and channel alteration. In addition, other valuable parameters include the frequency of riffles or bends, bank stability, riparian vegetative protection, riparian vegetative zone width, pool substrate characterization, and pool variability (Appendix B) (DFO, 2007a) and stream characteristics (Appendix C) (Gordon, Thomas, and Finlayson, 1992). Knowledge of the local habitat characteristics is extremely important to Fish Habitat Biologists for the determining potential effects that a proposed project could have on these features.

2.1.2 Species Habitat Preferences/Requirements

Many fish species over winter in lakes and large rivers and in spring travel up through smaller and smaller tributaries to their historical spawning grounds. Habitat requirements for fish can differ between species and between life stages of the same species (eggs, fry, juveniles, adult: migration and spawning) (Stewart & Watkinson, 2004). From a biological point of view, high quality habitats including spawning sites and migratory access routes to these areas should remain intact and undisturbed to ensure that the current species diversity be maintained. This biological necessity, along with the legislated mandate of the *Fisheries Act* establishes the requirement for Fish Habitat Biologists to try to minimize habitat alteration and avoid the destruction of high quality habitat to ensure that preferred habitats and access to these habitats is maintained or enhanced (Table 1).

Table 1: Summary of habitat preferences of various indicator fish species in Manitoba.

Indicator Species	Spawning				Eggs	Adult		
	Timing	Temp °C	Substrate	Velocity	Note	Habitat	Substrate	Velocity
Hiodontidae								
Hiodon alsoides Goldeye	In the Red River, most likely during spring runoff in mid water. Substrate is not a factor because the eggs are boyant.[1]					Larger rivers and lakes that have turbid waters. There is apparently no preference for substrate or velocity. Where mooneye are present they prefer faster velocities.		
Hiodon tergisus Mooneye	In the Red River, most likely after spring runoff in mid water. Substrate is not a factor because the eggs are boyant.[2]					Larger lakes and rivers in less turbid and slower moving water than the goldeye.		
Catostomidae								
Carpoides cyprinus, Quillback	Mid - late April	5-6	Coarse - fine gravel[3], sand[4]	Riffles[3], Runs[4]		Turbid lakes & larger streams	Sand - silt	Low
Catostomus catostomus, Longnose Sucker	Mid April - mid May	5+	On gravel over riffles with velocities between 30-45 cm/s, lake spawning is known to occur. Eggs adhere to gravel in clusters.			Lakes & flowing waters, use small streams only for spawning		
C. commersoni, White Sucker	Mid - late April	10+	Sand - boulders, usually gravel	Still - rapids	Adhere to substrate	All types	Commonly sand, silt and mud	Pools below riffles
Moxostoma anisurum, Silver Redhorse	Hypothesize that spawning occurs late May or early June, over gravel to rubble substrates in main channels in water less than a meter deep.5					Primarily riverine	Finer grained substrates and deeper, low velocity water than shorthead redhorse	
M. macrolepidotum Shorthead Redhorse	Late April - early May	8-10	Fine sand - cobble with boulders	Riffles	Broadcast over substrate	Lakes & streams at shallow depths	Rocky	Riffles & runs
Ictaluridae								
Ictalurus punctatus Channel Catfish	Late June- early July	21+	Gravel - rubble	High		Larger rivers & lakes, commonly between 2-5 m deep.	Gravel - rubble	Strong currents
Esocidae								
Esox lucius Northern Pike	Early April		Any, must have vegetation	Low	Adhere to vegetation	All types where velocity is lowest	All, with vegetationo r other cover	Low

[1]Turbidity of the water has prevented observation of Goldeye spawning.

[2]Turbidity of the water has prevented observation of Mooneye spawning.

[3]During high discharge periods

[4]During low discharge periods.

[5]No data of Silver Redhorse spawning in MB. Stewart & Wakinson 2002, used Becker (1983) notes from Wisconsin for hypothesis.

Table 1 Continued: Summary of habitat preferences of various indicator fish species in Manitoba.

Indicator Species	Spawning				Eggs	Adult		
	Timing	Temp °C	Substrate	Velocity	Note	Habitat	Substrate	Velocity
Salmonidae								
Oncorhynchus mykiss Rainbow Trout	Do not spawn successfully in the wild in Manitoba. In native ranges they spawn in spring. Females make nests (redds) in gravel in riffles. The eggs are deposited, and then covered.					More commonly in lakes than streams	In lakes they are mid-water schooling fish, in streams they inhabit pools & runs	
Salmo trutta Brown Trout	Do not spawn in the wild in Manitoba. In native ranges they spawn in fall. Typically they spawn on riffles, in Lake Superior they have been observed spawning on rocky reefs along the lakeshore.					Lakes & streams	Can live within a wide range of velocities, but prefer deep pools and runs.	
Salvelinus fontinalis Brook Trout	Fall (Aug - Dec)		On riffles over gravel in streams; gravel bottoms with spring water percolation in lakes. Female builds redd, & covers eggs.			More commonly in streams than lakes.		
Salvelinus namaycush Lake Trout	Oct- Nov		In lakes at depths of 0.3 - 0.35 m on reefs that have bedrock, boulder, or rubble substrate. Eggs sink between crevices in substrate.			Lakes that provide well oxygenated waters that are 10°C or colder year round. Sometimes found in rivers in extreme northern Manitoba.		
Gadidae								
Lota lota Burbot	In the Red and Assiniboine Rivers spawning is nocturnal and occurs mid winter usually in 2-4 meters of water. The non-adhesive and semi-pelagic eggs are broadcast over sand or gravel substrates.					Found offshore in lakes in the main stems of rivers, they are benthic at all life-life history stages.		
Moronidae								
Morone chrysops White Bass	early - mid June	Spawning occurs in lakes and rivers in 1-2 m of water over hard bottoms ranging from sand to bedrock outcrops.			Eggs are scattered, sink and are adhesive.	Are pelagic and prefer shallow, productive lakes & larger slow flowing rivers.		
Centrarchidae								
Ambloplites rupestris Rock Bass	Hypothesize that spawning occurs in June, in water temperatures between 16-17oC. The male digs a shallow nest which is defended against other males. The male guards the nest & fans eggs during development, abandoning nest once hatched young disperse from nest.[6]					Rocky habitats in littoral zone in lakes; pools & runs in streams & rivers.		
Micropterus dolomieu Smallmouth Bass		16-18	Gravel - rubble		Male builds nest	Lakes & lake-like portions of rivers	Rocky	
Pomoxis nigromaculatus Black Crappie	Hypothesize that spawning occurs in June & July in water temperatures of 18-20oC. The male makes a nest on substrate ranging from clay to fine gravel.					Lakes & rivers.	Cover (weed beds or woody debris)	

[6]No studies have been done on Rock Bass spawning in MB. Stewart & Watkinson, 2002, present in Scott and Crossman (1979) information.

Table 1 Continued: Summary of habitat preferences of various indicator fish species in Manitoba.

		Spawning				Eggs	Adult		
		Timing	Temp °C	Substrate	Velocity	Note	Habitat	Substrate	Velocity
Indicator Species	**Percidae**								
	Perca flavescens Yellow Perch	May - early June	>6	Eggs are expelled in a thick pleated strand which is bound together by a gelatinous mucus tube. The egg strands are slightly buoyant and usually become entangled in vegetation.			Requires cover (vegetation, woody debris, or human made structures)		Still or low
	Sander canadensis Sauger	May - early June		On shoals or reefs with gravel - rubble substrates in lakes; in rivers, high velocities over rocky substrate.			Shallow, more turbid waters than walleye on substrates range from clay or silt to rubble and boulders, although more common over rocky substrates.		
	S. vitreus Walleye	Mid April - late May	4	Rocky		Broadcast over substrate	Lakes & rivers in areas that are deeper, less turbid than the sauger prefer.		
	Sciaenidae								
	Aplodinotus grunniens Freshwater Drum	Mid - late June	20-23	Silt & clay - rubble	Spawning done in mid water, eggs float to surface		Mainstems of large rivers & Manitoba Great Lakes		
SARA Species	**Petromyzontidae**								
	Ichthyomyzon castaneus Chestnut Lamprey[7]	In mid to late June adults migrate from large rivers upstream into tributaries to spawn and die after spawning. They have a two phased life history. A school of spawning lampreys have been observed building a communal nest. The ammocoetes larva burrow in firm sand-mud substrates in fast flowing water and probably lives for seven years in Manitoba before transforming into an adult, most likely in the fall. The adults feed and the live for one year.							
	Ichthyomyzon fosser Northern Brook Lamprey	In mid June dead spawned out adults have been observed. Spawning occurs in riffles up to 30 cm deem over rubble and clean gravel substrate. There is no migration and adults die after spawning. They have a two phased life history.The ammocoetes larva lives for three to seven years before transforming into an adult in late September.Adults do not feed. Adults overwinter in the substrate over winter, emerging in the spring to spawn.8							
	Acipenseridae								
	Acipenseridae fulvescens Lake Sturgeon[9]	Late May - mid June	11	boulders, bedrock	rapids, base of falls	adhere to bottom	Larger lakes & rivers	sand (fine - medium)	
	Cyprinidae								
	Notropis percobromis Carmine Shiner[10]	May - June	>21	Gravel - rubble	riffles	Adhesive	mid-water, in rivers & streams	gravel to boulders	Riffles & runs
	Catostomidae								
	Ictiobus cyprinellus, Bigmouth Buffalo	Mid May - late June		Any, must have vegetation	Low	Adhere to vegetation	Large rivers or lakes	-	Low

[7]Listed as a species of special concern with COSEWIC.

[8]Listed as a species of special concern with COSEWIC.

[9]Sturgeon is not yet classified as a SARA species, but it is expected to be within the next few years.

[10]Spawning is not observed in MB; information obtained from species observed in Wisconsin. Stewart & Watkinson, 2002, used Becker (1983) notes.

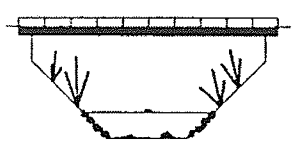
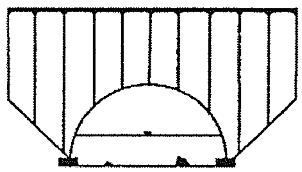
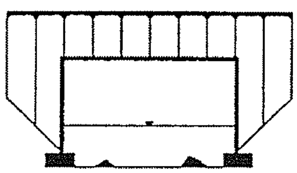
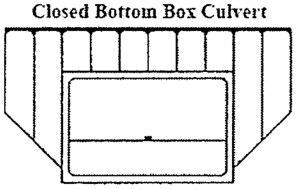
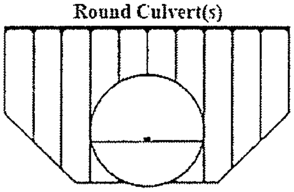
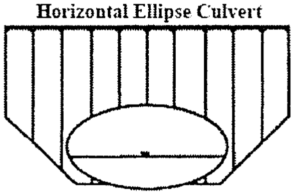
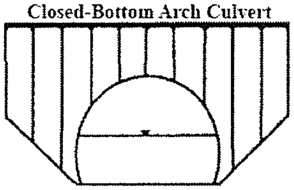
Adapted from Stewart & Watkinson 2002.

Trying to ensure quality habitats, and to maintain and enhance access to them for all species is the ultimate biological goal and realistically speaking is impractical from a management point of view given the historical and current drainage development in agro-Manitoba. DFO, HFOM, has established an index of species that are harvested by either commercial, recreational or subsistence fisheries (indicator species) (Wenig 1999). Despite the difficulties in trying to manage for various indicator species and the preservation of habitat diversity, best management practices have been established for many types of projects that are being done in or near water. The Manitoba Stream Crossing Guidelines has been developed to identify methods that should be used when designing and constructing watercourse crossings (DFO and MB Natural Resources 1996)

2.1.3 Watercourse Crossing Infrastructure

Originally, there were 1250 bridges and 1150 culverts under the jurisdiction of the Bridges and Structures Department of the Manitoba Infrastructure and Transportation (MIT) formerly Manitoba Transportation and Government Services (MTGS). When MIT was formed, management jurisdiction over an additional 1600 bridges and 3500-4000 culverts was transferred from MWS to MIT (Richardson 2007). Replacement costs for the MTGS structure inventory were estimated at $2.25 Billion dollars in 2006. Yearly bridge maintenance activities alone cost $2,072,537 as reported in the Manitoba Transportation and Government Services 2005 – 2006 Annual Report.

There are various types of culverts that can be used in crossing infrastructure: open bottom arch culvert, open-bottom box culvert, horizontal ellipse culvert, closed-bottom arch culvert, closed bottom box culvert, and round culvert. Each has different fisheries and design concerns (Figure 6). The most prevalent and cost effective type of culvert used in agro-Manitoba are the round corrugated metal culverts. However, during periods of extreme run off (spring and heavy rainstorms) if a culvert's diameter is small, water is

Type of Structure	Fisheries Considerations	Design Considerations
Bridge 	• Can retain existing bottom substrate, bank structure and riparian vegetation. • Does not alter bed load transport capacity of stream reach. • Can retain natural fish passage stream qualities.	• No limit to stream hydraulic capacity if encroachment of piers or footings is limited. • Ability to cross large streams and rivers. • Structure can often be designed with no instream work required.
Open-Bottom Arch Culvert 	• Does not limit fish passage if properly designed and constructed. • Retains natural stream substrate. • Water velocities are not significantly increased if culvert is as wide as the natural stream. • Potential loss of riparian vegetation.	• Design to normal stream width. • Wide bottom area provides good flow capacity with limited depth increase. • Large waterway opening for low clearance installations.
Open-Bottom Box Culvert 	• Does not limit fish passage if properly designed and constructed. • Retains natural stream substrate. • Water velocities are not significantly increased if culvert is as wide as the natural stream. • Potential loss of riparian vegetation.	• Design to normal stream width. • Can be placed in multiple units to provide wider section and larger end area. • Provide suitable footing for wall section to prevent undermining by stream erosion.
Closed Bottom Box Culvert 	• Can limit fish passage at low flows by reduced water depth in culvert. • Baffles can be easily installed to provide fish passage. • Wide bottom area allows retention of bottom substrates. • Loss of natural stream substrate beneath culvert.	• Can design to maintain stream width. • Can be placed in multiple units to provide wider section and larger end area. • Precast units can be installed quickly limiting instream construction time.
Round Culvert(s) 	• Generally poor for fish passage situation. • Difficult to provide passage in small diameters. • Concentrates flows and velocities. • Loss of habitat because of infilling around culvert. • Loss of natural stream substrate beneath culvert.	• Concentrates flows and increases velocities and potential scour at high flows. • Reduced depths at low flows may require backwatering. • Can have poor bed load transport through culvert.
Horizontal Ellipse Culvert 	• Avoid use in fish bearing stream or incorporate appropriate design modifications. • Stream substrate not easily retained in culvert. • Loss of natural steam substrate beneath culvert.	• Squat profile useful in low fill situations. • Shape results in deeper water depth than a closed-bottom arch culvert, but does not offer as broad a bottom area.
Closed-Bottom Arch Culvert 	• Can limit fish passage at low flows due to reduced water depth in culvert. • Baffles can be installed to provide fish passage. • Wide bottom area allows retention of bottom substrates. • Loss of natural stream substrate beneath culvert.	• Design wide bottom area for good flow capacity with limited depth increase. • Good for low clearance installation. • Multiple units can be installed to provide greater capacity. • Reduced depths at low flows may require backwatering.

Source: Chilibeck, et al. (1993); McCubbin et al. (1985).

Figure 6: Common watercourse infrastructure types used in Manitoba and associated fisheries and design considerations.

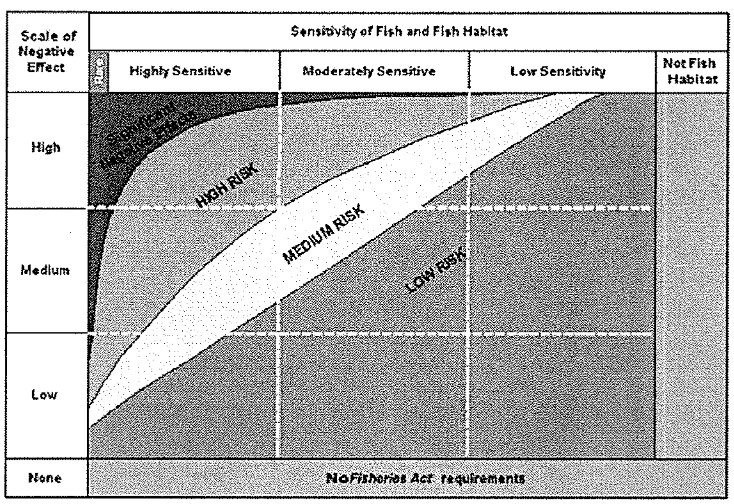
channelled through at velocities that are often far too high to permit any fish passage (Kenny et al. 1992; Katopodis and Gervais 1991). The extreme velocities also have a potential to erode adjacent banks more quickly than the natural erosion process, which increases sediment loads in the water and is potentially detrimental to fish and financially costly as banks must be stabilized to reduce the risk of bank failure (Kenny et. al. 1992; McKinnon and Hnytka 1985).

The Manitoba Stream Crossing Guidelines recommend designing culverts to achieve a maximum velocity of 1 meter per second for culverts less than 25 meters in length, and 0.8 meters per second for culverts that are 25 meters or longer. These numbers were derived from swimming velocity/distance curves developed by Fish Habitat Engineers through the research of ichthyomechanics (Katopodis 1993; Katopodis & Gervais 1991). These recommended velocities are sometimes viewed as too conservative, which translates to higher development costs using larger diameter culverts, which are more expensive than small diameter culverts. New studies have been done by Dr. Steven Peake using a different approach for establishing fish passage that suggest the curves developed by Katopodis are too conservative. Many proponents would like to see the guidelines changed to reflect up to date scientific test research (Kristofferson 2007).

Culverts tend to be the cost effective option to bridges, as they are cheaper to install and have less associated maintenance costs. That is not the only factor that must be considered. Public safety is always a major concern (Richardson 2007). The decision to install a bridge or culvert is site specific dependent on a number of factors such as visibility and turning movements. Bridges are the preferred option in heavily wooded watercourses where beavers and debris are a major maintenance cost, and they are the only option on large rivers. Bridges are usually installed where design flows are above 50-60 cubic meters per second. (Richardson 2007).

2.1.4 Pathways of Effects

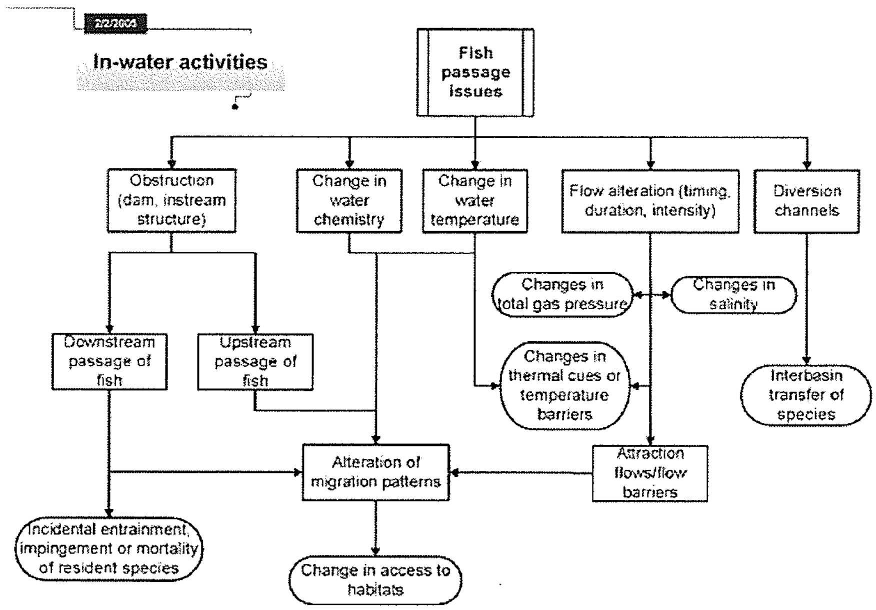
DFO has developed a Pathways of Effects (PoE) model for a range of developmental activities including fish passage issues and placement of material or structures in water. The PoE describes the kinds of cause-effect relationships that exist; and "the mechanisms by which stressors ultimately lead to effects in the aquatic environment" (DFO 2007d). The pathway representing each cause-and-effect relationship is a line showing the connection between a potential stressor and some ultimate effect on fish habitat and the fish themselves. Mitigation measures can be applied at each pathway to reduce or eliminate a potential effect. Where mitigation measures cannot fully address a stressor or cannot be applied at all, the Risk Matrix can be used to assess the remaining residual effect (Figure 7). "Risk is categorized according to the scale of the effect; and the fish and fish habitat sensitivities in the location of the proposed activity" (DFO 2007f).



Source: DFO (2007f).

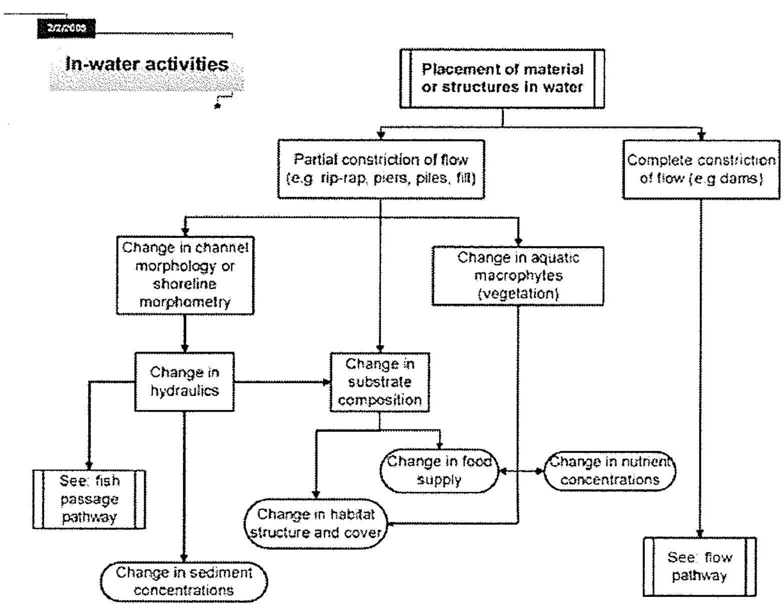
Figure 7: The Risk Matrix used by DFO Fish Habitat Biologists for assessing residual effects.

For fish passage issues, the PoE identifies incidental entrainment, impingement or mortality of resident species, change in access to habitats, changes in total gas pressure, changes in salinity, changes in thermal cues or temperature barriers and inter-basin transfer of species as residual effects (Figure 8) (DFO 2007d). For in water activities the residual effects that the PoE identifies are a change in habitat structure and cover, change in food supply, change in nutrient concentrations, change in sediment concentrations and



Source: Department of Fisheries and Oceans (2007d).

Figure 8: Department of Fisheries and Oceans' Pathway of Effects for fish passage issues.



Source: Department of Fisheries and Oceans (2007d).

Figure 9: Department of Fisheries and Oceans' Pathway of Effects for placement of material or structures in water.

what the likelihood the watercourse crossing project will be in causing a long term and/or permanent harmful alteration, damage, or destruction (HADD) to fish habitat (Figure 9) (DFO 2007d). Please see Appendix D for a description of each residual effect identified.

2.1.5 Impacts

"[C]ulverts installed at stream crossings often create a barrier to fish passage, as fish are unable to get over the lip or through the culvert during low flows, and are swept away by the velocity of the water during high flows" (Forster and Gaboury 1996). The impacts of water crossing projects can vary greatly in terms of duration and extent of impact depending on factors such as project design, water quality, type of aquatic and terrestrial riparian vegetation present, watercourse substrate type, bank composition, water velocities experienced over the course of the year, sediment and erosion control practices used, amount of stream channelization, crossing infrastructure (size, type, length of culvert or bridge) and number of crossings on the watercourse to name a few. It is understood that all culvert construction projects degrade fish habitat to an extent in the present and potentially in the future when compared to the natural alternative of not having any construction or crossing. Depending on substrate type and water velocities, embedded culverts may actually become perched over time as the sediment is eroded and carried away by the water, identifying the need for monitoring and potential maintenance (Kenny et. al. 1992).

Small, perched round culverts are of special concern to DFO as not only can velocities exceed fish passage requirements in high flow events but also the associated erosion causes scour pools and potential culvert perching, which prevents fish from accessing the culvert in the first place during normal or low flows. Fish passage can be obtained by using larger culverts to reduce velocities during high flows, embedding the culvert in the substrate or replacing it with arch-type culverts to ensure fish have access to the passage structure and installing a flow-control structure over culvert entries to create deeper water and ensure minimum flows are attained (Forster and Gaboury 1996). Improper culvert alignment can also contribute to increased erosion further downstream of the crossing.

This contributes to increased turbidity and sedimentation in pool habitats and other low flow areas. The result is lower quality habitat and/or less habitat availability and diversity. Maintaining or restoring natural riparian vegetation upstream, downstream and culverts provides shade, cover, food production areas and helps to stabilize the banks minimizing erosion and disturbance to fish habitat.(DFO 2007c)

DFO has narrowed their regulatory scope by primarily focusing on the habitat requirements of indicator species. From a management point of view, it is important to consider sedimentation issues and fish passage requirements for forage fish and aquatic benthic invertebrate species since they are an important food source for many of the indicator fish species during various life stages.

2.2 Government Agencies

2.2.1 Regulators

At the federal level, the *Fisheries Act* is the driving force for the management and protection of fish, fish habitat, and fresh waters in Canada. Two governmental bodies have taken the responsibility of administering this Act. DFO has taken on the regulatory role of conservation and protection of fish habitat and compliance with the Act, and Environment Canada (EC) has taken on the role of regulator of water quality and the deposit of deleterious substances (chemical spills). However, DFO remains the primary enforcer of the Act.

In Manitoba, DFO has delegated some of the responsibility to the Province. At the provincial level, the Fisheries Department within the MWS is responsible for day-to-day management of Manitoba's fisheries such as licensing and delivering quotas (DFO and Manitoba Conservation 2003). The *Water Protection Act* (2005) is an important piece of provincial legislation as it is the first provincial act that recognizes the interdependence of land and water ecosystems, and calls for comprehensive planning for watershed to provide protection and stewardship of Manitoba's water resources and aquatic ecosystems (Government of Manitoba 2005). At present, no department has specifically assigned themselves as the administrator and enforcer of the act to carry out the all of the duties required by the act.

DFO's regulatory duties include reviewing development proposals (referrals) to assess their compliance with the *Fisheries Act,* conducting enforcement activities, and conducting environmental assessments under the *CEAA (Canadian Environmental Assessment Act)* that are triggered by regulatory decisions under the *Fisheries Act* and/or *Navigable Waters Protection Act.* All three components are essential in protecting fish habitat. However, project proposal reviews are the first step, identifying what is and is not a HADD. Currently Fish Habitat Biologists are endeavouring to provide proponents with more information to help them understand the requirements and obligations of the *Fisheries Act.*

To properly review development proposals, the Fish Habitat Biologist must first examine all related referral documentation provided to them. In many cases, the information provided does not paint a clear enough picture about the project to allow the biologist to adequately assess the potential habitat impacts of the project. The biologist must seek additional information from the proponent and/or alternative sources and in many cases conduct a site visit. From the information collected the biologist must then determine the impacts of the project on fish and fish habitats, identify mitigation and compensation requirements if any, and make a decision on whether or not the project proceeds as submitted or requires additional modifications including re-location of the project. A letter of advice (LOA) or authorization that effectively communicates that decision, the mitigation requirements, and any other pertinent information will be then written and sent out to the proponent(s) (DFO and MB Conservation 2003).

The Governments of Canada and Manitoba explicitly recognize the importance of fish habitat and the fisheries resources "to the economic well being and social fabric of provincial communities and Aboriginal Peoples" (DFO and MB Conservation 2003). These governments have publicly stated their commitment to protecting, conserving, and enhancing fish habitat. While this recognition and commitment are essential to ensuring the sustainable development of the province's fisheries resources for Canadians, it must also be realized that their decisions have an impact on other stakeholders, like farmers, whose livelihoods and interests are equally important, so a middle ground or way to accommodate both sectors' interests must be found. The Environmental Process Modernization Plan (EPMP) is a step in the right direction.

The EPMP aims to modernize the key federal regulatory program, the Fish Habitat Management Program (FHMP), through policy, programming and organizational changes (DFO 2007c). The EPMP was designed to carry out the program's mandate, to conserve and protect fish habitat more effectively, making the delivery of services more efficient, while integrating the interests and responsibilities of others. It is a continuous improvement plan to improve timeliness, consistency, and transparency in decision-making and to strengthen partnerships with other stakeholders to capitalize on opportunities to conserve and protect fish habitat (DFO 2007c).

To modernize the FHMP the EPMP focuses on six key elements: streamlining regulatory review of low risk activities, developing a program wide RMF, strengthening partnership arrangements, improving coherency and predictability in decision-making, improving the management of major projects and modernizing habitat compliance activities (DFO 2007c).

2.2.2 Developers

The Province of Manitoba is responsible for most drains other than municipal ones (Richardson 2008). The departments of MWS, MIT and Intergovernmental Affairs and Trade (MIAT) all are all involved with infrastructure projects including watercourse crossing projects in Manitoba. While MIAT mainly deals with funding issues, MIT has responsibility over crossing infrastructure at highways and on Provincial Waterways. The Water Control and Structures branches of MIT supervise the planning, design, construction, rehabilitation, and damage repair to structures throughout the province (Richardson 2008).

MWS's Water Control Infrastructure Program's sub program, Provincial Water Resources Projects, is responsible for policy, feasibility studies, and long range planning of water control infrastructure. The program is structured to service the needs of RMs, planning districts, CD boards, the Manitoba Departments of Agriculture, Conservation and Infrastructure, and Transportation and Highways, other sections of MB Conservation, as well as, engineering consultants, contractors, and the flood/drought affected public with respect to operational direction for water control and conveyance infrastructure and prompt access to databases, products and services. MIT is responsible for the maintenance of the crossing infrastructure.

The objectives of the Water Control Infrastructure Program are concerned with long range planning for maintaining, refurbishing, and building infrastructure such as bridges, crossings and waterways; licensing drainage systems as mandated in the *Water Rights Act* (MWS 2007). Their goal is to ensure effective program operation; investigating and resolving drainage issues; and providing plans, data, and information on infrastructure for investigations related to water resources amongst other flood related issues (MWS 2007). MWS also houses the Fisheries Department, which is concerned with day-to-day activities related to fisheries such as licences and quotas.

From a policy perspective, the minister of MWS is responsible for the administration of the Manitoba Water Strategy and applying Manitoba's Water Policies. The sixth policy outlined in "Applying Manitoba's Water Policies" identifies a need to "enhance the economic viability of Manitoba's agricultural community through the provision of a comprehensively planned drainage infrastructure" (MWS). This coincides with the section in the Manitoba Water Strategy that directly speaks to the drainage issue. It speaks to the understanding that a watershed view should be taken to protect downstream habitats including wetland areas and fish habitat. The Strategy identifies drainage enforcement, infrastructure maintenance and drain reconstruction as key issues. There is explicit recognition of the need to improve the provincial drainage system and the co-ordination amongst stakeholders in addition to the need to develop methods to better incorporate drainage, fish habitat, and water quality requirements into the planning licensing, construction and maintenance of drainage projects. One of the recommended actions the Water Strategy calls for is the promotion of reasonable drainage guidelines that improve drainage and support DFO's effort to protect fish habitat.

2.2.3 Memorandum of Understanding

The Governments of Canada and Manitoba recognize that they share mutual interests in cooperating to protect and conserve fish and fish habitat. In 2003, to facilitate a collaborative approach to increase the efficiency, consistency, and effectiveness of the protection, conservation and enhancement of fish habitat in the Province of Manitoba using federal and provincial legislation, regulations, policies, and programs a Memorandum of Understanding (MOU) was developed. The MOU was signed by DFO and MB Conservation representing their respective level of government (DFO and MB Conservation 2003).

The MOU applies to the enforcement and administration of the fish habitat protection provisions of the *Fisheries Act* (sections 20-22, 26, 28, 30, 32, and 35). Whereby DFO will solely handle approvals and enforcement of these sections and will work collaboratively on the review of these sections. The agreement focuses on clear communication and collaboration between Manitoba and Canada; the harmonization of policies, standards and guidelines; and integrated conservation and protection of fish habitat. Strategic joint objectives and priorities to reduce workloads will be created, information/research needs will be identified, and integrated watershed planning processes will be supported. The two governments will also ensure that fish habitat needs are incorporated into all land use planning processes and natural resource allocation decisions where applicable (DFO and MB Conservation 2003).

2.2.4 Scientific Basis for Regulatory Work

The Governments of Canada and Manitoba have committed themselves to conduct and communicate research in support of regulatory, integrated watershed management and community outreach activities (DFO and MB Conservation 2003). This research has been deemed necessary to determine and ensure the effectiveness of decisions and techniques related to referrals and integrated watershed projects (DFO and MB Conservation 2003). Scientific research examining biological aspects (habitat preferences, behaviour and swimming mechanics); engineering aspects (hydrodynamics, stream mechanics, crossing design), geography (location, elevation, connectivity); and their immediate, long term and cumulative integrated effects as well as economic and social costs and benefits are all necessary to ensure the effectiveness of decisions and techniques related to watercourse crossings projects.

Table 2: Acts, Policies, and Regulations that may apply to water-course crossings in agro- Manitoba.

FEDERAL
Fish habitat protection provisions of the *Fisheries Act* The *Canadian Environmental Assessment Act* The Policy for the Management of Fish Habitat Habitat Conservation and Protection Guidelines Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat
PROVINCIAL
The *Environment Act*
The *Fisheries Act* (Manitoba)
The *Conservation Districts Act*
The *Crown Lands Act*
The *Dangerous Goods Handling and Transportation Act*
The *Forest Act*
The *Mines Act*
The *Municipal Act*
The *Planning Act*
The *Public Health Act*
The *Sustainable Development Act*
The *Water Resources Administration Act*
The *Water Rights Act*
The *Water Power Act*
The *Water Protection Act*
Manitoba Fishery Regulations
Manitoba Fisheries Policies 1996

Source: DFO & MB Conservation (2003), and Government of Manitoba (1997).

By doing so best management practices can be developed and used in conjunction with collaboration and integrated thinking, which is essential for upholding various legislation, policies, and guidelines (Table 2).

2.2.5 Interactions with Other Stakeholders

MIT's Regional Offices provide management, administration, and field engineering services for the Provincial Highway Systems, the Provincial Drainage Network, and the Provincial Flood Control Infrastructure (Richardson 2008). Activities include preparation of project proposals, budgets, project design, supervising construction activities, co-ordination, and maintenance of operations and monitoring of contract work. Most roadwork projects are financed either 100% by the province or on a 50/50 basis between RMs and the province (MTGS 2006).

The Department provides services that are not available at a reasonable price from any other source, including emergency funding for provincial road and provincial trunk highway systems that have been damaged by flooding (MTGS 2006). It would be quite costly for each RM to purchase the required equipment and obtain required specialized knowledge that is necessary for many of the projects would put a tremendous burden on their taxpayers and in many cases, it would be a duplication of effort (MTGS 2006). Some cases could involve an individual landowner may be required to talk to a contractor or the local RM for expertise, to identify funding options, and obtain help in submitting the referral, or he can proceed to draw up a development proposal and submit it to DFO on his own.

The Governments of Canada and Manitoba also must pursue cooperative arrangements with Aboriginal Peoples, all orders of government, non-government organizations and industries to advance the MOU's goal of using a collaborative approach to increase the consistency, efficiency and effectiveness in the protection, conservation and enhancement of fish habitat in the Province of Manitoba to achieve the MOU's objectives (DFO and MB Conservation 2003). This would include providing public information and education, pursuing public consultation, and developing and maintaining cooperative arrangements with stakeholders.

2.3 Case Studies

2.3.1 Introduction

Local studies that focus specifically on fish passage in drains and through watercourse crossings in Manitoba were not found. Three separate studies that focused on fish passage issues and culverts will be presented here. Two of the studies are from Canada, one based in the Arctic, the other based in the Maritimes, and the third study is based in the United States (Maryland). Studies from very different geographical regions were selected to identify the similarities or common themes that exist. Please note that the physical, biological, and political aspects of these studies do not reflect the present Manitoba experience/circumstances exactly, however the lessons learned have been taken into consideration when these culvert crossings were looked at in Manitoba.

2.3.2 Case Study I

McKinnon, G., and Hnytka, F. 1985. Fish passage assessment of culverts constructed to simulate stream conditions on Liard River tributaries. Canadian Technical Report of Fisheries and Aquatic Sciences 1255, Department of Fisheries and Oceans. Western Region, Winnipeg, M.B.

This study assessed fish passage issues resulting from culvert installations on Liard River tributaries in the Northwest Territories as a result of the Liard Highway development project. The study was established in response to observed impairment to fish migration during construction of a culvert crossing for a previous section of the highway development project. Field studies were conducted on four tributaries over four years (1978-1981), collecting biological and physical data including velocity measurements at varying depths, water quality, suspended solids, conductivity, dissolved oxygen, fish collection, identification and tagging data, as well as aging and fecundity measurements. The study identified erosion as the biggest problem experienced from the installation of the culverts, both immediate because of construction and chronic from the lack of sediment and erosion control measures placed on the banks. Lack of environmental awareness and concern was also a recognized issue, along with the lack of baseline data (climatological, physiographical, and biological) for the use in planning. Local data collected over a number of years would be beneficial to understand the fluctuations and changes in the physical and biological parameters that the area experiences. This information is critical in designing effective and long lasting watercourse crossings.

Some of the recommendations the authors gave were to keep the number of watercourse crossings to a minimum, to design the route of roads to be as far away from the watercourse as possible, and to perform all construction activities (culvert and riprap installation and bank stabilization) within a single period. The study found that a few of the culverts were installed over two years (same season in both years) which caused further erosion problems.

2.3.3 Case Study II

Langill, D.A., and Zamora, P.J. 2002. An Audit of Small Culvert Installations in Nova Scotia: Habitat Loss and Habitat Fragmentation. Canadian Technical Report of Fisheries and Aquatic Sciences 2422, Department of Fisheries and Oceans. Maritimes Region, Habitat Management Division, Dartmouth, N.S.

This study examined possible associated fish habitat loss and or fragmentation from the installation of small culverts in Nova Scotia. The study audited a random sample of 50 culvert installation notifications that encompassed four counties and spanned two years (1999 & 2000). Culvert dimensions, material composition and slope measurements were taken. Habitat characteristics within the immediate area were recorded and any fish species or *SARA* species present were noted. In Nova Scotia, a culvert notification system has been established by Nova Scotia Department of Environment and Labour to regulate the installation of small culverts spanning streams of widths less than one meter across, so no formal referral process is required for watercourse crossings like it is in Manitoba.

The introduction identified the many biological and engineering requirements that should be taken into watercourse crossing project, noting that culverts are the main infrastructure type utilized in the Maritimes. The study noted a distinction between drainage and stream culverts, implying that drainage ditches adjacent to roads are not considered fish habitat in Nova Scotia. In Manitoba, given our species composition, any drain that is connected to the waterway system could be fish habitat. Northern Pike are known to these watercourses to reach terrestrial habitats (fields) that become spawning grounds when flooded.

The study stressed the importance of interconnectivity of fish habitat to support populations and identified culverts as potential barriers to fish passage if designed and or installed incorrectly. "There are many cases where a properly designed and installed culvert is appropriate as a water crossing, from both an environmental and economic point of view." (p2) Results of the study indicated that out of the sites that did have a culvert installed and were considered fish habitat, only one culvert installation project, an open bottom box culvert, did not leave an ecological footprint. This suggests that many of the self-assessed installations were done poorly and there is some degree of risk associated with every installation. Maintenance issues were identified suggesting that the function of culverts that were not properly maintained were problematic. This highlights the need for a good monitoring program to identify these problems and ensure they are fixed.

In addition to the bank stabilization and siltation problem resulting from improper culvert installations, the study found that assessing the cumulative effects from many culverts in close proximity was difficult.

2.3.4 Case Study III

Kenny, D., Odom, M., and Morgan II, R. 1992. Blockage to Fish Passage Caused by the Installation /Maintenance of Highway Culverts. Final Report, Volume 1, Appalachian Environmental Laboratory Center for Environmental and Estuarine Studies, the University of Maryland System, Frostburg, Maryland.

This study examined fish passage issues as it related to watercourse crossing infrastructure in Maryland. The researchers were presented with forty-eight watercourse crossing sites from the Maryland Department of Natural Resources. Thirty-two of the sites were highway structures that were believed to be barriers to fish passage; the remaining sixteen sites had modified culverts in place. The culverts had been modified to incorporate different kinds of fish passage measures. The study spanned the years 1988 to 1990 starting in the fall, ending in the spring. The goal was to identify construction methods for culverts that permit fish passage in various circumstances, which includes identifying possible retrofitting methods for culverts that already present a problem. This is important as Maryland has a stream classification system based on species use. It was noted that "measures taken to assure fish passage through culverts should be tailored to the type of fish that need to be passed" (p.86).

The study identified vertical drop at the inlet or outlet and low water depth as the prime causes that prevented fish passage. Of the sixteen modified culverts studied, twelve succeeded in allowing the migration of fish upstream for all but extreme high and low flow years and four presented a risk for seasonal blockage due to low water depth. An in-depth discussion on scour hole creation and the various designs to prevent culvert perching and low water depth, as well as designs to minimize water velocities in culverts was included.

A review of culvert and fish basics and their interaction was presented providing the reader with a good overview of the considerations that should be involved when designing culverts. A discussion of culvert shapes, materials and design criteria were put forward, preceding an exploration of ideas related to fish swimming abilities. A table outlining the costs of bridge and culvert on a linear foot or square foot basis was very effective in illustrating the point of why most developers prefer using culverts. The cost of a pre-stressed concrete slab bridge at $112 per square foot would not be even considered if a couple of 60-inch diameter circular corrugated metal pipe culvert at $43 per linear foot could be installed. Although the cost of the bridge was an estimate for a fully installed structure in 1989, and the culvert price was the cost of materials only in 1990, the culvert would still be much cheaper than the bridge to install in the end.

Another section of the study assessed Manning's Parameter or "n" which is a term used to gauge the roughness or texture of the culvert. The more turbulence there is higher "n" values result in more available resting spots for fish. This also means as "n" increases flow rates decrease. So if all other factors are equal, a larger cross-sectional area is needed for a CMP to transport the same amount of water as a smooth walled. It is important to consider fish behaviour along with swimming ability to assess how or if they will use a culvert given other technical parameters. The issue of swimming speed determination was examined. Several swimming speed curves of various species were presented to show there is a difference in values as a result of different techniques.

This issue could have significant impacts in Manitoba. DFO currently uses Katopodis' swimming curves for maximum swimming velocity of pike, which are conservative to Dr. Peake's calculations from his more recent study. If DFO used Dr. Peake's calculations as a requirement for minimum culvert velocities, velocities for culvert design could be higher, enabling the use of smaller culverts. This could significantly reduce watercourse crossing project costs in Manitoba.

2.3.5 Case Study Discussion

While each study had a different focus, and the study areas themselves were very different possessing different fish species, habitats, geologies, climates, social, political and economic aspects etc., each presented ideas or findings that needed to be considered for developing a management approach to watercourse crossings in Manitoba. While all cases were looking at fish passage issues, it was interesting to view the studies from a chronological and focus oriented manner to see how complex the issue was and how the information base had increased, diversified, and specialized over the years.

Case I was by far the oldest and written in a time when environmental knowledge was at a relative fledgling state in the late 70s, early 80s. The study obtained baseline biological and hydrological data from a very small subset over four years, essentially documenting the impacts of culvert installation in a remote, unpopulated area. The focus was on biology and environmental conditions and data collection. Conclusions and recommendations presented in the study are for the most part common knowledge now within the field of watercourse crossings, but at the time, they were at the forefront of the literature. Lack of environmental awareness was noted as one problem faced.

Case III was written roughly ten years later in the late 80s early 90s. A larger number of culverts (48) were examined and slightly different data were collected. The study took roughly two years and was within in a populated area in a time with more access to data and better technology. The focus was technical and narrow, looking at biological and engineering parameters involved in culvert design for fish passage, and on data collection and problem solving. The conclusions were technical in nature (drop in inlet/outlet, low water depth, and high water velocities).

Case II was the most recent being written in 2002, roughly ten years after Case III. A similar number of culverts were examined (50) as Case III, but the culverts chosen were by random as opposed to be specifically selected and handed to the researchers. Access to a database (HRTS) that provided the original project information should have given the researchers the history and baseline data of the sites they were visiting. This study only took two seasons, which could have been because less time was required to collect background information. The focus was broad and managerial, looking at connectivity, fragmentation, and habitat loss. The conclusions were systemic in nature looking at the ecological big picture.

In conclusion, these studies showed that there are a number of factors that interconnect within the realm of fish passage through watercourse crossing infrastructure. For a viable management approach to work it needs to reflect that interconnectivity; the ecological, social, economic, and technical information must be integrated and examined collectively to promote the level of understanding required to meet the needs of the stakeholders and legislation.

2.4 Datasets

2.4.1. DFO's Internal Interactive Mapping System

DFO has an internal interactive mapping system (IMS) that combines information from the Manitoba Fisheries Information Network, DFO data including Agricultural Drainage Inventory (ADI) data, MB Data, and Prairie Farm Rehabilitation Association (PFRA) Data as separate layers over a base map of Manitoba. The IMS has provided valuable information for the study and it was be the model for this study's interactive integrative map.

2.4.1.1 Manitoba Fisheries Information Network

The Manitoba Fisheries Information Network had collected information at sites on various lakes and streams in Manitoba including lakes Winnipeg and Manitoba, and the Red and Assiniboine Rivers. This data, represented as 13 separate layers, included data on harvest, dissolved oxygen, land use, habitat conditions, lake and stream morphology, fish stocking, summer temperatures and water chemistry.

2.4.1.2 Agricultural Drainage Inventory

During the past 5 years, DFO collected detailed ecological data from many streams and channels throughout agro-Manitoba as a part of the ADI. With this data, they have built an interactive mapping system that classifies drains from class A to E based on habitat conditions present and presence of fish species collected. Combining this data with abundance and fishery data collected by the province and others will allow for the identification of primary corridors/routes that indicator/important species use. Please see Appendix E for a description of the of habitat classification parameters.

2.4.1.3 Manitoba Data

The Manitoba data came from the province and included layers on provincial fish collection data, Township/Range, RMs, Manitoba wild rice areas, and Orthophotos (black and white photos of the landscape taken from an airplane).

2.4.2 Manitoba Lands Initiative

The Manitoba Lands Initiative (MLI) provided on-line access to geographic based data on Manitoba that was collected by the Province of Manitoba. The site provided data files on administrative boundaries, base map, cadastral, digital elevation models, digital imagery, environment, forest inventory, geographical names, geology mapping, land use/cover maps, municipal maps, provincial trunk highways (PTHs), quarter section grids, soil classification, spatial referencing, topographic maps, town & village plans, and water related maps (basins & watersheds of Manitoba, and designated drain watercourses). The information was provided in numerous formats: snapshots (GIF), tagged images (TIF), ESRI (SHP), Autocad (DXF), and Mrsid (SID) in addition to the document file with the data documentation. This information was critical in providing baseline data to design the integrative interactive map. DFO used some of the files for their IMS, and it has provided additional information for this research.

2.4.3 Red River and Lake Winnipeg Studies

Various reports were identified to collect additional information on abundance and migration routes of indicator species for this research as needed. The reports looked at were:

Kristofferson, K.1994. The Walleye Sport Fishery of the Lower Red River. M.N.R.M practicum, Department of Natural Resource Management. The University of Manitoba, Winnipeg, MB.

Franzin, W., Stewart, K., and Hanke, G. 2003. Fish and Fisheries of Lake Winnipeg: the First 100 Years. Canadian Technical Report of Fisheries and Aquatic Sciences 2398, Department of Fisheries and Oceans, Central and Arctic Region, Winnipeg, M.B.

Watkinson, D., Franzin, W., and Podemski, C. 2004. Fish and Invertebrate Populations of Natural, Dyked and Riprapped Banks of Assiniboine and Red Rivers. Canadian Technical Report of Fisheries and Aquatic Sciences; 2524, Department of Fisheries and Oceans, Central and Arctic Region, Winnipeg, M.B.

Information obtained has provided insightful and pertinent information that was incorporated into this research.

2.5 Discussion

The complexity of the issue and amount of knowledge and information required make it difficult to fully comprehend what is involved and required to manage and complete watercourse crossing projects in an effective ecologically, economically, and socially conscious manner. A basic understanding of the various ecological, technical, economic, social, and legal considerations involved is critical to managing watercourse crossing developments in a sustainable way. Collecting and combining data into strategic maps is a step towards sustainable development and integrated watershed management. Reviewing available provincial, federal, and other stakeholders' data sets and using the applicable ones will not only not provide a better picture for managing watercourse crossing projects but it may build connections and create prospective partnerships within the greater community.

Developing a class approach to watercourse crossing projects in agro-Manitoba can be beneficial to all stakeholders. For the developers, it will provide clearer direction on what DFO requirements are well in advance of the annual budgetary planning processes and allotments where more cost effective measures can be used in crossing construction and maintenance. For the regulators it will free up much needed time to focus on critical habitats and larger scale issues.

3.0 METHODS

3.1 Introduction

The Morris River sub-watershed, located within the Red River Basin, was the primary focus area of the research, with the assumption that the observed results and underlying rationale may be applicable throughout agro-MB. An inductive approach was used involving qualitative and quantitative methods to achieve the research's objectives. The primary research methodology used to obtain the necessary information was to conduct oral/written interviews and a spatially limited watercourse crossing inventory.

To identify legislative, ecological, economic, social, and other issues associated with watercourse crossings in agro-Manitoba, it was deemed necessary to interview experts involved with watercourse crossing projects. Employees of Federal, Provincial and Municipal agencies and others who have a direct role in, responsibility for, or knowledge associated with the regulation and or development of the design, construction, maintenance and management of watercourse crossings in the research area were identified using a non-probabilistic snowball sampling method (Palys 2003). The interview subjects' responses were combined with information collected from a thorough literature review to identify best management practices for watercourse crossings and key elements that could be used in an operational statement for low risk projects.

To develop an integrated watershed map, information on fish species composition and habitat classification was obtained from DFO's IMS (Information Management system) in combination with provincial data and overlain with information collected from a small watercourse crossing inventory. Crossing type inventories do not currently exist in any GIS based provincial or federal database, although information on crossings may exist in limited locations within the RMs (Baker 2008; Harder 2008).

3.2 Crossing Inventory

An inventory was conducted to gain an understanding of the types and physical characteristics of the crossing infrastructure in the research area to determine the potential availability of the watercourses for fish passage. Originally, the entire Morris River watershed was chosen for this inventory, as it is adjacent and connected to the Red River and located within the agricultural heartland that has extensive road and drainage networks. Additionally, the area is within a reasonable daily travel distance from the city so that the number of crossing sites to sample could be done in the shortest period of time. Relief is an important consideration in culvert design. The research area was chosen because the terrain had minimal relief (relatively flat with low slopes) thereby reducing the additional variability that would have been introduced by increasing water velocities due to increasing relief gradients as identified in the case studies.

It is important to use a watershed in which fish passage connectivity between the smaller watercourses and Lake Winnipeg is readily identifiable. By doing so, the link between the potential value of these upstream fish species distributions where spawning, feeding and migratory activities may be taking place, and the commercial, recreational, and subsistence fisheries in Lake Winnipeg and the Red River (Figure 10) can be easily understood. The Red River is a large river known for its diverse fish species and its use as a corridor by indicator species connecting Lake Winnipeg to smaller upstream tributaries where spawning areas are located (Watkinson, Franzin and Podemski 2004; Franzin, Stewart and Hanke 2003; Kristofferson 1994). It is also important to choose an area with extensive drainage and road networks to maximize the number of sites visited and information obtained in the shortest amount of time.

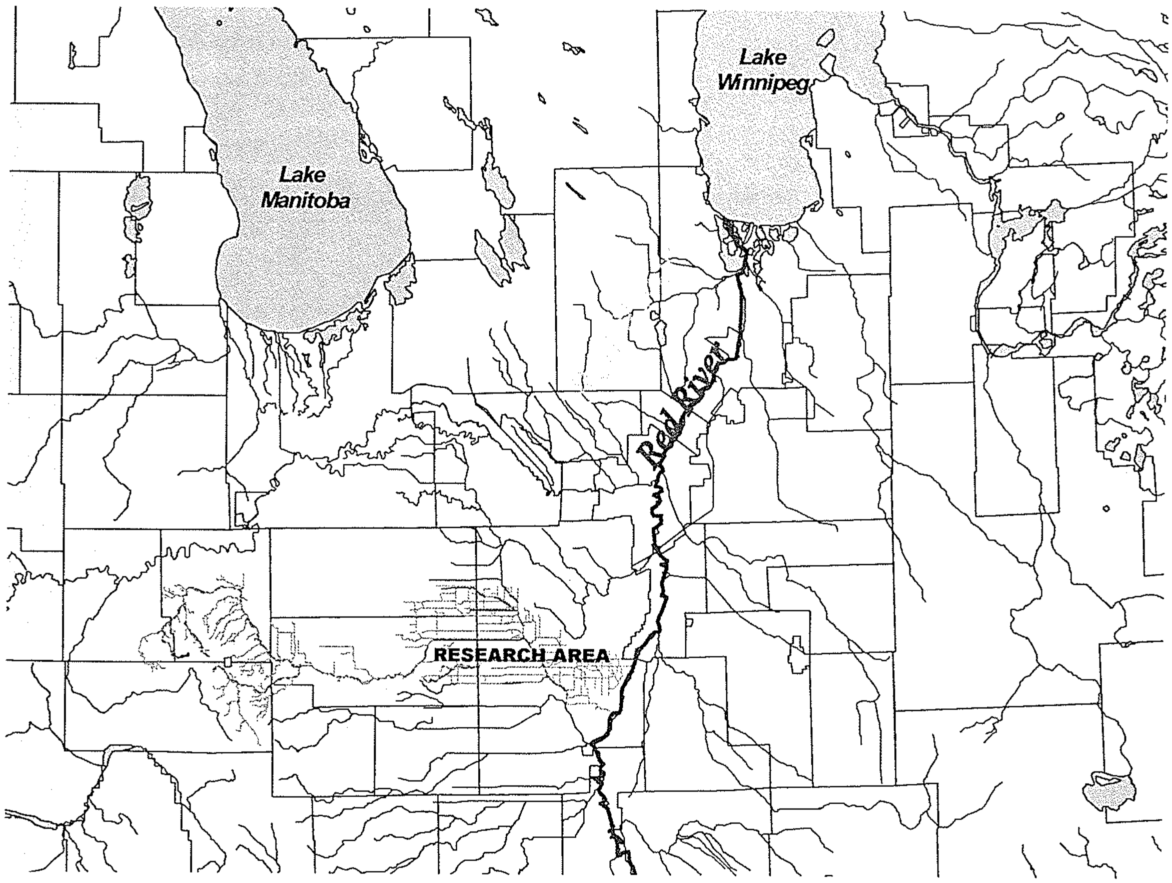


Figure 10: Map illustrating the connectivity between the research area and Lake Winnipeg via the Red River.

The crossing inventory sampling timeframe was limited to a one-month period. The occupational health and safety policy within DFO prevents individuals from conducting fieldwork alone and the availability of assistants presented an additional constraint on sampling. Seventeen working days were used to collect data in the field, which was dependent on researcher and assistant daily work schedules and weather. Given the time frame in which the researcher had to collect data, the nature of the inventory, and the methods used, case studies identified earlier in the report were not applicable beyond identifying a need to measure the culvert dimensions. The biological habitat characteristics that were measured in Cases I (McKinnon and Hnytka 1985) and II (Langill and Zamora 2002) have been measured to some degree through the sampling done by the ADI and translated into DFO's habitat classification maps. As a result, the research needed to establish independent sampling methods given the unique constraints of the research that would compliment and not overlap with the information contained and used in the classification system.

3.2.1 Procedures

It was decided to limit sampling to watercourses that were shown on Provincial drainage area maps (DES) as these were the maps used to do the ADI. As a result, many of the municipal drains were not included in the research, are not on the provincial maps, and have not been formally classified. The provincial DES maps were obtained from a DFO internal library. The Morris River Watershed is divided into four sub watersheds and is represented by four DES maps (map numbers 16-20). The research was designed such that inferential statistics could be applied to the data collected and was based on a random sampling technique. Originally, each watercourse was given a number. The sampling sites were selected using a list of numbers obtained from a random number table. Out of the first 100 numbers chosen from the provincial drainage maps, the numbers from DES 19 were used for the first two days, to save time and increase sampling efficiency. The intent was to visit the ones from DES 20 the following week, the ones from DES 22 the third week and the remainder for the fourth week.

It soon became apparent that the driving time between sites using this approach was excessive, and that sampling efficiencies could be increased by visiting adjacent/consecutive crossings along a watercourse. It was decided that a large amount of geographically concentrated data could be obtained by focusing in on a smaller area (DES 19 and 20) (Figure 11) and would be preferable to using a smaller amount of geographically scattered data that would be obtained from using the entire Morris River. This adjustment did preclude the use of any inferential statistics on the reduced data set. However, given that the areas adjacent to the Red River within the other non-sampled DES are very similar, it is still possible to make theoretical inferences on the data.

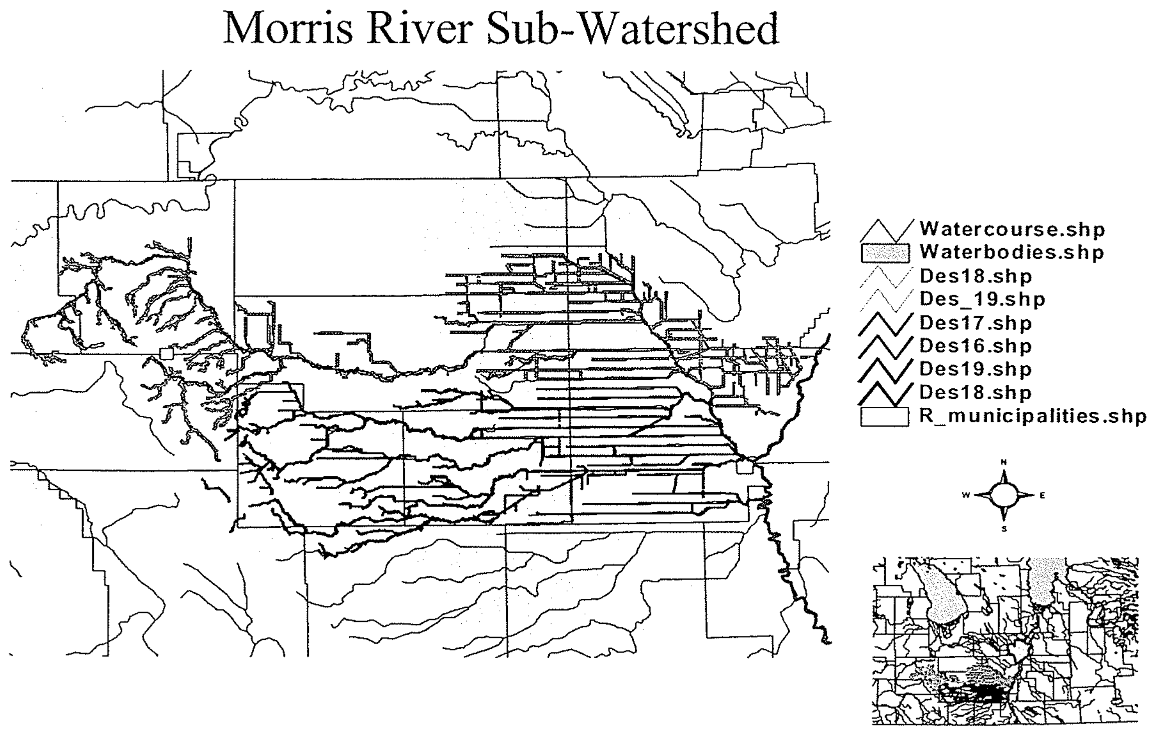


Figure 11: Map identifying research areas DES 19 and 20 nested within Morris Watershed.

The crossing inventory field sheet (Appendix F) was designed using the ADI inventory field sheet and from discussions with Chris Katopodis DFO's Regional Engineer and Dave Walty from Alberta, who participated in a study (Tchir, Hvengaard, and Scrimgeour 2004) on forestry crossings in northern Alberta. Upon arriving at each site, geographic coordinates were obtained from a *Garmin eTrex Vista* GPS unit and recorded on the crossing inventory field sheet. Digital photographs were taken at each site looking upstream and downstream from the middle of the crossing and at the inlets and outlets of culverts or at both sides of bridges. Photo numbers and captions were recorded on the data sheet.

If the site had culverts, either a hand held or reel type tape measure was used to measure the height and width and the reel type tape measure was used to measure the length. Height and width dimensions were usually taken on the outlet side of the culvert unless the outlet was too damaged in which case the inlet was measured with a note indicating the damage on the field sheet. Lengths were measured either by traversing through the culvert if it was large enough or above if the culvert was smaller. If there was more than one culvert at the crossing, each culvert was measured individually for height and width, but the lengths were only measured individually if the culverts did not appear to be the same. These procedures were established to minimize the time spent at each site and maximize the number of sites visited during the research period to increase the overall sampling efficiency and to establish a standardized sampling methodology.

Additional observations that could be useful for future operational considerations were recorded, such as culvert type (arch, round), culvert design (full or bevelled), placement (embedded or perched), water or substrate in it, outlet scour, damage, and erosion potential. Erosion potential was recorded on subjective scale of low, medium and high based on the amount of outlet scour, bank stability, vegetation type, and density. The culvert damage category was ranked on a scale of 0-5 based on both damage and conveyance capacity (Photos 1-6). A higher rank corresponds to a greater level of damage and the potential for altered flows. The ranking system is as follows:

Level 0 – No or very minimal damage

Level 1 – A large amount/percentage of rust is present

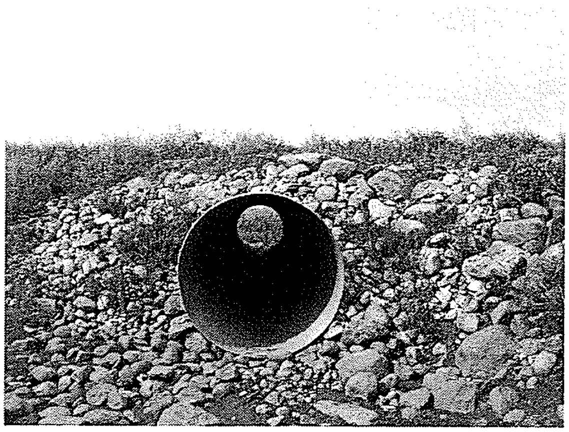
Level 2 – Small dents, tears or holes are present

Level 3 – The culvert is compressed throughout its length

Level 4 – Large dents, tears, holes are present

Level 5 – The culvert is crushed or mangled to the point where flows would be impeded.

A higher level of damage supersedes lower levels. For example, if a culvert was rusted, small holes were visible, and it was compressed throughout the length, its recorded level of damage would be three.

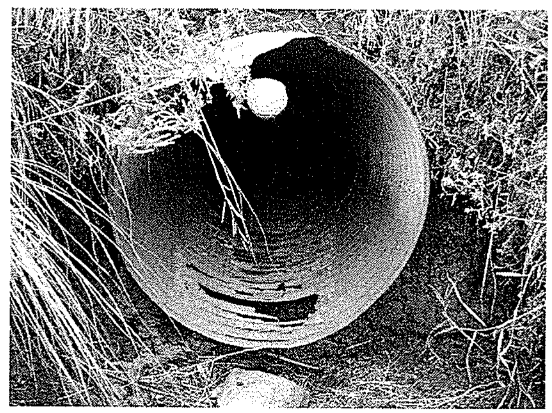



Photos 1: Damage Level 0 – Culverts possessing minimal visible damage.


Photos 2: Damage Level 1 – Culverts possessing a large portion of rust.


Photos 3: Damage Level 2 – Culverts possessing small dents, tears, and or holes.


Photos 4: Damage Level 3 – Culverts that are compressed throughout their length.

Photos 5: Damage Level 4 – Culverts that had large dents, tears and or holes.


Photos 6: Damage Level 5 – Culverts that were mangled and could impede flows.

3.2.2 Obstacles

Existing workloads of the researcher and assistant, as well as DFO Operational Health and Safety policy limited the number of sampling days. During heavy and localized rain events, data collection was limited to gravel roads and highways and prevented sampling of the remaining crossings in DES 18 and 19.

3.3 GIS Mapping

3.3.1 Procedures

A shapefile of the Manitoba and Topographic Base Map (1996 edition, Scale 1:1000 000) was obtained from the MLI website which was loaded as a theme into ArcView. Shapefiles of DFO's habitat classification maps for DES 18 and 19 were obtained from Dave Milani as a part of prior involvement with DFO's ADI. Permission from Keith Kristofferson was obtained for the use of the information for this research.

Information collected from the crossing inventory was entered into Excel, organized information into three worksheets (Site Info, Culvert Info, and Pictures) and saved as tab delimited text files. In ArcView the text files were added as tables, then under *View,* site info was added as an *Event Theme*, specifying x as longitude and y as latitude. Culvert info and pictures were added as text tables, both tables were joined to the site info table by using the common field "crossing". Once joined the theme "site info" was converted to a shapefile.

The coordinates for the MLI data were in UTM (NAD 83, Zone 14) but the rest of the data including the habitat classification shapefile was recorded in decimal degrees, which caused a projection error. The decimal degree data had to be re-projected as UTMs, the same projection as the MLI data. To do this ArcView Projection Utility function was used, and the resulting new themes were saved as new shapefiles.

Provincial Fisheries Inventory data was obtained from DFO's IMS, put into an excel worksheet added to the projection in the same manner as described above. The crossing inventory data within excel worksheet was reorganized and other shapefiles were created for showing culvert damage and culvert type. Using the *Legend Editor* function under the *Theme Option* different symbols and colours were chosen to identify culvert types and damage. See Figure 12 for a better visual illustration of the data

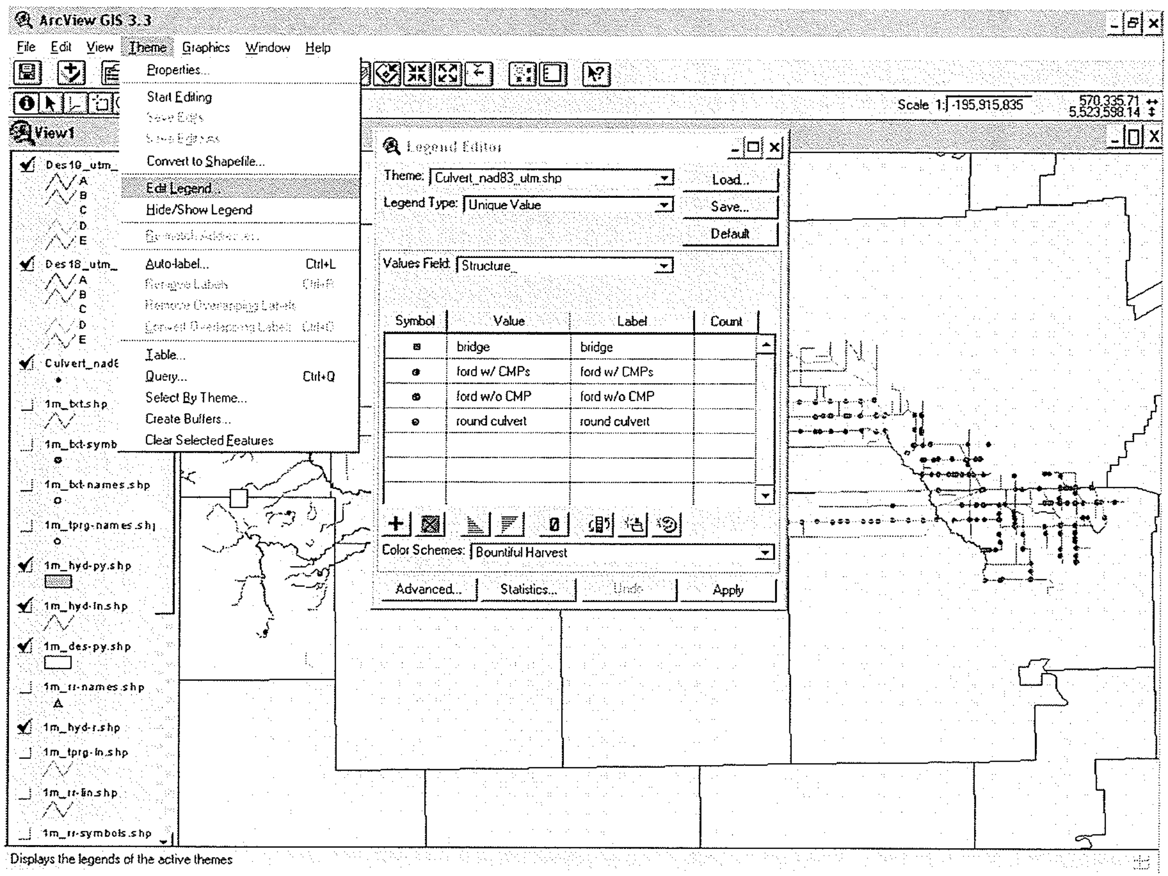


Figure 12: Looking at ArcView procedure to express differentiated categories within a single theme (culvert type).

3.3.2 Obstacles

Despite having an introductory textbook and taking a GIS course in the past, it was necessary to seek out additional help from colleagues who were more skilled and had more experience working with ArcView. Allyson Demski and Ronald Hemple were of great help in figuring out problems and feeling out nuances of the program.

3.4 Information Survey Interviews

3.4.1 Procedures

Selection of potential interview subjects was based on their experience in project management and operations and regulatory assessment and licensing of watercourse crossings in Manitoba. This included engineering, planning and design, construction and maintenance activities and biological assessment of project reviews.

Provincial experts were identified by committee members, and the majority of contact information was provided by Keith Kristofferson who established the initial contact on behalf of the researcher. Two public works managers working for the RMs of MacDonald and Morris were identified through researcher initiated cold call conversations. Their respective RM offices were contacted directly. Thomas Henley identified a local consultant, who had experience working on water policy and watershed governance research with IISD and had helped complete a watershed management and research plan for the Tobacco Creek Model Watershed, as an ideal candidate for the survey for his academic, local, non-government perspective. He was also contacted directly by the researcher.

Originally, the interview agenda was formulated into a series of 32 questions designed to obtain information on best practices, management approaches, and knowledge/awareness of related concepts. Specifically, the questions were designed to acquire responses that provided insights as to what could work, what clearly could not work, where information is lacking, and where potential problems may exist in terms of the management, design, construction and maintenance issues of watercourse crossings.

However, it became apparent that the questions should be reorganized to encourage conceptual flow and interview efficiency. The modified questions (Appendix G) were then emailed to the interview subjects with the option of either providing written responses that were to be emailed to the researcher, or to schedule a one on one interview.

Interviews were conducted with an Area Engineer from DFO; a Regional Water Control Engineer, a Design Engineer, and a Biologist from MIT; a Hydraulics and Litigation Engineer and a Water Resource Officer from MWS; and a local consultant with experience working with individuals from the Morris River Watershed. From the municipal level, a Public Works Manager from the RM of Morris and another Public Works Manger from the RM of MacDonald were interviewed. The Public Works Manager from the RM of MacDonald wished to have two colleagues, the Assistant Manager and Surveyor, sit in on the interview to provide comments in addition to his own. Written responses were obtained from a Regional Fisheries Manager from MWS, and a DFO Habitat Biologist. A Design Engineer from MIT provided some responses in writing and an interview was conducted to obtain answers for the rest of the questions.

3.4.2 Obstacles

Originally, the intent was to conduct one on one interview after the questions had been distributed giving subjects a time to reflect on their potential responses. However, upon conducting the first interview it became apparent it was not feasible to carry out this approach in a timely manner. We concluded the first interview after the first 12 questions, which took three hours. In response, the questions were revamped (shortened, clarified, and reorganized) to follow a consistent logical direction. The questions were then separated into general, technical, and biological categories.

3.5 Climate Change Data

Discussions with Jay Anderson and Rhonda Pankratz led the researcher to the Canadian Regional Climate Model (CRCM) developed by the Climate Simulation Team at Ouranos, found an interactive web server on the Environment Canada website (Environment Canada 2007). The CRCM 3.36 was used to obtain past (1970-1994) and future (2039-2063) modelled climate data for the crossing inventory sampling area (an area bounded by -101.64630 W and -95.17704 W longitudinally, and 53.72748 N and 48.92060 N latitudinally) using monthly means. Predictions for indicators such as maximum and minimum daily mean temperatures, precipitation, and evaporation were obtained, organized into excel files and charted to better analyze trends.

4.0 RESULTS

4.1 Crossing Inventory

The crossing inventory was conducted over 17 working days during the month of September 2007; 233 crossings sites were sampled (Figure13).

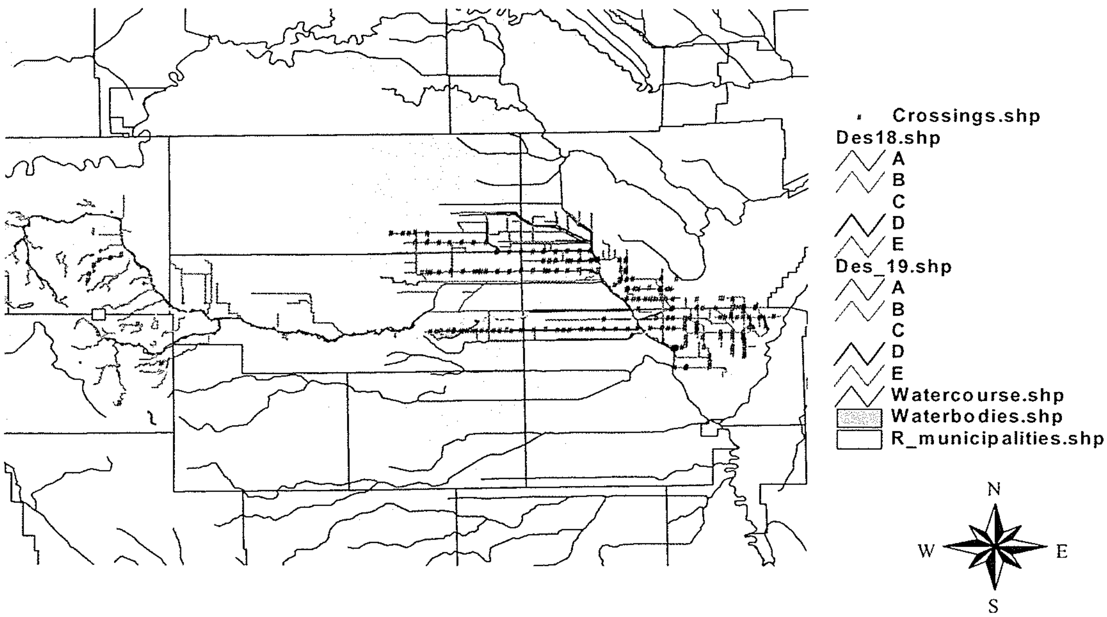


Figure 13: Location of crossing inventory sites sampled on Class E and D habitats.

Simple summary statistics on the data identified that round culverts were the most prevalent crossing infrastructure, found at eighty percent of the sites visited. Thirty-nine sites featured a bridge infrastructure and even less had a type of ford infrastructure (Table 3). Figure 14 presents the location of the infrastructure type found at each site.

Table 3: Table showing the breakdown of crossing structures sampled.

Crossing Inventory Statistics

Type of Structure at Site	Count	Percent of Sampled Total
Bridge	39	17
Round Culvert	187	80
Ford	7	3
(with culverts)	*(5)*	*(2)*
(without culverts)	*(2)*	*(1)*
Total number of sites	233	100

Note: These are descriptive statistics only; sampling design is not suited for actual inferential statistics.

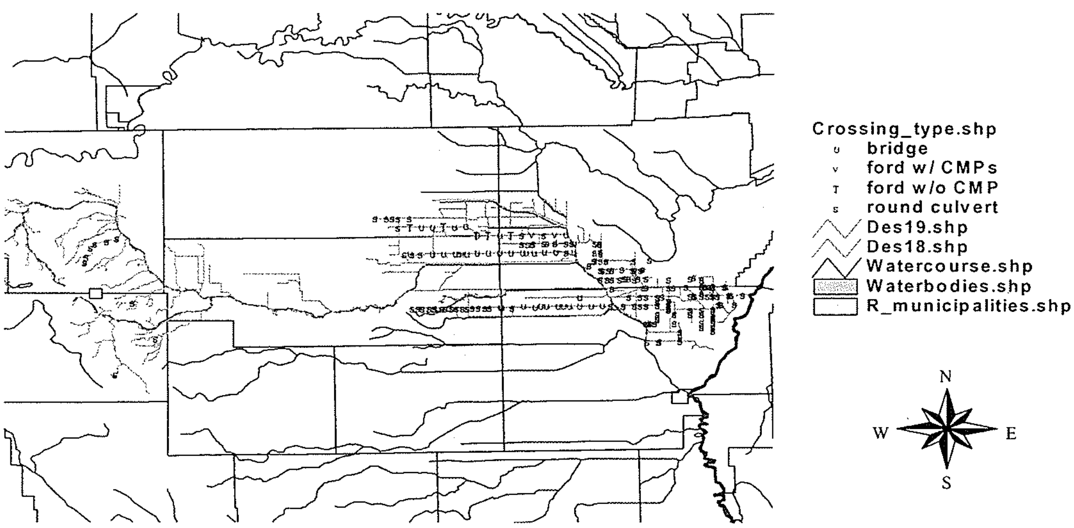


Figure 14: Type and location of crossings structures identified from the crossing inventory

The condition of the structures is paramount in planning maintenance and replacement activities. Table 4 illustrates that the majority of culverts sampled had minimal damage and only a few required immediate attention. Figure 15 shows the location of the ranked culverts on the landscape.

Table 4: Table showing breakdown by damage of ranked culvert sampled.

Culvert Damage Statistics

Damage Rank	Number of Culverts	Percent of Sampled Total
0	142	50
1	11	4
2	79	28
3	11	4
4	30	11
4\5	1	0.4
5	9	3
Total	283	100

Note: These are descriptive statistics only; sampling design is not suited for actual inferential statistics.

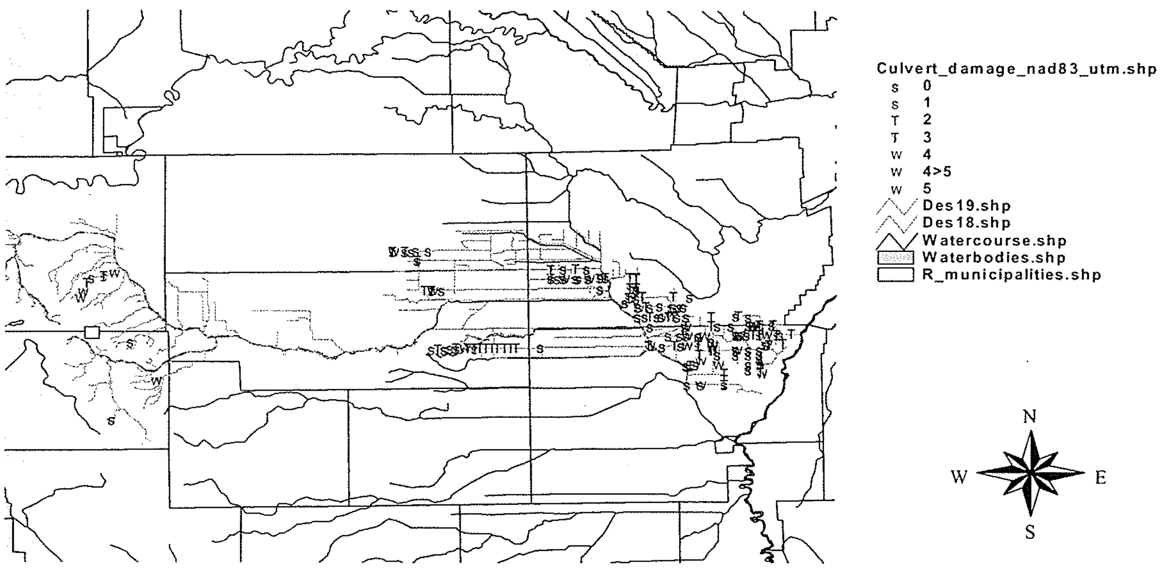


Figure 15: Damage Assessment – location of ranked culverts from the crossing inventory.

4.2 Interactive Map

Dissimilar datasets were compiled and used to create an interactive map that combined provincial DES, habitat classification, provincial sampling, and crossing inventory layers. See Figures 16 -20.

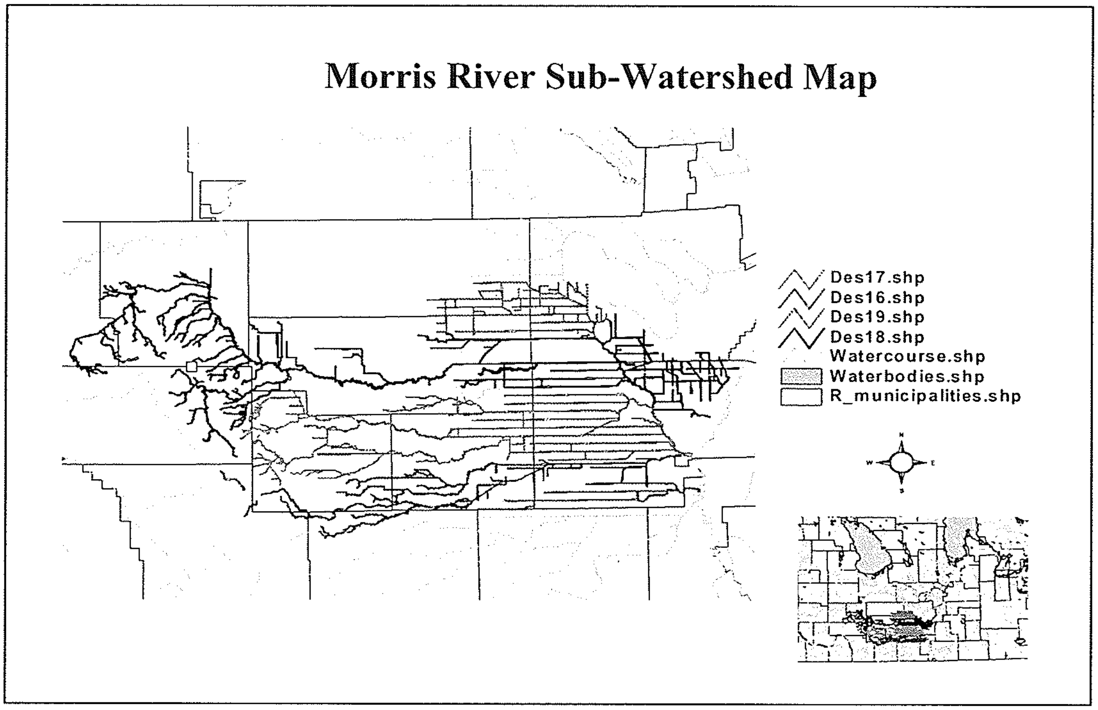


Figure 16: ArcView Layer Representing Provincial DES Maps 16-19 for Morris River Sub-Watershed.

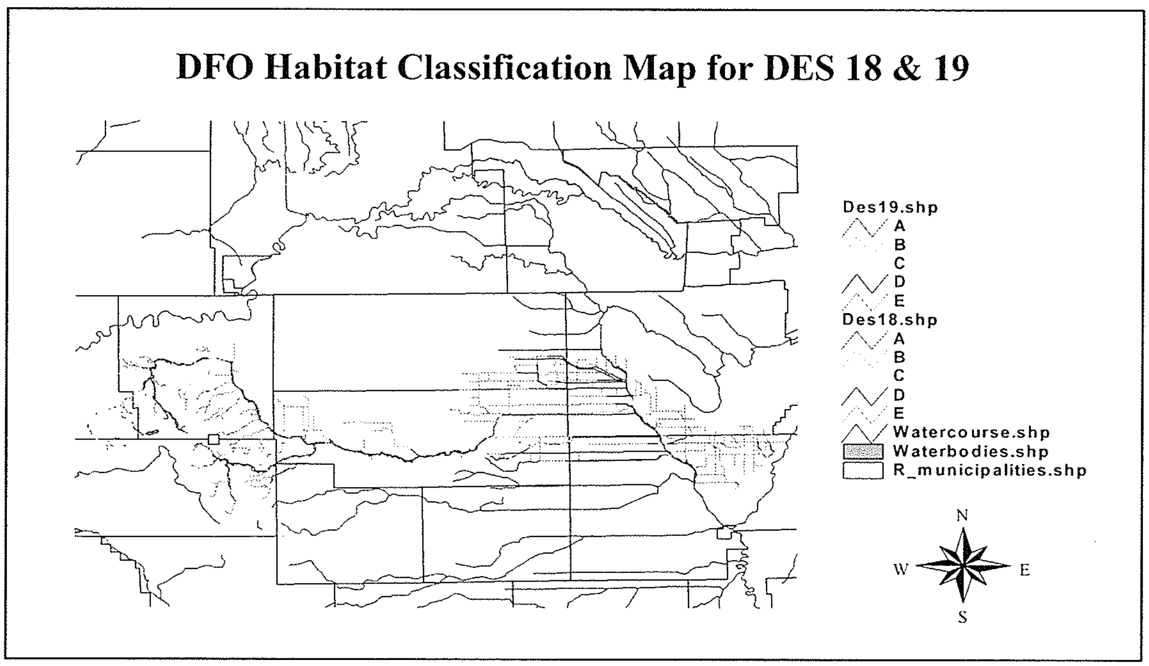


Figure 17: ArcView Layer Representing DFO's Habitat Classification Scheme for DES 18 & 19.

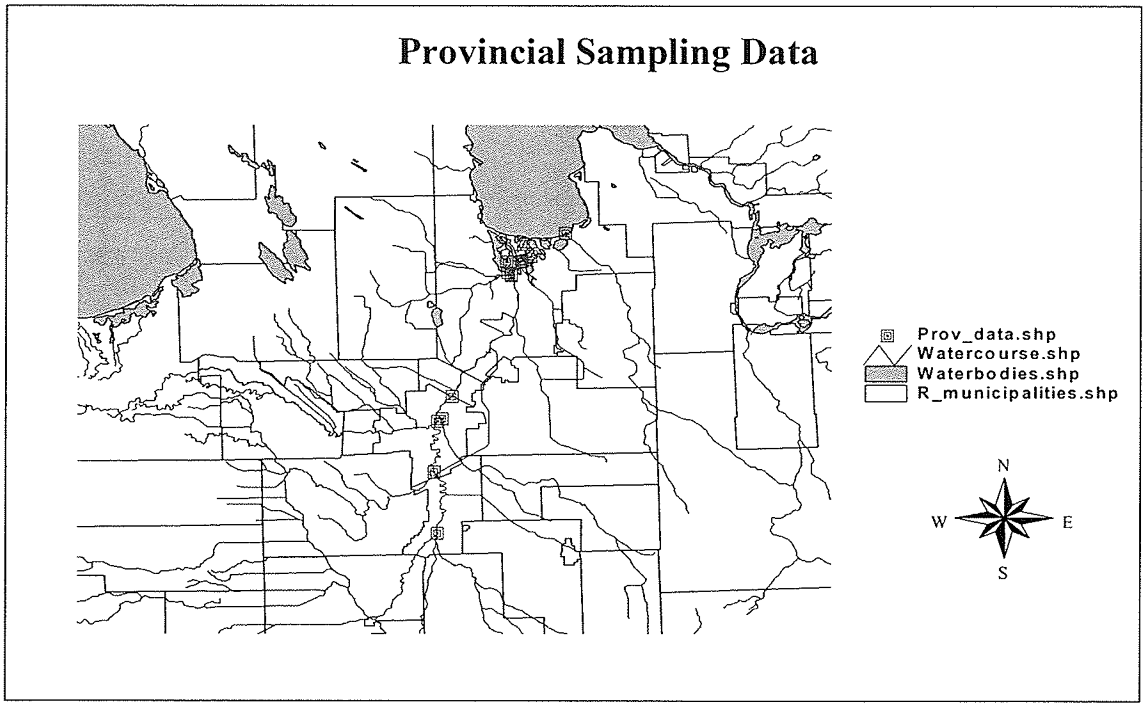


Figure 18: ArcView project showing base map and the summarized provincial data layers (data obtained from DFO's IMS).

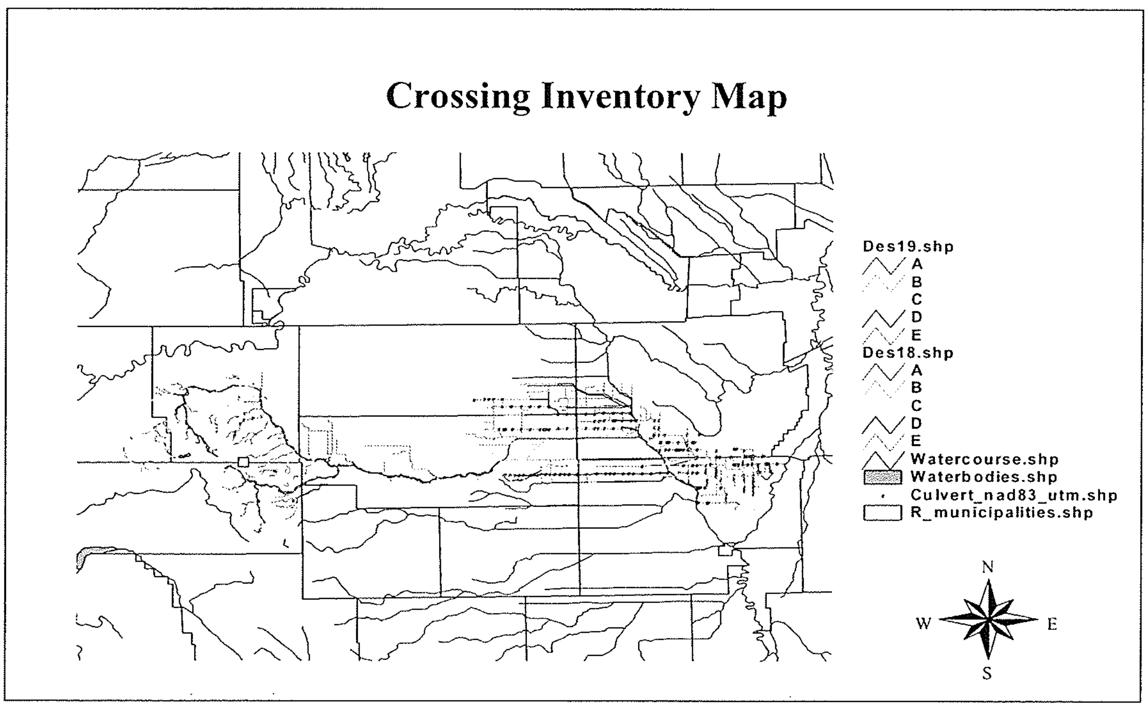


Figure 19: ArcView projection showing base map, habitat classification, and crossing sites that were sampled.

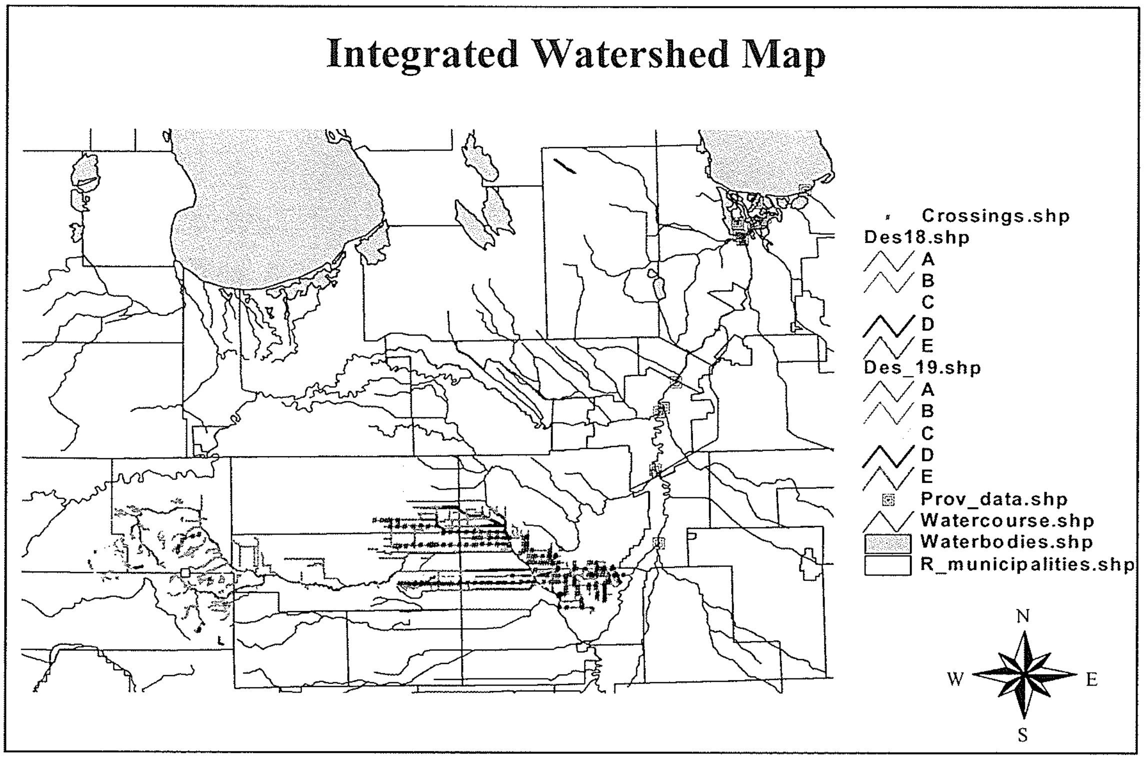


Figure 20: ArcView projection showing the integration of datasets represented as map layers.

To assess the utility of the integrated map, interview subjects from DFO, MWS, MIT, and RMs were asked to provide their thoughts, opinions and insights with respect to the potential utility of this map as a decision making tool in watercourse crossing projects. All agreed that map layers showing the different watershed components would be very useful for anyone involved in watercourse crossing projects.

4.3 Information Survey Interviews

The interviews provided a basis to gain valuable insights into the complicated issues at hand and created the first step in opening a dialogue and facilitating a new path of communication between federal, provincial, municipal government and non-government.

4.3.1 Interview Subjects

Interviews were conducted with 11 individuals from federal, provincial, municipal, and local backgrounds who have experience in the management and operations involving the planning, design, construction, maintenance, assessment and licensing of watercourse crossings in Manitoba. Their responses provided a set of contrasting perspectives, knowledge, and information on administrative and operational requirements, which comprehensively describe the complex and dynamic nature of the issues at hand. Table 5 provides a list of the administrative jurisdiction, roles and responsibilities of the various interview subjects.

Table 5: Subjects interviewed for research, providing a description of their perspective.

Administrative Level	Agency	Interview Subject's Title
Federal	DFO	Design Engineer
		Fish Habitat Biologist
Provincial	MWS	Regional Fisheries Manager
		Hydraulics and Litigation Engineer
	MIT	Design Engineer
		Regional Water Control Engineer
		Water Resource Officer
		Biologist
Municipal	Morris	Manager
	MacDonald	Manager, Assistant Manager, Surveyor
Local	NGO	Consultant

4.3.2 Results

The main issues identified by the interview subjects involved fish passage and velocity requirements, improper design standards, excessive costs, infrastructure ownership, administration and governance issues, division of labour/human resources, stakeholder input/pressure, education/training, lack of information and transparency and accuracy in project assessment reviews. All subjects expressed a willingness to work together to facilitate a more partnered and conciliatory approach that was fundamentally based upon the integration of information and knowledge.

Figure 22 was developed from the interview responses to visually depict the dynamic nature of the current management situation as it pertains to crossing infrastructure in Agro-MB; transcribed answers are available at the NRI. The federal, provincial, and municipal governments that are involved with watercourse crossings in MB are represented as concentric circles. The circles' size and location is dependent on jurisdictional hierarchy, budgetary funding, and access to resources from a legislative level. This is notwithstanding the fact that the province owns the land, manages the fish stocks, and has the legislated authority for watershed planning as a result of the *Natural Resources Transfer Act* of 1930, while DFO retains the habitat protection provision under the *Fisheries Act.*

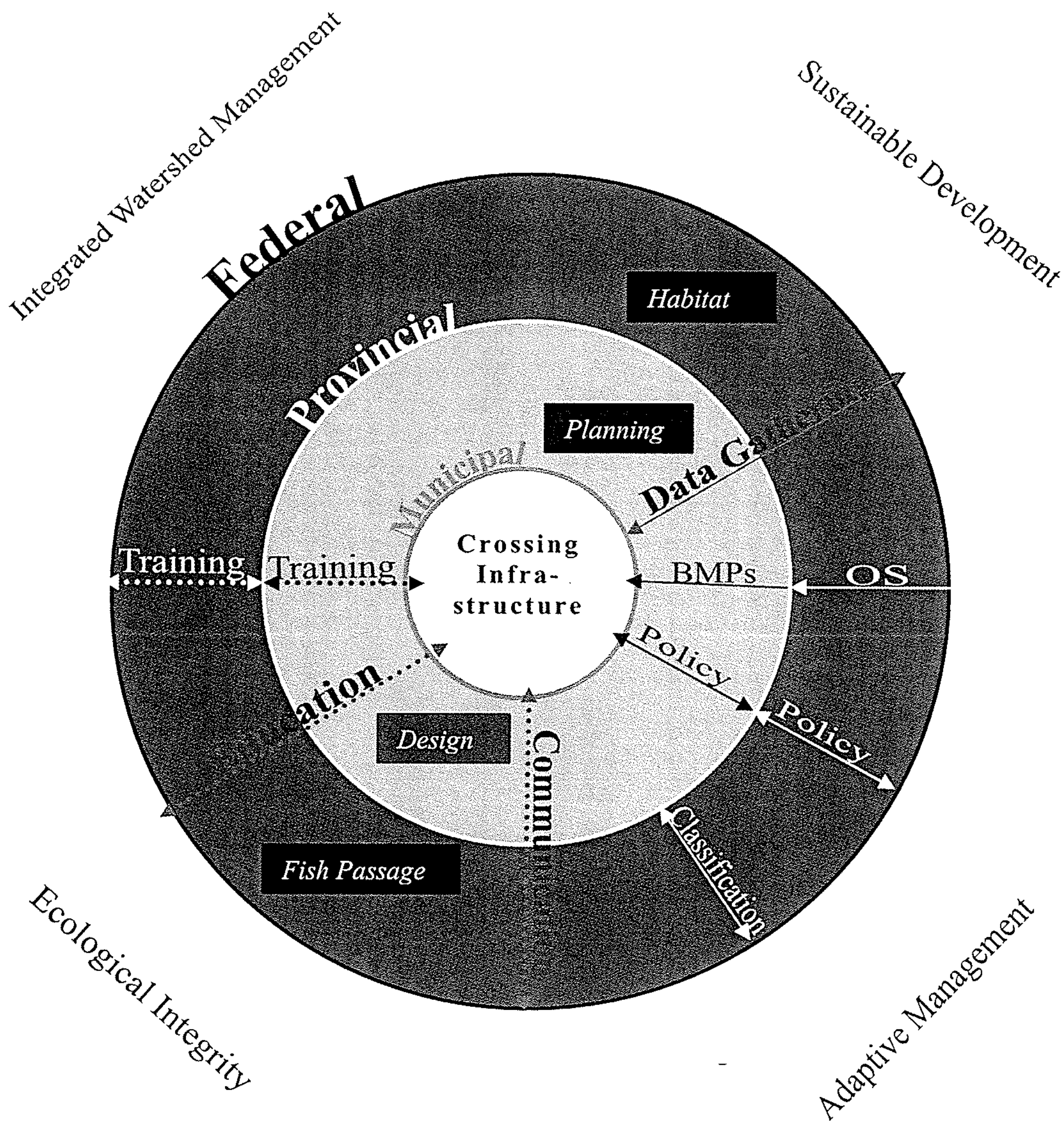


Figure 21: Current and Future Watershed Planning Dynamics – A visual construct representing the integration of key issues identified by interview subjects, within the three levels of government in Manitoba and theoretical concepts.

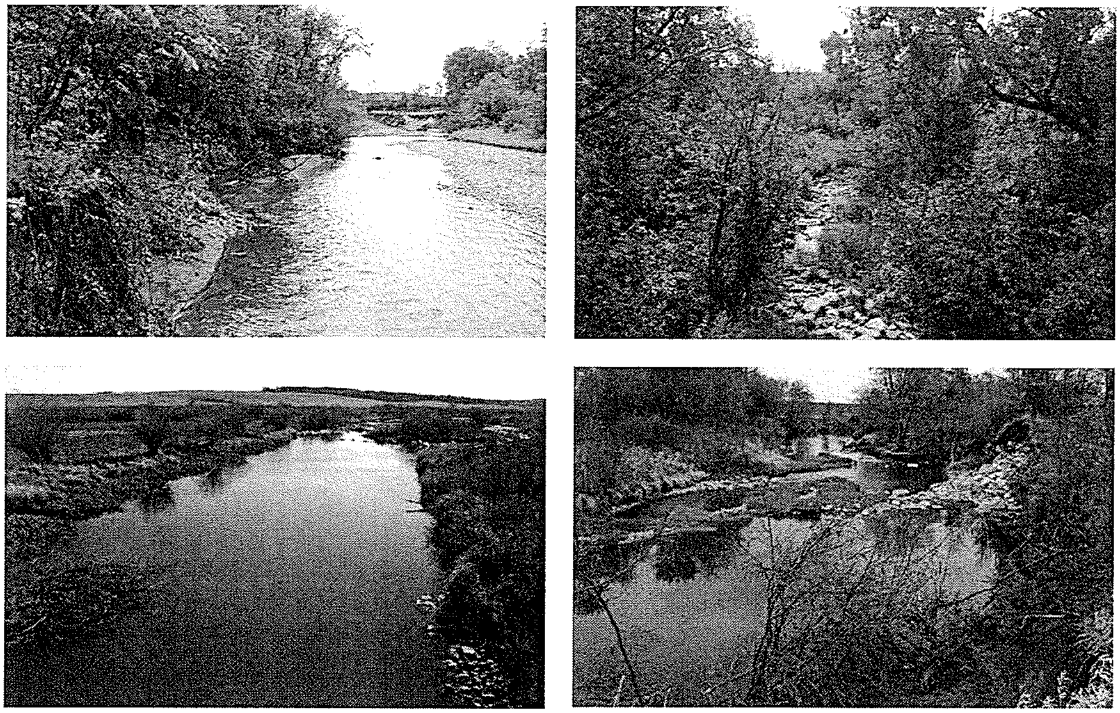
Outside the circles of legislated authority are the theoretical concepts of integrated watershed management, ecological integrity, sustainable development, and adaptive management that need to be considered for future planning and management actions to achieve the goal of sustainable development in MB. Hypothetically they are depicted peripherally, above all levels of government and represent an ideal goal that must be collectively pursued by all stakeholders alike. Working inwards in bolded italic letters are the transcending issues identified through the interview responses. These are inserted in between circles, as both levels of government on either side are directly involved or concerned with them.

The arrows represent action items, issues identified through responses that need to be done or improved upon. The direction of the arrow indicates at which level of government the initiative should originate from and where efforts need to be directed to achieve the desired benefits. In the case of a multi-directional arrow, initiatives should originate from those levels spanning the arrow and the benefits that will accrue will be shared amongst those stakeholders. Red arrows represent integrated planning activities that span all levels, where concerted effort and focus should be placed on developing and practicing these activities within and between each level and other stakeholders. Solid arrows represent tangible physical entities such as reports, guidelines, and maps; dotted arrows represent non-physical conceptual outputs such as knowledge, increased awareness, changes in attitudes and working relationships.

4.4 Habitat Classification and Map Availability

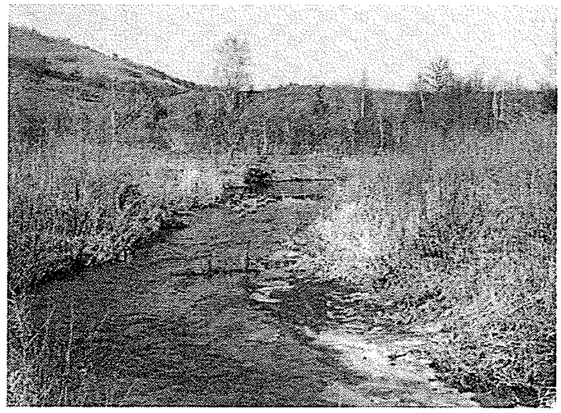
4.4.1 DFO's Proposed Habitat Classification System

The photographs listed below (photos 7-11) were included to provide a visual reference of the types of habitat that have been identified under the five habitat classifications that have been identified under DFO's proposed Habitat Classification System. Although there is considerable variation within each class, the general characteristics of stream sinuosity, vegetation cover, substrate characteristics, and water levels can be readily identified.

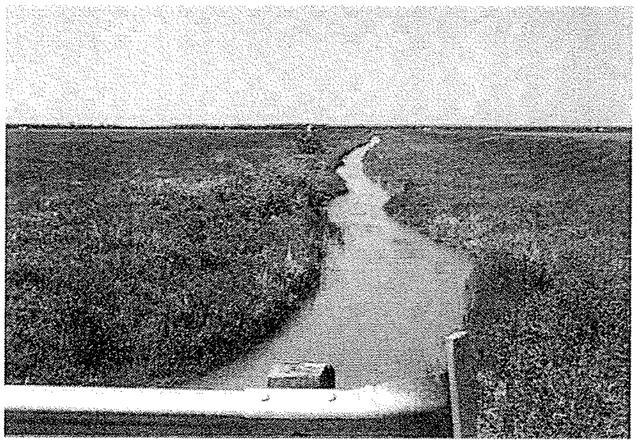


Photos 7: Examples of Class A Habitats.

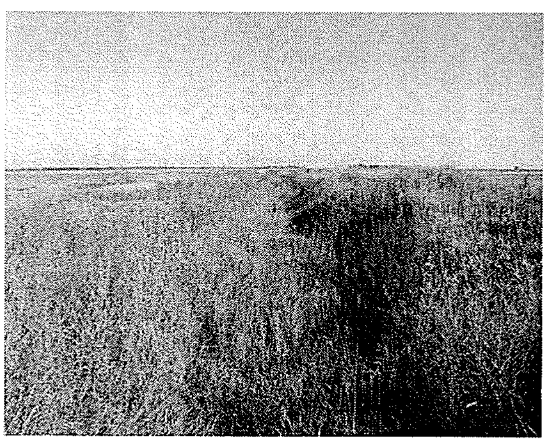
Photos 8: Examples of Class B Habitats.

Photos 9: Examples of Type C Habitats.

Photos 10: Examples of Type D Habitats.

Photos 11: Examples of Type E Habitats.

4.4.2 DFO's Habitat Classification Map Availability

DFO's maps have not been approved for release for use by the general public yet.

4.5 DFO's Proposed Risk Management Framework

Risk management is a federal government wide decision-making process approved by the treasury board for all departments to incorporate into their daily activities and is the general model that has be used in all DFO referrals for the past two years. The risk matrix (Figure 22) visually depicts how DFO habitat biologists incorporate risk into their decision making when reviewing referrals.

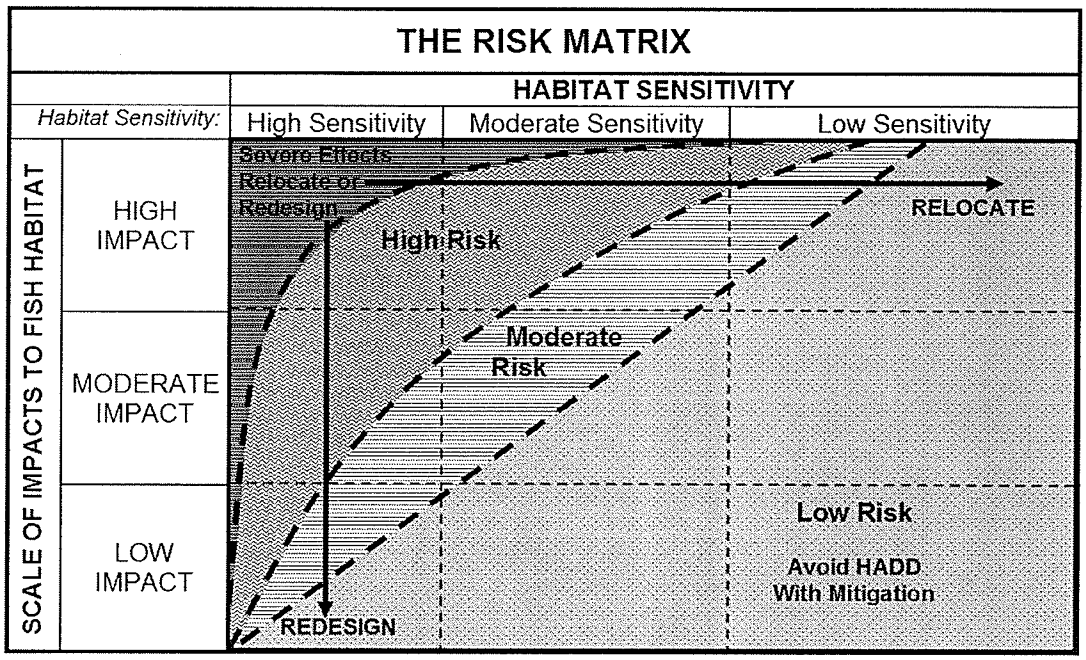


Figure 22: The risk matrix incorporating appropriate management actions

Figure 23 illustrates how DFO could potentially incorporate its proposed Habitat Classification System into the risk matrix. The concept presents a good reason to exclude Class D habitats from a class approach at least initially, since culvert replacements tend to cause high impacts to fish habitat depending on project specifics. While the majority of projects within class E habitats would be considered as low risk, only a very small number of projects would be of moderate risk. This establishes a theoretical reason to legally permit the development of an OS for watercourse crossing projects on class E habitats under the RMF.

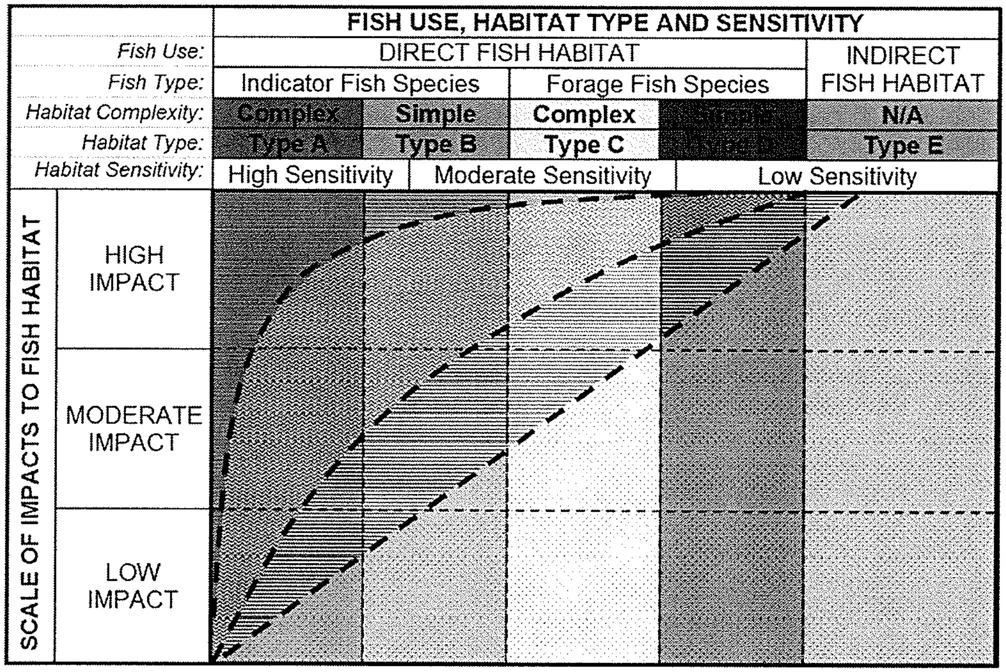


Figure 23: The risk matrix incorporating proposed the DFO's proposed Habitat Classification System.

Projects posing a higher risk (moderate- very high) require review by a DFO Fish Habitat Biologist. Authorization may be granted alone or in conjunction with compensation requirements. In the rare case, the biologist may ask for the project to be redesigned or relocated. For this reason, watercourse crossing projects on Class A-C habitats require review, and operational statements are not applicable. With Class D habitats, a larger percentage of the projects would fit into the moderate risk category and some would even be deemed as high risk. For this reason Class D habitats should be excluded from an OS at least until further information is obtained and or better technology is developed that reduces the risk of projects negatively impacting these habitats.

These issues do not arise with low risk projects. In low-risk situations, DFO would normally prescribe mitigation measures to avoid a potential HADD. If these mitigation measures, along with the habitat conditions and project methods required for the measures to be effective, could be identified and agreed upon, an operational statement could easily be developed for class E habitats.

4.6 Operational Statement & Best Management Practices

As stated previously an operational statement (OS) is a document that provides mitigation measures for a narrowly defined project within specifically prescribed parameters. The measures contained in the OS are the minimum actions required to maintain the quality of fish habitat in the area. The use of an OS precludes the need to submit the project to DFO for review. However, all of the mitigation measures outlined in the OS must be carried out by the proponent in order to use the OS. The purpose of these statements is to streamline the referral review process in an attempt to make the process more efficient, cost effective, transparent, and timely.

4.7. Climate Change

The CRCM 3.6 Model predicted various climatological data over two periods 1970-1994 and 2039-2063. Data for the period between 1995 and 2038 is absent and unavailable from Environment Canada's website. It is important to note that the absence of these data points may affect the trend lines obtained, and may thus effect the current interpretations and consequences on the landscape.

According to the CRCM 3.6 Model, trends show increased daily mean maximum and minimum temperatures and evaporation for all seasons. Precipitation trends increase in all seasons except fall in which case there is no change or a very slight decrease. Soil moistures are predicted to increase in all seasons except for winter in which case it is predicted there will be a decrease. Spring and fall will see larger increases in evaporation relative to increases in precipitation, which may reduce flows off the land. Summer and winter will see larger increases in precipitation relative to increases in evaporation, which may increase flows off the land. Graphs of predicted trends for spring max/min temperatures and evaporation/precipitation are presented in figures 24 and 25. See Appendix I for other the seasons' trends.

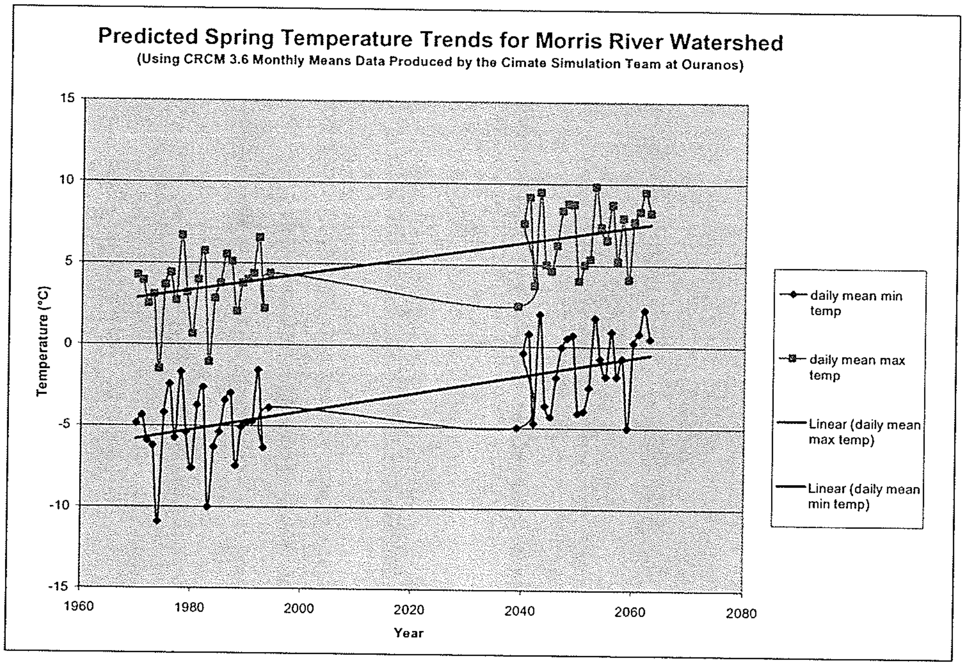


Figure 24 CRCM 3.6 Model maximum and minimum daily mean temperature predictions for 1970 - 1994 and 2039-2063 for the research area

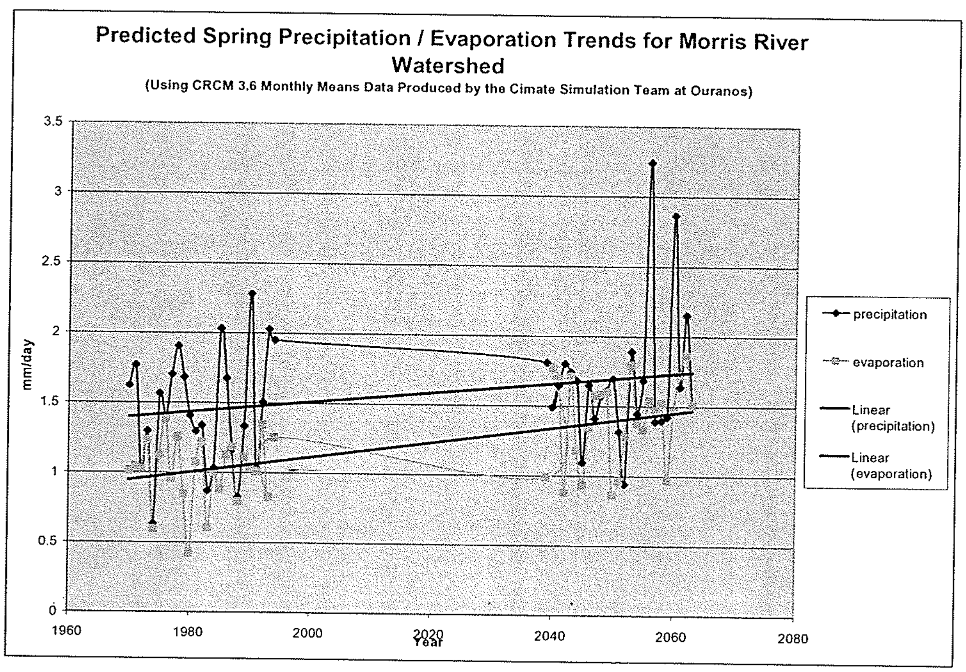


Figure 25: CRCM 3.6 Model precipitation and evaporation predictions for 1970 -1994 and 2039-2063 for the research area

5.0 DISCUSSION

While habitat classifications have already been developed by a committee involving federal and provincial stakeholders, the initial maps are awaiting formal approval from DFO National Headquarters in Ottawa before they can be released to the stakeholders. However, MIT, MWS, and the RMs are the agencies that should conduct further inventories to ground truth the existing habitat classifications if they feel a need to do so, to increase their confidence in the initial assessments. In this case, DFO could then collaborate with any or all of the above agencies to accept inventories as a means to develop a broader understanding and more effective and efficient means of compensation, in addition to identifying appropriate compensation projects for culvert crossings. This additional information would then be entered into an Integrated Watershed Mapping GIS. Formal agreement is also required to determine which agency should be responsible for updating and maintaining the system, as MWS has the mandate to develop a watershed management plan and DFO has developed an interactive GIS Habitat Classification System. Access should be given to all agencies to ensure consistency and good communication.

Education and communication are required at every level and between every level to ensure that everyone involved understands the collective jurisdictional needs and expectations as it applies to watercourse crossings. Continual training at every level is needed to ensure that all employees involved in the planning and operational aspects of design, installation, maintenance, and removal have current knowledge on technical aspects as well as on evolving policy and administrative requirements. Best management practices could be developed within an agency to best fulfill their specific administrative level requirements and are communicated to other agencies through regular meetings.

Regular meetings between regulatory groups are also necessary to provide the level of communication and trust between individuals of the different agencies to establish good working relationships that are needed for effective integrated watershed management.

5.1 Meeting Objectives

Through the interviews, crossing inventory and research into the literature, the research has met all the proposed objectives except for the actual physical testing of the interactive map due to staff resource and time constraints. A pilot study would have to be implemented to physically test such a tool with long term monitoring being required to assess feasibility.

5.1.1 Objective 1

"To identify the various businesses, resources and agencies that were concerned with or affected by watershed management of the research area."

This research identified the primary resource/business as agriculture, which surrounds the watercourses. The interests of downstream fisheries resources (commercial, recreational, subsistence) in the Red River and Lake Winnipeg must be considered, as many of the important indicator species populations are dependent on successful spawning in smaller upstream tributaries. In addition, it is important to consider the overarching governance structure consisting of federal (DFO), provincial (MWS, MIT, MB Conservation) and municipal (RMs, CDs) agencies, and local interests (individuals, farmers). Their involvement has a major impact on watershed management activities and the amount of available resources.

5.1.2 Objective 2

"Determination of the application of a class approach for watercourse crossings in agro-Manitoba based on proposed habitat classification and risk management"

The interview subjects provided a general endorsement of the proposed Habitat Classification System despite some inherent problems associated with it. These problems revolve around how the original data were obtained for the classification maps. In

Manitoba there are seasonal and yearly variations that could affect the data obtained including temperature, precipitation events, quantity of water, and fish spawning cycles to name a few. The Agricultural Drainage Inventory was a four-year project that aimed at sampling as many watercourses as possible. Most sites were only sampled once, so the year and season in which the site was sampled plays a large role in determining whether there were indicator species present or not, based on whether there was water in the drain at all. Additional sampling may be required to capture this variability and to establish confidence limits in areas of uncertainty.

There appears to be general administrative support from biologists and engineers for the potential applicability of an OS for low risk Class E habitats although for differing reasons. Engineers tended to favour the concept of the OS to save time and identify DFO expectations for the crossing with the provision that additional biological information be collected to instil confidence in the proposed Habitat Classification System. Biologists tended to focus on the use of the OS to address the large numbers of low risk projects that currently must be reviewed in a timely manner, the risk of non-compliance, and the requirement for monitoring and education. Increased regulatory compliance will go a long way towards ensuring ecological integrity. All respondents thought it would be possible (feasible) to develop an operational statement based on class E (low-risk) habitats using the proposed DFO Agricultural Drainage Classification System, provided that the information used to assess the classes is accurate, kept up to date as changes in habitats occur on the landscape and that the various stakeholders have confidence in the level of detail in the information provided.

Additionally, compliance monitoring of a certain percentage of these projects must be conducted to ensure that appropriate mitigation measures are being implemented and are effective in protecting fish and fish habitat. Education must also be provided to educate individual stakeholders on the appropriate crossing design, construction, and maintenance activities and best management practices with an accompanying rationale for doing so. This should be a joint effort between DFO and the province to provide a consistent and comprehensive message that includes expert knowledge on technical and biological issues.

All subjects agreed on the inherent value of the higher habitat classifications (A, B, C) where a high level of risk associated with them would clearly prohibit the development of an operational statement for these crossings. A need for accessible and documented minimum DFO requirements for crossings on Classes A, B, and C was identified. This information is needed to help proponents better assess budget and time requirements for watercourse crossing projects with an added provision that depending on site-specific requirements additional mitigation measures may be required.

5.1.3 Objective 3

"To develop and test an integrated watershed map as a decision making tool in watercourse crossing projects based on fish species composition and abundance, fish habitat and road crossing inventories and downstream dependent fish populations of concern."

While there was general support for the development of an Integrated Watershed map as a decision making tool, the actual testing of it would clearly be outside the scope of the present project due to the limits of time and financial resources. However, the expansion of this approach to include other areas was clearly endorsed by all and should be undertaken in partnership by the collective regulators and interested stakeholders. To properly test the Integrated Watershed map as a decision making tool, a pilot project that implemented the GIS map and OS over a well-defined area should be funded on a long-term basis. The value to management as well as the biological, social, and economic benefits resulting from the implementation of the OS and map can be assessed through continual compliance and project monitoring. Testing over time also could be used to refine the approach and provide data updates and accuracy to improve compliance and applicability.

5.1.4 Objective 4

"To assess best practices available for watercourse crossing projects."

Three best practices manuals were identified through research into the literature and from the interviews: The Manitoba Stream Crossing Guidelines (1995) (Biologically focused), MIT's Environmental Best Management Practices Manual for Working In and Near Water (Draft) (Engineering/Design focus) and Alberta's Fish Habitat Manual (400 pages) which is not generally applicable to Manitoba because of different terrain, fish species, as well as socio-political elements. MIT's BMPs manual should be completed by the end of 2008 with the aim of making it a public document for anyone to use. This document along with the Manitoba Stream Crossing Guideline should be referred to for every watercourse crossing project in Manitoba to identify and implement the current available best management practices. The practices outlined in the Manitoba Stream Crossing Guidelines should also be incorporated into the operational statement.

5.1.5 Objective 5

"Development of concepts that could be used to develop an operational statement."

BMPs along with the issues and recommendations identified by the interview subjects should form the primary basis for the development of an OS. Any related biological and water management research literature should also be considered and used in the development of the OS.

The OS must ensure that proponents work within DFO timing windows, which restrict construction activities in water during the annual spring and fall spawning periods. The OS should confine any in water work to dry (water free) time periods where possible, and where not possible provide mitigation measures as outlined in the MB stream crossing guidelines to temporarily divert flows. Proper sediment and erosion control measures must be included such as sediment traps, silt fences, brush barriers, riprap, revegetation and /or slope modification procedures to prevent sediment from entering the watercourse. Finally, site restoration techniques including bank revegetation and slope stabilization are required to prevent sedimentation problems during spring runoff or heavy rainfall events. Culverts should be embedded to provide for forage fish connectivity and to aid in preventing washouts.

In addition, the following ideas could also be used to develop a useful culvert crossing inventory that could be included in the development of an integrated GIS map. The GIS map would be used with the OS and could be used to manage watercourse crossings on the other habitat classes. The inventory should include the recording all specific technical (culvert dimensions, slope of culvert and banks, velocity calculations if done) and biological (soil type, average flow velocities, fish species presence, vegetation present in drain and on banks) information. Records of every culvert upgrade/ maintenance and new crossing installation should be kept and integrated into a GIS map and made available to other levels of government. This would be relatively easy as multiple Excel databases can be easily integrated prior to adding them to ArcView.

5.1.6 Objective 6

"To describe implications or next steps."

In order for best practices to be implemented consistently, efforts must be taken to remove the potential operational impediments identified through the interviews. Misunderstandings often arise between other levels of administration / government from the infrastructure, mitigation measures and associated costs that are recommended by Fish Habitat Biologists to protect fish and fish habitat. DFO staff requires more training to ensure decisions are made in a consistent manner across the board to standardize decision-making. There is also a requirement for more scientific research on habitat classification, fish swimming performance, and fish lifecycle habitat preferences that should be collaboratively conducted by federal and provincial departments.

Additional human resources (staff and researchers) and funding increases for scientific research on the specific topics is required. Proponents should be collecting and providing additional biological data for every project to improve the accuracy in the proposed classification system. Management approaches should be developed to reduce the number of referrals being reviewed to reduce workloads. An education program for the developers and anyone engaged in culvert crossing projects should be developed by DFO to improve communication and understanding of DFO responsibilities and initiatives, as well as the biological and technical aspects associated with fish and fish habitat.

At the provincial level, there are many potential operational impediments. The sheer numbers of aging physical crossing infrastructure and the substantial cost of replacement, maintenance, and/or upgrades that are needed present a major challenge to developers. In addition, standardized design requirements are needed to accommodate DFO's fish passage velocity requirements. The ownership and jurisdiction over infrastructure between the province and rural municipalities is problematic from a cost and legal perspective. There is a need for increased budgets and staff training and guideline development. Limited hydrological and biological data compound these issues.

To aid in resolving these provincial impediments, larger budgets, and more staff and training are required to collect more data and address the problems associated with the physical infrastructure, guideline development and development of standardized guidelines, as DFO will not develop standardized guidelines due to legal issues. Communication between the province and RMs is essential to work out ownership and jurisdictional issues.

At the municipal level, the potential operational impediments identified are limited budgets, staff, and training. In addition, jurisdictional issues on crossing ownership and liabilities exist. A large problem is that there is no information exchange between the federal and municipal level, meaning that very little compliance to federal expectations occurs. This is further complicated by the turnover frequency of elected officials in RMs Councillors are not required to have any particular knowledge or training of the intergovernmental process of watercourse crossing projects and as such their directives do not require proposals to be submitted to DFO.

To address these municipal impediments larger budgets, increased staff and more training of staff and councillors is required. DFO should develop and implement an education program that could include meetings, workshops, and or presentations. This would provide an introduction to DFO (what it does, what it expects, and what the municipality is required to do to ensure good governance as it applies to watercourse crossings) and an overview of the inter-governmental process. The province could do something similar, although the municipalities are much more aware and familiar with provincial processes. The presentation could be given at the beginning of a councillor's term to ensure there is understanding of the issues, with the expectation that their knowledge will be transferred to the foreman actually doing the work.

Increased staff, larger budgets, training, and education are required at all levels. A possible solution to resource (staff and time) constraints is to partner with NGOs where the government provides money and the directive, and the NGO conducts the operation. Education will allow each agency to communicate their needs to other levels of government and establish mutual understanding of expectations. Training is essential for all levels to ensure consistency and competence in performing required duties.

Large increases in government budgets are not the norm and as such, good working relations between all levels of government and open communication must be established to compensate. Meetings, workshops and/or presentations developed by any agency to educate other stakeholders on their programs, initiatives, and needs or solicit help in solving a particular problem are necessary. They present an opportunity to bring individuals together, facilitate the understanding of other jurisdictional needs and requirements, and promote good working relationships. Good working relations and open communication will create education opportunities, promote compliance, and reduce friction between and amongst different levels of government. The province and public works employees from the RMs have shown they are receptive and have a willingness to improve by participation in meetings, workshops etc. Action on this willingness is now needed.

The interviews created a level of awareness amongst the respondents towards these issues. The willingness to work together, integrate information (possessed and being obtained) and share individual knowledge was present in all subjects (to varying degrees). MWS should capitalize on this willingness, since the movement towards future integrated management planning involving stakeholders (Federal, Provincial, RM, CD, and producers) is being initiated by MWS.

5.2 Crossing Inventory

Given that the number of crossings the research found in a relatively small area greatly exceeded the number of the other structures combined, and assuming other DESs are similar, the importance of culvert crossings on the landscape in agro-Manitoba could be thought of as quite high. Therefore, logistically speaking this presents a major administrative issue for any jurisdictional authority involved with watercourse crossing management, design, installation, or maintenance.

Culvert inventories that capture a range of biological and technical information, providing that there are regular updates to the data, allows managers to plan and strategize maintenance and replacement activities while maximizing the efficient use of limited human and capital resources. It is important to note there may be different ways to determine damage that may be more effective than the design used in this research. This could result in a more precise and specialized ranking of damage specific to the needs of the agency using them.

Similarly, the determination of the erosion potential for this research was somewhat subjective; consistency in ranking was an issue and for this reason, it is not presented here. A potential ranking system for a future inventory looking at watercourse erosion may include a set of individual designed criteria using objective observations based on the combination of streambed erosion and erosion from culverts. Erosion from culverts is limited to scour hole development and localized bank erosion (5-10m) from the outlet, or if the culverts are misaligned further bank erosion sites need to be considered (Richardson 2008).

5.3 Interactive Map

All interview subjects agreed that map layers showing the different watershed components would be very useful for anyone involved in watercourse crossing projects even though individual use may vary greatly depending upon the specific application. DFO's Fish Habitat Biologists could use the map to assess current and future impacts an individual project may have on the watercourse as well as the cumulative impacts that may have already occurred from multiple projects in the same watershed.

The province could use the map to plan their activities from the initial budget stage right through to the implementation and operational levels including maintenance and replacement based on DFO's informational requirements, review timelines, and habitat classification data. Conversely, both the province and RMs would need to provide infrastructure inventories (size, type, damage level) to be integrated into the map to further increase timeliness of DFO's referral system. The map could also be used by DFO staff to conduct compliance monitoring of watercourse crossing to ensure mitigation measures were being implemented and that they were functioning as expected.

Using ArcView, detailed site information from the component datasets can be displayed just by clicking on the individual site in question, as shown in figure 26. This tool could essentially make the management of watercourse crossings and other projects on the landscape a desktop exercise for many potential stakeholders, specifically employees of federal, provincial, and municipal governments alike. This tool has the potential to reduce wait times for referrals and to facilitate good communication and understanding between stakeholders. It could also facilitate planning, and be used for operational implementation, and compliance monitoring aspects.

Integrated Watershed Mapping Tool

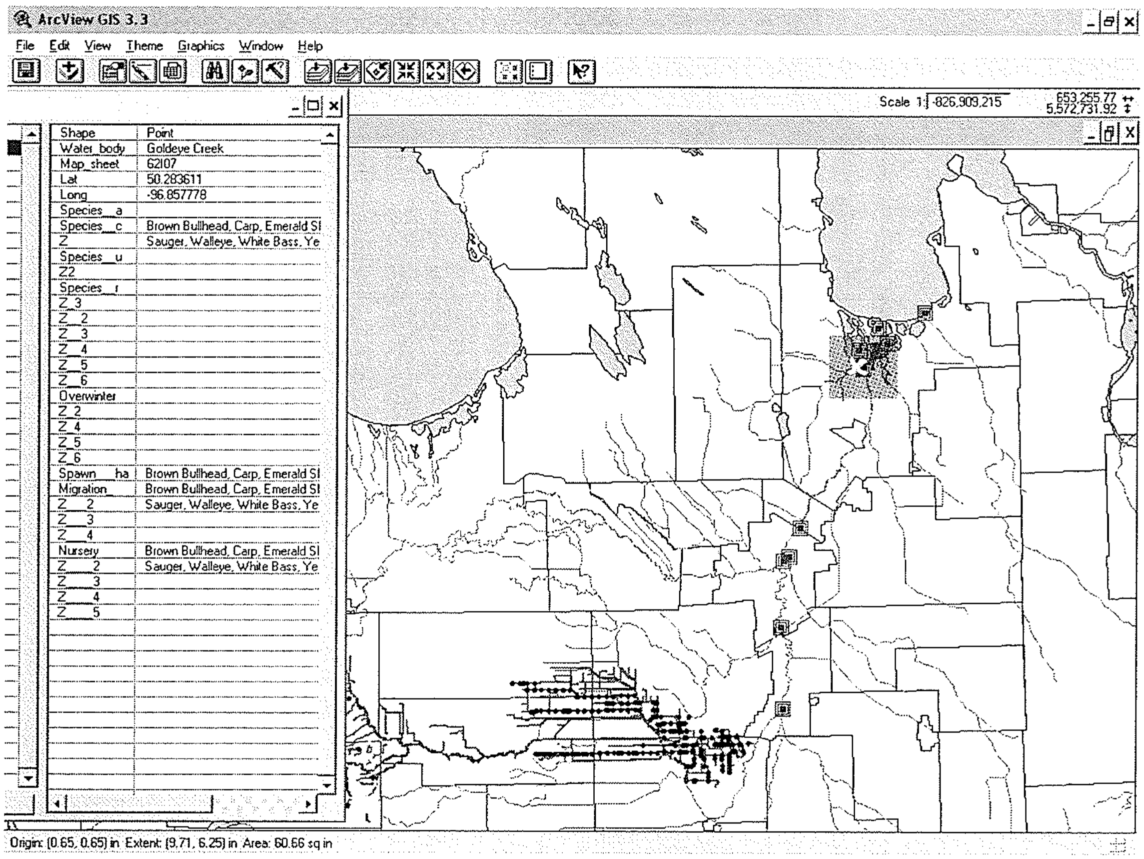


Figure 26: Snapshot of the integrated watershed map being used as a management tool.

5.4 Validity of Interview Responses

Since the majority of the interview, subjects were employed with government it is important to recognize that the responses obtained were a combination of both personal and departmental opinion. Perspectives were based on personal, individual experiences, knowledge, and education, which may or may not be consistent with the official policy of the agency they are representing.

When conducting the interviews it was important to consider whether or not the subject was responding to what they thought the question was pertaining to and/or what the expected response was. At the outset interview subjects were assured that the approach being taken was entirely academic in an effort to understand the current situation, the needs of the individuals/agencies involved and obtain valid input for a management approach that DFO would have access to, but may or may not use. Subjects employed by government agencies may have toned down their responses and or chosen their words more carefully for political reasons, but by in large their responses appeared to be candid.

5.5 Habitat Classification and Map Availability

Many of the provincial staffs were familiar with DFO's Agricultural Drainage Inventory and the proposed habitat classification maps. The general consensus was that the maps are and can be very useful and should be made more broadly available to all potential stakeholders. Currently they are only available to DFO internal staff although small sections depicting a project area may be provided to proponents upon request. Both MIT and MWS staff indicated that having a hard copy of these maps would improve the province's planning capability and efficiency to help them become more compliant with the *Fisheries Act* habitat provisions. However, DFO staff have indicated that there are some concerns and potential problems with releasing the maps at this time mainly arising out of potential legal issues that could arise from the fact that a HADD may be caused from a proponent misusing a DFO classification map or using an outdated version of a map. Provincial and DFO staff have both agreed upon a need for more and continued habitat data collection to improve and instil confidence in the manner of classification and the classification process itself. Additional observations at each site could provide further documentation to verify and confirm the initial accuracy of an existing classification. For example, the presences of tadpole or ferry shrimp in the water at a particular site are a good indication of the ephemerality of the watercourse at that reach, as their eggs require a desiccation period to be viable (Stewart 2008). Another potential indicator that a stream is lacking fish indicator species could be based on evidence of amphibian (specifically the boreal chorus frog and American toad) breeding through either vocalization or egg identification (Stewart 2008).

While DFO has been the first to take the initiative in collecting the relevant habitat data for the purpose of classifying habitat and creating a GIS, other levels of government are close to doing their own inventories. MIT has an inspection program that is underway to assess all crossings within Manitoba. Information collected will be used to assess replacement, repair, and maintenance needs and to plan future crossing projects.

The RMs are currently conducting their own inventories of their infrastructure as a part of the private sector accounting program that requires them to determine the value of their infrastructure. Data collection is underway in both RMs (MacDonald and Morris) and both are developing a GIS mapping system with the Drain Master program.
Given that each level is amassing its own database of information relevant to their specific needs and in light of a progression towards integrated watershed management planning it is intuitive that sharing the data (once obtained) would benefit everyone. A system that integrates municipal, provincial, and federal information on crossings (type, age, and requirements), planning (proposed works), acute and cumulative effects of projects, and field studies along with other data would be extremely useful for management.

5.6 Operational Statement & Best Management Practices

Fifteen OS are currently in use in Manitoba. The interviews conducted in this research have identified a need to develop an OS for low-risk watercourse crossings. The risk involved in producing and releasing an OS for crossings is higher than any previously released OS, due to biological uncertainty, negative effects of not following mitigation measures and the potential for unaccounted cumulative impacts on the ecosystem as a whole. Given the biological uncertainties and risk involved, it has been determined that only class E habitats would be suitable for an OS on watercourse crossings.

The interviews revealed that the majority of RM drains are on class E habitats, that these projects are seldom submitted to DFO for review, and an OS for these crossing types would be desirable. With an operational statement in place, the RMs would have access to information on BMPs, and DFO would be able to assess cumulative effects more accurately. While this is only one class out of five, development of an OS for this class will facilitate more efficient and effective watercourse crossing reviews by DFO habitat staff, by eliminating these projects from DFO's referral system, and reducing staff workloads. This would allow the Fish Habitat Biologists to spend their time on the more biologically important projects that have greater risk attached to them.

According to one MWS engineer, field drains do not require water licenses; because MWS wants to maximize its available resources, licensing is only required for projects that change the hydraulic capacity of a crossing or original crossing design. It would be logistically prohibitive to attempt to licence the vast number of field drains in the province. DFO faces a similar challenge for project reviews on Class E habitat over the next few years, strongly underscoring the need for an OS for type E habitat.

Since these habitats typically do not provide sufficient flows (volume or duration) for fish to complete all of their life processes (spawning, rearing, feeding, migration, or overwintering) except during extreme flood events, creating an OS for class E habitats would not be in direct violation of the *Fisheries Act*. With the increasing numbers of crossing projects on the horizon and the need to prioritize referrals according to risk and significance, it makes sense that DFO proceed with the development of an OS for crossings on class E habitats. This would be entirely appropriate within the present context of risk management and would free up resources to focus on higher quality habitats and higher risk projects.

Best management practices (BMPs) are practices that aim to produce the optimum outcomes under any given set of current circumstances. There are different types of BMPs for different areas of management. For example, mitigation measures can be seen as technical best management practices while developing and using the interactive map against a backdrop of the risk management framework is a theoretical BMP. Developing an OS for watercourse crossings on class E habitats, if proper monitoring and compliance were done, would itself be considered a best management practice.

When developing an OS it is important to consider three important issues: the environment, the socio-economic context, and the judicial system. First, will the environment be better off with or without the operational statement, considering the effect the OS has on the ecological landscape? Next, what effect will the OS have on society and the economy, and finally how will litigation proceed through the courts as a result of any enforcement action and subsequent court rulings?

For the OS to be successfully implemented on the landscape level with all participating stakeholder, education, communication and compliance monitoring are required as part of a due diligence defence effort to ward off any potential legal liabilities through the courts. Since the OS will be used in indirect habitat, there will be little difference (ideally) between having and not having an OS in terms of negative ecological impacts. The OS will improve efficiency, reduce costs, and have positive effects on society and the economy.

An additional problem with developing an OS for type E watercourse crossings is that it must be detailed enough to provide mitigation measures and knowledge to individuals/public with little to no experience on the subject, while at the same time, ensuring that the mitigation measures are not too cumbersome, onerous, technical, or financially prohibitive for the average individual to implement. However once developed it would provide a consistent approach which could be continually upgraded and improved through monitoring practice, effectively standardizing DFO requirements and providing exactly what the provincial and municipal people are currently requesting, albeit on a smaller scale. This would also begin a process that would lead to improved communications and working relations between multilevels of government.

5.7 Research Limitations

An operational statement for watercourse crossing projects could and should be applied to low risk Class E habitats within the research area and extended to parts of the LaSalle, Morris and Plumb River sub-watersheds due to their similar surficial geologies, land use and relief, and close geographic proximity (all are within the larger Red River Watershed). The operational statement developed for the research area could also be applied to parts of the eastern side of the Red River watershed (the Seine, Rat, and Roseau River sub-watersheds), since topographical relief, land use, and climate are among the main contributing factors to the amount and type of drainage required by farmers. However, general applicability to other watersheds across agro-Manitoba would require further research and assessment that are beyond the scope of the present research. In addition to differing surficial geology and relief, these areas may have different flows, fish habitat and fish species collections, which may have specific needs and management issues, which this research has not addressed.

5.8. Climate Change

According to the climate change discussion in *The Fish and Fisheries of Lake Winnipeg,* warmer temperatures may lead to the expansion of certain warm and cool water species including indicator species such as Sucker, Northern Pike, Catfish and Perch and the contraction of cold water species such as Whitefish and the soon to be SARA enlisted Lake Sturgeon.

It is predicted, with warmer temperatures, there will be a corresponding increase in the length of the growing season, allowing fish to get bigger and increase chances of over winter survival, which would contribute to population growth. However, with the predicted wetter winters and drier springs it is difficult to say what kind of spring runoff conditions will be experienced. Less runoff would reduce spawning habitat availability, in which some farmers may call for smaller culverts to hold back water resulting in increased velocities reducing fish access and further decreasing available spawning sites. More runoff would increase general velocities and flows, which may delay planting for farmers and be problematic for managers who have to upgrade or replace more culverts and may experience more public/political pressure to modify drainage and crossing structures to allow for more rapid drainage.

If the overall increases in evaporation are greater than the increases in precipitation, we can expect lower water levels across the province, which would be aggravated by an increase need for irrigation for agriculture, and this could lead to even greater long term lowering of water levels. This may have significant impacts on Stephenfield Reservoir in the research area along with other reservoirs in the province that are not only needed to supply water to towns and agriculture but act as man made lakes for fish populations. Reductions in water levels effectively reduce habitats available to fish.

5.9 Administration/Policy

Administration seems to be at the heart of many of the problems associated with watercourse crossings including issues such as ownership over infrastructure, differing departmental mandates and practices, and project approvals. All parties involved with DFO's current project referral process considered it time consuming, costly, and inefficient as project review times are sometimes measured in months and years, and the majority of RM work is done within weeks and often without DFO review as a result of these constraints.

In addition, submitting a project for DFO review could potentially increase the developer's infrastructure costs by having to provide for fish passage. The project's timeline could be delayed which is problematic to RMs with limited budgets as general costs increase over time. Increased costs means fewer projects can be completed within a season, which in turn frustrates their immediate clients, the farmers, who depend on timely drainage and project completion for their crops and livelihoods.

While the RMs are primarily focused on the agricultural community, the provincial agencies straddle the line between environmental conservation and protection (MWS – Fisheries) on one hand, and the more technical aspects of water management (MWS Water Licensing), and infrastructure maintenance, upgrades, and replacement for public safety and economic viability (MIT) on the other. DFO Habitat Management is primarily concerned with the protection of fish and fish habitat, a requirement under the Federal *Fisheries Act*. Each department has its own established practices based on their focus and stakeholder requirements and this often makes it difficult to establish and maintain good working relations and open lines of communications.

Attitudes are changing and new policies are being developed, but some existing policies and practices make changes difficult to initiate. For instance, MWS deals with water services such as flooding, long range planning on drainage, water quality use, and allocation issues including project licensing and is responsible for the administration of Manitoba's Water Policy. The policy identifies a requirement to practice/initiate integrated watershed management planning, thus focusing on inclusion of other departments and stakeholders. This is in direct opposition to the exclusionary practice of the licensing division.

The licensing division requires proponents to obtain a licence for any work that changes the capacity of the crossing or original design and within that license there is a directive to obtain DFO approval. In the past, DFO approval was required prior to the issuance of a license, but now licenses are issued leaving the responsibility to contact DFO up to the proponent, which in many cases does not occur. Although this change in practice occurred out of legal reasons, it is a good example of how an existing practice can hinder communication and makes the initiation of a new compliance policy more difficult.

The CDs do not fit into the current legislative authority chain. They fall outside this arrangement but functionally they fit between the province and municipalities.
In terms of watershed management, Conservation Districts are the bodies helping MWS achieve its mandate through the development of individual watershed management plans.

5.10 Design Standards / Guidelines

Many of the provincial people who were interviewed expressed a desire for DFO to develop culvert design standards to ensure fish passage criteria were met when they submit proposals to DFO for review. DFO has not prescribed design standards in the past, and is unlikely do so in the future, as potential liability concerns could arise should the design fail hydraulically. However, DFO should work collaboratively with the province to establish appropriate guidelines on water velocities requirements where fish passage is involved, which would in turn allow the province to come up with their own design standards that would satisfy these requirements.

A similar issue was identified with DFO issuing a set of crossing guidelines. For instance, any works that cause a harmful alteration, disruption, or destruction (HADD) is prohibited under the *Fisheries Act* unless it is specifically authorized by DFO in which case habitat compensation is usually required. Given that DFO is charged with responsibility of upholding and enforcing the tenets of the *Fisheries Act*, the risk is potentially too high given the biological, technical, and human variability and uncertainty that could in part result in the guidelines or standards themselves causing a HADD. This is one reason why DFO will not prescribe standards to be used for all projects, and why design standards and guidelines are left to the province.

This report can facilitate an approach to this issue by providing an understanding of the informational requirements that DFO habitat biologists are looking for in water crossing projects depending on stream classification. For Class A and B habitats (indicator species and species at risk) the proponent must provide the maximum precautions and design for fish passage which includes meeting specific velocity and flow criteria which is outlined in the Manitoba Stream Crossing Guidelines (some consider this document out of date and in need of revision that reflects current situation and information).

The main fish passage requirements are:

- For culverts < 25 meters long, the mean barrel velocity during the 7Q50 does not exceed 1m/s
- For culverts > 25 meters long, the mean barrel velocity during the 7Q50 does not exceed 0.8m/s

- For culverts >50 meters long, lower velocities may be required by DFO depending on specific conditions

Note: The 7Q50 is the 1 in 50 year, 7-day discharge, meaning that the discharge occurring in a 1 in 50 year flood will not delay migrating fish for more that seven consecutive days. Although in Manitoba DFO has been accepting a slightly less restrictive 3Q10 discharge.

(DFO and MB Natural Resources 1996)

For Class C and D habitats (forage species), the highest level of fish passage design is not expected; DFO is primarily concerned with connectivity especially during lower flows. The proponent should prevent the culvert from perching by ensuring the culvert(s) is/are imbedded a minimum of 30 cm or 10% of culvert diameter below the stream bed (which ever is greater) (DFO and MB Natural Resources 1996). For Class E (indirect) habitats, DFO does not normally require fish passage. These habitats typically do not provide sufficient flows (volume or duration) for fish to complete one of their life processes (spawning, rearing, feeding, migration, or overwintering) except during extreme flood events. These habitats do provide nutrients and water to downstream areas.

It is important to realize that while most Class A and B habitats have higher risk associated with them and require individual assessment to ensure indicator species populations are safeguarded, maintaining forage fish populations through connectivity is also important. It is essential that migration measures in low risk operational statements (Class E) as well as those for Class C and D habitats be met to ensure forage species populations are maintained not only for their intrinsic value, and *Fisheries Act* requirements (bait fishery), but also because they are the primary food source for many indicator species. It is very important to note however, that exceptions can and do routinely occur, particularly if the stream or watercourse has been incorrectly classified due to a lack of sufficient data at the time of the classification.

5.12 Further Investigative Research into the Literature

The three major problems hindering effective water resource management identified in the book "Integrated Resource Planning and Management", a case study on an ecosystem approach taken for the Great Lakes Basin, are present in agro-Manitoba. The boundaries of the watersheds of many of the watercourses in Manitoba do not fall inline with political jurisdictions at the municipal, provincial or federal levels. Past and current management practices were/are often too narrowly focused and miss the bigger picture, and there has been and continues to be a failure to consider the complexity involved with the interactions between all resources (natural and otherwise) within the ecosystem as a whole. The author depicted her version of an ecosystem approach as:

"1. Primary focus on ecological integrity
2. Perception that the ecosystem is somewhat self-sustaining
3. Using natural ecological boundaries (not political)
4. Holistic orientation towards natural resource management – develop an ecologically sound and sustainable socio-physical system"

This approach was feasible in the Great Lakes Area, and produced successful results for the goal of integrated watershed management. This approach has been somewhat applied in Manitoba through the development of CDs. The theoretical concept behind CDs in Manitoba coincides with the vision. They are based on ecological boundaries and they do possess the perception that the current altered ecosystem is self-sustaining. Ecological integrity is a goal to be achieved along with socioeconomic integrity; holistic orientation towards natural resource management is an option but must be chosen by the particular CD. Since many CDs are in their infancy it will probably be some time before any successes can be readily identified.

6.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

6.1 Summary

The purpose of this research was to assess the applicability of an operational statement (OS) and develop a management approach that the Department of Fisheries and Oceans Canada (DFO) could use to incorporate economic, ecological, and social elements to achieve good governance as it applied to watercourse crossing projects in agro-Manitoba that reflected stakeholder needs and mandates.

A small watercourse-crossing inventory was conducted in the Morris River sub-watershed to obtain data that was combined with existing provincial data on fish species composition and abundance, and federal habitat classification data, to develop a a small scale integrated GIS map to demonstrate the potential utility of it as a management planning and assessment tool.

Interviews were conducted with representatives from federal, provincial, and municipal governments who have a direct role in, responsibility for, or knowledge related to watercourse crossings, including a private consultant with local area knowledge.

A thorough literature review identified the many elements involved with watercourse crossing projects and their management to provide an understanding of the underlying complex issues. Climate change data was also examined to identify additional impacts that could also affect the development and implementation of an operational statement for Class E habitats.

6.2 Conclusions

This research determined that an operational statement for watercourse crossing projects could and should be applied to low risk Class E habitats within parts of the LaSalle, Morris and Plumb River sub-watersheds and extended to parts of the Seine, Rat, and

Roseau River sub-watersheds as well, to accommodate the growing numbers of watercourse crossing projects that are anticipated over the next few years. The development and use of this OS and integrated GIS - based watershed map constitute the management approach that DFO should follow.

While the interview responses determined that a class approach using an operational statement for crossing projects on the lowest risk Class E habitats was applicable and needed in light of the many upcoming ncreasing numbers of crossing projects and the fact many RM projects are not being submitted to DFO for review in the first place. There is general support for the potential applicability of an OS for low risk Class E habitat from biologists and engineers that were interviewed from multiple levels of government, although for differing reasons. Using the proposed risk matrix, high impact projects like watercourse crossing projects currently pose too great a risk for developing an OS for any other habitat class besides Class E.

The development and implementation of an operational statement for watercourse crossing projects within class E habitat would enable DFO to comply with its mandate to protect fish habitat under the *Fisheries Act* while being sensitive to provincial and municipal government needs and mandates and while recognizing the importance of the economic and social needs of the surrounding agricultural communities.

The interviews identified many of the legislative, ecological, economic, social and other issues related to watercourse crossings in Agro-Manitoba. It can be argued that the concerns and ideas expressed in the interviews are not limited to the confines of the research area but are valid throughout agro Manitoba. The main concerns that came up involved fish passage and velocity requirements, improper design standards, excessive costs, infrastructure ownership, administration and governance issues, division of labour/human resources, stakeholder input/pressure, education/training, and lack of information transparency and accuracy in project assessments reviews.

The need to increase the efficiency of the project referral system, increase information sharing, training and education, reduce costs, and consider the needs of the primary business in rural agro-Manitoba namely, the agricultural community, were among the issues identified. All subjects expressed a willingness to work together to facilitate a more partnered and conciliatory approach that was fundamentally based upon the integration of information and knowledge.

The research also identified there could be additional impacts caused by climate change could also affect the development and implementation of an operational statement for Class E habitats, such as the changes in water suppy and demand and changes in fish species life cycle requirements and distribution.

The use of an operational statement on low risk Class E Habitat should be combined with a current, up to date and accurate integrated GIS-based map, an effective monitoring program, a comprehensive education initiative, and a willingness of all government agencies to openly work together. It must be understood that the OS applicability has not yet been assessed for watersheds outside of the research area and that to do so would require further research.

While an operational statement for crossing projects on the lowest risk Class E habitat was applicable, operational statements for the other habitat classes was not as watercourse crossing projects in general have the potential to create high impacts on fish habitats. Since Class C, B, and A habitats are moderately to highly sensitive habitats, there is a corresponding risk of moderate to very high negative impact on such habitat classes by watercourse crossing projects. Such risks require careful review, habitat compensation, and in some cases project relocation and/or redesign. Therefore an operational statement would not be applicable in these situations.

An operational statement for Class D habitats is also not applicable, at least at this time. Although Class D habitats are less sensitive habitats than Classes A-C, there is still a moderate to high risk associated with watercourse crossing projects on them. An operational statement could apply in the future but would be dependent on very detailed information being available on an integrated GIS map to provide the level of confidence in the proposed Habitat Classification System so that follow-up compliance monitoring could determine it's effectiveness and administrative applicability.

If the integrated GIS map was expanded to include all of agro-Manitoba, the province and RMs could use the map to help them plan their watercourse crossing projects from start to finish, including initial project budgeting, construction sequencing and maintainence and replacement scheduling. DFO staff could use the map to decrease the time required for Fish Habitat Biologists to review watercourse crossing projects and to strategically identify locations and times for future compliance monitoring.

The potential development of an OS for Class E habitat crossings would reduce the numbers of watercourse project referrals for DFO Fish Habitat Biologists to review thus freeing up their time to focus on projects within critical and higher valued fish habitat that requires a higher level of protection. Together with an integrated map, the operational statement would reduce the current backlog on DFO's project referral system, and improve and streamline provincial watercourse project planning, making it more cost effective, environmentally friendly, and within regulatory compliance. DFO could satisfy *Fisheries Act* requirements and ensure that habitat protection strategies were being met or exceeded in the most productive habitat areas.

On a provincial and municipal level, this management approach could increase regulatory compliance and reduce overall costs. The Province, RMs and CDs, would be provided with clear and consistent direction as to what is expected of them from DFO for stream crossing maintenance and construction in class E habitat. This management approach could also aid in strategic budgetary and logistical planning when maintaining and replacing ageing watercourse crossing infrastructure by identifying sensitive watercourse habitat and potential sites where an operational statement could apply.

5.3 Recommendations

- DFO staffs require more training to ensure decisions are made in a consistent manner across the country. Although this fundamental requirement was identified and instituted previously by DFO under the Environmental Protection and Modernization Plan (EPMP) more fine-tuning of project reviews may be accommodated through project specific workshops.

- There is also a need to involve more scientific research in habitat classification, fish swimming performance, and fish lifecycle habitat preferences and to obtain the resources to do so (staff/funding) to enable better management decisions to be made. This initiative should be collaboratively conducted by both federal and provincial departments.

- Proponents should be collecting and providing additional biological data for every project to improve the accuracy in the currently proposed Habitat Classification System.

- More adaptive and strategic management approaches should be developed and undertaken by DFO to reduce the number of projects being reviewed to reduce staff workloads, increase timeliness in referral turnaround and to improve regulatory compliance.

- An education program for the province and RMs should be developed by DFO to improve communication and understanding of DFO's roles and responsibilities as well as the biological and technical aspects associated with fish and fish habitat.

- At the provincial level, to reduced the potential operational impediments identified an inventory system needs to be developed and/or expanded across the province where applicable to assist management in the operational planning of these watercourse crossing works either by the province alone, or collaboratively with other levels of government.

- Standardized design requirements are needed to accommodate DFO's fish passage velocity requirements. Communication among and between DFO, MWS, MIT, the RMs and CD's is essential to work out ownership and jurisdictional responsibilities.

- There is a need for increased budgets, staff training, and guideline development at the provincial level. Since hydrological and biological data are limited, more effort needs to be directed by provincial and municipal governments to collect, maintain, and share such information within and between agencies.

- Although increased staff, larger budgets, more training, and education would be beneficial to help resolve many of these issues, this is highly unlikely given the current fiscal restraint programs that most government agencies are experiencing at the present time and therefore partnerships and collaboration should be actively pursued as a viable alternative.

- Education will allow each agency to communicate their needs to other levels of government and help to establish mutual understanding of individual expectations.

- An information program should be developed by each agency to educate the public at large and individuals including agricultural producers on the technical and ecological issues and values of agricultural drains and to communicate each agency's requirements and expectations on past, present and future initiatives.

- Training is essential for all levels of government to ensure consistency and competence in performing required duties. This should be an internal initiative of every agency.

- Good working relations between all levels of government must be established through open communication to help facilitate good governance. Meetings, workshops, and presentations should be developed by individual agencies to educate all stakeholders on their programs, initiatives, and requirements.

- A sub-committee under the current DFO-Manitoba Habitat Management Agreement (MOU) needs to be created that is focused specifically on watercourse crossings in Manitoba. This sub-committee will provide the basis and terms of reference for agencies within federal and provincial levels of government to work together to improve the management of watercourse crossing projects within the province. Further elaboration on data sharing and data collection activities along with any cost sharing and funding provisions that may be required would also have to be worked out by this sub-committee.

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APPENDIX A – Manitoba Indicator Species

Indicator species found in Manitoba Drains by the Department of Fisheries and Oceans' Agricultural Drainage Inventory.

Common Name	***Scientific Name***
Quillback	*Carpoides cyprinus*
White Sucker	*Catostomous commersoni*
Bigmouth Buffalo	*Ictiobus cyprinellus*
Silver Redhorse	*Moxostoma anisurum*
Shorthead Redhorse	*Moxostoma macrolepidotum*
Channel Catfish	*Ictaluras punctatus*
Northern Pike	*Esox lucius*
Rainbow Trout	*Oncorhynchus mykiss*
Brown Trout	*Salmo trutta*
Brook Trout	*Salvelinus fontinalis*
Burbot	*Lota Lota*
Rock Bass	*Ambloplites rupestris*
Smallmouth Bass	*Micropterus dolomieu*
Black Crappie	*Pomoxis nigromaculatus*
Yellow Perch	*Perca flavescens*
Sauger	*Sander Canadensis*
Walleye	*Sander vitreus*
Freshwater Drum	*Aplodinatus grunniens*

Source: DFO (2007a)

APPENDIX B – ADI Field Data Sheet

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (*i.e.*, logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabi or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered o removed entirely.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water o shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Source: DFO (2007a)

APPENDIX C – Stream Characteristics

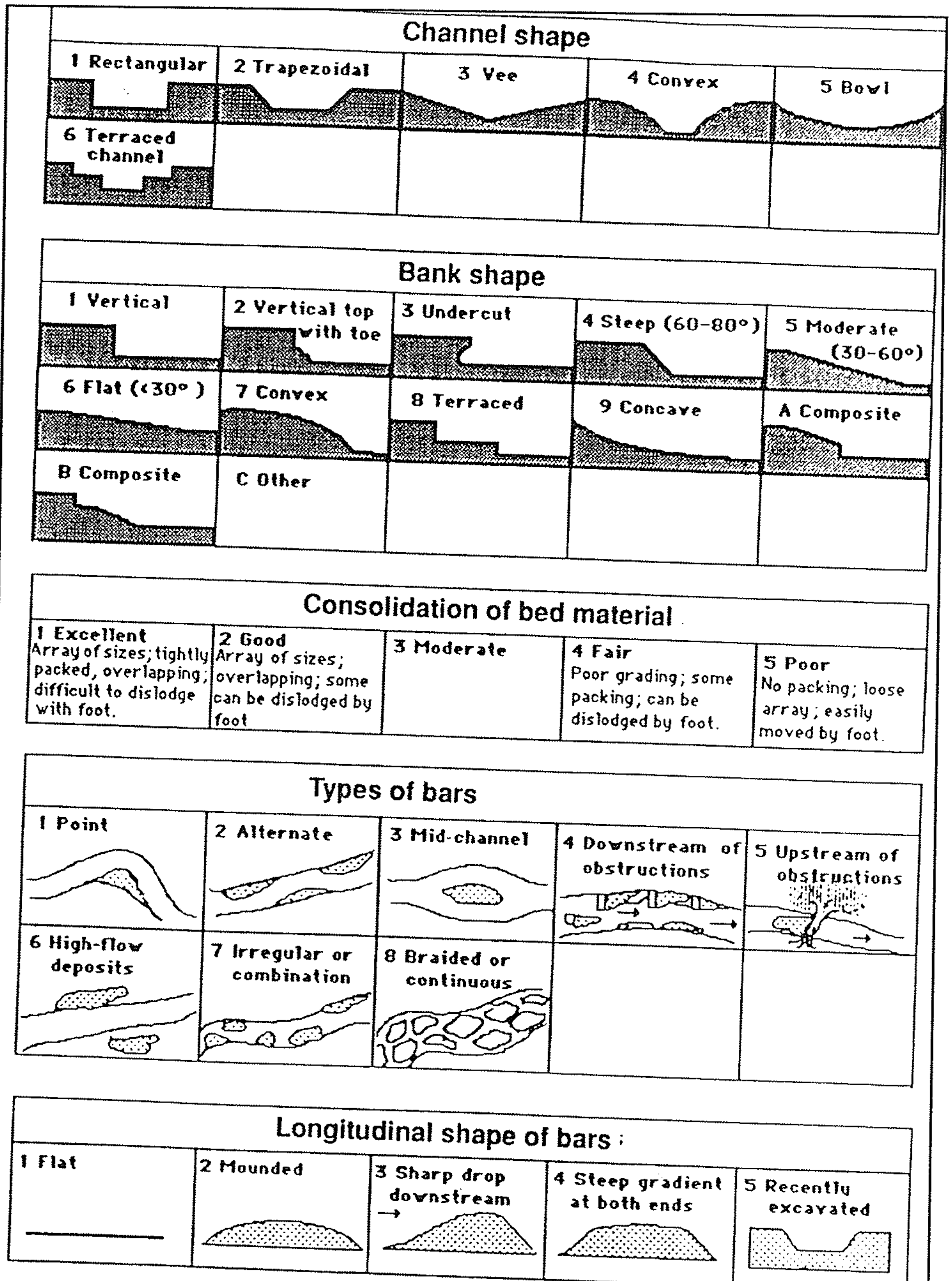


Figure 4.4. Examples of field criteria used in the State of the Streams Survey, Victoria, Australia. Reproduced by permission of the Department of Water Resources, Victoria

Source: Gordon et al. (1992)

APPENDIX D – Description of Residual Effects

Residual Effects of Pathways of Effects for Fish Passage Issues

Change in total gas pressure: Dissolved gases may become supersaturated when air gets trapped in water and submerged to sufficient depth (e.g., at the base of spillways associated with hydroelectric facilities). Total gas pressure above certain levels may subject organisms to injury or mortality.

Change in salinity: Increased volume freshwater flows into estuaries at certain times can decrease salinity levels which can affect the diversity and abundance of sensitive sea grass and also affect the distribution of some fish species. Alternatively, fish eggs, larvae may not tolerate higher salinities of the marine environment that may result from decreased freshwater flows. The quantity and seasonal timing of freshwater flows are critical at sensitive stages (e.g., larval, hatching).

Change in thermal cues or temperature barriers: Temperature often serves as a behavioural cue for fish. Anadromous fish, such as salmon, and shellfish, need temperature to trigger reproductive behaviour. Thermal pollution resulting in higher temperatures can cause a shift in the timing of reproduction and changes in the community structure

Interbasin transfer of species: Diversion channels can promote the inter-basin transfer of water which can promote insurgence of invasive species or other non-native aquatic organisms

Incidental entrainment impingement or mortality of resident species: Fish may become entrained through intakes, turbines, spillways, etc. or impinged at screens and can result in injury or mortality.

Change in access to habitat/ migration: An alteration in water depth, flow, and/or substrate size causing a disruption in access to fish habitats essential for various life processes within given fish populations such as spawning and rearing

Residual Effects of Pathways of Effects for Placement of Materials or Structures in Water

Change in food supply: The aquatic food supply must be plentiful and diverse to sustain the productivity of a watershed. An increase or decrease in the quantity or composition of the food supply, beginning with plants and organic debris that fall into a waterway, can alter the structure of the aquatic community

Change in habitat structure and cover: The addition of in-stream organic structure and the deposition of eroded soil can affect the capacity of a watercourse to maintain a dispersed and diverse community of aquatic organisms by restricting habitat connectivity and the opportunities for organisms to use, colonize, and move between existing aquatic environments. The removal of in-stream and riparian vegetation can reduce channel stability, cover and protection from predators and physical disturbances, and the availability of diverse and stable habitats.

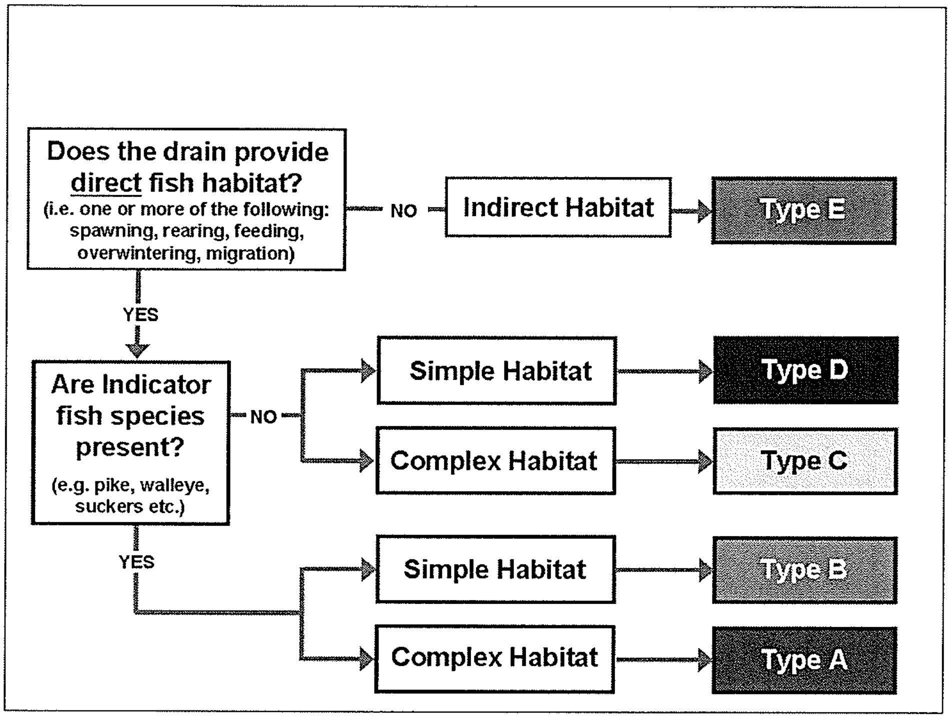
Change in sediment concentrations: Increased erosion of stream bank soils and rocks result in an excess of fragmented organic and inorganic material which is transported by water, wind, ice, and gravity. These sediments, which contain nutrifying elements and can capture or absorb contaminants, are suspended or else settle and collect in waterways affecting physical processes, structural attributes, and ecological conditions such as water clarity (by reducing visibility and sunlight and damaging fish gills) and reducing the availability and quality of spawning/ rearing habitat (through infilling)

Change in nutrient concentrations: Some activities may cause an increase in nutrifying elements such as nitrogen and phosphorus and mineral compounds such as ammonia, nitrates, nitrites, orthophosphates. This leads to 'eutrophication', thick growths of aquatic plants (especially algae) that block light needed by aquatic vegetation, either by clouding the water column or coating the vegetation itself. When the algae die, they settle to the bottom and are consumed by bacteria during the decomposition process. This process consumes oxygen, depleting it from bottom waters. The resulting low dissolved oxygen concentrations drive fish from their preferred habitat and can cause other organisms to die.

Source: DFO (2007c)

APPENDIX E – Proposed Habitat Classification Parameters

The decision flowchart proposed by DFO in MB to determine watercourse classification in agro-Manitoba.



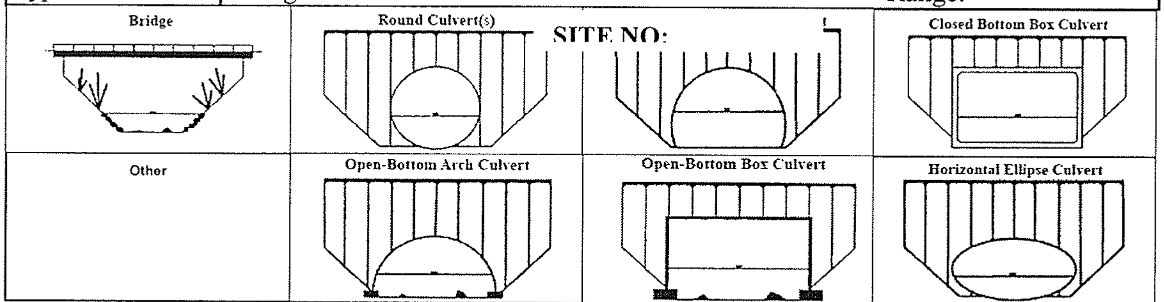
Source: DFO (2007a)

APPENDIX F – Culvert Crossing Inventory Field Data Sheet

SITE NO:________

Time:

Watercourse:		Date:
Site Name:		Section:
GPS Coordinates:	Lat:	Township:
Type of Structure:	Long:	Range:



Measurements (m)

	Height	Width	Length	Water in Pipe	Visible Damage	Specs
Culvert 1						
Culvert 2						
Culvert 3						
Culvert 4						
Culvert 5						
Culvert 6						

	Substrate in culvert	Perched/Embedded		Scour depth		Erosion Potential	
		inlet	outlet	inlet	outlet	inlet	outlet
Culvert 1							
Culvert 2							
Culvert 3							
Culvert 4							
Culvert 5							
Culvert 6							

perched (p) / embedded (e); full (f) / bevelled (b); metal (m) / concrete (c) / other (o); baffles (ba)

Pictures

ID	Description	Azimuth
	u/s from middle of crossing at edge	
	d/s from middle of crossing at edge	
	outlet	
	inlet	

Notes

APPENDIX G – Ethics Approval

UNIVERSITY OF MANITOBA | OFFICE OF RESEARCH SERVICES
Office of the Vice-President (Research)

CTC Building
208 - 194 Dafoe Road
Winnipeg, MB R3T 2N2
Fax (204) 269-7173
www.umanitoba.ca/research

APPROVAL CERTIFICATE

06 November 2007

TO: **Jaime Clarke** (Advisor T. Henley)
Principal Investigator

FROM: **Wayne Taylor, Chair**
Joint-Faculty Research Ethics Board (JFREB)

Re: **Protocol #J2007:134**
"Development of a Management Approach as it Applies to Watercourse Crossings in agro-Manitoba"

Please be advised that your above-referenced protocol has received human ethics approval by the **Joint-Faculty Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement. This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- if you have funds pending human ethics approval, the auditor requires that you submit a copy of this Approval Certificate to Kathryn Bartmanovich, Research Grants & Contract Services (fax 261-0325), including the Sponsor name, before your account can be opened.

- if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/ors/ethics/ors_ethics_human_REB_forms_guidelines.html) **in order to be in compliance with Tri-Council Guidelines.**

Bringing Research to Life

APPENDIX H – Interview Responses

General

1. What are your key concerns regarding watercourse crossing projects in agro Manitoba?
2. What would you like to see happen in the future?
3. What approach(es) do you think should be taken to achieve future outcomes?
    a. What are the benefits and potential set backs do you for see of each approach?
4. How do watercourse crossing projects impact your organization/position?
5. What is your understanding of best practices/best mitigation measures, current practices/current mitigation measures as is applies to watercourse crossing projects in agro-Manitoba?
    a. Compare best and current practices/mitigation measures.
    b. How have these practices/measures changed over time/from past practices/measures?
    c. What potential alternatives to today's best practices can you identify?
6. What strategies can you provide that would help assist various stakeholders in promoting best practices and sustainable development as is applies to watercourse crossings in the southern agro-Manitoba?
7. Do you know how ecological decisions are made as they would apply to a watercourse crossing project? If yes, please explain.
8. How could consistency in overall decisions in watercourse crossing projects, as it applies to design, construction, and maintenance, be achieved from the various regulator staff and stakeholders involved?
9. What does sustainable development and ecological integrity mean to you?
10. Are you familiar with the concept of ecosystem management?
11. Do you think it is possible to develop southern agro-Manitoba in a sustainable manner? (Specifically as it applies to watercourse crossing projects.) Please explain.
    - How would you define adaptive management and integrated watershed management?
12. Are adaptive management and integrated watershed management planning things that should be strived for? Why or why not?
    a. What are the potential benefits & draw backs of their implementation on the large scale?
13. How would integrated watershed management planning affect you / your position?

14. How would you implement adaptive management in your position?
15. What steps could be taken to achieve better inter level government communication and collaboration to facilitate good governance?
16. What steps could be taken to achieve integrated watershed management planning?
17. Can you provide any other suggestions to improve management and integration of biological, ecological, and economic considerations as it applies to watercourse crossings in southern agro-Manitoba?

Biological

18. What do you think the specific ecological and technical requirements are for fish passage to be realized in watercourse crossing projects in the study area?
19. What do you think should be done to mitigate potential and cumulative biological effects of watercourse crossing projects?
20. Which areas in agro-Manitoba do you think are more biologically, economically and or socially sensitive?
21. Do you think a class approach and or the use of an operational statement for the use in watercourse crossing projects is feasible from a biological point of view? Please explain.
22. Are you familiar with the concept of risk management in general?
    a. How would you incorporate risk management into the design, budget, construction, and operation/maintenance or watercourse crossing projects? (specifically in the Morris River Watershed, and agro- Manitoba)

Technical

23. What information do you think is necessary, utilizing the existing (draft) fish Habitat Classification System to develop a standardized and formalized water crossing approach for class E (indirect) habitat?
24. Do you think a class approach for low risk watercourse crossing projects would be more economically efficient and timely than the current system? Please explain.
25. What constraints are there to developers and regulators as they apply to the budget, construction, operation/maintenance of watercourse crossings projects in southern agro-Manitoba?
26. Summarize how financial decisions are made to plan, budget, and install a watercourse crossing and provide a sample cost breakdown of a project.
27. Would an integrated map based on fish species composition and abundance, fish habitat, road crossing inventories and downstream populations of concern be useful as a decision making tool in watercourse crossing projects?

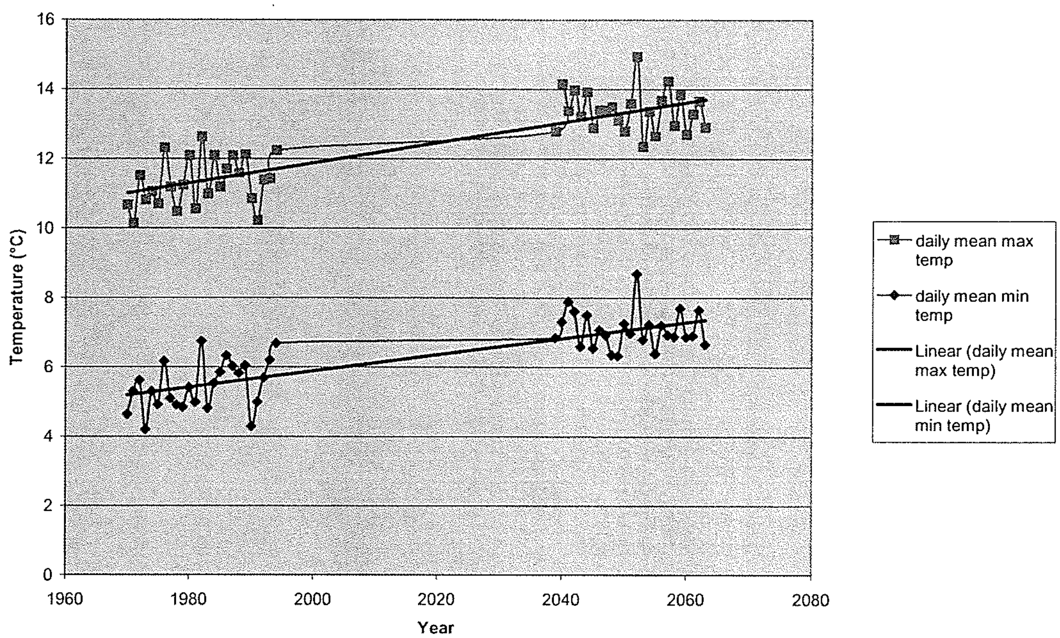
a. Would the map be compliant with regional fisheries practices/policies?
b. How do you think an interactive map with a layer describing culvert information would aid in managing for watercourse crossing projects?
c. How do you think a class approach to watercourse crossing projects aid in managing for watercourse crossing projects?
d. How would an interactive map, like the one proposed in this study, benefit you? (as a biologist, engineer, manager)
e. Which areas within southern agro Manitoba may need future works, within the next 5 years? (either maintenance or construction activities)
f. Which areas within southern agro-Manitoba may require emergency construction to prevent instances of washouts or flooding?

28. How would you ensure due diligence is incorporated in the budget, construction, maintenance phases on the part of the developer and regulator?

APPENDIX I – Graphs Identifying Climate Change Trends for Temperature, Evaporation/Precipitation and Total Soil Moisture Content

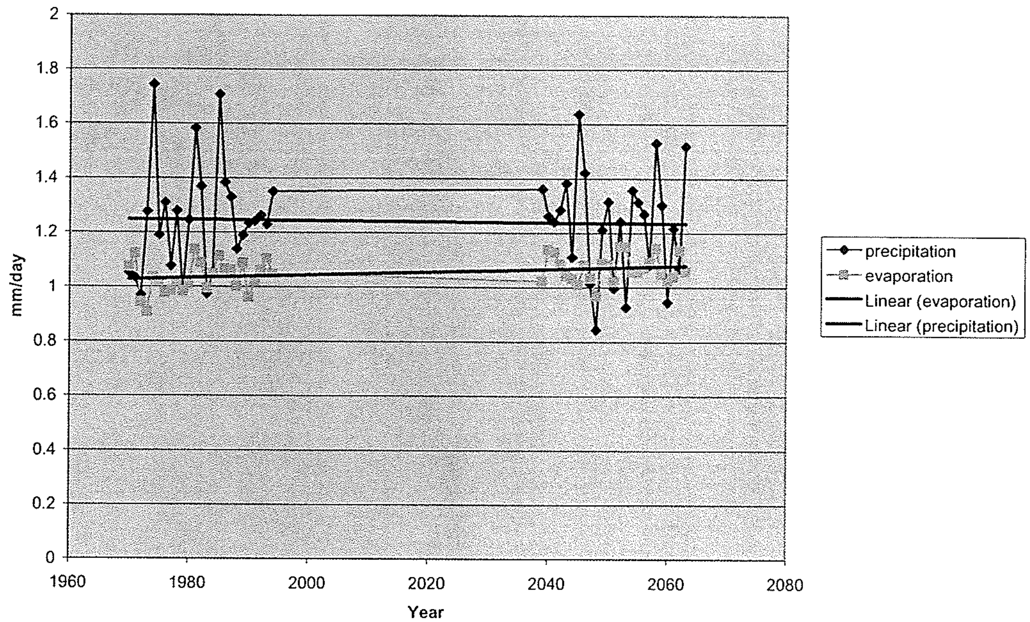
Modelled Fall Temperature Trends for the Sampling Area within the Morris River Watershed

(Using CRCM 3.6 Monthly Means Data Produced by the Cimate Simulation Team at Ouranos)



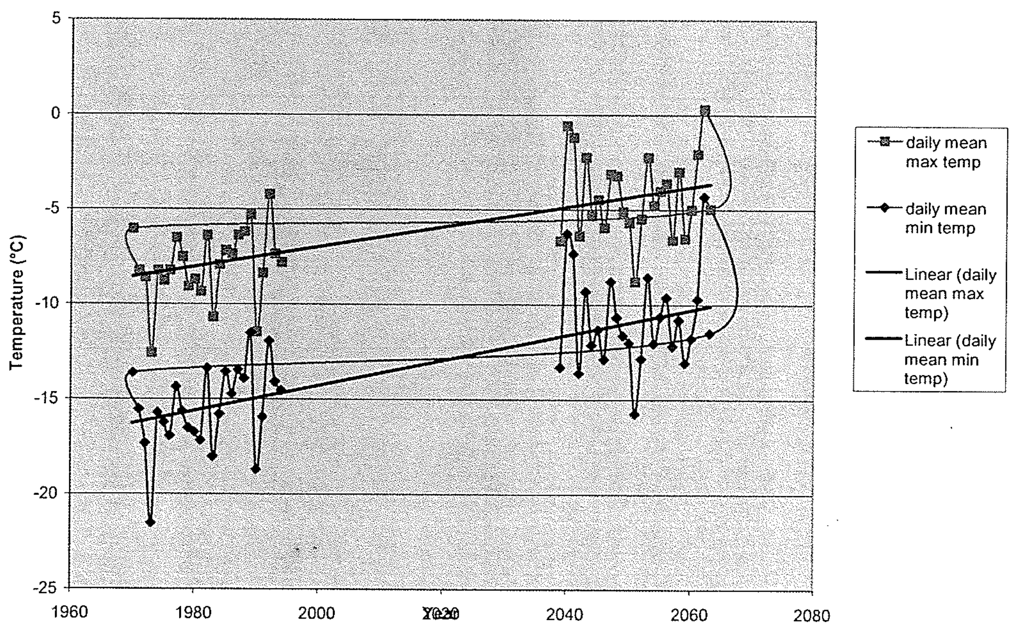
Modelled Fall Precipitation / Evaporation Trends for the Sampling Area within the Morris River Watershed

(Using CRCM 3.6 Monthly Means Data Produced by the Cimate Simulation Team at Ouranos)



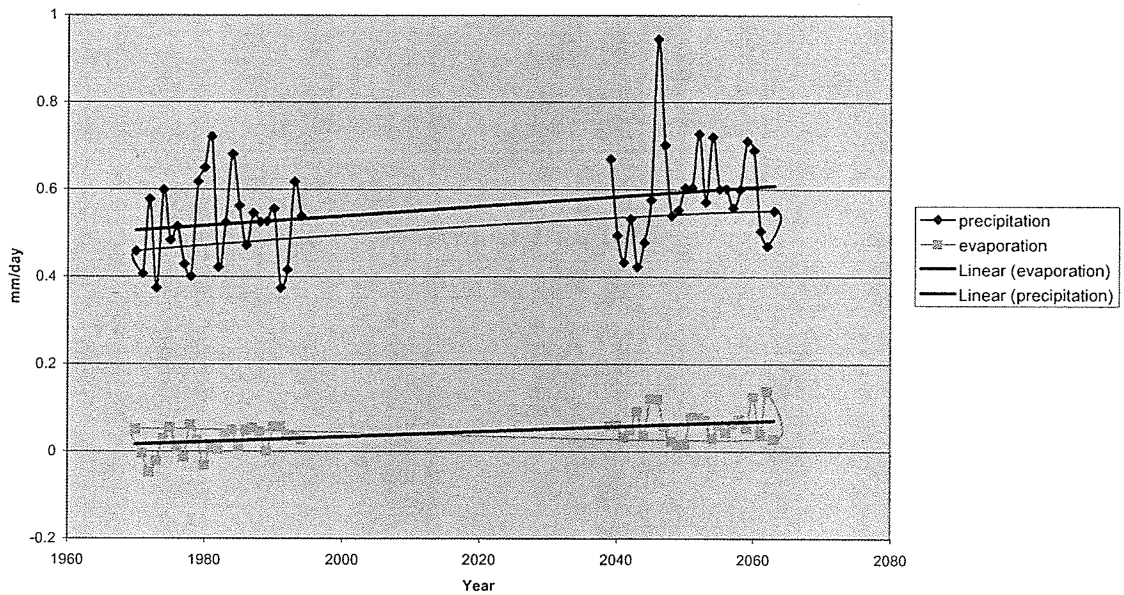
Modelled Winter Temperature Trends for the Sampling Area within the Morris River Watershed

(Using CRCM 3.6 Monthly Means Data Produced by the Cimate Simulation Team at Ouranos)



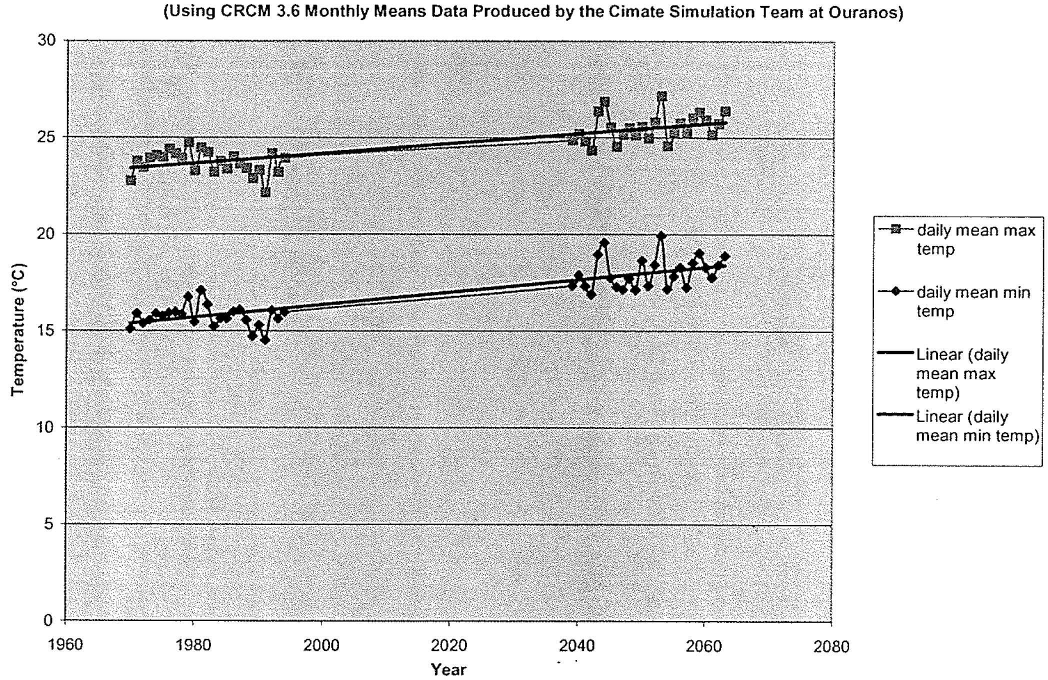
Modelled Winter Precipitation / Evaporation Trends for the Sampling Area within the Morris River Watershed

(Using CRCM 3.6 Monthly Means Data Produced by the Cimate Simulation Team at Ouranos)



Modelled Summer Temperature Trends for the Sampling Area within the Morris River Watershed

(Using CRCM 3.6 Monthly Means Data Produced by the Cimate Simulation Team at Ouranos)



Modelled Summer Precipitation / Evaporation Trends for the Sampling Area within the Morris River Watershed

(Using CRCM 3.6 Monthly Means Data Produced by the Cimate Simulation Team at Ouranos)