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FINAL REPORT

NORTH SASKATCHEWAN RIVER INSTREAM FLOW NEEDS SCOPING STUDY

Submitted to:

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May 2007 **06-1337-007**

EXECUTIVE SUMMARY

The North Saskatchewan Watershed Alliance (NSWA) is the Watershed Planning and Advisory Council for the North Saskatchewan River and is responsible for the development of Water Conservation Objectives (WCOs) for the river. Managing the North Saskatchewan River's water supply presents an emerging challenge as demands for water increase due to population and economic growth. The NSWA is addressing these management challenges, in part, by the development and implementation of an Integrated Watershed Management Plan (IWMP), which is overseen by an IWMP Committee. The entire length of the North Saskatchewan River within Alberta is included within the scope of the NSWA's IWMP: the Battle River and Sounding River sub-watersheds are excluded from this specific undertaking. A determination of the Instream Flow Needs (IFN) for the maintenance of the integrity of the aquatic ecosystems within the North Saskatchewan River Basin is required as a component of the IWMP.

To this end, the NSWA retained Golder Associates Ltd. (Golder) to develop a scope of work for the development of an IFN assessment framework for the North Saskatchewan River. The NSWA struck an Instream Flow Needs Technical Advisory Committee (IFN-TAC) to direct the implementation of the IFN scoping study and to provide recommendations on the IFN back to the IWMP Committee.

The final Terms of Reference for the study are:

- an identification of North Saskatchewan River segments in Alberta, that is carried out through an examination of topographic maps, hydrological information, water quality information, and basic fish distribution information;
- identification of key data sources, and a subjective review of the quality and comprehensiveness of these data for each of the main ecosystem components to be considered in an IFN study based on the concepts of the Natural Flow Paradigm;
- preparation of a comparison of key IFN methods suitable for use in a study of the North Saskatchewan River in the context of the overall goals of the NSWA with a focus on water quality modelling, including potential costs, timelines and limitations of each method;
- design of a GIS database and mapping interface with a focus on the interactions between land-use practices and water quality modelling; and,
- a presentation to the NSWA on the study findings.

The river segmentation analysis resulted in 17 IFN reaches being identified using standard protocols for setting reach boundaries. Of the 17 reaches, 9 are located below the Bighorn Dam and 8 are upstream of the dam. The reach boundaries were largely driven by changes in the hydrology of the river, particularly in the upstream reaches, with changes in fish distribution, land-use practices, river morphology and changes in water quality also contributing to the segmentation analysis in the downstream reaches.

Over 200 reports and data sources were reviewed as part of the scoping study covering a wide range of disciplines. In general, water quality studies were most prevalent, although numerous sources of data are also available for fisheries, benthic invertebrates, channel morphology and hydrology. Limited data are available on riparian ecosystems. The data tended to have a pronounced spatial bias, with a majority of reports for all disciplines focused on Reach 3 through Reach 5, associated with studies completed within the vicinity of the City of Edmonton. Reaches upstream of the Bighorn Dam typically have the least amount of data, if any, for all disciplines.

As part of the scoping study, a geographic information system (GIS) was developed for use in the IFN development with the flexibility to be applied to other components of the IWMP. The approach used for creating the GIS system was based on the direct advice and interaction with the IFN-TAC. The main deliverable provided for the GIS component of the study are:

- Spatial data used in mapping prepared for the July 20, 2006 update meeting, as well as that used in reporting. The data will be accompanied by FGDC compliant metadata. In addition, MXD (ESRI GIS mapping) files and PDF files of the maps will be provided.
- Spatial data that has been acquired, but not necessarily used for the project’s current purposes, accompanied by reports with an explanation about the data origin, processing, and intended use.
- An ESRI ArcReader PMF file. ArcReader is a GIS viewer freely distributed by ESRI that must be installed on the user’s computer; it does not utilize a web browser. ArcReader allows the user to do basic GIS functions – pan, zoom, query data, measure distance, and print a map. On the GIS side, an MXD file with basic functionality is published using ArcGIS Publisher. The map showing the final reach segmentation will be published and provided to members of the IFN-TAC and the Board. Within the application, features will be hyperlinked to documents, so that by

clicking on a feature, documents will open up. More than one document can be linked to a feature and will include summary descriptions of each reach break to the reach features, a list of the references for each reach as well as available naturalized flow data.

A review of potential IFN methods was completed and an assessment of general suitability to the North Saskatchewan River was completed based on the results of the data summaries. An IFN framework is proposed, although several key decisions are required by the IWMP Committee prior to moving forward with the IFN study. These considerations include, but are not limited to:

- time and budget constraints;
- objectives for data uncertainty and ability to evaluate scenarios for each component of the IFN; and,
- an understanding of the legal and institutional framework for the development of an IFN should be investigated. This includes an understanding of the current allocation commitments and possible limitations to future water management actions those allocations may pose.

The proposed IFN framework and associated general costs and timing are provided in the following table.

Summary of Proposed IFN Framework for the North Saskatchewan River

Task	Possible Timing	Duration[1]	Approximate Cost[2]
Channel Morphology (CM)			
Option 1: Determine CM flows from Shield's equation using existing data	Q1(2007)	🕐	$
Option 2: Determine CM flows from Shield's equation using field data at habitat modelling sites	Q3(2007)	🕐	$
Hydrology			
Option 1: Create weekly naturalized flows by IFN reach (per reach)	Q1(2007)	🕐	$
Option 2: Create daily naturalized flows (for use with threshold-type assessment) (per reach)	Q1-Q2 (2007)	🕐	$
Riparian Ecosystem			
Option 1: Conduct historical airphoto analysis for reaches 1 - 3	Q1(2007)	🕐	$
Option 2: Collect reach-specific field data for developing Poplar Rule Curve	Q3(2007)	🕐	$$

Summary of Proposed IFN Framework for the North Saskatchewan River (continued)

Task	Possible Timing	Duration[1]	Approximate Cost[2]
Fisheries			
Option 1: Enter historical data into FMIS database	Q1-Q4 (2007)	🕐🕐🕐	$$$
Option 1: Enter updated FMIS data in GIS	Q1(2008)	🕐	$
Option 2: Use existing information on target management species to identify critical habitats (e.g., lake sturgeon, bull trout)	Q1 (2007)	🕐	$ (participant dependant)
Option 3: Conduct basin-wide seasonal inventory and habitat use data	Q2(2007)-Q2 (2008)	🕐🕐🕐🕐	$$$$
All Options: Update Fisheries Management Objectives	Q1-Q2 (2008)	🕐🕐	internal costs
Habitat Modelling			
Option 1: Expert workshop to update HSC curves and select habitat modelling sites based on critical habitat areas	Q1(2007)	🕐	$ (participant dependant)
Option 1: Establish habitat modelling sites and collect open-water data (per site)	Q2-Q3 (2007)	🕐🕐🕐	$$
Option 1: Collect under-ice data (per site)	Q1(2008)	🕐	$$
Option 1: Calibration of models and calculation of habitat (per site)	Q1-Q2 (2008)	🕐🕐	$$
Option 2: Expert workshop to establish mesohabitat approach	Q1(2007)	🕐	$ (participant dependant)
Option 2: Habitat mapping using aerial photography	Q2-Q3 (2007)	🕐	$$
Option 2: Establish habitat modelling sites at representative reaches and collect open-water data (per site)	Q2-Q3 (2007)	🕐🕐🕐	$$
Option 2: Collect under-ice data (per site)	Q1(2008)	🕐	$$
Option 2: Calibration of models and calculation of habitat (per site)	Q1-Q2 (2008)	🕐🕐	$$
Water Quality			
All Options: Expert workshop to determine variables and thresholds	Q1(2007)	🕐	$ (participant dependant)
Option 1: Establish mainstem river model (simplistic – possible on all reaches)	Q1-Q4 (2007)	🕐🕐🕐	$$$
Option 1a: Establish mainstem river model (complex – only possible for lower reaches 1-6)	Q1-Q4 (2007-08)	🕐🕐🕐🕐	$$$$
Option 2: Establish watershed model (simplistic–possible on all reaches)	Q1-Q4 (2007-08)	🕐🕐🕐🕐	$$$$
Option 2a: Establish watershed model (complex – only possible for lower reaches 1-6)	Q1-Q4 (2007-??)	🕐🕐🕐🕐🕐	$$$$$
IFN Development			
Option 1: Integrate data from ecosystem components using SSRB approach	Q4(2008)	🕐	$$
Option 2: Series of expert panels to establish flow thresholds	Q2-Q4 (2007)	🕐🕐🕐	$ - $$$ (participant dependant)
Flow Scenario Development			
Set up WRMM or RBAM model	After water allocation study	🕐🕐	$$

[1] Duration: 🕐 < 3 months; 🕐🕐 3 months - 6 months; 🕐🕐🕐 6 months - 1 years; 🕐🕐🕐🕐 1 year - 2 years; 🕐🕐🕐🕐🕐 > 2 years.

[2] Cost range (2006 CAD): $ <10,000; $$ 10,000 - 50,000; $$$ 50,000 - 100,000; $$$$ 100,000 - 250,000; $$$$$ > 250,000.

TABLE OF CONTENTS

SECTION **PAGE**

LIST OF TABLES

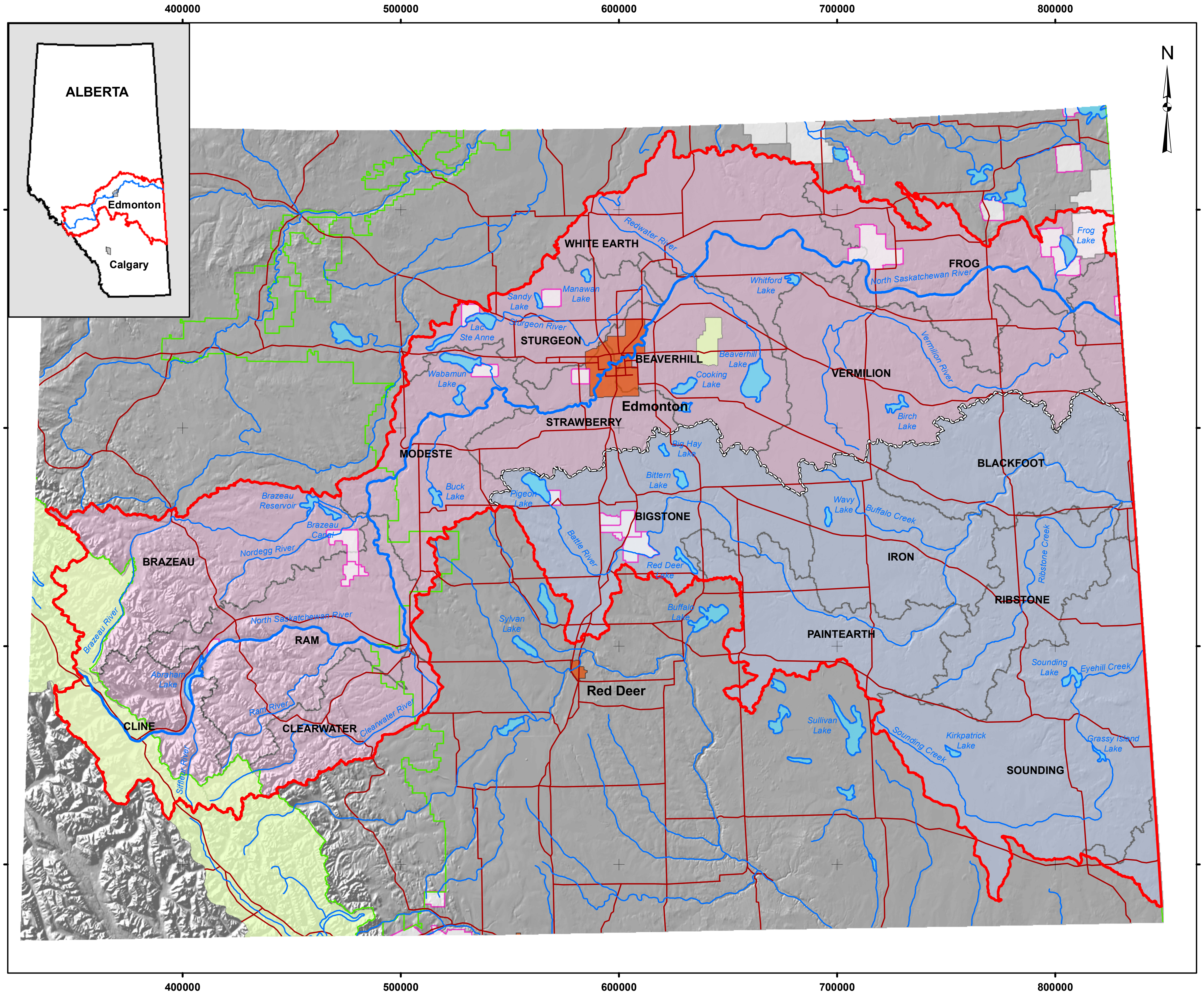
LIST OF FIGURES

LIST OF APPENDICES

1. INTRODUCTION

The North Saskatchewan River Basin is one Alberta's major river basins, covering about 80,000 km^2 or 12.5% of the province (www3.gov.ab.ca/env/water/basins/BasinForm.cfm). The North Saskatchewan River is the sixth largest river in Alberta with a mean annual outflow of 7.3 billion m^3 at the Alberta-Saskatchewan Border (www3.gov.ab.ca/env/water/GWSW/quantity/learn/what/SW_SurfaceWater/SW2_rivers.html). The North Saskatchewan River flows for about 1,000 km in Alberta in generally an eastward direction from its source near the Continental Divide in the Rocky Mountains, through the City of Edmonton, to the Alberta-Saskatchewan Border (Figure 1). The North Saskatchewan River continues in Saskatchewan until it's junction with the South Saskatchewan River east of Prince Albert, Saskatchewan. The major tributaries that flow into the North Saskatchewan River within Alberta include the Brazeau, Nordegg, Ram, Clearwater, Baptiste, Sturgeon, Redwater and Vermilion rivers. The Battle River sub-watershed and Sounding River sub-watershed both originate in Alberta but join the North Saskatchewan River in Saskatchewan.

Major dams in the watershed include the Brazeau on the Brazeau River and the Bighorn on the mainstem of the North Saskatchewan River, which forms Abraham Lake. Both dams are hydropeaking facilities operated by TransAlta Utilities Corp. The North Saskatchewan River also serves as a major municipal water supply and the river receives municipal and industrial effluent from a variety of sources, mainly in the Edmonton to Ft. Saskatchewan area. The eastern portion of the watershed is dominated by agricultural areas. Over 2 billion m^3 of water is allocated from the North Saskatchewan River Basin (as of 2004, excluding the Battle and Sounding basins), almost entirely from surface water sources (www3.gov.ab.ca/env/water/GWSW/quantity /waterinalberta/allocation/AL1_consumption.html).Detailed descriptions of the current conditions of the North Saskatchewan River sub-watersheds are provided in the State of the Watershed Report (NSWA 2005).



LEGEND

- WATERSHED BOUNDARY
- IWMP BOUNDARY
- SUBWATERSHED CONTRIBUTES IN ALBERTA
- SUBWATERSHED CONTRIBUTES IN SASKATCHEWAN
- CITY LIMITS
- GREEN ZONE BOUNDARY
- INDIAN RESERVE
- METIS SETTLEMENT
- NATIONAL PARK
- WATER BODY
- RIVER
- ROAD

REFERENCE

Base Data and Digital Elevation Data from Natural Resources Canada;
Watersheds from PFRA, used under license;
Green Zone Boundary from ASRD;
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: Alberta 10TM False Easting 500,000 at 115° W.

50 0 50
SCALE 1:1,750,000 KILOMETRES

PROJECT
NORTH SASKATCHEWAN WATERSHED ALLIANCE
IFN SCOPING STUDY

TITLE
OVERVIEW MAP OF NORTH SASKATCHEWAN RIVER BASIN

Golder Associates
Calgary, Alberta

PROJECT No. 06-1337-007.2000			SCALE AS SHOWN	REV. 0
DESIGN	MM	27 June 2006		
GIS	MM	31 May 2007		
CHECK	KC	28 Sep. 2006		
REVIEW	KC	31 May 2007		

FIGURE: 1

I:\2006\06-1337\06-1337-007\Mapping\MXD\overview_map11x17.mxd

The North Saskatchewan Watershed Alliance (NSWA) is the Watershed Planning and Advisory Council for the North Saskatchewan River and is responsible for the development of Water Conservation Objectives (WCOs) for the river. Managing the North Saskatchewan River's water supply presents an emerging challenge as demands for water increase due to population and economic growth. The NSWA is addressing these management challenges, in part, by the development and implementation of an Integrated Watershed Management Plan (IWMP), which is overseen by an IWMP Committee. The entire length of the North Saskatchewan River within Alberta is included within the scope of the NSWA's IWMP: the Battle River and Sounding River sub-watersheds are excluded from this specific undertaking. A determination of the Instream Flow Needs (IFN) for the maintenance of the integrity of the aquatic ecosystems within the North Saskatchewan River Basin is required as a component of the IWMP.

Additionally, an appropriate tool or set of tools is required to enable integration of the IFN with that of other user needs within the basin, to assist in achieving stakeholder acceptance of the IWMP, as well as the WCOs that will be an integral component of the IWMP. Consideration of the impacts of land-use practices on the aquatic ecosystem will also be an important aspect of establishing WCOs. Based on experience in southern Alberta, development of WCOs is a two-step process that first requires completion of an IFN study to help understand the ecological implications of water management, followed by a public consultation process to develop the appropriate balance between the ecosystem-based IFN and water withdrawals for human use. The determination of an ecosystem-based IFN, and many of the tools that have been developed for the IFN assessment, are often applied to evaluate the consequences of various water management alternatives to assist in defining a WCO. While this is a valid use of the tools, it should be noted that many of the IFN tools are best suited to assess larger-scale changes in water use (e.g., dam operations, major diversions for irrigation, municipal or industrial purposes) relative to a defined baseline condition rather than assessing smaller-scale changes (e.g., water use by individual land owners).

To this end, the NSWA retained Golder Associates Ltd. (Golder) to develop a scope of work for the development of an IFN assessment framework for the North Saskatchewan River. The NSWA struck an Instream Flow Needs Technical Advisory Committee (IFN-TAC) to direct the implementation of the IFN scoping study and to provide recommendations on the IFN back to the IWMP Committee.

2. TERMS OF REFERENCE AND SCOPE

Developing an IFN determination for even the smallest stream can be a challenging task. Looking at a river system the size of the North Saskatchewan River can be even more daunting. However, most of the principals involved in developing an IFN remain the same, regardless of the scale. The Instream Flow Council, an organization of instream flow practitioners from the United States and Canada, identified five main ecosystem components that should be considered in an IFN study: hydrology, channel morphology, water quality, biology, and connectivity (Annear et al. 2004). In following this lead, and the direction of other recent IFN studies in Alberta (Clipperton et al. 2002, 2003), the approach specified by the NSWA in the initial Request For Proposals indicated that an IFN strategy should be proposed that:

- outlines appropriate environmental metrics for use in the IFN study;
- identifies the data requirements to carry out the study;
- identifies existing data deficiencies; and,
- identifies/recommends appropriate evaluation tools that will allow the IFN-TAC to develop an ecosystem-based IFN recommendation.

The NSWA also requested more specifically that the outcomes of the IFN scoping study tasks should include:

- recommending environmental indicators for the study, and a strategy for collecting the relevant information for use of these indicators;
- a definition of the best approach for conduction an all-season IFN study;
- using this approach, describe the means of identifying the final IFN recommendation;
- identify uncertainties associated with the method of choice for the IFN study, and identify a strategy for dealing with these uncertainties within the Instream Flow Needs Incremental Methodology (IFIM) process to deal with these in setting the WCOs;
- define the best approach for using the IFIM approach to move from the IFN recommendation to stakeholder acceptance of the WCOs;
- develop a work plan to achieve the recommended approach; and,

- review and summarize land-use practices that impact the riverine aquatic ecosystem, with emphasis on the IFN indicators of choice, identify measures to mitigate these impacts, and develop a suitable mitigation plan that could be used by land-use planners and managers.

Although all of the tasks identified are likely required at some point in the IFN process, attempting to deal with all of those tasks up front in a scoping study on the scale of the North Saskatchewan River within Alberta was optimistic at this stage in the planning process. As budgets and timelines typically prevent an IFN study from being able to incorporate every possible dimension, selecting the most appropriate set of tools to address the IFN should consider legal limitations to major changes in the flow regime (i.e., restrictions to changes in water management based on existing water licenses), an understanding of predicted future water use and the timing and magnitude of that water use, and an understanding of how those factors might influence the type of tools that are most suitable for inclusion in the development of an IFN. During the project kick-off meeting, the IFN-TAC members identified the top priority area to be addressed in the scoping study which was the interaction between water quality and land-use practices and the development of a Geographic Information System (GIS) tool to address both of these issues. The GIS tool was also seen as a tool to be used throughout the IWMP process and therefore should not be restricted to its suitability for use in the development of an IFN. With these considerations in mind, the final Terms of Reference for the study are:

- an identification of North Saskatchewan River segments in Alberta, that is carried out through an examination of topographic maps, hydrological information, water quality information, and basic fish distribution information;
- identification of key data sources, and a subjective review of the quality and comprehensiveness of these data for each of the main ecosystem components to be considered in an IFN study based on the concepts of the Natural Flow Paradigm;
- preparation of a comparison of key IFN methods suitable for use in a study of the North Saskatchewan River in the context of the overall goals of the NSWA with a focus on water quality modelling, including potential costs, timelines and limitations of each method;
- design of a GIS database and mapping interface with a focus on the interactions between land-use practices and water quality modelling; and,
- a presentation to the NSWA on the study findings.

Completion of this study phase would be a milestone, and a recommendation by the IFN-TAC to the IWMP Committee on a path forward would be required. Following identification of the preferred approach by the IWMP Committee, the next phase of the study would commence, and would involve development of the remainder of the deliverables identified by the NSWA, or a variation of the deliverables depending on the selected approach. This decision point is critical in the IFN process, as regardless of the approach selected, a fundamental requirement for developing an IFN is consensus by the stakeholders, the NSWA membership in this case, of the method to be used. If consensus is not achieved at this stage of the process, the chance of achieving consensus on developing any WCOs is limited. Studies on current water use and licensed water allocations and any social or economic studies necessary for development of a WCO are not part of the IFN assessment framework presented in this document, but should be undertaken simultaneously, or preferably prior to, moving forward with any future stages of IFN development.

3. METHODS

3.1 Segmentation Analysis

Definition of the Study Area and delineation of river reaches within the Study Area are critical components of any IFN study. The Study Area for the IFN scoping study was determined by the IFN-TAC to be the same as the IWMP boundaries and involved the mainstem North Saskatchewan River from the headwaters of the river in Banff National Park through to the Alberta-Saskatchewan Border. The river segment (or reach) is the basic management unit for defining instream flow needs and evaluating the available habitat under alternative flow management conditions (Bovee et al. 1998). The key features of a river segment are homogeneity of flow regime and channel geomorphology that makes the reach distinct from adjacent segments. The flow and channel characteristics at the top of a segment at any time of the year should be similar to the characteristics at the bottom of the segment (Bovee et al. 1998). Biological considerations such as species distribution, and physical characteristics such as water temperature regime can also be used for segment boundary delineation. Point sources of contamination or thermal effluent may also be considered to define segment boundaries; even where the contributions to water supply is not substantial. Bovee (1982) outlines the typical conditions for defining segment boundary locations, which are summarized below.

Segment delineation based on changes in the flow regime are typically defined where the water supply changes significantly, such as at major tributary confluences or major diversions. As a rule of thumb, a significant change in water supply can be considered as an accretion or depletion in the average base flow of the river that is greater than 10%. River segmentation based on flow regime will incorporate some aspects of channel morphology changes but not all of them. Channel morphology is also influenced by slope, sediment supply, bank materials and vegetation. Segment boundaries are placed at sites of abrupt changes in channel morphology which result in a change in the habitat characteristics of the stream or river. Where changes in channel morphology are more subtle or gradual, placement of segment boundaries may be somewhat arbitrary, based on the distinctiveness of the majority of geomorphic characteristics. Segment boundaries are also placed wherever the confinement of the stream changes, where there is a change in sinuosity (the ratio between channel length and valley length), or where the channel pattern (i.e., straight, meandering, or braided) changes.

River segmentation was carried out by examination of 1:50 000 NTS topographic maps to evaluate changes in river slope and channel form. Additional information on channel form and substrate composition was found from the literature review, from the Alberta Transportation Hydrotechnical Information System bridge crossing database and from two key reports produced by the Alberta Research Council (Kellerhals et al. 1972, Shaw and Kellerhals 1982). The naturalized flow for the North Saskatchewan River (Stantec 2005) and Water Survey of Canada stream gauge data were used to identify locations where increases in flow at confluences exceeded 10% of mean annual flow. An existing segmentation of the North Saskatchewan River based on fish distribution was available in an Alberta Environment (AENV) report (Allan 1984). The quality of contributions at point sources from major tributary systems or from urban/industrial activity was also considered in deriving the final river segmentation. Final segment boundary locations were reviewed with the IFN-TAC and by the Golder study team to derive a common set of boundaries that satisfied the criteria for each component of the overall IWMP.

3.2 Literature Review

Government publications and the published scientific literature were searched for relevant information. Golder personnel familiar with the North Saskatchewan River and the Golder library system were also interviewed to identify relevant internal reports. Many of the Golder reports are held under client confidentiality and require permission from the client prior to the NSWA using any of the data contained within those reports. The IFN-TAC was provided a preliminary list of available references during the July 20 progress update meeting for the purpose of allowing members of the committee to identify any missing reports or data sources that were not readily found during the initial searches. The objective of the data review was to identify the suitability of existing data for use in an IFN evaluation as well as identify any data gaps that would hinder the completion of a science-based IFN study. No new data analyses were conducted at this point in the scoping process.

3.2.1 Water Quality Data Summary

Over 1500 provincial water quality stations on the North Saskatchewan River and its tributaries have been monitored within Alberta between 1953 and the present. These data are stored in

AENV's Water Quality Data System (WDS) and maintained regularly by AENV staff. Data from the WDS are easily accessed and therefore the provincial water quality dataset represents the most readily available and comprehensive water quality dataset available for the North Saskatchewan River.

Relevant information from the WDS have been summarized to both supplement the water quality literature review and to illustrate the trends observed from the literature review (i.e., the relative amount of information available for each reach). To determine the amount, type and spatial distribution of water quality data available for the North Saskatchewan River and its major tributaries (i.e., tributaries that could have a substantial effect on water quality in the North Saskatchewan River), the provincial data within each reach of the North Saskatchewan River and four of its tributaries were summarized.

The number of stations, monitoring time-period and counts of results for 15 key water quality variables were reported for the 17 reaches of the North Saskatchewan River and the Brazeau, Clearwater, Sturgeon and Vermilion rivers. In addition, a qualitative review of the available continuous data for field water quality variables (i.e., dissolved oxygen, conductivity, pH and water temperature) was completed.

The 15 key variables represent variables of potential relevance to the IFN study. They include the following:

- nutrients (total ammonia, nitrate, total phosphorus, total dissolved phosphorus chlorophyll *a*);
- conventional (pH, total suspended solids and total dissolved solids);
- major ions (chloride, calcium, sodium, magnesium and potassium);
- metals (iron); and,
- pesticides (2,4-D).

The five nutrient variables were selected because they can be found in high concentrations in runoff from agricultural areas and in point sources originating from urban areas, such as wastewater treatment discharges. Nutrients have the potential to affect aquatic life in the North Saskatchewan River and can be influenced by changes in flow regime. Higher levels of total ammonia and nitrate can have toxic effects on fish and other aquatic life. Both forms of nitrogen (i.e., ammonia and nitrate), together with phosphorus, can also stimulate aquatic plant growth, which may lead to the depletion of dissolved oxygen. Chlorophyll *a* provides an indication of that amount of aquatic plant growth that is occurring in the system, although its relevance to rivers dominated by rooted aquatic plants or benthic algae may be limited.

The five major ions listed above include variables such as sodium, potassium and magnesium, which are critical for maintaining healthy crops. Sources of major ions can include runoff from agricultural areas with high levels of irrigation, discharges from municipal wastewater treatment plants and runoff from urban areas, particularly if road salting occurs in those areas. Some major ions, such as chloride and calcium, can be toxic to aquatic life. Chloride and total dissolved solids can also be used as ‘tracer’ variables, because they are relatively conservative in the water.

Total suspended solids was selected as a key variable, because it typically increases in watercourses as urban and agricultural land use increases. High levels of total suspended solids can be harmful to fish and reduce the suitability of fish habitat. In addition, other substances, such as bacteria, metals, pesticides and phosphorus are often adsorbed to total suspended solids that are introduced to watercourses through runoff.

The two remaining variables, iron and 2,4-D, were selected to provide an idea of the amount of available metals and pesticides data, respectively. Both metals and pesticides can be toxic to fish and other aquatic life, depending on in-stream conditions, the type of metal or pesticide and their abundance.

The field water quality variables typically collected during continuous monitoring include water temperature, dissolved oxygen, conductivity and pH. Water temperature, dissolved oxygen and pH can directly affect fish health. pH and temperature can also affect the toxicity of other variables, such as ammonia and aluminum. Temperature and dissolved oxygen are also typical variables that have been assessed in instream flow studies, as both parameters can be affected by changes in the flow regime.

3.3 Developing the IFN Framework

The flow evaluation framework and work plan for Phase I of the scoping followed from the results of the background review. IFN methods have been previously reviewed for several recent IFN scoping studies in Alberta (Golder 2004a, 2004b). Many key decisions will be required by the NSWA from now until a final flow evaluation tool is developed, and the exact direction the NSWA deems appropriate cannot be predicted at this time. Timelines and approximate effort for the immediate next steps have been identified with a general work plan to move the NSWA forward. The type of information required and tools that can be used for an IFN study are dependant on the assessment capabilities desired by the NSWA, availability of data and identifying flow-related issues considered to be of concern for the North Saskatchewan River. The final IFN evaluation framework will provide water managers with a tool to evaluate current or future water management conditions relative to the recommended IFN condition. The type of information collected and approaches used for an IFN study, such as water quality modelling or fish habitat modelling, are designed to act as a proxy measure for the response of an ecosystem to changes in water management and are not designed to predict exact population response to changes in water management. Many other factors can influence a “healthy” aquatic ecosystem, such as land-use or fisheries management (harvest) practices, that are not directly incorporated into an IFN study (i.e., they are independent of changes to the flow regime), but must be considered in the overall IWMP to achieve protection of the aquatic ecosystem.

3.4 Geomatics

3.4.1 User-needs Survey

As part of the project, the need for a Geographic Information System (GIS) tool or application was identified by the IFN-TAC. The tool or application is intended to be used to analyze and show in a graphic manner the relationships between land use in the North Saskatchewan Watershed and water quality characteristics in the mainstem of the North Saskatchewan River. The tool was also to be developed to allow for the future development of applications necessary for use in the IWMP process that are outside of the current scope of work.

GIS is an acronym for an integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed.[1]

One of the characteristics of GIS data is the tabular data that are linked to the spatial features of the area of interest. In a GIS, by clicking on a feature, a listing of the tabular data related to that feature can be displayed. The tabular data are attributes, or characteristics, of the feature. Attributes can range from very simple to very detailed, depending on the type of data being considered.

A GIS can be used to analyze and display spatial relationships between different data layers: for example, a set of soil sampling locations and a set of polygon data containing attributes of the physical characteristics of the soil. A GIS can also be used to model, or simulate, events or processes that have spatial characteristics.

With respect to a GIS application related to land use and water quality, a user-needs survey was developed and completed by members of the IFN-TAC. The survey was created to:

- understand the capabilities, with respect to GIS hardware and software, of the organizations that might be using the application;
- identify data that might be of use for the application;
- gather information as to what direction the application might take, including how information developed by the application could be disseminated; and,
- understand the motivations of the IFN-TAC members and the NSWA.

The survey was e-mailed to all members of the IFN-TAC on June 30, 2006 with a request to return the survey by July 14. The initial delivery of the survey was followed up with reminders via e-mail and telephone over the course of the next few weeks to try to get as many responses as possible. The survey initially included members of the IFN-TAC at the request of the Committee, as it was felt that they would be most suited to comment on the applicability or utility

[1] GIS Dictionary at http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.gateway

of GIS in the context of an IFN study at this stage of the process. The complete survey is provided in Appendix I.

3.4.2 Spatial Data Compilation

At the project kick-off meeting in May 19, 2006, the GIS Team was provided with direction to determine what spatial data were available for GIS use that are relevant to land use and water quality, and that are available at no cost. We extended this direction to take into account data that would be available at low cost. Due to the partnership between the NSWA and the provincial government to implement the IWMP, some data would be available from government sources that might not normally be available to the private sector.

A wide variety of spatial data were assembled or sourced for this project. In the early stages of the project, a DVD containing spatial data and GIS mapping files (MXDs and PDFs) was provided by the NSWA that was assembled during preparation of the State of the Watershed report. A full inventory of the DVD was undertaken to determine if it contained files that could be of use to the project. It was determined that most data obtained for that project were typically licensed for one-time use only and cannot be used for other projects.

In addition, a number of sources were consulted regarding the availability and utility of spatial data. Most of these were provincial or federal government sources, with data available through the Internet. Another potential data source was in the non-profit sector. In the private sector, forestry companies were approached regarding the provision of forestry data in their respective Forest Management Agreement Areas. The possibility of acquiring imagery data, either satellite imagery or digital aerial photography, from other private sector sources was also investigated. A review and discussion of data sources was a primary focus of the IFN-TAC progress meeting on July 20, 2006.

3.4.3 Land Use / Water Quality GIS Application

Some valuable insights around a GIS application related to land use and water quality in the North Saskatchewan River Watershed were provided in the user-needs survey. A number of other information sources were also investigated, including:

- search of the Environmental Systems Research Institute, Inc., (ESRI) website for specific references to water quality and water quality modelling (ESRI is the world's most widely used GIS software and this software is most-often used by Golder);
- search of other general GIS websites for references to water quality and water quality modelling;
- a general Internet search for literature on the subject of linkages between GIS and water quality; and,
- discussions with Water Quality discipline experts at Golder.

4. RESULTS

4.1 River Segmentation

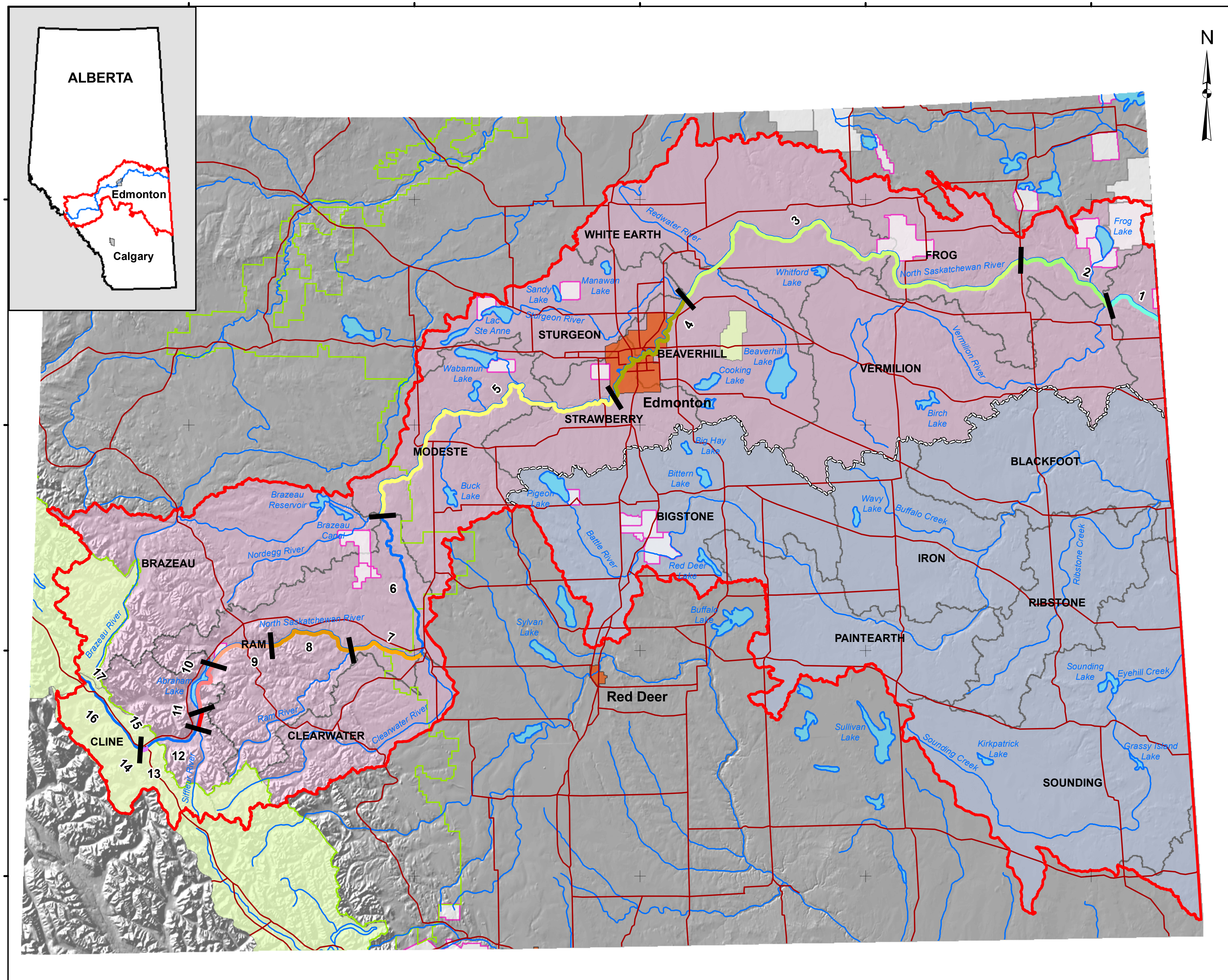
Preliminary river segmentation results were presented during the July 20, 2006 IFN-TAC progress update meeting. The preliminary segment (or reach) boundaries were based on identifying sections of river with homogeneous hydrology, channel morphology, water quality and fish distribution characteristics. Many of the segment boundaries were common amongst disciplines and were associated with the confluences of major tributaries. In practice, in IFN studies where a tributary confluence defines a reach boundary, the tributary flow contributes to the downstream segment. In cases where segment boundaries did not overlap, either separate segments were created or the boundary was moved to a location that still met the criteria for segmentation outlined in Section 3. The final segment boundaries were selected, based in part on the professional judgment of the study team and the IFN-TAC, to minimize the total number of segments in an effort to simplify water management considerations along the mainstem while still maintaining the criterion of homogeneous segment characteristics. The description and rationale for each segment is provided in Table 1. The location of the final segment boundaries is illustrated in Figure 2.

4.2 Data Availability and Applicability to Developing an IFN

A complete list of references found in the literature search of studies pertaining to hydrology, geomorphology, water quality, biology and water management in the North Saskatchewan River mainstem is provided in Appendix II. This list of references was narrowed down, based on professional judgment, to identify a list of key references with potential relevance to an IFN study. A brief summary of the key references is provided in Table 2. The overall relevance of each study to an IFN investigation was given a qualitative ranking of low, moderate or high based on duration, seasonality and spatial extent of the study and the type of data collected. A rating of high was typically given when studies had multi-year, multi-season, multi-parameter data covering multiple river reaches or studies that have information that is directly applicable to potential IFN assessment tools (e.g., habitat use data for fish species). A low rating was typically given for studies with limited duration or spatial extent with no directly applicable data for use in the development of the IFN assessment tools. An overview of the data for each main ecosystem component is also provided in Sections 4.2.1 to 4.2.6.

Table 1
North Saskatchewan River Segmentation Analysis

Segment	Upstream Boundary	Downstream Boundary	Rationale for Upstream Boundary Location
1	Vermilion River Confluence	Saskatchewan Border	Major point source input for water quality
2	Elk Point Bridge	Vermilion River Confluence	Geomorphic change from gravel to sand bed river
3	Sturgeon River Confluence	Elk Point Bridge	Major tributary, end of urban/ industrial reach
4	Devon	Sturgeon River Confluence	Start of urban/ industrial reach, upstream end of coolwater fish species zone
5	Brazeau River Confluence	Devon	Major tributary input increases flow > 10%, transition zone for fish species distribution
6	Clearwater River Confluence	Brazeau River Confluence	Major tributary input increases flow > 10%, downstream end of coldwater fish species zone
7	Ram River Confluence	Clearwater River Confluence	Major tributary input increases flow > 10%
8	Upstream of "The Gap"	Ram River Confluence	Change from a braided river to a channelized river
9	Bighorn Dam	Upstream of "The Gap"	Flow control structure, hydropeaking reach
10	Abraham Lake Inflow	Bighorn Dam	Impounded habitat
11	Siffleur River Confluence	Abraham Lake Inflow	Major tributary input increases flow > 10%
12	Mistaya River Confluence	Siffleur River Confluence	Major tributary input increases flow > 10%
13	Howse River Confluence	Mistaya River Confluence	Major tributary input increases flow > 10%
14	Arctomys River Confluence	Howse River Confluence	Major tributary input increases flow > 10%
15	Alexandra River Confluence	Arctomys River Confluence	Major tributary input increases flow > 10%
16	Nigel Creek Confluence	Alexandra River Confluence	Major tributary input increases flow > 10%
17	Below Saskatchewan Glacier	Nigel Creek Confluence	Headwaters



I:\2006\06-1337\06-1337-007\Mapping\MXD\Reaches\final_reaches_map11x17.mxd

LEGEND

- WATERSHED BOUNDARY
- IWMP BOUNDARY
- SUBWATERSHED CONTRIBUTES IN ALBERTA
- SUBWATERSHED CONTRIBUTES IN SASKATCHEWAN
- CITY LIMITS
- GREEN ZONE BOUNDARY
- INDIAN RESERVE
- METIS SETTLEMENT
- NATIONAL PARK
- WATER BODY
- RIVER
- ROAD

REACH DESCRIPTION

- Reach 1 - Saskatchewan Border to Vermilion River Confluence
- Reach 2 - Vermilion River Confluence to Elk Point Bridge
- Reach 3 - Elk Point Bridge to Sturgeon River Confluence
- Reach 4 - Sturgeon River Confluence to Devon
- Reach 5 - Devon to Brazeau River Confluence
- Reach 6 - Brazeau River Confluence to Clearwater River Confluence
- Reach 7 - Clearwater River Confluence to Ram River Confluence
- Reach 8 - Ram River Confluence to Upstream of "The Gap"
- Reach 9 - Upstream of "The Gap" to Bighorn Dam
- Reach 10 - Bighorn Dam to Abraham Lake Inflow
- Reach 11 - Abraham Lake Inflow to Siffleur River Confluence
- Reach 12 - Siffleur River Confluence to Mistaya River Confluence
- Reach 13 - Mistaya River Confluence to Howse River Confluence
- Reach 14 - Howse River Confluence to Arctomys River Confluence
- Reach 15 - Arctomys River Confluence to Alexandra River Confluence
- Reach 16 - Alexandra River Confluence to Nigel Creek Confluence
- Reach 17 - Nigel Creek Confluence to Below Saskatchewan Glacier

REFERENCE

Base Data and Digital Elevation Data from Natural Resources Canada;
Watersheds from PFRA, used under license;
Green Zone Boundary from ASRD;
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: Alberta 10TM False Easting 500,000 at 115° W.

50 0 50
SCALE 1:1,750,000 KILOMETRES

PROJECT
NORTH SASKATCHEWAN WATERSHED ALLIANCE
IFN SCOPING STUDY

TITLE
NORTH SASKATCHEWAN RIVER REACH SEGMENTATION

Golder Associates
Calgary, Alberta

PROJECT No. 06-1337-007.2000			SCALE AS SHOWN	REV. 0
DESIGN	MM	27 June 2006		
GIS	MM	31 May 2007		
CHECK	KC	28 Sep. 2006		
REVIEW	KC	31 May 2007		

FIGURE: 2

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Environmental Impact Assessment	TransAlta Utilities Corporation 2001	Public	5	Evaluation of the potential effects of expansion of the Keephills Thermal Electric Plant on the hydrology and aquatic biology of the NSR upstream of Edmonton.	Hydrology, water quality, benthic invertebrates, fisheries	One Year – multi seasonal	Moderate
Environmental Impact Assessment	EPCOR Utilities Inc. 2001	Public	5	Evaluation of the potential effects of expansion of the Genesee Thermal Electric Plant on the hydrology and aquatic biology of the NSR upstream of Edmonton.	Hydrology, water quality, benthic invertebrates, fisheries	One Year – multi seasonal	Moderate
Environmental Impact Assessment	Shell Canada Ltd. 1998	Public	4	Evaluation of the potential effects of expanding the existing Scotford Upgrader on the NSR.	Hydrology, water quality, benthic invertebrates, fisheries	One Year – multi seasonal	Low
State of the Watershed	North Saskatchewan Watershed Alliance 2005	Public	1 - 17	State of the watershed report.	Land use, hydrology, water quality, benthic invertebrates, fisheries	Summary report	Moderate
Benthic Invertebrates/Water Quality/Periphyton	RL&L Environmental Services Ltd. 1996	Proprietary	4	Effects of combined sewer overflow and stormwater discharges from Rat Creek on water quality, periphyton and benthic invertebrates.	BOD, nutrients, ammonia, coliform bacteria, TSS, benthic invertebrates, periphyton	One time event	Low
Benthic Invertebrates/Water Quality/Periphyton	RL&L Environmental Services Ltd. 1998	Proprietary	4	Effects of combined sewer overflow and stormwater discharges from Rat Creek on water quality, periphyton and benthic invertebrates.	BOD, nutrients, ammonia, coliform bacteria, TSS, benthic invertebrates, periphyton	One time event	Low
Benthic Invertebrates/Water Quality/Periphyton	RL&L Environmental Services Ltd. 2000a	Proprietary	4	Effects of discharges from the Quesnell storm sewer on water quality, periphyton and benthic invertebrates.	BOD, nutrients, ammonia, coliform bacteria, TSS, benthic invertebrates, periphyton	One time event	Low
Benthic Invertebrates	Golder Associates Ltd. 1997	Proprietary	3	Evaluation of the potential effects of elevated salt concentration in porewater on the benthic invertebrate community of the NSR.	Benthic invertebrate, water discharges, water depth, velocity, substrate	One year (open water)	Low
Benthic Invertebrates	Reynoldson 1973	Public	3-4	Bottom fauna survey during spring and fall 1973.	Benthic invertebrate, flows, discharges	One year-multi seasonal	Low
Benthic Invertebrates	Stantec Consulting Ltd. 2000	Proprietary	4	Aquatic study of the NSR in the vicinity of the Rossdale Power Plant- benthic invertebrate survey.	pH, conductivity, DO, temperature, benthic invertebrates	Single event (26, 27, 28, 30 August 2000)	Low
Benthic Invertebrates	Alberta Fish and Wildlife Division 1971	Public	3-4	Summary of the biological results obtained during the period of August 1969 to May 1970..	Number of clean water organisms, number of pollution tolerant animals	August 1969 to May 1970	Low
Benthic Invertebrates	Reynoldson and Exner 1978	Public	3-4-5-6	Benthic fauna surveys were conducted during the spring and fall of 1974 and 1975 on the Oldman, Bow, Red Deer, and North Saskatchewan rivers.	Longitudinal profile, discharge, benthic invertebrates	Multi-year, multi-seasonal (spring and fall of 1974 and 1975)	Low
Benthic Invertebrates	Anderson 1991	Public	1-3-5	Zoobenthos were sampled in spring and fall from 1983 to 1987 at 20 long-term monitoring sites in major rivers of Alberta. Data represent the first 5 years of a proposed long-term monitoring database.	Benthic invertebrate species and numbers	Multi years, multi-seasonal (spring and fall from 1983 to 1987)	Moderate
Fisheries	D.A. Westworth & Associates Ltd. 1990	Proprietary	5	Inventory and evaluation of environmentally sensitive and significant areas on public and privately-owned lands within the county of Leduc.	Environmentally sensitive areas significant features, overview of natural features and landscapes, cultural and historic features, and fish and wildlife	1989-1990	Low
Fisheries	RL&L Environmental Services Ltd., 2000b	Proprietary	4	Brief field survey of summer season aquatic habitat and fish utilization patterns in the vicinity of a future bridge over the NSR in the southwest margin of Edmonton.	Discharge and water level, channel width and depth characteristics, substrate composition, fish community and relative abundance, CPUE, length, weight, sex, habitat data	Single event (16-18 August 2000)	Low
Fisheries	Golder Associates Ltd. 2001c	Proprietary	4	Impact assessment of the inspection and possible cleaning of the concrete slab at the water intake for the Scotford Shell Canada petrochemical plant.	N/A	N/A	Low

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Fisheries	Golder Associates Ltd. 1998c	Proprietary	9	Fish salvage operations during temporary shutdowns of the Bighorn dam.	Fish species, water temperature	One time event	Low
Fisheries	Golder Associates Ltd. 1998e	Proprietary	9	Fish salvage operations during temporary shutdowns of the Bighorn dam.	Fish species, water temperature	One time event	Low
Fisheries	Golder Associates Ltd. 2002	Proprietary	8-9	Overwintering fisheries investigations of the North Saskatchewan River below the Bighorn dam. Investigation included monitoring known brown trout (*Salmo trutta*) spawning sites under winter conditions for potential dewatering and/or freezing and monitoring potential overwintering habitats for anchor ice formation and frazzle ice accumulation.	Brown trout spawning sites and overwintering habitat monitoring	One year event- multi-seasonal	Moderate
Fisheries	Golder Associates Ltd. 2001b	Proprietary	5-9	Summary of fisheries investigations conducted from 1996 to 2001 for the north Saskatchewan River in relation to flow outages at the Bighorn dam. Impacts that could result from partial dewatering and flow reduction.	Water temperature, summary of fish salvage results	Multi-year-multi seasonal	Low
Fisheries	Golder Associates Ltd. 1998d	Proprietary	9	Fish salvage operations during temporary shutdowns of the Bighorn dam.	Fish species, water temperature	One time event	Low
Fisheries	Munson 1978	Public	5	Biology of goldeye from NSR. Analysis of mercury concentration in goldeye sampled in 1973 from the NSR.	Goldeye catch records, frequency distribution, age-weight relationships, ovary development, mercury level in fish	May 15 to August 13, 1975	Low
Fisheries	Golder Associates Ltd. 2001a	Proprietary	5	Fisheries investigation conducted in 2001 for the NSR in the vicinity of two TransAlta water intakes, in order to asses the fish species and life stages that utilize this region of the river.	Fish stage, length	One year, single season (spring 2001)	Low
Fisheries	Bramm 1979	Public	5	Development of a simple index that would indicate existing suitability of river water for aquatic life, primarily fish.	Range of parameter values that are considered suitable for fish habitat, water quality	Water quality data: 1970-1978	Low
Fisheries	Watters 1993	Public	1-5	Lake sturgeon monitoring in the NSR for the year 1993 and comparison to 1991 data.	Lengths, weights, average displacement, CPUE	Single year, multi-seasonal (1993)	Low
Fisheries	Ramarmoorthy et al. 1985	Public	1 to 6	Mercury levels in fish, water and sediments were determined during 1982 along 600 km stretch of the NSR in the province of Alberta.	Mercury levels in fish, sediment and water	Single-year, multi-seasonal (1982)	Low
Fisheries	Tebby 1974	Public	10	Pre-impoundment and early impoundment survey of a hydroelectric reservoir, Abraham Lake, located on the NSR. Study of the life history and distribution of the fish species above the damsite.	Secchi values, stomach contents, fish catch, weight, age	Multi-year, multi-seasonal (8 June to 23 November 1972, March 1973, 8 May to 30 October, and 15 April and 11 May 1974	Low
Fisheries	RL&L Environmental Services Ltd. 2001	Proprietary	6	Assessment of aquatic habitat and fish resources at the ATCO Pipelines Ltd crossing site near Drayton Valley, as well as recommendations relating to mitigation and compensation.	Temperature, conductivity, pH, turbidity, fish catch, CPUE, length, weight, eggs, bank characteristics	Single event (October 2001)	Low
Fisheries	RL&L Environmental Services Ltd. 1992	Proprietary	4	Late fall survey of the NSR in the vicinity of a proposed footbridge (Hawrelak/Buena Vista Park).	Fish community, length, weight, maturity, age, depth, velocity	Single event (21 October 1993)	Low
Fisheries	Golder Associates Ltd. 1998a	Proprietary	8	Estimate of the flows below the Bighorn dam that would provide protection for the aquatic resources of the NSR in event of a shutdown.	Transect data, water surface elevation	Single event (August 1998)	Moderate

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Fisheries	Golder Associates Ltd. 1996	Proprietary	4	A fisheries habitat investigation was conducted in the vicinity of the proposed crossing to assess the potential impacts of the proposed crossing to the aquatic community of the North Saskatchewan River.	Fish habitat mapping, general characteristics of the creek, bank characterization, substrate, erosion, water flow, water quality, habitat features, fish species, instream cover, overhead cover	Single event (October 10 and 11, 1996)	Low
Fisheries	Golder Associates Ltd. 2000	Proprietary	8-9-10-11-12	Investigation of the effects of the Bighorn reservoir operation on the fish community of the NSR, use of the river by recreational paddlers and the effects of water drawdowns on Abraham Lake.	Water temperature monitoring, brown trout spawning locations, Abraham Lake isolated pools profile data	Two years, multi-seasonal (1998, 1999)	Moderate
Fisheries	Allan 1984	Public	1 to 17 (whole basin)	This overview report describes what is presently known of fish habitat, fish production and distribution, recreational and commercial demand and use of the fish populations, water quality, environmental impacts and gaps in existing information on the fisheries resources of the NSR.	River profile, overview of the fish species of the NSR Basin, commercial fishing, water quality, water chemistry, sport fishing	Multi-year, multi-seasonal	High
Fisheries	Earle 2002	Public	1 to 5	This report reviews and summarizes current and historical information and provides a quantitative analysis of population data collected over the past decade as a step in updating the status of this species in Alberta.	Length and weight (data from 1993 to 2000), distribution, population size, maturity, age class distribution, mortality rate, age structure cohort model.	N/A	Moderate
Fisheries/ Water Quality	RL&L Environmental Services Ltd. 1980	Proprietary	4	Inventory and analysis of the aquatic component in the NSR valley and ravine system.	Channel width, depth, velocity, substrate type, cover type, fish resources (1966 and 1970 data sources)	Single –year, multi season	Moderate
Fisheries/ Water Quality	Merkowsky 1987	Public	1	Comprehensive survey of the fish population and habitat inventory during 1985 and 1986 to provide biological data on the NSR.	Temperature, oxygen, transparency, pH, alkalinity, calcium, magnesium, hardness, chloride, TDS, TSS, plankton, benthic invertebrates, fish species	Multi-year (1985-1986)	Low
Fisheries/Water Quality	Golder Associates Ltd. 1998f	Proprietary	4	Pipeline crossing assessment 8 km downstream of Fort Saskatchewan.	Turbidity, TSS, sediment deposition, fish movement	One year-single season	Low
Fisheries/Water Quality	Golder Associates Ltd. 1999a	Proprietary	6-7-8-9	Assessment of the effects on fish, fish habitat and water quality, of reservoir operation on Abraham Lake and the river below the Bighorn dam.	Fish species and relative abundance, seasonal use, fish habitat, water temperature, water quality, total dissolved gas (winter), water level and discharge	One year-multi seasonal	Moderate
Fisheries/Water Quality	Golder Associates Ltd. 1998b	Proprietary	6-7-8-9	Assessment of the effects on fish, fish habitat and water quality, of reservoir operation on Abraham Lake and the river below the Bighorn dam.	Fish species and relative abundance, seasonal use, fish habitat, water temperature, water quality, total dissolved gas (winter), water level and discharge	One year-multi seasonal	Moderate
Fisheries/Water Quality	Munson and Daniel 1974	Public	1-2-3-4-5	This report summarizes two years of research on the level of mercury pollution found in the Edmonton area and in the North Saskatchewan River system.	Mercury levels in sediments, benthic invertebrates, fish	Two years-multi seasons	Low
Fisheries/Water Quality	Alberta Environmental Centre 1984	Public	1 to 6	This study describes the partitioning of polychlorinated biphenyls (PCB) in the North Saskatchewan River.	PCB in intestinal fat of fish, muscle tissue of fish, water, and fine sediments	Starting August 1980 and finishing in September 1983	Low
Fisheries/Water Quality	Alberta Environmental Centre 1983a	Public	Fish: 2-4 Sediment: 3-5 Water: 2-5	Total and methyl mercury were determined in several species of fish, sediment, and water samples from the NSR from upstream of Edmonton to the Saskatchewan border.	Mercury level in fish tissue, sediment and water	May 4 to June 2 1982	Low

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Fisheries/Water Quality	Alberta Environmental Centre 1983b	Public	2-3	Description of the concentrations of pesticides and PCBs in fish collected between 1980 and 1982 from the NSR and the Red Deer River.	PCB concentration in muscle and intestinal fat samples, and in sediments	Fish collected 12 times between August 1980 to June 1982 Bottom sediment collected in 1981	Low
Fisheries/Water Quality	HydroQual Canada Ltd 1990	Proprietary	1 to 4	The aquatic fates of potential contaminants in leachate from the proposed Aurum landfill are predicted with the Water Analysis Simulation Program (WASP Version 4.2n; Ambrose et al., 1985). The model is used to predict the aquatic fates of four metals and eight organic compounds.	Historical loading of metals, concentrations of selected metals and organics in receiving water and fish tissue	N/A	Low
Fisheries/Water Quality	Shewchuk 1967	Public	4	Investigation report on a complaint received on September 19, 1967 by the Department of Natural Resources regarding the presence of dead fish floating by the Redwater Bridge construction site on the NSR.	Concentration range of heavy metals	One time sampling event (September 19, 1967)	Low
Geomorphology	Tedder 1986	Public	4	This report presents a slope movement inventory and establishes set-back guidelines based on the ultimate angle of stability theory, for the NSR and tributary creek valley slopes located between the urban areas of Edmonton and Fort Saskatchewan.	Slope movement, type of movement, absolute age, present status, slope height, slope inclination, displaced material	One year, August to October 1983	Low
Geomorphology	Galay 1973	Public	5	Regime characteristics of NSR near Drayton Valley.	River regime data, channel cross section dimensions, coarse bed material analysis, height of bed material, bed forms, channel properties	1965 and 1966	Low
Geomorphology	Doyle 1979	Public	5-9	Channel cross-section data in the reach from Berrymoor Ferry to Edmonton for a dam-break flood routing analysis.	River profile, channel geometry, discharge, velocity, surface width, mean depth, maximum depth, bed material size	Multi-years, multi-seasonal	Low
Geomorphology/ Hydrology	Phillips Planning and Engineering 1994	Public	4	This report presents the flood risk maps for the reach from the High Level Bridge to the northeast boundary of the city of Edmonton.	Flood risk and floodway boundary, flood frequency estimates, manning roughness, water surface elevation	Multi-year, multi-seasonal	Low
Geomorphology/ Hydrology/Water Quality	Alberta Environment 1991	Public	1-4	Water quality study (Leopold-Maddock equations) for NSR from Edmonton to the Saskatchewan Border	River cross-sections	N/A	Low
Geomorphology/ Hydrology	Associated Engineering 2003	Public	6	Flood risk mapping study for the NSR at Rocky Mountain House	River cross-sections and hydrology	Multi-year, multi-seasonal	Low
Geomorphology/ Hydrology	Alberta Environment (Unreferenced)	Public	1-17	NSR cross-sections surveyed from headwaters to the Saskatchewan border by Alberta Research Council, 1968 to 1971	River cross-sections	N/A	Low
Geomorphology/ Hydrology	Nwachukwu and Neill 1972	Public	1-4	This report consists essentially of a consolidation and analysis of survey data collected mainly in 1967 between Edmonton and the Saskatchewan border.	Hydrologic data, cross-section and channel geometry, cross-sectional area, velocity, depth and width ratio	One year, single season (Summer 1967)	Moderate
Water Quality	Limno-Tech inc. 1995	Public	1-4	Technical review of the Golder Associates Ltd. calibration report of the NSR and screening report. Review of the modified WASP4 model code and computer files that were available from Golder.	Sensitivity of NSR WASP4 Model Dispersion Coefficients	N/A	Low
Hydrology	Kelly 1985	Public	10-12	Thesis reviewing the orientation of watershed in the East Slopes with particular reference to the Upper NSR Basin. Identification and evaluation of the deficiencies in this traditional approach. Assessment of watershed condition and ideal land management requirements identification.	N/A	N/A	Moderate

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Geomorphology/ Hydrology	I.D. Group Inc. 1995, Vol. 1 of 3	Public	4	This report presents the flood risk maps for the reach from the High Level Bridge to the southwest boundary of the city of Edmonton. The flood map were generated using the Flood Plain Management System (FPMS) developed by CartoLogix.	Flood risk and floodway boundary, flood frequency estimates, manning roughness, water surface elevation	Multi-year, multi-seasonal	Low
Geomorphology/ Hydrology	Yaremko 1971	Public	7-17	Development of a methodology for measuring and recording any of the possible regime changes which might occur because of the presence of the Bighorn Dam on the NSR.	N/A	Multi-year, multi-seasonal	Low
Hydrology	Alberta Environment 1974	Public	4	Flood plain study conducted on the NSR through Edmonton with the objective to determine the 1.33% and 2% floods and to record the encroachment of these floods onto the flood plain throughout the developed areas.	Maximum annual daily discharge	Multi-year, multi-seasonal (1911-1973)	Low
Hydrology	Alberta Environment 1981	Public	1-13	Information and data concerning the recorded floods in the NSR Basin.	Flood frequency analyses, discharge hydrographs, maximum discharges, date of first and last ice	Multi-year, multi-seasonal (1911 to 1978)	Moderate
Hydrology	DeBoer 1986	Public	4-17	This study determines flood magnitudes for the NSR at Edmonton. Both natural and regulated annual maximum flood flows are examined in the assessment of the frequency of occurrence of future peak flow rate.	Natural flows, regulated flows, flood frequency estimates	Multi year, multi-seasonal (1899 to 1986)	Low
Hydrology	Alberta Department of the Environment 1981	Public	1-9	Mean monthly unregulated flow sequences for the period of 1912 to 1978.	Regulated flows, deregulation method	Multi-year, multi-seasonal (1912-1978)	Moderate
Hydrology	T. Blench and Associates 1968	Public	4	Hydraulic study to assess the effects of proposed works (construction of fills, new bridge) planned in conjunction with the Jasper Freeway, on the regime of the NSR from Mackinnon Ravine to Rossdale Generating Station.	Discharge	1911 to 1978: discharge	Low
Hydrology	Prairie Provinces Water Board (Canada) 1976	Public	1	This report outlines the results of the study to develop procedures for the determination of flows required for apportionment purposes.	N/A	N/A	Low
Hydrology	Robinson 1975	Public	1-17	A method to determine the natural flow in the NSR Basin at Alberta and Saskatchewan boundary.	N/A	N/A	Low
Hydrology	Alberta Environmental Protection, 1994	Public	4	The flood risk area for a reach of the NSR extending upstream from the eastern city limits at Fort Saskatchewan to the High Level Bridge in central Edmonton.	Flood risk and floodway boundary, flood frequency estimates, manning roughness, water surface elevation	Multi-year, multi-seasonal	Low
Hydrology	Berner et al. 1971	Public	4	This study attempts to determine the extent of mixing of effluents discharged into the NSR in the Edmonton-Fort Saskatchewan area.	Chloride Ion, Bacteria, mean velocity, discharge	Single year, single season (summer 1971)	Low
Hydrology	Alberta Forestry, Land and Wildlife 1990	Public	4	Hydrography of the NSR within the City of Edmonton.	Hydrography maps	Single Event (May 1988)	Low
Hydrology	Stanley Associates Engineering 1990	Public	4	Hydrological assessment of the proposed City of Edmonton Waste Management Centre landfill development..	Rainfall intensity, flow, runoff volumes, hydrographs	Single event (March 1990)	Low
River Hydraulics	Beltaos and Anderson 1979	Public	3-4	Results of a slug injection tracer test on the NSR below Edmonton.	Discharge, depth, width, area	One time sampling event	Low

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Tourism and recreation	Alberta Environment 1985	Public	1-17	The purpose of this report is to investigate recreation and tourism significance of major water bodies and watercourses in the NSR Basin, and to address relevant implications for water resource management.	Recreational opportunity and facilities, activities participated in	One Year (open water)	Moderate
Water Quality	TransAlta Utilities Corporation and EPCOR Utilities Inc. 2005	Public	5	NSR Water Quality Monitoring Program.	Temperature, oxygen pH, conductivity, etc.	One Year	Low
Water Quality	PPWB Secretariat and M-R-2 McDonald & Associates 1988	Public	1	The report provides background on the PPWB water quality mandate, describes the water quality rationale used to formulate site specific water quality indicators for the quality of water in the NSR crossing the inter provincial boundary.	Hydrologic characteristic, dissolved major ions, pH, suspended solids, trace inorganics, nutrients, dissolved oxygen, organic compounds, microbiological indicators	Historical data 1974 to 1982	Moderate
Water Quality	Hardy Associates LTD 1985, App B and H	Public	N/A	Initial environmental evaluation of the water supply pipeline from the NSR to a storage reservoir west of Cold Lake. Water pumped near Lindbergh to a sedimentation pond. Interbasin pipeline alternative.	Vegetation, wildlife, water quality	Single event (7-10 January, 1985)	Low
Water Quality	Abrahams and Kellerhals 1973	Public	N/A	This study investigates to what degree the discharge hydrograph can serve as a predictor for concentration of suspended solids and suspended loads.	Mean daily loads, flows, concentration	3 year period	Low
Water Quality	Alberta Environment 1977	Public	1-5	Summary of water quality data NSR routine monitoring (NAQUADAT summary report).	Temperature, pH, conductivity, alkalinity, hardness, DO, turbidity, colour, residue, TDS nutrients, sodium, major ions, organic compounds, phenols, chlorophyll *a*, coliforms, bacteria, heavy metals	Multi-years, multi-seasonal (1970-1977)	Low
Water Quality	Pospisilik 1972	Public	4	Dispersion of dyes and pollutants in the North Saskatchewan River.			Low
Water Quality	Golder Associates Ltd. 2003	Proprietary	4	Establishment of Total Maximum Loading Limits (TMLLs) for pollutants in Edmonton city's drainage system. This includes storm sewers, combined sewers overflows, the Gold Bar Wastewater Treatment plant, the Capital Region Sewage Treatment plant, and several licensed releases.	Water quality data	One time sampling event, multi seasonal	Moderate
Water Quality	Golder Associates Ltd. 1995b	Proprietary	N/A	To provide a more refined evaluation of potential water quality impacts related to effluent discharges to the NSR.	N/A	N/A	Low
Water Quality	Golder Associates Ltd. 1999b	Proprietary	2	Sediment monitoring study of the NSR Athabasca pipeline water crossing.	Turbidity, TSS	One-year event- multi seasonal	Low
Water Quality	Stanley and Smith 1990	Public	4	Assessment of the environmental impacts of chlorine residual discharges to receiving water bodies.	Minimum average NSR discharge	N/A	Low
Water Quality	Ahmad 1985	Public	3-4	Summary of the available information about the NSR water quality, and discussion of the various issues related to the river water quality, and outlines four wastewater management alternatives.	Pollutants load, water quality, metals	N/A	Moderate
Water Quality	Environmental Management Associates, 1991	Public	1-4	The potential impacts of effluents from an OSLO heavy-oil upgrader on water quality in the NSR downstream of Edmonton were examined using the water quality model WASP, and effluent profiles and discharge volumes provided by OSLO.	Historical industrial and municipal loadings, predicted concentration of pollutants	N/A	Low

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Water Quality	Anderson et al. 1986 (Part I)	Public	3-5	Assessment of the major impacts of the greater Edmonton area on the river biota and water quality (Part I).	Water quality, metals, organics, pesticides, sediment, algal chlorophyll-*a*, and bacteria.	11 sites sampled in 1982 and 6 in 1983	Moderate
Water Quality	Anderson 1986a	Public	3-5	Assessment of the major impacts of the greater Edmonton area on the river biota and water quality (Part II).	Zoobenthic	One year- multi seasonal 1982: Spring: May 17 to June 3 Summer: Aug 9 to Aug 17 Fall: Sept 23 to Oct 10	Low
Water Quality	Anderson et al. 1986b	Public	3-5	Assessment of the major impacts of the greater Edmonton area on the river biota and water quality (Part III). Compendium of data for Part I and II.	Water quality, metals, organics, pesticides, sediment, algal chlorophyll-*a*, bacteria, and zoobenthic	N/A	Low
Water Quality	Reynoldson 1983	Public	3-5	Summary of the water quality of the mainstem NSR over the period 1970-1981.	Water quality data, metals, nutrients, pesticides and herbicides, bacteria	Historical data 1970 to 1981	Moderate
Water Quality	Alberta Environment 1989	Public	1-17	Brief description of the background and status of the North Saskatchewan River Basin Planning Program and the process for its completion.	N/A	N/A	Low
Water Quality	Alberta Environment 1983	Public		Summary of the seasonal water quality for the NSR between 1977 and 1981. Routine monitoring sites.			Low
Water Quality	A.A. Aquatic Research Limited 1996	Public	3-5	Evaluation of the impacts of the combined sewer overflows (CSOs) on the NSR water quality and its water users.	BOD, total suspended solids, nutrients, phenols, metals, lead, fecal coliforms, sediments, algal chlorophyll *a*, macrophytes, zoobenthos	Historical data from 1983 to 1992	Low
Water Quality	Masuda 1972	Public	1-9	Basic information and water quality data for the NSR.	Hydrometric data, loadings, DO, BOD, nitrogen compounds, phenols, threshold odour number, oil and grease, heavy metals, bacteriological constituents.	5 monthly surveys between Nov 2 1971 and March 1 1972	Low
Water Quality	Bouthillier 1984	Public	3-5	History of pollution control on the NSR in the Edmonton vicinity.	pH, temperature, turbidity, DO, hardness, coliforms, heavy metals, phenols, nutrients, chlorophyll *a*	1983 summary report (NAQUADAT)	Low
Water Quality	Reynoldson and Livingstone 1983	Public	4	Identification of the possible causes of the taste and odour problems associated with spring runoff in Edmonton drinking water.	Heavy metals, major ions, alkalinity, fluoride.	Spring 1982	Low
Water Quality	Mitchell 1998	Public	1	Sampling to determine the source of PPWB water quality excursions.	Metals and fecal coliforms	Spring 1997	Low
Water Quality	Mitchell 1994b	Public	1-12	Characterization of the water quality from the river's headwaters to the Alberta-Saskatchewan border, in different seasons of the year and among different years. Identification and characterization of natural and human influences that affect water quality in the river. Assessment of how an effluent plume mixes across the river at different locations.	Physical variables, suspended solids, pH, turbidity, alkalinity, hardness, TDS, major ions, fluoride, phenols, DO, metals, cyanide, nutrients, organic compounds, bacteria, algal chlorophyll *a*, coliforms	1978-1989	Moderate
Water Quality	Focus Corporation Ltd. 2004	Public	4	Water quality sampling program for the NSR at Edmonton during the summer of 2003..	Coliforms, parasites, VOC, total chlorine, *E. coli*, metals, pesticides, TSS, nutrients, coliforms, discharge	One year- multi-seasonal (summer and spring 2003)	Low

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Water Quality	Focus Corporation Ltd. 2002	Public	4	Water quality sampling program for the NSR at Edmonton during the summer of 2001.	Coliforms, parasites, VOC, total chlorine, *E. coli*, metals, pesticides, TSS, nutrients, coliforms, discharge	One year- single season Summer 2001	Low
Water Quality	Focus Corporation Ltd. 2003	Public	4	Water quality sampling program for the NSR at Edmonton during the summer of 2002.	Coliforms, parasites, VOC, total chlorine, *E. coli*, metals, pesticides, TSS, nutrients, coliforms, discharge	One year-multi-seasonal (summer and fall 2002)	Low
Water Quality	Focus Corporation Ltd. 2005	Public	4	Water quality sampling for the NSR at Edmonton during 2004.	Coliforms, parasites, VOC, total chlorine, *E. coli*, metals, pesticides, TSS, nutrients, coliforms, discharge	One year – multi-season (winter, spring and summer)	Low
Water Quality	Mitchell 1989	Public	1-12	Studies to characterize water quality in the NSR from its headwaters to the Saskatchewan borders.	N/A	Multi-year, multi seasonal (1985 to 1989)	Moderate
Water Quality	Hebben 2005	Public	3-5	The purpose of this report was to assess water quality conditions and trends in the NSR from 1977 to the end of 2002.	Temperature, pH, conductivity, alkalinity, hardness, DO, turbidity, colour, residue, TDS nutrients, sodium, major ions, organic compounds, phenols, chlorophyll *a*, coliforms, bacteria, heavy metals	Multi-year, multi-seasonal (1977 to 2002)	Moderate
Water Quality	Hocking et al. 1971	Public	4	This report is to evaluate the nature and extent of pollution of the NSR that occurs in and near the city of Edmonton.	Surface water quality criteria	1969-1970	Low
Water Quality	Mitchell 1994a	Public	1-5	The purpose of this study was to determine the proportions of various substances contributed by storm and combined sewer discharges during a rainstorm, as compared to other sources, and to determine the impact on river water quality downstream as far as the border with Saskatchewan.	Concentration of various substances in storm water: TSS, conductivity, major ions, nutrients, TOC, BOD, metals, phenols, coliforms	Single event (September 1991)	Low
Water Quality	Cochrane Engineering 1999	Public	4	Water quality sampling program for the NSR at Edmonton during the summer of 1998.	Discharge, coliforms, TSS, depth, temperature, pH, DO, BOD, nutrients	Single year, single season (summer 1998)	Low
Water Quality	Paterson 1966	Public	4	The limnology of the NSR was studied in the vicinity of Edmonton.	Average monthly flows (1961-1964), temperature, conductivity, turbidity, TSS, pH, DO, BOD, alkalinity, nutrients, metals, major ions, detergents, benthic invertebrates, fish fauna	Mid-may 1964 to August 1965	Moderate
Water Quality	Cochrane Engineering 1997	Public	4	Water quality sampling program for the NSR at Edmonton during the summer of 1996.	Discharge, coliforms, TSS, depth, temperature, pH, DO, BOD, nutrients	Single year, single season (summer 1996)	Low
Water Quality	Environmental Management Associates 1993	Proprietary	4	Series of toxicity tests on Sherritt Gordon's effluent from the Fort Saskatchewan plant to the NSR. The intent of the present work was to confirm whether the relationship between pH and toxicity of ammonia holds in the chemical environment of Sherritt-Gordon's final effluent.	Toxicity of the effluent to rainbow trout, LC50s for total ammonia, trout survival test results for various pH levels, lethal concentration of total ammonia	N/A	Low
Water Quality	Mitchell et al. 1986	Public	4	Overview of the study assessing the major impacts of the greater Edmonton area on the river biota and water quality.	Water quality, metals, organics, pesticides, sediment, algal chlorophyll-*a*, bacteria, and zoobenthic	Historical Data	Moderate
Water Quality/Benthic invertebrates	Golder Associates Ltd. 1995a	Proprietary	3-4	Determination of the effects of waste discharges, individually and collectively, on water quality and aquatic health in the river, and which and waste components are principally responsible for those effects. The study was conducted in the Edmonton vicinity to the Redwater River.	Metals, water chemistry and toxicity, benthic invertebrates	Multi-year-single event	High

Table 2
Annotated Summary of Key Studies on the North Saskatchewan River with Applicability to Developing an IFN (continued)

Topic	Reference	Report Availability	Reach Location	General Study Description (NSR = North Saskatchewan River)	Type of Data (Parameters)	Duration	Relevance to IFN
Water Quality/Benthic invertebrates	Reynoldson 1982	Public	4	Impact of waste discharges from city of Edmonton water treatment plants on biological water quality of the NSR.	Benthic invertebrates	Fall 1980, spring 1981	Moderate
Water Quality/Benthic invertebrates	Shaw et al. 1994	Public	1-12	Overview of the water quality in the NSR between 1985 and 1989.	Physical variables, suspended solids, pH, alkalinity, hardness, TDS, major ions, fluoride, DO, metals, cyanide, nutrients, organic compounds, bacteria, algal chlorophyll *a*, macrophytes, zoobenthos	Between May 1985 and March 1989, multi seasonal	Moderate
Water Quality	Clayton 1972	Public	1-5	Data compilation and evaluation of NSR water quality from 1966 to 1971.	DO, BOD, residue, nutrients, phenols, oil, coliforms, bacteria	1966 to 1971	Low
Water Use	Alberta Environment 1982	Public	1-17	Forecast the water use in the NSR Basin, from 1981 to the year 2001.	Water use, intake water requirement	N/A	Low

4.2.1 Fisheries

A general overview of the fish populations and distributions within the entire North Saskatchewan River was last prepared over 20 years ago (Allan 1984). The distribution of fish assemblages throughout the North Saskatchewan River Basin, including major tributaries, is driven largely by water temperature with three major zones identified: coolwater, transitional, and coldwater (Allan 1984). The coolwater zone incorporates IFN Segments 1 through 4 and extends from the Alberta-Saskatchewan Border to upstream of Edmonton. The transitional zone corresponds with the IFN Segment 5 and contains both coolwater and coldwater species. The coldwater zone extends from IFN Segment 6 upstream to the headwaters in IFN Segment 17. Species present in the North Saskatchewan River Basin identified by Allan (1984) are summarized in Table 3.

Since the Allan (1984) summary was completed, additional information on fish distribution has been collected from a variety of sources, mainly in response to specific development activities (Table 2). Current and some historical fish distribution data for the North Saskatchewan River are available in the provincial Fisheries Management Information System (FMIS), including data from unpublished reports not captured in Table 2. Additional data entry of historical fish studies into FMIS is required for all reaches of the NSR (D. Christiansen, S. Spencer, P. MacMahon, ASRD Regional Fisheries Biologists, pers. comm.). Spatial data from FMIS on fish distributions throughout the NSR could be imported into the GIS system being developed for this project.

Of particular note, a great deal more information on lake sturgeon has been collected within the North Saskatchewan River since the 1984 summary (Watters 1993, Earle 2002), including age-class data that could potentially be used to correlate strong age classes with environmental factors such as stream flow. The western population of lake sturgeon, including that of the North Saskatchewan River, has been listed as Endangered (COSEWIC 2005) and is under consideration for listing under the Species at Risk Act. Previous experience with using lake sturgeon in an IFN analysis would indicate that it is a species that generally requires the highest flow conditions in order to meet its habitat requirements (Clipperton et al. 2003), which makes lake sturgeon a good target management species for conducting an IFN assessment. Information on primary habitat areas for lake sturgeon is available for adult lake sturgeon in the North Saskatchewan River and could be used as the basis for identifying study sites for the development of a fish habitat model. Additional unpublished data from ASRD should be reviewed to identify potential spawning sites (M. Sullivan, ASRD, pers. comm.).

Table 3
List of Common and Scientific Names of Coldwater, Coolwater and Non-game Fish Species Found in the North Saskatchewan River Basin (from Allan 1984)

	Common Name	Scientific Name [a]
Coldwater Species	brook trout	*Salvelinus fontinalis*
	brown trout	*Salmo trutta*
	bull trout	*Salvelinus confluentus*
	cutthroat trout	*Oncorhynchus clarkii*
	golden trout	*Oncorhynchus aguabonita*
	lake trout	*Salvelinus namaycush*
	mountain whitefish	*Prosopium williamsoni*
	rainbow trout	*Oncorhynchus mykiss*
Coolwater Species	goldeye	*Hiodon alosoides*
	lake whitefish	*Coregonus clupeaformis*
	mooneye	*Hiodon tergisus*
	northern pike	*Esox lucius*
	sauger	*Sander canadensis*
	walleye	*Sander vitreus*
	yellow perch	*Perca flavescens*
	burbot	*Lota lota*
	lake sturgeon	*Acipenser fulvescens*
Non-game species	brook stickleback	*Culaea inconstans*
	emerald shiner	*Notropis atherinoides*
	fathead minnow	*Pimephales promelas*
	flathead chub	*Platygobio gracilis*
	finescale dace	*Phoxinus neogaeus*
	Iowa darter	*Etheostoma exile*
	lake chub	*Couesius plumbeus*
	longnose dace	*Rhinichthys cataractae*
	longnose sucker	*Catostomus catostomus*
	mountain sucker	*Catostomus platyrhynchus*
	northern redbelly dace	*Phoxinus eos*
	shorthead redhorse sucker	*Moxostoma macrolepidotum*
	pearl dace	*Margariscus margarita*
	quillback sucker	*Carpiodes cyprinus*
	river shiner	*Notropis blennius*
	silver redhorse sucker	*Moxostoma anisurum*
	spoonhead sculpin	*Cottus ricei*
	spottail shiner	*Notropis hudsonius*
	trout-perch	*Percopsis omiscomaycus*
	white sucker	*Catostomus commersonii*

[a] Scientific names updated from original table.

Draft Fisheries Management Objectives (FMOs) have been developed by ASRD for the upper reaches of the NSR to the boundary of Banff National Park (i.e., Reaches 5 through 11). For the purpose of development of the FMOs, the upper reaches were separated into three management sections, a lower section (Reaches 5 and 6), a middle section (Reaches 7 though 9) and an upper section (Reaches 10 and 11). The top priority management species identified by ASRD for Reaches 5 and 6, in order of importance, are lake sturgeon, bull trout, mountain whitefish and brown trout. For Reaches 7 through 9, the top priority management species identified by ASRD, in order of importance, are bull trout, mountain whitefish, cutthroat trout, brown trout and rainbow trout. For Reaches 10 and 11, the top priority management species identified by ASRD, in order of importance, are bull trout, mountain whitefish, lake trout, cutthroat trout, and rainbow trout. A recent unpublished study on bull trout movement, abundance and key spawning habitat locations is available for Reach 11 (D. Christiansen, ASRD, pers. comm.).

Updated Fisheries Management Objectives for the lower reaches of the North Saskatchewan River have not been developed and are not currently in progress (P. MacMahon, pers. comm., Regional Head, Fisheries Management, Alberta Fish and Wildlife), but enough existing information in the literature and through the FMIS database is available to allow for the development of FMOs without the need for a basin-wide inventory program.

4.2.1.1 Habitat Suitability Information

A basic requirement for completing an IFN assessment with the inclusion of fish habitat as one of the assessment variables is the use of habitat suitability criteria (HSC) curves. These are rule curves that relate the suitability of habitat for use be fishes in terms of hydraulic and physical stream characteristics that can be represented and modelled in hydraulic simulation model.

Habitat suitability information has not been developed specifically for the North Saskatchewan River. It has become common practice to use an expert workshop to generate this type of information; however, this approach is best applied when some site-specific data are available. Unpublished habitat use data for some reaches of the NSR are available from ASRD based on key habitat locations for lake sturgeon (M. Sullivan, ASRD, pers. comm.) and spawning locations of bull trout (D. Christiansen, ASRD, pers. comm.). Workshop curves have been developed in Alberta for the South Saskatchewan River Basin (Addley et al. 2003) and the Athabasca River

(A. Locke, ASRD, pers. comm.) for all life stages of bull trout, mountain whitefish, brown trout, and rainbow trout for use in the coldwater reaches and for walleye, northern pike, and longnose sucker for the coolwater zone. Workshop curves have also been created for lake sturgeon (Addley et al. 2003), although these curves were based primarily on professional judgment and should be re-examined. All of the workshop curves would generally be suitable for application to the North Saskatchewan River, although a review of the data would be warranted to incorporate any available regional information.

The summary prepared by Allan (1984) remains generally relevant to the North Saskatchewan River with respect to species distribution and could be used as a template for the development of fisheries management objectives for the lower reaches of the North Saskatchewan River.

4.2.2 Benthic Invertebrates

Numerous benthic invertebrate studies have been conducted on the North Saskatchewan River, often associated with the monitoring of effluent discharges in the Edmonton to Fort Saskatchewan region (Table 2). With long-term benthic invertebrate data, there is the potential to investigate if a relationship exists between a response in the population or community structure with certain flow conditions. The usefulness of the data on the North Saskatchewan River is likely limited since most of the studies would have some effect from effluent streams and separating a response to flow from those of the effluent streams may be difficult. Although many of the studies would have an upstream control station, those control stations are also typically downstream from effluent releases further upstream, which would limit the suitability of the control data for use in an IFN study. Although studies have shown responses of benthic invertebrates to changes in flow regime (see Bunn and Arthington (2002) for a review), they have not been used an indicator species for an IFN in Alberta and would likely require multiple years of carefully designed monitoring data to develop a specific flow relationship.

4.2.3 Water Quality

Water quality data for the North Saskatchewan River are available in a wide range of literature sources and the provincial water quality database (WDS). A summary of water quality and ecosystem health is currently under way for the North Saskatchewan River as part of a larger provincial initiative, but at the time of preparing this report, was not available for distribution. Literature sources in addition to the WDS, which include provincial, municipal and industry reports and studies on water quality in the North Saskatchewan River, are summarized in Table 2 and briefly described in the following. To supplement the data found in the literature, the water quality information in the WDS are also briefly summarized and discussed in Section 4.2.3.2.

4.2.3.1 Literature Sources

Literature sources for water quality within the North Saskatchewan River are most numerous within the Edmonton and Fort Saskatchewan reaches (Reaches 3 to 5). Water quality studies have been completed within these reaches to monitor or predict the water quality changes in the North Saskatchewan River resulting from the input of treated municipal wastewater (e.g., Golder 1995a, 1995b, 2003), industrial runoff (e.g., Golder 1995a, 1995b, 2003) stormwater runoff (e.g., Golder 2003; A.A. Aquatic Research Limited 1996, Mitchell 1994a), landfill leachate (HydroQual Canada Limited 1990) and materials potentially released during the construction of pipeline crossings (Golder 1998f). A wide range of water quality variables, including conventional variables (e.g., total suspended solids, water temperature, dissolved oxygen and pH), nutrients, metals, organics, salts and pesticides have been monitored and/or modelled during different seasons for one or multiple years between Reach 3 and 5.

At least two studies have evaluated the effects of the Bighorn Dam on water quality in the North Saskatchewan River and within the lake created by the dam (i.e., Abraham Lake) (e.g., Golder 1998b; Golder 1999a). Data from these studies, which covered Reaches 6 to 10 of the North Saskatchewan River, were collected during different seasons in a single year.

Studies that have summarized and analyzed data from the provincial water quality database, including temporal trend and seasonal analyses (e.g., AENV 1983; Hebben 2005), are described in Table 4. Some of these studies are focused around the Edmonton area (Reaches 3 to 5) (e.g., Anderson et al. 1986), whereas others report on conditions throughout the North Saskatchewan River (e.g., Mitchell 1994b).

Table 4
Summary of the Number of Data Entries by Parameter in the Provincial Water Quality Data in Reaches of the North Saskatchewan and Four Major Tributaries

River Segment	Period of Record	Number of Stations	Number of Individual Records for Selected Water Quality Variables														Continuous Monitoring?[3]
			Nutrient-related					Conventional			Major Ions				Other		
			Nitrate	Ammonia	Total Phosphorus	Soluble Phosphorus	Chlorophyll *a*	pH	Total Suspended Solids	Total Dissolved Solids	Chloride	Sodium	Calcium	Magnesium	Pesticides (2,4-D)[1]	Metals (Iron)[2]	
North Saskatchewan River																	
1	27-May-97 ~ 15-Feb-02	3	3	3	3	3	2	0	3	0	2	2	0	0	1	0	Yes
2	22-Dec-53 ~ 14-Feb-02	25	147	194	145	61	37	223	122	41	203	77	61	67	10	18	Yes
3	20-Oct-53 ~ 11-Apr-06	81	1104	1344	1527	528	380	1388	1157	625	1390	1049	611	792	195	277	Yes
4	13-Mar-52 ~ 11-Apr-06	202	936	1125	1555	278	284	1278	1500	548	1247	985	454	654	65	149	Yes
5	29-Sep-53 ~ 30-Sep-05	33	657	767	1036	687	294	636	820	229	570	591	329	370	152	165	Yes
6	16-Jun-83 ~ 3-Oct-05	8	79	75	75	74	24	48	75	48	63	63	48	48	7	0	No
7	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
8	6-May-85 ~ 9-Oct-86	1	8	8	8	9	0	8	8	8	8	8	8	8	0	0	No
9	28-Nov-72 ~ 7-Oct-86	2	41	41	32	16	8	41	19	33	41	41	32	41	3	17	No
10	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
11	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
12	6-May-85 ~ 7-Oct-86	1	8	8	7	8	8	8	8	8	8	8	8	8	2	0	No
13	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
14	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
15	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
16	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
17	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	No
Tributaries of the North Saskatchewan River																	
Brazeau	13-Mar-62 ~ 6-Oct-05	1	60	62	55	7	0	57	14	12	55	22	15	21	1	15	No
Clearwater	8-Sep-83 ~ 7-Oct-91	8	35	32	44	44	8	34	27	34	34	34	34	34	3	16	No
Sturgeon	31-May-72 ~ 11-Apr-06	15	295	295	251	156	125	292	216	255	282	281	127	244	35	86	No
Vermilion	16-Jun-70 ~ 23-Sep-97	34	111	112	113	33	3	107	74	47	110	76	56	51	21	45	No

Notes: 1 2,4-D was selected to represent the number of samples analyzed for a suite of pesticides.
2 Iron was selected to represent the number of samples analyzed for a suite of metals.
3 The answer (yes or no) indicates the presence or absence of substantial amounts of continuous monitoring of field measurements of water temperature, dissolved oxygen, conductivity and pH.

A number of studies of specific variables have been conducted in the reaches that span from upstream of Edmonton to the Alberta/Saskatchewan Border (Reaches 1 to 5). The specific variables have included chlorine (Stanley and Smith 1990), total and methyl mercury (Munson and Daniel 1974; AEC 1983a), polychlorinated biphenyls (PCBs) (AEC 1983b; AEC 1984), and a number of pesticides (AEC 1983b). These studies tend to include one or two years of data collected over multiple seasons.

From the literature review, it appears that a large amount of water quality data are available for Reaches 3 to 5, in the vicinity of Edmonton. Reaches 1 and 2, downstream of Ft. Saskatchewan to the Alberta/Saskatchewan Border also have substantial water quality datasets. In contrast, it would appear from the literature review that water quality data are more limited for Reaches 6 to 10 (upstream of Edmonton to Abraham Lake). Little or no data are available in Reaches 11 to 17, upstream of Abraham Lake.

4.2.3.2 Alberta Environment Water Quality Data

The spatial distribution of the water quality data available from AENV's database is consistent with the literature sources. The three North Saskatchewan River reaches that span upstream to downstream of Edmonton (i.e., Reaches 3 through 5) have the highest number of results for each of the variables examined (Table 4). Monitoring of the potential effects of Edmonton's stormwater and wastewater treatment plant on the North Saskatchewan River has contributed to the large dataset available in Reach 4. In addition, two long-term monthly monitoring stations are located in Reaches 3 and 5, which contribute to the large amount of data available for these areas.

Although limited provincial water quality data are available in Reaches 1 and 2, water quality has been monitored at two long-term federal stations near the Alberta/Saskatchewan Border. The data available from these two stations, and the abundance of data in upstream Reach 3 would likely be sufficient to characterize water quality in Reaches 1 and 2.

Continuous readings of dissolved oxygen, pH, conductivity and water temperature have been collected at rotating sites in Reaches 1 to 5 since 1990 (Brian Jackson, AENV, pers. comm.) (Table 4).

Limited provincial water quality data are available from Reach 6, and no water quality data are available for the selected 15 variables in Reaches 7 and 10 to 17.

With respect to key tributaries, the Sturgeon River has the most abundant and most recent water quality data out of the four tributaries that were assessed. Water quality data in the Sturgeon River are sufficient to characterize variability in loadings to the North Saskatchewan River from this tributary. The amount of data available for the Vermilion River would be sufficient to model loadings to the North Saskatchewan River from this tributary. However, this information is somewhat dated, and additional information would likely be required to confirm the current water quality conditions in the Vermilion River. Less data are available for the Brazeau and Clearwater rivers, which could limit the ability to accurately estimate how inflow from these two tributaries affects water quality in the North Saskatchewan River.

In general, nutrient variables (particularly total phosphorus, ammonia, and nitrate) and total suspended solids were the best characterized for any given reach. Less data were available for major ions and dissolved solids; however, the amount of data available for these variables would likely be sufficient for use in a water quality model. The representative variables for metals and pesticides had the lowest number of results, and the ability to accurately simulate these variables is likely to be limited.

In summary, it would appear from the literature review and the analysis of data obtained from AENV that sufficient water quality data are available for Reaches 1 to 5 to characterize water quality in the North Saskatchewan River for use in simple to moderately complex water quality models. The limited data available upstream of Reach 5 would suggest that a relatively simple water quality model would be most applicable to these upstream reaches.

4.2.4 Channel Morphology

4.2.4.1 Available Data

The reach break analysis presented in this scoping study was based on a desktop assessment of channel morphology that relied primarily on published materials including 1:50 000 scale NTS mapping and publicly available published materials including Kellerhals et al. (1972) and Shaw and Kellerhals (1982). Additional information that could be used to characterize the fluvial geomorphology of, and variation within each reach is summarized below:

1:50 000 scale NTS mapping: This mapping was used in the scoping study to identify the location of major tributaries and geomorphological changes.

Aerial photography: Coverage for the entire North Saskatchewan River mainstem is available from Alberta Sustainable Resource Development. The record generally extends as far back as 1949, with additional photography at regular intervals. Areas within Banff National Park may have less coverage, although additional coverage may be available through the Government of Canada.

Kellerhals et al. (1972): This document provides a comprehensive review of the hydraulics and geomorphology of major rivers in Alberta, including the North Saskatchewan River. It includes:

- a summary of hydraulic and geomorphic characteristics at five locations on the North Saskatchewan River in Alberta, including Saskatchewan Crossing, Saunders, near Rocky Mountain House, at Edmonton and at Lea Park;
- a water surface profile from above the Alexandra River to the Alberta/Saskatchewan Border, referenced to a geodetic datum, which includes locations of gauging stations, bridge and ferry crossings and major tributaries, as well as bedrock and valley top elevations;
- aerial and oblique photographs and cross-sections for the North Saskatchewan River at Saskatchewan Crossing and Edmonton;
- reference to detailed surveys performed between 1961 and 1970 for a 42 km reach of the North Saskatchewan River below Bighorn Dam;
- reference to studies on river ice conditions;
- reference to a slope stability study for the North Saskatchewan River, including classification and mapping of landslides;
- bed material data for 31 locations along the river;
- a list of special investigations on river channel processes, including:
    - channel depth surveys on the North Saskatchewan River near Drayton Valley (Galay 1967);

  - an investigation on bed load transport in the North Saskatchewan River at Nordegg (Samide 1971);
  - investigations on bridge scour, channel morphology and hydraulics of the North Saskatchewan River from Edmonton to the Alberta/Saskatchewan Border (Hollingshead and Schultz 1970; Nwachukwu and Neill 1972); and,
- a list of hydrophone observations on the beginning of bed movement for the North Saskatchewan River near Rocky Mountain House.

Nwachukwu and Neill (1972): This study consolidates and analyzes survey data, collected mainly in 1967, from the NSR between Edmonton and the Saskatchewan Border. It includes geomorphic data including cross-sectional and planform geometry and flow width, depth and velocity.

Galay (1973): This study focuses on regime characteristics of the NSR near Drayton Valley and includes analysis of geomorphic data including cross-sectional and planform geometry, bedforms and bed material.

Doyle and Thompson (1979): This study reported the results of a dam-break routing analysis for the reach from Berrymoor Ferry to Edmonton. It includes channel cross-sections, profiles and bed material data.

Shaw and Kellerhals (1982): This document presents bed material characteristics of major rivers in Alberta, including the North Saskatchewan River. It includes:

- a water surface profile from above the Alexandra River to the Alberta/Saskatchewan Border, referenced to a geodetic datum, which includes locations of bridge and ferry crossings, as well as bedrock elevations;
- grain size data for 34 locations along the river; and,
- bed material composition data for 29 locations along the river.

Alberta Infrastructure and Transportation (AIT): The AIT Hydrotechnical Information System (HIS) records 59 bridge crossings of the North Saskatchewan River in the province, each of which is assigned a unique Bridge File number. This includes bridges owned by the governments of Alberta and Canada, the City of Edmonton, CN and CP railways and other private owners, and includes ferries, aerial cableways and planned bridges that have not been constructed. The HIS presents bridge structure information, basic channel geometry and hydrological data, and historical flood data where available.

More extensive information is available in bridge files maintained by AIT in Edmonton, including design drawings and hydrographic survey data collected to provide a basis for bridge analysis and design.

Alberta Environment (AENV): The River Engineering Team of AENV Northern Region has data from studies they have commissioned for flood risk mapping and other purposes. These include:

- AENV (1991): cross-sections surveyed during a water quality study on the NSR from the City of Edmonton to the Saskatchewan Border;
- Phillips Planning and Engineering (1994): cross-sections surveyed during Phase I (lower reach) of the Edmonton Flood Risk Mapping Study;
- I.D. Group (1995): cross-sections surveyed during Phase II (upper reach) of the Edmonton Flood Risk Mapping Study; and,
- Associated Engineering (2003): cross-sections surveyed for the Rocky Mountain House Flood Risk Mapping Study.

Additional unreferenced material available from AENV includes cross-sections surveyed by the Alberta Research Council from the NSR headwaters to the Saskatchewan Border from 1968 to 1971.

Golder (2005, 2006): Extensive hydrographic surveys were performed for TransAlta Utilities Corp. over the period 2003 to 2005 at the North Saskatchewan River reach near Genesee. This includes channel cross-sections, erosion surveys and 2-D flow velocity measurements over a range of river stages. Use of this data would be subject to the permission of TransAlta Utilities Corp.

4.2.4.2 Applicability to Developing an IFN

A great deal of geomorphological data appears to be available for the North Saskatchewan River, including channel geometry and bed material information. This will provide a solid basis towards characterizing channel morphology at IFN study reaches. However, much of the channel geometry data are dated, are located at existing crossings (disturbed sites) and may not provide adequate coverage for all study reaches. It is also unlikely that detailed flow velocity data are available for many sites.

Future actions could include compilation of available data, including that referenced above, assessment of data quality and identification of data gaps, depending on the IFN method ultimately pursued by the NSWA. It is expected that as the IFN study progresses, it may be necessary to perform additional hydrographic surveys to fill data gaps and to provide ground truthing to verify existing information.

4.2.5 Hydrology

4.2.5.1 Available Data

Discharge monitoring data for the North Saskatchewan River are available for periods of record extending as far back as 1911 for some stations. These data are distributed by Environment Canada through the HYDAT database (Environment Canada 2003) and are summarized in Table 5.

Table 5
Available Hydrometric Data for North Saskatchewan River and Major Tributaries

Mainstem	Tributary	Station Number and Name[a]	NSR Mainstem Distance from Source[b] (km)	Downstream Drainage Area (km^2)		Period of Record[e]
				Station[c]	NSR[d]	
X		05DA006 NSR at Saskatchewan Crossing	33	1290 G 1290 E	1290 G 1290 E	1950 - 1970
	X	05DA007 Mistaya River near Saskatchewan Crossing	34	249 G 249 E	1540 G 1540 E	1950 - present
X		05DA009 NSR at Whirlpool Point	55	1920 G 1920 E	1920 G 1920 E	1970 - present
	X	05DA002 Siffleur River near the Mouth	63	515 G 515 E	2540 G 2540 E	1915 - 1996
X		05DC007 NSR below Tershishner Creek	108	3890 G 3890 E	3890 G 3890 E	1953 - 1968
X		05DC010 NSR below Bighorn Plant	108			1972 - present

Table 5
Available Hydrometric Data for North Saskatchewan River and Major Tributaries (continued)

Mainstem	Tributary	Station Number and Name[a]	NSR Mainstem Distance from Source[b] (km)	Downstream Drainage Area (km^2)		Period of Record[e]
				Station[c]	NSR[d]	
X		05DC002 NSR at Saunders	164	5160 G 5160 E	5160 G 5160 E	1915 - 1978
	X	05DC006 Ram River near the Mouth	198	1860 G 1860 E	7190 G 7190 E	1967 - 1999
	X	05DB001 Clearwater River near Rocky Mountain House	244	3220 G 3210 E	11000 G 11000 E	1914 - 1975
	X	05DB002 Prairie Creek near Rocky Mountain House		859 G 859 E		1922 - present
	X	05DB006 Clearwater River near Dovercourt		2230 G 2230 E		1975 - present
X		05DC001 NSR near Rocky Mountain House	246	11000 G 11000 E	11000 G 11000 E	1913 - present
	X	05DC012 Baptiste River near the Mouth	285	1350 G 1350 E	13150 G 13150 E	1984 - 1999
	X	05DD005 Brazeau River below Brazeau Plant	326	5660 G 5660 E	20100 G 20100 E	1956 - present
	X	05DD009 Nordegg River at Sunchild Road		875 G 875 E		1971 - present
X		05DE006 NSR near Lodgepole	358	20500 G 20400 E	20500 G 20400 E	1969 - 1977[f]
	X	05DE007 Rose Creek near Alder Flats	371	551 G 551 E	21300 G --- E	1972 - present
	X	07DE009 Tomahawk Creek near Tomahawk	442	105 G 105 E	23600 G --- E	1984 - present
	X	05DE003 Wabamun Creek near Duffield	488	513 G 464 E	24700 G --- E	1927 - 1995
	X	05DF004 Strawberry Creek near the Mouth	516	584 G 582 E	25600 G --- E	1966 - present
	X	05DF006 Whitemud Creek near Ellerslie	582	335 G 335 E	28000 G 27300 E	1969 - present
	X	05DF003 Blackmud Creek near Ellerslie		643 G 494 E		1935 - present
X		05DF001 NSR at Edmonton	592	28000 G 27300 E	28000 G 27300 E	1911 - present
	X	05EB902 Pointe-aux-Pins Creek near Ardrossan	628	106 G --- E	29300 G --- E	1979 - present
	X	05EA001 Sturgeon River near Fort Saskatchewan	643	3350 G 2490 E	33000 G --- E	1914 - present

Table 5
Available Hydrometric Data for North Saskatchewan River and Major Tributaries (continued)

Mainstem	Tributary	Station Number and Name[(a)]	NSR Mainstem Distance from Source[(b)] (km)	Downstream Drainage Area (km^2) Station[(c)]	Downstream Drainage Area (km^2) NSR[(d)]	Period of Record[(e)]
	X	05EC003 Redwater River near Redwater	666	1490 G 1060 E	34700 G --- E	1972 - 1978
	X	05EC005 Redwater River near the Mouth		1550 G 1110 E		1978 - present
	X	05EB015 Beaverhill Creek near the Mouth	668	2930 G --- E	37100 G --- E	1975 - 1986
	X	05EC004 Namepi Creek near the Mouth	690	720 G 586 E	38100 G --- E	1975 - 1995
	X	05EC002 Waskatenau Creek near Waskatenau	697	312 G 205 E	38600 G --- E	1966 - present
	X	05EC006 White Earth Creek near Smoky Lake	712	1000 G 934 E	41500 G --- E	1985 - 1995
	X	05ED002 Atimoswe Creek near Elk Point	887	364 G 250 E	45900 G --- E	1975 - present
X		05EF003 NSR at Lea Park	950	47700 G 38200 E	47700 G 38200 E	1958 - 1971
	X	05EE002 Vermilion River at Lea Park	951	7940 G 3630 E	55640 G 41830 E	1964 - 1970
	X	05EE004 Vermilion River near Hazeldine		7830 G 3570 E		1971 - 1979
	X	05EE007 Vermilion River near Marwayne		7270 G 3110 E		1979 - present
X		05EF001 NSR near Deer Creek (Saskatchewan)	1021	57100 G 42700 E	57100 G 42700 E	1917 - present

(a) 36 stations are listed of the 105 hydrometric stations that have operated in the NSR watershed. Stations were screened to remove those with short (<10 years) periods of record and tributaries where flow records are captured by downstream hydrometric stations. None of the 18 lake water level stations are listed.
(b) Distance at point on NSR mainstem or where tributary enters NSR, derived from Shaw and Kellerhals (1982).
(c) As reported by Environment Canada (2003); G = gross area; E = effective area.
(d) Derived from data presented by Environment Canada (2003); G = gross area; E = effective area.
(e) As reported by Environment Canada (2003); may include discontinuous periods.
(f) Discharges are reported at Station 05DE006 for the period 1969 – 1977; water levels are reported for the period 1978 – present.

Flows in the North Saskatchewan River are greatly influenced by precipitation in the mountain and foothill headwater areas. Mean annual water yields (depth of runoff) in mountain areas are close to 900 mm, while those in prairie areas, such as the Vermilion River watershed, can be less than 10 mm. Many tributaries in the eastern part of the watershed also have “sink” areas that do not contribute runoff to the North Saskatchewan River.

Flows on the North Saskatchewan River have been regulated since 1961 by the Brazeau Dam and since 1972 by the Bighorn Dam, and additional impoundments and water withdrawals with a consumptive use of approximately 300 million m^3 are currently licensed (Stantec 2005). These uses can be expected to slightly reduce mean annual discharge in the North Saskatchewan River, as well as reduce the variability and temporal distribution of discharge downstream of the dams.

A naturalized flow study was recently conducted to derive a flow record for the period 1912 – 2002 for selected gauging stations in the North Saskatchewan River Basin (Stantec 2005). Table 6 presents a comparison of recorded and derived mean annual discharges at selected North Saskatchewan River mainstem locations. Recorded flows correspond to the period after construction of the Brazeau and Bighorn dams. The data show that mean annual discharges have been reduced by approximately 3% due to human activities within the watershed.

Table 6
Recorded and Derived Mean Annual Discharges at North Saskatchewan River Mainstem Locations

Station	Effective Drainage Area (km^2)	Mean Annual Discharge		
		Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)
05DC010 - NSR below Bighorn Plant	3890	78.1	78.1	76.3
05DC001 - NSR at Rocky Mountain House	11000	135	128	[a]
05DF001 - NSR at Edmonton	27300	216	202	195
05EF001 - NSR near Deer Creek	42700	230	221	214-[b]

[a] Mean annual discharges cannot be calculated because flows are not monitored during winter months.
[b] Based on the available period of record 1973-2000.

Tables 7 to 10 present a comparison of mean, minimum and maximum monthly mean discharges for the four locations referenced in Table 6. The data in Tables 7 through 10 show that mean monthly discharges have been affected by human activities within the watershed. Winter mean flows have more than quadrupled in the reach immediately downstream of Bighorn Dam, while in that reach summer mean flows have typically been reduced to less than half of natural levels. Downstream reaches are less affected, and near the Alberta/Saskatchewan Border, natural mean flows are slightly more than doubled in the winter and typically reduced by one-third in the summer.

Table 7
Recorded and Derived Mean Monthly Discharges at Station 05DC010
(NSR below Bighorn Plant)

Month	Minimum			Mean			Maximum		
	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)
January	6.89	6.94	35.0	11.1	13.9	66.0	24.4	24.4	83.9
February	5.59	7.54	29.8	10.4	13.1	67.9	19.4	19.4	103.6
March	5.49	6.28	41.6	10.9	14.1	76.0	24.1	24.1	105
April	3.16	3.16	37.1	27.4	22.0	83.9	128	34.2	121
May	21.5	21.5	47.7	81.1	76.8	82.6	256	140	146
June	90.0	128	39.9	208	197	92.0	434	288	155
July	116	159	18.9	235	235	83.5	446	429	153
August	101	127	26.4	175	181	72.6	296	265	136
September	53.5	71.0	29.6	97.4	96.5	69.1	263	135	115
October	12.7	12.7	40.4	42.3	41.0	70.0	81.1	81.0	112
November	10.3	14.8	40.2	18.3	21.7	76.5	32.1	32.1	105
December	2.11	2.11	47.9	12.6	15.8	75.0	23.2	23.2	102

Table 8
Recorded and Derived Mean Monthly Discharges at Station 05DC001
(NSR at Rocky Mountain House)

Month	Minimum			Mean			Maximum		
	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)
January	16.8	25.6	(a)	28.6	34.7	(a)	54.0	54.0	(a)
February	16.7	18.3	(a)	27.0	33.6	(a)	54.9	54.9	(a)
March	17.9	30.5	(a)	29.2	37.6	(a)	47.6	47.6	(a)
April	24.7	44.5	(a)	71.1	72.9	(a)	225	109	(a)
May	61.4	61.4	85.0	163	148	150	422	241	261
June	167	181	120	345	304	197	632	488	391
July	213	213	118	362	337	192	661	580	382
August	150	173	77.3	266	246	141	455	396	288
September	80.6	94.6	69.7	163	147	121	410	219	174
October	48.6	48.6	76.2	84.2	78.7	107	154	131	144
November	25.5	31.9	(a)	43.3	43.3	(a)	86.8	57.0	(a)
December	16.0	24.5	(a)	30.9	34.9	(a)	57.4	41.5	(a)

[a] Discharge data available for winter months at this station are too sparse for statistical analysis.

Table 9
Recorded and Derived Mean Monthly Discharges at Station 05DF001
(NSR at Edmonton)

Month	Minimum			Mean			Maximum		
	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)
January	15.7	15.7	82.2	35.9	31.8	114	70.5	69.3	160
February	16.8	16.8	82.6	34.8	33.1	116	65.6	57.0	153
March	14.7	14.7	90.8	46.1	54.9	133	111	111	192
April	67.4	89.7	149	156	160	228	407	407	432
May	102	128	135	290	265	246	1100	429	431
June	240	266	188	547	485	327	1080	1030	857
July	288	322	138	560	552	365	1210	1030	851
August	225	225	134	390	365	231	820	601	479
September	126	126	108	250	227	182	738	371	298
October	49.2	49.2	91.1	135	128	152	293	273	260
November	25.1	25.1	79.2	65.4	57.4	128	130	127	188
December	16.9	16.9	76.0	37.1	30.8	120	83.8	83.8	192

Table 10
Recorded and Derived Mean Monthly Discharges at Station 05EF001
(NSR near Deer Creek)

Month	Minimum			Mean			Maximum		
	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)	Naturalized (1912-2002)	Naturalized (1973-2002)	Recorded (1973-2002)
January	20.0	20.1	79.4	38.6	32.8	109	78.3	78.3	148
February	19.5	19.7	77.9	37.8	34.5	115	71.4	59.6	145
March	23.1	23.1	84.4	47.5	53.7	133	121	121	202
April	75.5	112	178	192	208	289	558	558	626
May	116	126	137	306	282	281	1260	655	696
June	241	287	198	560	511	357	1170	992	828
July	305	352	165	588	588	405	1280	1070	828
August	233	233	137	414	394	254	735	623	512
September	149	149	126	278	251	201	822	407	342
October	71.2	71.2	96.2	156	148	167	331	306	294
November	37.7	37.7	75.1	79.0	74.2	133	151	132	186
December	20.1	20.1	86.9	42.6	34.8	120	81.1	54.0	182

The Stantec (2005) naturalized flow study presents weekly discharge data, so the data are not suitable for conducting a frequency analysis of daily discharges. Daily data presented by Environment Canada (2003) can be used to assess changes to flood and low flow regimes at stations with adequate periods of record prior to, and subsequent to, flow regulation. Table 11 presents the results of frequency analyses of flood discharge data from three of the four stations discussed previously, and Table 12 presents the results of a frequency analysis of low flow discharge data for those stations.

Table 11
Frequency Analysis of Maximum Mean Daily Flows

Return Period (years)	05DC001 NSR near Rocky Mountain House		05DF001 NSR at Edmonton		05EF001 NSR near Deer Creek	
	Pre-Dam (1913-1960) (m^3/s)	Post-Dam (1973-1997) (m^3/s)	Pre-Dam (1911-1960) (m^3/s)	Post-Dam (1973-1997) (m^3/s)	Pre-Dam (1918-1958) (m^3/s)	Post-Dam (1973-1997) (m^3/s)
2	676	304	1170	681	1080	771
5	997	443	1780	1180	1700	1280
10	1300	553	2300	1670	2250	1760
20	1680	675	2930	2320	2900	2360
50	2370	860	3950	3540	3990	3430
100	3060	1020	4920	4840	5040	4500

Table 12
Frequency Analysis of Minimum Mean Daily Flows

Return Period (years)	05DC001 NSR near Rocky Mountain House		05DF001 NSR at Edmonton		05EF001 NSR near Deer Creek	
	Pre-Dam (1914-1960) (m^3/s)	Post-Dam (1973-1997) (m^3/s)	Pre-Dam (1912-1960) (m^3/s)	Post-Dam (1973-1997) (m^3/s)	Pre-Dam (1918-1957) (m^3/s)	Post-Dam (1973-1997) (m^3/s)
2	(a)	(a)	20.9	63.8	19.5	65.1
5	(a)	(a)	15.1	47.7	14.6	51.8
10	(a)	(a)	12.0	38.8	12.5	44.8
20	(a)	(a)	9.61	31.2	11.0	39.1
50	(a)	(a)	7.09	22.9	9.71	33.1
100	(a)	(a)	5.56	17.4	9.04	29.3

(a) irregularities were noted in the HYDAT data that warrant additional investigation.

The data show that, as for the mean monthly flows, the influence of human activities (primarily operation of the Bighorn and Brazeau dams) has caused flood discharges to be reduced and low flows to be increased.

4.2.5.2 Applicability to Developing an IFN

A great deal of high quality historical flow data exists for the North Saskatchewan River, including mainstem and tributary hydrometric stations with periods of record extending as far back as 1911. This information provides a solid basis for characterizing the hydrological regime at IFN study reaches. However, it may be necessary to perform more detailed analyses of low flows, due to the weekly discrimination of the derived naturalized discharge record. Operating rules for the Brazeau and Bighorn dams should also be acquired to further define the anticipated future hydrological regime.

Future actions could include compilation and analysis of available discharge data, including that referenced above, assessment of data quality and comprehensive characterization of natural and post-development flow regimes. It is expected that as the IFN study progresses, these data could be used in conjunction with hydrographic surveys to provide input to calibrated flow models as part of an IFN assessment. The naturalized flows may also have to be expanded to correspond with each of the IFN river segments, depending on the IFN method of choice by the NSWA.

4.2.6 Riparian Issues

The investigation of the current literature on riparian ecosystems of the North Saskatchewan River mainstem rendered no useful results. There are many reports that describe the function of Albertan riparian ecosystems and impacts to these systems from agricultural and industrial development (e.g., Rood and Mahoney 1991; Tellman et al. 1993). However, these reports generally focus on arid regions and southern Alberta river systems, which are not applicable to the wetter conditions found within the North Saskatchewan River Watershed.

Rood (1996) suggested that northern boreal riparian forests may not be as dependant on surface water flows as southern cottonwood forests due to differences in water availability and the interaction between surface water and the riparian water table. In southern arid regions, survival of the riparian community is dependant in part on trees maintaining access to the riparian water table, which is directly linked to the surface water level. High flows are critical for establishing nursery sites to allow seedling establishment and recruitment to occur. High flow events are still likely critical to the development of northern riparian ecosystems; however, the link between lower flows and riparian survival in northern forests has not been established.

Note, however, that the eastern portion of the North Saskatchewan River closer to the Alberta/Saskatchewan Border receives much less precipitation compared to the mountains and foothills regions to the west, and here the riparian forests may respond to changes in river water levels in a manner similar to southern Alberta streams. Since the hydrology of the North Saskatchewan River has been altered by hydropeaking operations, which has reduced the peak flows, a historic air photo analysis would be warranted to determine if there has been a change in the riparian forest composition along the North Saskatchewan River, particularly in Segments 1 through 3.

4.3 Geomatics

In addition to the IFN scoping review completed for the study, a separate task of identifying an appropriate GIS tool was also incorporated into this study phase. The following sections describe the results of the development of a GIS tool that could be used initially as an integrated tool to assist with the IFN work, but also a tool that will be flexible in adapting to all stages of the IWMP process.

4.3.1 User-needs Survey and GIS Application

As of July 11, 2006, seven individuals had responded to the user-needs survey. Attempts were still being made up to the delivery of this report to acquire more responses, but none were forthcoming. This section summarizes the responses to some of the key questions in the user-needs survey.

4.3.1.1 Utility of GIS

All respondents felt that the use of GIS would be of value. However, and not surprisingly, opinions varied with responses to questions that suggested specific approaches to the use of GIS.

4.3.1.2 Internet Dissemination

When asked whether information or data related to the application or tool should be disseminated via the Internet, this was seen as generally favourable. However, one response seemed to indicate some hesitation, and another response indicated that data should be available for key relationships or locations only. A follow up question asked whether the existing NSWA website should for used for information dissemination. It is quite likely that the NSWA website would not be capable of serving up spatial (map) data, but maps and documents could be made available from the site.

4.3.1.3 Modelling Scenarios

One of the key questions in the survey asked respondents for suggestions on what sort of scenarios the application should address. Perhaps this question was somewhat premature as the application is dependent on the type and scale of data that are available, as well as expectations in terms of modelling land-use/water quality relationships. The factors with respect to data availability and quality are generally well understood now, but this question may need to be revisited after a water quality model is selected that is suitable to the intended scale of the modelling.

4.3.1.4 Mapping Website

One of the approaches suggested by Golder in the user-needs survey was the development of a mapping website. GIS data would be hosted on this site, and users would be able to access it with a standard Internet web browser. Functionality such as pans, zooms, and feature (attribute) identity would be available. This would presume that modelling was done offline and the results made available on the mapping website. The website would be basically viewer only. The technology that would be utilized would be ArcIMS from ESRI.

AENV currently hosts a GIS website to provide information related to meteorological, hydrometric, and groundwater data. It may be possible to utilize the AENV website to host spatial data related to the NSWA, subject to any conditions that AENV might place on use of their website. In that case, data would be provided to AENV in compliance with their data and metadata standards.

Golder could develop an ArcIMS website for the project, which could be linked to the existing NSWA website. If desired, the website could be password protected so that only key persons could access it. The initial cost to set up the website would be $500, plus the cost of the labour to prepare the data for the website. This would vary depending on how many data layers were used on the site. There would also be a monthly hosting fee of $800. This would cover the costs of maintaining the application, the website, and the data.

4.3.1.5 Interactive Application

Another possibility that was suggested in the user-needs survey was an interactive web-based application. As an example, with this application, the user would be presented with an interface that would require input of some values, the model would run, and the output from the model would cause one or more reaches of the North Saskatchewan River to be identified as experiencing an effect, based on pre-set values for a parameter of interest.

Respondents felt this would be of some value on a general level, but probably not a priority at this time. In addition, there was a concern expressed that the model should be reliable and verifiable, otherwise it might lead to misinterpretations. There were also concerns about potential cost.

It is expected that there would be a significant amount of development time to create such a system, perhaps three to four months, as well as implications around data management that would need to be considered. The technology used would be ESRI's ArcGIS Server. Functionality for an ArcGIS Server can be extended beyond the viewing and querying capabilities of ArcIMS. The initial cost to set up an ArcGIS server site would be $2700, plus the cost of labour to prepare the data for the site. Monthly hosting fees would be $1200.

Any work with respect to data done in anticipation of using ArcIMS or ArcGIS Server would follow appropriate standards so that these systems or data could be "connected" to existing systems within the provincial government information technology infrastructure.

4.3.1.6 Future Needs

Work done toward developing a GIS model may change during the IWMP process due to additional needs identified by the IWMP Steering Committee or by the Regional Advisory Committees.

4.3.2 Other Considerations for a GIS Application

4.3.2.1 Existing Water Quality/GIS Applications

An Internet search of various websites using a range of search terms was undertaken to determine availability of software that directly links GIS and water quality modelling applications, with input and/or output in a format that is spatial in nature and directly usable by a GIS system.

There has been much academic work done in this sphere, but there is very little software that is publicly or commercially available. The United States Environmental Protection Agency (USEPA) makes available at no cost a wide variety of water quality modelling software, that are meant to be utilized at various scales, and that model different aspects of water quality.

Only one of these applications links directly to GIS software. BASINS, standing for Better Assessment Science Integrating point and Nonpoint Sources, is a system that uses Arcview 3.2, an older GIS software sold by ESRI. BASINS is currently at version 3.1. BASINS, by default, expects to find data pre-formatted and available from US government spatial databases. However, it is not tied exclusively to these datasets, and can accept similar data from other sources. The system does provide choices of several watershed and water quality models that may be used. Output from the models is in the form of reports and maps, but GIS datasets are also created. Because the underlying software is Arcview, there would be no opportunity to integrate this into an interactive tool. On the other hand, the GIS datasets (shape files) could be used in an ArcIMS setting.

The next version of BASINS (v. 4) will not require ESRI software, but will use an open-source (i.e., not tied to proprietary software) platform called MapWindow. However, it will still operate with ESRI applications so that ESRI format data can be input to and output by the application. USEPA expects to have the production version of BASINS 4 released by the end of 2006.

The United States Department of Agriculture (USDA) also distributes a water quality modelling application at no cost, AGNPS (AGricultural Non-Point Source) for modelling water quality in agricultural areas. AGNPS utilizes a GIS called GRASS, which imports from and exports to ESRI format data. Training would be required for most users to use GRASS or AGNPS.

DHI Software sells a GIS-based application called MIKE Basin, which is integrated with ArcGIS, and performs broad-scale water quality modelling. MIKE Basin adds extensive functionality to standard ArcGIS for hydrological and water quality modelling, but for the purposes of this project (and future related projects), it is probably more than is necessary. The loading coefficients that would be an input to a DHI-based model would be developed by water quality experts, and the resulting processing emulated using programming within the standard ArcGIS environment

Additional detail relating to the MIKE Basin and other software from the water quality modelling perspective is provided in Section 5.1.1.

4.3.2.2 Water Quality Modelling Requirements within the GIS

Three of the main factors that control loadings into watercourses are land use or land cover, soil drainage, and topography. As a result of this scoping study, various datasets have been sourced that address these three factors. Some of these datasets are in hand now, while others could be obtained if a determination is made to proceed with a particular water quality model. Please see the summary table in Section 4.3.3 for a description of these and other datasets of relevance to this scoping project.

Watercourse loading is only one aspect of water quality modelling. While it can serve as an indication of likely water quality, consideration should be given to processes that occur instream. A loading model could be developed to run in the GIS environment that combined these three data types (i.e., land use, soil drainage and topography), with a loading value for each combination of data in a defined area. If desired, a more sophisticated model could be developed to take into account the distance to the North Saskatchewan River or its tributaries. It would also need to take into account specific land use in some areas (e.g., intensive agriculture or certain types of industry).

4.3.3 Spatial Data Compilation

Following is a discussion of the data that were acquired or may potentially be available from various sources. The information is summarized in Table 13, where it is organized by broad themes. The spatial extent of the data is shown in Figure 3. Most of the headings in the table are self-explanatory, but three may warrant more explanation.

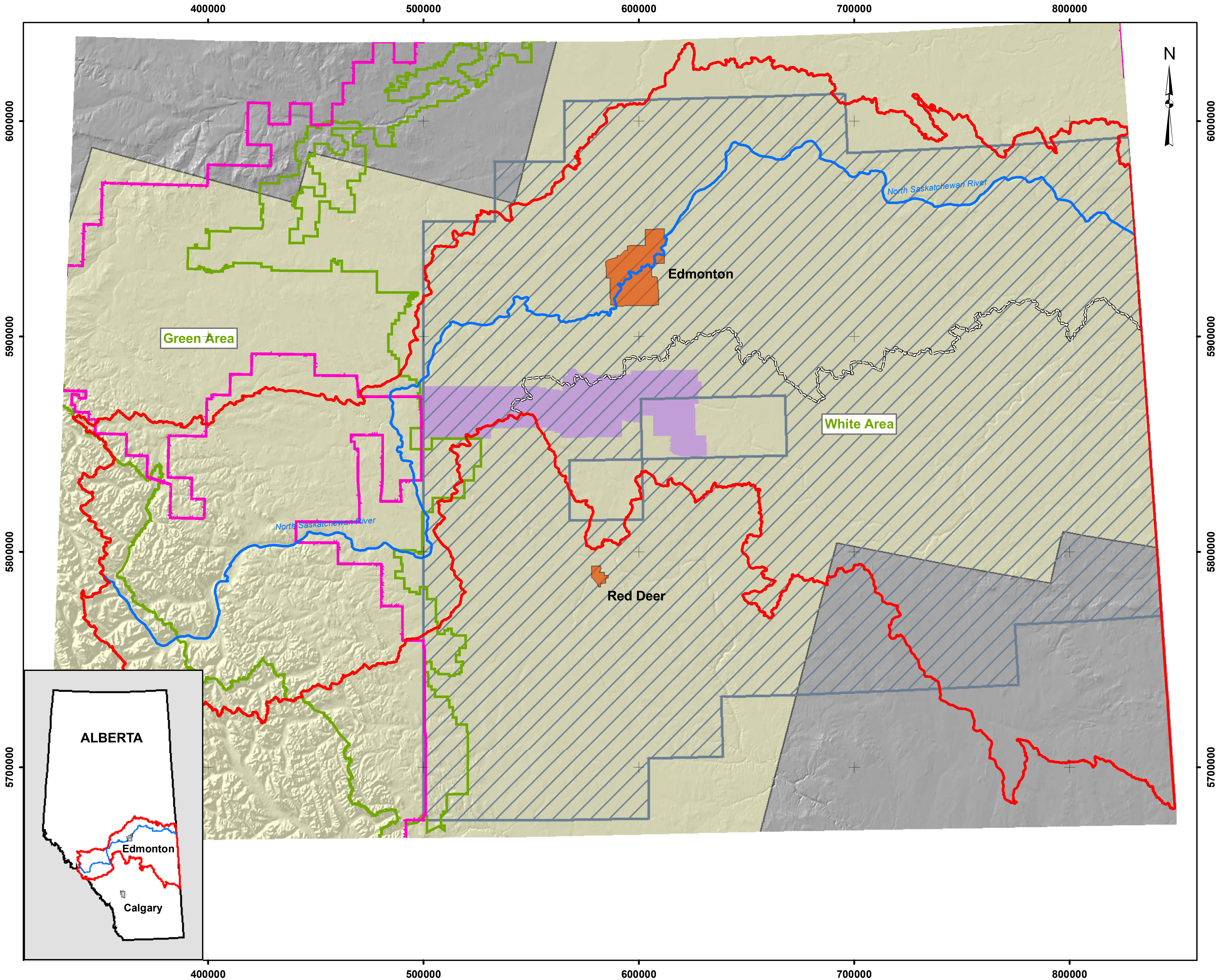
- Base data includes data such as lakes and rivers, roads, administrative boundaries and political units.
- Appropriate scale of use refers to the manner in which the data are intended to be used for GIS analysis, modelling, or mapping. The larger the geographic area of coverage, the more generalized the data tends to be. An example would be a map of Canada versus a map of a township. The map of Canada would show only major rivers and highways, whereas the township map would likely show every road or trail, and every creek, even those that only flow intermittently. The entry in the column refers to an area of a certain geographic entity to provide an idea of the kind of area for which the data are most appropriately utilized.
- Data complexity attempts to encapsulate how general or detailed the data's features are, both in their shape and their attributes.

Table 13
Summary of Spatial Data Reviewed for Application to the North Saskatchewan River Basin

Data Theme	Data Name	Source	Appropriate Scale of Use	Scale of Data Compilation	Data Complexity	Coverage	Cost (if any)	Project Use of Data	Comments
Base data	Base Features	Alberta Sustainable Resource Development (ASRD) – Resource Data Distribution Branch (RDD)	Township	1:20,000	Straightforward, both spatially and attributes	All of Alberta; all of North Saskatchewan River Basin (NSRB) for project	None	Acquired, but not used. Deliverable.	
Base data	National Framework Data	Natural Resources Canada (NRCan)	Subwatershed to province	1:50,000; 1:250,000; 1:1,000,000	Straightforward, both spatially and attributes	All of Canada; all of Alberta for project	No cost for all scales.	1:1,000,000 scale data used in mapping for July update meeting and reporting. Deliverable. Larger scales potential acquisition.	
Land use/land cover	Land Cover	Prairie Farm Rehabilitation Administration (PFRA)	Subwatershed to North Saskatchewan River Basin (NSRB)	Depends on horizontal resolution	Polygons derived from satellite imagery and are generalized; 9 classes of cover type	Most of NSRB	None	Used in mapping for July update meeting. Deliverable.	
Land use/land cover	Alberta Ground Cover Classification (AGCC)	ASRD, Forest Protection Division	Subwatershed to NSRB	Depends on horizontal resolution	Polygons derived from satellite imagery and are generalized; approximately 15 classes of cover type	Most of Alberta, including NSRB	None	Potential acquisition.	
Land use/land cover	Prairie Native Vegetation Inventory (PNVI)	ASRD	Township to subwatershed	1:50,000	Straightforward, both spatially and attributes	Parkland Natural Region	None	Acquired, but not used. Deliverable.	
Land use/land cover	Alberta Wetlands Inventory	Ducks Unlimited Canada (DUC)	Township	1:30,000	Straightforward, both spatially and attributes	Very limited at moment. Vermilion subwatershed released to ASRD, Iron subwatershed to be released soon	None	Potential acquisition.	Not likely much more available until 2008
Land use/land cover	Alberta Vegetation Inventory (AVI)	ASRD and forestry companies	Township to subwatershed	1:30,000	Polygons are fairly detailed; lot of information in attributes	Green Zone	None	Potential acquisition.	May be difficult to acquire from companies
Soil	Canadian Soil Information Service (CanSIS)	Agriculture and Agri-Food Canada (AAFC)	NSRB to province	1:1,000,000	Polygons are generalized and cover large areas; lot of information in attributes	All of Canada; all of Alberta for project	None	Used in mapping for July update meeting. Deliverable.	
Soil	Canada Land Inventory Soil Capability for Agriculture	AAFC – National Land and Water Information Service (NLWIS)	Subwatershed	1:250,000	Polygons are fairly detailed; attributes relate to agricultural capability	All of agricultural Canada	None	Reviewed.	Probably not suitable for this project
Soil	Agrasid	Alberta Agriculture, Food and Rural Development (AAFRD)	Subwatershed	1:100,000	Polygons are fairly detailed; lot of information in attributes	White Zone	None	Used in mapping for July update meeting. Deliverable.	
Imagery	National Topographic System digital topographic maps	NRCan	Township to subwatershed	1:50,000, 1:250,000	N/A	All of Canada; all of NSRB for project	$5.00 per map sheet	1:250,000 scale data used in mapping for July update meeting. Deliverable. 1:50,000 scale a potential acquisition.	

Table 13
Summary of Spatial Data Reviewed for Application the to North Saskatchewan River Basin (continued)

Data Theme	Data Name	Source	Appropriate Scale of Use	Scale of Data Compilation	Data Complexity	Coverage	Cost (if any)	Project Use of Data	Comments
Imagery	Digital Imagery	Valtus	Township to county	Depends on horizontal res.	N/A	All of NSRB	Depends on resolution; $250,000 for 1m resolution	Potential acquisition.	Colour imagery; currency varies. According to Valtus, ASRD cannot provide.
Imagery	Satellite Imagery	Iunctus / SPOT	Subwatershed	Depends on horizontal res.	N/A	All of NSRB	Depends on resolution; $22,000 for 10 m, $113,000 for 2.5 m	Potential acquisition.	Grey scale imagery; maximum of 3 years old
Imagery	Satellite Imagery	Landsat / Geogratis	Subwatershed to NSRB	Depends on horizontal res.	N/A	All of Canada; all of NSRB for project	None	Acquired, but not used. Deliverable.	Free data is a few years old
Digital elevation data	Digital Elevation Model and Hillshade	NRCan	Township to subwatershed	1:50,000, 1:250,000	Straightforward, both spatially and attributes	All of Canada	None	1:250,000 scale data used in mapping for July update meeting. Deliverable. 1:50,000 scale a potential acquisition.	
Watershed boundaries	Environment Canada 4 character sub-basins	PFRA	Subwatershed to province	1:50,000	Complex shape, attributes straightforward	Western provinces and some Territories and USA; all of NSRB for project	None	Used in mapping for July update meeting and reporting. Deliverable.	
Monitoring stations	Hydrometric Gauging Stations	PFRA	Up to NSRB	N/A	Straightforward, both spatially and attributes	Western provinces and some Territories and USA	None	Acquired, but not used. Deliverable.	
Monitoring stations	Water Quality Stations	AENV	Up to NSRB	N/A	Straightforward, both spatially and attributes	All of Alberta; all of NSRB for project	None	Used in mapping for July update meeting. Deliverable.	
Ground water	Hydrogeological datasets	PFRA	County	Not known		All of NSRB, except Wetaskiwin County	None	Potential acquisition.	Little information available on data
Census data	Demographic census	Statistics Canada	Enumeration area	N/A	Fairly complex spatially, very complex attributes	All of Canada	Unknown	Potential acquisition.	Not available yet
Census data	Demographic census	Alberta Municipal Affairs	Municipality	N/A	Straightforward	All of Alberta	None	Potential acquisition.	
Census data	Agricultural census	Statistics Canada	Enumeration area	N/A	Fairly complex spatially, very complex attributes	All of Canada	$700	Potential acquisition.	May be able to get data generalized through AAFRD



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LEGEND

- WATERSHED BOUNDARY
- IWMP BOUNDARY
- LANDSAT/AGCC
- PFRA LAND COVER
- PRAIRIE NATIVE VEGETATION INVENTORY
- GREEN/WHITE ZONE BOUNDARY (AGRASID DATA WITHIN WHITE ZONE)
- CITY LIMITS
- WETASKIWIN COUNTY

NOTE

The following datasets have full coverage of NSRB:
Base Features, CanSIS, NTS, Valtus Imagery, SPOT Imagery, Digital Elevation Model, Demographic and Agricultural Census Data.
PFRA ground water data available for all municipal jurisdictions, except Lacombe County.

REFERENCE

Base data and Landsat extents from Natural Resources Canada;
Watersheds from PFRA, used under license;
Green Zone Boundary and PNVI extents from ASRD.
Projection: Transverse Mercator Datum: NAD 83
Coordinate System: Alberta 10TM False Easting 500,000 at 115° W.

50 0 50

SCALE 1:1,750,000 KILOMETRES

PROJECT

NORTH SASKATCHEWAN WATERSHED ALLIANCE
IFN SCOPING STUDY

TITLE

EXTENTS OF DATA AVAILABLE FOR THE PROJECT

Golder Associates
Calgary, Alberta

PROJECT No. 06-1337-007.2000			SCALE AS SHOWN	REV. 0
DESIGN	MM	27 June 2006		
GIS	MM	31 May 2007		
CHECK	KC	23 Aug. 2006		
REVIEW	KC	31 May 2007		

FIGURE: 3

A small number of datasets are described as having been acquired but not used. These are datasets that were either:

- on the DU data disk provided to Golder early in the project – Prairie Native Vegetation Inventory;
- discussed as a useful dataset to have in hand for this or follow-on projects for the NSWA, but were not used in mapping or analysis for this project – Base Features from ASRD; and,
- determined by Golder as a useful dataset to have in hand for this or follow-on projects for the NSWA, and available for no cost and low effort, but were not used in mapping or analysis for this project – 1:50 000 scale digital elevation data, Landsat imagery, and PFRA gauging stations.

ArcHydro was discussed with the IFN-TAC as a potential data source to be linked with this project. ArcHydro is a data model that was developed by ESRI as a standard way of describing relationships between various kinds of spatial data in the hydrologic sphere. Examples of the kinds of spatial data that it models are hydrometric or gauging stations, watercourses and reaches, control structures, and watersheds. In the Alberta context, it is being developed to predict natural flows and watershed boundaries at any location within province, including the North Saskatchewan River Basin. Although likely useful for the IWMP, this data set is not likely required for the IFN task as the naturalized flows for the North Saskatchewan River are largely already available.

4.3.3.1 Land Use/Land Cover Data

With respect to land use/land cover, the three main datasets mentioned in Table 13 were the PFRA land cover, AGCC, and AVI. AVI covers the green zone (non-agricultural area) only, and distinguishes between tree species at a subwatershed scale of modelling. In terms of its contribution to a watercourse loading model, it could be generalized to a scheme along the lines of: forested, rock, water, disturbed. In spite of the fact that the AVI would only cover the headwaters and some of the northeastern part of the North Saskatchewan Watershed, this generalization would still result in a large number of polygons.

The PFRA land-cover dataset has a very general classification scheme, and mainly covers the white zone (agricultural area), with a small amount of data in the green zone. The classification scheme is quite simple: trees, water, forage, cropped, wetlands, other (mostly urban or industrial, and may include bare areas).

AGCC has complete coverage of the North Saskatchewan Watershed and uses a detailed classification scheme. It would be available to the project in raster format, and would require further processing before it could be used.

With GIS data, the broadest typing of data is vector or raster. Vector data is basically point, line, and polygon features. Raster data on the other hand is composed of pixels, with every pixel being the same size and usually square. Each pixel represents a patch of ground and contains a value. Pixels can be of any size, but the smaller the pixel, the larger the dataset. Common raster data types are digital elevation models and satellite imagery. With digital elevation models, the value of the pixel is the average elevation of the patch of ground represented by the pixel. The value of each pixel in a satellite image is the “colour” of the ground picked up by the sensor. The AGCC data was developed from Landsat satellite imagery, and its pixel size is 30 metres on a side. Thus, each pixel represents 900 square metres. There tends to be a “salt and pepper” effect in the AGCC data. This is an artifact of the processing, and would need to be cleaned up.

AVI and the PFRA land-cover data are polygon (vector) data. The PFRA land cover was developed from satellite imagery, but what is available to the public has been converted to a polygon format.

There are two possible approaches to use of the land-cover data. The first would be to combine a generalized AVI with the PFRA land cover, with the AVI taking precedence over the PFRA data. This generalization and combination would take about two or three days of effort.

The second approach would involve using the AGCC data only, so that there would be one homogeneous dataset over the entire Study Area. Processing the data to remove salt and pepper, along with other pre-processing, is estimated to be about one to two weeks of effort, but more actual elapsed time, due to the amount of data and computer processing time.

Whichever approach was utilized, any available wetlands data from Alberta Wetlands Inventory or Native Prairie Vegetation Inventory should be utilized as well. Combining this data would add about one day the process.

Considering that the scale of modelling is at the least at the subwatershed level, it may be appropriate to do the modelling using all raster data. Raster data are suitable for mapping and modelling over large areas. Very large numbers of polygons make it difficult, if not impossible, and very time consuming, to run a model.

4.3.3.2 Soil Data

There are two data sources for soils information. In the white zone, there is AGRASID, which is quite detailed in terms of the spatial extents of the polygons, and very detailed in terms of its attributes. However, considering that soil drainage is a main factor in watercourse loading, the polygons could be agglomerated. It is very likely that many polygons that are adjacent to one another share the same drainage characteristics, but differ in other ways. By generalizing, or agglomerating the polygons based on drainage, the number of polygons would be greatly reduced.

Reduction of polygons would be desirable, as outside the white zone, the second soil data source would come into play, which is the CanSIS polygons. These polygons are very generalized, and in order to get complete coverage of the Study Area, they would need to be combined with the AGRASID polygons. CanSIS covers all of Canada, but it would be appropriate to use AGRASID in the white zone. With generalized AGRASID polygons, there would not be as much of a mismatch of data sources. The two different datasets are at great variance with respect to their attributes, so care would need to be taken to develop a set of attributes and values based on the two datasets that would work for modelling of watercourse loadings. The generalization of the AGRASID polygons, and the physical combination of the two datasets would not take long, but developing an appropriate set of attributes would likely take some time. Total effort for developing a suitable soil dataset is about one week.

If the modelling was done in a raster environment, the conversion to raster should be covered by the time estimates above.

4.3.3.3 Topography

Digital elevation data at scales of 1:250 000 and 1:50 000 covering the North Saskatchewan watershed has been acquired from Natural Resources Canada at no cost for the data. The data has been processed into a form suitable for GIS mapping and modelling, and is already in a raster format. Depending on the requirements of modelling, slope and aspect datasets and classifications of these datasets can easily be developed.

4.3.4 GIS Deliverable

The GIS deliverable for this project consists of three components:

- Spatial data used in mapping prepared for the July 20, 2006 update meeting, as well as that used in reporting. The data will be accompanied by FGDC compliant metadata. In addition, MXD (ESRI GIS mapping) files and PDF files of the maps will be provided.
- Spatial data that has been acquired, but not necessarily used for the project's current purposes. This data will be accompanied by reports with an explanation about the data origin, processing, and intended use.
- An ESRI ArcReader PMF file. ArcReader is a GIS viewer freely distributed by ESRI that must be installed on the user's computer; it does not utilize a web browser. ArcReader allows the user to do basic GIS functions – pan, zoom, query data, measure distance, and print a map. On the GIS side, an MXD file with basic functionality is published using ArcGIS Publisher. The map showing the final reach segmentation will be published and provided to members of the IFN-TAC and the Board. Within the application, features will be hyperlinked to documents, so that by clicking on a feature, documents will open up. More than one document can be linked to a feature and will include summary descriptions of each reach break to the reach features, a list of the references for each reach as well as available naturalized flow data.

5. IFN FRAMEWORK DEVELOPMENT

5.1 Comparison of IFN Methods

The NSWA requested the development of a general IFN framework for the North Saskatchewan River IFN study based on the principles of the Instream Flow Incremental Methodology (IFIM) (Bovee et al. 1998). The IFIM is a decision support system developed by the US Fish and Wildlife Service designed to help solve water resource allocation problems. Although many of the tools developed for use with IFIM are only applicable to open-water conditions, there are typical steps that should be followed to support rational water management decisions. Several key principles that are particularly relevant to a successful IFN study on the North Saskatchewan River include:

- agreement on the approach by all stakeholders at the planning stage;
- assemble an inter-disciplinary team to conduct the work;
- select an appropriate method to address specific problems; and,
- identify concise study objectives that are feasible in terms of data collection limitations, modelling approaches, and realistic timeline constraints.

Early applications of the IFIM were often single-species focussed and often resulted in single value minimum flow recommendations. The latest thinking in IFN science is that multiple ecosystem components and processes must be incorporated to achieve aquatic ecosystem protection (Annear et al. 2004). In developing a science-based IFN approach that can be considered protective of the aquatic ecosystem, the IFN study plan must consider flow requirements beyond a few key fish species. Recent IFN work conducted in Alberta (Clipperton et al. 2002, 2003) has incorporated the concepts of the natural flow paradigm (Poff et al. 1997; Richter et al. 1997) in the formulation of an IFN determination by considering multiple ecosystem components. Reviews of applicable tools and methods for completing a study have recently been prepared in response to other watershed management plans in the province (Golder 2004a, 2004b).

During the kick-off meeting, the NSWA indicated a preference to focus efforts on the development of a GIS tool and evaluation of water quality models that could be used to link changes in land use with changes in water quality. In addition, at the present time, there may be very limited ability to make significant changes to the hydrograph of the North Saskatchewan River downstream of Segment 9 since TransAlta Utilities Corp. have an existing water licence under the Alberta *Water Act*. Any significant changes to the existing hydrograph to return the river closer to the natural flow regime would require cooperation with TransAlta Utilities Corp. and would involve the loss of hydroelectric power generation flexibility. The major focus of IFN methods therefore concentrated on GIS development and land use - water quality interactions.

5.1.1 Water Quality Models

Modelling changes in water quality in the North Saskatchewan River from changes in land use, point-sources and best management practices (BMPs) requires a two-step approach. Loadings from non-point and point sources to the North Saskatchewan River and its major tributaries must first be estimated or modelled, and then these results can be combined with an instream model to examine how changes to land use and other practices influence water quality in the North Saskatchewan River.

Numerous modelling tools are available to complete these two steps. Some of these tools combine the runoff and instream components into a single model, whereas others need to be used in combination. Some of these tools are also integrated with or need to be manually linked to GIS applications.

The strengths and limitations of eight water quality models, one GIS-based application used to link GIS data with selected water quality models, and an in-house loadings model are discussed below briefly.

5.1.1.1 AGNPS

The United States Department of Agriculture (USDA) has developed and provides continued support for a continuous watershed loading model called AGNPS (Agricultural Non-Point Source) (USDA 2006a). The model uses a GIS interface to predict loadings, primarily from agricultural lands, to nearby water bodies. The model routes flows, sediments, nutrients and pesticides across the land and eventually deposits them outside of the watershed or to a water body. Each variable can be identified at its source and tracked as it moves through the watershed.

The advantage of using AGNPS is that it can link directly with GIS, which will likely improve the accuracy of the loading estimates from agricultural areas. One of the major drawbacks to using this model would be that a separate instream model would be needed to determine how the loading rates predicted by AGNPS may affect water quality in the North Saskatchewan River. In addition, while the model can estimate loadings from urban sources, these calculations are substantially less sophisticated than the equations used to calculate agricultural loadings.

5.1.1.2 WASP

The United States Environmental Protection Agency (US EPA) has developed and provides continuous support for a dynamic instream water quality model called WASP (Water Quality Analysis Simulation Program) (US EPA 2006a). This model assesses the fate and transport of conventional and toxic pollutants in surface water bodies. Some of the features of WASP include the ability to be linked to hydrodynamic models, the ability to model in one to three dimensions, and the inclusion of relatively sophisticated routines for modelling nutrients and toxic contaminants.

One major advantage of using WASP for the North Saskatchewan River is that the City of Edmonton has already developed a WASP model for a section of the North Saskatchewan River which includes the downstream portion of Reach 5, all of Reach 4 and the upstream portion of Reach 3. Another significant advantage is that, although WASP is a comprehensive and relatively sophisticated model, it can also be readily simplified when less data are available. WASP can also simulate the growth of both macrophytes and algae for the purposes of modelling eutrophication processes.

The largest disadvantage of WASP is that it does not include a loadings model. Loadings would, therefore, need to be generated using another method or tool. However, because loadings have already been well-defined within the Edmonton reaches, only loadings from agricultural and natural areas would need to be calculated. Another disadvantage of WASP is its limited ability to model ice-cover. However, if additional accuracy in ice-cover modelling is deemed critical, an improved ice algorithm from another model (i.e., CE-QUAL-W2) could be incorporated into WASP.

5.1.1.3 CE-QUAL-W2

The United States Army Corp of Engineers has developed and maintains a two-dimensional, laterally averaged, hydrodynamic and water quality model called CE-QUAL-W2 (United States Geological Survey 2006). Because the model assumes lateral homogeneity, it is best suited for relatively long and narrow water bodies exhibiting longitudinal and vertical water quality gradients. Although the model can be applied to rivers, lakes, reservoirs and estuaries, it was originally developed for lakes and reservoirs. The water quality portion of the model includes eutrophication and a single algal compartment. The bottom sediment compartment stores settled particles, releases nutrients to the water column and exerts sediment oxygen demand based on user-supplied fluxes.

The advantages of using CE-QUAL-W2 are that it has been used in Alberta for another IFN study, it explicitly accounts for changes in flows (as can WASP) and its ability to model ice-cover is superior to most other water quality models. Drawbacks to using CE-QUAL-W2 are that it does not perform as well in rivers compared to lakes and reservoirs, and it is relatively complicated to set-up and run. In addition, a separate tool would be needed to generate water quality loadings for input to the model.

5.1.1.4 QUAL2K

QUAL2K is a one-dimensional, steady-state, instream model that was developed and is currently maintained by the US EPA (US EPA 2006b). QUAL2K is an updated version of the US EPA's QUAL2E model. Although the model is steady-state, diurnal variations in water quality variables, including temperature, are accounted for. Other features of QUAL2K include accounting for sediment interactions, nutrient cycles and the influence of bottom algae.

The primary advantage of using QUAL2K is that it is relatively simple to set up and run, and its simplicity lends itself well to rivers with limited water quality data. The disadvantage is that it only considers steady flows and a separate model or manual method would be needed to generate water quality loadings for input to the model.

5.1.1.5 HSPF

HSPF (Hydrological Simulation Program - Fortran) is a hydrodynamic water quality model that integrates loading and instream processes. It is maintained by United States Geological Survey and the US EPA (US EPA 2006c). HSPF can simulate nutrient cycles, effects of algae, sediment-water quality interactions and the fate of conservative and non-conservative water quality variables in watercourses.

The major advantage of HSPF is that it is a comprehensive watershed model that models both loadings and instream water quality. Another advantage is that it can be linked to a GIS application through BASINS, although there are drawbacks to using BASINS, as described below. The major drawbacks to using HSPF are the extensive requirements for input data, as well as the large amount of time and effort required to set up the model.

5.1.1.6 SWAT

SWAT (Soil and Water Assessment Tool) is a continuous water quality model that integrates loadings and instream processes and is maintained by the United States Department of Agricultural (USDA 2006b). The equations for modelling instream nutrient transformations in SWAT are based on the equations used in QUAL2E. In-stream processes for total suspended solids and pesticides can also be modelled in SWAT. SWAT can be linked to a GIS application either through a GIS interface specifically developed for SWAT or BASINS.

Advantages of SWAT include its connection to the GIS system through BASINS, it models both loadings and instream processes, and it has been used in Alberta by the Department of Agricultural Food and Rural Development to determine non-point source loadings in the province. A disadvantage of using SWAT over HSPF is that SWAT has less user-defined inputs that can be adjusted to calibrate the model.

5.1.1.7 PLOAD

PLOAD is a simple loadings model maintained by the US EPA that is part of the GIS application BASINS (US EPA 2006d). PLOAD uses relatively simple algorithms to estimate loadings of user-defined water quality variables from rural and urban non-point sources and can also account for point source loadings and BMPs

The advantages of using PLOAD include that it is a relative simple model to set-up and run, and it can be directly linked to GIS data through BASINS. Disadvantages of PLOAD are that it does not include an in-stream model, and the standard output of the model is loadings on an annual average basis, which may not be sufficiently detailed for certain applications.

5.1.1.8 MIKE BASINS

MIKE BASINS is a loadings and instream water quality model developed and maintained by DHI Water and Environment in Denmark (DHI Consulting 2006). The model uses a GIS interface to predict loadings to nearby water bodies and can simulate steady-state reactive transport of selected water quality variables, including nutrients.

One advantage of using MIKE BASINS is that the model automates the link between the GIS application and the loadings model to generate loadings for the instream model. The major drawbacks of using MIKE BASINS include the cost to purchase the software (approximately $10 000 CDN) and the lack of expertise and documented success in North American watersheds.

5.1.1.9 BASINS

BASINS (Better Assessment Science Integrated Point and Non-Point Sources) software has been developed and is maintained by the US EPA for performing watershed and water quality-based studies (US EPA 2006e). Although BASINS is not a water quality model, it integrates environmental data within a GIS interface, which can be linked directly to a number of different water quality models, including HSPF and QUAL2E.

The advantage of using BASINS is that it provides a direct link between GIS and the underlying water quality model(s) (i.e., HSPF, SWAT or PLOAD). However, because the software has been developed for use in the United States, the effort to include data from other sources (i.e., for the North Saskatchewan River) can limit the benefits of using the program. Our experience with trying to use BASINS in another Canadian watershed demonstrated that it was more efficient to manually link the GIS application to the water quality model, rather than use BASINS to automate this process. However, we understand that Alberta Environment has successfully used BASINS to delineate watersheds and has integrated BASINS with other water quality models.

5.1.1.10 Golder In-House Loadings Model

Methods for calculating loadings to a watercourse can vary from simple to highly sophisticated. As the level of complexity increases, so does the need for input data and effort to complete the calculations. The simplest of methods for estimating loads for a given water quality variable uses pollutant export coefficients to calculate a total load for a specified reach of the river. Loads can be adjusted based on distance of the source to the watercourse, the remedial effects of BMPs and seasonal variations.

The export coefficient method calculates annual or seasonal loads for a variable to each reach by multiplying the loading rate for a specific land type by the area of that land contributing flow to the receiving reach. This can be represented mathematically using the following equation:

$$L_V = \sum_U (EC_{VU} \text{ x } A_U)$$

Where:

L_V = total load of variable “v” going to river reach “y” (mass units per year or season)

EC_{VU} = export coefficient for variable “v” for land type “u” (mass units per area unit area per year or season)

A_U = area of land type “u” (area units)

Export coefficients can be estimated from literature (e.g., US Army Corps of Engineers 2004; Line et al. 2002; Reckhow et al. 1980), whereas the area of each land type can be calculated using GIS. More sophisticated loadings equations could also be included in an in-house loadings model to account for other effects on loadings, such as the distances between sources of loading and the watercourse, changing rainfall amounts, and soil conditions.

The export coefficient method for calculating loads could be completed using a model developed in-house and would take substantially less time and effort to setup and run compared to other more comprehensive loading tools that already incorporate GIS interfaces (i.e., AGNPS, HSPF or MIKE BASINS). As more sophisticated equations are incorporated into the in-house loadings model, the benefits of using an in-house model compared to an existing loadings model or sub-routine will diminish.

A comparison of some of the key features of the six models described above is provided in Table 14.

5.1.2 Other Ecosystem Components

Although water quality was identified as the primary focus of the scoping study, a review of tools to address other ecosystem components is provided for the purpose of future planning. Regardless of approach or ecosystem component to be assessed, the naturalized flow for each segment will be required. The naturalized flow available for the North Saskatchewan River is currently available only for the four mainstem flow gauging stations in a weekly time step (i.e., mean weekly flows). Data are available to extend the naturalized flows to all reaches. The completion of the ArcHydro tool being developed by AENV may be useful in defining the naturalized flows for all of the segments on the North Saskatchewan River. Regardless of approach, incorporating the concept of the natural flow paradigm has become critical in the development of IFN flow regimes. Most of the available ecological data resources for the North Saskatchewan River are from after the construction of the major water control structures within the watershed. As a result, a quantitative assessment of ecosystem change as a result of current water management practices is not possible for most ecosystem components to be addressed in an IFN. Reliance on modelling applications or professional judgement will be required in moving forward with developing a water management framework.

Table 14
Summary of Watershed Water Quality Models and Related Applications

Available Models	General Attributes of Model or Application						Modelling Capabilities			
	Used in the NSR	Link to GIS[(a)]	Ease of Use[(b)]	Cost[(c)]	Flexibility to Adapt and Customize Model	Range in Spatial Scale of Model	Models Loadings to Watercourses	Models In-stream processes	Ability to Model Aquatic Plant Growth for Eutrophication	Ability to Model Ice-Covered Conditions[(d)]
AGNPS	No	Direct	2	None	Low	Watershed	Yes	No	N/A[(e)]	N/A[(e)]
WASP	Yes	Manual	2	None	High	Reach(es) to Watershed	No	Yes	Algal and macrophyte growth	1
CE-QUAL-W2	No[(f)]	Manual	4	None	Moderate	Reach(es) to Watershed	No	Yes	Algal and macrophyte growth	2
QUAL2K	No	Manual	1	None	Low	Reach(es) to Watershed	No	Yes	No	1
HSPF	No	Direct	4	None	Moderate	Reach(es) to Watershed	Yes	Yes	Algal growth only	0
MIKE BASINS	No	Direct	3	~$10,000	Low	Watershed	Yes	Yes	No	0
SWAT	No[(f)]	Direct	2	None	Low	Watershed	Yes	Yes	No	1
PLOAD	No	Direct	1	None	Low	Watershed	Yes	No	N/A[(e)]	N/A[(e)]
BASINS	No[(f)]	N/A[(g)]	2	None	Low	Watershed	No	No	N/A[(e)]	N/A[(e)]
Golder In-House Loadings Model	No	Direct	1	None	High	Reach(es) to Watershed	Yes	No	N/A[(e)]	N/A[(e)]

Notes: NSR = North Saskatchewan River.
(a) Direct = GIS interface included in model; Manual = needs to be linked manually to a GIS application, NSR = North Saskatchewan River.
(b) Ease of Use rating ranges from most simple (1) to most complicated (4).
(c) Direct licensing cost, does not include cost of training staff.
(d) Ability to Model Ice-Covered Conditions rating ranges from no ability (0) to sophisticated ability (2).
(e) Not applicable, because the model does not model in-stream processes.
(f) Used in Alberta but not in the NSR.
(g) Not applicable, because BASINS is an application that links HSPF, PLOAD and SWAT to GIS data.

5.1.2.1 Office-Based Assessments

Office-based assessments can range from very low effort (i.e., less than a day) to moderate effort to complete. An office-based IFN assessment for the North Saskatchewan River can be completed quickly and at virtually no cost using an approach developed in Alberta. The assessment uses naturalized flows as a benchmark condition and applies an "15-80" flow rule that is intended to provide a conservative estimate of flows necessary to protect all ecosystem components (A. Locke, ASRD, pers. comm.). This flow rule dictates that a maximum instantaneous diversion of 15% from the natural flow is allowed with a minimum flow restriction at the weekly 80^{th} percent exceedence flow (i.e., the flow that is equalled or exceeded 80 percent of the time calculated separately for each week of the year). This assessment provides an initial visual assessment of potential conflict areas for water management. Due to hydropeaking on the North Saskatchewan River, Segments 1 through 9 have flows that are below the office-based IFN during peak flows in the spring and flows that are augmented above the IFN during the winter. This method does not provide an ability to assess how differences in the recorded flow from the recommended IFN flow affect fish habitat, water quality or any of the other ecosystem components.

An extension of the office-based IFN assessment would be to evaluate changes to the hydrograph using a formalized system such as the Indicators of Hydrologic Alteration (IHA) or the Range of Variability Approach (RVA) to identify changes to timing, frequency, duration and magnitude of flow (Richter et al. 1996, Richter et al. 1997). The long-term daily flow records would allow for this type of analysis although daily naturalized flows are not currently available. Extending this effort may have limited applicability as the basic hydrologic summary presented in Section 4.2.5 and visual comparison of recorded flows to the office-based IFN intuitively show where the largest differences in the hydrograph exist. The results of an IHA or RVA assessment would indicate areas in the hydrograph that have been altered the most but it will not define an acceptable flow regime to be used as an IFN or provide an evaluation of alternate flow scenarios.

Recent scientific efforts have focussed on developing thresholds for defining environmental flows which are linked to an environmental response (e.g., Arthington et al. 2006, Henrikson et al. 2006, Acreman et al. 2006). These approaches are common in that they focus on maintaining natural flow variability, they use a classification approach for defining similarity in streams for defining a threshold and are essentially an office-based approach (although much development is required at the front end to develop the classification). As promising as these approaches may be, they are largely regional in application and require a number of unaltered benchmark streams to compare with altered streams to identify the thresholds. Even though similar type of classification approaches have been investigated for Alberta (Golder 2004c) and continue to be investigated (A. Locke, ASRD, pers. comm.), it is likely not applicable to a river the size of the North Saskatchewan River, which would likely be considered unique within a classification system, nor would it be available for application in the short term. Alternate methods that rely almost entirely on professional judgement to develop environmental flow thresholds are available from other jurisdictions (e.g., King et al. 2003); however, these approaches have not been applied in Alberta. Any approach based solely on professional judgement requires buy in from all interested stakeholders that the results will be accepted, even when the level of uncertainty may be high.

5.1.2.2 Fish and Fish Habitat

The basic requirements for completing a detailed fish habitat assessment are availability of habitat suitability criteria (HSC) for each key management fish species and a hydraulic/habitat model. This information will allow the development of a model to assess changes in fish habitat by species and life stage with changes in flow regime. Due to the size and hydraulic complexity (e.g., islands, braided channels) of the North Saskatchewan River, a two-dimensional hydraulic model is recommended over a one-dimensional model such as the physical habitat simulation model (PHABSIM). A two-dimensional modelling approach can also be used to evaluate habitat impacts of hydropeaking, which would be relevant for an assessment within Reach 9. With current technologies, data collections and data processing time for establishing a two-dimensional model on a large river is just as cost effective as running a tradition one-dimensional model such as the PHABSIM. The current standard within Alberta is the River2D model developed at the University of Alberta. This model has the added benefit of having an integrated ice module for modelling under ice conditions should that be required. The disadvantage of this approach is that a separate study site is required for each reach of interest, and the cost for establishing a study site and completing the modelling phase is expensive. Identifying critical habitat areas for each life stage of lake sturgeon is recommended for selecting River2D sites in Segments 1 through 5.

Species present in the coldwater segments of the North Saskatchewan River have HSC curves developed at an expert workshop for several of the main management species including bull trout, mountain whitefish, brown trout and rainbow trout. Species present in the coolwater segments with available HSC curves include walleye, northern pike, longnose sucker and lake sturgeon, although all of these are based on limited or no field data and would require updating. Refinement of these curves can be completed by collecting site-specific habitat suitability data or by conducting an additional expert workshop with input from regional biologists. In particular, lake sturgeon, which are classified as Endangered, should be a key focus of any IFN study in selecting a suitable study site for two-dimensional modelling. Collecting site-specific HSC data would be challenging on a river the size of the North Saskatchewan River. Snorkelling is the preferred approach for collecting habitat use data, which would be difficult in the lower reaches due to poor water visibility.

As an alternative to an HSC approach, which evaluates habitat at a microhabitat scale, an assessment of mesohabitat conditions is also be possible. This approach may be beneficial when collecting regional HSC data is difficult. Habitat types (e.g., riffle, runs, pools, backwaters etc.) have distinct physical characteristics that can be defined, similar to HSC curves, and the relative abundance of each habitat type can be evaluated over a range of simulated flows within a hydraulic model. This type of approach has been used in Alberta in the past, with attempts at looking at habitat diversity as a metric for defining an IFN (Bovee 1995, 1996). As an alternative to a habitat diversity approach, a mesohabitat assessment could also be used to identify changes in habitat conditions at known key habitat locations for lake sturgeon. Measured physical characteristics of the mesohabitats at locations where higher lake sturgeon abundance could be collected to validate a mesohabitat model. This approach would also require completing a detailed habitat map of the North Saskatchewan River, which is best accomplished with the use of low elevation aerial photography during low flow conditions.

5.1.2.3 Winter Issues

The flows in the North Saskatchewan River are augmented above natural flows due to the operation of the hydropeaking facilities at Bighorn and Brazeau. These augmented flows likely provide improved overwintering habitat conditions in the North Saskatchewan River. Reductions to the winter flows to meet future water-use demands may need to be assessed to determine potential changes to fish habitat or water quality characteristics. Winter approaches have recently been reviewed (Golder 2004a), and the option of running a winter River2D model is a possibility. Alternate winter approaches have been applied in Quebec, mostly for hydroelectric developments, where a steady winter flow is prescribed for the entire winter period. The determination of the flow has been based on the amount of fall habitat available for fall spawners such that a loss of incubating eggs is avoided during the winter (M. LeClerc, pers. comm., Professor, Institut National de la Recherche Scientifique). This approach would be suitable and achievable for the North Saskatchewan River if agreement on the approach by the IFN-TAC is reached.

5.1.2.4 Riparian Issues

It is likely that riparian issues are not as directly reliant on river flow as in the arid regions of southern Alberta. However, a historical airphoto assessment is warranted to determine if reduced peak flows have resulted in evidence of changes in the riparian zone in the eastern portion of the basin (i.e., Segments 1 through 3). If it is apparent that changes in the riparian zone are occurring, a similar protocol as was used for the South Saskatchewan River Basin for defining a riparian flow (Gom and Mahoney 2002) can be applied.

5.1.2.5 Channel Morphology

Inclusion of a channel morphology component in the IFN is possible with existing and future data likely to be collected for other components of the IFN study. Calculations of the initiation of bed transport have been used in Alberta in previous studies to define a range of channel morphology flows (Clipperton et al. 2003). The data required for this approach would include the D50 substrate size and hydraulic gradient, both of which are available for most segments of the North Saskatchewan River. Site-specific data could also be collected at habitat modelling locations, if such sites are established, to validate historical data.

5.2 IFN Framework for the North Saskatchewan River

A range of possible approaches to developing an IFN that incorporates multiple ecosystem components should be considered and may range from office-based techniques to detailed field studies. The selection of an approach and level of effort is often more reflective of the potential for water management to alter a particular component of the ecosystem and the potential for conflict amongst water users that correspond to the flow ranges when each ecosystem component is being considered. As a result, the primary focus for the North Saskatchewan River has been on land use – water quality interactions. Prior to moving to the next phase of an IFN study, a clear understanding of the legal framework that the WCOs will be developed under (i.e., limitations due to existing water allocations and infrastructure) and the potential for competing water interests amongst stakeholders, including the potential for social and economic consequences of altering the current flow regime, should be well understood. The set of IFN tools chosen will likely reflect the legal and institutional setting for water management in the North Saskatchewan River Basin, where larger scale changes or an increase in competing water demands, typically warrant a more detailed assessment approach. Final establishment of an IFN framework would remain open for discussion after this document with the IFN-TAC providing a final recommendation to the IWMP Committee.

5.2.1 Water Quality Modelling

5.2.1.1 Recommended Modelling Approach

Although the focus of the scoping study is the IFN for the North Saskatchewan River, there has been some discussion by members of the NSWA of the need to look at broader issues in the watershed. Modelling requirements to support the development of an IFN can be quite different from those needed to support broader watershed management objectives. Recommendations are, therefore, provided for each of the two different focus points (i.e., establishing an IFN versus developing a broader watershed management tool). In both bases, the recommendations outlined below take into account the amount of water quality data available in the literature and the provincial water quality database, as well as the advantages and disadvantages of the water quality modelling tools identified in Section 5.1.

IFN Approach

If the NSWA opts to focus on developing an IFN for the North Saskatchewan River, then modelling efforts should focus on the mainstem of the North Saskatchewan River and accurately representing in-stream processes. In Reaches 1 to 6, a more complex modelling approach is possible using available data and the recommended modelling approach would be to use WASP and a loadings model developed in-house by Golder. The extension of the current WASP model in the North Saskatchewan River (in Reaches 3 to 5) to model water quality from Reach 1 to Reach 6 can be readily completed given the water quality data available in these additional reaches (i.e., Reaches 1, 2 and 6). Although the City of Edmonton owns the existing North Saskatchewan River version of the model, it is expected that the City, as a partner in the NSWA, would allow such an extension of the model. The current WASP model for Edmonton accounts for loadings to the North Saskatchewan River within the urban boundaries of Edmonton. Loadings upstream and downstream of the urban boundaries could be estimated using GIS information on land-use. The degree of complexity and automation of links (i.e., linking the GIS application directly to WASP) of such a loadings model could be adapted to suit the needs and resources of the NSWA.

For Reach 7 and upstream, a more simplistic modelling approach would be required and the recommended modelling approach would be to use QUAL2K and a similar loadings model developed-in house. The lack of water quality data in these upstream reaches requires a simpler approach to instream modelling, to which QUAL2K is well-suited. In addition, the level of effort to set-up and run this model is consistent with the level of analysis and results that will likely be required for these upper reaches of the North Saskatchewan River. A simplistic modelling approach, such as using QUAL2K, could be applied for all reaches, if desired, but may not provide the level of detail desired for conducting an assessment in the lower reaches.

Watershed Management Approach

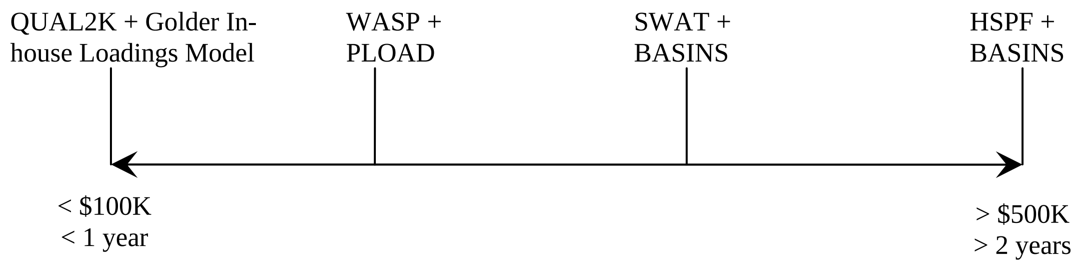
If the NSWA opts to shift their focus from developing an IFN to developing a watershed management tool, the selected modelling approach would need to adequately incorporate the mainstream of the North Saskatchewan River, its main tributaries and the surrounding landscape.

Models that are not recommended for a watershed management approach include AGNPS, MIKE-BASINS and CE-QUAL-W2. AGNPS is not recommended, because its strengths lie in modelling agricultural loadings as opposed to urban loadings. Although a large portion of the land use in the North Saskatchewan River watershed is agricultural, urban land uses around the Edmonton and Fort Saskatchewan notably influence water quality in the North Saskatchewan River, and AGNPS may not be able to adequately model these urban loadings. MIKE-BASINS is not recommended because the budget that would be required to purchase the software for this model could likely be better invested in setting up BASINS for the North Saskatchewan River, which is a free application and is familiar to some members of the NSWA, or customizing a Golder in-house loadings model for the North Saskatchewan River. CE-QUAL-W2 is not recommended, because it is a complex model that would still require an external loading model (unlike HSPF), it is not well suited for river systems (having been developed primarily to model lakes and reservoirs) and it cannot simulate variations across the width of a river, which may be of value when looking at conditions in Reaches 1 through 6. The remaining models and GIS applications, some of which would need to be combined for a complete watershed model, include:

- Golder in-house loadings model;
- QUAL2K;
- PLOAD;
- SWAT;
- WASP;
- HSPF; and,
- BASINS.

The recommended modelling approach is heavily influenced by the resources available to the NSWA and the timeline by which the NSWA would like the tool to be operational. As illustrated in Figure 4, costs and time requirements can vary substantially depending on the complexity of the selected modelling approach and the level of detail incorporated into the resulting models. Figure 4 is meant to serve as a guide, showing relative, approximate estimates for four possible modelling approaches. Other combinations of the preferred models can be created. For instance a Golder in-house loadings model could be combined with WASP, with cost and time requirements falling somewhere between the two model combinations shown on the left side of the figure. The relative rankings shown in Figure 4 take into account that a WASP model already exists for a portion of the North Saskatchewan River. However, more detailed costing would be required prior to initiating any modelling effort, regardless of the models used.

Figure 4
Relative Cost and Time Requirements to Develop a Watershed Management Tool Based on Different Modelling Approaches



In Reaches 1 to 6, a more complex approach to modelling is recommended, because the activities and land uses within the catchments contributing to these reaches have the potential to notably affect water quality and are subject to change over time. Recommended model combinations range from a relatively comprehensive instream model (i.e., WASP) combined with a simple loadings model (i.e., PLOAD) to a comprehensive watershed model (i.e., HSPF) that is directly connected to a GIS application (i.e., BASINS). Simpler models are recommended for the upper portion of the watershed (Reach 7 and upstream) because of the limited data available in these reaches and the anticipated lack of major land use changes in the catchments contributing to these reaches of the NSR.

5.2.1.2 Next Steps

The first key step for the NSWA is to determine whether it wishes to focus on developing a modelling tool to support the development of an IFN for the mainstem of the North Saskatchewan River, or if it wishes to broaden the scope of the modelling effort to produce a watershed management tool. Once this initial decision has been made, there are several important tasks that should be completed before moving further with the selection and application of a water quality model to the North Saskatchewan River Watershed. These include:

- identifying the budget available to complete this work;
- identifying the key water quality variables of concern;
- developing instream thresholds for each of the selected variables; and,

- agreeing upon a modelling approach that will efficiently provide the relevant information required to meet the objectives of the NSWA within the desired time frame.

Hundreds of different of water quality variables can be assessed using water quality models but most of these will have minimal or no relevance to the North Saskatchewan River Watershed. Therefore, the establishment of a list of variables of concern for the watershed is critical to focus the assessment effort on the key variables that are of concern for stakeholders in the North Saskatchewan River. To narrow down the list of variables, it is recommended that a workshop be held to solicit comments from watershed stakeholders on their concerns relating to water quality in the North Saskatchewan River and their priorities of water uses in the North Saskatchewan River (i.e., power generation, fisheries habitat, ecosystem integrity, assimilation capacity, recreation, etc.).

Once the list of variables of concern has been established, the next step is to develop targets for each variable. The information on priorities of water use from the workshop recommended above will provide some guidance for setting targets. Other factors that may need to be accounted for include existing water quality conditions in the watershed and any water quality targets that have already been developed for the watershed. In their simplest form, these targets could be set equivalent to already established water quality guidelines (e.g., CCME guidelines) or instream objectives.

The development of a water quality model allows for an infinite number of scenarios to be assessed. While this is primarily an advantage, it can also lead to the expenditure of substantial amounts of time and effort modelling scenarios that do not lead to effective decisions on water quality management. Input from stakeholders is recommended to build consensus on the preferred modelling approach for the North Saskatchewan River, including the future scenarios that are worthwhile assessing. One method for limiting the number of scenarios is to build a few scenarios around snapshot dates in the future (e.g., ranging from near future to far future) and management themes (e.g., ranging from do nothing to implementation of a wide range of BMP’s) for the watershed or large portions of it. This method captures the range of possible scenarios without spending the large amount of resources that would be required to model a whole series of minor incremental changes.

If the NSWA wants to focus on developing a watershed management tool, then additional consideration should be given to the spatial and temporal scale at which water quality management decisions will be expected to be made. The spatial scale of water quality models can range from accounting for changes in land uses in areas of less than 1 ha to whole watershed areas. The temporal scale can range from predicting hourly (or even more frequent) changes in water quality concentrations to predicting changes in annual average concentrations. The larger the scale required, the more time and effort will be needed to develop and run any given water quality model. As noted in Table 14, some water quality models are better suited to modelling water quality in large scale or small scale scenarios (see Table 14).

5.2.2 Fish Habitat

The office-based IFN available for the North Saskatchewan River will most likely provide suitable habitat protection for all species involved. If achieving this flow regime is not realistic or if alternative flow scenarios are to be evaluated, a River2D application is recommended. A separate study site for each segment would be required as results are not scalable from one reach to another. Recognizing that completing 17 River2D sites is not realistic in the short term, both from a cost and implementation perspective, priority segments should be identified.

The first step in completing an IFN assessment based on fish habitat is to prepare updated fisheries management objectives for the entire length of the North Saskatchewan River. These should include identification of key management species, seasonal timing of habitat use by each life stage, and any known critical habitat areas within each segment. Critical habitat areas are most often associated with spawning locations but can also include primary overwintering locations or juvenile rearing habitat. It is recommended that critical habitat areas for the key management species be used to help identify priority segments and for locating River2D study sites.

An expert workshop would be required to review and update HSC curves for the key management species. Although not necessary, site-specific habitat data are useful for validation of the workshop curves to ensure that they are regionally applicable.

If a River2D model is established, evaluation of a recommended IFN for fish habitat could follow the approach currently used for Alberta (Clipperton et al. 2003), but the likely application of any habitat model output would be in response to evaluating alternate flow management scenarios. Although no protocol is available for relating the change in habitat model output to fish population responses, the model does allow a quantitative assessment of relative change in the habitat output to benchmark cases such as the naturalized flow scenario or current flow scenario.

5.2.3 Channel Morphology

Due to the altered flow regime of the North Saskatchewan River downstream of Segment 9, it is recommended that a basic assessment of channel morphology requirements be conducted by calculating the initiation of bed transport as has been applied in previous Alberta studies (Clipperton et al. 2003) to define a range of channel morphology flows.

5.2.4 Hydrology

Once the spatial extent for the initial phases of an IFN study is established (i.e., all reaches or a select few critical reaches), naturalized flows should be generated for each IFN reach of interest where the existing naturalized flow may be that are not currently available. Depending on the IFN assessment approach selected, creation of daily naturalized flows may also be required.

5.2.5 Scenario Evaluation

At some future point in the IWMP process, it is likely that a range of flow scenarios will be created to evaluate different uses of water within the North Saskatchewan River. Developing these scenarios can be quite complex and must consider current and future allocations of water, timing and location of withdrawals and series of other water management priorities. Development of scenarios has been completed using the Water Resources Management Model (WRMM) for the South Saskatchewan River Basin in Alberta. The River Basin Allocation Model (RBAM) is a more complex version of the WRMM and is better-suited to handling reservoir outflows and hydropeaking operations, both of which are applicable to the North Saskatchewan River. As a key input to either model, the development of an IFN is required.

Scenario evaluations have been used as the primary tool in developing WCO in southern Alberta. The risk with this approach is that an infinite number of scenarios can be generated, which may simply slow down the process of defining a WCO. The models outlined above for the IFN study are capable of providing an output value for a very small change in flow; however, interpretation of very small incremental changes are difficult, if not impossible, to correlate to changes in ecosystem health or population size of a particular species. The purpose of scenario evaluations should be understood by the IFN-TAC as providing a qualitative assessment of relative change of a particular output to a benchmark condition.

5.3 Summary of IFN Framework

A wide range of possible tools remain open for consideration by the IFN-TAC prior to making a recommendation on an approach to addressing the IFN issue to the IWMP Committee. To provide some additional guidance, a summary of time and cost implications of what the authors believe to be the most likely approaches is presented in Table 15. The table presents options for different approaches, but alternate approaches not presented in the table may also be selected, and generally, each component can be addressed independently. Within each main component, either option, or no option could be pursued depending on final study objectives. Within each option presented for a particular ecosystem component, steps are presented in sequential order that generally cannot be skipped.

Several key steps are required by the NSWA to assist in selecting the final approach. Although the entire North Saskatchewan River within Alberta was reviewed in this scoping study, one or a few key reaches may be selected for initial study due to timing and funding limitations. Initial reaches can be selected based on such factors as upcoming water allocation pressures and/or critical habitats. Detailed study may focus initially on a single component and use office-based techniques or expert judgment to address the remaining components. Not all components have to be addressed equally or directly.

Table 15
Summary of Proposed IFN Framework for the North Saskatchewan River

Task	Timing	Duration[1]	Approximate Cost[2]
Channel Morphology (CM)			
Option 1: Determine CM flows from Shield's equation using existing data	Q1(2007)	🕐	$
Option 2: Determine CM flows from Shield's equation using field data at habitat modelling sites	Q3(2007)	🕐	$
Hydrology			
Option 1: Create weekly naturalized flows by IFN reach (per reach)	Q1(2007)	🕐	$
Option 2: Create daily naturalized flows (for use with threshold-type assessment) (per reach)	Q1-Q2 (2007)	🕐	$
Riparian Ecosystem			
Option 1: Conduct historical airphoto analysis for reaches 1 - 3	Q1(2007)	🕐	$
Option 2: Collect reach-specific field data for developing Poplar Rule Curve	Q3(2007)	🕐	$$
Fisheries			
Option 1: Enter historical data into FMIS database	Q1-Q4 (2007)	🕐🕐🕐	$$$
Option 1: Enter updated FMIS data in GIS	Q1(2008)	🕐	$
Option 2: Use existing information on target management species to identify critical habitats (e.g., lake sturgeon, bull trout)	Q1 (2007)	🕐	$ (participant dependant)
Option 3: Conduct basin-wide seasonal inventory and habitat use data	Q2(2007)-Q2 (2008)	🕐🕐🕐🕐	$$$$
All Options: Update Fisheries Management Objectives	Q1-Q2 (2008)	🕐🕐	internal costs
Habitat Modelling			
Option 1: Expert workshop to update HSC curves and select habitat modelling sites based on critical habitat areas	Q1(2007)	🕐	$ (participant dependant)
Option 1: Establish habitat modelling sites and collect open-water data (per site)	Q2-Q3 (2007)	🕐🕐🕐	$$
Option 1: Collect under-ice data (per site)	Q1(2008)	🕐	$$
Option 1: Calibration of models and calculation of habitat (per site)	Q1-Q2 (2008)	🕐🕐	$$
Option 2: Expert workshop to establish mesohabitat approach	Q1(2007)	🕐	$ (participant dependant)
Option 2: Habitat mapping using aerial photography	Q2-Q3 (2007)	🕐	$$
Option 2: Establish habitat modelling sites at representative reaches and collect open-water data (per site)	Q2-Q3 (2007)	🕐🕐🕐	$$
Option 2: Collect under-ice data (per site)	Q1(2008)	🕐	$$
Option 2: Calibration of models and calculation of habitat (per site)	Q1-Q2 (2008)	🕐🕐	$$
Water Quality			
All Options: Expert workshop to determine variables and thresholds	Q1(2007)	🕐	$ (participant dependant)
Option 1: Establish mainstem river model (simplistic – possible on all reaches)	Q1-Q4 (2007)	🕐🕐🕐	$$$

Table 15
Summary of Proposed IFN Framework for the North Saskatchewan River (continued)

Task	Timing	Duration[1]	Approximate Cost[2]
Option 1a: Establish mainstem river model (complex – only possible for lower reaches 1-6)	Q1-Q4 (2007-08)	🕐🕐🕐🕐	$$$$
Option 2: Establish watershed model (simplistic–possible on all reaches)	Q1-Q4 (2007-08)	🕐🕐🕐🕐	$$$$
Option 2a: Establish watershed model (complex – only possible for lower reaches 1-6)	Q1-Q4 (2007-??)	🕐🕐🕐🕐🕐	$$$$$
IFN Development			
Option 1: Integrate data from ecosystem components using SSRB approach	Q4(2008)	🕐	$$
Option 2: Series of expert panels to establish flow thresholds	Q2-Q4 (2007)	🕐🕐🕐	$ - $$$ (participant dependant)
Flow Scenario Development			
Set up WRMM or RBAM model	After water allocation study	🕐🕐	$$

[1] Duration: 🕐 < 3 months; 🕐🕐 3 months - 6 months; 🕐🕐🕐 6 months - 1 years; 🕐🕐🕐🕐 1 year - 2 years; 🕐🕐🕐🕐🕐 > 2 years.
[2] Cost range (2006 CAD): $ <10,000; $$ 10,000 - 50,000; $$$ 50,000 - 100,000; $$$$ 100,000 - 250,000; $$$$$ > 250,000.

6. CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

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APPENDIX I

GIS USER-NEEDS SURVEY

Golder Associates Ltd.

1000, 940 - 6th Avenue S.W.
Calgary, Alberta, Canada T2P 3T1
Telephone 403-299-5600
Fax 403-299-5606

Golder Associates Ltd. (Golder) has been contracted by the North Saskatchewan Watershed Authority (NSWA) to conduct an In-stream Flow Needs (IFN) study as part of the Integrated Watershed Management Plan for the North Saskatchewan watershed. As part of this study, it has been proposed that a GIS tool be developed that would help to graphically communicate the relationship between land use and water characteristics on the main stem of the North Saskatchewan River. This survey is being conducted to help to understand what stakeholders would like to see in such a tool, and to assist in developing a path forward. The survey starts with some standard questions to identify yourself and your organization, then gets more into GIS requirements.

Identification

Name:

Address:

Phone number:

Fax number:

Organization:

Position:

Extent of GIS knowledge within your organization:

System

Does your organization have any GIS capability?

If yes, what GIS software do you use?

What is the version number (if known)?

Does your organization have the capability to print or plot maps in colour?

What is the maximum size you can print / plot?

Do you have access to the internet?

Is the access high speed?

Data

Data that has been acquired for the project to this point includes the following:

- Small scale base data layers (hydrography, roads, etc.) suitable for analysis or mapping at a national level,
- PFRA watersheds – various levels,
- PFRA land cover classification
- Land capability for various uses (agriculture, recreation, wildlife),

- Alberta soil data (Agrasid),
- Soil landscapes (small scale),
- Surficial materials (small scale),
- Ecoprovinces, zones, regions, and districts,
- Native vegetation project data,
- PFRA land cover classification,
- Water quality monitoring locations.

Data that should be acquired includes larger scale hydrography and roads, digital elevation data, current municipal boundaries, green / white zone boundary. These all fall into the general category of base data.

What other more specific data do you feel should be acquired for the purposes of this project?

Application

Would it be desirable for information or data related to this tool be disseminated via the internet?

Would this be through the existing NSWA website, or possibly a new site set up specifically for this purpose?

One possible approach to the dissemination of information would be to have maps created for various scenarios and have the maps posted as images to a website. A variation of this would be to have PDF maps of these scenarios posted, and available for the viewer to download. Would this be a viable approach?

If either of these approaches was taken, what scenarios would need to be presented in map format?

Another approach would be to have map data available on a webGIS site. This would allow viewing of map layers that could be turned on or off, along with basic GIS functionality like querying the data, pans, and zooms. Would this be desirable?

A final approach would be to develop a higher end interactive application that would present output of models differently according to values input by the user. For example, by changing the amount or intensity of a particular type of land in the North Saskatchewan watershed, a reach of the river would reflect a change in some water characteristic by changing colour.

Audience

Who is your potential audience or set of users, and what would their level of sophistication be?

Consider this over both the short term and longer term.

Other Considerations

Are there any other points that you wish to discuss in the context of the GIS tool?

APPENDIX II

DETAILED BIBLIOGRAPHY

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